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Correlations between Concentrations of Plant Nutrients in Runoff from Small Catchments in Norway

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Factor analysis investigated the relationship between different compounds of nitrogen, phosphorus, potassium and suspended dry matter in runoff from catchments in agricultural areas in southern and central Norway. The plant nutrients were grouped in three factors: phosphorus factor, nitrogen factor and erosion factor. In south-eastern Norway there was a significant correlation between runoff and concentration levels of phosphorus and suspended dry matter in winter and spring erosion periods. Climate, agricultural practices and soil conditions caused seasonal variation of the different factors. In the catchments in south-western Norway there was a decreasing trend in concentration level of nitrogen due to changed practice for slurry application. In the catchments in eastern and central Norway there was a decreasing concentration level of phosphorus. The reduction in applied phosphorus was 15-50% but the decrease in concentration level of phosphorus in runoff accounted for 5 to 15% of the variation.

Introduction

Since 1985, investigating the leaching of nutrients from small agricultural catchments has been a part of a Norwegian monitoring programme (Rognerud *et al.* 1989, Haraldsen *et al.* 1992). Four counties in southern and central Norway, different in climate, soil type and agricultural practice, were selected for the investigation. The monitoring programme aimed at: documenting runoff and loss of nutrients under field conditions, implementing different measures to reduce soil and nutrient losses, and studying the effect on water quality, and gaining economic experience in implementing techniques to reduce soil and nutrient losses.

Our study was based on data from the Norwegian monitoring programme. The aims were to use: i) statistical analyses to study relationships between concentration levels of plant nutrients, suspended dry matter and runoff; ii) factor analysis to study variation in concentration levels of plant nutrients due to different agricultural practise; iii) trend analysis (regression) to detect effects of different agricultural practices on concentration levels of plant nutrients.

Material and Methods

Material

Information about the catchments are listed in Table 1. The four counties (Fig. 1) represent regions with different climate, agricultural production and soils, and for these reasons the patterns of soil and nutrient losses were different: south-eastern Norway, erosion was due to marine loamy sediments and soil cultivation in autumn; south-western Norway, nutrient losses were attributed to intensive animal husbandry, heavy use of fertilizer and leaching of manure and slurry; eastern and central Norway, erosion and leaching of nutrients from mixed agriculture.

Table 1 – Description of the catchments

Region (County)	Catchment	Area km2	Period	Soil	Production	Author
SE Norway	Lodding	2.1	1985-88	Loam, clay loam (marine)	Cereals	Øygarden (1989)
(Akershus)	Hauger	1.5	1985-88	Loam, clay loam (marine)	Cereals	Øygarden (1989)
E Norway	Kolstad	3.1	1985-90	Sandy, loam, loam (till)	Mixed farming	Eide (1989)
(Hedmark)	Hersoug	0.6	1985-88	Sandy loam, loam (till)	Mixed farming	Eide (1989)
SW Norway	Time	1.1	1985-90	Loamy sand (till)	Animal husbandry	Undheim (1989)
(Rogaland)	Herikstad	2.0	1985-88	Loamy sand (till)	Animal husbandry	Undheim (1989) Haraldsen *et.al.* (1992)
C Norway	Musum	1.7	1985-88	Loam, clay loam (marine)	Mixed farming	Vorum (1989)
(N-Trøndelag)	Holo	1.7	1985-90	Loam, clay loam (marine)	Mixed farming	Vorum (1989), Haraldsen *et.al.* (1992)

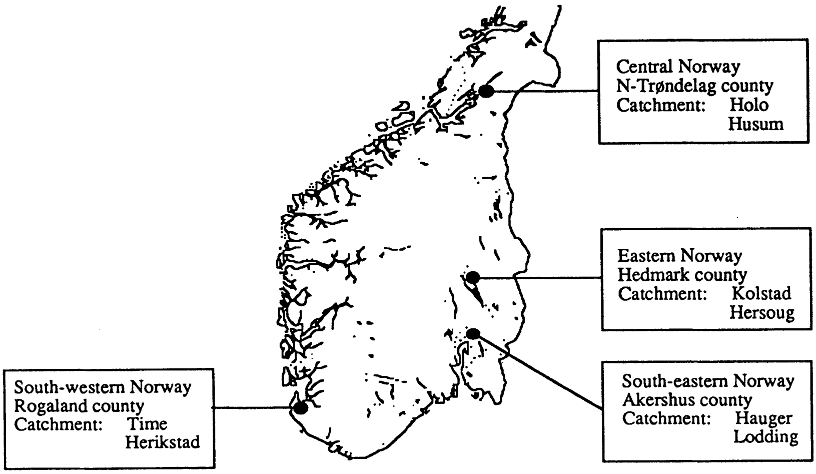

Fig. 1. Location of the different catchments.

A monitoring station was established in each catchment. Water level was registered continously. A water proportional sample represented seven days as a mean. However, the sampling period lasted in dry periods up to two weeks and in flood periods three to four days. Chemical analyses were performed according to the Norwegian Standard (Norges Standardiseringsforbund 1991). The parameters were: total-P, dissolved total-P, phosphate-P, total-N, nitrate-N, ashes, suspended dry matter and total-K. The discharge was calculated as mean runoff per day (m^3/day).

One catchment in each county was selected as a reference area (Hauger, Hersoug, Herikstad and Holo), where the farmers were to continue their traditional agricultural practices. In adjacent catchments (Lodding, Kolstad, Time and Musum) the farmers were asked to implement different measures (*e.g.* simplified soil tillage, scientifically based fertilization, hydrotechnical means) to reduce soil and nutrient losses.

