



AARHUS
UNIVERSITY

DCA - DANISH CENTRE FOR FOOD AND AGRICULTURE

PERSPECTIVE

ANNUAL REPORT 2017

DCA – DANISH CENTRE FOR FOOD AND AGRICULTURE

Food and agricultural science
Research-based policy support
Knowledge exchange and industrial collaboration
National and international research alliances

Unique interdisciplinary research environment creates **synergies between agriculture and the environment**

It is a well-established dogma that there is a dilemma in the relation between agriculture and environment. The dogma is that intensive agricultural production will always be at the expense of the environment and nature, while applied environmental protection will always result in limitation of agricultural production. However, a new approach may be the solution. This edition of Perspective describes how research seeks to develop solutions that create synergies between agriculture and environment - solutions in which higher yields can combine with reduced impacts on climate and the environment.

Ongoing research and development in biomass and green protein is a good example. Growing more perennial crops can reduce nitrogen leaching. This also reduces pesticide use and increases storage of carbon in the soil. It is technically possible to extract protein from green biomass to replace pig and poultry feed concentrate based on imported soya in conventional and organic farming. The residual product can be fed to cattle and used for energy. In addition, biomass production can contribute to the economy and employment in rural areas.

This is an example of sustainable intensification, and of how interdisciplinary bioeconomy research makes it possible to combine industrial and social interests. Companies, together with agricultural organisations, nature groups and the authorities are thus strongly supporting this development.

This type of problem-solving research is carried out in an interdisciplinary collaboration between research environments in agroecology, animal science, engineering, food science and genetics and with contributions from chemistry and the social sciences; i.e. the entire range of research areas comprised by DCA.

The vital point is that with DCA – Danish Centre for Food and Research, Aarhus University has a unique and extraordinary interdisciplinary research environment not found elsewhere.



Photo: Lise Batsby

This unique collaboration is only possible if the necessary research facilities are present. Denmark is exceptional in that Aarhus University, with research centres in Foulum, Flakkebjerg and Aarslev, can carry out coherent, problem-solving research covering the entire agricultural and food sector, i.e. research that can connect crop cultivation, environmental impact, animal production and food quality. Such interdisciplinary and interconnected research is hard to find in other places.

Our possibilities for this are due to – as can be said of the academic world in general – close relations between researchers' skills and their access to research facilities. Coherence in use of our experimental fields and housing systems, research laboratories and other experimental facilities is essential to carrying out interconnected and interdisciplinary research that addresses complex problems across traditional research areas.

Our unique opportunities to carry out problem-oriented research from farm to fork is an important prerequisite for our high-quality policy support, which is also described in this annual report.

Aarhus University is strongly focused on maintaining and developing the relations between skills and facilities to the benefit of research, policy support and industrial collaboration. This approach is central to the university's new interdisciplinary and thematic centres, which are also described in this report.

The new centres have been established in areas in which Aarhus University possesses positions of strength. Although the centres have different purposes, their joint vision is to gather competences across departments and faculties and thus contribute to strengthening research and, not least, co-operation with the outside world.

iFOOD – Centre for Innovative Food Research and CBIO – Centre for Circular Bioeconomy in particular aim to strengthen interdisciplinary collaboration in the food and agricultural sector.

iFOOD draws on skills from the faculties Science and Technology, Aarhus BSS and Health at Aarhus University with a view to interdisciplinary research, innovation and talent development in the food sector.

CBIO unites research activities that can contribute to establishing new companies and business areas in the biobased economy.

We hope that you will enjoy reading more about food and agricultural research at DCA in this annual report.

Niels Halberg

Director, DCA – Danish Centre for Food and Agriculture

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COVER PHOTO

Professor Hanne C. Bertram has contributed significantly to the development of the metabolomics technique, which researchers can use to study food metabolism in the body. She was awarded the EliteForsk Prize in 2017 from the Danish Ministry of Higher Education and Science. Read more on page 7.
Photo: Jens Michael Madsen

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The annual report "Perspective" contains information about the research that underpins Aarhus University's research-based policy support in food and agriculture. The articles provide examples of research in crop production, livestock production, engineering, food science, and molecular genetics. The texts describe recent research results, collaboration with commercial companies and organisations, and how these efforts help strengthen the foundation for important societal decision-making. It is our vision that the articles will inspire interest and understanding – in research as well as policy support.

We hope you will enjoy reading the report!

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About DCA – Danish Centre for Food and Agriculture

DCA – Danish Centre for Food and Agriculture comprises the departments at Aarhus University that carry out research activities in food and agricultural science. These departments include the Department of Agroecology, Department of Animal Science, and Department of Food Science, parts of the Department of Molecular Biology and Genetics, and parts of the Department of Engineering. In addition, DCA collaborates closely with the MAPP Centre at the Department of Management. The activities in DCA are supported by a centre unit, which is in charge of tasks relating to research-based policy support, sector and industry cooperation, international cooperation and communication.

Policy support

The DCA centre unit coordinates the agreement between the university and the Ministry of Environment and Food of Denmark regarding provision of research-based policy support within the areas of crop production, livestock production, and food quality and consumer behaviour.

Researchers from DCA-related departments provide research-based policy support ranging from short memorandums to extensive reports and knowledge syntheses. The agreement with the Ministry respects the arm's length principle, and DCA's policy support is based solely on the scientific contributions provided by the researchers. The authorities are responsible for the subsequent political and administrative considerations.

In addition, DCA is also obligated to regularly assess which areas may become topical for policy support. Such assessments can result in initiatives for carrying out research in areas in which there may be a need for further or new knowledge.

Sector collaboration

An advisory panel contributes to organising research and development collaboration with national users and collaborative partners. Members of the advisory panel include the Ministry of Environment and Food of Denmark, other authorities, industry representatives and a well-developed committee network.

The main task of the advisory panel is to provide advice on the centre's overarching supervision and strategy, including the relevance of research in relation to society's future needs for advisory services, national and international research topics, communication of knowledge to society and the framework for research-based policy support.

The advisory panel includes representatives from the Danish Veterinary and Food Administration, Danish Agricultural Agency, Seges, Danish Crown, Organic Denmark, Arla Foods, Coop Denmark, Confederation of Danish Industry, and Danish Society for Nature Conservation.

Communication

The DCA centre unit carries out communication tasks in relation to policy support and other DCA assignments. A weekly DCA newsletter communicates knowledge about policy support tasks and new research from the DCA departments.

The centre unit publishes DCA reports, primarily based on policy support tasks. In addition, the centre unit coordinates DCA events allowing researchers, authorities and the public to be informed about research efforts and exchange knowledge.

At AU Foulum guided tours are available for companies, associations and relevant educational institutions.

You can find DCA reports, news articles and other information at dca.au.dk/en

International cooperation

Via its centre unit, DCA is in charge of a number of tasks in relation to international research and policy support. On behalf of the Ministry of Environment and Food of Denmark, DCA attends to responsibilities in the European Innovation Partnership on Agricultural Sustainability and Productivity (EIP-AGRI), the Collaborative Working Group of Sustainable Animal Production, NordGen Council for Farm Animal Genetic Resources and Animal Task Force. Via its engagement in several ERA-nets, DCA participates in a series of European research programmes. The centre also supports collaboration in major applications to European research programmes, primarily Horizon 2020.

About **research-based policy support** at DCA

Research-based policy support comprises commissions from the Ministry of Environment and Food of Denmark requesting DCA – Danish Centre for Food and Agriculture to examine or clarify various current topics concerning food and agriculture. The resulting studies constitute the basis for the ministry's legislation and questions presented in the Danish parliament.

The Ministry of Environment and Food of Denmark has entered into a new four-year framework agreement with Aarhus University on the provision of research-based policy support. According to the agreement, DCA received approximately 262.3m DKK in 2017.

Research-based policy support comprises the policy support provided by the researchers in relation to actual commissions from the Ministry as well as the underlying research. In addition, the concept includes a series of tasks and services in relation to surveillance, support etc.

Policy support must be transparent and, basically, all deliverables may be freely published unless they contain information that is confidential.

The framework agreement comprises three performance agreements within the DCA-related effort areas: plant production, livestock production and food quality and consumer behaviour.

The performance agreements constitute the scientific frame of DCA's research-based policy support and describe the scientific focus areas. For each focus area, the actual tasks and projects agreed for the coming year are described.

The framework agreements are adjusted annually, and this means that ongoing tasks and projects are included. In addition, the researchers must solve any urgent tasks or problems that may appear. The agreements are available in Danish at dca.au.dk.

Financing food and agricultural research

Different sources fund food and agricultural research, and DCA's contract with the Ministry of Environment and Food of Denmark is the main income source.

The grant from the Ministry of Environment and Food of Denmark allows DCA to attract and carry out research projects in collaboration with organisations and companies. This collaboration, together with grants from national funds and research programmes, was the main reason why the total

research and development funding amounted to 658m DKK in 2017.

DCA also participates in a significant number of international research collaborations at both Scandinavian and EU levels as well as in major global research consortia. International funding ensures increased research activities and allows DCA to provide research-based policy support at the highest possible international level.

Antibiotics counteract the beneficial effects of whole grain

The use of antibiotics may counteract the positive health effects of eating whole grain, especially for women.

Several studies have demonstrated a positive correlation between dietary intake of whole grain and a reduced risk of developing lifestyle diseases, including cancer, cardiovascular diseases and type 2 diabetes. According to recommendations from the Danish Veterinary and Food Administration, adult Danes should eat at least 75 g whole grain a day.

However, vitamins, minerals and fibres are not the only compounds that make whole grain products such as rye bread and oatmeal healthy. Phyto-oestrogens such as lignans, which are found in all grain types, are also important. The concentration of lignans is higher in whole grain than in refined grains. Rye, in particular, has a high content of lignans.

Once ingested, our intestinal bacteria metabolise the plant lignans into enterolignans, which have a chemical structure similar to estrogen. The similarity in chemical structure between estrogen and enterolignans is the most likely reason why enterolignans have a positive effect against developing breast cancer.

Study demonstrates the negative effect of antibiotics

A population study carried out in collaboration between Aarhus University and The Danish Cancer Society has demonstrated that the use of antibiotics may counteract the positive health effects of eating whole grain, specifically in relation to the impact of enterolignans.

The study builds on extensive data from a study of the Danish population "Diets, Cancer and Health" in which more than 57,000 Danes from 1993 to 1997 submitted detailed information on their diets and lifestyles as well as biological material in the form of blood, fatty tissue, urine and toenails. Subsequently, more than 2200 of the participants developed cancer in the period 1996-2009. This particular group of people was examined in detail.

Maintain a restrictive use of antibiotics

- It turns out that there was a significant correlation between antibiotic use and lower enterolignan concentrations in the blood, especially for women. For women who had used antibiotics up to three months prior to blood sampling, the concentration was as much as 40 percent lower than for

the women who had not used antibiotics, explains Professor Knud Erik Bach Knudsen, Department of Animal Science at Aarhus University.

- The results supported our hypothesis, but they also confirmed the importance of maintaining a restrictive use of antibiotics. You will not be able to obtain the full positive health effect of whole grains when the intestinal bacteria are negatively affected by antibiotics. The negative effect found in the conversion of plant to enterolignans most likely also applies to a number of other substances that need the microflora to fully express their beneficial health effect, says Knud Erik Bach Knudsen.

