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LEACHING RESULTING FROM LAND APPLICATION OF SEWAGE SLUDGE AND SLURRY

Tiivistelmä

Jätevesilietteestä ja lietelannasta aiheutuva huuhtoutuminen

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Sewage sludge (16—20 t ha^{-1} DM), cow slurry (45—50 m^3 ha^{-1}) and mineral NPK fertilizer (350—400 kg ha^{-1}) were applied on a clay soil and a sandy soil. Movement of nutrients, heavy metals, organic matter and (indicator) micro-organisms was monitored in a four-year experiment which included one calibration year. Two of the years were hydrologically exceptional: weather conditions had a strong effect on leaching. In the clay soil: (1) mostly over 80—90 per cent of total leaching was through subdrainage; (2) no harmful leaching of heavy metals or micro-organisms through subdrainage or surface was found; (3) the treatments had the most profound effect on nitrogen leaching and on conductivity of runoff waters; effect duration was (at least) two years; (4) application of sludge on snow immediately increased NH_4 concentrations of surface and subdrainage waters; in the long run, applications on snow and on nonfrozen soil yielded equal nitrogen leaching. In the sandy soil, raised levels of nitrate were observed in ground water (effect of the treatments could not, however, be distinguished because of high initial levels); contamination of ground water by heavy metals or micro-organisms was not found.

Index words: Sewage sludge, slurry, land application, cereal crops, subdrainage, leaching, environmental effects, clay soil, sand soil, latin square.

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1. INTRODUCTION

Sewage sludge and slurry contain macronutrients and micronutrients needed by plants. Their application on cultivated land thus maintains soil fertility. Increasing energy costs and environmental awareness support the idea of maximal utilization of the fertilizing potential of sludges and slurries.

The amount of municipal sewage sludge has grown rapidly in Finland: from 40 000 t a^{-1} DM (dry matter) in the early 1970s to over 100 000 t a^{-1} DM in 1980. Thirty five per cent of the sludge was disposed of for agricultural or similar purposes (such as park construction) at the beginning of this decade; the National Board of Waters has adopted a policy to double the figure in the near future.

If applied carelessly, sludge or slurry may have serious adverse effects on the environment or on man himself. Leaching phosphorus and nitrogen cause eutrophication in watercourses. There may be a risk of contamination of ground water by nitrates. Pathogens and constituents causing taste or odour problems may be washed to recipients. High rates of application may yield an accumulation of heavy metals in crops if the sludge contains large amounts of metals. For these reasons, land application is generally regulated by guidelines, the adequacy of which is continually evaluated.

1.1 Guidelines in Finland

The National Board of Health and the National Board of Waters have released guidelines on the land application of sludge (Lääkintöhallitus 1977, Vesihallitus 1979a) and slurry (Vesihallitus 1981a) in Finland.

It is recommended that sewage sludge should not be spread more than 20 t ha^{-1} DM once in every five years (Latostenmaa 1976, Lääkintöhallitus 1977). If applied more often, the maximum dose is 4 t ha^{-1} DM a year. Cadmium content may limit the use of sludge: the highest acceptable amount is 100 g ha^{-1} Cd once in five years, or 20 g a year. Sludge is not recommended to be applied for a growing ley. It is best for crops grown for seed yield, and for sugar beet.

According to the regulations, the sludge which is spread on cultivated land should be both stabilized and dewatered, or have equivalent characteristics. Particularly, sludge which has not been dewatered should be mixed into soil immediately after application. In general, sludge should be spread on nonfrozen soil and mixed into it within one day. Application of liquid sludge on frozen soil is allowed only exceptionally. Dewatered sludge can be stored in heaps in a field in the wintertime and be spread in the spring or summer. A protection zone of 20—50 metres with no sludge application is required by watercourses. Spreading is not allowed in the vicinity of drinking-water wells or important ground-water aquifers (Latostenmaa 1976, Lääkintöhallitus 1977, Vesihallitus 1979a).

Slurry is recommended to be used 20—50 m^3 ha^{-1} at a time. It should be spread on nonfrozen soil and mixed into the soil immediately. Application on frozen soil is allowed exceptionally, if the field is flat and has subdrainage (Vesihallitus 1981a).

1.2 Leaching from cultivated lands

1.21 General features

Leaching of nutrients from soil strongly depends on weather conditions; there may be great variations between different years. The higher the precipitation and the longer the soil is unfrozen, the more effectively water leaches nitrates; high surface runoff increases losses of phosphorus. Seuna and Kauppi (1981) observed that subdrainage increased the leaching of nitrogen because it reduced the portion of surface runoff. No clear effect on phosphorus was found.

Soil type, cultivated crop and fertilization influence the amount of leaching. Fine-textured soils are able to retain more water than coarse-textured soils, in which small amounts of rain water may cause runoff. Nitrate can avoid leaching in the small pores of fine-textured soils (Hartikainen 1978). In clay soils, a greater amount of water runs through drains than in coarse-textured soils, where the water percolates more easily into deeper layers. The nitrate content of ground water is usually observed to be higher in areas where water can easily percolate through the soil than in clay soil areas (Yrjänä 1983, Vainio 1984).

The organic matter of soil and organic fertilizers release nitrogen gradually, also when there is no vegetation to use it. Plants such as ley crops, which take up nutrients till late summer, decrease leaching. Great amounts of nitrogen are mobilized and leached from a fallow.

1.22 Previous studies

About 100—200 kg km^{-2} of nitrogen is annually lost by leaching from natural — noncultivated — lands; in southern Finland more than in northern Finland (Kauppi 1979a). The annual losses of phosphorus are 4—6 kg km^{-2}. The average amounts of nitrogen and phosphorus leached annually from cultivated lands in Finland are 1 200 kg km^{-2} N and 57 kg km^{-2} P according to Kauppi (1979b).

A rate of leaching of 200—700 kg km^{-2} a^{-1} of nitrate nitrogen through surface runoff was observed in field experiments in Jokioinen, southern Finland, by Jaakkola (1984b) in 1976—1983. From a fallow, 2 600 kg km^{-2} a^{-1} N was leached through subdrains. After the fallow, 3 800 kg km^{-2} a^{-1} N was lost and 100—1 000 kg km^{-2} a^{-1} N in the next years. The amount leached was greatly influenced by runoff. The leaching loss of phosphorus was roughly 10—50 kg km^{-2} a^{-1} through subdrainage and, usually, 20—30 kg km^{-2} a^{-1} in surface runoff. In 1976—1981, 100—1 000 kg km^{-2} a^{-1} of potassium was lost from the surface and 200—800 kg km^{-2} a^{-1} through subdrains (Jaakkola 1982).

According to Jaakkola (1984a, 1984b), 1—4 per cent of the nitrogen given in spring in fertilizers is lost through subdrainage. In his experiments, crop and intensity of fertilization influenced the leaching of nitrate through drains in 1980—1982 in the following way:

	Barley		Ley	
N fertilization in kg ha^{-1} a^{-1}	50	100	100	200
Leaching of N_{NO_3} in kg ha^{-1} a^{-1}	6.8	6.4	1.4	3.0

Increasing phosphorus fertilization did not increase the leaching of phosphorus. In fact, it seemed to decrease, which could be explained by a more effective uptake of phosphorus by a higher yield. Soil phosphorus was probably a more important cause for leaching than was the phosphorus contained in fertilizer.

Pekkarinen (1979) reports of leaching losses of nitrate and phosphorus in the Siuntionjoki watercourse in southern Finland. The loss of nitrate nitrogen from cultivated land was 2 100 kg km^{-2} during the spring flood of 1977, 3 200 kg km^{-2} in the whole year and 500 kg km^{-2} during the spring flood of 1978. The leaching losses of phosphorus were 34, 63 and 83 kg km^{-2}, respectively. The reason for a high leaching of nitrate and a low loss of phosphorus in 1977 was the small soil frost penetration: this increased runoff through subdrains.

Brink and Linden (1980) report that leaching of nitrogen through subdrains from a clay soil was moderate when the amount given in fertilizer did not exceed 100 kg ha^{-1}, but it increased rapidly when more fertilizer was applied. Winter and spring cereals were grown in this experiment. Most of the leached nitrogen, often over 90 per cent, was in nitrate form.

1.23 Ground-water problems

In Denmark, the nitrate content of ground water has increased threefold in 20—30 years and is continuously growing (Overgaard 1984). The concentration often exceeds 50 mg l^{-1} (11 mg l^{-1} as N_{NO_3}); on average it is 13 mg l^{-1}. At the same time plant and animal production and the use of fertilizers in agriculture have increased.

Vainio (1984) studied the nitrate contents of water of wells in the vicinity of cultivated areas in southern Finland. The highest concentrations were found near fields but the differences were not statistically significant. Little nitrite and ammonium nitrogen was observed. The nitrate content in the wells near cultivated fields was, on the average, 20—30 mg l^{-1} (5—7 mg l^{-1} as N_{NO_3}). In half of them, the nitrate concentration occasionally exceeded 30 mg l^{-1}.

Seppänen and Kuukka (1982) have analysed the nitrate content in wells in cultivated areas where potato and sugar beet were grown. The average content was 31 mg l^{-1} in the immediate vicinity of fields.

1.3 Effects of application of sewage sludge and slurry

1.31 Macronutrients

Finnish sewage sludges and slurries contain, on the average, the following amounts of plant nutrients (Latostenmaa 1976) (figures in per cent of dry matter):

Nutrient	Sludge		Slurry	
	dewatered	liquid	cattle	pig
N	3.0—5.0	3.0—7.0	1.0—4.5	2.0—9.5
P	1.0—5.0	1.0—5.0	0.1—1.0	0.3—3.0
K	0.2—0.5	0.2—0.5	0.5—4.0	1.5—4.5
Ca	0.5—3.0 1)	0.5—3.0 1)	0.3—1.6	0.5—3.0
Mg	0.3—1.5 1)	0.3—1.5 1)	0.1—0.5	0.1—1.0

1) The contents of Ca and Mg are much higher if lime is added

Only part of the nitrogen of sewage is left in sludge. The drier the sludge, the less nitrogen there is. Most of the phosphorus remains in sludge. There is little potassium in sewage sludge. Slurries contain relatively little phosphorus, but the amount of potassium is high.

In a Finnish experiment in Mietoinen in 1978 (Isotalo 1979), 25 t ha^{-1} DM of dewatered sewage sludge (29 % DM) and 87 m^3 ha^{-1} of pig slurry were spread on snow-covered clay soil. The soil frost penetration was deep and snow-melting waters did not enter subdrains. The leaching losses from surface in spring were as follows (in kg km^{-2} and per cent of the amounts added):

Nutrient	Sewage sludge	Pig slurry
N kg km^{-2}	2 800	7 600
%	6.5	15
P kg km^{-2}	67	1 600
%	0.13	9.4
K kg km^{-2}	190	5 300
%	3.6	44

The slurry caused higher losses than the sewage sludge. A great part of the slurry was obviously immediately lost through open ditches. It was concluded that the amount of slurry was too big for spreading on a snow-covered field.

Brink (1971) reports of Swedish experiments where less than 4 t ha^{-1} DM of liquid sewage sludge was spread on snow-covered clay soil. Leaching of nitrogen and phosphorus through subdrains did not increase compared with that from a field which was fertilized with urea. On the other hand, high amounts of sludge (15 and 30 t ha^{-1} DM) clearly increased leaching; the effect of nitrogen could be observed for two years and that of phosphorus for one year. When 9—25 t ha^{-1} DM of sludge was applied, Brink (1972) found that nitrogen and phosphorus contents grew in subdrain waters compared with leaching caused by mineral fertilizers. Higher concentrations were also measured in ground water down till 4.7 metres.

In Denmark, a high amount (45 t ha^{-1} DM) of liquid sewage sludge was spread on an acid sandy forest soil (Grant and Olesen 1983). The nitrate and ammonium content of soil water increased considerably for one year (to 30—40 mg l^{-1} N at a depth of 50 cm). The concentrations in ground water reached a peak after 1.5—2 years from the application and persisted for 3—4 years; the nitrate content even exceeded the limit (45 mg l^{-1}) given by WHO for drinking water. Ground-water effects could no longer be observed after 6.5 years. Sludge application had no influence on phosphorus contents.

Huylebroeck (1981) summarizes the effects of sludge application on ground water, reported by several European laboratories. Application of sludge usually causes an increase in the nitrate content. This increase is comparable with that resulting from high doses of inorganic fertilizers. There is usually no increase in phosphorus contents.

An optimal time of application for slurry is in connection with sowing. The stores of slurry are often not big enough, however, and spreading must also take place in autumn and winter. An optimal use of slurry is difficult because of problems in estimating exactly the availability of nutrients (Kemppainen and Heimo 1981).

Over half of the easily soluble nitrogen of slurry, spread in autumn, is usually lost by leaching before spring. In a field experiment (Kemppainen 1984), crop yield was especially low when slurry (40 m^3 ha^{-1}) was spread in late autumn, because the soil was wet and became compacted. Spreading on frozen soil in winter or spring also gave a relatively low yield owing to leaching and volatilization losses.

Leaching from sandy soil was studied in Kesälahti in 1974 when 70 m^3 ha^{-1} of slurry was applied in winter (Vesihallitus 1974). Total nitrogen in ground water increased from 0.6 to 34 mg l^{-1} in April-May and total phosphorus from 0.03 to 0.7 mg l^{-1}. Effects on surface runoff could not be studied. The amount of slurry was obviously too high. On the basis of these results, winter application of slurry should be considered only in the middle of a wide and flat area with subdrainage.

Miettinen (1974) argues that the leaching losses from slurry spread in winter are not necessarily higher than from that applied on nonfrozen soil. He supposes that slurry quickly penetrates snow and soil-frost layers. At the North Savo Research Station, the effect of a winter-applied slurry on yield in 1972 was as good as that of a slurry which was spread in autumn before ploughing. Winter application was even the best practice in 1973. The amount of slurry in this experiment, 80—100 m^3 ha^{-1}, was obviously too high from the viewpoint of plant needs. It is possible that leaching losses in winter partly decreased adverse effects of excessive fertilization.

Vetter and Steffens (1981) report on an experiment in West Germany where slurry was spread on a sandy soil in autumn. The amounts were 30 m^3 ha^{-1} (180 kg ha^{-1} N), 60 m^3 ha^{-1} and 90 m^3 ha^{-1}. The nitrogen content of ground water, at a depth of 2—3 metres, grew from 30 mg l^{-1} to 40, 57 and 80 mg l^{-1}, respectively. About 20—30 per cent of nitrogen was lost through leaching.

After application of slurry in winter, the following leaching losses were observed during the melting of snow in a Swedish experiment (Brink 1973):

	Spreading		Leaching	
	m^3 ha^{-1}	t ha^{-1} DM	kg ha^{-1} N	kg ha^{-1}P
Winter wheat	25	2	2.4	0.09
Stubble field	25	2	1.5	0.13
Stubble field	125	10	28	3.9

On the basis of these results, the rate of application of slurry should be less than 4—5 t ha^{-1} DM; plants cannot effectively use higher doses and a risk of water pollution arises.

Vainio (1984) observed that the nitrate content of well waters slightly increased when slurry was spread in the vicinity.

1.32 Heavy metals

Sewage sludge contains heavy metals, such as copper, manganese, zinc, molybdenum and cobolt, which plants can use; high doses may however be toxic. Cadmium is considered the most harmful among heavy metals; mercury and lead are other clearly toxic elements.

The median concentrations of heavy metals in Finnish municipal sewage sludges and the highest acceptable contents for agricultural use are as follows (Latostenmaa 1976):

Metal	Median mg kg^{-1} DM	Highest acceptable mg kg^{-1} DM
Zn	920	5 000
Mn	350	3 000
Cu	160	3 000
Pb	150	1 200
Ni	52	500
Cr	46	1 000
Co	23	100
Cd	5.2	30
Hg	3.0	25

According to Huylebroeck (1981), raised concentrations of heavy metals in ground water have been reported to a minor extent.

De Haan (1981) did not find any clear change in leaching of cadmium from a depth of 0.7 metres in a sandy soil, when 22.5 t ha^{-1} DM of sewage sludge was applied.

In Danish experiments (Larsen 1983), even a high dose of sludge (up to 30 t ha^{-1} DM) did not increase leaching of heavy metals (Cd, Pb, Ni) into subdrains and ground water. Most of cadmium was still in the top soil layer of 25 centimetres after seven years; no increase of cadmium could be observed in deeper layers when compared with test plots which received treatment with mineral fertilizers.

In another Danish experiment (Grant and Olesen 1983), a high amount (45 t ha^{-1} DM) of liquid sludge was spread on sandy forest soil. Almost all of the added cadmium, chromium, nickel and copper were still found in the top layer of the soil after 3.5 years. Lead and zinc had partly leached below 0.5 metres; only the content of zinc had increased in ground water.

1.33 Organic matter and solids

Brink (1972, 1973) reports that large amounts of sewage sludge remarkably increase leaching of organic matter. Liquid sludge was spread on snow in one of the experiments and this caused the following leaching losses:

Spreading in t ha^{-1} DM	0	3.8	7.5	15	30
Leaching of organic matter (COD_{Mn}) in kg km^{-2} O_2	300	300	700	2 500	3 900

Most of the organic matter was lost during the melting of snow.

