MONITORING AND ASSESSMENT OF NON-POINT SOURCE POLLUTION IN NORWAY

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Biographical sketches of authors

Johannes Deelstra is an agro-hydrologist. Before working in Norway he obtained extensive experience with agriculture and water related issues in Kenya and Egypt. At present his main activities are related to agriculture and environment. He has been working with the Agricultural Environmental Monitoring Programme in Norway (JOVA) since 1992 and is since 1993 also involved with agriculture and environmental issues in the Baltic countries.

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Marianne Bechmann is an environmental scientist. Since 1989 her main field of work has been nutrient dynamics and monitoring nutrient losses at catchment scale, e.g. as co-ordinator of the nutrient part of the Agricultural Environmental Monitoring Program in Norway. Now she is a Ph. D student working on risk assessment of phosphorus losses. Bechmann have several international publications in this field

Hans Olav Eggestad is an environmental scientist. His main tasks are related to the Agricultural Environmental Monitoring Programme in Norway (JOVA) in which he is responsible for the development of software and database management. In addition, he is working with statistical modelling in relation to data reporting both at national and international level.

Nils Vagstad has long experience within agro-hydrology, agronomy, environmental issues in agriculture, land resources and watershed management. He has an extended network within agriculture/environment including monitoring in the Baltic Sea Region and in Northern Europe and is participating in various working groups and task forces under e.g. HELCOM, Baltic 21, OSPAR.

Abstract

The Agricultural Environmental Monitoring Programme (JOVA) in Norway monitors and assesses nutrient losses and erosion from 10 small agricultural catchments under different agricultural systems and climatological, topographical and geo-hydrological conditions. The core of the monitoring activities consists of discharge measurement and water sampling, providing data for nutrient load calculation. Routines have been developed for automatic downloading of recorded data on a daily basis, control of runoff data and water analysis results in addition to load calculations. Relevant information regarding farming practices is collected yearly at the level of the individual farmer field and entered into a database while reporting routines concerning farming practices have been developed. The monitoring program is integrated into existing national networks and provides on a yearly basis relevant data to comply with both national and international obligations. The JOVA-programme includes components dealing with modelling nutrient loads and erosion and when necessary additional measurements are carried out to support these activities. To enhance the sustainability of the monitoring programme, the design and implementation is such that it is suitable and attractive for research and educational purposes while the applied measuring methods and procedures are sufficiently advanced to comply with international scientific standards.

INTRODUCTION

Jordforsk is in charge of the Agricultural Environmental Monitoring Programme (JOVA) in Norway. One of the major objectives of the programme is to document the effect of different agricultural production systems and site – specific characteristics on erosion and nutrient losses to surface waters and to advice local and central policymakers about agricultural production systems and their environmental effects. JOVA is a joint effort between the Norwegian Centre for Soil and Environmental Research (Jordforsk), the Norwegian Crop Research Institute (Planteforsk), Rogaland Research, the Norwegian Institute for Water Research (NIVA) and the County Department of Environmental and Agricultural Affairs. The programme is funded by the Norwegian Agricultural Authority. The JOVA-programme also includes a component dealing with monitoring of pesticides. Many of the data collection routines presented in this paper are applicable to that component, however detailed results are not presented here. In relation to the JOVA-programme also a monitoring of 8 fresh water lakes has been carried out with the objective to illustrate the water quality effects of agricultural pollution. This programme and its results are not presented here.

JOVA - THE AGRICULTURAL ENVIRONMENTAL MONITORING PROGRAMME IN NORWAY

The programme has been in operation since 1992 in 10 agricultural catchments varying in size from 1- 20 km^2. The catchments represent different geo-hydrological conditions, agricultural practices and climatological conditions (Table 1). Three of the catchments are dominated by cereal production, four by grass production/livestock husbandry while two are characterised by a combination of cereal/grass production (with cereal as the dominating crop). One catchment has a combination of potatoes, vegetables and cereals. Field scale studies (Bye and Vandsemb) are related to 2 monitoring catchments but the results are not presented here.

Figure 1. Geographical location of monitoring stations (above), the Mørdre catchment outlet (right, top) and Naurstad during winter (right, bottom).

Within the JOVA - programme, information concerning agricultural practices is collected yearly for individual farm fields in the catchments and any changes in practices are thereby recorded. In addition, nutrient and soil loss is measured. Measuring those losses at catchment scale is not necessarily a straightforward task. The choice of methodology regarding the accuracy and precision of the collected data has to be a compromise between costs (e.g. equipment and operation & maintenance costs) and end-users demand (e.g. researchers, managers, public authorities). There is no one specific method which can be recommended, except that each case has to be considered separately on the basis of the site specific conditions like catchment size, topography, channel characteristics, climatological conditions and the geo-hydrological settings. Correct measurements of nitrogen (N) and phosphorus (P) losses (loads in surface waters at catchment scale) require reliable and precise data on concentrations as well as on water discharge. The reliability of the data may be affected by both field procedures as well as analytical procedures.