Confirmed in pig trials

In order to attain an in-depth understanding of the negative effect of antibiotic use, a controlled intervention study with pigs was carried out. This study also demonstrated that treating the pigs with antibiotics resulted in a 37 percent lower plasma concentration of enterolignans.

- This is the first time that an animal experiment confirms a direct relationship between enterolignan concentrations and antibiotic treatments, says Knud Erik Bach Knudsen.



Several studies have demonstrated a positive correlation between whole grain intake and a reduced risk of developing lifestyle diseases. Photo: Colourbox

iFOOD - New Centre for Innovative Food Research
In 2017, Aarhus University opened the new iFOOD Centre to bring together leading skills in food research. Read more about iFOOD on page 44.

Prestigious Elite Research Prize awarded to food scientist

Professor Hanne Christine Bertram, Department of Food Science, Aarhus University, was awarded the Elite Research Prize for her research in the links between diet and health.

How does the body respond to the intake of specific foods, and what does diet mean for our health? Professor Hanne Christine Bertram, Department of Food Science, Aarhus University, has been working on these questions for more than a decade.

In 2017, she was awarded the Elite Research Prize for her contribution to the development of advanced food analysis and in recognition of her position as a frontrunner in this field. The Danish Ministry of Higher Education and Science awards the prize to five outstanding researchers of international excellence.

- Apart from the personal recognition, I'm extremely happy that I can pave the way for an Elite Research Prize to Danish food research, which undoubtedly is in Europe's premier league, says Hanne C. Bertram.

Development of a new research method

The newly appointed elite researcher has received particular attention for her contribution to the development of metabolomics – an advanced method for studying how the body metabolises food. When the body metabolises nutrients, various molecules are formed and excreted into the blood or urine. By analysing and mapping the content of these molecules, researchers can study whether a particular food product is associated with a specific effect in the body.

The metabolomics method has been used for generating knowledge about why foods like cheese are healthy, and how milk proteins can influence weight control.

Better knowledge about meat and health

The new prize includes 1m DKK in free research funds.

Professor Bertram expects to use the money to conduct research in how healthier meat products can be developed.

- There is focus on how meat intake exerts impact on our health, but there are many unclarified factors. I have a great desire to contribute to improving our understanding of how meat is metabolised and affects us when we eat it, and I hope this can provide knowledge so that we can strategically design the meat products to achieve an overall healthier solution, says Hanne C. Bertram.

Focus on industrial collaboration

In addition to strengthening research with regard to generating knowledge that can lead to the development of healthier meat products, Hanne C. Bertram would like to use the Elite Research grant to study how we are affected by what we get from our parents.

- There is actually increasing evidence that our parents provide us with more than genes. The dietary pattern we get from our mothers seems to leave its mark on our health right up into adulthood, says Hanne C. Bertram.

Professor Bertram also hopes to use the attention associated with the prize to focus on the importance of strong collaboration between the universities and the Danish food industry.

The Elite Research Prize 2017 was presented by HRH Crown Princess Mary and the former Minister for Higher Education and Science Søren Pind at a ceremony at Ny Carlsberg Glyptotek in Copenhagen.

Professor Hanne C. Bertram was awarded the Elite Research Prize 2017 for her internationally excellent research. Photo: Jens Michael Madsen





Generally, women are more willing to pay extra for good quality products.

Photo: Colourbox

Consumer satisfaction with foods in retail industry on the increase

Danish consumers are generally satisfied with the quality of foods available in Danish grocery stores.

In 2014, researchers from Aarhus University developed a quality index to examine the factors influencing Danish consumer perceptions of quality foods and to see how these perceptions change over time.

A representative cross section of Danish consumers responsible for grocery shopping and cooking answered an exhaustive questionnaire. Results from the first quality index survey were published in 2014, and with the recent index from 2017, certain development patterns are evident.

Larger supply of quality foods

- We can see that consumers are more satisfied when we ask them what they think of the quality of foods available in grocery stores. This indicates that the retail industry generally offers more quality food. As an example, discount stores now focus more on organic foods demanded by quality-conscious consumers, says Associate Professor Tino Bech-Larsen, MAPP Centre at Aarhus University, and one of the authors of a report regarding the quality index 2017 with a focus on family meal patterns.

The Ministry of Environment and Food of Denmark commissioned the report based on a desire to encourage and follow the Danes' interests in quality foods. The report (in Danish) was published by DCA - Danish Centre for Food and Agriculture, and is a part of Aarhus University's agreement on research-based policy support.

Women are willing to pay more for quality foods than men are

To consumers, the most important quality indicator is the fact that the product is Danish. Women are willing to pay 21 percent more for Danish products than for foreign produce, whereas men are willing to pay 15 percent more.

- Generally, women are more willing to pay extra for good quality products, in particular, when it comes to parameters such as healthy nutritional contents, products with no additives and Danish products. Men however, are more willing to pay extra for foods that taste good, says Tino Bech-Larsen. The general willingness to pay more has remained stable since 2014.

Danish consumers readily choose convenience food

Consumers buy convenience food to save time and consider it a necessity in modern households.

When is a meal home-cooked? Must every part of lasagna be prepared from scratch or is it still considered home-cooked if the béchamel sauce and the spice mix are bought in a store and ready for use?

As a part of a study on Danes' food satisfaction, researchers from the MAPP Centre at Aarhus University examined this issue. The study was commissioned by the Ministry of Environment and Food of Denmark.

- Generally speaking, Danish consumers consider convenience foods as a natural and necessary part of everyday cooking. They agree that convenience is about saving time, says Research Assistant Gitte Lundberg Hansen from the MAPP Centre, one of the authors of the study.

Meat is the most important part of a home-cooked meal

The range for considering whether a product is home-cooked is wide. The study shows that consumers consider processed meat products as the most important food category when determining whether a meal is home-cooked. On the other hand, most consumers consider canned tomatoes as a raw material that would not make sense to prepare yourself.

Consumers also want ready-made gourmet meals

Consumers are positive towards purchasing gourmet meals from the supermarket's refrigerated display counter.

This is demonstrated in a study about growth potentials in Danish gastronomy commissioned by the Ministry of Environment and Food of Denmark as part of Aarhus University's agreement on research-based policy advice and carried out in collaboration between the MAPP Centre and the Department of Food Science, Aarhus University.

The results unambiguously demonstrate the existence of a customer segment willing to purchase these so-called gastro-convenience products. Consumers do not consider gastronomy and ready-made meals to be opposites.

The consumer segment that already buys ready-made meals and rarely spends more than two hours cooking seems particularly interested in gourmet ready-made meals. In addition, the target group is singles under the age of 30 or between 40 and 59 years of age.



Highly educated men are more open to the idea of eating insects

About one third of Danish consumers, particularly men living in the Copenhagen area, are positive towards the notion of eating insects.

Feeding the world in 2050 will require at least a doubling of food production. This is one of the reasons why insects are increasingly being considered as a new food source. Insects are rich in protein and have a minor environmental impact compared to other protein sources.

Researchers from the MAPP Centre, Aarhus University, have studied the Danes' willingness to eat insects. The study was commissioned by the Ministry of Environment and Food of Denmark as part of Aarhus University's agreement with the ministry on the provision of research-based policy support and the results are published in a report (in Danish) from DCA – Danish Centre for Food and Agriculture.

Young people are more inclined to eat insects

28 percent of the consumers asked in the survey were positive towards eating insects, and the majority of these were men. In addition, most of them were highly educated. About 23 percent of the consumers were against insect consumption and considered it disgusting.

- Younger consumers are more willing to eat insect products, and most of the potential insect consumers come from the Copenhagen area. We also noticed that consumers who have previously tasted insects are more positive to the thought of doing so again, says Research Assistant Pernille N. Videbæk from the MAPP Centre at Aarhus University. She is one of the authors of the report.

Insects should be processed

Danish consumers clearly prefer processed insects in food products. However, social norms play a significant role in relation to the willingness to eat insects. If your family considers insects disgusting, you may not want to taste them.

- It is a problem that insect consumption in general is considered to be gross, as this means that you are less likely to try eating them yourself. Therefore, we need initiatives to change the general attitude in large segments of society and provide them with a different view on insect consumption. Instead of being considered gross, the ideal solution would be to consider insects as food and maybe – with time – even a delicacy, says Pernille N. Videbæk.



AU report reveals how the elderly view their food and meals

A report published by Aarhus University sheds light on the attitudes of senior citizens to their food and meals.

What do the elderly think of their meals? And does it make a difference, if the meal is homemade or delivered by a "meals on wheels" service? These are just a couple of the questions that researchers from the Department of Food Science and the MAPP Centre at Aarhus University have sought to answer.

The collaboration took place within the framework of a study commissioned by the Ministry of Environment and Food of Denmark as a part of Aarhus University's agreement on research-based policy support. The background for the commissioned research was the lack of knowledge about elderly people's desires and opinions about food and meals served and eaten in their own home.

- In this study, we have focused on elderly people's opinion about the quality of their food, the importance of the social context around meals and food-related quality of life. Furthermore, we have examined the elderly's weight status and food-related functional capabilities, says Postdoc Barbara Vad Andersen from the Department of Food Science at Aarhus University. She is part of a team of researchers that conducts research in healthy ageing.

Results from across the country

In the study, a total of 1041 elderly people, in the age group 65+, from six Danish municipalities answered a questionnaire. Common for all respondents was the fact that they live in their own homes (and not in e.g. a nursing home). The group includes self-sufficient elderly, elderly people eligible for municipal home help and elderly appointed to a public meal service.

- It was important for us to select municipalities based on factors such as economy and geography, as this would allow us to apply and compare the results across the country.

It is important to most elderly that their food is prepared from Danish raw materials in season.

Photo: Colourbox

However, it is important to emphasise that our results do not necessarily apply to all parts of Denmark, says Barbara Vad Andersen.

Positive towards meal services

In the light of current criticism of meal services in Denmark, one of the surprising results from the study was the fact that most elderly who receive meals from a public meal service are satisfied with their food. However, there is still room for improvement, particularly in relation to food variation and the use of spices.

With regard to meal services, most elderly stated that it is important that the food is prepared using Danish raw materials in season, and that there are several meals to choose from in the menu. However, geographical variations do exist. For instance, in Gentofte municipality more of the elderly indicated a desire for organic food than was the case for the municipality of Ringkøbing-Skjern, where traditional Danish dishes were desired.





Dinner groups help elderly people who have lost their partner

The study was an interdisciplinary collaboration between the MAPP Centre and the Department of Food Science at Aarhus University and was commissioned by the Ministry of Environment and Food of Denmark as part of Aarhus University's agreement on research-based public sector consultancy. The results have been published (in Danish) by DCA - Danish Centre for Food and Agriculture.

Meal enjoyment disappears

The researchers conducted a qualitative study among people over 60 years of age who have lost a cohabiting partner. The study clearly shows that the missing social interaction related to the meal has a negative impact on the elderly people's quality of life.

- When people lose the social interaction along with their partner, many also lose the enjoyment associated with eating meals, says Lise Bundgaard.

Social interaction helps

A number of people have benefitted from dinner groups. These groups may consist of family and friends or people whom the elderly have sought out themselves or were introduced to after their cohabiting partner passed away. Meals can take place in a flat-share, with neighbours, in the local sports centre, cultural centre or in a dinner club for single men.