When dewatered sewage sludge and pig slurry were applied in winter in Mietoinen (Isotalo 1979), the following losses were observed:

	BOD_7 leaching kg km^{-2} O_2	%
Sewage sludge 25 t ha^{-1} DM	14 000	3.2
Pig slurry 87 m^3 ha^{-1}	27 000	12

Patni (1978) studied in Canada the quality of subdrainage water and the effect of slurry application on it, when slurry was immediately ploughed into the soil (mostly clay). No harmful decrease was found in the amount of dissolved oxygen. The total and suspended solids contents increased slightly, as did conductivity. Mineral fertilizer however raised the conductivity more than slurry did. No change could be observed in pH value. It was concluded that the following factors explained the relatively good quality of water: (1) slurry was ploughed into the soil immediately, (2) application during dry weather, (3) rotation of fields for slurry application, and (4) slurry was not spread in the vicinity of recipients.

1.34 Pathogens

Both sewage sludge and slurry contain fecal bacteria, viruses and the eggs of parasites. Stabilization of sludge decreases their amount. There are fewer pathogens in digested sludges than in sludges which are aerobically stabilized. Lime stabilization (pH is raised over 11) gives the best hygienic quality; lime-stabilized sludges contain few pathogens as do composted sludges. The effect of aerobic stabilization on fecal bacteria is not as good as the effect of other methods.

Salmonella bacteria are the most harmful of the bacteria of sludges. The eggs of parasites tolerate sludge treatment rather well; thus the risk of infection depends on the possibility of parasites continuing their normal life cycle after sludge spreading. Species, moisture conditions, temperature, pH and ultraviolet radiation on the soil surface determine the persistence of pathogens in soil. They can be washed to recipients primarily through surface runoff. When sludge is ploughed into soil, the risks of infection decrease and pathogens gradually vanish (Latostenmaa 1976, Lääkintöhallitus 1977).

Brink (1971) reports that application of less than 4 t ha^{-1} DM of liquid sewage sludge did not considerably increase the bacteria content in drainage water. A rate of application of 15 or 30 t ha^{-1} DM however raised the amount of bacteria and the effect could be observed for two years. In another experiment (Brink 1972), 9—25 t ha^{-1} DM of sludge was found to increase the amount of thermotolerant coliforms in drainage water.

Huylebroeck (1981) does not give any indication in his summary of bacteriological contamination of ground water resulting from sludge or slurry application.

Grant and Olesen (1983) report that Salmonella bacteria disappeared from the soil in 4.5—5 months from sludge application on a forest soil. Eggs of parasites survived longer; they however almost died out in 15 months.

In a Finnish experiment by Korkman (1971), 50 m^3 ha^{-1} of pig slurry was spread on clay soil in spring. About 63 per cent of the fecal streptococci vanished in one week; there was no hygienic risk after about eight weeks.

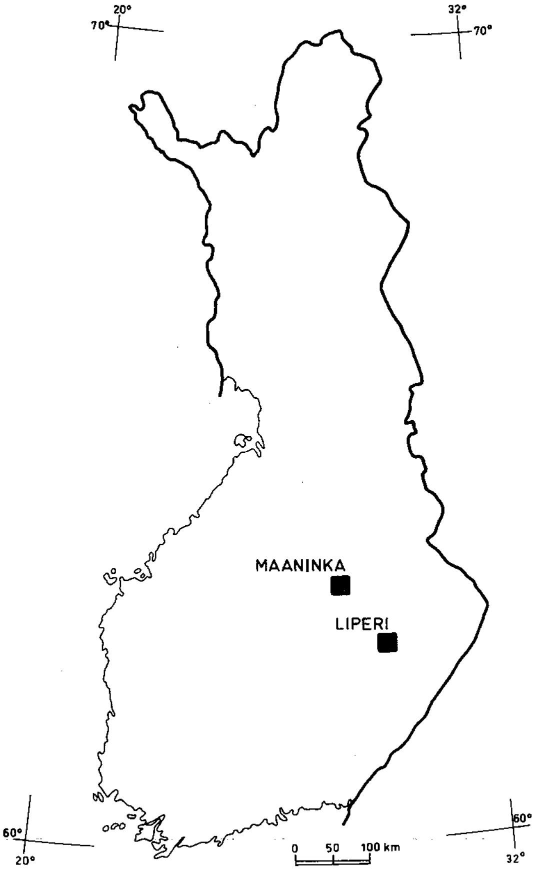


Fig. 1. Location of the test fields.

1.4 Experiments in Liperi and Maaninka

Because few experiments had been made on the effects of sewage sludge application in Finland, two test fields were constructed in 1978, one in Liperi (Siikasalmi Agricultural School: 62°32'N, 29°22'E) in eastern Finland and the other in Maaninka (North Savo Research Station of the Agricultural Research Centre: 63°09' N, 27°19' E) in central Finland (Fig. 1).

A joint research project has been carried out since autumn 1978 by the National Board of Waters, the North Karelia and Kuopio Water District Offices, the Agricultural Research Centre, the two research stations and the local municipalities.

The main objective of the project was to study movement of the constituents (nutrients, trace elements, organic matter, indicator microorganisms) of sewage sludge and slurry, which results from land application in accordance with the present Finnish guidelines. Uptake by plants was another important subject studied in the project.

In this report, leaching of constituents in the years 1979—1982 is analysed from the viewpoint of the pollution of surface and ground waters. Preliminary papers, dealing with the Liperi results, have been presented by Ahtiainen (1984) and Lutz (1983). Later, another report will be released in which the Liperi and Maaninka results will be studied from the agricultural point of view. The field experiments have continued since 1982. These results will be dealt with in further reports.

2. MATERIALS AND METHODS

2.1 Test fields

Subdrainage of the Liperi field (Figs. 2—3) was constructed in 1976. The plastic drains are 40 millimetres in diameter, at a depth of 0.9—1.16 metres and 15—16 metres apart. The average slope of the field is 0.5—1 per mille.

According to sampling in the middle point of the Liperi field (Table 1), the soil type is clay down to a depth of three metres where it turns into clayey silt. In the top layer, 0.1—0.6 metres, and in the layer between 2.5—2.9 metres the clay fraction is over 60 per cent. In the layer between 0.7—2.4 metres, the soil contains a silt fraction of 55—65

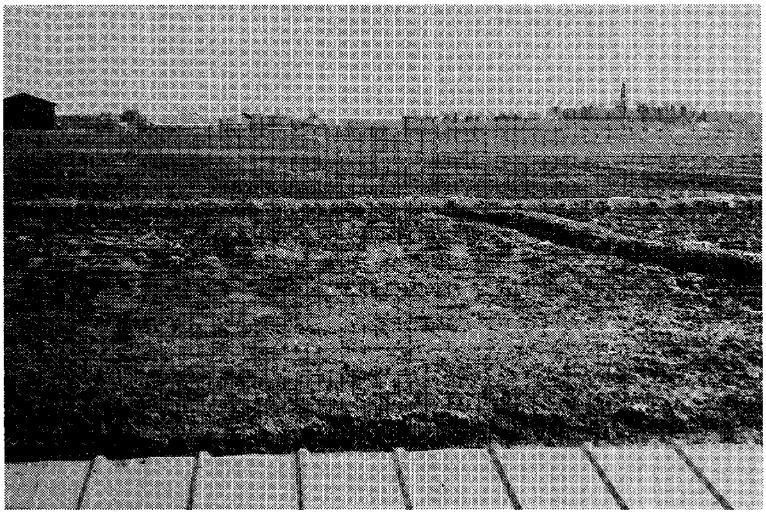


Fig. 2. View of the Liperi field.

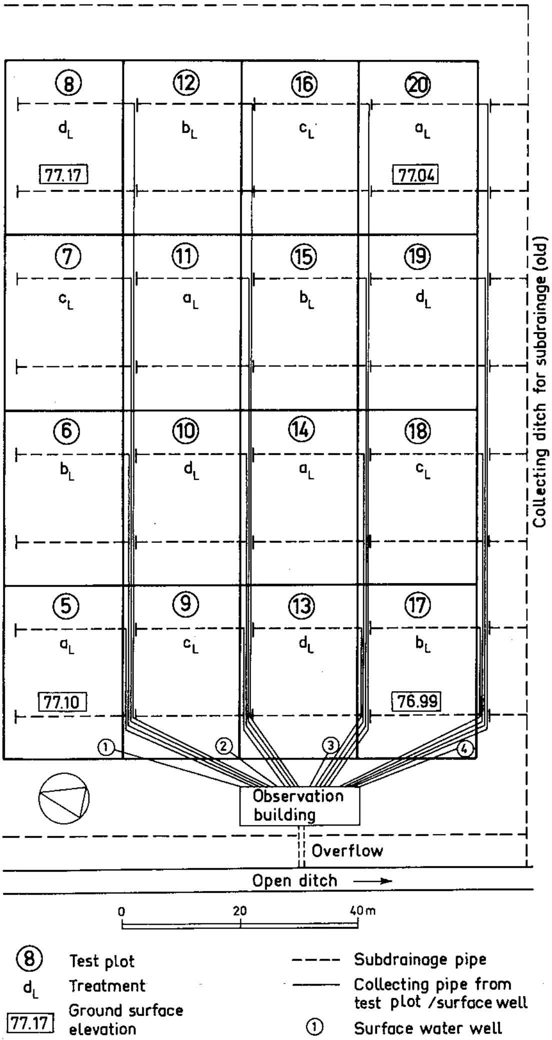


Fig. 3. Layout of test arrangements in the Liperi field.

per cent and a clay fraction of 35—45 per cent. In the clayey silt the clay fraction is roughly 20 per cent. The measured humus and water contents are typical of the soil type. According to the measurements, the top soil layer is remarkably homogenous in the entire test field, reflecting a low hydraulic conductivity. Typically, just 0—10 per cent of precipitation percolates to ground-water storage in soils of this kind.

In the Maaninka field (Figs. 4—5), the subdrainage is older, constructed in the 1930s. The tile drains are 50 millimetres in diameter, installed at a depth of 1.2 metres and 25 metres apart. The slope of the field is on the order of 3—8 per mille.

Soil type was examined in detail in two points of the Maaninka field: in the test plots 3 and 10 (Table 2, Fig. 5). The soil in the sampling point 3 is poorly graded, sand with a silt fraction of 10—20 per cent, down till 1.5 metres. Underneath, there is a clayey silt layer, with a lower hydraulic conductivity, which in 3.5 metres turns into sandy silt and in 4.5 metres into silty sand. In 5.5 metres a glacial till layer begins, the thickness of which was not measured. In the sampling point 10, soil is well-graded silty sand down till 1.5 metres, turning then into silty glacial till, the layer depth of which was not measured either. The water contents measured are typical of the soils under study. The hydraulic conductivity of the top soil layers is high: in natural conditions, 30—80 per cent of precipitation percolates in soils of this type.

Table 1. Geological characteristics of the soil layer in the middle point of the Liperi field. Measurements by the Technical Research Office.[1]

Depth from ground level m	Soil type	Humus content %	Water content %
0.1—0.6	Clay (clay fraction > 50 %)	1.0	40.2
0.7—1.2	Clay (clay fraction 30—50 %)	0.9	33.3
1.3—1.8	Clay (clay fraction 30—50 %)	0.9	37.4
1.9—2.4	Clay (clay fraction 30—50 %)	0.7	34.5
2.5—2.9	Clay (clay fraction > 50 %)	1.1	37.0
3.0—3.5	Clayey silt	0.7	34.3
3.6—4.0	Clayey silt	0.7	26.4
4.1—4.7	Clayey silt	0.6	24.1

1) Swedish weight sounding was applied to examine the soil in the corners and the middle point of the field. On the basis of the soundings, the middle point was selected for further investigation in which a soil sample was taken with a Swedish ram sounding device.

Table 2. Geological characteristics of the soil layer in test plots 3 and 10 of the Maaninka field. Measurements by the Technical Research Office.[1]

Sampling point in plot 3				Sampling point in plot 10			
Depth from ground level m	Soil type	Humus content %	Water content %	Depth from ground level m	Soil type	Humus content %	Water content %
0.2—0.5	Sand	0.8	14	0.2—0.5	Silty sand	0.8	17
0.6—1.5	Sand	1.0	22	0.6—1.5	Silty sand	0.5	17
1.6—2.5	Clayey silt	0.6	30	1.6—2.5	Glacial till (moraine)	0.1	11
2.6—3.5	Clayey silt	0.5	25				
3.6—4.5	Sandy silt	0.3	23				
4.6—5.5	Silty sand	0.2	17				
5.6—6.5	Glacial till (moraine)	0.2	16				
6.6—7.5	Glacial till (moraine)	0.1	11				

1) Swedish weight sounding was applied in 15 points of the field on the basis of which soil samples were taken in the two points with the Swedish ram sounding device.

Table 3. Treatments applied in the Liperi field. Plant order: in 1979 mixture of pea and oats (no fertilization); in 1980—1982 barley (variety Eero).

Treatment	Year	Fertilization
a_L	1980	No fertilization
	1981	No fertilization
	1982	NPK fertilizer[1]
b_L	1980	Dewatered sewage sludge on snow[2]
	1981	No fertilization
	1982	NPK fertilizer[1]
c_L	1980	Dewatered sewage sludge on nonfrozen soil[3]
	1981	No fertilization
	1982	NPK fertilizer[1]
d_L	1980	Dewatered and limed sludge on nonfrozen soil[4]
	1981	No fertilization
	1982	NPK fertilizer[1]

1) Date of application: May 25, 1982; 2) March 26—28, 1980; 3) May 14—16, 1980; 4) May 19—22, 1980

Table 4. Treatments applied in the Maaninka field. Plant order: in 1979 barley (variety Eero) (no fertilization); in 1980—1981 barley (Eero); in 1982 barley (Eero) and ley (timothy 75 per cent, meadow fescue 25 per cent).

Treatment	Year	Fertilization
a_M	1980	NPK fertilizer[1]
	1981	No fertilization
	1982	NPK fertilizer[2]
b_M	1980	Cow slurry on snow[3]
	1981	No fertilization
	1982	NPK fertilizer[2]
c_M	1980	Dewatered sewage sludge on nonfrozen soil[4]
	1981	No fertilization
	1982	NPK fertilizer[2]
d_M	1980	Cow slurry on nonfrozen soil[5]
	1981	No fertilization
	1982	NPK fertilizer[2]

1) Date of application: May 14, 1980; 2) May 24, 1982; 3) March 31, 1980; 4) May 16—21, 1980; 5) May 27, 1980

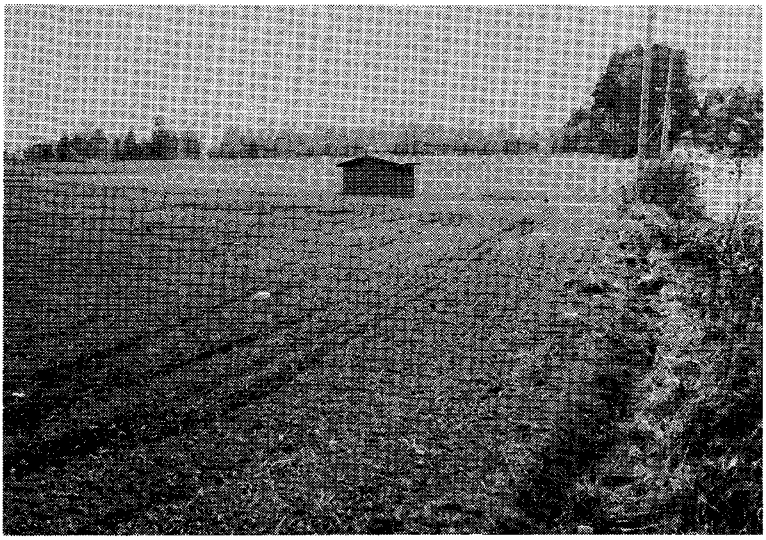


Fig. 4. View of the Maaninka field.

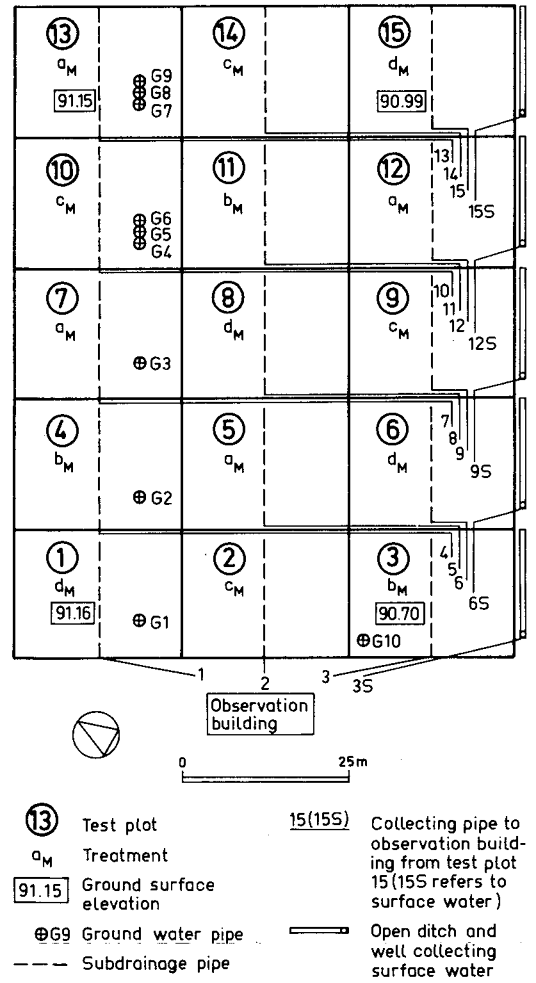


Fig. 5. Layout of test arrangements in the Maaninka field.

