

The basis of bioeconomics is the utilisation and management of fresh photosynthesis, rather than a fossil economy based on preserved photosynthesis (oil). NIBIO is to become the leading national centre for development of knowledge in bioeconomics. The goal of the Institute is to contribute to food security, sustainable resource management, innovation and value creation through research and knowledge production within food, forestry and other biobased industries. The Institute will deliver research, managerial support and knowledge for use in national preparedness, as well as for businesses and the society at large.

NIBIO - Norwegian Institute of Bioeconomy Research was established July 1 2015 as a merger between the Norwegian Institute for Agricultural and Environmental Research, the Norwegian Agricultural Economics Research Institute and Norwegian Forest and Landscape Institute.

Green knowledge

32 examples of research from NIBIO



Green knowledge

32 examples of research from NIBIO

Editor: Camilla Baumann
Title: Green knowledge – 32 examples of research from NIBIO

Text and photos: Anette Tjomsland, Kathrine Torday Gulden, Kjersti Kildahl, Liv Jorunn Hind, Jon Schärer, Siri Elise Dybdal, Lars Sandved Dalen, Morten Günther, Erling Fløistad and Camilla Baumann

Photo editor: Erling Fløistad
Chief editor: Ragnar Våga Pedersen

Cover photo and photo on page 6-7: Lars Sandved Dalen

NIBIO BOK 2(9) 2016 (English)
ISBN: 978-82-17-01909-1
ISSN: 2464-1189

This is a translation of the original Norwegian publication “Grønn kunnskap - 32 smakebiter fra NIBIOs virksomhet”, NIBIO Bok 2(9) 2016. ISBN 978-82-17-01685-4.

Production: www.xide.no

www.nibio.no

Preface

NIBIO – the Norwegian Institute of Bioeconomy Research – develops knowledge on what the Norwegian bioeconomy actually is. NIBIO has a strong focus on sustainability, value creation and the primary industries' knowledge requirements. At the same time, the environment, resource base and climate are core areas in our work. This gives us a unique combination of expertise, with which we can integrate questions of production with environmental challenges, and where economic and social dimensions are included. Basic knowledge of biology and biological processes linked to advanced technology provides us with opportunities for new understanding, new solutions and increased value creation.

It is important for NIBIO that our knowledge is of use for industry, the administration, decision makers and other research institutions.

NIBIO – Norwegian Institute of Bioeconomy Research was established July 1 2015 as a merger between the Norwegian Institute for Agricultural and Environmental Research, the Norwegian Agricultural Economics Research Institute and Norwegian Forest and Landscape Institute.

In this brochure we present a taste of the projects we have worked on in NIBIO's first year, examples that show the institute's breadth and potential.

Nils Vagstad
CEO

This is NIBIO



Division of Food Production and Society

The Division is a leader in central research areas such as agronomy, crop production, the cultural landscape and social research. Researchers contribute to innovation and value creation in the whole value chain for agriculture and food production, and produce applied knowledge for the administration, industry and society.



Division of Biotechnology and Plant Health

The Division has the country's greatest expertise in plant health and plant protection, carrying out research on the diagnosis, biology, charting and combating of organisms leading to plant diseases, pests and weeds. Other themes are biotechnology, algae, pesticides and chemistry of natural substances.



Division of Geography and Statistics

The Division's core expertise is within the areas of economic statistics and analysis, resource mapping and geomatics. The Division works among other things with data capture, data management, comprehensive analysis and wide dissemination. The Norwegian Genetic Resource Centre and the Budget Committee for Agriculture are included in the Division. The administration, industry and political leadership are the Division's target groups.



Division of Forest and Forest Resources

We conduct research, chart and disseminate our findings for knowledge-based management and value creation in forest and outlying areas. This includes sustainable resource use, optimal forest production, registration of forest and outlying areas, the climate impact of forest and other land use, and the development of the industry and efficient value chains.



Division of Environment and Natural Resources

We are an innovative research and development environment in the areas of soil, water, bioenergy and environmental technology. Climate and environmental measures are central, and we are working to develop sustainable, holistic solutions and services. The Division has significant international activity.

Selected Key Figures:

Number of employees: approximately 700

Operating income first 12 months: about 701 million Norwegian crowns

Number of international projects: approximately 100 where half are EU or EEA projects

Present in all regions of Norway

Content

Preface.....	3
This is NIBIO.....	4
Not enough research in the food industry.....	8
Nature’s report card.....	9
30 years of forest health monitoring.....	10
Forest Gallup poll.....	11
Agriculture affects water less than thought.....	12
It has come to the soil and in the soil it should remain.....	13
Soil is more than ‘just soil’.....	14
The world sees Norway’s “Tilbakeblikk”.....	15
Blackcurrants can give new life to old greenhouses.....	16
Norwegian beer to become more Norwegian.....	17
High-tech Kinder Eggs for agriculture.....	18
Quality leads the way for Norwegian wool.....	19
Smart tobacco.....	20
Towards a zero emission society.....	21
Fish sludge can become plant fertilizer.....	22
Warning lights for West Norway’s “Vestlandsk raudkolle”.....	23
The Forest Portal ensures forestry and the environment.....	24
How much water can grain tolerate?.....	25
Bioeconomy and environmental considerations in the forest.....	26
Deer die on the road.....	27
Scientists collect seeds from healthy ash trees.....	28
Freezing healthy plants for the future.....	29
Climate change leads to an increased northern bark beetle population.....	30
Small roundworms cause expensive damage.....	31
Potato defence against common scab.....	32
Integrated plant protection in the entire food chain.....	33
Effects of tillage on flat areas.....	34
The global water footprint – not suitable for Norwegian forests.....	35
Excrement in water – from animals or people?.....	36
Recreation replaces production at mountain summer farms.....	37
The milking robot – important in modern agriculture.....	38
Breakdown of pesticides in the Norwegian climate.....	39





32 EXAMPLES OF RESEARCH FROM NIBIO



Photo: Erling Fløistad



Not enough research in the food industry

Despite increased value creation in the food industry, the proportion used for research is low, as shown by the NIBIO report “Food and Industry 2015”. This report describes the status and trends for key areas of the Norwegian food industry.

The report shows a generally positive development in the Norwegian food industry, with increases in the number of companies, production value, gross investment and value creation. However, at the same time the use of own funding for research is at a level far below that of other Norwegian industries.

Norway has high wages and raw material costs compared with the European Union. Even with the protection afforded by tariffs, the industry notes increased competition from abroad. The Norwegian share of the domestic market has dropped by just under 10% in the latest ten-year period, the NIBIO report shows.

Research and research-based innovation are prerequisites for the Norwegian food industry to remain competitive. They are also essential for adapting to a bioeconomic future.

Bioeconomy is about abandoning a fossil fuel-based economy based on coal, oil and gas, and instead using and managing renewable, biological resources from land and sea. Sustainable, effective and profitable food production is an important part of the bioeconomy.

Statistics on the food industry are available on the website www.matogindustri.no (Norwegian).

Purpose:	The annual NIBIO report “Food and Industry” describes the status and trends for key areas of the Norwegian food industry.
Funding:	FoodDrinkNorway, the Research Council of Norway, Federation of Norwegian Agricultural Cooperatives, the Norwegian Food and Allied Workers Union and the Norwegian Agriculture Agency.
Contact:	Senior Adviser Ivar Pettersen, e-mail: Ivar.Pettersen@nibio.no , mobile phone: +47 905 97 320. Division for Geography and Statistics.



Photo: Per Vesterbukt



Nature's report card

What is the state of nature in Norway? The Norwegian Nature Index provides answers.

The Norwegian Nature Index describes the development of biodiversity in the major ecosystems sea, coast, freshwater, open lowlands, forests, wetlands and mountains. The index also provides knowledge of how humans affect nature, for example through farming, forestry or road building. This makes it possible for authorities to implement targeted interventions based on knowledge of the problem areas.

Each ecosystem gets a "grade" in the form of a value from 0 to 1. A value of 1 is given when nature is more or less untouched by human influence. The closer the value is to zero, the more the ecosystem has been damaged. Index values in 2014 were highest in freshwater (0.75) and the marine ecosystems (0.62-0.72), and lowest for forest (0.37) and open lowlands (0.47).

To arrive at these values researchers have used over 300 indicators, based on things in nature that can be counted, measured or calculated, and that are important in their ecosystems. They could for example be animals or trees.

Research Scientist Line Johansen at NIBIO has participated in the expert group for the ecosystem open lowlands, which received the lowest value in 2014. Johansen points out that this is the result of changed land use.

"Since 1950, there has been a change in agriculture from extensive operating methods to more intensive and effective methods of food production. This has affected the biodiversity negatively. On the other hand, many farms have been discontinued and large areas of open lowlands have been laid fallow and are undergoing afforestation," explains Johansen.

Another purpose of the Nature Index is to uncover where there is a need for more knowledge to assess the development of biological diversity.

"There is a lack of knowledge about the proportion of these areas that are undergoing afforestation, that have been fertilised or otherwise changed, and about the speed of these changes," says Johansen.