Statistical Methods

To describe the relationship between the different variables (concentration levels of nutrients, suspended dry matter and runoff) in terms of underlying factors, we used factor analysis.

We assumed that we have n observations on p variables $X_1, X_2, \ldots, X_p$. The variables were for example, the concentration level of nutrients, suspended dry matter and runoff in the same periods. The factor analysis model assumes that there are m underlying factors (where $m<p$) which we denote by $f_1, f_2, \ldots f_m$, and that each observed variable is a linear function of these factors together with a residual variate, so that for observation j we have

$$X_{ij} = l_{1j}f_{j1} + l_{2j}f_{j2} + \dots + l_{mj}f_{jm} + e_{ij}, \quad i = 1,2,\dots,n, \quad j = 1,2,\dots,p$$

The weights $\{l_{kj}\}$ are called "factor loadings", so that l_{kj} is the loading of the j^{th} variable on the k^{th} factor. The factors $\{f_{jk}\}$ are called "common factors" or "factor scores". This means that factor loadings are related to different variables, while factor scores are related to the time for the measurements. The variate e_{ij} describes the residual variation specific to the j^{th} variate. In this paper we used the method of principal component analysis as the estimation procedure for factor loadings and factor scores. We based the analysis on the correlation matrix of X, and the number of factors corresponded to the numbers of eigenvalues larger than 1.0, but we included additional components until the explanation was sufficient.

To interpret the different factors, we plotted factor loadings for different factors. High factor loadings for different phosphorus compounds in one factor show that there is high correlation between different compounds of phosphorus in the water (P-factor). Similarly, high factor scores of the P-factor at a given time reflect high concentration levels of phosphorus compounds in the water.

If a solution exists, it will not be unique. Any orthogonal rotation of the factors will give a new set of factors that will satisfy the equation. The lack of uniqueness means that one can always rotate a solution to an alternative solution, which gives a better interpretation than the first one. As a rotation procedure, in order to get a good interpretation of the results, we used the orthogonal rotation procedure named VARIMAX (Mardia *et al.* 1979).

To investigate changes in the concentration levels of nutrients we conducted regression analysis. Factor scores were used as the dependent variable and time was used as the independent variable.

All the data analyses were carried out by the software package Statistical Analysis System (SAS) (SAS Institute Inc. 1989).

Results and Discussion

Correlations between Concentrations of Plant Nutrients and Suspended dry Matter

Catchments in South-Eastern Norway – The correlations between concentrations of plant nutrients and suspended dry matter in the catchments Lodding and Hauger were explained in five factors. These factors described 94% of the variance in Lodding and 91% in Hauger. The number of factors were relatively high compared to the number of variables in the matrix, and one more factor than in the other catchments. The rotated factors are grouped as dissolved P-factor, N-factor, erosion factor, K-factor and discharge factor. The loadings are listed in Tables 2 and 3.

In both catchments were similar patterns with an N-factor and a discharge factor.

Table 2 – Rotated factor loadings for Hauger

Variables	Dissolved P-factor	N-factor	Erosion factor	K-factor	Discharge factor
Dissolved total-P	96	2	3	19	3
Phosphate-P	96	2	12	13	4
Total-P	11	4	23	91	10
Total-N	13	97	6	7	-1
Nitrate-N	-8	97	1	-7	7
Susp. dry matter	9	3	94	4	2
Ashes	5	4	79	25	34
Total-K	33	-5	1	76	-40
Runoff	7	5	21	-9	94
Explained variance,%	22	21	18	17	13

Table 3 – Rotated factor loadings for Lodding

Variables	Dissolved P-factor	N-factor	Erosion factor	K-factor	Discharge factor
Dissolved total-P	96	1	1	4	1
Phosphate-P	96	0	3	0	5
Total-P	10	9	93	20	7
Total-N	8	98	5	3	5
Nitrate-N	9	97	-5	-1	11
Susp. dry matter	-3	1	86	9	38
Ashes	-2	11	95	11	12
Total-K	3	1	26	96	0
Runoff	7	16	36	-1	91
Explained variance,%	30	21	21	11	11

There was also a separate factor containing high loadings for phosphate-P and dissolved total-P. The dissolved P-factor had weak loadings for the other parameters, including total-P, and the loadings for the dissolved phosphorus compounds were weak in the other factors.

In the N-factor, both total-N and nitrate-N had high loadings and were correlated. Loadings for nitrogen near to zero in the other factors indicated no correlation of the concentration levels of nitrogen with other parameters. Leaching of nitrogen was independent of erosion and not correlated with losses of phosphorus.

Both catchments had an erosion factor. The high loadings for total-P, suspended dry matter and ashes in Lodding indicated correlation between these parameters.

The erosion factor for Hauger had high loadings for suspended dry matter and ashes, but not for total-P. This might mislead to the conclusion that eroded particles in Hauger did not cause as high phosphorus losses as in Lodding. The phosphorus content of the soil was at the same level in the two catchments. The difference, however, was due to agricultural activity. In Lodding 91% of the cultivated area produced cereals, and the water course was also exposed to erosion. In the Hauger catchment 30% of the area was ley and many farms combined animal husbandry and production of cereals. Pollution problems associated with manure, slurry and silage were observed in periods with no erosion (Øygarden 1989).

