# Reducing runoff of plant nutrients

With the ultimate goal of reducing nutrient pollution, Drs Marianne Bechmann, Johannes Deelstra and Marit Hauken share insights into how monitoring can contribute to improved decision making for improved water quality

**How would you define the Norwegian Agricultural Environmental Monitoring Programme's (JOVA's) vision and its principal objectives?**

The vision is to identify how important runoff from different agricultural areas is for water quality in Norway and investigate the effect of different productions systems and mitigation methods on nutrient and pesticide losses.

The objective of the programme is to document the level of nutrient and pesticide losses from the agricultural landscape to Norwegian water bodies, and then identify the most important factors influencing these losses.

**What comparisons has JOVA made between the different catchment areas?**

Nutrient balances – the balance between input of nutrients in fertiliser and manure and the removed nutrients with yield – have been compared between the different catchments. This indicated a much higher surplus of nutrients in areas with intensive livestock production compared to areas with cereal production. Correspondingly, the soil phosphorus status was much higher in the livestock-dominated areas. In the runoff data, the livestock-dominated areas correspond to higher concentrations of dissolved nutrients in the stream.

**Which mitigation measures are you currently evaluating?**

The mitigation measures being evaluated are, first of all, soil tillage methods to reduce erosion from areas with arable cropping. The positive effect of this is reduced phosphorus loss from agricultural areas. Unfortunately, this measure includes a dilemma in regard to the use of pesticides, which increases under reduced tillage, and therefore runoff of pesticides may increase. Another important mitigation measure is the rate of nutrient application. This is evaluated both in relation to yield level and to loss of nutrients to water. Additionally, the effect of a sedimentation pond has been assessed for one of the catchments.

**With a focus on soil and nutrient practices, can more be done to improve and develop management in the Norwegian agricultural landscape?**

During the monitoring period, only minor changes in soil tillage have occurred. The farmers traditionally ploughed all fields in autumn. Around 1990, they started ploughing in spring to reduce soil erosion and phosphorus loss. Our monitoring started in 1992 but the effect of autumn ploughing could only be documented in the first few years. Additionally, the change from autumn ploughing to no till in autumn was incomplete, since some farmers still plough in autumn to sow winter cereals. Increasingly large areas are also being cultivated through the use of harrowing in autumn, which has also contributed to increased risk of erosion and phosphorus loss compared to no tilling in this season.

Overall, the changes in soil tillage have not been sufficient to create significant changes in measured losses, which are, of course, also due to the huge variation caused by variation in weather conditions. One important lesson to learn from these results is that the consequences of changed soil tillage methods could not be expected in such a short timeframe when implementation remained incomplete.

**Where is your team focusing its efforts in terms of agricultural policy? What will be the key determinants for changes to this policy?**

Although agriculture has a significant effect on water quality in Norway, it is important to remember that even without agricultural production there will still be a certain level of nutrient loss from these areas, since areas with marine clay have a relatively high natural content of nutrient. For pesticides, however, the relationship between use and detections are obvious from the data. Yet, it is important to evaluate the dilemma between methods to mitigate losses of nutrient and losses of pesticides.

**In which areas are you hoping to channel your research focus in the coming years?**

Nitrogen is becoming increasingly important because of its role in greenhouse gas emission. Agriculture has an important role to play here and it is essential to look at the environmental effects of agriculture with a holistic perspective. The effect of production systems and mitigations methods should be evaluated both with regards to effect on water quality and their effect on climate gas emissions.

**Overall, what do you hope to be the major implementations of your research findings?**

We hope that our findings will contribute to a more efficient strategy for implementation of methods to improve water quality. Even though mitigating nutrient losses from the agricultural sector seem to be cost-effective when looking at results from plot-scale studies, the effect at the landscape scale measured in the catchments shows that the effectiveness in the recipient is lower and the results only obtained in a very long term. However, the outcomes also indicate that even though mitigation methods has been implemented, other changes in the agricultural production system have caused increased risk of nutrient losses from these areas, eg. increased livestock density.