- Dinner groups and other forms of social interaction centred around the meal improve people's quality of life. They strengthen people's social relations and in some cases also their cooking skills. That is why it would be a good idea to try and create more opportunities to form these dinner groups. They might also fulfil a need for social interaction that some of the elderly may tend to replace with media consumption during the meal. Studies show that watching TV and reading newspapers are distractions and remove the focus from the meal. This in turn affects the appetite. That is why it could be interesting to start refocusing on the meal, says Lise Bundgaard.

When elderly people suddenly have to eat their daily meals alone, they experience a decline in life quality. However, dinner groups can have a positive effect.

Many elderly people lose their motivation to prepare hot meals when their cohabiting partner passes away. Instead, the dinner table often features rye bread, a bowl of yoghurt or ready-made dishes.

- We can see that some people who lose their partner have difficulties eating a varied diet. This can mean that their nutritional needs are not met, says Research Assistant Lise Bundgaard, who is one of the authors behind a study of whether new life situations lead to changes in meal habits and alternative needs for information about a healthy diet.

Legs and tails in particular may cause **welfare problems**

In their efforts to improve animal welfare, researchers at Aarhus University have examined a number of conditions in pigs, cattle and poultry.

Modern animal production systems must meet numerous expectations and requirements. The systems must be efficient, economic, environmentally friendly, work-friendly and last but not least animal-friendly. In their continuous development of production systems, researchers from the Department of Animal Science at Aarhus University keep an eye on animal welfare.

Over time, the department's researchers have contributed evidence-based knowledge on causes and solutions to various animal welfare problems, and 2017 was no exception.

How can sow mortality be reduced even more?

In 2015, sow mortality in Danish herds was 11.4 percent. The pig industry aims to reduce this to 9 percent in 2018. Dead sows are divided into two categories – sows that are euthanised and sows that die naturally.

- Sows are typically euthanised due to leg problems. The causes of death among sows that die naturally comprise problems in relation to farrowing, disorders in the gastrointestinal tract or heart problems, says Professor Jan Tind Sørensen, Department of Animal Science. He recommends establishing a systematic monitoring system in the dry sow housing, and development of criteria for when sows should be moved to sick pens as well as an increased focus on the quality of sick pens. He further points out that there is a need for more research in how to prevent lameness and the reasons for spontaneous deaths.

Physical conditions are important

Slaughter pigs are likely to sustain injuries. A study of slaughter findings in organic, conventional outdoor and conventional indoor pigs – based on three years of data from almost 1.1 million slaughter pigs – demonstrated that differences between production systems exist.

Tail injuries, skin lesions, fractures, arthritis and liver spots from parasites were most common in outdoor systems, whereas pigs in indoor systems had increased risks of leg lesions, umbilical hernias and abscesses. Respiratory tract infections were the most common disorder in all three systems with a prevalence of 20 percent.

Various housing and management systems can be at the root of some of the injuries. For example, the increased risk

of leg injuries and hoof abscesses found in indoor pigs may be caused by hard bedding and hooves getting caught in slatted floors.

The higher frequency of fractures found in outdoor systems – half of the injuries were broken ribs – is most likely due to the sow's laying on her piglets in the farrowing pen.

Most of the tail injuries in free range pigs compared to indoor pigs occurred primarily because the tails of free range pigs are not docked. In another study, carried out within the framework of the EU project FareWellDock, researchers from the Department of Animal Science demonstrated that tail docking may cause increased sensitivity in the tail for up to four months after the docking.

Sore feet in cows and chicken

Cattle and poultry may also suffer from leg problems. In cows, lameness can be a major problem for animal welfare, yield, fertility and life expectancy. Researchers from the Department of Animal Science have demonstrated that it is possible to determine lameness in a cow based on her activity level. It is possible to identify even a slight level of lameness this way. Equipping cows with activity monitors allows farmers to intervene in time.

Wet feet may be a problem for broilers. According to a study commissioned by the Ministry of Environment and Food of Denmark, researchers from the Department of Animal Science established that this problem occurs in both organic and conventional broilers with the highest frequency in organic broilers.

Chickens can get burns on their footpads when they walk on humid bedding and their own manure sticks to their footpads. Feed and manure can be contributory causes, according to the researchers. One of the reasons that the problem is more frequent in organic broilers is that they are older at slaughter, and therefore spend more time in housing than conventional broilers.

Read more in the report "Identification of risk factors and strategies for reducing sow mortality", available for download from the DCA website.

Should we let the pigs loose?

Allowing finisher pigs to forage in the field has its pros and cons.

The possibilities of raising free-range finisher pigs are good but there are certain problems that need to be addressed.

- Free-range finisher production poses environmental challenges. One of the reasons is a large input of nutrients due to a high feed consumption, says Senior Researcher Anne Grete Kongsted, Department of Agroecology at Aarhus University.

Instead of being fed in a trough, the pigs in the studies had to forage. In order to encourage them to do so, their feed rations were reduced to as much as 25 percent of standard rations in some of the groups.

The pigs found up to half of their daily intake of protein and energy by foraging. The greenhouse gas emissions were reduced by 8-17 percent compared to organic systems with pigs in housing or with access to clover grass, as it allowed a reduction of purchased pig feed.

Other advantages were that foraging allowed the pigs to express their natural behaviour, and that a varied crop rota-

tion may contribute to increased soil fertility and can reduce the prevalence of pests and diseases.

However, there is an upper limit to everything. This type of management system leaches more nitrogen to the environment, and the pigs grow more slowly when they get a significant share of their feed by foraging compared to being raised in housing systems.

- Evident development opportunities exist, such as an integrating finisher production with production of tree biomass. Or, mobile units could enable integrating the pigs into a crop rotation. These concepts could be combined with feeding strategies and targeted compensatory growth, says Anne Grete Kongsted.

The experiments were carried out within the framework of two research projects coordinated by Department of Agroecology under research programmes coordinated by the International Centre for Research in Organic Food Systems (ICROFS), and funded by the Green Development and Demonstration Programme (GUDP) and EU. The projects are described in a report published by DCA (in Danish).



Free range finisher pig production faces challenges that need to be addressed, such as slower growth and the leaching of nitrogen to the environment.

Photo: Janne Hansen

Ramsons and lingonberries can inhibit *E.coli* bacteria which often cause diarrhoea in piglets. Photo: Colourbox

Can ramsons and acidic berries replace antibiotics?

Certain plants may potentially replace antibiotics and medicinal zinc oxide for treating diarrhoea in piglets.

During the last two years, researchers from Aarhus University have experimented with identifying alternatives to antibiotics and zinc oxide in Danish organic pig production. In the initial tests, the researchers demonstrated – by means of an in vitro laboratory model – that certain plants could inhibit the growth of enterotoxigenic *E. coli* (ETEC) from pigs. There was therefore a good reason to conduct an in vivo pilot study on how these plants would affect *E. coli* in live pigs.

- In the laboratory, a mixture of ramsons and lingonberries inhibited the ETEC types that often cause diarrhoea in piglets. These plant species contain allicin and organic acids, respectively, both with antibacterial properties. We therefore carried out an in vivo pilot trial and tested the mixture on pigs, says Senior Researcher Martin Jensen, Department of Food Science at Aarhus University and manager of the project entitled 'Multicomponent antibacterial feed additive for weaning piglets against intestinal diseases' (MAFFRA).

Martin Jensen points out that the point of the project was to focus on organic pig production, but since certain plants can significantly inhibit diarrhoea-inducing bacteria, there is potential for developing a product that may reduce the use of antibiotics and zinc oxide in conventional production as well.

Quick and significant impact

The two-week pilot experiment included two pig groups: a control group and a group that was given the promising plant cocktail. Both groups were fed standard pig feed. All pigs were weaned at four weeks of age, and the experiment started when the pigs were five weeks old. Already after the first week, the level of *E. coli* in faeces was 100 times lower in pigs fed the plant cocktail compared to the control group.

E. coli bacteria are inhibited

- We collected faecal samples three times during the experiment, and at the end of the experiment we took samples from the entire gut (stomach, small intestine, caecum and colon). The effect was significant in all gut segments. In ad-

dition, the plants did not have any negative impact on feed intake, says Senior Researcher Nuria Canibe, Department of Animal Science at Aarhus University.

Another important aspect of the experiment was to study the population of natural lactic acid bacteria. These bacteria are considered important in maintaining a balanced gut environment and preventing diarrhoea, and no differences were observed in the level of lactic acid bacteria between the control group and the pigs fed the plant cocktail.

The cost-effective solution of the future

The tested plants have significant potential as alternatives to antibiotics and zinc oxide. The positive pilot experiment results have encouraged the researchers to apply for funding of a larger project that will include the industry in relation to producing the necessary, efficient plant material and the feed mixtures to be used in practice.

In addition, the project will document and demonstrate if the new, plant-based feed products can prevent or treat diarrhoea in weaner pigs and thus contribute to reducing the use of antibiotics and replacing zinc oxide; the use of the latter will be phased out by 2022.

Facts about the project

The MAFFRA project is part of the Organic RDD 2.2 programme coordinated by ICROFS (International Centre for Research in Organic Food Systems). The project is funded by the Green Development and Demonstration Programme (GUDP) under the Ministry of Environment and Food of Denmark.

The project was carried out by Senior Researchers Martin Jensen and Kai Grevsen, Department of Food Science, Aarhus University, and Senior Researchers Nuria Canibe and Ole Højberg, Department of Animal Science, Aarhus University, with support from the company NORFEED.

More frequent sow feedings reduces the number of stillborn piglets

If sows are fed at least three times daily, they will repay with shorter farrowings and considerably fewer stillborn piglets.

New research at the Department of Animal Science, Aarhus University, shows that the duration of farrowing increases with increasing time from the sow's last meal until the beginning of farrowing. The results are based on a study at AU Foulum, where researchers achieved quicker farrowings (3.8 hours) and fewer stillborn piglets (5 percent) when the sows were fed no later than three hours before farrowing began. The study included 166 farrowings, with the sows giving birth to a total of 2,889 piglets.

- The sow's energy stores are depleted up to and during farrowing if the period between her last feeding and the beginning of farrowing is too long, explains Senior Researcher Peter K. Theil from the Department of Animal Science at Aarhus University and leader of the study.

Feeding at least three times daily prior to farrowing

Sows in late gestation are typically fed twice daily up to farrowing and often within regular working hours, e.g. between 7:00 am and 3:00 pm. This means that a sow who

starts farrowing at 6:00 am has not been fed for the last 15 hours before farrowing.

The clear message from the researchers is therefore that the prolific Danish sows should be fed at least three times daily prior to farrowing and, even better, four times a day if the farmer has an automatic feeding system. Another benefit is that farrowing assistance is not needed for sows with adequate energy status.

- All told, it appears that there is huge potential for reducing the number of stillborn piglets and thereby increasing piglet survival rates significantly. By ensuring a more constant energy supply to the sow 24/7 up to farrowing it would not be unrealistic to expect improved liveborn piglet vitality, which would contribute to a higher survival rate. This study can improve sow and piglet welfare and looks like a great breakthrough to reduce piglet mortality, leading to potentially large financial gains for Danish pig farmers, says Peter K. Theil.