- Purpose:** The Norwegian Nature Index makes it possible for authorities to implement targeted interventions based on knowledge of different nature types and problem areas.
- Collaboration:** The University of Oslo and the Norwegian Institute for Nature Research (NINA).
- Funding:** Norwegian Directorate for Nature Management (now part of the Norwegian Environment Agency).
- Contact:** Research Scientist Line Johansen, e-mail: Line.Johansen@nibio.no, mobile phone: +47 920 50 697. Division of Food Production and Society.



Photo: Volkmar Timmermann.

30 years of forest health monitoring

There are over 11 billion trees in the Norwegian forest. The timber value alone amounts to several hundred billion Norwegian crowns. To protect these values, researchers follow the forests' state of health and monitor harmful fungi and insects.

The Norwegian Monitoring Programme for Forest Damage was among other things initiated due to extensive forest death in central Europe in the mid-1980s. As part of the European forest health monitoring, tree health is measured at 2600 measurement points around the country. These measurements can be compared to a national health survey, in which a group of people are followed throughout their lives, and in which blood samples are taken which may say something about the population's health status.

But trees do not have blood vessels, so instead the condition of the tree crown is evaluated. Branches and needles or leaves make up the crown, and the trees' health is therefore judged from observation of the crowns' condition.

“Low crown density reflects the degree of stress or damage the tree has been subjected to,” NIBIO-biologist and expert on fungi Volkmar Timmermann explains.

Researchers have established monitoring sites in three places in Norway where intensive and detailed surveys are carried out. Samplers that collect rain or snow have been set up to, among other things, measure the acidity (pH) of the precipitation. In addition, measurements are made in the water that falls through the canopies, throughfall. Water in the soil under the trees is also collected and analysed for contents of nutrients, aluminium, pH and sulphur and nitrogen compounds. In addition, measurements are made of needle chemistry, tree growth, and changes in vegetation.

However, the monitoring programme's regular registrations are not always sufficient to detect new pests. Thus, it is important that those who visit the forests are observant and report damage they see. One way to report damage is through the Web portal skogskader.no (Norwegian).



Purpose: Researchers follow forest health status and monitor harmful fungi and insects in order to protect forest value.

Collaboration: Norwegian Institute for Air Research (NILU)

Financing: The Norwegian Ministry of Agriculture and Food

Contact: Research Scientist Volkmar Timmermann, e-mail: volkmar.timmermann@nibio.no, mobile phone: +47 971 59 901, Division of Biotechnology and Plant Health.



Photo: Lars Sandved Dalen.

Forest Gallup poll

The National Forest Inventory's statistics provide important knowledge for sustainable management of our forest resources.

The National Forest Inventory does not count and measure all of Norway's over 11 billion trees. Instead a sample consisting of 300 000 trees is taken. These trees are representative of the country's forests and selected at random for the inventory.

Norway is divided into a grid of squares which make out 3 x 3 km each. Every square contains one study site. In all, there are 13 000 forested sites like this spread out over the whole country. If there are trees there, the site is visited by field workers every fifth year.

From the forest registrations, forest researchers can calculate how many trees are present in the forest and how much timber there is in different types of forests, for example how many cubic metres of timber the trees amount to. Forest statistics also provide information on growing conditions, how much forest is found in steep and inaccessible terrain, how far it is to the nearest forest road, and how profitable it is to harvest the forest based on given prices and demand.

The National Forest Inventory's figures also provide knowledge about Norway's future forest resources.

How the forest appears today provides us with information concerning when the forest is ready for harvest.

"This is important information for the wood products industry, for example, for planning a new wood product factory or a new sawmill," explains Aksel Granhus, leader of the National Forest Inventory at NIBIO.

Over the last ten years it has become increasingly important to gain knowledge about the forest as habitat for insects, fungi, birds and other animals. Thus, habitats for red-listed species have, through environmental inventories in the forest (MiS), become a part of the forest inventory.

"Many red-listed species are located in the forest. It therefore goes without saying that it is important to manage the forest properly and also important with knowledge of the forest as habitat for these endangered species," Granhus says.



- Purpose:** Forest statistics provide important knowledge for sustainable management of our forest resources.
- Collaboration:** Norwegian Biodiversity Information Centre, Norwegian Institute for Nature Research.
- Funding:** The Norwegian Ministry of Agriculture and Food.
- Contact:** Head of Department, National Forest Inventory, Aksel Granhus, e-mail: aksel.granhus@nibio.no, mobile phone: +47 974 82 012, Division for Forest and Forest Resources.



Photo: Ragnar Våga Pedersen

Agriculture affects water less than thought

GIS analyses reveals that over half of the 3000 Norwegian streams and rivers today characterized as “influenced by agriculture” should be re-evaluated.

A large percentage of Norwegian water bodies are at risk of not achieving the goals of the Norwegian water regulation due to agricultural impact. To date, agriculture is number three on the list of factors affecting water, after hydropower development and long-range transported pollution.

Only 3% of Norway’s land is used for agriculture and it is important to find out whether or not a large percentage of the country’s water bodies actually are as greatly affected by runoff from farming as is assumed today. To study whether the influence of agriculture has been estimated correctly, NIBIO developed a GIS-based methodology for the characterization of rivers and streams. During the spring of 2015 over 3000 river bodies were analysed, all characterized as “influenced by farming” in the management tool Vann-nett. The results from the analyses suggest that over half of these water bodies are not affected by agriculture.

Water management in Norway is divided into 11 water regions, which in turn are divided into 105 water districts and 30,000 water bodies. Some of these water bodies are relatively large because of the desire to have a reasonable number of management units. A possible result of a characterisation like this is that a stream which is not affected by agriculture is still registered as such because it is part of a larger water body.

“The results of our GIS analysis show that the impact from agriculture as it is presented today is overestimated,” says project leader Stein Turtumøygard from NIBIO.

Out of the river segments characterized as affected by agriculture, 53% can most likely be re-evaluated as the opposite. The results from the GIS analysis contribute to making it easier to prioritize which water bodies should be broken up into smaller units.



Purpose: To provide a more accurate picture of the impact agriculture has on rivers and streams in Norway than has been the case based on previous characterisation work.

Collaboration: The Norwegian Agriculture Agency and the Norwegian Water Resources and Energy Directorate/<http://vann-nett.no> (Norwegian)

Funding: The Norwegian Ministry of Agriculture and Food.

Contact: Senior Adviser Stein Turtumøygard, e-mail: stein.turtumoygard@nibio.no, mobile phone: +47 926 48 180. Division of Environment and Natural Resources.



Photo: Ove Bergersen



It has come to the soil and in the soil it should remain

In collaboration with archaeologists, scientists from NIBIO have examined soil layers on construction sites to find out whether cultural heritage can be removed, or if it is best left where it is.

According to Norwegian law, cultural heritage monuments from the Middle Ages are kept *in situ* if the conditions are right for it, i.e. they are preserved for posterity where they are, in the soil or on the ocean floor. Old organic material such as wood can be destroyed if it is exposed to oxygen.

Senior Research Scientist Ove Bergersen travels around the whole country to take soil samples from different building sites.

“From the Middle Ages and onwards people just built on top of what was already lying there. They trampled down dirt and rubbish and laid out new buildings and other things on top. These soil layers, which can include everything from wood chips to food leftovers and other traces of human activity, are called culture layers and are currently being analysed,” he says.

The goal is to find out through examination whether the conditions for preservation in the soil in and around cultural heritage monuments are good or bad.

Then the culture layers are monitored over time both before and after finished construction work. One can then see whether the preservation conditions in the culture layers change or remain stable.

An oxygen poor environment is best. High water saturation provides good conditions for the preservation of cultural heritage because the soil’s pores block oxygen supply. “It is not uncommon, for example, to find a human body from the Middle Ages in mire, where the body, hair and clothes are all completely intact, if somewhat shrivelled,” says Bergersen.

For cultural heritage of inorganic material, there are other conditions that determine if it is well preserved or not. The researchers therefore also measure the pH, salt content and temperature.

Time will tell, but so far, Ove Bergersen can ascertain that, if the right conditions apply, the best thing is to leave the cultural heritage monuments where they are rather than remove them.



Purpose: Find out whether the preservation of cultural heritage in situ is a good solution or not.
Collaboration: Norwegian Institute for Cultural Heritage Research (NIKU).
Funding: Norwegian Directorate for Cultural Heritage and various entrepreneurs.
Contact: Senior Research Scientist Ove Bergersen, e-mail: ove.bergersen@nibio.no, mobile phone: +47 918 45 072. Division of Environment and Natural Resources.



Photo: Siri Svendgård-Stokke



Soil is more than ‘just soil’

– “If it is necessary to use agricultural land for development, one should use the least valuable soil,” says soil surveyor Siri Svendgård-Stokke.

Soil is under continuous pressure for development. Some soil is taken out of production, while some is lost for good under asphalt and concrete. The resource that nature has spent thousands of years in making may be lost during one bout of building.