2.2 Treatments

The test fields were arranged in the form of a latin square (see App. 1): there were 16 test plots (ranging from 609—620 m^2 in area) in the Liperi field and 15 plots (500 m^2 each) in the Maaninka field (Figs. 3 and 5).

The year 1979 was a calibration year when there was no fertilization in the fields; the cultivated crop was a mixture of peas and oats in the Liperi field, and barley (variety Eero) in Maaninka.

The treatments were given in 1980 (Tables 3—4). In Liperi, municipal sewage sludge was spread on both snow and nonfrozen soil in spring; there were four different treatments (a reference with no fertilization plus three types of sludge), each having four replicates (Fig. 3). In the Maaninka field, cow slurry was spread on snow and nonfrozen soil and municipal sewage sludge on nonfrozen soil; respectively, there were four various treatments (a reference with mineral NPK fertilizer) and (three to) four replicates (Fig. 5). The cultivated crop was barley (variety Eero).

Spreading was done (parallel to the slope) mainly by tractor, only in the final phases by hand. After the spreading of sludge or slurry on nonfrozen soil, it was ploughed in immediately. No fertilizers were added when sludge or slurry was applied. A protection zone of one metre was left around each test plot.

Table 5. Properties of the sewage sludges and NPK fertilizer applied in the Liperi field.

Constituent	Content (% of sludge volume for TS and ASH, % of TS for the others) in			Content (% of weight) in NPK fertilizer (a_L—d_L)
	Dewatered sludge on snow (b_L)	Dewatered sludge on nonfrozen soil (c_L)	Dewatered and limed sludge on nonfrozen soil (d_L)	
TS	9—10$^{1)}$	10—12$^{1)}$	11—12$^{1)}$	..
ASH	2.0	5.2	4.7	..
N_{tot}	8.0	4.8	2.9	16
P_{tot}	3.2	2.5	2.7	7.0
K	0.82	0.50	0.16	13
Ca	0.95	0.20	5.0	2.4
Mg	0.35	0.56	0.30	0.10
Mn	0.033	0.027	0.027	0.010
Zn	0.048	0.041	0.039	0.0020
Cu	0.038	0.028	0.014	0.0010
Cr	0.00070	0.0023	0.0014	..
Ni	0.0085	0.0070	0.0030	0.00090
Cd	0.00030	0.00022	0.00022	0.00020
Hg	0.00017	0.00013	0.00017	0.0000010
Pb	0.013	0.017	0.0065	0.00010
pH	6.3—7.3$^{1)2)}$	6.7—7.1$^{1)2)}$	8.4$^{2)}$	..

1) Variation in different analyses during the application days; 2) pH value

Table 6. Properties of the cow slurries and sewage sludge applied in the Maaninka field. (Properties of the NPK fertilizer as in Table 5.)

Constituent	Content (% of volume for TS, % of TS for the others) in		
	Cow slurry on snow (b_M)	Dewatered sludge on nonfrozen soil (c_M)	Cow slurry on nonfrozen soil (d_M)
TS	1.2	17	2.4
N_{tot}	9.1	4.7	5.2
P_{tot}	1.3	2.5	0.85
K	11	0.070	4.4
Ca	2.1	1.1	1.3
Mg	0.88	0.23	0.60
Na	2.0	0.030	0.92
Fe	0.13	8.7	0.12
Mn	0.021	0.036	0.018
Zn	0.038	0.042	0.032
Cu	0.011	0.016	0.0070
Cr	0.000060	0.00045	0.00011
Ni	0.00017	0.0092	0.00020
Cd	0.0000010	0.000033	0.0000070
Pb	0	0.000055	0.0000010
pH	8.1	7.0	7.7

The sewage sludges spread on the Liperi field came from two sewage treatment plants of the Liperi municipality (Vesihallitus 1981c): the Kirkonkylä plant (built in 1975, simultaneous-precipitation process with ferrous sulphate, population equivalent of 1 400 inhabitants or 720 m^3 d^{-1} in 1980, dewatering of sludge with filter presses) (treatments b_L and c_L) and the Ylämylly plant (built in 1968 and extended in 1976, treatment process as in the Kirkonkylä plant, population equivalent 1 800 inhabitants or 410 m^3 d^{-1} in 1980) (treatment d_L). The sludge applied to the Maaninka field (treatment c_M) was taken from the Jynkänniemi sewage treatment plant of the municipality of Siilinjärvi (built in 1975, treatment process as above, 6 700 inhabitants or 2 200 m^3 d^{-1} in 1980). The cow slurries spread on the Maaninka field came from the North Savo Research Station.

Sewage sludges and slurries were examined several times prior to application (Tables 5—6). Owing to small size of the sewage treatment plants, sludge characteristics varied during various tests. Tables 5 and 6 thus give averages of the properties in the first place.

The dry matter contents of the Liperi sludges were on the average lower than those achieved by filter presses. This reflects technical problems faced in sludge dewatering in small sewage treatment plants. In treatment d_L in Liperi, lime was added to the dewatered sludge to stabilize it. The result cannot be called a lime-stabilized sludge, however, (pH should be over 11) and this sludge is therefore referred to as limed sludge (Table 5).

The nutrient contents of the sludges did not, in general, differ from averages observed in Finnish municipal sewage sludges. The following medians (mg kg^{-1} DM) of heavy metals have been recently reported (Vesihallitus 1979b):

Zn	690
Mn	450
Cu	220
Pb	77
Cr	37
Ni	34
Cd	3.1
Hg	1.1

The heavy metal contents under study were thus generally close to (or slightly less than) average. The Maaninka sludge however contained less lead, chromium and cadmium than sludges on the average.

The approximate amounts of constituents spread on the test fields in 1980 with the sewage sludges, cow slurries and NPK fertilizer are given in Tables 7—8. Regarding the sludges, the amount was calculated according to 20 tons per hectare as dry matter. Owing to variation in sludge characteristics, referred to above, and the several technical problems involved in field spreading, the amounts of sludge applied in the Liperi field remained slightly lower than the objective; they were however of the same order of magnitude in each treatment.

Consequently, some differences can be observed in the amounts of constituents spread in various treatments in the Liperi field (Table 7). A higher amount of nitrogen and potassium was spread in treatment b_L, of magnesium in treatment c_L, and of calcium in treatment d_L (because of lime adding). In treatment d_L, a smaller amount of nitrogen, potassium, copper and nickel was spread than in the others.

In the Maaninka field, the amount of constituents spread per hectare was generally higher in the

Table 7. Approximate amounts of constituents spread in the Liperi field with sewage sludges and NPK fertilizer. Volume of sludge per plot: 11 m^3 for the sludge on snow (b_L); 10 m^3 for the sludge on nonfrozen soil (c_L); 9 m^3 for the limed sludge on nonfrozen soil (d_L). Amount of NPK fertilizer = 350 kg ha^{-1}.

Constituent	Amount spread (kg ha^{-1}) in 1980 with			Amount spread (kg ha^{-1}) in 1982 with NPK fertilizer (a_L—d_L)
	Dewatered sludge on snow (b_L)	Dewatered sludge on nonfrozen soil (c_L)	Dewatered and limed sludge on nonfrozen soil (d_L)	
TS	16000—18000	16000—20000	16000—18000	350
ASH	~3500	~8500	~7000	..
N_{tot}	1300—1400	750—950	450—550	55
P_{tot}	500—600	400—500	450—500	25
K	130—150	80—100	25—30	45
Ca	150—170	30—40	800—900	8.5
Mg	55—65	90—110	50—55	0.35
Mn	5.5—6.0	4.5—5.5	4.5—5.0	0.035
Zn	7.5—8.5	6.5—8.0	6.0—7.0	0.0070
Cu	6.0—7.0	4.5—5.5	2.0—2.5	0.0035
Cr	0.10—0.15	0.35—0.45	0.20—0.25	..
Ni	1.4—1.5	1.0—1.5	0.50—0.55	0.0030
Cd	0.050—0.055	0.035—0.045	0.035—0.040	0.00070
Hg	0.025—0.030	0.020—0.025	0.025—0.030	0.0000035
Pb	2.0—2.5	2.5—3.5	1.0—1.5	0.00035

Table 8. Approximate amounts of constituents spread in the Maaninka field with cow slurries, sewage sludge and NPK fertilizer. Volume of slurry or sludge per hectare: 45—48 m^3 for the cow slurry on snow (b_M); 120 m^3 for the dewatered sewage sludge on nonfrozen soil (c_M); 50 m^3 for the cow slurry on nonfrozen soil (d_M). Amount of NPK fertilizer = 400 kg ha^{-1}.

Constituent	Amount spread (kg ha^{-1}) with			Amount spread (kg ha^{-1}) with NPK fertilizer (a_M—d_M)
	Cow slurry on snow (b_M)	Dewatered sludge on nonfrozen soil (c_M)	Cow slurry on nonfrozen soil (d_M)	
TS	550—600	20 000	1 200	400
N_{tot}	50—55	950	60	65
P_{tot}	7.0—8.0	500	10	30
K	60—65	15	50	50
Ca	10—15	200	15	9.5
Mg	5.0—5.5	45	7.0	0.40
Na	10—15	6.0	10	..
Fe	0.70—0.80	1 700	1.5	..
Mn	0.10—0.15	7.0	0.20	0.040
Zn	0.20—0.25	8.5	0.40	0.0080
Cu	0.060—0.065	3.0	0.085	0.0040
Cr	0.00030—0.00035	0.090	0.0015	..
Ni	0.00095—0.0010	2.0	0.0025	0.0035
Cd	0.0000055—0.0000060	0.0065	0.000085	0.00080
Pb	0	0.010	0.000010	0.00040

case of the sewage sludge (treatment c_M); potassium and sodium were however spread more with the cow slurries (Table 8).

2.3 Observation techniques

Swedish weight sounding (Isotalo et al. 1982) was used in geological and geotechnical investigation of soil layers. Soil samples were taken with a Swedish ram sounding device. For an agricultural study, samples were taken from the plough layer (0—20 cm). Easily soluble phosphorus and exchangeable potassium, calcium and magnesium were extracted by an acid (pH 4.65) ammonium acetate solution (Vuorinen and Mäkitie 1955). Soluble iron, manganese, zinc, copper, chromium, cadmium and lead were analysed from an acid ammonium acetate — EDTA — extract (Lakanen and Erviö 1971). Conductivity and pH were measured from a water solution.

Standard procedures adopted by the National Board of Waters (Vesihallitus 1982a, 1981b) were used in the sampling and analysis of sludges and slurries.

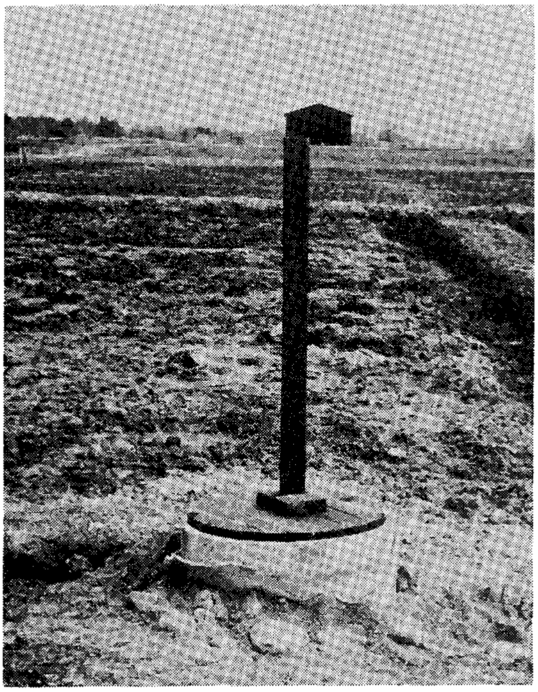


Fig. 6. Well used to collect surface runoff in four test plots of the Liperi field (under construction).

Precipitation and air temperature were measured with Finnish standard rain gauges and thermometers in the climatological stations of the Finnish Meteorological Institute: the Kaatamo Station (8 km W of the Liperi field), Maaninka Research Station (Maaninka field), Joensuu Airport (20 km NE of the Liperi field) and Kuopio Airport (30 km SE of the Maaninka field).

Standard techniques of snow depth and density measurement were used to determine the water equivalent of snow. Soil frost penetration was measured with metylene-blue tubes.

In the Liperi field, surface runoff from four test plots (Fig. 3) was collected by a surface water well, which was a tube of PVC plastic, 500 mm in diameter and 1 500 mm in depth (Fig. 6). Holes in the tube walls at the level of ditch bottom served as inflow points of runoff. Runoff from the surface wells and subdrainage pipes was conveyed to an observation building (Fig. 3) by plastic collecting pipes, 34 mm in diameter. In the building, runoff volume from each surface well and subdrainage plot was continually recorded by a tipping bucket (Fig. 7). Part of the water volume in every tipping of the can was stored in a sampler, located under the can, thus yielding flow-proportional composite samples. Standard methods (Vesihallitus 1981b) were applied in water quality analyses. Subdrainage and surface runoff measurement and sampling in the Maaninka field (Fig. 5) followed, in principle, the arrangements used in Liperi (there were some minor differences regarding the structure of surface water wells and the size of collecting pipes).

Ten ground-water tubes were installed in the Maaninka field in order to observe effects of the land application on ground-water quality (Fig. 5). The tube was a plastic one, two inches in diameter and 6—7 metres deep. A filter was located at a depth of 5—7 metres from ground level. Groundwater samples were taken from the tube with a suction pump. (All samples were centrifugated after October 1979.)

2.4 Statistical methods

The Mann-Whitney rank-sum test (Malik and Mullen 1973), which is the nonparametric counterpart of the two-sample t test for independent samples, was used to test the hypothesis that two samples come from populations with the same distribution (App. 1).

The Latin-square procedure of the analysis of variance (Cochran and Cox 1957) was applied to test the effect of treatments (App. 1).

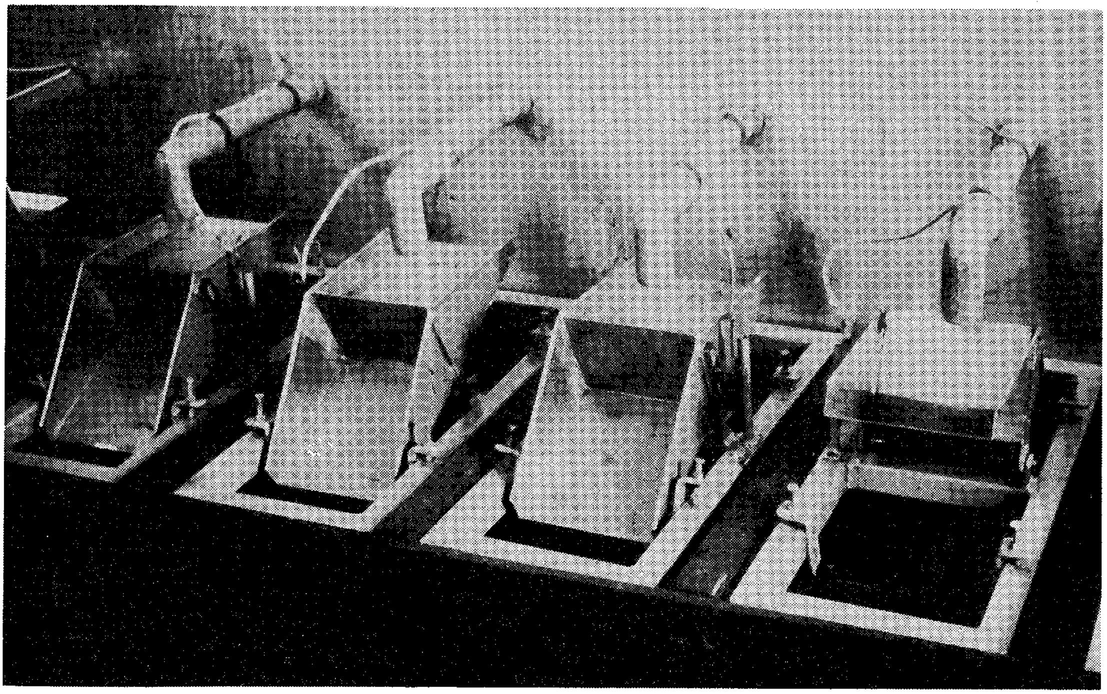


Fig. 7. Tipping buckets used to measure the volume of runoff waters and to collect the quality samples.

Spearman's rank correlation coefficient (Owen 1962) was used to test the independence of two variables (App. 1).

All computations were done with the Eclipse MV/6000 computer of the National Board of Waters, utilizing the BMDP Statistical Software of the University of California.

3. RESULTS AND DISCUSSION

3.1 Hydrological and meteorological conditions

3.11 Precipitation

Table 9 and Fig. 8 show the measured monthly precipitation in Liperi and Maaninka in the hydrological years (Nov. 1—Oct. 31) 1978—1982. Measured seasonal and yearly precipitation and their long-term averages, at selected stations of the Finnish Meteorological Institute, in the Liperi and Maaninka regions are given in Table 10 and Fig. 9.