By ensuring a more constant energy supply across the day for sows prior to farrowing, there is a great potential for reducing the number of stillborn piglets and thus increasing piglet survival markedly.

Photo: Colourbox

Unique wheat passes the test

A unique, patented wheat can have significant importance to agriculture, the environment and undernourished people in developing countries.

Stronger legs in fast-growing broilers, reduced phosphorus emissions to the environment, improved health for undernourished populations in developing countries and better use of scarce resources – these are some of the perspectives of a unique type of wheat; a wheat with a specific ability to increase the digestibility of phosphorus and other important minerals.

Scientists from the Department of Molecular Biology and Genetics, Aarhus University, have developed and patented the new type of wheat. Following years of research and development, the wheat then needed to prove its worth in the tough environment of the digestive system – and it succeeded.

Phosphorus is tied up

It all started with a single wheat plant. The researchers were on the lookout for certain cereal genes that affect the availability of vital minerals in feed and foods. Minerals such as phosphorus are often tightly bound in phytate. The enzyme phytase helps to break down phytate, thus increasing mineral availability.

Monogastrics such as pigs and poultry are unable to produce phytase. Cereals contain genes that code for phytase activity but the activity is not sufficient to break down all phytate compounds in the feed. Therefore, enzymes are added to the feed in conventional farming to help the animals utilise phosphorus. If the animals do not utilise phosphorus optimally, it can affect their growth and health. In addition, the non-digested surplus is excreted and ends up in the environment.

Researchers demonstrated phytase genes

The scientists succeeded in finding the genes controlling phytase activity, which in itself was an important step. Next,

they looked for a mutant wheat plant. This means that the plant's gene composition is a little different from "normal" wheat. This was the beginning of something big.

- We found the specific genes that are important to phytase activity in cereals. Then we found a mutant in which the phytase genes are expressed more powerfully than in ordinary cereals, resulting in an increased phytase activity, explains Professor Henrik Brinch-Pedersen, Department of Molecular Biology and Genetics.

The unique wheat type was optimised and patented in co-operation with the British company Plant Bioscience Ltd. The name of the new wheat is HIGHPHY.

Coping with the digestive system

The next question was if this super wheat with its increased phytase activity would be able to cope with the digestive system. The wheat was tested in broilers at Nottingham Trent University in Great Britain.

The broiler experiments showed that feed in which ordinary wheat had been completely replaced by HIGHPHY wheat improved digestion coefficients for calcium and phosphorus by 14.6 and 22.8 percent, respectively, compared to feed containing ordinary wheat and with a supplement of phytase.

Exciting perspectives for the new wheat

The new cereal may also benefit humans.

- 700 million people worldwide suffer from iron deficiency because of the high phytate level of their diets. If wheat containing its own phytate-metabolising enzyme became available, this could significantly improve the health of the population in many of these countries, says Henrik Brinch-Pedersen.

AU researchers have developed a unique wheat with specific abilities to increase the digestibility of phosphorus and other important minerals
Photo: Janne Hansen



Gene technology can combine **fertility with high milk yield**

Researchers have found several specific genes that affect fertility in dairy cows. This can give rise to improved selection without affecting milk yield.

For decades, intense genetic selection has increased the milk yield of dairy cows but has had a negative effect on their fertility. Researchers from the Department of Molecular Biology and Genetics at Aarhus University have, in collaboration with colleagues from China Agricultural University, come a step closer to solving the problem.

By investigating data from Holstein cows from the Nordic countries and China, the scientists have identified several genetic variants that are connected to dairy cow fertility. They found six specific genes that are strong candidates for dairy cow fertility.

The next step is to make detailed mapping of the genome to narrow down more precisely which genes are responsible. The researchers hope that this information can improve the possibilities for selecting for higher milk yield without compromising cow fertility.

Organic pig farmers may benefit from breeding for lower litter size and higher birth weight

Using sows that are bred to give birth to fewer but more robust piglets can contribute significantly to reducing early piglet mortality in organic pig farming.

Large litters and low birth weights are important risk factors related to high piglet mortality in organic pig production, according to an extensive on-farm study carried out by researchers from the Department of Animal Science at Aarhus University. There are therefore benefits to be reaped by using sows that give birth to fewer but larger piglets than by using highly prolific sows adapted to intensive indoor production systems.

Sows that give birth to more piglets than they can raise pose a major challenge in organic pig production. Large litters also result in reduced piglet birth weights, which is one of the reasons that many piglets die. If surplus piglets from fertile sows are to survive, they must be fostered by nursing sows. Otherwise, the piglets will die if not euthanised.

- The main problem for Danish organic farmers is that they use sows bred for intensive conventional production and not for organic production. In conventional production, which takes place indoors, there are management tools that can help the numerous small, weak, and surplus piglets that the sows cannot raise on their own. This is not an option to the same extent in outdoor systems where the sows farrow in huts in the field, says Professor Lene Juul Pedersen from the Department of Animal Science at Aarhus University.

She has been involved in research projects that have studied reasons for and possible solutions to the high piglet mortality seen on Danish organic pig farms. A possible solution is to use genetics that are better at fulfilling the needs of organic pig farmers for a more robust type of pig. In this connection, TN70 sows from the pig genetics company Topigs Norsvin were compared to traditional LY sows from Danbred with regard to, among other things, litter size and piglet traits. All the sows were inseminated with semen from Duroc boars from Danavl.

Both sow groups weaned the same number of pigs, but the pigs from the TN70 sows had higher birth and weaning weights. The TN70 sows gave birth to fewer piglets. However, that meant that there were teats enough for the majority of piglets. Therefore, the need for using nurse sows and/or euthanasia of weak and surplus piglets was reduced.

- Important criteria for a continued growth in the organic pig sector is to uphold good animal health and welfare. Being able to reduce mortality and wean heavier and more robust piglets is therefore crucial for organic farmers to comply with organic principles concerning high animal health and welfare and a resource-conscious production, says Lene Juul Pedersen.

Facts about the projects

- The project VIPiglet is part of the Organic RDD 2 programme coordinated by ICROFS (International Centre for Research in Organic Food Systems) and has received funding from the Green Development and Demonstration Programme (GUDP) under the Ministry of Environment and Food of Denmark.
- The project "Styrket beslutningsgrundlag og dyrevelfærd i økologisk svineavl" ("Stronger decision support and animal welfare in organic pig farming") is supported by Fonden for Økologisk Landbrug (Organic Farming Fund).
- Project partners include Aarhus University, Udviklingscenter for Husdyr på Friland (Development Centre for Free-range Farm Animals), Seges Økologi Innovation (Seges Organic Innovation) and organic pig farmers.

Some atmospheric sulphur comes from agriculture

For the first time, researchers can determine how much animal manure contributes to the atmosphere's sulphur content.

Existing emission estimations and climate models do not include agricultural production as a source of atmospheric sulphur. This assumption is incorrect, according to a study from Aarhus University.

Livestock manure emits sulphur in the form of hydrogen sulphide, which is quickly converted into sulphur dioxide in the atmosphere. The study shows that in areas with a high livestock density, sulphur from animal manure accounts for about half of the known sulphur emissions (in the form of sulphur dioxide) to the atmosphere. This means that hydrogen sulphide from animal manure accounts for approximately one third of total Danish sulphur emissions to the atmosphere.

On the face of it, it may seem odd that agriculture's contribution to atmospheric sulphur is so great. However, there have only been few and limited studies in this area in Denmark and abroad.

- This is partly due to the difficulties of measuring sulphur emissions from livestock production, explains Associate Professor Anders Feilberg, Department of Engineering at Aarhus University. He is one of the researchers behind the study.

- The development of PTR-MS (proton transfer reaction - mass spectrometry) allows us to monitor the emissions of sulphur compounds from livestock production very accurately and with a high time resolution, which provides extensive and very detailed data material, says Anders Feilberg and explains that in principle, PTR-MS is an online scale that weighs and counts air molecules.

New opportunities to limit emissions

In the atmosphere, sulphur forms chemical compounds with other elements and produces particles that are harmful to health.

Because of this, recent years have witnessed significant efforts to reduce atmospheric sulphur content. For obvious reasons, focus has been on well-known sulphur emission sources – primarily oil, coal and natural gases, which emit sulphur to the atmosphere via combustion engines, power stations, etc.

This study provides new opportunities to increase the focus on reducing sulphur emissions from livestock production. Aarhus University currently carries out research targeted towards the development of air purification technologies for animal housing, and technologies to reduce evaporation from animal manure. These technologies will contribute to reducing sulphur emissions.

Affects climate models

This new knowledge is important to the development of climate models. As mentioned previously, sulphur forms chemical compounds with other elements to create airborne particles. These particles reflect the rays of the sun, which in turn helps reduce global warming caused by climate gases. The particles also contribute to cloud formation, which increases reflection.

- The agricultural contribution has not been included in the climate models so far, and in the global perspective, this new knowledge will contribute to improving climate models. There is still a need for more measurements in more countries before we can clarify the significance in a global perspective, says Anders Feilberg.

Read more

The results are described in the article "Contribution of livestock H₂S to total sulfur emissions in a region with intensive animal production" published in Nature Communications.

Improved measurements of ammonia losses from dairy barns

Newly developed advanced equipment enables precise measurements of ammonia emissions from dairy barns.

Air pollution has negative consequences for human health, nature and the environment. In Denmark, agriculture accounts for more than 95 percent of the national emission of ammonia. One of the major challenges in Denmark is ammonia from livestock production, including ammonia emissions associated with livestock housing, storage of livestock manure, and manure application.

Dairy barns contribute significantly to the national emission. Therefore, the Danish Environmental Protection Agency requires implementation of reduced ammonia losses when new dairy barns are built or old ones are renovated – the Best Available Technology requirements.

Knowledge about ammonia losses from different floor and barn types is important. However, in practice it is difficult to measure ammonia emissions from naturally ventilated barns, resulting in uncertainty as to which floor types and technologies are the best in relation to reducing ammonia emissions.

A new study remedies this. Researchers from the Danish Technological Institute, Seges and Aarhus University examined ammonia emissions in eight cattle barns, four of which had slatted floors and four had solid drained floors.

The measurements showed that on average there were only minor differences between ammonia emissions from the two systems. Barns with slatted floors had on average an annual ammonia emission of 1.2 kg ammonia-nitrogen

per m², while barns with solid drained floor had an annual emission of 1.0 kg. When corrected for differences in feeding and space allowance per animal, barns with slatted floors had an average annual emission of 1.16 kg ammonia-nitrogen per m² while the corresponding figure for barns with solid drained floors was 0.89 kg.

These figures are contrary to Dutch studies from the early 1990's, where there was a 50 percent reduction in ammonia emission from barns with solid drained floors compared to slatted floors.

The new studies were carried out using recently developed and very accurate measuring equipment that can detect microscopic amounts of ammonia. Contrary to previous studies, the researchers now have significantly more data.

- Developments in measuring equipment have provided us with new and improved opportunities to develop floor and barn types that can reduce ammonia emissions, explains Senior Advisor Peter Kai, Department of Engineering, who was responsible for the study.

- We will be better able to detect precisely where ammonia emissions take place, and thereby pinpoint where to improve the housing systems, he says.