The value of knowledge on soil

For most people soil is ‘just’ soil, but we know that it varies from place to place. Decision-makers need the best available knowledge to make wise choices regarding the use of soil.

This kind of knowledge is produced by professionals at NIBIO who survey soil types and properties, where these soil types exist and how much soil there is. As a result, the farmer receives important information for choice of crop and soil treatment methods. The administration gets a useful basis for reporting and planning, for the pricing of soil for sale or renting, and for considering drainage needs and risk for erosion. This surveying is primarily requested by agricultural

municipalities. In growing municipalities with abundant agricultural land, it is unavoidable that there will be questions about the use of agricultural land for development.

Current example

One of the municipalities that recently made use of NIBIO’s services as part of their basis for decision-making is Randaberg in Jæren. In the spring of 2016 there was a process with the pricing of soil. The case is of principle interest also for other municipalities.

“We needed a uniform and professional basis for evaluation,” says Anne Grethe Bø Cazon, agricultural administrator in Randaberg. “It has to be the potential of the soil that determines the value and the price, not the activity seen ‘above the soil’,” she adds.

In cases such as these it is good to have professionals who can provide the data on which to base the evaluations.



Purpose: To document and confirm soil properties as a resource.
Funding: The Norwegian Ministry of Agriculture and Food.
Contact: Head of Department, Agricultural Soil Survey, Siri Svendgård-Stokke, e-mail: siri.svendgard-stokke@nibio.no, mobile phone: +47 902 34 080. Division of Geography and Statistics.



Photo: Oscar Puschmann

The world sees Norway's "Tilbakeblikk"

The photographic project "Tilbakeblikk" has been running since 2005, and is continually being developed. Changes in the Norwegian landscape are shown through re-photography and exhibition of previously photographed motifs. In 2015, these pictures of a changed Norwegian landscape reached the rest of the world.

If it was the 54 new pairs of photos on tilbakeblikk.no in 2015 or increased interest through strong growth in the number of followers on the project's Facebook page is not known, but suddenly a series of "Tilbakeblikk" photos appeared in the respected American magazine *The Atlantic*. Afterwards "then and now" photos followed quickly on Spanish, Polish and Dutch web sites.

In this way, parts of NIBIO's landscape monitoring have become known far beyond Norway's borders. "Through a ten-year tour, many different exhibitions, over 300 lectures and a number of news items that together have reached several tens of millions of people, we can safely say that the project has succeeded," says Hanne Gro Wallin, who is responsible for the project. "The photos engage people and create interest in just the way we were hoping for when the idea was conceived in 2004," she adds.

New images are added annually to the "Tilbakeblikk". In 2015, extra resources were used to obtain further photo pairs, together with rebranding of existing exhibition materials and a new brochure.

Landscape photographer Oskar Puschmann continues to follow in the footsteps of the two legendary landscape photographers Lindahl and Wilse, always looking for old motifs to re-photograph. A smaller project is planned where winter motifs are re-photographed to show how the landscape is an arena for activities throughout the year. In addition, the photos will be made more easily accessible via platforms for mobile phone and tablet users.



- Purpose:** Raise consciousness of and attention to the landscape and landscape changes, reflection on these changes, and on how land use shapes the landscape.
- Collaboration:** Norsk Folkemuseum (the Norwegian Folk Museum).
- Funding:** The Norwegian Ministry of Agriculture and Food.
- Contact:** Head of Department, Land Resource Surveys, Hanne Gro Wallin, e-mail: hanne.gro.wallin@nibio.no, mobile phone: +47 902 41 612, Division of Geography and Statistics.



Photo: Anne Kvitvær



Blackcurrants can give new life to old greenhouses

Blackcurrant is the latest to arrive of summer berries. These super-healthy berries are mainly used for juices and jams, but with new growing techniques blackcurrants are now also being harvested for fresh berry consumption.

New life in old greenhouses

As elsewhere in agriculture, there is a structural rationalization within the greenhouse sector. Bigger and more cost-efficient greenhouses take over, and older greenhouses are being phased out. In the greenhouse county of Rogaland there are therefore many empty greenhouses.

“These could be used for less energy-intensive production,” says Adviser Åge Jørgensen at NIBIO.

“Consumption of fresh berries in Norway has increased greatly in recent years,” he says. Jørgensen works towards the development of this concept, and believes that old greenhouses can be suitable for growing strawberries, raspberries, sweet cherries, redcurrants and blackcurrants.

Early harvesting

Berries were originally grown only on open land. Now, an increasingly large proportion is cultivated under roofs, particularly strawberries and raspberries. Rain roofs and tunnels give control of water

supply, a better climate and fewer problems with plant diseases. By moving the berry production to a greenhouse, further control is obtained as well as the possibility to prolong the growing season.

“Here production can be managed so that the berries mature outside the regular season. It’s more expensive to produce them in greenhouses, but the out-of-season berries can also be sold at a higher price. In addition, the greenhouses give much larger crops.”

Blackcurrants in strawberry country

Norway is a strawberry country, with raspberry as a good number two. While black- and redcurrants are usually used as the raw material for juices and jams, these berries have experienced a large upswing as so-called “health products” in the Netherlands, Germany and England.

“If we can produce black- and redcurrants with long clusters, large berries and good taste, they will have a lot of potential as fresh produce in Norway as well,” says Jørgensen.



Purpose: By taking advantage of old greenhouses for cultivation of raspberries, cherries, redcurrants and blackcurrants, one can obtain large berries, good taste and a longer growing season.

Collaboration: Selvåg Horticulture, Stavanger.

Funding: VRI Rogaland and Innovation Norway.

Contact: Adviser Åge Jørgensen. E-mail: age.jorgensen@nibio.no, mobile: +47 452 29 234, Division of Food Production and Society.



Photo: Erling Fløistad



Norwegian beer to become more Norwegian

Researchers from NIBIO and a selection of Norwegian breweries are testing Norwegian varieties of grain, hops and herbs for beer production. The goal is to be able to brew a real all-Norwegian beer based on Norwegian ingredients only.

Historically, beer in Norway was brewed using Norwegian malt, hops and herbs of various kinds. Today most of these ingredients are imported seeing as this type of large scale production was deemed unprofitable.

However, increased focus on short-distance-travelled food and drink, as well as knowledge of where the ingredients come from, means that many breweries in Norway now would like to use Norwegian raw ingredients to produce traditional beer - with local associations, history and flavour. The big breweries, microbreweries and home brewers all call for raw ingredients with local associations and history.

To meet this demand NIBIO, in collaboration with several breweries, initiated the project "Norwegian malt, hops and herbs - the taste of Norwegian beer" in 2013. Here the researchers test grain varieties for

malting as well as hop varieties and cultivated wild herbs for use in an all-Norwegian beer.

Producing all the ingredients is challenging. Good malt and a good beer require grain of high and consistent quality. NIBIO's researchers are investigating both old and new barley varieties with regard to malting properties and possibilities for growing in different parts of the country.

Another important ingredient in an all-Norwegian brew is hops. The final ingredient NIBIO is testing is herbs. Herbs have been used for brewing beer as far back as there are records - long before hops entered into the equation.

NIBIO is in collaboration with Valdres Farm Brewery in central, southern Norway. In the autumn of 2015 the brewery tested brewing an all-Norwegian beer.



- Purpose:** Norwegian varieties of grains, hops and herbs are being tested with the intent to be able to brew an all-Norwegian beer.
- Collaboration:** 16 large and small breweries partake in the project, among others the microbrewery Nøgne Ø and Ringnes, Mack and Aass. In addition: Graminor, NORBRYGG - the Norwegian Homebrewers Association and institutions in Denmark.
- Funding:** The Research Council of Norway and the participating breweries.
- Contact:** Head of Department, Grassland and Livestock, Ragnar Eltun. E-mail: ragnar.eltun@nibio.no, mobile phone: +47 975 83 073, Division of Food Production and Society.



Photo: Jon Schärer



High-tech Kinder Eggs for agriculture

Scientists use satellites, drones and robots in pursuit of a more environmentally friendly agriculture, increased food production and higher incomes for farmers. At NIBIO Apelsvoll, it is the 10th anniversary of the use of drones in research.

How big is the crop before harvest, and how good is the quality? Where in the field are the weeds? Do the plants need more or less water, fertilizer or pesticides? These are all questions that high-tech precision farming can help to answer.

Precision agriculture is all about exactly that, precision. “When you fertilize only as needed, the utilization rate of nitrogen increases, at the same time reducing both greenhouse gas emissions and water pollution. Similarly, when it comes to pesticides, one should spray exactly where needed. This could reduce the use of chemical plant protection by up to 90% in some cases,” says Senior Research Scientist and Head of Agricultural Technology and Systems Analysis, Audun Korsæth.

Satellite images can be used to keep track of larger areas, while drones can provide detailed information about a specific field. Robots can be used to zoom even closer to the plants. But what is important is the

equipment hanging on the drone or the robot.