When data for the factor analysis were split into seasons (winter, spring, summer, and autumn), total-P was related to suspended dry matter and ashes in winter and spring erosion. In summer and autumn, with little erosion, total-P was not related to suspended particles. In periods with low runoff, point sources dominated the water quality. Both leakage from manure storage and seepage from silage caused high concentrations of potassium. In the same periods there were also higher concentrations of organic matter and dissolved phosphorus compared to the rest of the year.

Catchments in Eastern Norway – The correlation between different compounds of plant nutrients and suspended dry matter in the catchments Kolstad and Hersoug was described in four factors: P-factor, N-factor, erosion factor and discharge factor. These factors described 96% (Kolstad) and 97% (Hersoug) of the variance. As total-K and ashes were analysed in only a few samples, these variables were omitted in the factor analysis. The factor loadings were quite similar for the two catchments. Therefore we present only factor loadings for Kolstad, Table 4.

The P-factor contained information about different fractions of phosphorus. Total-P, dissolved total-P and phosphate-P all had strong positive loadings in this factor. Consequently, these parameters were correlated. In the nitrogen factor, total-N and nitrate-N both had strong positive loadings and were correlated. Runoff had weak

Table 4 – Rotated factor loadings for Kolstad

Variables	P-factor	N-factor	Erosion factor	Discharge factor
Dissolved total-P	98	6	-7	1
Phosphate-P	97	7	-6	-1
Total-P	86	5	39	12
Nitrate-N	2	97	-2	18
Total-N	12	96	12	18
Susp. dry matter	4	6	98	12
Runoff	5	31	14	94
Explained variance,%	38	28	16	14

positive loadings in the nitrogen factor. The opposite situation was observed in the discharge factor, with strong positive loadings for runoff and weak positive loading for nitrogen. The information in these factors indicated a weak correlation between runoff and nitrogen concentrations. There was high loadings for suspended dry matter in the erosion factor.

Catchments in South-Western Norway – The correlations between different compounds of plant nutrients and suspended dry matter for the catchments Time and Herikstad were described in four factors: P-factor, N-factor, erosion factor and water factor, which explained 91% (Time) and 89% (Herikstad) of the variance. As only a few samples were analysed for ashes, this variable was omitted in the factor analysis. The factor loadings were quite similar for the two streams and only factor loadings for Time are presented, Table 5. Sæbø (1988) carried out principal component analysis with log-transformed data from Time and Herikstad for the period June 1985 to April 1988. In his analysis the total organic carbon and ashes of the variables were included, and runoff was omitted. Three factors explained 81% of the variations in the 9 measured variables. The factors were similar to those found in this investigation: P-factor, erosion factor and N-factor.

The P-factor contained information on different fractions of phoshorus and potassium. Total-P, dissolved total-P, phosphate-P and total-K had positive loadings and were correlated. The N-factor had high loadings for total-N and nitrate-N. The loadings were slightly higher for nitrate-N than for total-N. This indicated that the correlation between total-N and nitrate-N was not as strong in these catchments as in the catchments described above. One explanation was a higher proportion of ammonium-N in losses from slurry spread on the surface. In the erosion factor strong positive loadings were found for suspended dry matter and total-P.

Loss of nutrients due to slurry application have been reported to be a main source

Table 5 – Rotated factor loadings for Time

Variables	P-factor	N-factor	Erosion factor	Discharge factor
Dissolved total-P	94	-4	15	19
Phosphate-P	93	-6	14	22
Total-P	61	-2	73	5
Total-K	60	29	55	-19
Nitrate-N	-24	91	-3	-17
Total-N	28	84	36	-13
Susp. dry matter	6	15	94	8
Runoff	24	-23	5	92
Explained variance,%	33	21	24	13

for pollutants in Time and Herikstad catchments (Undheim 1989). Both phosphorus and potassium were easily leached from slurry applied on the soil surface, and might have been one reason why the fractions of phosphorus and potassium had strong positive loadings in the P-factor.

Catchments in Central Norway –The correlations between different compounds of plant nutrients and suspended dry matter in the catchments Musum and Holo were described in four factors: P-factor, erosion factor, N-factor and discharge factor, which explained 91% (Musum) and 89% (Holo) of the variance. The factor loadings were quite similar in the two catchments thus only factor loadings for Holo is presented , Table 6.

Similar to the catchments in south-western Norway, the P-factor for Holo and Musum had strong positive loadings for total-P, dissolved total-P, phosphate-P and total-K. In the erosion factor there was strong positive loadings for suspended dry matter, ashes and total-P. The N-factor had the same pattern as the other catchments, with high positive loadings for total-N and nitrate-N. Relatively strong negative loadings for total-K and strong positive loadings for the discharge factor indicated a dilution effect for potassium.

Table 6 – Rotated factor loadings for Holo

Variables	P-factor	Erosion factor	N-factor	Discharge factor
Dissolved total-P	96	10	-4	4
Phosphate-P	95	8	-9	1
Total-P	63	98	6	9
Total-K	49	-9	20	56
Nitrate-N	-12	3	96	-6
Total-N	6	10	97	-4
Susp. dry matter	6	98	4	12
Ashes	5	98	6	9
Runoff	-7	28	-21	81
Explained variance,%	28	28	22	11

Seasonal Changes in Nutrient Concentrations

While the loadings of the factors were used to interpret correlations between the chemical variables, the factor scores gave information about high or low levels of the variables, which influenced the different factors. The hydrology in small catchments varies considerably with the seasons of the year. Processes like snow melt, heavy precipitation, and dry periods with low runoff influence the water quality (Demayo and Whitlow 1986). Keller *et al.* (1986) point out that each case study needs individual attention and consideration of the characteristics involved. A study of factor score distribution during the year, or during a continuous time period, for each of the different catchments, gave relevant information about variation in the underlying variables.