DCA report detailing the results

The results of the study can be found in DCA report no. 110, "Ammonia emission from Danish cubicle barns for dairy cows - Effect of floor type and manure scraping", which is available at dca.au.dk/en.

Quantifying **nitrate leaching** using models and measurements

Calculation of the extent of nitrate leaching from agricultural soils includes knowledge about the effects of fertilisation, crops, soils and climate on leaching.

It is important for both the environment and farmer that nutrients are utilised as well as possible. This is particularly true for nitrogen, where nitrate can leach to the aquatic environment if it is not utilised by the crops during the growing season, and if there are no catch crops or other vegetation that can take up nitrate during the drain season (autumn and winter).

Nitrate loss from the individual field depends on a range of soil, management and climatic factors that include level of fertilisation, crops, catch crops, soil type and weather.

Quantifying the extent of the losses is important for agriculture to modify crop management and fertilisation for minimising losses. In order to estimate nitrate leaching loss from all Danish fields, researchers from Aarhus University have developed the root zone model NLES4, which – based on the most important factors – describes the average leaching in Denmark. NLES4 scenario calculations were part of the basis for the government's Agriculture and Food Package that was adopted in 2016.

Determination of leaching

Nitrate leaching loss is determined by collecting soil water that percolates from the root zone and measuring the water's nitrate content. Leaching is expressed as the measured nitrogen concentration times the amount of percolation, the

latter of which is calculated using a water balance model. The water balance model (Daisy model) uses local climate data, local soil type and crop type grown in the field in its calculations.

Such measurements are extensive and demand considerable resources, so it is not realistic to measure nitrate and runoff from each and every field in Denmark. That is why models are used. The NLES model has been developed on the basis of comprehensive measurements and experiments. NLES4 includes 1467 field observations, approximately 1200 of which were collected from 1990 to 2004.

Explanatory factors for leaching in the model are the amount of applied nitrogen fertiliser, crop type, including which crops were grown the year before, catch crops, soil type and water percolation, especially during the autumn and winter.

- The collected data show that soil type, crops and percolation are particularly important for the differences in nitrate leaching. The amount of nitrogen fertiliser applied is less important for the amount leached as long as the level of fertilisation is less than the crops can effectively utilise. This is because there is a very low level of nitrate leaching from grass crops and somewhat higher from cereals and maize – that is, the difference between crops has the great-

est importance, explains Senior Researcher Christen Duus Børgesen from the Department of Agroecology. He is one of the researchers behind the development of the model.

NLES4 and the agricultural package

In connection with policy support prior to adoption of the so-called agricultural package, Aarhus University prepared a background analysis. In this analysis, the effect on nitrate leaching of a rollback of the nitrogen fertiliser norms, and thereby the possibility of higher levels of nitrogen fertilisation, were calculated using NLES4. The calculations, which comprised all cultivated fields in Denmark, were based on reported nitrogen use for the harvest year 2011. The analysis thus represented a situation in which the level of fertilisation was under the economically optimal nitrogen fertiliser level, i.e. from before the adoption of the agricultural package.

NLES4 estimated the effect of the increased use of commercial fertiliser on the national total average marginal leaching to be approximately 20 percent. This means that for every 10 kg nitrogen fertiliser applied to the field above the 2011 level, nitrate leaching is increased by 2 kg nitrogen. This is the so-called marginal leaching.

Marginal leaching re-evaluated

The data behind the agricultural package were subject to a heated debate in 2017. It was postulated that the NLES4 figures were not sufficiently validated and that the uncertainty of these estimates had not been quantified. Analyses using a previous version of the NLES model (NLES3) had shown a marginal leaching of about 30 percent, and the reasons for the lower marginal leaching rate of 20 percent from NLES4 was therefore debated.

- We all agree that it would have been better if we had calculated statistical uncertainty of NLES4 prior to the adoption of the agricultural package. Unfortunately, there was not enough time in the actual situation. The results were therefore published with the necessary reservations, but unfortunately without uncertainty estimates, says Christen Duus Børgesen.

- Recent studies, that were not included in the NLES4 dataset, have since corroborated the level of marginal leaching figures from NLES4. We can therefore confirm that the level

of leaching and marginal leaching calculated by NLES4 are on a roughly correct level, says Christen Duus Børgesen.

NLES4 better at reflecting real life

The explanation for changing the estimate of marginal leaching from 30 to 20 percent is quite simple. NLES4 is better at reflecting the marginal leaching that is valid for current agricultural practice. In particular, it better reflects the influence of cropping sequence on nitrate leaching.

For example, previous practice for applying animal manure in the autumn and winter led to greater marginal leaching. Today the level of fertilisation is lower and the manure is not applied until the spring when it is utilised more efficiently.

In addition, marginal leaching for grass, fallow and cereals with catch crops is very low. If these types of crops cover a greater portion of the cultivated land then marginal leaching will be lower.

Long-term effect is the most important

Another aspect is to which extent marginal leaching changes over time and with a different level of fertilisation. NLES4 calculates both the short-term and long-term effects of increased nitrate fertilisation on leaching. The long-term effect is calculated from the level of nitrogen fertilisation over a five-year period. The 20 percent is an equilibrium situation in relation to current practice and an increased level of fertilisation.

Professor Jørgen E. Olesen from the Department of Agroecology at Aarhus University is studying the long-term effects on long-term crop rotations.

- There are indications that long-term marginal leaching does not increase as sharply as short-term marginal leaching at a fertilisation level that is around the optimum. This is in agreement with the response in NLES4. The point is that the marginal leaching that we use – and must use – when evaluating the agricultural package and other political initiatives is the long-term effect. There are very few experimental studies of this, but the ones we are aware of from Denmark and other countries corroborate the level in NLES4, says Jørgen E. Olesen.

On the lookout for new agro-environmental measures

Denmark is among the best to test and adopt new measures for realising action plans for the aquatic environment, so it is difficult to find new ideas in other countries.

In Denmark a range of measures are applied to reduce nutrient leaching from agricultural fields to the aquatic environment. Even more measures expect to be added to the list, including possibly constructed wetlands with or without filter, paludiculture, buffer zones and controlled drainage.

In the hope of finding new or improved measures and approval procedures, the Ministry of Environment and Food of Denmark asked DCA – Danish Centre for Food and Agriculture to have a look at how seven other European regions with comparable climatic and growing conditions do things.

Unfortunately, there were not many new ideas to glean. The survey showed that the regions in question did not use more or better measures than Denmark.

- In fact, Denmark was among the best to test and adopt new measures. Neither did we find ideas for quick and easy approval processes for development and implementation of new measures. In many places, it rather seemed as though the approval process does not give the farmer the same possibilities that we provide in Denmark by a long

shot, says one of the researchers behind the study, Postdoc Martin Hvarregaard Thorsøe from the Department of Agroecology at Aarhus University.

The strength of the Danish system is particularly due to the facts that key researchers are always included early in the process and that there is great emphasis on documenting the measures and on taking measurements in the field before implementation.

However, the study did reveal a few good tips. With regard to the application procedures, it is important to evaluate the measures holistically, and to include more aspects, such as biodiversity, hunting, and climate effects when evaluating new measures.

Denmark can also be better at engaging in a dialogue with the affected landowners and other parties. The report also recommends that approvals be based on individual assessments of the measures and not on standard procedures.

Development of mini-wetlands with biofilters is underway

The sod has been turned for a new mini-wetland with biofilter. The aim is to generate more knowledge about this particular measure against nitrogen loss to the aquatic environment.

The first sod has been turned for the establishment of a new full-scale mini-wetland with biofilter (bioreactor with wood chips) at the manor Gyldenholm Gods in southwest Zealand. The system will help generate more knowledge and evaluation of how well mini-wetlands with biofilters are at removing nitrogen in both the short and long term and what the cost efficiency is.

Establishment of the system at Gyldenholm Gods is part of a new four-year project for which the Ministry of Environment and Food of Denmark has granted 15m DKK. The project, which is led by senior researcher Finn Plauborg from the Department of Agroecology at Aarhus University, is a collaboration between the Department of Agroecology and the Department of Bioscience.

The plan is to establish mini-wetlands with biofilters at various locations in Denmark. The aim is to work with system designs in order to maximise the nitrogen removal effect for the location in question. The nitrogen removal effect is dependent on temperature and hydraulic retention times, i.e. how long time a unit of water resides inside the filter.

The new test plant is located in an area with a system-drained catchment area. In connection with a previous project funded by the Green Development and Demonstration Programme (GUDP), there is already documentation for the relevant amount of water and nitrogen passing through the main drain at Gyldenholm Gods.

The unit receives water from a 120 ha catchment area and its hydrodynamics are significantly different in their runoff patterns and amounts from the existing research unit in Gjærn, upon which a large portion of the present knowledge about mini-wetlands with biofilters under Danish conditions is based.

- The unit at Gyldenholm Gods will reflect some of the challenges that can arise in connection with mini-wetlands with biofilters – and hopefully lead to proposals for how these challenges can be met, says Finn Plauborg.

Which new compulsory catch crops are most suitable?

There are differences between the effect and efficiency of potential compulsory catch crops in relation to their ability to reduce nitrogen leaching.

What will we be seeing as compulsory catch crops in Denmark in the future? Will the fields be filled with sunflowers, chicory, buckwheat or borage after the summer harvest and until the fields start to green with the next spring crop? Or will the catch crops be white mustard, grass or fodder radish?

Catch crops are one of the measures that farmers can use to reduce leaching of nitrogen from agricultural fields to the aquatic environment. The question is if new catch crops can be found that are more efficient at absorbing nitrogen from the soil – and that is what a research project at Aarhus University aims to elucidate.