“An ordinary camera can measure the RGB, which are three colour bands. Our latest acquisition is two hyperspectral snapshot cameras that can measure many more colour bands, also in the near infrared area that we cannot see with the naked eye. It gives us a tremendous amount more information in each and every pixel in the image,” says Korsæth.

The goal is that a lot of the technology will eventually end up on the farmer’s tractor, so that sensors scan the field in real time and appropriate measures can be introduced immediately. Sensors like these already exist for spreading fertilizer, but researchers at NIBIO are working on making fertilisation even more precise, more accurate spraying with pesticides and better weed management in the field.



- Purpose:** Precise fertilization and reduced use of chemical pesticides, in order to protect the environment, produce more food and improve farmers’ incomes.
- Collaboration:** Yara, Adigo and Norwegian Agricultural Purchasing and Marketing Co-operation.
- Funding:** A number of projects are involved. These are funded by among others the Research Council of Norway’s Research Funding for Agriculture and the Food Industry, private actors such as Yara and Norwegian Agricultural Purchasing and Marketing Co-operation, and key actors in the agricultural sector.
- Contact:** Head of Department, Agricultural Technology and Systems Analysis, Audun Korsæth: audun.korsaeth@nibio.no, mobile phone: +47 404 82 560. Division of Food Production and Society.



Photo: VARP & VEFT AS, etphotography.eu

Quality leads the way for Norwegian wool

Wool is part of the national soul, but Norwegian knitted sweaters are not produced in Norway. Research is being carried out on how to ensure the quality of Norwegian wool, so that we can in the long term make use of more of our own wool and get a more sustainable textile industry.

To use locally produced food is 'in'. In the textile market, 'onshoring', the establishment of the textile industry in one's own country, is a growing trend in the United States and the United Kingdom. Internationally, 'slow fashion', short-distance-transported and sustainable clothing of good quality, is an increasing trend.

NIBIO is working to ensure the quality of Norwegian wool, for example by increasing knowledge of the variation in wool quality and through breeding measures. The work is part of the interdisciplinary project Krus, which aims to bring forth the quality of Norwegian wool and improve the market, marketing and value of Norwegian-produced wool.

"Norway has world-class raw materials and a textile industry with great potential," says Tone Skårdal Tobiasson, editor for NICE Fashion (Nordic Initiative Clean & Ethical Fashion) and collaborator in the Krus project.

The goal of this project is to achieve the same with textiles as we have seen with short-distance-transported, local food. The product is often more expensive, but the willingness to pay for such a product is often greater.

Today, there is little focus on wool in Norway despite that only 20 % is further refined in Norway.

"Most Norwegian sheep farmers get most of their income from meat production," says Lise Grøva, Research Scientist at NIBIO.

Norwegian wool and the qualities of the different breeds play an important role in the Norwegian textile tradition. It is especially challenging with older breeds of sheep because the quality of some of the wool sorts is falling.

"Change is needed. Wool is an amazing product that can be used for many things and it is important that it is profitable for the farmer to focus on wool quality," says Grøva.



- Purpose:** The use of Norwegian wool can contribute to a more sustainable fashion and textile industry. It is important with increased consciousness of this in Norway.
- Collaboration:** Consumption Research Norway (SIFO), NICE Fashion, the Norwegian Association of Sheep and Goat Farmers, Animalia.
- Funding:** The Research Council of Norway.
- Contact:** Research Scientist Lise Grøva, e-mail: lise.grova@nibio.no, mobile phone: +47 909 54 835, Division of Forest and Forest Resources.



Photo: Erling Fløistad

Smart tobacco

Genetically modified tobacco plants can act as “green factories” where cheap vaccines for humans and animals, eco-friendly fuel and special products for industry are produced.

The possibilities inherent in genetically modified tobacco plants can be compared to the development of the mobile phone. Today’s smart phones are so much more than just a regular telephone. Similarly, today’s tobacco plants can in the future become “smart tobacco”.

“A tobacco plant is still a tobacco plant, but we can insert various snippets of DNA, which can steer the production of the substances we’re after,” says Research Professor Jihong Liu Clarke.

Plant scientists insert DNA or genetic material in the plants. DNA molecules, for example from bacteria or fungi, “programme” the tobacco plant to produce the substances that researchers want. When the tobacco plants have grown, the leaves are harvested and the relevant substances extracted.

In principle, this method can be used to produce vaccines against various diseases. Both the aquaculture industry and forest industry also need special products which could be produced in tobacco at a reasonable cost, for example fish vaccines or enzymes that can break down wood for production of bioethanol. Enzymes are the most costly part of the production of bioethanol, aside from the actual raw materials. If the researchers succeed with this research, it could be the start of a cheaper way to produce enzymes.

The technology is the same, and can be used to produce many different products. That is what makes it so smart and sustainable.

“If one can build simple greenhouses for the cultivation of tobacco plants for the production of enzymes, and later perhaps for fish vaccines, there are great opportunities for farmers all over Norway,” says Liu Clarke.



- Purpose:** Use existing biotechnological knowledge to develop technology for commercial production of various biological products such as vaccines and enzymes.
- Collaboration:** The Norwegian University of Life Sciences (NMBU), the Norwegian University of Science and Technology (NTNU), the Max Planck Institute of Plant Physiology and Molecular Cell Biology, the Chinese Academy of Agricultural Sciences (CAAS), The Massachusetts Institute of Technology (MIT), the Romanian Academy of Sciences, the John Innes Institute, VTT Technical Research Centre of Finland.
- Funding:** The Research Council of Norway, the European Research Area Networks (ERA-NET) and the European Economic Area Financial Mechanisms (Norway-Romania).
- Contact:** Research Professor Jihong Liu Clarke, e-mail: jihong.liu-clarke@nibio.no, mobile phone: +47 995 94 790. Division of Biotechnology and Plant Health.



Photo: Adam O'Toole

Towards a zero emission society

In a large interdisciplinary project, scientists follow new paths to find out what is needed to achieve increased production and use of biochar in agriculture.

Ploughing biochar into the soil is an effective way to reduce national greenhouse gas emissions, as biochar binds carbon in a simple and cheap way. Biochar also has a positive effect on heavy metal uptake by plants from contaminated soil and adds vital nutrients to the soil. In addition, biochar improves the soil's ability to retain water and may be an important contributor in achieving a climate-neutral agriculture.

So why isn't biochar used to a greater extent than it is today? The production method pyrolysis, where organic material is heated to about 500 degrees under oxygen-free conditions, is seldom tested for large scale production. There are also no incentives to farmers to make use of biochar which effects are long-term.

Adapt research

Researchers from NIBIO and several other institutes work together in the interdisciplinary project

Capture + (*Sustainable biochar systems for a zero emission society*), developing sustainable and profitable solutions for the production and implementation of biochar in Norwegian agriculture.

“The most critical aspect in the project is not only to find good technological solutions for biochar production. We also need to adapt the research to economics, logistics and politics,” says Erik Joner at NIBIO.

Farmers, foresters and other participants are all involved in the work, so that biochar could be put to use in Norwegian agriculture in future. The researchers will also work with other stakeholders in the field towards the possibilities for large scale production and implementation of biochar internationally.

As a result of the project, scientists from NIBIO have contributed to five chapters in a new book about biochar – *Biochar in European Soils and Agriculture*.



Purpose:	Developing sustainable and profitable solutions for the production and implementation of biochar in Norwegian agriculture.
Collaboration:	The Centre for Rural Research, Det Norske Veritas (DNV), the Norwegian University of Life Sciences (NMBU), and two institutes at SINTEF, coordinated by SINTEF Technology and Society.
Funding:	The Research Council of Norway.
Contact:	Research Professor Erik Joner, e-mail: erik.joner@nibio.no, mobile phone: +47 928 33 168, Division of Environment and Natural Resources.



Photo: Ragnar Våga Pedersen

Fish sludge can become plant fertilizer

Every year around 75% of the phosphorus applied in fish farms will be lost. This is a waste of a very limited resource. NIBIO has, in collaboration with the Norwegian University of Science and Technology (NTNU), tested the use of fish sludge as plant fertilizer. The results are good.

Phosphorus is necessary for all life, be it people, plants or animals. Therefore, phosphorus is applied to different parts of the food system, and both mineral fertilizer and fish food contain this nutrient. Because phosphorus utilization in plants and animals is relatively poor, some phosphorus is wasted, for example in agriculture where excess phosphorus accumulates in the soil. This is problematic because the rock from which phosphorus is recovered is a very limited and non-renewable resource. Researchers from NIBIO and NTNU work together to get an overview of how phosphorus flows in the Norwegian food system can be exploited more effectively.

Research shows that phosphorus losses in Norwegian aquaculture are on a par with phosphorus losses in Norwegian agriculture. Every year, 12,000 tonnes of phosphorus are applied to fish farms in fish food.

Of this, as much as 9,000 tonnes goes to waste, either through food waste or because it is not taken up by the fish and thus is lost with the fish's excrement. If new technology is not developed and the aquaculture industry continues as today, phosphorus losses will increase as the industry grows. It is estimated that the industry will be five times larger by 2050.