Catchments in South-Eastern Norway – The nitrogen factor scores showed a seasonal variation pattern for both Lodding and Hauger. High factor scores in June and the lowest scores in July were found in both catchments (Fig. 2a). Similarly increased factor scores during the autumn were followed by decreased factor scores. The variation pattern of nitrogen factor scores reflected the variation in total-N and nitrate-N concentrations during the year.

South-eastern Norway usually has little precipitation May-June when the cereals germinate. In such periods the grains of compound NPK-fertilizer are not yet dissolved until sufficient precipitation has moistened the soil.

In the three years during this investigation the first precipitiation after a dry period in spring gave high concentrations of nitrogen. The reason was mineralisation of organic N and N dissolved from NPK-fertilizer. This possibly explained the high nitrogen factor scores in June. The precipitation in June 1987 was almost 100 mm above normal, and this caused unusually high runoff in three days. The nitrogen concentrations increased in Hauger from about 5 mg/l to 32 mg/l, and in Lodding from about 1 mg/l to 14 mg/l. Most of the samples with high factor scores in June were from this episode. There was less increase in the other two years of the investigation. Although runoff in June had a high concentration of nitrogen, the runoff normally was small and the total leaching of nitrogen was negligible. The effect of extreme periods on the result underlined that data analysis of short time series should be carefully interpretated. Schulte-Wülwer-Leidig and Mollenhauer (1983) found that nitrate concentrations in storm runoff showed a gradual increase in catchments of 35-46 ha dominated by agricultural activity. Maximum nitrate levels occurred a considerably time (>24 hours) after maximum flow.

In July the crop was well-established and all available N was utilized by the plants. Runoff was usually low during the summer months. Mineralisation of organic matter continued after harvest until the ground froze, normally in December-January in this region. The soil was usually frozen until March/April. The increase of nitrogen concentrations in autumn may have been related to mineralization of N.

Periods with highest N-losses were in snowmelt (April) and in the autumn. High runoff during snow melt caused great losses of nitrogen although the concentration level and was moderately high.

High erosion factor scores in April were related to snow melt (Fig. 2b). The combination of bare soil and water caused high load of particles in runoff. During snow cover (January to March) there was no surface runoff and the scores of the erosion

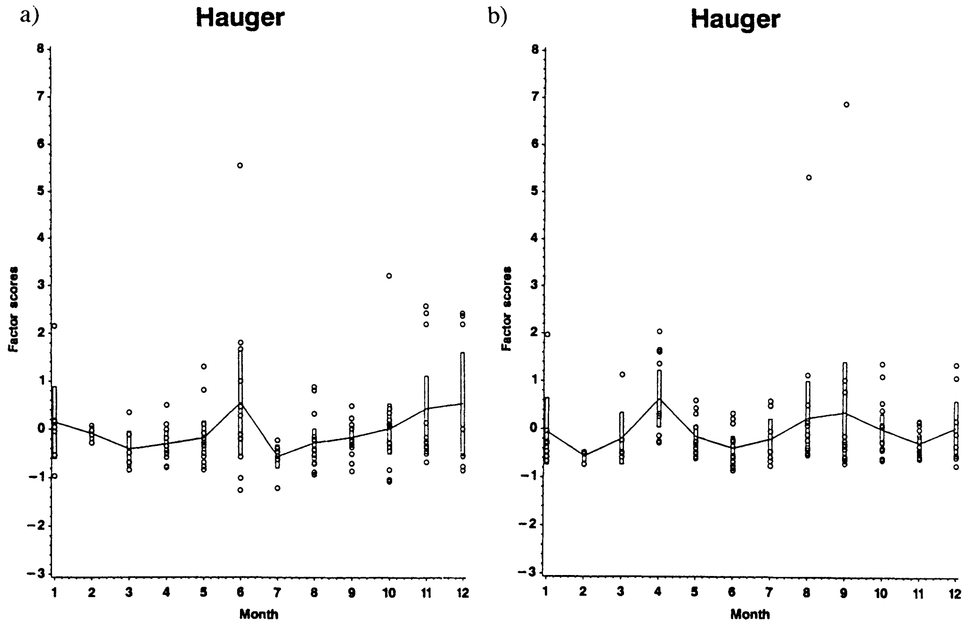

Fig. 2. Factor scores for the different months for Hauger catchment: a) Nitrogen factor, b) Erosion factor. The bars are 2 times standard error of the mean.

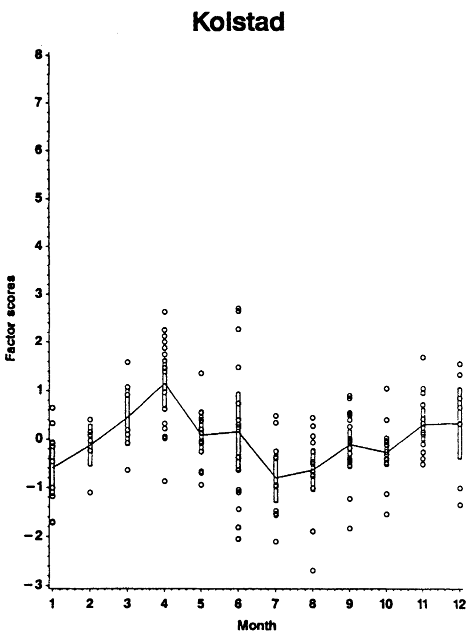

Fig. 3. Factor scores for the different months for the nitrogen factor for Kolstad catchment. The bars are 2 times standard error of the mean.

factor were low. Runoff in October 1987 was unusually high. In 1988 even higher runoff occurred late in August and early September, just before autumn tillage started. After tillage there was almost no runoff and consequently minor erosion. Erosion losses in autumn were strongly related to heavy rain and the rate of area tilled. The four autumns during the project had such different runoff conditions that no month occurred as a special erosion month. This also illustrated how weather conditions influence the results of short-time series.