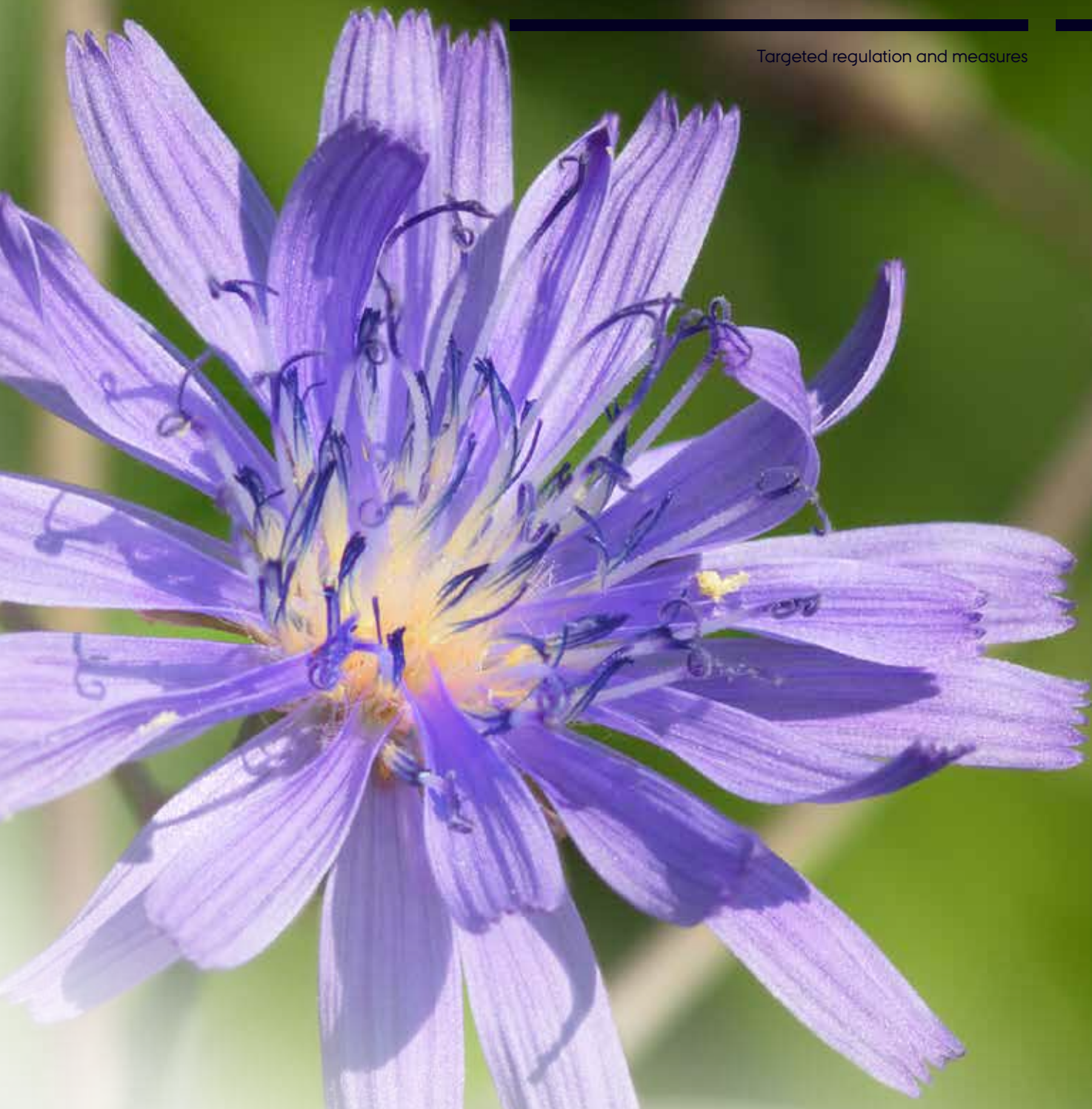
Researchers from the Department of Agroecology at Aarhus University are presently investigating a series of new catch crops with regard to their nitrogen uptake efficiency. They

are also looking at how well undersown catch crops can compete with the main crop – or if they cope too well and out-compete the main crop.

Potential new catch crops

In the screening trials, the researchers compare sunflower, mallow, common corn-cockle, linseed, buckwheat, borage, black oat and common oat with three of the present catch crops approved for use as compulsory catch crops in Denmark, namely fodder radish, spring barley and many-stalked rye. These species were sown after a spring barley harvest.

The study also includes the legumes common bird's foot, sainfoin, lentil and white clover in two grass mixtures and red clover in one grass mixture. These mixtures were all undersown in spring barley in the spring.



- There is a great demand for new compulsory catch crops. Present compulsory catch crops include cruciferous catch crops such as white mustard and fodder radish. The problem with these is that there is a risk that they will maintain or even propagate the serious fungal disease clubroot, explains Senior Researcher Elly Møller Hansen from the Department of Agroecology at Aarhus University.

Clubroot can lie in wait in the soil as a dormant danger for years and prevent the farmer from growing rapeseed for many years. Another challenge among the present compulsory catch crops is with the legumes.

- Legumes are in demand because they can fix nitrogen from the atmosphere and thus enrich the soil with nitrogen. However, the compulsory catch crops are first and foremost

supposed to reduce nitrogen leaching – not act as green manure. If you get a strong legume catch crop, such as vetch, then you risk greater leaching afterwards than if the catch crop had not been a legume. This is because legumes will contribute additional organically bound nitrogen which can be released outside of the following crop's growth season, says Elly Møller Hansen.

The best of the new catch crops must be able to cope with the main crop without out-competing it and they must absorb sufficient amounts of nitrogen. The most promising of the catch crops will be included in leaching studies in 2018.

The Danish Agricultural Agency has set up a committee to deal with selecting the most promising new species for the leaching trials.

Cultivation in plant residues **affects yields and the agroecosystem**

Planting white cabbage directly in withered legume residues without tilling the soil can give good yields and increase biodiversity.

Researchers from the Department of Food Science at Aarhus University are investigating new methods for organic vegetable cultivation in the European project SoilVeg. One of the methods that the researchers are studying is if weeds can be controlled and the agroecosystem promoted by planting the main crop, e.g. white cabbage, directly in plant residues from the service crop, e.g. winter faba beans and peas.

- For vegetable farmers, it might seem somewhat revolutionary to plant high-value crops like cabbage directly in plant residues and without tillage, but we can see that it has had

several favourable effects. One of the main reasons is that weed plants do not germinate to the same extent when plant residues cover the soil, says Science Leader Hanne Lakkenborg Kristensen, Department of Food Science, Aarhus University. She is in charge of the Danish project activities.

A roller crimper flattens the service crop

- Three to four weeks prior to planting the main crop, the service crops are flattened by means of a roller crimper.

- It breaks the stems instead of cutting or chopping them, and this stops their growth. When planting, we first use a harrow tooth and then the planting machine, explains Hanne Lakkenborg Kristensen.

You need to use the roller crimper before the service crop flowers to prevent re-growth or drop of seeds that can give weed problems later in the season.

Service crops ensure nitrogen fixation and biodiversity

It is also important to choose the right legume species to use as service crops. The Danish part of SoilVeg has had good experience with winter faba beans and winter peas.

Legume service crops have the additional benefit that they fix nitrogen. The plant cover and the reduced tillage promote insect diversity and improve the soil fertility in the long term.

The cropping method gives a yield somewhat lower than growing following traditional green manure mulching but requires less labour and fuel.

Facts about SoilVeg

Funding and coordination

The Danish part of the project is funded by the Green Development and Demonstration Programme (GUDP) and the EU via the ERA-net CORE Organic Plus under EU's Framework Programme 7.

CORE Organic is coordinated by the International Centre for Research in Organic Food Systems (ICROFS).

Duration

2015-2020

Partners

35 researchers and stakeholders from nine countries. Trials at 13 different experimental fields in Europe.

Danish seeds in the lead

Researchers from the Department of Agroecology are partners in a project that aims at reducing pesticide use and increasing grass and spinach seed yields.

Seeds do not take up much space individually but seen as a whole the production and export of grass and spinach seeds is important for Denmark. Danish farmers account for approximately half of EU's total production of grass and clover seeds and 75 percent of the world's spinach seed production.

Danish farmers are very good at seed production but the production can still be improved. Higher yields and reduced pesticide use are at the top of the wish list. At the same time, customer demands are high. Top quality grass seed is a must in order to produce turf that is slow-growing, very dark and absolutely weed-free. With regard to spinach seeds, only three weed seeds are permitted in a 250 g sample that typically contains 20,000-25,000 spinach seeds.

More and better grass seeds

Researchers from the Department of Agroecology, Aarhus University, are partners in a research project, Vinderfrø2025, which aims at developing sustainable solutions for reducing the need for herbicides while producing higher, top quality seed yields.

One of the goals of the project is therefore to achieve a better and more stable effect of plant growth regulators via differentiated and targeted nitrogen application and determination of the crop's precise requirements based on optimised crop monitoring. The goal is to find the optimal combination of developmental stage, climate, growing conditions, nitrogen rate, and application time and dosage of the plant growth regulators by means of sensor technology, among other things.

Another goal of the project is to reduce the use of herbicides in seed grass crops. This will be achieved by developing row cropping systems in which a combination of band spraying and inter-row mechanical weeding with treatments with selective herbicides in the rows will be used.

- In this way, we expect to reduce herbicide treatment frequency by 50-70 percent, says Senior Researcher Birte Boelt from the Department of Agroecology.

Super spinach seeds

Weeds and fungal diseases are the main challenges in spinach seed production. With regard to fungal diseases, the researchers will screen various cover crops for their preventive effect on wilt disease in spinach and investigate biological measures.

To prevent weeds, the researchers will investigate the possibilities for combining strip tillage and band spraying in the spinach rows with mechanical weeding or band spraying between the rows.

Facts about the project

Name

Vinderfrø2025

Duration

Four years beginning in 2017

Funding

15m DKK from the Green Development and Demonstration Programme (GUDP)

Partners

- The Danish Seed Council (project leader)
- Department of Agroecology at Aarhus University
- Seges
- DLF
- DSV-Frø Danmark A/S
- Barenbrug Danmark Aps
- Jensen Seeds A/S
- Vikima Seed
- Syngenta Danmark.

A man with short brown hair, smiling, stands in a field with his arms crossed. He is wearing a black jacket over a dark turtleneck and black trousers. The background features a clear blue sky, bare tree branches on the left, and a field of dry grass. A long shadow is cast on the grass to his right.

New times ahead for **European weed management**

Researchers from Aarhus University coordinate a European project supporting the implementation of sustainable weed management in Europe. Photo: Janne Hansen

Integrated weed management is the way to go for sustainable and resilient agriculture. A new Horizon 2020 project will support and promote its implementation in Europe.

Weed management in Europe will become more environmentally friendly if the concept of integrated weed management takes better hold on European farms – and that is the goal of a new Horizon 2020 project coordinated by Professor Per Kudsk from the Department of Agroecology at Aarhus University. The five-year project, which has been granted 6.6m Euros, aims to support and promote integrated weed management in Europe.

- The project will demonstrate that integrated weed management (IWM) supports more sustainable cropping systems that are resilient to external impacts and do not jeopardise profitability or the steady supply of food, feed and biomaterials, says Per Kudsk.

Overcoming barriers and spreading the word

The project will develop, test and assess management strategies delivered across whole cropping systems for four different management scenarios representing all the important crops in Europe.

The project partners will review current socio-economic and agronomic barriers to the adoption of IWM in Europe, develop and optimise new, alternative weed control methods, and create a toolbox of validated IWM methods.

The project will also design, validate and assess the performance and environmental and economic sustainability of context-specific IWM strategies for the various management scenarios that address the needs and concerns of end users and the public at large.

The project results will be available to end users via online information, farmer field days, educational programmes, dissemination tools and knowledge exchange with advisors and others who deal with IWM.

National clusters at the core

National clusters will be established in each of the participating countries. The concept of national clusters is a novel feature of the project. The national clusters are networks consisting of farmer organisations, advisory services, SMEs and research institutions. They will be responsible for de-

signing, on-farm testing, and conducting the preliminary validation of the IWM strategies studied in their country.

- The concept of national clusters is a result of experience and observations from earlier European and national crop protection programmes that show that true innovation only happens if all actors, i.e. end users, research, extension, and technology providers, work closely together and innovative solutions are customised to local conditions, says Per Kudsk.