NIBIO has tested the use of the nutrient-rich fish sludge from aquaculture as a fertilizer in growth experiments. The sludge is a valuable resource; it has properties that can be compared to manure.

On this basis, researchers at NIBIO call for stricter policies around the growth of Norwegian aquaculture, and not least the development of new and better technology to capture and recycle phosphorus from the nutrient-rich fish sludge.



Purpose: The recycling of phosphorus in organic waste for crop production.

Collaboration: Norwegian University of Science and Technology.

Financing: CenBio (Bioenergy Innovation Centre, 193817/E20).

Contact: Research Scientist Eva Brod, E-mail: eva.brod@nibio.no, mobile phone: +47 902 77 760, Division of Environment and Natural Resources.



Photo: Anna Caroline Rehnberg



Warning lights for West Norway's "Vestlandsk raudkolle"

This breed is the only one of our at-risk cattle breeds for which there has been a recent decline in the number of breeding cows.

In 2015 a decline of 5% was registered in the number of breeding stock. Thus, it is important for the 139 cows and their owners to preserve the "Vestlandsk raudkolle"'s genes and provide for an increase in the number of animals.

Every year, the Norwegian Genetic Resource Centre publishes updated figures for at-risk cattle breeds. The report for 2015 also includes numbers that show the development over five years.

The main trend in the last five-year period shows an increase. The greatest recruitment is in meat production, but the number of dairy herds is also increasing. In the work to secure the at-risk breeds for the future, the number of breeding cows is an important indicator.

"In 2015 the "Telemarkfe" breed crossed the magic limit of 300 females, and has, together with the "Østlandsk rødkolle" advanced from a "critically endangered" status to "endangered"," says Nina Sæther, leader of the Norwegian Genetic Resource Centre.

The categories are determined by FAO, the Food and Agriculture Organization of the United Nations. To move up to the next category, which is "vulnerable", more than 3000 females are required.

Of the six at-risk Norwegian cattle breeds, "Vestlandsk raudkolle" and "Dølafe" are considered to be "critically endangered", while "Telemarkfe", "Sidet Trønderfe and Nordlandsfe", "Vestlandsk fjordfe" and "Østlandsk rødkolle" are considered to be "endangered".

"Genetic diversity is an important prerequisite for selection," says Sæther. If we do not have the variation, we do not have the ability to select the best characteristics.

"We do not know today what characteristics we will need tomorrow. Maybe we will require small cows which can manage by themselves on the steep grazing slopes on Norway's west coast? They manage to survive without soya imports, and yet they produce milk with high cheese yield."



Purpose: Document and track the development of at-risk livestock/cattle breeds to ensure their future survival.

Funding: The Norwegian Ministry of Agriculture and Food

Contact: Head of the Norwegian Genetic Resource Centre Nina Sæther, e-mail: nina.sather@nibio.no, mobile phone: +47 993 89 469. Division of Geography and Statistics.



Photo: Morten Nitteberg



The Forest Portal ensures forestry and the environment

The new map service Forest Portal (“Skogportalen”) provides environmental information from different databases all on one website. Whether one works in the forest industry or administers environmental regulations, updated and relevant information is needed.

In the Forest Portal, data on the various nature types and species that exist in forests are sorted according to current environmental regulations. The new website was launched in the autumn of 2015 and is a meeting place for anyone seeking information about conditions in the forest. Here, business interests, environmental interests and management can find relevant documentation for different purposes. All parties have access to the same information.

Norwegian forestry has amassed knowledge and statistics over many years. In the Forest Portal, these data are linked with other relevant environmental information, and shared with the world in a new way. All relevant environmental information for forest management is now gathered in one place.

“To show society how Norwegian forestry manages forest resources and takes responsibility for the

environment was central to this innovation,” says Department Director Ivar Ekanger of the Norwegian Ministry of Agriculture and Food of the new portal.

The environmental and planning data in the Forest Portal are sorted out according to the laws and regulations that apply for management of forest and biodiversity. This gives an overview of environmental registrations and age classes for the forest, together with the species and nature types that exist there. Cultural heritage, contours and protected areas are included.

Broad collaboration between public administration and industry has been important for the new portal which has been developed as part of NIBIO’s map service “Kilden”.



- Purpose:** To offer a useful tool for informed and wise choices as far as forest resource utilisation is concerned while at the same time protecting forest biodiversity.
- Collaboration:** The Norwegian Ministry of Agriculture and Food, the Norwegian Agriculture Agency, the Norwegian Environment Agency, the Norwegian Biodiversity Information Centre.
- Funding:** The Norwegian Agriculture Agency, the Norwegian Forestry Research and Development Fund.
- Contact:** Lead Engineer Tove Vaaje-Kolstad, e-mail: Tove.Vaaje-Kolstad@nibio.no, mobile phone, +47 930 08 377, Division of Geography and Statistics.



Photo: Tove Sundgren



How much water can grain tolerate?

After a rainy summer the question arose again – how much water can grain tolerate? This is also a question for the future. How will grain cope with climate change with more and sometimes heavy rain?

As part of the Agropro project (Agronomy for Increased Food Production), scientists survey what varieties of grains are the most robust and can best withstand wet conditions in the soil.

35 millimetres of rainfall on average each day for a good two weeks is in excess of what a grain farmer likes. So what practical measures can be put in place in this instance? At NIBIO's research station Apelsvoll in Toten, Senior Research Scientist Wendy Waalen applied about 35 mm of water daily in an experimental field site. She examined the effects of additional fertilization, increased sowing amount, and weed harrowing.

So far, tests at Apelsvoll have shown that additional fertilization has a positive effect. Measurements of chlorophyll in the leaves showed that increasing

the amount of nitrogen fertilizer led to greener and better leaves. However, the harvests were still smaller in the water-saturated pilot plots compared to control plots that were not water-saturated.

Previous greenhouse experiments have showed great differences in which varieties can tolerate most water. Oats had the highest tolerance; the harvest was reduced by 50% only after 15 days. Peas, however, were reduced by 50% already after three days. Barley and wheat generally tolerate slightly less water than oats.

Norwegian and Nordic varieties do seem to manage better than non-Nordic varieties. This was shown by an intensive irrigation experiment carried out by the Norwegian University of Life Sciences as part of Agropro.



- Purpose:** Survey which grain varieties are most robust and can best withstand climate change with more and sometimes heavy precipitation.
- Collaboration:** The Norwegian University of Life Sciences (NMBU), Centre for Rural Research, the Norwegian Agricultural Extension Service and Inland Norway University of Applied Sciences (formerly Hedmark University of Applied Sciences).
- Funding:** The Research Council of Norway.
- Contact:** Head of Grain and Forage Seed Agronomy, Wendy Waalen, e-mail: wendy.waalen@nibio.no, mobile phone: +47 452 86 790, Division of Food Production and Society.



Photo: Svein Grønvold



Bioeconomy and environmental considerations in the forest

Forests are a renewable resource and an important part of the bioeconomy. Over 20 000 species have their habitat in the forest, and an increased use of forest resources requires evidence-based methods to take care of the environment and biodiversity. “Environmental inventories in the forest” (MiS) is one such method.

Logging of forests alters the living conditions for many plants and animals. In areas where forestry takes place, forested areas that are especially important for biodiversity are set aside. These areas are called key biotopes, and have been selected on the basis of environmental inventories in the forest (MiS).

Since the method was launched in 2000, 119 000 habitats have been registered, of which 87 000 are included as key biotopes, areas set aside as part of environmentally certified forestry.

”If Norway succeeds with the green transition, from a petroleum-based economy to a bioeconomy, the exploitation of forest resources and thus associated environmental challenges will increase, not least when it comes to biodiversity. Therefore it is good that we have already built up a lot of knowledge about

the species and habitats in the forest,” says research professor Ivar Gjerde at NIBIO, who was in charge of the research behind this method.

Environmental registrations give the forest owner information about areas with habitats that are especially important to conserve. These are habitats of which there are fewer when the forest is felled, such as old and dead trees.

Such habitats, left as key biotopes in areas where forestry is carried out, will be especially important for large numbers of species of invertebrates, fungi, vascular plants, mosses and lichens.

”If the exploitation of forest resources is intensified, there will be a need for a corresponding simultaneous strengthening of environmental measures, if we are to preserve biodiversity. Then we need smart, cost-effective measures,” explains Gjerde.



- Purpose:** Increased use of forest resources requires evidence-based methods to take care of the environment and species diversity. “Environmental inventories in the forest” (MiS) is one such method.
- Funding:** Ministry of Agriculture and Food, the Research Council of Norway.
- Contact:** Research Professor Ivar Gjerde, e-mail: ivar.gjerde@nibio.no, mobile phone: 915 15 139, Division of Forest and Forest Resources.



Photo: Dan Aamlid

Deer die on the road

Each year, thousands of deer are hit by road traffic. The animals follow fixed migratory paths and their behaviour is little affected by roads. Management boundaries should therefore follow the deer's migration routes, and not necessarily today's administrative boundaries.