# Protecting against pollution

In an effort to highlight the significance of agricultural pollution upon water quality, the **Norwegian Agricultural Environmental Monitoring Programme** is monitoring catchment nutrient runoff

**AGRICULTURAL LAND ACCOUNTS** for 902,000 ha of Norway's territory (3 per cent of the total land mass) and, while larger farms exist, the average is small at around 55 acres. Over time, there has been an increase in livestock density in the southwestern regions, with intensive dairy farming and grass production. The main areas of crop production include cereals in the southeast and the midlands; and more extensive grass production in the mountains and in the north. Terrain challenges for agriculture in many regions consist of steep slopes, artificial land levelling and high risk of erosion – especially during periods of snowmelt in winter and spring. These landscape and climatic conditions cause significant transfer of soil and plant nutrients from farmland to water systems in Norway, which in turn has a negative impact on local aquatic ecosystems.

## EUTROPHICATION

Pollution of lakes and rivers occurs most frequently in low lying areas, near settlements and close to agricultural land. The increased level of phosphorus and nitrogen in water leads to algal blooms, and also in some cases production of algal toxins, which are poisonous to humans and prevent the use of lakes for recreation. Additionally, the degradation of algal blooms by bacteria results in hypoxia, reducing the oxygen content of the water. This can kill local wildlife such as fish and waterborne organisms. The reduced quality of water leads to a reduction in local food sources such as fishing, impaired possibilities for drinking water and damage to the entire local ecosystem.

## A NEED TO REDUCE PHOSPHORUS LEVELS

To achieve high production yields of food requires nutrients input in the form of fertilisers or manure which contain phosphorus and nitrogen. One disadvantage of these nutrient sources is the significant environmental impact they have, if applied in surplus, on the surrounding streams, rivers and lakes due to runoff of these chemical elements. In 1985, a national action plan against agricultural pollution was launched in an attempt to mitigate the amount of soil and phosphorus transfer occurring from agricultural land into water sources.

SKUTERUD MONITORING STATION

Strategy focus has emphasised reducing soil erosion and improving nutrient management planning, resulting in farmers reducing fertiliser use by 40 per cent between 1985 and 2000 (Statistics Norway). Despite reductions in fertiliser use, Norway still has a high surface nutrient balance at the third highest of European countries. With increasing livestock levels, the surplus amount of nutrients in manure is a challenge to farmers in the most intensive production areas.

## WATER QUALITY MONITORING

Dr Marianne Bechmann and her colleagues at The Norwegian Agricultural Environmental Monitoring Programme (JOVA) have been working on mitigation options to reduce nutrient losses. Natural conditions, types of farming techniques and meteorological events all contribute to the levels of phosphorus transferred to water. The project's objective is to evaluate the effect of agriculture on water quality. Understanding the complex phenomena that result in phosphorus and nitrogen transfer is essential in the battle to reduce pollution levels, whilst maintaining the efficacy of local farming. The team monitored eight individual catchments around in Norway for effects of farming practices: type of crop, time of sowing/harvesting, type of animals, amount of fertiliser, manure application, tillage methods and pesticide use on the amount of discharge in local water systems.

## CATCHMENT SCALE MONITORING

The catchments scale used in the JOVA programme represents the area of land which contributes in totality to the recipient water body of that area, including contribution from groundwater, surface and subsurface water. Bechmann explains that in evaluating transfer of nutrients all aspects of land usage and environmental processes must be assessed, the monitoring of which is essential for modelling of the system to be accomplished: "As such, the total effect of agricultural practice, implemented mitigation methods and natural processes on nutrient and pesticide loss is documented. The measured loss at this scale is the actual contributions experienced by the receiving water body".

By monitoring stream water quality at the catchment scale, the group has been able to define the essential importance of weather on the system as a whole. The amount of precipitation, duration and intensity, as well as distribution and overall temperature, accounts for most of the variation in total loss of soil and nutrients into the water table system. The temporal variation in losses is great: "One week of rain with snowmelt in April has caused the same loss of soil as the average annual soil loss during the monitoring period," Bechmann remarks. "One of the main findings is therefore that the annual soil, nutrient and pesticide loss from agricultural catchments is highly influenced by weather conditions and may erase the expected effect of mitigation methods implemented."