Facts about IWM PRAISE:

Budget

7.1m Euros

Grant

6.6m Euros from EU's Horizon 2020 scheme

Duration

Five years beginning in June 2017

Project consortium

37 partners from eight different European countries

Partners

11 leading universities and research institutions in the area of weed management, 14 SMEs and industrial partners, and 12 advisory services and end user organisations

Danish partners

- Department of Agroecology at Aarhus University (project leader)
- Seges
- VKST
- Foreningen for Reduceret Jordbearbejdning i Danmark
- Agrolntelli
- Frank Poulsen Engineering Aps

Development of intelligent solutions requires access to data

Technological solutions that pave the way for sustainable agriculture of the future

EU project to pave the way for smart IT solutions in agriculture

The agricultural sector faces a technological paradigm shift where production is transformed to a web of interconnected objects (Internet of Things) that can be identified, measured, controlled and operated by remote control. In a major EU project, millions of Euros are dedicated to demonstrating and developing possibilities. The project is called "The Internet of Food & Farm 2020" and the purpose is to demonstrate – via 19 case studies – how smart technologies can help improve productivity and sustainability in European agriculture.

Finding the right nitrogen balance for clover grass and seed grass

The project SmartGrass coordinated by Aarhus University will develop methods that can help ensure that a precise amount of nitrogen is applied to fields with clover grass and grass seed. The project will develop camera technology to determine the proportion of clover in clover grass fields and to map yield potential and nitrogen status in seed grass with the aim of gathering knowledge about precise field fertiliser requirements. This knowledge will be converted into a nitrogen application map. A very accurate fertiliser spreader can ensure application of the correct amount of nitrogen.

Artificial intelligence reduces herbicide use

The purpose of the RoboWeedMaPS project is to develop a system by means of which camera and sprayer collaborate to recognise weeds and only spray if necessary. In collaboration with the company Datalogisk, researchers from Aarhus University will develop a system that can automatically recognise weeds detected in the field. The aim is to develop a sprayer-mounted camera. The camera will recognise the weed when the sprayer passes over it and only spray if necessary. This allows for a very efficient and targeted spraying of specific weeds.

Machines with artificial intelligence can help optimise nutrient and pesticide application. This will benefit the farmer's economy and reduce environmental impact. However, access to huge amounts of data are needed to train the computers.

For most people it is fairly simple to learn to recognise ordinary weeds and distinguish them from crops - at least if you remember to keep your knowledge of crop science up to date.

Computers are quite different. If a computer learns to recognise weeds, it will not forget, and the knowledge is easily shared with other computers. Once the computer learns to recognise a weed, the farmer will be aware of the situation in his fields with regard to weed composition and their growth stages in relation to the crop's competitiveness.

This will allow for an unprecedented optimisation of weed-ing measures. We can spray with the best possible herbicide mixture and dosage, spot spray or use robots to micro-spray at individual plant level. Perhaps a total weed overview will - in close interaction with the farmer's advisor - result in a realisation that a crop rotation change is the best solution for the environment and economy.

The problem with a robot is that it can easily recognise weeds only if the weed looks exactly like the previous weed. However, weeds never do; different degrees of light and shade, wind, humidity, turgidity or plant cover can make it difficult or impossible for the robot or programme to recognise the weed or other complex structures.

Machines can identify the problem and find the solution

How do we get machines to recognise complex structures such as plants that look different in different situations? This is done by providing them with a kind of artificial intelligence, also known as machine learning. Artificial intelligence means that the machine learns to recognise structures in something very complex, i.e. something that is very different from traditional, usual software. This is also known as deep learning. The more complex a structure, the more data are required. A significant amount of data and complexity is known as big data. Recognition of weeds is just one example of an area in which artificial intelligence will hugely influence today's farming.

- Big data gives us the possibility to develop machines that can notice problems in the field and provide the solutions or diagnoses themselves. We will have machines that remember how a certain field was cultivated in previous growth seasons and use this experience to optimise future treatments, explains Senior Researcher Rasmus Nyholm Jørgensen from the Department of Engineering at Aarhus University.

Lack of access is a barrier

Many data are collected in agriculture. They come from combine harvesters, tractors, field sprayers and sowing machines as well as satellites, aerial photos and drones. The general idea of deep learning is that data do not come from just one tractor or one machine. Big data comes from thousands of machines performing the same procedures repeatedly. Could a machine's lack of ability to apply fertiliser precisely be turned into an advantage? If a machine can document precisely where and how much fertiliser it applies, then even the "faulty" applications can give valuable information, since the field now becomes one big and complex fertiliser application study.

The problem in Danish agriculture is that data often do not make it further than the tractor or the data terminal. There are no joint platforms for data collection, and machinery manufacturers use different data standards. In addition, there are many unsolved questions regarding data ownership.

- There are enormous gains to be had for the industry if data from crop cultivation could be gathered in usable data formats that could freely be used in the development of machines with artificial intelligence, says Rasmus Nyholm Jørgensen.

Nurture the soil – it's worth it

Profitability and sustainability can go hand in hand in crop production – especially if cropping systems that protect the soil are developed and applied.

Researchers from the Department of Agroecology at Aarhus University are partners in a new EU project, SoilCare, that aims to test and promote soil-improving cropping systems across Europe. The project is based on the concept that profitability and sustainability in crop production can be combined and improved, but that it requires thought.

European crop production faces great challenges: Farmers need to maintain their competitiveness while at the same time minimising negative climate and environmental impacts. It may seem like a difficult task to combine these two things but it is possible if, for example, farmers apply cropping systems that contribute to nurturing the soil instead of depleting it.


- For generations an increasingly higher level of production has been maintained by increasing input, such as nutrients,

pesticides and energy consumption for soil tillage. This has contributed to masking losses in productivity due to reduced soil quality, says one of the partners in the project Professor Tommy Dalgaard from the Department of Agroecology at Aarhus University.

Agricultural soil quality is threatened by human actions that lead to erosion, compaction, loss of organic matter, pollution and loss of biodiversity.

Research-based development of new systems

The SoilCare project aims to alleviate these problems via research-based development of soil-improving cropping systems in a collaboration between farmers, businesses and researchers across Europe. The term cropping system refers to the farmer's choices, including crop type, crop rotation and agronomic management techniques such as tillage

A man with glasses, wearing a dark jacket over a patterned sweater, is crouching in a field of young green plants. He is holding a clump of dark, rich soil with roots in his hands. The background shows a vast, rolling green landscape under a clear sky, with some distant buildings and trees.

practice, strip sowing, irrigation, fertilisation, plant protection and planting of hedgerows.

Part of the project involves comparing different soil-improving cropping systems and thereafter identifying and testing promising systems that have a positive effect on profitability and sustainability in 16 different locations in Europe, including Denmark. The various locations represent different soil conditions, climatic zones and socio-economic conditions.

The particular problems that Danish agriculture experiences are reduced soil organic matter, soil compaction, erosion, and nutrient loss (nitrogen and phosphorous), and there is a need to investigate how to improve the incorporation of these issues into advisory and agricultural practice.

Facts about SoilCare

Budget

7.6m Euros

Financing

7.0m Euros from the EU's Horizon 2020 scheme

Partners

28 partners from 17 different European countries, including the Department of Agroecology at Aarhus University

Project leadership

Wageningen Environmental Research, The Netherlands

Duration

From 2017 to 2021

Website

soilcare-project.eu

It is worthwhile to take good care of our agricultural soil; researchers from Aarhus University are partners in an EU project that targets this issue.

Photo: Janne Hansen

New climate research infrastructure in place

Aarhus University is part of a new European research infrastructure that aims to examine changes in ecosystems due to changes in the climate and environment.

Decisions that farmers, consumers and politicians take in the face of climate change must be based on facts. By generating strong and verifiable facts, researchers are better able to provide the evidence for taking well-informed decisions. This is exactly what a new research infrastructure, in which Aarhus University is a partner, and which is led by the University of Copenhagen, aims to do.

The new research infrastructure is called Analysis and Experimentation on Ecosystems Denmark (AnaEE Denmark) and has been granted 20m DKK from the Ministry of Higher Education and Science for a five-year period from 2018 to 2022. Danish universities have granted an additional 25.5m DKK so the research infrastructure is ensured funding for the next ten years.

AnaEE Denmark is part of the European AnaEE, which is a common European research structure in which Aarhus University and the other partners commit themselves to providing access to studies in fields and other ecosystems as well as to instruments and data for other researchers. Sharing data and knowledge will make it easier for researchers to carry out studies across several types of ecosystems, thus strengthening the data basis for use in e.g. climate and ecosystem modelling.

From Aarhus University, the Department of Agroecology and the Department of Bioscience will participate with field experiments in cropping systems, artificial ponds and grasslands.

Read more about AnaEE Denmark at anaee.dk.

Measurements of changes **in global land** use improved

A new database can be used to assess how land use changes affect the climate on the global level.

The world's growing demand for food and feed as well as biomass for bioenergy means that increasingly larger natural areas are being used for agricultural production. This has a significant impact on greenhouse gas emissions and biodiversity, and has socioeconomic consequences, among other things.

If we are to have an overall understanding of how human land use affects the environment, including the climate, then it is crucial to have a correct picture of how the world's land is being used and of the changes that are taking place in this land use. Researchers from the Department of Agroecology at Aarhus University have created such an overview in a new database based on satellite data and FAO statistics.

By combining data on how much land is covered by forest with data that indicates if the green canopy is primary forest, secondary forest, planted forest or permanent crops, the researchers have made it possible to see the bigger picture.

- Since more than 10 percent of total greenhouse gas emissions are due to land use changes, it is important to be aware of these changes when estimating the derived consequences of land use changes or assessing the total effect on greenhouse gas emissions of a given production. The new database provides a total overview on a comparable basis, says one of the researchers behind the studies, Senior Researcher John E. Hermansen from the Department of Agroecology at Aarhus University.

Growing green **biomass** can reduce **nitrogen leaching** and provide farmers with sustainable protein

Researchers from Aarhus University and the University of Copenhagen are examining the potential of increasing biomass production in the Limfjord area. Farmers are positive.

In recent years, research activities at Aarhus University in Foulum have demonstrated that increased cultivation of perennial crops such as grass and clover grass can reduce the agricultural loss of nitrogen to the aquatic environment. A shift in this direction can also contribute to a reduced use of pesticides and increased soil carbon stocks.

Green grass crops contain up to 20 percent protein. Trials at AU Foulum have shown that it is possible to extract a significant amount of protein with a quality that means it can be fed to pigs and poultry. Grass protein can thus replace imported soy protein.

The experiments also demonstrated that the residual pulp seems to have a better cattle feed value than regular grass feed. The likely reason for this is that the juicing makes the grass fibres more available to the microorganisms in the rumen. Pulp can thus replace maize, the growing of which has a high nitrate loss.

Possible solution of the Limfjord problem

According to the Danish Action Plans for the Aquatic Environment, there must be a significant reduction in nitrogen emissions to the Limfjord by 2027. In some parts of the Limfjord area, it can be difficult to achieve these targeted reductions by means of well-known measures such as wetlands and catch crops. This means it could be necessary to leave agricultural land fallow.

Cultivation of perennial grass crops can provide a measure to solve the problems related to the aquatic action plans in the Limfjord area and similar areas.

The Ministry of Environment and Food of Denmark therefore commissioned DCA – Danish Centre for Food and Agriculture to examine the potential of increased biomass production in the Limfjord area. Senior Researcher Uffe Jørgensen from the Department of Agroecology is in charge of the study.

In connection with the study, AU Foulum held a workshop in the autumn 2017. Farmer and chairman of the Farmer Association Limfjord Claus Clausen participated in the meeting. He has a dairy farm in the western part of Viborg Municipality, and therefore grows quite a bit of grass for feed.