The number of deer is growing. Sales of game meat and hunting rights are important sources of income for landowners. At the same time the large number of deer leads to conflicts, in the form of grazing damage to forests and meadows, and game being run over along the roads.

A total of 5501 roe deer, red deer and moose were hit by road traffic in the hunting season 2014-2015. There is a particularly high risk for accidents where infield grazing is located along the road and the deer cross the road to seek out these pastures. NIBIO research scientist Erling Meisingset has shown that the clearance of forests and reduced speed limits could reduce the number of accidents involving deer by half. These are simple measures that could give significant savings for society.

GPS tagging has provided new knowledge about how the deer move around and what areas they use. The researchers have examined the proportion of deer that migrate between winter and summer quarters,

when the animals migrate and how they use the landscape throughout the year. This is knowledge that can contribute to better management of game resources.

It is a challenge for game management that the deer wander and graze across administrative units.

- It is the management who should adapt to the deer and not vice versa. Today, there is a mismatch between deer land use and the size of the management units, Meisingset points out.

Knowledge of the animals' migrations and land use is important when granting hunting quotas, in order to hinder too large populations of deer and to be able to determine how many should be hunted.

- Collaboration across administrative boundaries will in the future be crucial to how we succeed with a sustainable management of deer and thus provide a good basis for developing hunting as a source of income for landowners, says Meisingset finally.



Purpose: Sustainable management of deer populations requires collaboration across administrative boundaries.

Collaboration: University of Oslo, Norwegian University of Life Sciences (NMBU), plus several others both nationally and internationally.

Funding: The Research Council of Norway, the Norwegian Environment Agency, dedicated funds from various municipalities and counties, and NIBIO.

Contact: Research Scientist Erling Meisingset, e-mail: erling.meisingset@nibio.no, mobile phone: +47 404 80 203, Division of Forest and Forest Resources.



Photo: Lars Sandved Dalen

Scientists collect seeds from healthy ash trees

Ash dieback came to Norway in 2006 and has so far attacked ash trees along the coast from Østfold to Nordmøre. Now forest scientists collect ash seeds to save future generations of ash from fungal attack.

Ash dieback threatens ash trees in large parts of Europe, including Norway. Since 2006, thousands of Norwegian ash trees have been attacked by ash dieback; however, some ash trees appear to be more resistant to fungal attack than others. Researchers therefore want to collect seeds from healthy ash trees.

NIBIO biologist Mari Mette Tollefsrud works with tree genetics and is one of the scientists who participate in this rescue work. The scientists have selected healthy trees from different places in East Norway, South Norway and West Norway.

After collection the seeds germinate and are planted out to expose them to natural infection of the fungus *Hymenoscyphus fraxineus*.

- Hopefully, the collected seeds will give healthier and more resilient ash trees. It is important to protect the trees that stay healthy and collect seeds

that can give rise to healthy trees, explains Tollefsrud. Forest scientist and fungus expert Halvor Solheim at NIBIO has done research on ash dieback for several years.

- We have followed the movements of ash dieback each summer for the last six years. Now it has come as far north as Nordmøre. In Europe it is spreading ever further south and west, says Solheim.

Ash dieback establishes itself on the leaves and petioles. If ash dieback gets past the node before autumn leaf-fall, it will grow in the branches and trunk during the tree's dormant period in autumn and winter. Next summer, the infected shoots are dead. Young ash trees die quickly, while older trees can survive for many years.

It is the fungus *Hymenoscyphus fraxineus* that causes ash dieback. There are no measures that can prevent the spread and further development of the disease.



Purpose: Collection of ash seeds will be able to provide healthier and more resilient ash trees.
Funding: Norwegian Genetic Resource Centre.
Contact: Research Scientist Mari Mette Tollefsrud, e-mail: mari.mette.tollefsrud@nibio.no, mobile phone: +47 907 60 870. Division of Forest and Forest Resources.

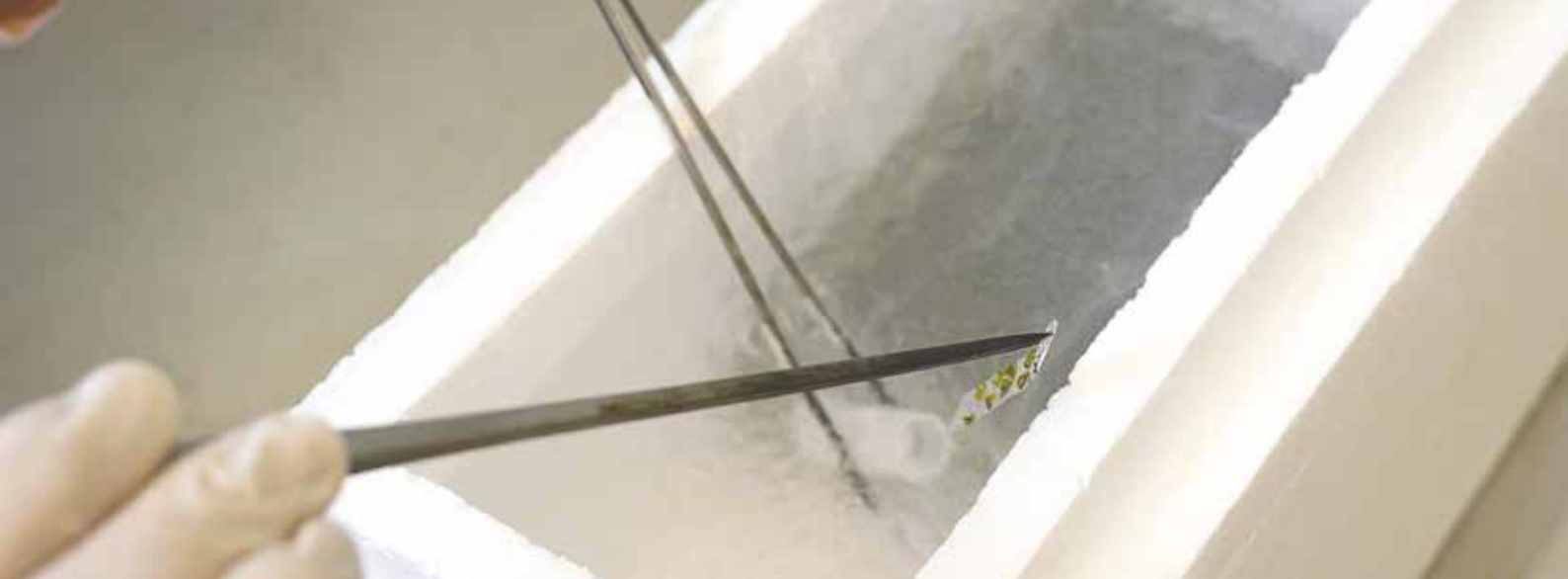


Photo: Håkon Sverdvik

Freezing healthy plants for the future

Potato and important horticultural crops such as strawberries and raspberries propagate vegetatively. To avoid ever-greater damage from viruses and other diseases that live inside the plants, there must be healthy mother plants.

It is costly both to produce and to maintain perfectly healthy mother plants from year to year. Therefore, plant producers need new technologies that reduce the costs of maintaining healthy mother plants.

Cryopreservation is defined as the storage of living cells, bits of tissue, organs and organisms at very low temperature, usually in liquid nitrogen at -196°C . Cryopreservation of plant material has undergone a huge development in the last 15 years, so that there are now good protocols for freezing and cryopreservation of many kinds of plant. Cryotechniques are now used also for the cleansing of sick plants.

Commercial actors therefore come to NIBIO to get completely healthy mother plants prepared that can be stored for a long time. Then we develop protocols for each kind of plant so that they can be frozen and stored for many years, and then thawed and grown again. First on the list are types of begonia, raspber-

ries, blackberries, strawberries, marguerite daisies, potatoes and shallots, spread over four different projects. NIBIO has the main scientific responsibility and the work is carried out in close cooperation with partners. Norwegian partners are: Sagaplant, the Norwegian University of Life Sciences, Graminor, the Norwegian Genetic Resource Centre, Grønn Næringskompetanse, Piql, Tiboplant and Norner.



- Purpose:** Cost effective and secure long-term storage of healthy mother plants of vegetatively propagated plants.
- Collaboration:** International partners in China, Belgium, Germany, Peru, Sweden, Scotland and the Czech Republic in addition to the Norwegian partners mentioned in the text.
- Funding:** The Research Council of Norway in interaction with interested companies, Gartnerhallen, NORGRO AS, and several nurseries and seed potato companies.
- Contact:** Research Scientist Dag-Ragnar Blystad, e-mail: dag-ragnar.blystad@nibio.no, mobile phone: +47 908 72 588, Division of Biotechnology and Plant Health.



Photo: Lars Sandved Dalen



Climate change leads to an increased northern bark beetle population

The spruce bark beetle killed close to 10 million cubic metres of Norway spruce during an outbreak in southern Scandinavia in the 1970s. New studies suggest more beetle attacks in northern spruce forests in the future.