The correction factor for the measured annual precipitation in the Liperi and Maaninka regions is 1.2 (Kuusisto and Mälkki 1982). The approximate real precipitation in millimetres was thus as follows:

Hydrological year	Liperi region	Maaninka
1978—1979	610—710	620
1979—1980	600—760	670
1980—1981	840—990	760
1981—1982	630—760	650

Precipitation in 1978—1979 and 1979—1980 was near normal; a special feature of summer 1980, however, was that most of the precipitation fell with few heavy rain events (the rest of the summer was dry and warm). In 1980—1981, both the winter and summer precipitations were generally 40—50 per cent higher than average; the annual precipitation was 30—50 per cent higher than the long-term mean. In 1981—1982, the winter and spring precipitations were 40 and 50 per cent higher than average. Summer 1982 had a precipitation which was lower than normal; the annual precipitation of

Table 9. Measured (uncorrected) monthly precipitation and air temperature in Liperi and Maaninka in the hydrological years studied. Liperi: precipitation at the Kaatamo station (8 km W of the test field), temperature at Joensuu airport (20 km NE of the field). Maaninka: precipitation on the test field, temperature at Kuopio airport (30 km SE of the field). Measurements by the Finnish Meteorological Institute. Long-term averages given in Heino (1976) and Helimäki (1967).

Year	Month	Precipitation (mm)				Air temperature (°C)			
		Liperi		Maaninka		Liperi		Maaninka	
		Meas.1)	Dev.2)	Meas.1)	Dev.2)	Meas.1)	Dev.3)	Meas.1)	Dev.3)
1978	XI	63.4	+18	56.0	+20	− 0.8	+ 1.8	− 0.4	+1.7
	XII	16.3	−16	12.0	−20	−17.6	−10.1	−16.9	−9.7
1979	I	29.0	− 7	38.9	+ 7	−12.4	− 1.3	−11.9	−1.5
	II	32.2	+ 8	30.4	+ 8	−12.8	− 2.5	−12.8	−2.8
	III	21.0	+ 1	21.6	+ 3	− 3.5	+ 2.4	− 2.8	+2.7
	IV	13.4	−15	15.2	−13	− 1.0	− 1.7	− 0.5	−1.5
	V	52.9	+20	38.4	+ 3	10.0	+ 2.2	10.3	+2.2
	VI	65.3	+ 7	45.8	−10	14.6	+ 0.2	15.6	+0.7
	VII	42.1	−24	70.2	+ 3	15.8	− 0.6	16.4	−0.4
	VIII	55.2	± 0	76.8	+12	15.0	+ 0.6	15.9	+1.1
	IX	86.8	+20	66.2	+ 8	8.3	− 0.6	9.3	±0.0
	X	36.5	−10	44.7	− 4	1.2	− 2.1	1.6	−2.2
	XI	59.5	+15	56.5	+21	− 0.9	+ 1.7	− 0.3	+1.8
	XII	41.8	+10	30.0	− 2	− 7.2	+ 0.3	− 6.6	+0.6
1980	I	36.6	+ 1	26.1	− 6	−12.3	− 1.2	−11.6	−1.2
	II	23.2	− 1	19.8	− 2	−12.1	− 1.8	−11.8	−1.8
	III	14.7	−15	14.1	− 5	− 8.4	− 2.5	− 8.1	−2.6
	IV	20.3	− 8	10.6	−17	1.7	+ 1.0	2.3	+1.3
	V	22.8	−10	47.0	+12	6.0	− 1.8	6.9	−1.2
	VI	78.5	+21	91.2	+35	17.3	+ 2.9	17.8	+2.9
	VII	59.2	− 7	56.4	−11	16.2	− 0.2	17.3	+0.5
	VII	66.8	+12	90.2	+25	13.9	− 0.5	14.8	±0.0
	IX	20.1	−47	29.5	−29	8.6	− 0.3	9.6	+0.3
	X	72.7	+27	90.9	+42	3.1	− 0.2	3.8	±0.0
	XI	52.8	+ 8	61.1	+25	− 6.6	− 4.0	− 6.0	−3.9
	XII	53.3	+21	50.0	+18	− 7.8	− 0.3	− 7.6	−0.4
1981	I	33.4	− 3	44.5	+13	− 7.4	+ 3.7	− 6.9	+3.5
	II	33.1	+ 9	18.8	− 3	−10.7	− 0.4	−10.3	−0.3
	III	32.8	+13	41.8	+23	−10.2	− 4.3	− 9.5	−4.0
	IV	29.2	+ 1	7.9	−20	− 0.6	− 1.3	0.2	−0.8
	V	24.7	− 8	6.4	−29	9.1	+ 1.3	10.3	+2.2
	VI	109.9	+52	147.5	+92	12.8	− 1.6	12.6	−2.3
	VII	95.7	+30	62.1	− 5	17.7	+ 1.3	17.8	+1.0
	VIII	93.2	+38	89.9	+25	13.2	− 1.2	13.4	−1.4
	IX	47.7	−19	28.7	−29	8.5	− 0.4	9.0	−0.3
	X	90.8	+45	76.0	+27	5.0	+ 1.7	5.3	+1.5
	XI	48.3	+ 3	86.7	+51	− 2.2	+ 0.4	− 1.9	+0.2
	XII	74.0	+42	74.7	+43	− 9.6	− 2.1	− 9.6	−2.4
1982	I	21.2	−15	27.0	− 5	−17.4	− 6.3	−16.6	−6.2
	II	11.9	−12	5.9	−16	− 9.4	+ 0.9	− 9.0	+1.0
	III	18.9	− 1	23.3	+ 4	− 2.6	+ 3.3	− 2.2	+3.3
	IV	34.5	+ 7	49.7	+22	1.3	+ 0.6	1.5	+0.5
	V	66.6	+34	65.9	+31	7.9	+ 0.1	8.2	+0.1
	VI	72.5	+15	44.0	−12	10.1	− 4.3	10.3	−4.4
	VII	29.2	−37	23.5	−44	16.8	+ 0.4	17.3	−0.5
	VIII	68.0	+13	66.9	+ 2	14.2	− 0.2	15.0	+0.2
	IX	41.5	−26	41.5	−17	8.4	− 0.5	9.3	±0.0
	X	36.6	− 9	30.2	−19	2.3	− 1.0	2.8	−1.0

1) Measured in 1978—1982; 2) Deviation from the mean of 1931—1960 (measured minus mean); 3) Deviation from the mean of 1961—1975 (measured minus mean)

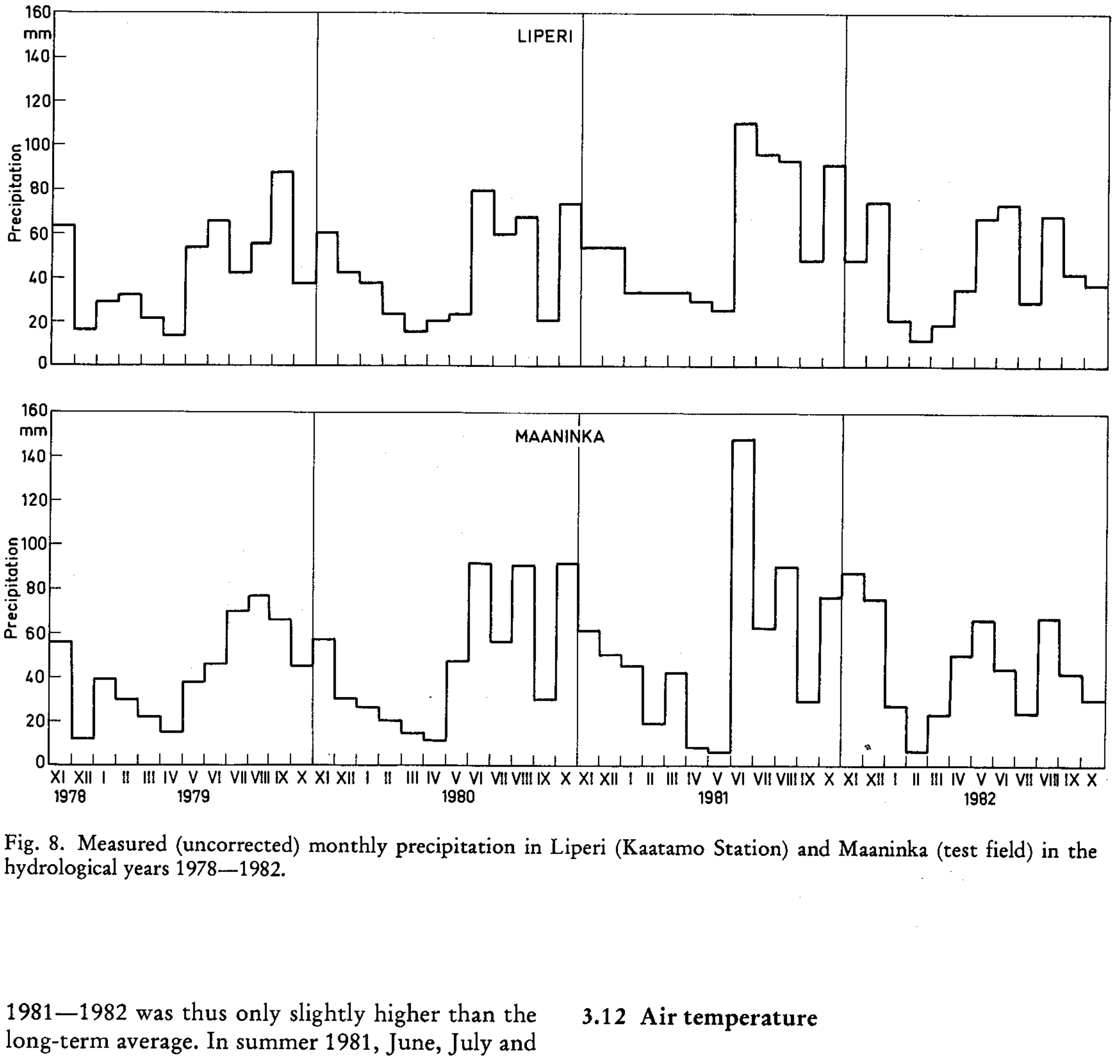


Fig. 8. Measured (uncorrected) monthly precipitation in Liperi (Kaatamo Station) and Maaninka (test field) in the hydrological years 1978—1982.

1981—1982 was thus only slightly higher than the long-term average. In summer 1981, June, July and August had an exceptionally high precipitation (Table 9). The measured value during these months in Liperi, 299 mm, was 67 per cent higher than the long-term average. The June—August precipitation in 1981 in Maaninka, 300 mm, was 60 per cent higher than normal.

3.12 Air temperature

Measured monthly air temperature in the Liperi and Maaninka regions is given in Table 9 and Fig. 10. The annual mean temperature was lower than on the average in both regions in 1978—1979, 1980—1981 and 1981—1982. In particular, low temperatures were measured in the winter seasons

Table 10. Measured (uncorrected) seasonal and annual precipitation in the Liperi and Maaninka regions in the hydrological years studied (Winter = Nov. 1—Febr. 28, Spring = March 1—May 31, Summer = June 1—Oct. 31). Measurements by the Finnish Meteorological Institute (1978—1982). Long-term averages from Helimäki (1967).

Climatological Station	Precipitation (mm) in hydrological year																Mean precipitation (mm) in			
	1978—1979				1979—1980				1980—1981				1981—1982				1931—1960			
	Winter	Spring	Summer	Total	Winter	Spring	Summer	Total	Winter	Spring	Summer	Total	Winter	Spring	Summer	Total	Winter	Spring	Summer	Total
Kaatamo	141	87	286	514	161	58	297	516	173	87	437	697	155	120	248	523	137	81	292	510
Joensuu airport	132	95	278	505	156	59	421	636	186	85	476	747	208	146	270	624	142[3)]	96[3)]	339[3)]	577[3)]
Tohmajärvi[1)]	137	106	351	594	203	62	355	620	243	109	472	824	219	127	268	614	174	103	335	612
Juuka[2)]	148	92	300	540	160	68	273	501	232	100	468	800	200	145	289	634	134	87	323	544
Maaninka	137	75	304	516	132	72	358	562	174	56	404	634	194	139	206	539	122	82	295	499

1) 60 km SE of the Liperi field; 2) 80 km N of the Liperi field; 3) Figures from the 1961—1975 period

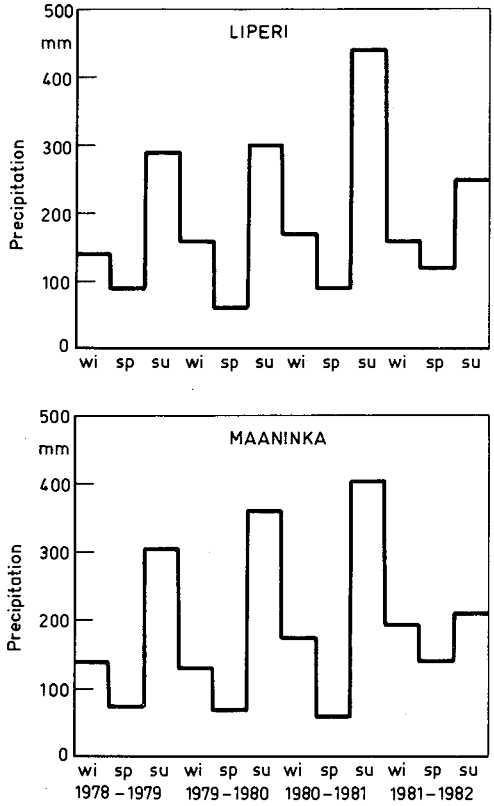


Fig. 9. Measured (uncorrected) seasonal precipitation in Liperi (Kaatamo Station) and Maaninka (test field) in the hydrological years 1978—1982 (wi = winter, sp = spring, su = summer; see Table 10).

of 1978—1979 and 1981—1982. In the melting period of 1981, May was warmer than average. In 1982, the period February — May was considerably warmer than average.

3.13 Snow accumulation and soil frost

A summary of the observations of snow accumulation and soil frost penetration in the test fields is given in Tables 11—12. Tables 13 and 14 show reference measurements from a ground-water station and two soil-frost stations in the regions.

The first snowfall in the Liperi field was observed on Oct. 23 in 1980 and on Oct. 27 in 1981. The Liperi and Maaninka regions usually receive their permament snowcover during Nov. 15—20 (Kuusisto and Mälkki 1982).

The average snow depth in eastern and northern Finland is 50—70 cm in mid-March (Kuusisto and Mälkki 1982). According to Solantie (1978), the average maximum snow depth exceeds the figure of March 15 by about 8—10 cm in central and northern Finland. The snow accumulation in the hydrological years 1978—1979 and 1979—1980 was thus normal. Instead, both in 1980—1981 and 1981—1982 snow accumulation was higher than on the average; the mid-March snow depths exceeded normal figures by 20—70 per cent, on the average (Tables 11—14).

The water equivalent of snow in the Liperi field reached an exceptional figure, 238 mm, in the end

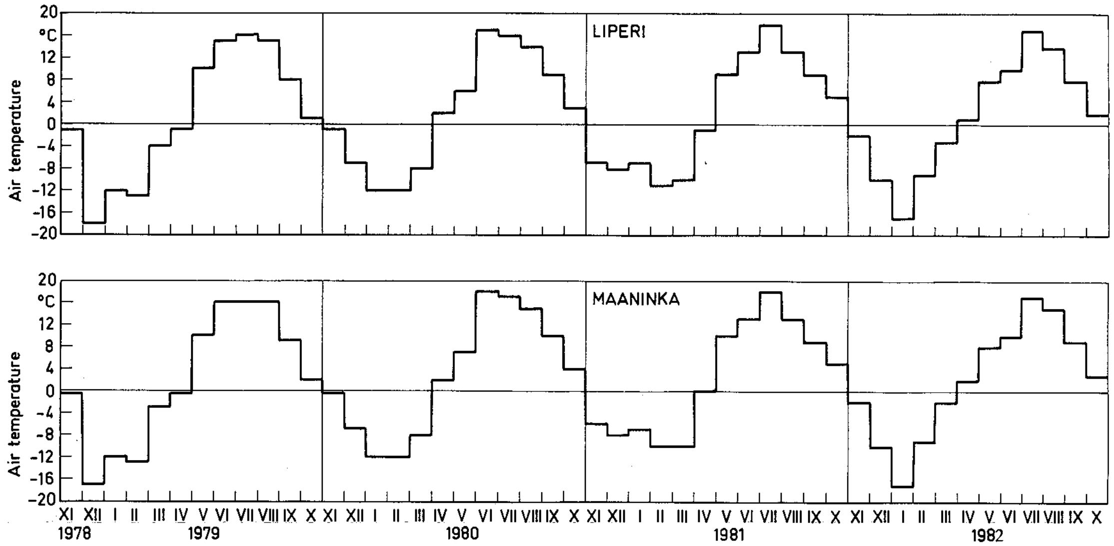


Fig. 10. Measured monthly air temperature in the Liperi and Maaninka regions (Joensuu and Kuopio Airports) in the hydrological years 1978—1982.