The dissolved phosphorus factor scores indicated no seasonal trend for Lodding. The watercourse in Lodding was vulnerable to erosion. According to Krogstad and Løvstad (1987) water with high sediment load has only low concentrations of dissolved phosphorus. Surface runoff from grassland areas with little erosion may, in periods, have higher concentrations of dissolved phosphorus due to leaching of lately applied manure. Hauger has marked maxima for factor scores of the dissolved P-factor in June and September. From 19th September to 26th September, 1988, the concentration level of dissolved phosphorus increased from 0.024 to 0.117 mg/l, and the precipitation was 32 mm. In the same period the concentration level of total-N increased by more than 50%. However, the nitrate-N concentration was only 40% of total-N in this period, compared to about 70% before and after. The episode was due to surface application of slurry just before rainfall. Thus we see how information about farm activities helps to explain short time series results. Keller *et al.* (1986) conclude that history and supplementary information on local conditions are essential to analyse long term data series as well.

Catchments in Eastern Norway – Since Kolstad catchment had a much longer recording period than the Hersoug catchment, only data from Kolstad are presented. The N-factor had a clear seasonal pattern (Fig. 3a), even though the variation in factor scores within months was high. Highest factor scores for the N-factor was during snow melt (April) and the lowest factor scores were in the growing season in July and August. In June there were some episodes (1987) with high N-factor scores. Also this region usually had low precipitation in the beginning of the growing season. The high nitrogen concentrations in June was a result of heavy rain, mineralised nitrogen and possibly dissolved fertilizer. The increasing N-factor scores during the autumn indicated mineralisation of nitrogen after crop maturity.

The phosphorus factor had no seasonal variation pattern. The scores of the erosion factor showed some episodes with high factor scores in May to July. The discharge factor showed, as expected, high scores during snow melt and low scores during summer and winter.

Catchments in South-Western Norway – The variation pattern during the year was quite similar for Time and Herikstad. Due to a longer recording period in Time than for Herikstad, results from Time catchment are presented. Precipitation in south-

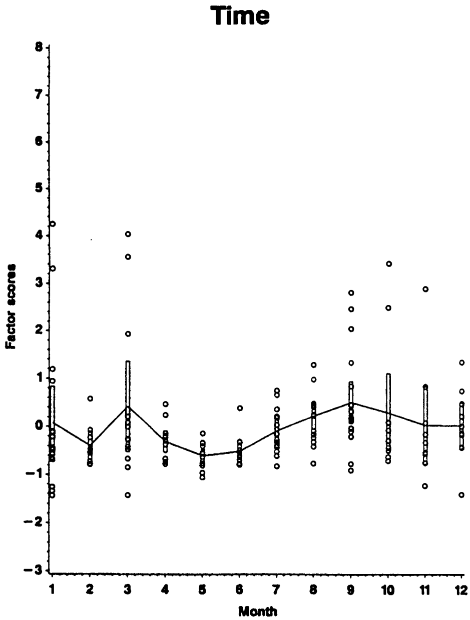

Fig. 4. Factor scores for the different months for the phosphorus factor for Time catchment. The bars are 2 times standard error of the mean.

western Norway is usually high in autumn, which also was reflected in the discharge factor.

The scores of the phosphorus factor had a clear seasonal variation pattern (Fig. 4). Episodes with high factor scores were observed during September to March. As reported by Undheim (1989), slurry was applied in this period in 1985 and 1986, and caused high concentrations of P in Time catchment.

The factor scores of the N-factor varied considerably and no seasonal trend was found. However, the lowest N-factor scores were found in April through July even though the variation in N-concentrations during the year was small. The total loss of nitrogen reached a maximum in autumn and winter.

The erosion factor showed great variations in factor scores. Although there were differences in the level of factor scores between the months with highest (June) and lowest (December) level, no clear seasonal trend was found. The concentrations of suspended dry matter, however, was very low in south-western Norway compared to the catchments in eastern and central Norway.

Catchments in Central Norway – The recording period in Holo catchment was much longer than in Musum. The factor scores in Musum varied considerably and no clear trends were observed for the P-factor, N-factor and erosion factor. Therefore only results from Holo are presented here.