The northernmost European spruce forests have so far been spared mass attacks of spruce bark beetles. The beetle is present here, but the temperature has probably been too low for it to cause damage. Scientists in both Finland and Norway now observe more bark beetles and signs of attacks also in these areas.

In Norway, spruce bark beetles are found in Trøndelag and Helgeland, but here there was no attack in the 1970s. In the warm summers of 2008 and 2009, however, there was a sharp increase in the number of bark beetles in monitoring traps and the level was equivalent with that in East Norway. Instances of forest death increased, which is unusual in this part of the country. Bark beetle attacks have also been unusual in Finland, but here too the level of beetles and attacks has been increasing, especially after 2010.

Several factors indicate that climate change can lead to increased bark beetle outbreaks in northern areas. It is likely that the spruce bark beetle, which is a cold-blooded organism, reacts to changes in the climate – especially increased temperature. It is also known that changes in the climate can weaken spruce and make it more susceptible to beetle attacks. Warmer summers may lead to our getting two generations of spruce bark beetles per summer instead of one, and thus two periods with beetle attack per year.

NIBIO coordinates an annual monitoring of the spruce bark beetle with pheromone traps in over 100 municipalities. In addition to providing data for research on climate effects, this is an important tool for forest management. With such information, forest management can introduce countermeasures to keep the beetle populations low, for example removing affected trees before the next generation of beetles fly out.



Purpose: Prevent large losses due to bark beetle outbreaks.
Collaboration: Norwegian forestry authorities.
Funding: Norwegian Ministry of Agriculture and Food.
Contact: Research Professor Bjørn Økland, e-mail: bjorn.okland@nibio.no, mobile phone: +47 916 28 225, Division of Biotechnology and Plant Health.



Photo: Erling Fløistad



Small roundworms cause expensive damage

Norwegian grain farmers today lose large amounts of money because of a small roundworm that damages the roots and weakens the plants. Better knowledge of the symptoms and awareness concerning the choice of grains can help reduce attacks.

Heterodera are small nematodes (roundworms) that damage the roots of grain crops and other grass species. These small freeloaders are found in all grain districts in Norway – from Agder to Nordland.

In recent years there has been an increase in the damage caused by *Heterodera* in oats, wheat, barley and winter rye. Today, Norwegian grain farmers lose large amounts because of *Heterodera*. Infection leads to a reduction of about 100 kilograms of grain per decare. Nationwide, the annual revenue loss will be more than 100 millions NOK.

Heterodera attacks show up as spots on short plants in the field. This is most visible in oats. The symptoms can be confused with nutrient deficiency and adverse pH. An indirect symptom of nematode attack can be that the field contains an abnormal amount of weeds. In oats, the leaves of affected plants often have a reddish colour. In barley, the leaves are often yellow,

while the root system has less apparent damage. On the leaves of wheat, nematode attack can give a reddish yellow colour, and the roots become very narrow with branches.

Increased insight and knowledge of these roundworms are necessary if we are to have a profitable grain production in Norway. Nematode attacks cannot be fought with spraying. All measures that give the plants better growing conditions can reduce crop losses somewhat, but not entirely.

Research at NIBIO shows that crop rotation is one of the most effective methods to combat *Heterodera*. Resistant grain varieties can also be used, but to choose the right cultivar, it is important to know which nematode types are found in the soil.



Purpose: Increased profitability in Norwegian grain production.
Collaboration: Norwegian Agricultural Extension Service.
Contact: Research Scientist Ricardo Holgado, e-mail: ricardo.holgado@nibio.no, mobile phone: +47 916 82 703. Division of Biotechnology and Plant Health.



Photo: Erling Fløistad

Potato defence against common scab

Potato is the second most important cultivated plant in Norway and the fourth most important in the world. Increased sales of washed potato products have contributed to the increased economic importance of scab diseases. Common scab is a quality disease on potato caused by a few *Streptomyces* species, a genus of bacteria that live in the soil. The disease produces quality loss and reduced market value.

For food potato, scab diseases are among the most important quality faults and make up a total of 40% of the overall quality loss. There are no good chemical methods for combating common scab, and no known potato varieties have complete resistance. The fact that some varieties are relatively robust against common scab suggests that the disease can be fought through targeted breeding.

It is currently unknown what causes some potato varieties to be more tolerant for common scab than others. NIBIO has studied the potato plant's defence against this bacterial disease.

The researchers have studied a resistant variety, Beate, and a susceptible one, Saturna, to find genes that play a role in the plant's defence against the disease.

The results from this study show that the resistant potato cultivar maintains the defensive response against the bacterium through the early stages of tuber development, while the response became weaker with the susceptible cultivar. Candidate genes that most likely are involved in defence in the resistant cultivar have been identified. The results have contributed to increased understanding of the potato plant's complex defence against common scab. This knowledge will be useful in breeding programmes for potato.

Dees, M.W., Lysøe, E., Alsheikh, M., Davik, J. and Brurberg, M.B. (2015) Resistance to *Streptomyces turgidiscabies* in potato involves an early and sustained transcriptional reprogramming at initial stages of tuber formation. *Molecular Plant Pathology*, doi: 10.1111/mpp.12323



Purpose: Find ways of breeding common scab-resistant potato varieties.
Collaboration: Graminor and Agrico (NL).
Funding: Graminor, Agrico and The Research Council of Norway.
Contact: Research Professor May Bente Brurberg, E-mail: may.brurberg@nibio.no, mobile phone: +47 926 09 364. Division of Biotechnology and Plant Health.



Photo: Erling Fløistad

Integrated plant protection in the entire food chain

SMARTCROP, or “Innovative methods, techniques and instruments for integrated plant protection (IPV) that can increase sustainable food production”, is a comprehensive 5-year research project that will contribute to the increased use of integrated plant protection in Norway.

Norway has introduced the EU directive on the sustainable use of pesticides. However, we lack both tools for IPV that growers can use in practice and instruments that lead to increased use and development of IPV. Through the project SMARTCROP we want to meet these challenges.

The project has four scientific work packages:

- 1: Development of new IPV tools for the farmer
- 2: Effects of various IPV measures
- 3: New models and decision support systems for IPV
- 4: New instruments for the use of IPV (attitudes, economy, available IPV tools)

We will test and demonstrate “best IPV practice” and study the impact on pests, their natural enemies, crops, economy and environmental risks under Norwegian conditions. New simulation models for

interactions between pests and beneficial organisms will be developed and existing models for warning will be improved. We will establish experimental sites for practical research and demonstration. Detailed laboratory experiments will be conducted to study the interactions between important organisms in various cultures.

Many of the project participants and the project’s reference group represent stakeholders and key end-users. All will participate actively in the research process and thus give scientists useful feedback about the IPV tools and instruments to be developed in the project. Such active participation will be important both to develop robust IPV tools and to ensure that they are applied, in addition to good implementation and understanding of IPV in the entire value chain.



Purpose: To develop innovative tools, methods and instruments that increase the use of and understanding for integrated plant protection (IPV) for the development of a sustainable food production.

Collaboration: A number of national and international actors among research institutes, agricultural consulting, farmers, companies that produce and sell IPV tools, authorities, wholesalers and food chains.

Funding: The Research Council of Norway.

Contact: Head of Department of Invertebrate Pests and Weeds, Ingeborg Klingen, e-mail: ingeborg.klingen@nibio.no, mobile: + 47 930 92 211. Division of Biotechnology and Plant Health.
(For more about the project see www.smartcrop.no or like us on Facebook).



Photo: Line Thomsen

Effects of tillage on flat areas

Today support is given for changed tillage methods, but most research trials are conducted on areas with high erosion risk. Now researchers from NIBIO are examining the effects of tillage on flat areas.

The question is what type of tillage gives least soil loss and least runoff of phosphorus and pesticides. Is it better for the environment to plough in the autumn or in the spring, and what soil loss results from cultivation of autumn crops? The findings could have consequences for current support schemes for tillage.

Most of the agricultural areas in Akershus and Østfold are located in areas without steep slopes. The experiment at Kjelle in Bjørkelangen was started in 2013 in order to shed light on the effect of tillage on areas which are only slightly sloping and with low erosion risk.

The most important conclusion from the experiment's first years (2014-2015) was that the autumn-ploughed plots had on average three times more soil loss than the spring-ploughed plots.

Phosphorus losses followed the same trend as for soil loss, but with slightly smaller differences between the treatments. The loss of dissolved phosphorus was less dependent on the type of tillage than loss of phosphorus that was bound to particles (particulate phosphorus).

The annual nitrogen losses were lowest from autumn grain and highest from that which was autumn-ploughed. Very high concentrations of nitrogen were determined in the spring water samples in the plots with spring grain, both those which were autumn-ploughed and those which were spring-ploughed.

Growth and uptake of nutrients through the summer has increased the risk for runoff of nitrogen from the autumn grain plots.



Purpose: Increase understanding of which tillage measures have the best effect on flat areas.
Collaboration: Kjelle High School.
Funding: Norwegian Agriculture Agency, water district Haldenvassdraget and NIBIO.
Contact: Research Professor Marianne Bechmann, e-mail: marianne.bechmann@nibio.no, mobile phone: +47 924 98 945. Division of Environment and Natural Resources.