Table 11. Snow accumulation and soil frost penetration in the Liperi field. Number of observation points: 5 to 17 for the snow depth, 4 to 5 for the snow density, 1 to 5 for the soil frost penetration. Measurements by the Hydrological Office.

Date	Snow depth cm	Snow density kg m^{-3}	Water equivalent of snow mm	Soil frost penetration cm
March 5, 1979	42	..	..	57
March 15, 1979	39	..	..	55
April 2, 1979	27	..	..	53
Febr. 28, 1980	40	..	..	38
March 14, 1980	40	..	..	38
March 26, 1980	43	..	..	38
Febr. 17, 1981	82	260	213	..
March 9, 1981	76	290	220	..
March 30, 1981	78	305	238	..
Febr. 8. 1982	64	230	147	1
March 22, 1982	78	305	238	18
April 13, 1982	22	355	78	..

Table 12. Snow depth and soil frost penetration in the vicinity of the Maaninka field (fine sand, open ground). Measurements by the North Savo Research Station.

Date	Observation point	Snow depth cm	Soil frost penetration cm
March 15, 1979	1	46	40
	2	47	66
	3	45	61
	4	38	56
	5	51	31
March 30, 1979	1	49	40
	2	49	66
	3	47	60
	4	38	55
	5	56	31
March 15, 1980	1	57	17
	2	60	14
	3	54	30
	4	55	22
	5	55	18
March 31, 1980	1	54	17
	2	57	16
	3	51	34
	4	52	24
	5	52	18
March 15, 1981	1	89	±0
	2	89	2
	3	80	5
	4	83	1
	5	83	2
March 31, 1981	1	95	±0
	2	94	2
	3	85	5
	4	86	1
	5	86	2
March 15, 1982	1	78	2
	2	81	3
	3	79	2
	4	78	3
	5	84	3
March 31, 1982	1	54	2
	2	55	3
	3	47	2
	4	48	3
	5	50	3

of March both in 1981 and 1982 (Table 11). The mean annual maximum water equivalent is 140—160 mm in the Maaninka and Liperi regions (Solantie 1981); the maximum with a return period of 20 years is about 230 mm (Solantie 1980). Kuusisto (1984) gives the maxima 210 mm and 240 mm with return periods of 20 and 50 years for the Kallavesi (Konnus & Karvio) river basin, and 230 mm and 250 mm for the Sotkamo watercourse. (The means for the 1963—1979 period were 140 mm for the Kallavesi basin and 160 mm for the Sotkamo watercourse (Kuusisto 1984).) The maximum water equivalent measured in the Liperi field in the springs of 1981 and 1982 thus has a return period in the order of 20—50 years.

Soil frost penetration measured in the Liperi and Maaninka fields and in the selected stations of the Hydrological Office are given in Tables 11—14. The depth of soil frost depends on several factors, such as soil and terrain type, frost sum and snowcover (Soveri and Varjo 1977). A wide variation can thus be expected in different years and sites, as shown in Tables 11—14. Soil frost penetration was exceptionally low both in the winter of 1980—1981 and 1981—1982. This can be explained by high snow accumulation and the early appearance of snowcover in the autumn.

On the average, the mean dates of first soil frost formation are Nov. 1—5 and those of the end of thawing May 10—June 1 in untouched sites in the Maaninka and Liperi regions (Soveri and Varjo 1977). Soveri and Varjo (1977) also report on maximum soil frost penetration of 54 cm in Maaninka (open ground) and 42 cm in Heinävesi (open ground) in untouched sites in 1955—1975. These match well with the values measured in the sites in 1979 and 1980.

Table 13. Snow depth and soil frost penetration in the Jaamankangas groundwater station (62°40′ N, 29°43′ E; sand soil, forest). Measurements by the Hydrological Office.

Date	Observation point	Snow depth cm	Soil frost penetration cm
March 1, 1979	1	50	82
	2	60	85
	3	60	80
	4	60	..
	5	45	121
March 15, 1979	1	45	80
	2	58	90
	3	55	80
	4	68	..
	5	40	105
March 31, 1979	1	35	73
	2	50	90
	3	50	110
	4	50	..
	5	35	116
March 1, 1980	1	45	45
	2	..	55
	3	60	40
	4	60	65
	5	..	45
March 15, 1980	1	50	45
	2	..	55
	3	65	40
	4	65	65
	5	..	45
March 31, 1980	1	40	60
	2	..	73
	3	60	60
	4	60	80
	5	..	50
March 1, 1981	1	85	5
	2	100	7
	3	90	6
	4	95	±0
	5	100	8
March 15, 1981	1	95	12
	2	110	8
	3	105	10
	4	110	±0
	5	110	8
March 31, 1981	1	90	11
	2	110	6
	3	100	10
	4	105	±0
	5	110	7
March 13, 1982	1	70	17
	2	90	14
	3	82	17
	4	84	3
	5	86	3
March 29, 1982	1	50	13
	2	72	..
	3	59	14
	4	62	..
	5	75	..

Table 14. Snow depth and soil frost penetration in the Tohmajärvi (62°14′ N, 30°22′ E; fine sand, open field) and Heinävesi (62°24′ N, 28°46′ E; fine sand moraine, open ground) soil frost stations. Measurements by the Hydrological Office.

Date	Snow depth (cm)		Soil frost penetration (cm)	
	Tohmajärvi	Heinävesi	Tohmajärvi	Heinävesi
March 6, 1979	42	50	27	40
March 16, 1979	43	55	29	35
March 26, 1979	42	53	28	32
March 6, 1980	64	64	2	8
March 16, 1980	63	62	1	8
March 26, 1980	63	60	4	9
March 6, 1981	79	75	±0	±0
March 16, 1981	96	90	±0	±0
March 26, 1981	86	82	2	±0
March 6, 1982	72	70	1	±0
March 16, 1982	72	72	1	±0
March 26, 1982	61	60	±0	±0

3.2 Crop growth and soil effects

3.21 Yields

The sludge treatments in Liperi (b_L, c_L, d_L) gave in the first year, 1980, a barley yield that was, on the average, 140 per cent higher than the yield from the treatment (a_L) which had no fertilization (Table 15). The difference was 60 per cent in 1981, and 20 per cent in 1982 when all test plots received a mineral fertilization.

Limed sludge (treatment d_L) gave the highest yield (4 700 kg ha^{-1}) in the first year in Liperi. In the next two years, sludge on snow (treatment b_L) was the most effective one; this treatment also gave the highest three-year average (3 300 kg ha^{-1}), although the difference between the various sludge treatments was only 6 per cent.

Table 15. Crop yields in the Liperi field. Barley (variety Eero). Each yield is an average of four replicates.

Treatment	Yield (kg ha^{-1}) in year			
	1980	1981	1982	1980—1982 (average)
a_L	1900	1400	2300	1900
b_L	4500	2500	3000	3300
c_L	4300	2400	2600	3100
d_L	4700	2100	2600	3100

Table 16. Crop yields in the Maaninka field. Barley (variety Eero). Each yield is an average of four replicates (three in treatment b_M).

Treatment	Yield (kg ha^{-1}) in year			
	1980	1981	1982	1980—1982 (average)
a_M	4 100	1 900	4 000	3 400
b_M	2 900	2 000	4 100	3 000
c_M	4 800	2 400	3 000	3 400
d_M	3 500	2 200	4 000	3 200

Sewage sludge on nonfrozen soil (treatment c_M) gave the highest barley yield (4 800 kg ha^{-1}) in the first year in Maaninka; the yield was 17, 37 and 66 per cent higher than that obtained from treatments with mineral fertilizer (a_M), cow slurry on nonfrozen soil (d_M) and cow slurry on snow (b_M), respectively (Table 16).

In Maaninka, mineral fertilizer (treatment a_M) and sewage sludge (treatment c_M) gave the highest three-year average (3 400 kg ha^{-1}) which was, however, just 6—13 per cent higher than the yields from the other treatments.

The barley yields, which were obtained in the Liperi and Maaninka experiments, were close to normal yields in these regions.

3.22 Accumulation in soil

No differences could be found in the contents of extractable nutrients and heavy metals of top soil layer (0—20 cm) in the Liperi field in the calibration year 1979 (Table 17, p. 24).

After the Liperi application, in 1980, in all sludge treatments (b_L, c_L, d_L), a higher content of soil phosphorus, potassium, iron, manganese, zinc and copper was observed than in the reference treatment (a_L, no fertilization); a difference could also be found in nickel, cadmium, lead, conductivity and pH as for treatments b_L (sludge on snow) and c_L (sludge on nonfrozen soil).

In 1981 in Liperi, higher contents still persisted in all sludge treatments as regards phosphorus, iron and zinc (and conductivity). The contents had however decreased since 1980. The treatments b_L and c_L yielded slightly higher contents of potassium, copper and nickel than did the others. In 1982, the differences were the same as in the previous year, regarding soil phosphorus and potassium. (There were no measurements of heavy metals in 1982.)

Table 18. Ammonium and nitrate nitrogen content profile in the soil of the Liperi field in 1981. Sampling date: Sept. 10, 1981. One sample from each plot in each depth layer.

Treatment	$N_{NH_4} + N_{NO_3}$ (kg ha^{-1}) in depth layer			
	0—20 cm	20—40 cm	40—70 cm	70—100 cm
a_L	15	6.1	3.6	3.1
b_L	23	11	12	11
c_L	26	15	25	19
d_L	18	6.8	4.6	4.3

Ammonium and nitrate were determined in four soil layers down till one metre in 1981 in the Liperi field (Table 18). Sludge on nonfrozen soil (treatment c_L) gave distinctly the highest contents in all layers. The second highest values were observed in treatment b_L, sludge on snow. Limed sludge on nonfrozen soil (treatment d_L) yielded only slightly higher contents than did the reference treatment (a_L).

In the application year 1980 in Maaninka (Table 19), sewage sludge (treatment c_M) caused distinctly the highest contents as regards iron and zinc and slightly higher contents as regards phosphorus and copper. Conductivity had increased considerably in the sewage sludge treatment; there was a slight decrease in pH. Mineral fertilization (treatment a_M) yielded the highest nickel content.

In 1981, the differences between various treatments in the Maaninka field were as before; conductivity in the sewage sludge treatment had decreased, but it was still slightly higher than in the other treatments.

Heavy metals were not measured in 1982 in the Maaninka field. Differences in phosphorus content no longer existed. Conductivity in the sludge treatment had furthermore approached that in the other treatments.

3.3 Runoff rates

3.31 Liperi field

The measured subdrainage and surface runoff of the Liperi field is given in Table 20 and Fig. 11. Appendices 2 to 4 show the seasonal (winter, spring, summer) variation. Table 21 gives total runoff from the four test plots (Nos. 5, 9, 13 and 17; Fig. 3) where both subdrainage and surface runoff were measured.

Table 17. Extractable nutrients and heavy metals in the top soil (0—20 cm) of the Liperi field. Sampling dates: Aug. 25, 1980; Sept. 10, 1981; Sept. 8, 1982. One sample from each plot.

Year	Treatment	Extractable nutrients and heavy metals (mg l^{-1} of soil)													
		P	K	Ca	Mg	Fe	Mn	Zn	Cu	Cr	Ni	Cd	Pb	γ_{25}[1]	pH[2]
1979	a_L	5.0	88	2 000	200	..	..	..	..	..	..	..	..	15	6.5
	b_L	5.7	80	1 900	220	..	..	..	..	..	..	..	..	15	6.5
	c_L	5.4	98	1 900	200	..	..	..	..	..	..	..	..	14	6.5
	d_L	4.6	88	1 900	210	..	..	..	..	..	..	..	..	13	6.6
1980	a_L	4.7	68	2 000	210	480	10	0.73	8.2	0.49	3.6	0.086	1.7	12	6.7
	b_L	12	83	2 000	220	660	12	2.5	10	0.39	4.9	0.099	2.4	35	6.4
	c_L	8.2	83	1 900	220	640	13	2.6	10	0.40	4.3	0.10	2.3	47	6.4
	d_L	12	75	2 200	220	680	15	2.1	9.1	0.39	3.5	0.085	1.8	16	7.0
1981	a_L	4.6	70	1 900	210	430	11	0.53	7.8	0.51	3.4	0.11	2.3	9.3	6.7
	b_L	7.2	79	1 900	220	470	9.7	1.1	8.6	0.48	3.8	0.12	1.2	9.9	6.6
	c_L	6.9	81	1 700	210	520	10	1.4	9.0	0.50	4.1	0.12	1.4	9.8	6.4
	d_L	9.5	71	1 900	220	490	13	1.1	8.1	0.48	3.4	0.11	1.2	10	6.7
1982	a_L	5.8	69	1 800	180	..	..	..	..	..	..	..	..	12	6.6
	b_L	11	78	1 700	190	..	..	..	..	..	..	..	..	14	6.5
	c_L	9.5	80	1 700	190	..	..	..	..	..	..	..	..	12	6.5
	d_L	11	70	1 800	190	..	..	..	..	..	..	..	..	13	6.7

1)γ_{25} in mS m^{-1}, 2) pH (H_2O)

Table 19. Extractable nutrients and heavy metals in the top soil (0—20 cm) of the Maaninka field. Sampling dates: Sept. 20, 1979; Sept. 22, 1980; Sept. 24, 1981; Sept. 8, 1982. One sample from each plot.

Year	Treatment	Extractable nutrients and heavy metals (mg l^{-1} of soil)													
		P	K	Ca	Mg	Fe	Mn	Zn	Cu	Cr	Ni	Cd	Pb	γ_{25} 1)	pH 2)
1979	a_M	9.5	200	1 200	150	..	..	..	..	..	..	..	..	5.8	6.1
	b_M	10	200	1 200	150	..	..	..	..	..	..	..	..	5.6	6.1
	c_M	11	180	1 200	180	..	..	..	..	..	..	..	..	5.7	6.0
	d_M	10	180	1 200	170	..	..	..	..	..	..	..	..	5.7	6.1
1980	a_M	9.4	210	1 200	150	290	48	1.9	2.1	0.12	0.47	0.045	1.5	6.7	6.2
	b_M	11	180	1 200	140	330	53	2.2	2.5	0.14	0.65	0.047	1.7	6.0	6.1
	c_M	14	170	1 100	140	520	58	3.8	3.0	0.11	0.69	0.048	1.7	14	5.8
	d_M	11	190	1 200	150	320	46	2.0	2.2	0.13	0.62	0.050	1.6	6.3	6.2
1981	a_M	10	170	1 100	130	250	38	1.9	1.7	0.12	0.48	0.060	1.1	6.0	6.1
	b_M	10	170	1 100	140	280	35	1.9	1.9	0.14	0.62	0.053	1.1	6.7	6.1
	c_M	14	150	1 000	120	400	41	3.5	2.6	0.12	0.63	0.054	1.0	8.4	5.8
	d_M	11	150	1 100	140	280	35	1.9	1.9	0.12	0.54	0.058	1.2	6.1	6.1
1982	a_M	9.1	140	1 000	120	..	..	..	..	..	..	..	..	5.8	6.1
	b_M	11	140	1 000	110	..	..	..	..	..	..	..	..	5.9	6.1
	c_M	12	130	1 000	110	..	..	..	..	..	..	..	..	6.7	5.9
	d_M	11	130	1 000	120	..	..	..	..	..	..	..	..	5.8	6.1

1) γ_{25} in mS m^{-1}; 2) pH (H_2O)

Table 20. Annual runoff (Nov. 1—Oct. 31), spring runoff (March 1—May 31) and percentage spring runoff of the annual in the hydrological years studied in the Liperi field. Four replicates per treatment for the subdrainage runoff, one replicate per treatment for the surface runoff.

Hydrological year	Treatment	Mean annual runoff Mq ($l\ s^{-1}\ km^{-2}$)		Annual runoff (mm)		Spring runoff (mm)		Percentage spring runoff (%)	
		Subdrainage	Surface	Subdrainage	Surface	Subdrainage	Surface	Subdrainage	Surface
1978—1979	a_L	6.3	1.2	200	37	190	35	95	95
	b_L	7.2	3.1	230	99	210	96	91	97
	c_L	7.0	1.7	220	54	210	53	95	98
	d_L	6.8	1.8	210	57	200	55	95	96
1979—1980	a_L	6.4	0.72	200	23	150	16	75	70
	b_L	5.8	0.97	180	31	130	24	72	77
	c_L	6.8	0.59	220	19	150	17	68	89
	d_L	6.0	1.6	190	49	130	47	68	96
1980—1981	a_L	19	2.5	610	78	270	58	44	74
	b_L	20	4.8	630	150	320	120	51	80
	c_L	23	9.4	720	300	380	280	53	93
	d_L	23	3.5	730	110	370	95	51	86
1981—1982	a_L	16	1.5	500	48	310	42	62	88
	b_L	19	2.3	590	71	370	66	63	93
	c_L	21	1.8	660	57	430	51	65	89
	d_L	19	1.7	600	53	400	50	67	94

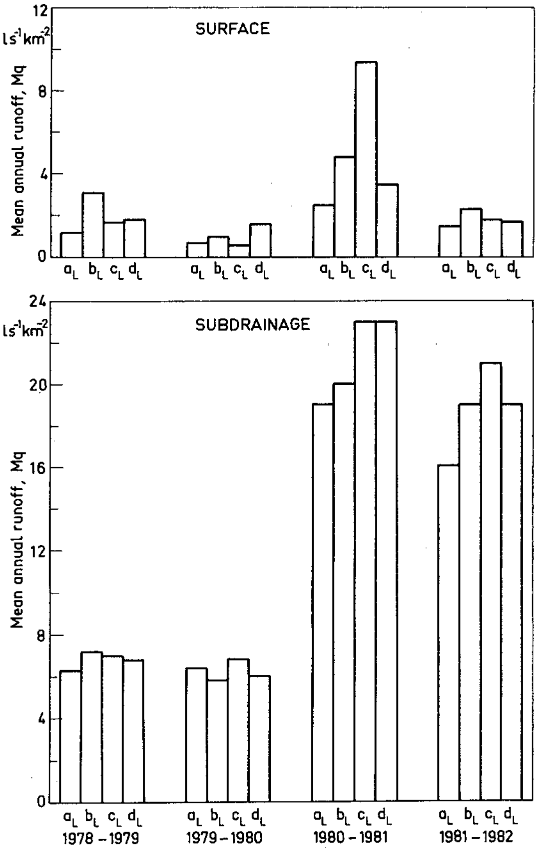


Fig. 11. Mean runoff measured in the Liperi field in the hydrological years studied.