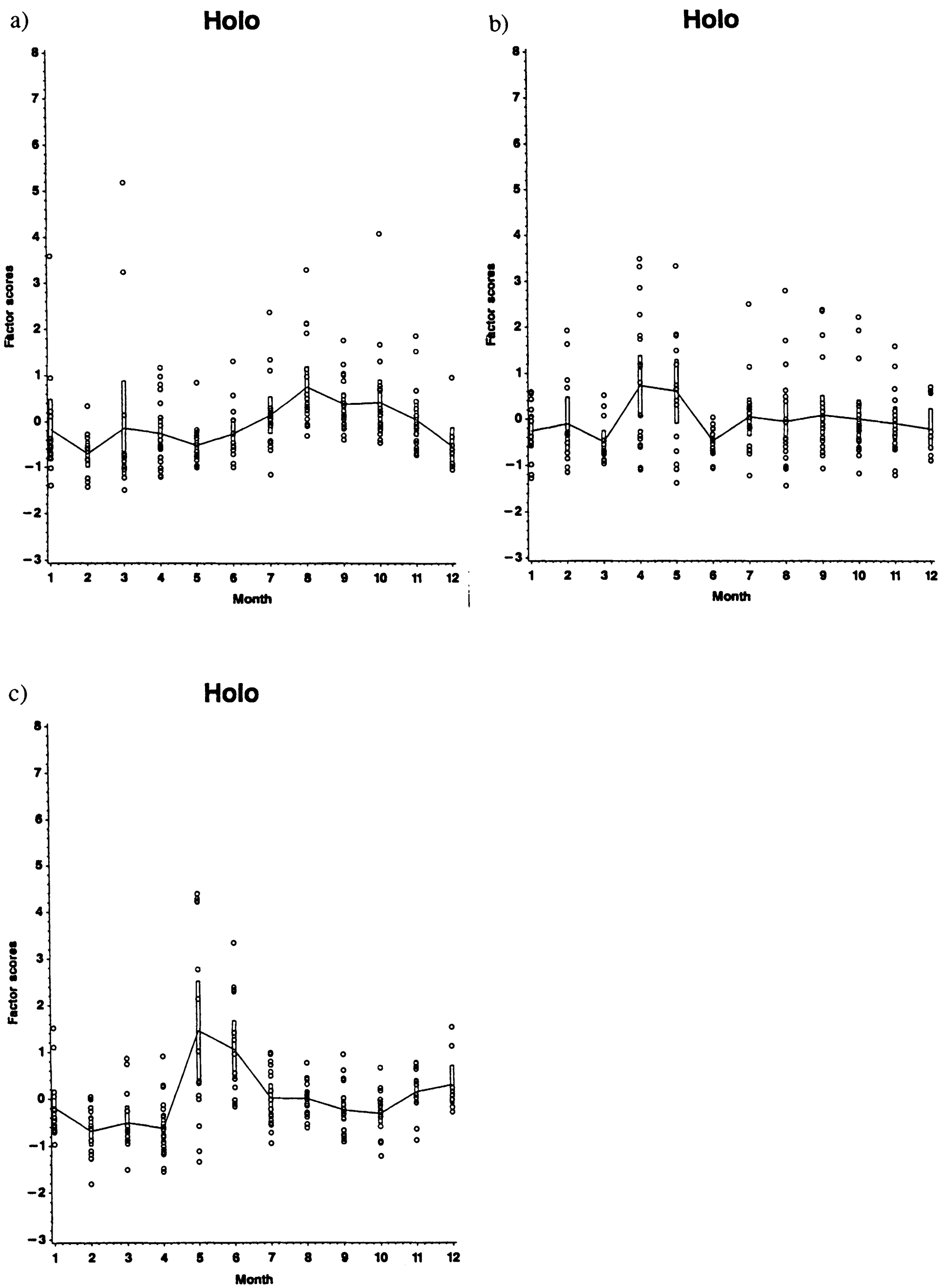

Fig. 5. Factor scores for the different months for Holo catchment: a) Phosphorus factor, b) Erosion factor, c) Nitrogen factor. The bars are 2 times standard error of the mean.

The scores of the P-factor showed a seasonal variation pattern (Fig. 5a). The score values were low in winter and spring. In autumn the level of scores for the P-factor was high and the highest level was reached in August. Pollution from point sources accounted for 15-30% of the P in Holo (Vorum 1989).

Episodes causing high factor scores in the erosion factor occurred both during snow melt and in the autumn (Fig. 5b). Highest mean factor score values were found in the snowmelt period (April and May).

High factor scores for the N-factor were found in May and June (Fig. 5c). Fertilizer was normally applied to the crops early in this period. High scores possibly reflected leaching of N before the crop was established. High scores of the N-factor occurred usually in periods with low runoff intensity. High scores for the discharge factor were found during snow melt and in autumn.

Changes in Nutrient Concentrations during the Recording Period

Catchments in South-Eastern Norway – The regression equations indicated no specific linear trend in factor scores by time in the Hauger and Lodding catchments. In the reference catchment, Hauger, there was no reduction in application of nitrogen and phosphorus or in soil cultivation intensity during 1985-1988. At the start in 1985, 96% of the area in Lodding was harrowed or ploughed in autumn. In 1987 and 1988 there was no stubble cultivation and the autumn ploughing was completed late in autumn (Øygarden 1989). As mentioned earlier, high precipitation occurred in October 1987 after autumn ploughing, and in 1988 there was very high runoff in August, before the ploughing started. Because of the unusual distribution of precipitation in the autumns 1987 and 1988 the regression analysis showed no effect of the measures against agricultural pollution.

Catchments in Eastern Norway – In the Kolstad and Hersoug catchments, application of phosphorus fertilizer decreased during the recording period. From 1985 to 1988; the amount of phosphorus applied to agricultural land Hersoug catchment was halved, and in Kolstad catchment phosphorus application decreased 36% (Eide 1989).