Photo: Erling Fløistad



The global water footprint – not suitable for Norwegian forests

The water footprint is a measure of how much water is consumed. But is it suitable for Norwegian forests? Scientists from NIBIO have helped to find out.

The water footprint is the sum of the consumption of what is called the blue, green and grey water. Blue water is for example surface water and groundwater. Green water is rainwater and water in the root zone that contributes to plant growth, while grey water is contaminated water. The amount of water that is consumed in the production of a product, such as paper, is calculated as the total volume of the blue and green water.

But the way the water footprint is defined is not unproblematic. Tree growth in Norway is not limited by water availability. Evaporation from leaves and needles also contributes to the formation of precipitation elsewhere, and is thus a part of the natural water cycle. Water that disappears from a catchment through transpiration is not consumed, but is merely transported to another location, easily available for re-use.

Norwegian forestry has only a limited impact on the natural water cycle. Forestry uses naturally occurring species, such as Norway spruce, Scots pine and birch, and transpiration from these trees would have occurred regardless of whether forestry activities took place or not.

The conclusion is therefore that countries with a surplus of precipitation, such as Norway, do not need and should not be required to put in place the same water saving plan as countries with real water shortages and drought.

The Water Footprint Network has prepared a global water footprint standard. Researchers from NIBIO participate in a joint Nordic-Baltic project that has provided input.



- Purpose:** Input to further development of the water footprint concept.
- Collaboration:** Centre of Advanced Research on Environmental Services from Nordic Forest Ecosystems
- Funding:** Nordic Forest Research (SNS).
- Contact:** Research Professor Nicholas Clarke, e-mail: nicholas.clarke@nibio.no, mobile phone: +47 974 80 327, Division of Environment and Natural Resources.
- Caption:** Stream in the forest, Bærøe, Hobøl, Norway. Photo: Nicholas Clarke.



Photo: Erling Fløistad

Excrement in water – from animals or people?

New methods reveal whether faecal pollution in water is from humans or animals. This makes it easier to prevent pollution.

Faecal contamination is one of the most common causes of diseases in humans. Our drinking water can be contaminated because of runoff from livestock grazing, leaks from pipelines and insufficient treatment plants in areas with few people. To date, it has not been common to specify whether it is animals or people that are the pollution source. This has made it difficult to implement efficient measures to reduce exposure and health risks.

NIBIO has tested out molecular biological methods to track faecal sources of water pollution. This is the first time that such methods have been used in Norway. These methods can provide answers as to whether faeces are of human or animal origin, and at the same time also provide a basis for assessing the infection potential of the different bacteria present.

In 2015, the method was tested in catchments for drinking water sources for Oslo, Bergen and Trond-

heim. These municipalities are responsible for monitoring the raw water quality and delivering safe drinking water. The information provides a good basis for the municipalities to implement targeted measures.

The analyses indicate that in some parts of the year and in some areas, runoff from farms with horses and matured horse manure can be the dominant source, while in the winter, discharge from inadequate treatment plants can be the source. Birds, pets, and rats in the sewer systems can also be sources of faecal contamination, especially in urban waterways.

The experiences that NIBIO has had with the method have been presented in three project reports published on nibio.no.



Purpose: Develop a method for tracking of pollution sources.
Funding: Norwegian Water Resources and Energy Directorate.
Contact person: Research Professor Adam Paruch, e-mail: adam.paruch@nibio.no, mobile phone: +47 924 58 374.
Division of Environment and Natural Resources.



Photo: Kari Stensgaard



Recreation replaces production at mountain summer farms

Mountain summer dairies have been very common in Norway, and created a landscape with great biological and cultural values. But the summer dairy landscape is changing. What is the state of summer dairies today? Are they in use? And are the values being preserved?

A seven-year project with the aim of answering these questions had its final season in the summer of 2015. 1700 summer dairies were visited, and information about buildings and meadows, condition and current usage was recorded.

For most Norwegians, summer dairies or farms in the mountains represent something positive. Nevertheless, the use of these areas has changed greatly over time. A vast number of summer farms are no longer in use. Holiday cabins take over for mountain farms, recreation takes over from production. In today's actively run summer farms, operations have been modernized. Many are open for visitors and welcome tourists.

-The buildings for production disappear, cattle and hay barns are gone, says project administrator Kari Stensgaard. In this way, the summer dairies gradually lose their historic and educational content. It will be more difficult for people in the future to understand, and we lose part of our culture, she says.

Around 1850 there were 50,000 farms in Norway that had one or several connected mountain summer farms.

Some findings and facts

- In about a quarter of the around 1700 registered summer dairies, there are no longer signs of use
- Only 4-5% of the 1700 summer dairies are actively working with dairying
- More than half are used as holiday homes
- Cutting and grazing are carried out on one third
- Barely 1% work with tourism in terms of serving food, information or accommodation
- All actively run summer farms have road access, while this is not the case for summer farms open for visitors
- A third are connected to the electricity grid

The project is part of the 3Q monitoring programme where the condition, changes and development tendencies in the agricultural landscape are being recorded.



Purpose: To contribute to an overview of mountain summer farms and dairies, so that these, their landscape and their use receive more attention as part of the national cultural heritage.

Collaboration: Directorate for Cultural Heritage.

Funding: Norwegian Ministry of Agriculture and Food.

Contact: Lead Engineer Kari Stensgaard, e-mail: kari.stensgaard@nibio.no, mobile phone: +47 902 32 230. Division of Geography and Statistics.



Photo: Lely

The milking robot – important in modern agriculture

When looking to improve the efficiency of agriculture, increase flexibility for the farmer and the well-being of the animals, a milking robot could be the answer.

It has certainly become part of everyday operation in many dairy farms and represent new technology in agriculture. This makes it interesting to compare the operation of farms with and without robots. What are the consequences of changing to robot use?

More time and less money with robots

The number of milking robots in Norway is increasing by close to 200 per year. The study suggests that it is largely social factors that are behind the choice to switch to robot-based milk production.

A milking robot gives higher production in a shorter time, as well as increased flexibility for the farmer. The economy of farms with robots is weaker than those without, both the financial performance before depreciation and measured as remuneration per year of work.

On average, a farmer with a robot uses 10 hours less time annually per cow, but gets 700 kilograms more

milk per animal, i.e. 8100 kilograms per cow-year. Farms without robots have better financial results (figures from 2014).

“When we see the same result for the second year running, we are able to day with greater confidence that these are real differences,” says Jostein Vasseljen in NIBIOs Department of Farm Economics.

Great variety among those using robots

Within the group using robots, there are clear differences in the economic results without any given factor providing an obvious explanation.

– The sum of many small differences pointing in the same direction seems to give the final result, says Vasseljen. In the end, it seems to be the quality of the management that makes the difference.

The difference is barely a half million NOK more in remuneration per man-year for those running their farms best in the group using robots.



Purpose: Study to investigate and compare farm economies with and without milking robots, based on data from NIBIO's accounting statistics.

Funding: Combination of public and private sources.

Contact: Adviser Jostein Vasseljen, e-mail: Jostein.Vasseljen@nibio.no, mobile phone: +47 941 35 739. Division of Geography and Statistics.



Photo: Lasse Weiseth



Breakdown of pesticides in the Norwegian climate

The Nordic climate can represent poor conditions for the breakdown of pesticides in the soil compared to the rest of Europe. This must be taken into account when approving pesticides for use in Norway.

The length of the growing season in Central and Southern Europe means that each year there are at least 60–140 additional days for efficient biodegradation of pesticides in the soil compared to here in the north. NIBIO's latest study sheds new light on the breakdown and fate of pesticides in Norway.

The project has demonstrated that pesticides in the group "fungicides in Norwegian soil" are broken down more slowly when the winters are longer. Decomposition of the fungicides Propikonazol and Boskalid by microbes in the soil, is very low at the two northernmost localities (Stjørdal and Tromsø). The amount of fungicides used needed more than 1000 days to be reduced by 50%.

The main cause of slow breakdown is that low soil temperatures lead to reduced microbial activity and thus reduced microbial decomposition of pesticides.

Fungicides are mainly strongly bound in the top soil layer (0–10 cm depth), but discoveries in deeper layers show that there can be a risk for fungicide leakage over time as the slow breakdown of pesticides means that the residence time, or persistence, of pesticides in the soil increases. This can lead to more leaching and runoff of pesticides to groundwater and surface water here in the north.



- Purpose:** Contribute to pesticides that are approved for use in Norway having the least possible adverse impact on health and the environment.
- Collaboration:** Norwegian Food Safety Authority.
- Funding:** Action plan for reduced risk with use of pesticides (2010–2015), Ministry of Agriculture and Food.
- Contact:** Research scientist Marit Almvik, e-mail: marit.almvik@nibio.no, mobile phone: +47 922 91 231. Division of Biotechnology and Plant Health.