Table 21. Mean annual total runoff (subdrainage runoff plus surface runoff) and percentage subdrainage runoff of the total in the Liperi field. Observations from the four test plots having both subdrainage and surface runoff measured. (See Fig. 3.)

Hydrological year	Treatment	Total runoff Mq $l\ s^{-1}\ km^{-2}$	Percentage subdrainage runoff %
1978—1979	a_L	9.0	87
	b_L	13	75
	c_L	8.6	80
	d_L	7.6	76
1979—1980	a_L	6.0	88
	b_L	9.0	89
	c_L	9.6	94
	d_L	8.2	80
1980—1981	a_L	25	90
	b_L	24	80
	c_L	34	72
	d_L	28	87
1981—1982	a_L	22	93
	b_L	20	88
	c_L	25	93
	d_L	20	92

Surface runoff caused 15—25 per cent of total runoff in the hydrological year 1978—1979 (Table 21), 10—20 per cent in 1979—1980, 10—25 per cent in 1980—1981, and about 10 per cent in 1981—1982. The higher portion of surface runoff in 1978—1979 is, obviously, mostly explained by the deeper soil frost penetration in that year (Table 11). Seuna and Kauppi (1981) report that 77 per cent of the total annual runoff came from subdrains and 23 per cent from surface runoff in the Hovi basin in southern Finland, in 1972—1978.

About 97 per cent of surface runoff came during the snowmelting period (March 1—May 31) in 1978—1979 (Table 20), 83 per cent in 1979—1980 and 1980—1981, and 91 per cent in 1981—1982. The snowmelting period accounted for 94 per cent of the total subdrainage runoff in 1978—1979, 71 per cent in 1979—1980, 50 per cent in 1980—1981, and 64 per cent in 1981—1982.

The mean annual subdrainage runoff (average of 16 test plots) was 6.8 $l\ s^{-1}\ km^{-2}$ in the hydrological year 1978—1979, 6.3 $l\ s^{-1}\ km^{-2}$ in 1979—1980, 21 $l\ s^{-1}\ km^{-2}$ in 1980—1981, and 19 $l\ s^{-1}\ km^{-2}$ in 1981—1982. The mean surface runoff (4 test plots) was 2.0, 0.97, 5.1 and 1.8 $l\ s^{-1}\ km^{-2}$, respectively. This variation follows well the variation of precipitation (Tables 9—10).

Tables 22 to 25 show the probability distributions, and measured values in 1980—1982, of mean annual runoff and spring runoff in the Hovi basin, mentioned above, and in selected six small basins of the Hydrological Office in central and eastern Finland. The mean annual runoff of 1980, in the small basins referred to, was near normal; runoff exceeds the 1980 value once in two years, on the average. The year 1981 was exceptional: in virtually all basins, the mean annual runoff had a value which has an average return period of about 30 years or more. The 1982 mean runoff is exceeded in most basins once in 5 to 10 years on the average. The spring runoff 1980 was in general smaller than in 1958—1977 on the average. The 1981 spring runoff is exceeded in Kesselinpuro, Kuokkalanoja and Mustapuro once in 15—20 years; in the others a higher runoff can be expected once in 3 to 5 years, on the average. The 1982 spring runoff was even more exceptional: it is exceeded in Korpijoki only once in 30 years, on the average, and once in 20 years in Kesselinpuro and Mustapuro.

The years 1981 and 1982 were thus rare in a hydrological sense (return periods ≥30 years for annual runoff in 1981, 20 to 30 years for spring runoff in 1982); this is naturally reflected in runoff measured in the Liperi field. The 1980—1981 and 1981—1982 runoffs however seem high. Especially high is the spring runoff: total runoff was about

Table 22. Probability distribution of the mean annual runoff of selected small basins of the Hydrological Office in 1958—1977 (Seuna 1982). Selected basin characteristics: Hovi = 0.12 km^2, cultivated land 100 %; Kesselinpuro = 21.7 km^2, cultivated land 4 %; Kuokkalanoja = 2.76 km^2, cultivated land 21 %; Mustapuro = 11.2 km^2, cultivated land 15 %; Korpijoki = 122 km^2, cultivated land 8 %; Ruunapuro = 5.39 km^2, cultivated land 22 %; Myllypuro = 9.86 km^2, cultivated land 2 %.

Basin	Annual runoff (l s^{-1} km^{-2}) of different probability levels					
	Mq	95 %	90 %	50 %	10 %	5 %
Hovi	7.1	2.8	3.7	6.6	12	14
Kesselinpuro	7.9	3.8	4.7	9.3	11	12
Kuokkalanoja	9.4	5.8	6.3	8.5	14	15
Mustapuro	10	5.2	6.3	10	14	15
Korpijoki	9.6	4.6	5.7	9.7	14	15
Ruunapuro	8.0	5.2	5.8	8.1	10	11
Myllypuro	12	5.8	7.1	12	16	17

Table 23. Mean annual runoff in selected small basins of the Hydrological Office in 1980—1982 (Vesihallitus 1980, 1981, 1982).

Basin	Mean annual runoff Mq (l s^{-1} km^{-2}) in		
	1980	1981	1982
Hovi	9.7	15	10
Kesselinpuro	6.5	14	11
Kuokkalanoja	9.6	16	12
Mustapuro	8.7	17	14
Korpijoki	10	15	12
Ruunapuro	6.7	15	8.8
Myllypuro	7.5	15	12

Table 24. Probability distribution of the spring runoff (March 1—May 31) of selected small basins of the Hydrological Office in 1958—1977 (Seuna 1982).

Basin	Spring runoff (mm) of different probability levels					
	Mean	95 %	90 %	50 %	10 %	5 %
Hovi	140	40	62	140	210	240
Kesselinpuro	130	72	85	130	180	190
Kuokkalanoja	170	100	120	170	220	230
Mustapuro	160	96	110	160	210	230
Korpijoki	190	92	110	180	250	270
Ruunapuro	130	93	100	130	170	180
Myllypuro	200	110	130	200	270	290

Table 25. Spring runoff (March 1—May 31) in selected small basins of the Hydrological Office in 1980—1982 (Vesihallitus 1980, 1981, 1982).

Basin	Spring runoff (mm) in		
	1980	1981	1982
Hovi	85	190	210
Kesselinpuro	89	180	190
Kuokkalanoja	120	230	210
Mustapuro	110	230	230
Korpijoki	170	190	280
Ruunapuro	92	140	170
Myllypuro	170	220	250

410 mm in both springs (treatment c_L excluded). This figure is even higher than the maximum water equivalent of snow, 238 mm, in the end of March (Table 11) plus the (corrected) precipitation in April—May (Table 9): about 37 per cent in spring 1981 and 14 per cent in 1982. There are two possible causes for this: flooding of the field from surroundings (especially from the open ditch shown in Fig. 3) and capillary rise of ground water, leaking to the subdrains. This conclusion is also supported by the results of Kuusisto (1984) who gives the following values of maximum water yield from snowcover within 30 days in the open sites of stake stations:

Station group	Return period in years	Maximum water yield in mm
Southern Finland	20	231
	50	261
Central Finland	20	238
	50	270
Northern Finland	20	252
	50	277

Beyond the exceptional hydrologic conditions high runoff is also explained by the soil type and the fact that subdrainage increases total runoff. Seuna and Kauppi (1981) report from the Hovi basin that annual runoff grew by 18 per cent, on the average, owing to subdrainage. This is because of decrease in evapotranspiration and, in particular, evaporation.

The differences in runoff from the various treatments (test plots) mostly proved to be statistically insignificant (Tables 42—44). Some column and row effects could be observed in 1982 (Table 46, App. 7—8) which reflect the probable flooding from the surroundings or the groundwater leakage.

3.32 Maaninka field

A problem in the Maaninka field was that not all test plots yielded any runoff at all (the plots in analysis are 1—3, 5, 6, 9—11 and 13; Fig. 5). This is mostly explained by the soil type, in which most precipitation percolates to ground water, and by the varying hydraulic conductivity in the field (Fig. 12).

The runoff measured in Maaninka thus gives an order of magnitude. Subdrainage runoff was 0.2 l s^{-1} km^{-2} in 1978—1979, 0.1 l s^{-1} km^{-2} in 1979—1980 and 0.5 l s^{-1} km^{-2} in 1980—1981. These figures are roughly two to three per cent of the ones measured in the Liperi field. Surface runoff

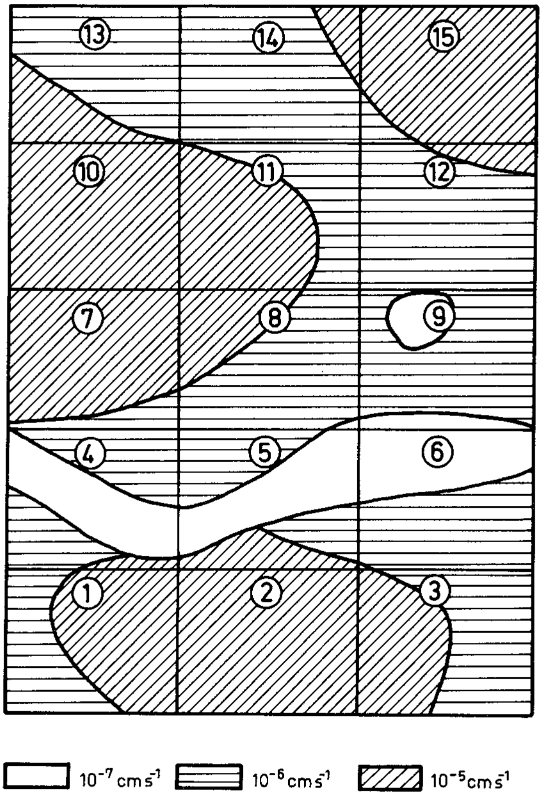


Fig. 12. Zones of hydraulic conductivity (cm s^{-1}) in the Maaninka field. Based on measurement in four points in each test plot.

was 1.3, 0.2 and 0.6 l s^{-1} km^{-2}, respectively (10 to 60 per cent of the Liperi values).

There were no statistically significant differences in runoff from the various treatments (test plots) (Tables 49—50).

3.4 Quality of and leaching with subdrainage and surface waters

3.41 Quality distributions

A large number of macro- and micronutrients, toxic heavy metals and other constituents were analysed on subdrainage and surface waters (Tables 27—30). Organic matter was measured by chemical oxygen demand (COD_{Mn}). Coliform bacteria and enterococci were used to indicate a possible contamination by pathogens.

The study period was divided into two parts: a calibration period before the applications and a period following them (Tables 26 and 29). Flow-weighted mean concentrations were calculated for hydrological years (Nov. 1—Oct. 31) or months (Tables 31—35, Figs. 13—14).

Distribution of the quality variables usually differed from a normal distribution (Tables 27—30); it was, in general, strongly skewed to the right. Especially high standard deviations, 100—300 per cent of the arithmetic means, were observed in the Liperi field for nitrogen and phosphorus, micronutrients, heavy metals, solids and bacteria.

Median intervals for runoff recording and sampling in the Liperi field were 7 days in the calibration period and 4—5 days in the period after the treatments (Tables 27—28). In Liperi, sampled runoff volume covered, in different years, roughly 50—70 per cent of the total runoff in the case of the most important constituents; this allows a relatively reliable calculation of leaching (for the other constituents, an order of magnitude of leaching can be computed with the measured concentrations). The surface-water results are far less reliable than the subdrainage results. In Maaninka, the number of observations was small (Tables 29—30) but they can be used to calculate levels of leaching.

Two seasonal peaks were generally observed in concentrations: one in the snow-melting period in spring and another in the autumn (Figs. 14—16).

On the order of 70—90 per cent of nitrogen, in both subdrainage and surface waters, was in nitrate form (Tables 31—32, 35). Effect of the treatments could usually be seen in both median and flow-weighted mean concentrations; the annual weighted mean concentration of total nitrogen in subdrainage water grew from about 10 mg l^{-1} in 1978—1979 to 33 mg l^{-1} in treatment c_L (sewage sludge on nonfrozen soil) in Liperi in 1980—1981 (Table 31) and to 36 mg l^{-1} in Maaninka (combined observations) (Table 35). (A considerable part of

Table 26. Periods before (period I) and after (period II) the application of sludge in the Liperi field, used in the quality analysis of subdrainage and surface waters.[1)]

	Period	
Code	Duration	Treatment
I	Autumn 1978[2)]—March 25, 1980	a_L, b_L
	Autumn 1978—May 13, 1980	c_L
	Autumn 1978—May 18, 1980	d_L
II	March 26, 1980—Autumn 1982[2)]	a_L, b_L
	May 14, 1980—Autumn 1982	c_L
	May 19, 1980—Autumn 1982	d_L
I—II	Autumn 1978—Autumn 1982	a_L—d_L

1) For the dates of application, see Table 3; 2) Observations begin and end in different days, mostly in October (variation between subdrainage and surface runoff, and different test plots)

Table 27. Properties of the distributions of subdrainage-water quantity and quality variables in the Liperi field. Four replicates per treatment. Periods studied as in Table 26. Statistics: min = minimum observed; m = median; x̄ = arithmetic mean; s = standard deviation; max = maximum observed.