In both catchments, episodes with high concentration levels of phosphorus occurred. Due to different measures against loss of nutrients from agricultural land in the catchments, the number of such episodes decreased during the project period. Mainly due to the influence of the outliers, the regression equations with phosphorus factor scores and time showed a significant decrease, R^2=0.25 for Hersoug and R^2=0.05 for Kolstad.

The scores of the N-factor varied considerably both in Hersoug and Kolstad. Because of very concentrated levels of nitrogen in spring 1987, due to unusual high precipitation after fertilization, linear regression models were not suitable to detect trends. More robust trend analysis methods, like those described by McLeod *et al.* (1991), would probably be suitable in such a case. In Kolstad catchment the application of nitrogen was nearly constant during the period 1985 to 1988. In the Hersoug catchment the application of N decreased by 14% from 1985 to 1986, but no further reduction in the N-application in the period 1986 to 1988 occurred (Eide 1989). Based on the recorded fertilizer application, a linear decreasing trend concentration level of nitrogen in the runoff was not expected.

The erosion factor scores and the discharge factor scores remained stable during the recording period in Hersoug and Kolstad.

Catchments in South-Western Norway – There was a significant decrease in N-factor scores both in Time and Herikstad catchments (Figs. 6a and 6b). The decrease in N-factor scores was most pronounced in spring and autumn. There was also a clear decreasing trend in summer. No decreasing trend in N-factor scores was found in winter. The continuing decrease in N-factor scores in Time underlined the importance of information and implementation to get a proper handling of resources in agriculture. The regression equation with N-factor scores and time in Time had the highest R^2 (0.21) and the corresponding value in Herikstad was R^2=0.11. The recording period is longer in Time catchment: June 1985 – November 1988 and January 1990 – November 1990, than in Herikstad catchment June 1985 – November

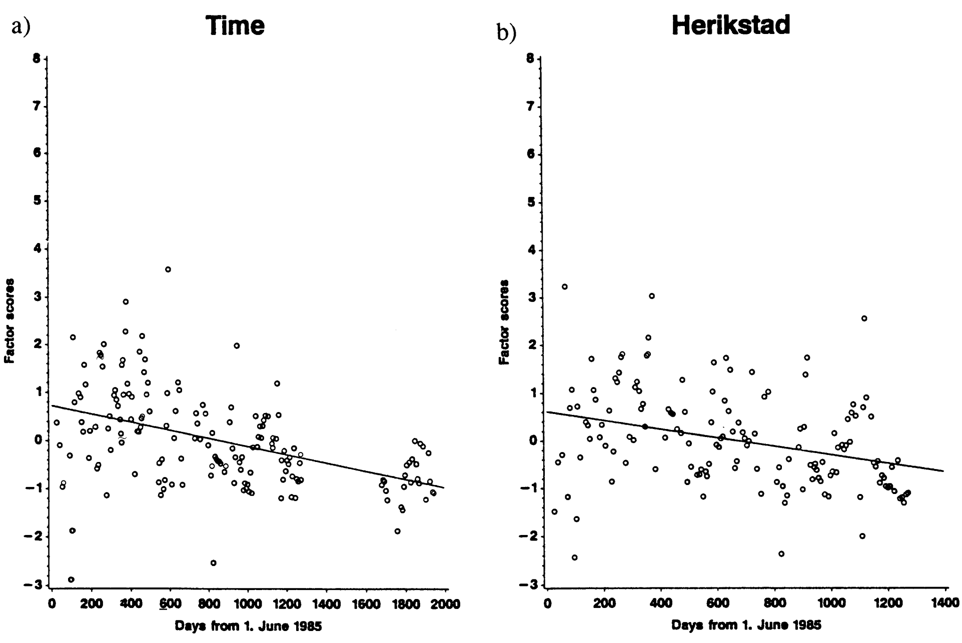

Fig. 6. Factor scores for the nitrogen factor for the recording period: a) Time catchement, b) Herikstad catchment

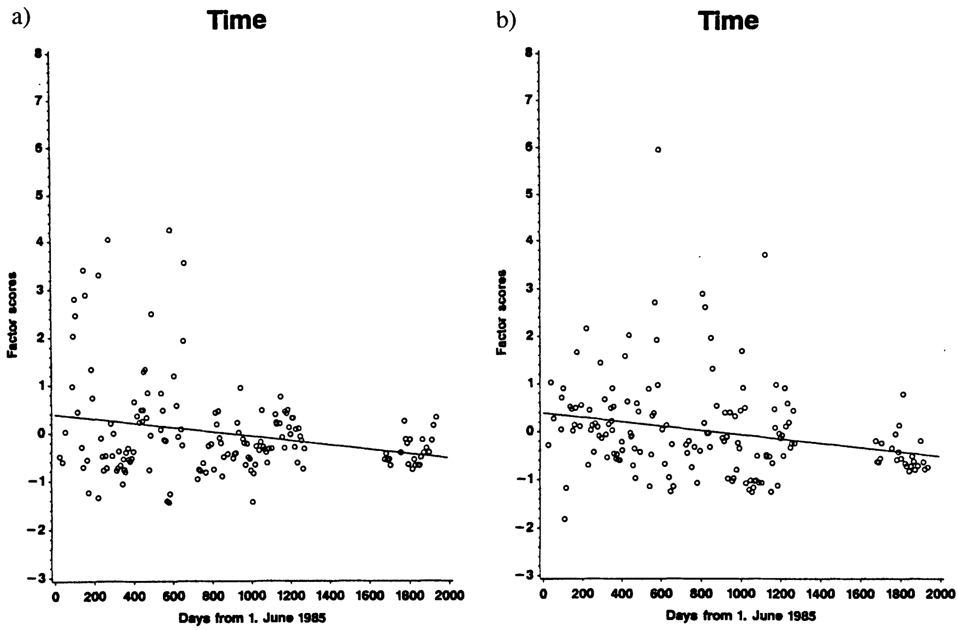

Fig. 7. Factor scores for the recording period for Time catchment: a) Phosphorus factor, b) Erosion factor

1988. In the recording period there was a decrease in N-application of 17% in the Herikstad catchment, while no decrease was recorded in the Time catchment during 1985-1988.