Table 1. Main catchment characteristics

Nedbørfelt	Total area (ha)	Farm land (%)	Temp (°C)	Precip. (mm)	Soil type	Major crop
Skuterud	449	61	5.5	785	Silty loam	Cereals
Mørdre	680	65	4.3	665	Silt and clay	Cereals
Kolstad	308	68	4.2	585	Humic loam	Cereals
Hotran	1940	58	5.3	892	Silty loam/clay	Cereals, grass
Naurstad	146	35	4.5	1020	Bog/fine sand	Grass
Skas-Heigre	2930	85	7.7	1180	Clay/sand/gravel	Grass, cereals
Volbu	168	41	1.6	575	Silty sand	Grass
Vasshaglona	65	62	6.9	1230	Sand	Vegetables, potatoes, cereals
Time	1140	85	7.2	1189	Silty sand	Grass
Grimestad	177	45	7.3	1080	Silty sand	Cereals, grass

DISCHARGE MEASUREMENT

Different methods can be used to obtain information about stream discharge but they are often based on the combination of direct measurement of the water level and a known head-discharge relation for the measurement location (Deelstra, J. et al, 1998). When natural profiles are used for discharge measurement, a head-discharge function has to be established. A problem often encountered is the change in flow conditions over time due to vegetative growth. This is especially true for small streams with a high relative influence of vegetative growth and can lead to large uncertainties in the head-discharge relation. When initiating a long term monitoring programme, fixed measuring devices are preferred with a known head-discharge relation and high accuracy in discharge measurement. In the JOVA - programme, both the V-notch and the Crump weir are used. The V- notch (Figure 1) is a widely used measurement structure in the Nordic countries (Granholm, 1989). When soil erosion is present, sedimentation can cause serious problems for the proper functioning of the V-notch. The Crump-weir (Figure 2) is a short crested weir (Bos, 1978) and is extensively used in the JOVA - programme. It can operate under partly submerged flow conditions while in addition it has the ability to transport sediments over the crest.

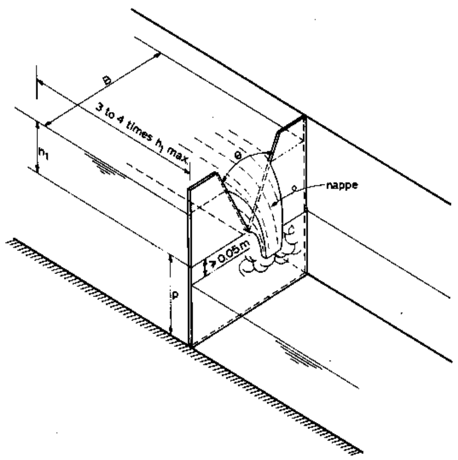

Figure 1. V-notch(after Bos, 1978)

The head - discharge relation, developed in the laboratory is;

$$Q = C_e \times \frac{8}{15} \times tg\alpha \times \sqrt{2 \times g} \times h^{2.5}$$

where

C_e - discharge coefficient
α - angle of V-notch
g - acceleration of gravity
h - water level

The head - discharge relation is

$$Q = B_c \times C_d \times C_v \times \frac{2}{3} \times \left(\frac{2}{3} \times g\right)^{0.5} \times h_1^{1.5}$$

where

C_d - discharge coefficient
C_v - approach velocitiy coefficient
B_c - width of structure
g - acceleration of gravity
h_1 - water level

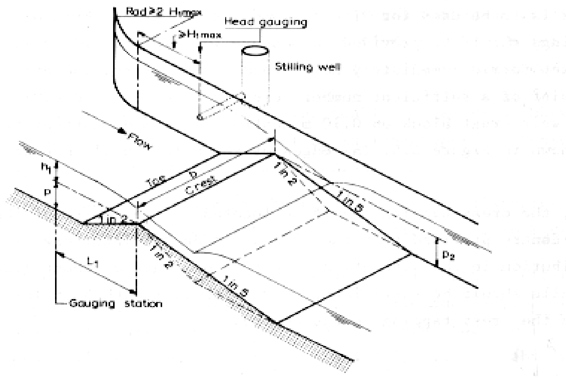

Figure 2. Crump weir(after Bos, 1978)

Within the JOVA - programme, discharge measurements are carried out automatically based on the known head - discharge relation of the measurement structure in combination with a data-logger. Water levels are recorded using a pressure transducer.