Variable	Unit	Period	Number of observations in treatment				Values of statistics in different treatments																			
							min				m				x̄				s/x̄				max			
			a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L
Q	m^3	I	138	141	173	179	0	0	0	0	0.38	0.39	0.57	0.48	4.3	4.6	5.9	5.2	2.5	2.8	2.1	2.2	59	97	72	61
		II	631	622	591	594	0	0	0	0	1.9	2.0	2.0	1.7	5.3	5.8	6.3	6.0	1.6	1.8	1.8	2.0	97	120	100	140
		I—II	769	763	764	773	0	0	0	0	1.6	1.6	1.7	1.5	5.1	5.5	6.2	5.9	1.8	1.9	1.9	2.0	97	120	100	140
t	d	I	138	141	173	179	1.0	1.0	1.0	1.0	7.0	7.0	7.0	7.0	15	15	13	13	1.5	1.5	1.6	1.4	98	98	99	98
		II	631	622	591	594	0.2	0.2	0.2	0.2	4.0	4.0	4.0	4.0	6.5	6.6	6.5	6.5	1.2	1.4	1.4	1.3	57	93	93	93
		I—II	769	763	764	773	0.2	0.2	0.2	0.2	5.0	5.0	5.0	5.0	8.0	8.1	8.1	8.0	1.5	1.6	1.6	1.4	98	98	99	98
N_{tot}	$mg\ l^{-1}$	I	79	72	96	89	1.1	0.99	0.96	1.5	5.3	5.3	5.6	5.8	6.2	6.7	6.1	6.7	0.57	0.72	0.71	0.62	16	32	31	24
		II	296	293	276	279	0.26	1.3	0.66	0.38	2.4	7.6	9.0	3.6	4.4	13	17	6.2	1.3	1.3	1.3	1.2	45	100	130	45
		I—II	375	365	372	368	0.26	0.99	0.66	0.38	2.9	7.3	7.8	4.3	4.8	12	14	6.3	1.1	1.3	1.4	1.0	45	100	130	45
N_{NH_4}	$mg\ l^{-1}$	I	63	61	81	77	0	0	0	0.001	0.006	0.006	0.008	0.009	0.013	0.013	0.019	0.023	1.4	1.3	1.5	1.6	0.11	0.084	0.15	0.19
		II	196	196	179	180	0	0	0	0	0.006	0.008	0.006	0.006	0.018	0.13	0.015	0.021	2.8	4.1	2.6	5.7	0.65	5.2	0.49	1.6
		I—II	259	257	260	257	0	0	0	0	0.006	0.007	0.007	0.006	0.017	0.10	0.016	0.022	2.7	4.5	2.2	4.7	0.65	5.2	0.49	1.6
N_{NO_2}	$mg\ l^{-1}$	I	78	76	95	93	0	0	0	0	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.87	1.0	0.82	0.77	0.007	0.013	0.008	0.009
		II	180	180	163	164	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.003	0.002	0.001	1.4	1.7	1.4	1.9	0.014	0.046	0.018	0.031
		I—II	258	256	258	257	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.003	0.002	0.002	1.2	1.7	1.1	1.4	0.014	0.046	0.018	0.031
N_{NO_3}	$mg\ l^{-1}$	I	78	76	95	93	0.85	0.74	0.78	0.94	4.3	3.7	3.8	4.2	4.6	4.7	4.3	5.1	0.61	0.66	0.65	0.69	15	18	14	21
		II	192	191	175	176	0	0.28	0.49	0.005	1.2	6.2	8.0	2.1	3.3	11	15	4.8	1.7	1.5	1.4	1.3	44	100	130	42
		I—II	270	267	270	269	0	0.28	0.49	0.005	1.8	5.1	6.0	2.9	3.7	9.4	11	4.9	1.3	1.5	1.6	1.1	44	100	130	42
P_{tot}	$mg\ l^{-1}$	I	86	84	103	101	0.008	0.012	0.006	0.023	0.050	0.038	0.046	0.049	0.050	0.043	0.047	0.051	0.35	0.45	0.43	0.34	0.11	0.13	0.094	0.10
		II	296	296	279	280	0.006	0.005	0.004	0.011	0.033	0.041	0.035	0.039	0.057	0.072	0.063	0.069	1.0	1.0	1.1	1.1	0.29	0.53	0.37	0.69
		I—II	382	380	382	381	0.006	0.005	0.004	0.011	0.038	0.040	0.039	0.042	0.055	0.066	0.058	0.064	0.95	1.0	1.0	1.1	0.29	0.53	0.37	0.69
P_{PO_4}	$mg\ l^{-1}$	I	83	79	99	97	0	0	0	0	0.026	0.021	0.025	0.027	0.028	0.024	0.026	0.029	0.49	0.46	0.57	0.38	0.065	0.049	0.093	0.061
		II	204	203	187	188	0	0.007	0	0.005	0.020	0.027	0.023	0.024	0.025	0.036	0.028	0.033	0.65	1.0	0.92	1.0	0.11	0.40	0.19	0.29
		I—II	287	282	286	285	0	0	0	0	0.021	0.025	0.024	0.025	0.026	0.033	0.028	0.032	0.61	0.99	0.83	0.90	0.11	0.40	0.19	0.29
K	$mg\ l^{-1}$	I	69	66	85	85	1.8	1.6	2.1	4.1	6.9	7.0	6.8	6.5	7.9	8.0	10	6.6	0.44	0.45	0.89	0.19	28	23	43	9.7
		II	209	209	195	195	2.2	3.5	3.8	2.1	7.1	7.9	7.7	6.6	8.3	9.5	13	7.1	0.45	0.51	0.95	0.31	24	30	62	16
		I—II	278	275	280	280	1.8	1.6	2.1	2.1	7.1	7.8	7.4	6.5	8.2	9.2	12	6.9	0.45	0.50	0.95	0.28	28	30	62	16
Ca	$mg\ l^{-1}$	I	69	66	86	85	40	10	11	28	66	67	53	57	70	68	61	60	0.30	0.32	0.42	0.33	130	120	130	110
		II	209	209	195	195	13	20	10	20	62	71	64	58	65	79	75	63	0.32	0.42	0.47	0.38	130	190	230	140
		I—II	278	275	281	280	13	10	10	20	63	70	61	58	66	76	71	62	0.31	0.41	0.47	0.37	130	190	230	140
Mg	$mg\ l^{-1}$	I	69	66	86	85	16	16	11	10	23	24	22	22	23	25	23	24	0.15	0.25	0.27	0.28	33	40	40	36
		II	209	209	195	195	1.3	1.8	1.5	1.5	22	27	26	23	21	27	26	24	0.26	0.37	0.33	0.34	30	50	52	42
		I—II	278	275	281	280	1.3	1.8	1.5	1.5	22	26	25	23	22	27	25	24	0.24	0.35	0.32	0.32	33	50	52	42
S_{SO_4}	$mg\ l^{-1}$	I	12	12	20	19	26	27	13	13	60	63	57	57	63	70	60	57	0.44	0.43	0.54	0.46	120	120	130	100
		II	84	84	75	76	10	10	10	6.7	57	60	57	47	57	63	60	57	0.43	0.46	0.46	0.51	120	130	140	120
		I—II	96	96	95	95	10	10	10	6.7	57	60	57	47	57	63	60	57	0.43	0.46	0.47	0.50	120	130	140	120
Na	$mg\ l^{-1}$	I	43	44	62	61	6.4	6.4	5.3	5.6	9.1	9.2	8.6	8.7	11	11	11	10	0.47	0.43	0.57	0.45	25	26	30	23
		II	194	193	179	179	3.1	2.9	3.1	2.7	8.8	9.6	9.4	8.5	11	12	12	11	0.59	0.56	0.62	0.59	39	37	38	32
		I—II	237	237	241	240	3.1	2.9	3.1	2.7	8.8	9.5	9.1	8.5	11	12	12	10	0.57	0.54	0.61	0.56	39	37	38	32
Cl	$mg\ l^{-1}$	I	86	84	103	101	8.7	6.0	7.0	7.9	27	27	22	23	31	33	28	31	0.58	0.67	0.65	0.68	81	83	68	89
		II	192	192	175	176	3.2	2.6	3.0	2.4	10	10	9.2	8.9	16	20	18	18	0.81	0.98	0.99	0.95	50	71	62	61
		I—II	278	276	278	277	3.2	2.6	3.0	2.4	14	16	13	16	21	24	22	22	0.79	0.89	0.86	0.87	81	83	68	89

Fe	mg l^{-1}	I	12	12	20	20	0.072	0.060	0.068	0.067	0.53	0.33	0.56	0.43	0.53	0.62	0.55	0.49	1.0	1.3	0.77	0.82	2.0	2.9	1.6	1.5
		II	84	84	75	76	0.017	0.010	0.010	0.007	0.22	0.15	0.21	0.16	0.81	0.59	0.60	0.78	1.7	1.9	1.5	3.3	5.9	8.1	5.5	21
		I—II	96	96	95	96	0.017	0.010	0.010	0.007	0.22	0.18	0.25	0.19	0.77	0.59	0.59	0.72	1.7	1.8	1.4	3.2	5.9	8.1	5.5	21
Mn	mg l^{-1}	I	12	12	20	20	0.045	0.031	0.016	0.031	0.059	0.065	0.063	0.061	0.066	0.10	0.30	0.21	0.40	0.81	2.4	2.2	0.14	0.29	3.2	2.0
		II	84	84	75	76	0.026	0.016	0.025	0.028	0.24	0.27	0.13	0.12	0.51	0.59	0.48	0.46	1.4	1.3	1.4	1.4	3.2	3.1	3.2	3.0
		I—II	96	96	95	96	0.026	0.016	0.016	0.028	0.18	0.22	0.13	0.11	0.46	0.52	0.44	0.40	1.5	1.4	1.6	1.5	3.2	3.1	3.2	3.0
Zn	mg l^{-1}	I	12	12	20	20	0	0	0	0	0.004	0.003	0.006	0.002	0.008	0.012	0.022	0.032	1.2	1.7	2.1	2.5	0.030	0.060	0.20	0.30
		II	80	80	71	72	0.003	0	0.003	0	0.023	0.017	0.020	0.013	0.035	0.037	0.033	0.020	1.1	1.1	1.3	1.0	0.20	0.16	0.21	0.090
		I—II	92	92	91	92	0	0	0	0	0.020	0.012	0.018	0.010	0.032	0.034	0.031	0.023	1.2	1.2	1.4	1.8	0.20	0.16	0.21	0.30
Cu	mg l^{-1}	I	12	12	20	20	0.010	0.009	0.003	0.002	0.015	0.013	0.012	0.010	0.017	0.016	0.015	0.040	0.40	0.71	0.69	3.1	0.031	0.050	0.050	0.55
		II	80	80	71	72	0.001	0	0	0	0.011	0.011	0.010	0.008	0.017	0.012	0.012	0.008	2.0	0.74	1.0	0.61	0.30	0.40	0.070	0.026
		I—II	92	92	91	92	0.001	0	0	0	0.011	0.012	0.010	0.009	0.017	0.013	0.012	0.015	1.9	0.74	0.94	3.8	0.30	0.050	0.070	0.55
Cr	mg l^{-1}	I	12	12	20	20	0	0	0	0	0	0	0.003	0.003	0	0	0.003	0.003	1.3	1.5	3.0	0.88	0.005	0.005	0.010	0.006
		II	80	80	71	72	0	0	0	0	0	0	0	0	0	0	0	0	2.1	2.1	2.4	2.3	0.025	0.022	0.018	0.018
		I—II	92	92	91	92	0	0	0	0	0	0	0	0	0	0	0	0	2.1	2.0	2.0	1.8	0.025	0.022	0.018	0.018
Ni	mg l^{-1}	I	12	12	20	20	0.012	0.008	0.008	0.005	0.024	0.020	0.023	0.020	0.027	0.030	0.045	0.029	0.49	0.91	1.5	1.0	0.058	0.090	0.32	0.12
		II	80	80	71	72	0.008	0.006	0.008	0.007	0.045	0.046	0.045	0.034	0.067	0.081	0.073	0.055	0.98	1.0	1.1	0.92	0.42	0.40	0.44	0.20
		I—II	92	92	91	92	0.008	0.006	0.008	0.005	0.041	0.036	0.043	0.029	0.062	0.075	0.066	0.050	1.0	1.1	1.2	0.97	0.42	0.40	0.44	0.20
Cd	mg l^{-1}	I	12	12	20	20	0	0	0	0	0	0	0	0	0.0002	0	0.0003	0.0001	3.5	.	2.5	2.1	0.0020	0	0.0030	0.0007
		II	80	80	71	72	0	0	0	0	0.0002	0.0002	0.0002	0.0002	0.0004	0.0004	0.0003	0.0003	1.2	1.3	1.4	1.1	0.0023	0.0023	0.0025	0.0010
		I—II	92	92	91	92	0	0	0	0	0.0002	0.0002	0.0002	0.0001	0.0003	0.0004	0.0003	0.0002	1.4	1.4	1.7	1.3	0.0023	0.0023	0.0030	0.0010
Hg	mg l^{-1}	I	12	12	20	20	0	0	0	0	0	0	0	0	0	0	0	0	.	3.5	.	3.9	0	0.0003	0	0.0007
		II	75	74	65	69	0	0	0	0	0	0	0	0	0	0	0	0	4.9	3.1	6.0	3.5	0.0007	0.0004	0.0014	0.0003
		I—II	87	86	85	89	0	0	0	0	0	0	0	0	0	0	0	0	5.3	3.2	6.8	4.4	0.0007	0.0004	0.0014	0.0007
Pb	mg l^{-1}	I	12	12	20	20	0	0	0	0	0.001	0.001	0	0.001	0.001	0.001	0.001	0.001	1.2	1.3	1.4	1.5	0.003	0.006	0.003	0.008
		II	80	80	71	72	0	0	0	0	0	0	0	0	0.001	0.001	0	0.001	2.6	3.3	2.8	2.9	0.010	0.022	0.008	0.020
		I—II	92	92	91	92	0	0	0	0	0	0	0	0	0.001	0.001	0.001	0.001	2.4	3.0	2.5	2.6	0.010	0.022	0.008	0.020
γ_{25}	mS m^{-1}	I	86	84	104	101	31	35	22	34	63	65	56	59	65	67	63	61	0.27	0.28	0.36	0.27	110	110	140	99
		II	296	296	279	280	9.3	8.1	7.4	7.7	52	58	59	48	53	64	63	52	0.34	0.42	0.46	0.40	93	140	170	120
		I—II	382	380	383	381	9.3	8.1	7.4	7.7	54	59	58	51	56	64	63	55	0.33	0.39	0.44	0.37	110	140	170	120
pH		I	86	84	104	100	6.0	6.0	5.6	6.0	6.5	6.5	6.5	6.5	.	.	.	.	.	.	.	.	7.7	7.9	7.8	7.8
		II	296	296	279	280	5.7	5.8	5.5	5.7	6.3	6.3	6.2	6.3	.	.	.	.	.	.	.	.	7.6	7.4	7.4	7.5
		I—II	382	380	383	380	5.7	5.8	5.5	5.7	6.3	6.3	6.3	6.4	.	.	.	.	.	.	.	.	7.7	7.9	7.8	7.8
$\mathrm{COD_{Mn}}$	mg $l^{-1}0_2$	I	86	84	104	101	1.6	1.5	1.8	2.1	7.8	7.3	7.2	7.9	8.3	8.0	8.2	8.9	0.61	0.59	0.61	0.58	20	18	19	19
		II	228	228	211	211	0	1.0	1.0	1.0	4.9	5.6	4.7	4.5	6.2	6.9	6.1	6.4	0.82	0.85	0.83	0.84	28	31	30	31
		I—II	314	312	315	312	0	1.0	1.0	1.0	6.1	6.1	5.9	6.6	6.8	7.2	6.8	7.2	0.76	0.78	0.76	0.75	28	31	30	31
SS	mg l^{-1}	I	8	8	24	24	0	0	0	0	9.6	10	6.4	3.5	11	12	7.7	9.6	1.0	1.0	1.0	1.6	26	34	29	73
		II	221	223	205	205	0	0	0	0	0	0	0	0	5.2	5.0	5.0	5.0	2.4	2.6	2.3	2.3	92	110	84	60
		I—II	229	231	229	229	0	0	0	0	0	0	0	0	5.4	5.1	5.0	5.0	2.3	2.5	2.1	2.2	92	110	84	73
TOCOL	counts/	I	9	9	17	17	10	16	0	0	140	90	20	14	1300	890	630	570	1.8	1.6	2.3	2.0	7200	4200	5800	4300
	100 ml	II	23	24	15	16	0	0	0	0	2.0	9.5	2.0	4.5	7.7	55	280	15	1.5	2.9	3.7	1.5	36	760	4100	73
		I—II	32	33	32	33	0	0	0	0	5.5	18	8.5	9.0	370	280	470	300	3.6	3.0	2.7	2.8	7200	4200	5800	4300
FECOL	counts/	I	9	9	25	25	0	0	0	0	0	0	0	0	0.44	1.4	0.040	0.24	2.0	2.8	5.0	2.5	2.0	12	1.0	2.0
	100 ml	II	40	41	23	24	0	0	0	0	0	0	0	0	0.83	2.3	1.0	3.8	2.4	2.1	1.9	3.1	9.0	20	5.0	59
		I—II	49	50	48	49	0	0	0	0	0	0	0	0	0.76	2.1	0.50	2.0	2.5	2.2	2.8	4.2	9.0	20	5.0	59
ENTCO	counts/	I	9	9	25	25	0	0	0	0	2.0	5.0	0	0	79	48	22	22	1.5	1.9	3.1	3.0	290	280	330	320
	100 ml	II	39	40	23	24	0	0	0	0	0	1.0	1.0	2.5	50	15	5.7	5.5	6.0	3.1	1.9	1.6	1900	240	48	38
		I—II	48	49	48	49	0	0	0	0	0	2.0	0	1.0	55	21	14	14	4.9	2.7	3.5	3.4	1900	280	330	320

Table 28. Properties of the distributions of surface-water quantity and quality variables in the Liperi field. One replicate per treatment. Legend as in Table 27.