- The Danish climate is perfect for grass production, and grass is relatively easy to grow. I am pleased that Danish research efforts focus on making biomass production a profitable industry. If we succeed, and it all comes together, we may have a new line of business, says Claus Clausen.

Together with a number of farmers and company representatives, Claus Clausen is part of a scientific focus group to provide input to the researchers' analyses of the potentials of shifting to biomass production. Focus group participants also include the Danish Society for Nature Conservation, represented by Senior Advisor Thyge Nygaard, who also participated in the AU Foulum workshop.

- It was an excellent opportunity for practitioners and researchers to meet in order to focus on solutions to the benefit of agriculture and the environment instead of arguing over reduction targets, says Thyge Nygaard.

National test plant in the pipeline

One of the world's first large-scale green biomass refineries is currently being established at AU Foulum. The Ministry of Environment and Food of Denmark, the Central Denmark Region and the companies Arla, Danish Crown, DLF and DLG have granted a total of 19m DKK to the project.

According to plan, the new plant will be ready by early summer in 2019 and will have a capacity of approximately 20 tons of biomass per hour, enabling it to document the possibilities of processing e.g. grass on a scale that resembles real life.

- The grant provides us with excellent opportunities to work on a major scale, says Associate Professor Ib Johannsen, Department of Engineering at Aarhus University. He is the manager of Centre for Biorefinery Technologies at AU Foulum.

- We are pleased that the first financial calculations indicate that the production may be profitable and become an actual business. However, we must have patience. We need further studies to answer many questions before building a full-scale plant, says Ib Johannsen.

Esben Lunde Larsen, former Minister of Environment and Food of Denmark, states that the aim of the grant is to ensure that Denmark will be in a leading position in biorefining.

- Denmark will now have Europe's largest and most advanced green biorefining demonstration platform. This will ensure the best conditions for creating as much value as possible from biorefining of grass – straight from the field to final high-value products for both humans and animals, says Esben Lunde Larsen.

Need for further knowledge about the production of protein from green biomasses

Green biomass has significant potential as an alternative to traditional protein sources. However, further knowledge is required about the economic and environmental consequences if commercial production is to be implemented, according to the DCA report "Green biomass - protein production through bio-refining", written by researchers from Aarhus University in collaboration with the University of Copenhagen, Aalborg University and Seges.

The report sums up current knowledge about biotechnological and economic problems in relation to the production of protein from green biomasses in Denmark.

The report is available for free download at dca.au.dk/en/

Practitioners and researchers exchanged experience

Conversion from production of annual crops to perennial crops depends on the ability to make green protein production profitable, and there are many unknowns. On 3 October 2017, farmers in the Limfjord area were invited to participate in a workshop at AU Foulum to get their input on how to implement this production cheaply and efficiently. The researchers presented the preliminary results of their studies, and the farmers were given a demonstration of protein extraction at the experimental plant at AU Foulum.



Aarhus University establishes new interdisciplinary thematic centres

The Faculty of Science and Technology at Aarhus University has established seven new interdisciplinary research centres with the purpose of focusing efforts on development of solutions to the "Global Grand Challenges".

The centres will gather researchers and students from different scientific disciplines and create synergies between the faculty's departments and other units. The centres are a portal for national and international collaborators from the industry. Via collaboration on joint research projects, the centres will focus on developing research-based technologies and solutions to societal challenges.

The departments related to DCA – Danish Centre for Food and Agriculture are part of four of these new centres. In addition, the centres iMAT – Aarhus University Centre for Integrated Materials Research, and DIGIT – Aarhus University Centre for Digitalisation, Big Data and Data Analytics were established in 2017.

iFOOD

– Aarhus University Centre for Innovative Food Research

With the establishment of a new strategic research centre in food research, Aarhus University will strengthen its focus on innovating sustainable foods of the future. The centre is called iFOOD and opened in September 2017.

iFOOD will bring together leading experts in food research from the Faculty of Science and Technology, Faculty of Business and Social Sciences and Faculty of Health. iFOOD's mission is to develop and carry out excellent research, innovation, and talent development in the food sector.

- The food sector affects our lives in ways we may not even realise. For instance, we are witness to an unsustainable relation between food consumption, lifestyle diseases and public health. We also need to focus on more sustainable production technologies in order to minimise food waste via the use of more appropriate packaging. We are now concentrating scientific expertise and focus to create new and valuable knowledge within the entire range of food research, says Professor Lotte Bach Larsen from Department of Food Science and head of the new research centre.

iFOOD will work towards a paradigm shift within food production and consumption; a shift that meets consumer expectations in relation to food that is healthy, nutritious, appetising and easy to cook, and based on a production system that can be sustained in the future. This can be achieved by e.g. increasing the selection of plant-based foods in modern supermarkets.

Read more at ifood.au.dk



CBIO

- Aarhus University
Centre for Circular
Bioeconomy

Denmark is developing towards a circular bioeconomy, and Aarhus University's new CBIO – Aarhus University Centre for Circular Bioeconomy will strengthen this development. The centre will gather research competences across Faculty of Science and Technology departments with the purpose of developing circular bioeconomy.

Generally, centre research activities will contribute to the establishment of new companies and business areas within biobased economy, including the production and marketing of new Danish protein for feed and food production.

- For a number of years we have studied all aspects of the value chain, and it holds significant potential to gather and strengthen these activities in a centre, thus ensuring improved synergies. I look forward to integrating knowledge along the entire production chain, and – in a long-term perspective – to develop, analyse and initiate actual product chains in collaboration with the industry, says Senior Researcher Uffe Jørgensen, Department of Agroecology, and head of the new centre.

Read more at cbio.au.dk



iCLIMATE

- Aarhus University In-
terdisciplinary Centre
for Climate Change

It will require a strong knowledge basis if Denmark is to maintain its leading position within climate research and adaption. Via the new strategic research centre, Aarhus University combines classic natural science, research-based policy support, engineering and social sciences in order to study the basic science challenges, and to provide practice-oriented solutions in collaboration with the industry and public authorities.

iClimate research centre partners comprise The Department of Environmental Science, Department of Bioscience, Department of Geoscience, Department of Agroecology, Department of Chemistry, Department of Engineering, Department of Animal Science and Department of Food Science; all Aarhus University. Further partners are DCE – Danish Centre for Environment and Energy as well as DCA – Danish Centre for Food and Agriculture.

Read more at iclimate.au.dk



WATEC

- Aarhus University
Centre for Water
Technology

Without comparison, pure water is the most limited resource globally speaking; no water – no society. Internationally, Danish expertise and research in water technology is in a league of its own within all aspects of water cycles, and now Aarhus University further strengthens these efforts via the strategic WATEC research centre.

WATEC partners include the Department of Bioscience, Department of Agroecology, Department of Engineering, Department of Environmental Science, Department of Geoscience, and the Interdisciplinary Nanoscience Center.

Read more at watec.au.dk



Bring wild cherry plums back on the plate

Wild cherry plums, European crab apple (wild apple) and blackthorn: wild Danish plants are a hit in the Nordic kitchen, and production based on these plants could offer a renewal in the Danish fruit industry. This is the conclusion of a research project in which researchers from the Department of Food Science at Aarhus University together with a team of chefs and producers of seeds from wild fruits examined the opportunities of developing new foods and ingredients based on wild Danish plants. The project resulted in a number of recipes involving the wild raw materials and, according to both researchers and chefs, the wild plants hold significant potential.



Agricultural science at Aarhus University in the world elite

According to the "Academic Ranking of World Universities" (ARWU) 2017, Aarhus University ranks as number 8 among the world's 500 best universities in the area "Agricultural Sciences". The universities are ranked according to various parameters, including number of publications in international scientific journals and how often other researchers cite these publications.

There are various global rankings and several of these also rank Aarhus University in the top 10 in agricultural research; one of these is the National Taiwan University (NTU) Ranking.



New knowledge about sow stress during transport

Researchers from Aarhus University have, together with colleagues from the University of Copenhagen, studied transport fitness in slaughter sows.

Each year, approximately 400,000 Danish sows are transported to abattoirs. Slaughter sows are a particularly vulnerable animal group with regard to transport fitness, as they are typically older than ordinary slaughter pigs, and may have various disabilities and injuries.

Results from the research project show that, under Danish conditions, transport to the abattoir is stressful for sows. Transport quality in particular – such as lorry temperature, duration of transport and time spent at the abattoir prior to unloading – stresses the sows.



Researchers and the horticultural industry control waste in potted plants

Danish plant nurseries produce 600 million potted plants annually, making Denmark the second largest exporter of ornamental plants. However, along the distribution chain from nursery to consumer, many plants are wasted. Researchers from the Department of Food Science at Aarhus University have studied this issue in the research project MinimalSpild (minimum waste), granting a wish from the horticultural industry.

One of the means to fight wastage of potted plants is implementation of new types of packaging, in which the plants are packaged in sealed instead of open bags. In this way, they can keep without water up to three times longer. The researchers have also developed a new measuring suitcase that can reveal where in the supply line that the plants are exposed to increased ethylene concentrations, which shorten shelf life. The researchers emphasise that the most important factor is that all parts of the horticultural industry cooperate to meet the challenges.



Focus on the role of livestock drivers

Farmers, slaughterhouses and livestock drivers all play central roles for dairy cow welfare at slaughter. However, so far no studies have focused on the role of livestock drivers.

Researchers from Department of Animal Science at Aarhus University has carried out the most extensive study so far of the role of livestock drivers in the assessment of dairy cow fitness for transport to slaughter. The study showed that 35 percent of the drivers stated that they are frequently in doubt when assessing dairy cow fitness for transport. The researchers conclude that this area should be given more attention e.g. in the form of new technology, rules that are more readily applicable, and training and advisory services.

The results have been published in the scientific journal Research in Veterinary Science.

DCA reports

about food and agriculture

DCA – Danish Centre for Food and Agriculture publishes reports describing research and test results targeted Danish conditions. The reports are often based on commissioned policy support tasks.

In 2017, DCA published the following reports, most of them in Danish, and all of which are available for free download at dca.au.dk:



Food and consumers

- Consumer interest in eating insects
- Will new life situations change meal habits and create a different need for information on healthy diets
- Diet information and new media – a pilot study on application and trust
- Food and meals at school
- Growth potentials in Danish gastronomy
- Quality index 2016
- Motivation for healthier diets at technical colleges
- Opinions on food and meals for the elderly in their own homes

Livestock production

- Ammonia emission from Danish cubicle barns for dairy cows
- Opportunities for antibiotic-free production of organic milk and pork in Denmark
- Employee experiences with and views on animal welfare in Danish livestock production
- Thematic meeting on current mink research
- Danish livestock genetic resources
- Causes of foot pad lesions in organic broilers
- Identification of risk factors and strategies for reducing sow mortality
- The importance of practical training to students' understanding of animal welfare

Agriculture and crop production

- Survey of neighbouring countries' nitrogen and phosphorus measures
- Protocol for biocarbonate extraction of inorganic phosphate from agricultural soils
- Nutrient balances and nutrient surplus in agriculture 1995/96-2015/16
- Applied Crop Protection 2016
- Green biomass - protein production through biorefining