WATER SAMPLING AND WATER ANALYSIS

The selection of the appropriate water sampling strategy is an important issue in catchment monitoring programmes (Deelstra et al, 1998). The water sampling strategy has to be able to cope with the dynamics involved in the loss generating flow processes. The losses of P, and to a lesser extend N, are typically event based, and depend on a combination of the prevailing geo-hydrological settings, climatological conditions and agricultural practices. In general one can differentiate between two sampling strategies i.e. 1) grab or “point” sampling and 2) volume proportional composite sampling. Also a combination of the two sampling strategies can occur, being point sampling during stable, low flow periods and volume proportional composite sampling during certain storm events.

Comparative studies of different sampling strategies in the Nordic countries revealed substantial differences in calculated loads depending on the method used (e.g. Rekolainen et al., 1991, Kronvang and Bruhn, 1996; Deelstra, 1996a; Deelstra, 1996b; Haraldsen, 2002). The general conclusion is that point sampling strategies tend to lead to erroneous estimates, particularly for the P losses. Eggestad et al. (1994), compared different grab sampling routines and found large deviations from the “true” load, calculated on the basis of volume proportional sampling. Weekly or forth-nightly sampling resulted in severe underestimated P - loads (< 10 % of the “true” figures) as well as severe overestimates (more than twice the “true” figure). The deviations of N were generally less than for P. One should, however, bear in mind the prevailing geo-hydrological conditions in the Norwegian catchments, with a low base flow component in the total runoff volume in addition to many event flow situations of rather short duration. In the JOVA-programme, composite water samples are collected on a volume proportional basis at all the monitoring stations. The water sampling routine is steered by a data-logger. Each time a certain volume of water has passed through the discharge measurement structure, a pre-set water sample volume is taken. The water sampling frequency is determined by the discharge intensity. The composite water sample is stored in a refrigerator at the monitoring site and collected every fortnight being subsequently analysed for among others plant nutrients, dissolved solids and pesticides.

DATA MANAGEMENT AND CONTROL

All the monitoring stations are connected by telephone to the main office. A system has been developed which establishes contact every day between the mainframe computer and the monitoring stations and taking care of an automatic download of the recorded data. At the main office (Jordforsk), each monitoring station has been appointed a person, responsible for the operation and management of the station, including monitoring functionality, validation of data and reporting. Control routines are carried out on the collected data before inserted them into a Sybase-database. In case of communication problems or missing data, error messages are generated automatically and send by email to the person in charge of the station, in this way guaranteeing that immediate action can be taken. The data control and verification process can be carried out in two ways. When direct access to the main computer through a local network is available, the data verification process is carried out by interactively running specific commands for data control on the mainframe computer.

External access to the data control and verification programmes is also possible. In this case, on a weekly basis, the mainframe computer automatically sends, via email an overview of the data collected during the last week, consisting of diagrams and data tables in Excel format presenting the observations. If errors are detected, the data can be corrected with a set of predefined macros for easy data editing. After this, the data are returned, by email, to the mainframe computer and automatically inserted into the database.

The data control programme is supported by a field programme, in which the monitoring stations are visited every fortnight to carry out routine control of measuring equipment and to collect the composite water sample. Water samples are brought to the laboratory for subsequent analysis while the results are sent by email to the mainframe computer. Also the analysis results are checked using control routines developed for the monitoring programme.

On the basis of the water analysis results and the measured runoff the total load calculation is carried out. Reporting routines have been developed and standard tables and graphs are produced to be included in the yearly reporting to the agricultural and environmental authorities. In addition, routines are available for more specialised data analysis.

FARMER INFORMATION

Information on management practices within the individual catchments is derived from different sources. For the majority of the catchments in the JOVA –programme, data on farming practices are available on an annual basis. Through yearly questionnaires, the farmers provide information on management practices for the individual farmer fields within the catchment. These data consist of planting (crop and time), nutrient application (time and rate), soil management, pesticide use (time and rate) and yield (time and amount). The farmer field scale is a management unit and varies in size from < 1 – 20 ha, with an average size of 2.3 ha. These data are stored in a database from which standard output files are available for the yearly reporting as well as data for more specialized data analysis. The database contains standard values for nutrient contents of crops and fertilizers for calculation of e.g. nutrient balances. Figure 3 gives an example of the use of farmer information, presenting the soil condition on the individual farmer fields during an autumn period.

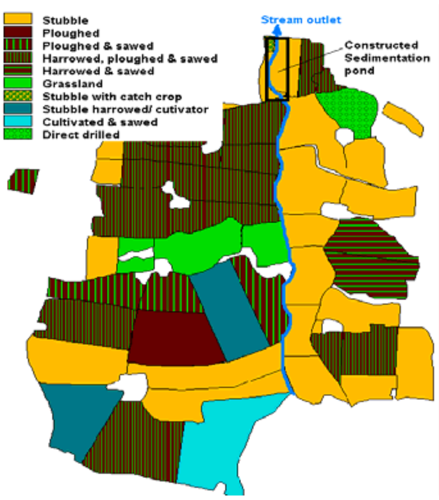

Figure 3. Soil conditions during autumn on fields in the Skuterud catchment

For some of the larger catchments in the JOVA programme, the information on agricultural practices consists only of data from Statistics Norway. Data from Statistics Norway contain information on distribution of crops, soil cultivation, and livestock density for all years and nutrient application (time and rate) for some years. Contrary to the data collected through the yearly questionnaires, the data from Statistics Norway are only available at farm scale.