Included in the runoff process is the impact of erosion occurring at stream banks as well as sedimentation and potential retention in the landscape. The team confirmed a relationship between suspended sediments and phosphorus, with the highest levels of transfer occurring alongside pronounced erosion. Agricultural production methods such as usage of fertiliser and manure, and frequency of soil tillage, can be an indicative factor in determining erosion and runoff. Land share for agriculture within the catchment is also an important factor, determining levels of erosion and therefore phosphorus transfer.

## STATISTICAL METHODOLOGY ILLUMINATES FINDINGS

Large inter-annual variations in discharges of nitrogen, phosphorus and suspended sediments from catchments can most likely be accounted for by differences in weather patterns of different seasons. It was found that there is a good relationship between precipitation levels and discharge of water from agricultural land with associated losses of nutrients. The monitoring programme found that there were large discrepancies between streams; the highest levels of concentrations of nitrogen were of streams in the Kolstad catchment, mostly producing cereals in combination with manure from pigs and hens. Levels of phosphorus were highest in streams of the Vasshaglona catchment, which are also dominated by cereal production. Low levels of phosphorus were usually characteristic for catchments with large pastoral areas.

In comparison to other Nordic countries, losses from agricultural land in Norway is proportionately high, which could be attributed to differences in hydrological pathways and higher runoff of water.

The JOVA project group: Rikard Pedersen; Geir Tveiti; Inga Greipsland; Marianne Stenrød; Marit Hauken; Johannes Deelstra; Marianne Bechmann; Hans Olav Eggestad.

Further, the JOVA scientists have been able to document that differences in farming practices have a pronounced effect on the amount of nutrient transfer in the region. However, no simple relationship exists. In 1998, Bechmann found that the correlation between nitrogen surface balances and nitrogen leaching varied across four catchment areas – they found a poor correlation between surface balances and leaching, indicating that other factors such as soil quality and farming techniques are also indicative.

## IMPROVED WATER QUALITY DUE TO A WETLAND

Since 1994, in order to combat the losses of nitrogen and phosphorus from land to water sources, Norway has established 'constructed wetlands' through public funding initiatives. In the Skuterud catchment, a constructed wetland was established in 2000 with 70 per cent funding from the government. Results of the monitoring programme have shown that since 2001 the water quality has improved due to the constructed wetland.

## CLIMATE CHANGE AND CATCHMENTS

JOVA has assessed the impact of climate change on four regions of Norway: Hotran, Time, Skas-Heigre and Skuterud. Increases in temperature and precipitation are predicted in all four of the catchments and it is thought this will lead to an increase in runoff of phosphorus. Other changes in seasonal weather patterns and freeze-thaw cycles have been predicted that will also change the erosion and transfer rates. Over the coming decades the JOVA scientists will have to work minimise the impact of climate change on catchment runoff processes. Thus far, the scientists have been able to quantify the transfer of soil and nutrients from agriculture to Norway's water sources and have documented the great variation in effect of mitigations measures. With this understanding, water managers will be able to better prioritise mitigation measures between different sectors, for the most efficient mitigation strategy. Further development of mitigation measures are necessary keeping in mind the impact of future climate changes.


AUTUMN PLOUGHING IS THE TRADITIONAL SOIL TILLAGE METHOD IN NORWAY

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INTELLIGENCE

# JOVA

### NORWEGIAN AGRICULTURAL ENVIRONMENTAL MONITORING PROGRAMME

### OBJECTIVES

To document the levels of losses of suspended sediments (SS) and nutrients in different parts of Norway and from different agricultural production systems and evaluate the effects of political strategies on these losses.

### PARTNERS

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**MARIANNE BECHMANN, PhD** has worked for more than 20 years with nutrient runoff from agricultural areas within the Norwegian Agricultural Environmental Monitoring Programme and in other projects. She is working on improved understanding on transport processes in agricultural catchments and on developing methods to mitigate nutrient losses.

In 2013, Marianne Bechmann and Johannes Deelstra edited a book on *Agriculture and Environment – Long Term Monitoring in Norway* summarising experiences from 20 years of Monitoring agricultural runoff. This book includes 21 independent chapters on hydrology, monitoring methods, trends in agricultural management, modelling catchment scale processes, results on nutrient and pesticide losses, and much more. This book can be acquired from Akademika Publishing: www.akademikaforlag.no.

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