The factor scores of the P-factor and the erosion factor had a significant decreasing trend by time in Time (R^2=0.06) (Figs. 7a and 7b). There was no significant decrease in the P-factor and erosion factor scores in the Herikstad catchment. Application of slurry during autumn and winter was reduced, especially in Time catchment. From 1987 to 1988 there was a decrease in application of slurry during autumn and winter also in Herikstad catchment (Undheim 1989). High P-factor score values in the first part of the recording period for Time (1985 and 1986) was due to application of slurry during autumn and winter. This type of outlier influenced the regression equation. The most pronounced and significant decrease in P-factor scores was in the autumn.

Suspended dry matter, total-P and total-K were the variables with high loadings in the erosion factor. High values of these parameters are often related to pollutants from point sources. Because the total loss of soil particles was very low (<100 kg/ha) (Undheim 1989), it was reasonable that the erosion factor described organic particles from slurry and manure.

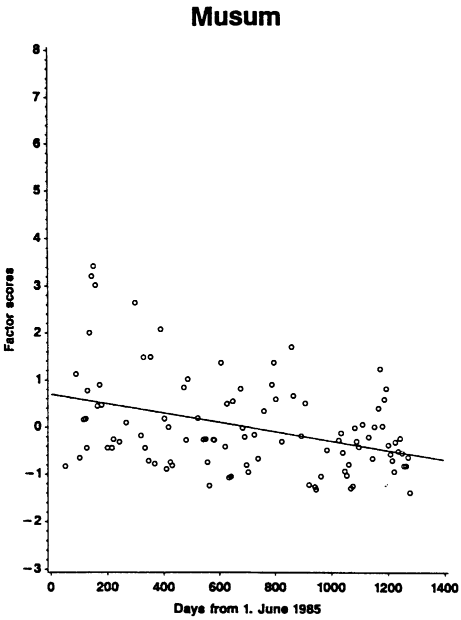

Fig. 8. Factor scores for the phosphorus factor for the recording period for Musum catchment.

Catchments in Central Norway – There was a significant decrease in P-factor scores both in Musum and Holo catchments, R^2=0.15 and R^2=0.05 respectively (Fig. 8). In both catchments the quantity of P applied to the crops was reduced by 15% during the period 1985-1988 (Vorum 1989). The recording period was June 1985 to December 1988 for Musum catchment and June 1985 to October 1990 for Holo catchment. Different length of recording periods may have influenced the results of the regression analysis.

There were no other significant trends for Musum and Holo catchments, neither for scores of the N-factor nor for scores of the erosion factor. These results were expected since the application rate of N was not reduced during 1985 to 1988 and simplified tillage systems only was applied on small areas.

Conclusions

Factor analysis indicated that plant nutrients in runoff from catchments in southern and central Norway could be grouped in three factors: phosphorus factor, nitrogen factor and erosion factor. The variables that influenced the different factors indicate some variation between the catchments. The different correlations found by the factor analysis could be used to detect differences between catchments due to various sources for pollution, *e.g.* point sources, erosion, areal loss of nutrients from surface spread slurry.

In the catchments in south-eastern Norway, where loss of nutrients was linked to erosion, concentration levels of total-P and dissolved P were not correlated as in the other areas, expressed by a dissolved P-factor. The variables dissolved total-P and phosphate-P were highly correlated, and contained the same information. A factor that described runoff indicated correlation between P and N with runoff during winter and spring periods in south-eastern Norway. The same correlation was levelled out when data was not split into seasons.

Due to different climatic conditions, soil types and agricultural practices the variation pattern for the different factors through the year was different in the four regions studied. In south-eastern Norway high concentration levels of suspended dry matter were observed in the snowmelt period, while the highest concentrations of nitrogen were found in June and in the autumn. In eastern Norway where stable snow cover and frozen ground are common in winter, the highest concentration levels of nitrogen occur during snowmelt in April. Application of slurry in autumn and winter caused high concentration levels of phosphorus in runoff during September to March in south-western Norway. In catchments in central Norway the highest P-concentrations were found in the autumn, with high precipitation after harvesting. The snow melt period in April and May caused high concentrations of suspended dry matter. Episodes of high concentrations of suspended dry matter were also observed in autumn in this region. The highest levels of nitrogen concentrations were found in May and June, in periods after fertilizer application but before the annual crop utilized all the available nitrogen.

During the recording period a little, but significant, decrease in concentration level of phosphorus was found in catchments in eastern and central Norway. The decrease was considerably less than the reduction of P applied to the crops. When application of slurry out of the growing season ceased in south-western Norway, the concentration level of nitrogen and phosphorus decreased significantly.

Extreme values of nutrient concentrations due to varying weather conditions and man-induced activity could be explained on the base of recorded background information about farmers activity in the catchments. Although the time series were short, an interpretation of trends in concentration levels of different plant nutrients and suspended matter could be given.

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