RESULTS

Table 2 presents the measured average runoff and loss of nitrogen, phosphorus and suspended solids from the catchments. As can be seen there are large variations. Although the highest runoff is observed in the Naurstad catchment, the highest losses for nutrient and soil loss occur in other catchments. A probable reason for the high variation in the losses is most likely the wide range in climatic and hydro-meteorological conditions, also indicated by the high range in runoff.

Table 2. Average measured runoff, loss of nutrients and soil loss.

	Runoff mm	Total Nit. kg/ha	Total Phos. kg/ha	Susp. Solids kg/ha
Skuterud	523	44	2.5	1550
Mørdre	287	20	1.5	1100
Kolstad	322	50	0.5	163
Hotran	769	54	3.8	2660
Naurstad	1151	30	4.0	751
Skas-Heigre	656	40	1.2	
Volbu	286	20	0.4	63
Vasshaglona	1277	100	6.9	1540

N losses are mainly the result of leaching processes and surface runoff is rarely being a significant pathway. Prerequisites for N-leaching are N availability in the root zone and surplus water for downward transport of N. The Norwegian soils in general are intensively drained and a large part of the leached N will therefore presumably be transported directly to the surface water. The greatest N-loss was 100 kg ha^{-1}, measured at a catchment which is dominated by vegetable production. The reason for the high loss can be attributed to a large amount of N available in the rootzone due the high N-fertiliser levels, in addition to a high precipitation. The cereal dominated catchments Skuterud and Mørdre show significantly different N-losses although the fertiliser and yield levels are approximately the same. Possible reasons for the difference are still under investigation.

The P-loss processes are quite different from the N-loss processes and depend less on biological soil processes. The P sorption capacity of most soils is very high, usually resulting in moderate leaching of P, the exceptions being coarse textured sandy soils or peat soils with low contents of clay minerals, Al, Fe or Ca. Soil erosion is a major source of P losses from arable land in which P containing soil particles are transported both via surface runoff and percolating water through macro-pores, cracks and finally through the tile drain systems reach the open water courses. In regions with a cold winter climate, P containing plant residues at the soil surface may also pose a risk for substantial P losses by surface runoff during melting periods. In areas with high livestock density, P-application may be another major cause of P-loss. Manure or slurry applications may also result in direct losses but strict regulations on the spreading of animal manure can significantly reduce this loss. The highest average P-losses have been observed at Vasshaglona, Naurstad and Hotran catchment. The Vasshaglona catchment is dominated by vegetable production and the soils have a very high P-content. Both field and stream bank erosion are the most likely reasons for the high P-losses in addition to the high suspended solid losses. Naurstad is dominated by peat soils and a low capacity for P-sorption, leading to high losses of P. The main reason for the high P-losses in the Hotran catchment is due to field and stream bank erosion processes, also leading to the highest loss of suspended solids. The high loss of suspended solids in the Mørdre and Skuterud catchment are mainly caused by field erosion processes during the period from late autumn until spring. During this period erosion often is caused by a combination of processes related to freeze and thaw periods combined with rain and snowmelt.

INFORMATION DISSEMINATION

The results of the monitoring programme are disseminated in different ways.

- At national level, every year the results are reported to and discussed with representatives from the Ministry of Agriculture, the Ministry of Environment and the Norwegian Pollution Control Authority. In addition, the yearly reports are distributed at the provincial and local agricultural and environmental authorities involved in the JOVA-programme.
- The results are available on the Internet.
- The data are also used to obtain the total annual nutrient load from Norwegian agriculture to the North Sea and is part of an obligatory reporting to the OSPAR - commission, dealing among others with the nutrient load to the North Sea.

- Researchers from Jordforsk participate at local level in meetings with farmers to discuss and explain the results obtained in the programme or present the results at national and international seminars and conferences.
- Twice per year the JOVA project group meets with the project advisory committee to discuss results and adjust priorities.

Through the JOVA-programme a large amount of data has become available. These data can be used for different research purposes, both by Jordforsk - researchers but also researchers from other institutions both at national and international level. Because an infrastructure for data collection is available, the monitoring fields are suitable as research areas.
Different projects already have been carried out or are under execution, among others dealing with modelling, scenario studies on nitrogen runoff and pesticide leaching, research projects on winter erosion processes and studies related to spatial variability in soil properties.

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