Variable	Unit	Period	Number of observations in treatment				Values of statistics in different treatments																					
							min				m				$\bar{x}$				$s/\bar{x}$				max					
			a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L		
Q	m^3	I	32	35	38	36	0	0	0	0	0.096	0.065	0.063	0.12	0.81	1.8	1.2	1.8	3.7	3.8	3.5	2.9	17	39	24	26		
		II	136	141	130	113	0	0	0	0	0.078	0.060	0.051	0.015	0.68	1.1	1.7	0.91	3.6	4.5	7.9	5.0	26	54	150	46		
		I—II	168	176	168	149	0	0	0	0	0.079	0.063	0.054	0.020	0.70	1.2	1.6	1.1	3.7	4.3	7.5	4.2	26	54	150	46		
t	d	I	32	35	38	36	1.0	1.0	1.0	1.0	7.0	7.0	7.0	6.5	16	15	15	16	1.3	1.5	1.6	1.5	83	83	99	90		
		II	136	141	130	113	0.2	0.2	0.2	0.2	4.5	4.0	4.5	4.0	7.5	7.2	7.4	8.5	1.5	1.5	1.3	1.7	90	85	77	87		
		I—II	168	176	168	149	0.2	0.2	0.2	0.2	5.0	5.0	5.0	5.0	9.2	8.8	9.2	10	1.5	1.6	1.6	1.7	90	85	99	90		
N_{tot}	$mg\ l^{-1}$	I	13	16	19	22	2.1	3.4	1.8	1.9	4.5	5.4	3.7	4.9	6.8	6.4	4.3	5.8	0.60	0.39	0.51	0.55	14	11	10	14		
		II	66	64	60	50	0.72	0.86	0.72	0.66	3.8	3.9	2.3	4.3	5.3	5.9	3.5	5.9	1.0	1.0	1.1	0.86	24	27	18	24		
		I—II	79	80	79	72	0.72	0.86	0.72	0.66	4.2	4.4	2.7	4.4	5.6	6.0	3.7	5.9	0.92	0.89	0.92	0.78	24	27	18	25		
N_{NH_4}	$mg\ l^{-1}$	I	13	15	17	19	0.001	0.002	0.001	0	0.017	0.017	0.012	0.015	0.035	0.030	0.029	0.030	1.1	1.1	0.97	1.0	0.13	0.12	0.076	0.10		
		II	40	42	37	32	0	0.003	0.001	0	0.018	0.017	0.012	0.011	0.029	0.18	0.023	0.026	1.6	2.4	1.1	1.3	0.29	1.8	0.10	0.12		
		I—II	53	57	54	51	0	0.002	0.001	0	0.017	0.017	0.012	0.012	0.030	0.14	0.025	0.028	1.5	2.7	1.1	1.2	0.29	1.8	0.10	0.12		
N_{NO_2}	$mg\ l^{-1}$	I	17	18	21	22	0.001	0.002	0.002	0.001	0.012	0.007	0.008	0.009	0.029	0.020	0.030	0.012	1.9	2.0	2.3	0.83	0.23	0.17	0.32	0.038		
		II	37	38	33	28	0	0	0	0	0.003	0.003	0.002	0.002	0.007	0.009	0.005	0.005	3.0	2.0	2.5	2.2	0.12	0.10	0.080	0.063		
		I—II	54	56	54	50	0	0	0	0	0.004	0.005	0.005	0.005	0.014	0.012	0.015	0.008	2.6	2.1	3.1	1.4	0.23	0.17	0.32	0.063		
N_{NO_3}	$mg\ l^{-1}$	I	17	18	21	22	1.5	2.3	1.4	1.4	6.3	4.4	2.9	4.2	6.6	5.2	3.5	4.7	0.54	0.43	0.48	0.58	14	10	8.5	11		
		II	40	41	36	31	0.14	0.073	0.031	0.033	3.5	3.4	1.8	5.6	4.0	5.0	2.7	5.8	1.0	1.2	1.3	0.85	22	23	18	23		
		I—II	57	59	57	53	0.14	0.073	0.031	0.033	3.9	3.9	2.3	4.8	4.8	5.1	3.0	5.3	0.86	1.0	0.98	0.78	22	23	18	23		
P_{tot}	$mg\ l^{-1}$	I	18	19	22	23	0.010	0.017	0.014	0.010	0.026	0.036	0.029	0.025	0.033	0.052	0.051	0.049	0.84	0.96	0.92	1.0	0.12	0.20	0.18	0.23		
		II	65	64	60	50	0.005	0.012	0.007	0.017	0.048	0.068	0.070	0.095	0.078	0.10	0.11	0.11	0.98	0.93	1.1	0.74	0.31	0.44	0.52	0.49		
		I—II	83	83	82	73	0.005	0.012	0.007	0.010	0.037	0.054	0.062	0.069	0.068	0.091	0.092	0.092	1.0	0.98	1.2	0.86	0.31	0.44	0.52	0.49		
P_{PO_4}	$mg\ l^{-1}$	I	17	18	21	21	0	0	0	0	0.005	0.011	0.008	0.006	0.008	0.016	0.021	0.017	0.89	0.79	1.3	1.1	0.023	0.050	0.097	0.072		
		II	43	44	39	34	0	0.008	0	0.011	0.012	0.022	0.020	0.044	0.021	0.035	0.028	0.052	0.94	0.91	0.85	0.67	0.076	0.14	0.099	0.15		
		I—II	60	62	60	55	0	0	0	0	0.011	0.018	0.019	0.028	0.018	0.030	0.026	0.039	1.1	0.98	0.97	0.89	0.076	0.14	0.099	0.15		
K	$mg\ l^{-1}$	I	14	15	17	19	4.8	5.7	5.6	5.6	8.1	8.0	8.4	8.9	7.8	8.6	8.3	9.7	0.18	0.28	0.20	0.41	9.4	15	12	25		
		II	43	45	39	33	4.0	5.6	3.4	3.0	6.8	7.7	7.0	8.6	6.7	7.8	7.8	8.5	0.19	0.17	0.48	0.29	10	12	21	15		
		I—II	57	60	56	52	4.0	5.6	3.4	3.0	6.9	7.8	7.3	8.7	7.0	8.0	8.0	8.9	0.19	0.21	0.40	0.35	10	15	21	25		
Ca	$mg\ l^{-1}$	I	14	15	17	19	43	17	33	35	60	66	53	66	62	63	63	71	0.24	0.29	0.40	0.33	98	86	140	130		
		II	43	45	39	33	19	18	8.0	8.0	53	67	53	75	57	69	54	77	0.40	0.40	0.48	0.50	120	120	100	140		
		I—II	57	60	56	52	19	17	8.0	8.0	53	67	53	72	58	68	57	75	0.36	0.38	0.46	0.45	120	120	140	140		
Mg	$mg\ l^{-1}$	I	14	15	17	19	15	13	12	10	22	19	19	21	22	23	20	23	0.21	0.42	0.32	0.35	29	51	27	36		
		II	43	45	39	33	2.0	2.0	1.5	1.0	19	19	19	21	19	20	19	22	0.32	0.34	0.45	0.47	35	34	40	38		
		I—II	57	60	56	52	2.0	2.0	1.5	1.0	19	19	19	21	20	21	19	22	0.30	0.37	0.41	0.43	35	51	40	38		
S_{SO_4}	$mg\ l^{-1}$	I	3	4	4	6	20	21	12	14	50	53	37	47	60	50	60	53	0.78	0.44	1.0	0.75	110	73	150	130		
		II	18	18	15	13	17	16	5.0	5.3	31	31	20	30	30	37	24	32	0.35	0.44	0.74	0.85	60	73	70	100		
		I—II	21	22	19	19	17	16	5.0	5.3	33	33	20	33	37	37	32	40	0.57	0.46	1.0	0.84	110	73	150	130		
Na	$mg\ l^{-1}$	I	10	11	13	15	9.5	9.1	8.2	2.3	12	11	13	9.8	13	14	13	12	0.37	0.55	0.21	0.82	25	31	18	45		
		II	39	41	35	30	4.2	3.0	2.0	1.0	8.0	7.9	10	7.6	7.9	8.2	9.5	7.9	0.22	0.25	0.38	0.42	11	12	15	16		
		I—II	49	52	48	45	4.2	3.0	2.0	1.0	8.7	9.1	11	8.0	8.8	9.4	10	9.4	0.36	0.49	0.36	0.71	25	31	18	45		

Cl	mg l^{-1}	I	18	19	22	22	15	12	15	13	37	44	36	34	37	38	34	33	0.34	0.41	0.29	0.36	56	64	50	52
		II	40	41	35	31	3.0	2.2	1.0	1.0	16	16	17	11	16	17	17	14	0.52	0.55	0.65	0.68	32	33	31	29
		I—II	58	60	57	53	3.0	2.2	1.0	1.0	21	23	26	25	23	24	23	22	0.61	0.64	0.58	0.63	56	64	50	52
Fe	mg l^{-1}	I	3	4	4	6	0.51	0.19	0.15	0.048	0.68	0.99	4.2	1.1	1.7	2.9	4.1	2.0	1.1	1.5	0.81	1.1	4.0	9.3	7.9	5.1
		II	18	18	15	13	0.018	0.26	0.028	0.021	2.1	2.0	1.9	1.4	2.8	5.1	3.9	4.7	1.0	1.6	1.3	1.8	10	31	15	32
		I—II	21	22	19	19	0.018	0.19	0.028	0.021	1.5	1.7	2.1	1.4	2.6	4.7	3.9	3.8	1.0	1.6	1.1	1.9	10	31	15	32
Mn	mg l^{-1}	I	3	4	4	6	0.071	0.035	0.11	0.063	0.14	0.081	0.26	0.096	0.21	0.11	0.32	0.14	0.89	0.85	0.74	0.96	0.43	0.23	0.66	0.42
		II	18	18	15	13	0.054	0.040	0.035	0.043	0.27	0.22	0.10	0.061	0.32	0.32	0.18	0.14	0.67	1.2	0.80	1.0	0.68	1.8	0.46	0.55
		I—II	21	22	19	19	0.054	0.035	0.035	0.043	0.27	0.20	0.12	0.080	0.30	0.28	0.21	0.14	0.68	1.3	0.82	1.0	0.68	1.8	0.66	0.55
Zn	mg l^{-1}	I	2	3	4	5	0.005	0.017	0	0.001	.	0.025	0.047	0.025	.	0.026	0.12	0.11	.	0.35	1.5	1.3	0.22	0.035	0.40	0.35
		II	15	17	14	13	0.005	0.010	0.004	0.007	0.022	0.043	0.019	0.030	0.075	0.071	0.078	0.23	1.4	0.89	1.6	1.8	0.33	0.20	0.38	1.3
		I—II	17	20	18	18	0.005	0.010	0	0.001	0.022	0.038	0.019	0.028	0.079	0.064	0.087	0.19	1.4	0.94	1.5	1.9	0.33	0.20	0.40	1.3
Cu	mg l^{-1}	I	2	3	4	5	0.013	0.008	0.003	0.004	.	0.012	0.014	0.014	.	0.014	0.11	0.021	.	0.49	1.8	0.87	0.39	0.021	0.39	0.050
		II	15	17	14	13	0.006	0.007	0.005	0.009	0.011	0.010	0.011	0.013	0.015	0.016	0.014	0.015	0.73	0.73	0.70	0.42	0.050	0.050	0.040	0.029
		I—II	17	20	18	18	0.006	0.007	0.003	0.004	0.013	0.011	0.011	0.014	0.037	0.016	0.034	0.017	2.5	0.71	2.6	0.64	0.39	0.050	0.39	0.050
Cr	mg l^{-1}	I	2	3	4	5	0.003	0	0	0	.	0.004	0	0.003	.	0.009	0	0.004	.	1.4	2.0	1.3	0.003	0.024	0.007	0.011
		II	14	16	13	12	0	0	0	0	0.003	0.003	0.003	0.003	0.005	0.007	0.006	0.004	1.3	1.8	1.6	1.0	0.023	0.052	0.038	0.013
		I—II	16	19	17	17	0	0	0	0	0.003	0.003	0.002	0.003	0.005	0.008	0.005	0.004	1.3	1.6	1.8	1.0	0.023	0.052	0.038	0.013
Ni	mg l^{-1}	I	2	3	4	5	0.014	0.010	0.008	0.005	.	0.035	0.026	0.026	.	0.032	0.050	0.040	.	0.64	1.2	1.2	0.11	0.050	0.14	0.13
		II	15	17	14	13	0.014	0.015	0.008	0.008	0.028	0.026	0.022	0.025	0.035	0.037	0.029	0.033	0.54	0.62	0.73	0.73	0.080	0.085	0.077	0.085
		I—II	17	20	18	18	0.014	0.010	0.008	0.005	0.028	0.027	0.022	0.026	0.038	0.036	0.034	0.035	0.69	0.61	0.98	0.90	0.11	0.085	0.14	0.13
Cd	mg l^{-1}	I	2	3	4	5	0	0	0	0	.	.	0.0002	0	.	.	0.0003	0	.	.	1.4	2.2	0	0	0.0010	0.0001
		II	15	17	14	13	0	0	0	0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.74	2.4	1.8	1.4	0.0002	0.0017	0.0009	0.0006
		I—II	17	20	18	18	0	0	0	0	0.0001	0	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.87	2.6	1.7	1.7	0.0002	0.0017	0.0010	0.0006
Hg	mg l^{-1}	I	2	3	4	5	0	0	0	0	.	.	0	0	.	.	0	0	.	.	.	.	0	0	0	0
		II	14	16	12	12	0	0	0	0	0	0	0	0	0.0004	0	0	0	3.6	4.0	2.3	2.5	0.0055	0.0001	0.0001	0.0002
		I—II	16	19	16	17	0	0	0	0	0	0	0	0	0.0004	0	0	0	3.9	4.4	2.7	3.0	0.0055	0.0001	0.0001	0.0002
Pb	mg l^{-1}	I	2	3	4	5	0	0.0001	0	0	.	0.002	0.001	0.001	.	0.002	0.001	0.001	.	0.66	1.2	0.70	0.003	0.004	0.002	0.002
		II	14	16	13	12	0	0	0	0	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.002	1.7	1.5	1.5	1.7	0.011	0.009	0.011	0.011
		I—II	16	19	17	17	0	0	0	0	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	1.6	1.4	1.5	1.6	0.011	0.009	0.011	0.011
γ_{25}	mS m^{-1}	I	18	19	22	23	29	30	20	21	66	66	56	62	61	62	59	65	0.24	0.23	0.28	0.27	84	79	100	100
		II	66	64	60	50	9.4	8.2	7.8	6.3	41	49	43	49	43	48	41	48	0.39	0.45	0.52	0.60	84	90	75	93
		I—II	84	83	82	73	9.4	8.2	7.8	6.3	46	51	50	46	47	51	46	53	0.38	0.41	0.47	0.50	84	90	100	100
pH		I	18	19	22	23	6.2	6.5	6.2	6.3	7.0	7.4	7.3	7.3	.	.	.	.	.	.	.	.	8.0	8.3	9.0	8.2
		II	66	64	60	50	6.2	6.4	6.9	6.8	7.2	7.2	7.2	7.4	.	.	.	.	.	.	.	.	8.0	8.2	8.1	8.0
		I—II	84	83	82	73	6.2	6.4	6.2	6.3	7.2	7.2	7.2	7.4	.	.	.	.	.	.	.	.	8.0	8.3	9.0	8.2
COD_{Mn}	mgl^{-1} O_2	I	18	19	21	22	5.2	4.8	3.1	4.4	6.2	7.5	5.2	5.9	6.5	8.1	5.9	6.9	0.18	0.24	0.33	0.36	9.9	11	10	12
		II	50	50	45	40	2.3	2.8	2.8	3.7	6.9	7.7	6.4	6.9	6.9	8.4	6.8	7.6	0.42	0.36	0.45	0.37	15	20	15	17
		I—II	68	69	66	62	2.3	2.8	2.8	3.7	6.5	7.7	6.0	6.8	6.8	8.3	6.6	7.3	0.37	0.33	0.43	0.36	15	20	15	17
SS	mg l^{-1}	I	14	15	17	18	0	0	0	0	5.0	6.2	13	5.6	14	34	28	23	1.6	1.9	1.7	1.8	75	220	170	170
		II	55	55	48	41	0	0	0	0	5.0	9.2	8.1	6.9	22	39	44	32	1.7	2.1	1.9	1.6	180	420	390	210
		I—II	69	70	65	59	0	0	0	0	5.0	8.4	9.7	6.7	20	38	40	29	1.7	2.1	1.9	1.7	180	420	390	210

Table 28. Continued.

Variable	Unit	Period	Number of observations in treatment				Values of statistics in different treatments																			
							min				m				x̄				s/x̄				max			
			a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L
TS	mg l^{-1}	I	14	15	17	18	240	340	250	220	510	470	420	460	470	480	470	520	0.24	0.20	0.32	0.31	630	630	830	830
		II	39	41	34	31	210	200	150	130	380	440	370	470	390	470	380	470	0.25	0.28	0.36	0.45	600	760	600	770
		I—II	53	56	51	49	210	200	150	130	410	450	400	460	410	480	410	490	0.26	0.26	0.35	0.40	630	760	830	800
ASH	mg l^{-1}	I	14	15	17	18	190	220	150	160	350	350	310	330	330	350	350	390	0.27	0.19	0.38	0.36	500	440	620	650
		II	39	41	34	31	160	110	94	87	270	350	280	320	280	350	290	350	0.22	0.27	0.37	0.45	400	500	530	550
		I—II	53	56	51	49	160	110	94	87	280	350	300	330	300	350	310	360	0.25	0.25	0.39	0.41	500	500	620	650
TOCOL	counts/ 100 ml	I	2	2	4	4	20	43	0	0	.	.	100	12	.	.	110	530	.	.	1.0	2.0	3600	17000	250	2100
		II	4	4	2	2	0	0	0	0	9.0	73	.	.	16	610	.	.	1.3	1.8	.	.	45	2300	6.0	44
		I—II	6	6	6	6	0	0	0	0	19	94	26	12	610	32000	77	360	2.4	2.1	1.4	2.4	3600	17000	250	2100
FECOL	counts/ 100 ml	I	2	2	6	6	0	8.0	0	0	.	.	0	.	.	.	2.8	.	.	.	2.5	.	5.0	25	17	.
		II	8	8	4	4	0	0	0	0	0	0	1.0	0	1.6	1.4	1.8	1.3	1.4	1.6	1.3	2.0	5.0	5.0	5.0	5.0
		I—II	10	10	10	10	0	0	0	0	0	0.50	0	0	1.8	4.4	2.4	0.5	1.3	1.8	2.2	3.2	5.0	26	17	5.0
ENTCO	counts/ 100 ml	I	2	2	6	6	2.0	200	0	0	.	.	1.0	6.0	.	.	35	840	.	.	2.0	2.4	29	900	180	5000
		II	8	8	4	4	0	0	0	0	0.50	7.0	5.0	1.0	1.3	43	3.8	1.8	1.5	1.5	0.67	1.3	5.0	190	5.0	5.0
		I—II	10	10	10	10	0	0	0	0	1.0	35	3.5	1.0	4.1	140	23	510	2.2	1.9	2.5	3.1	29	900	180	5000

Table 29. Properties of the distributions of subdrainage-water quantity and quality variables in the Maaninka field. Periods studied: I = Oct. 18, 1978—March 30, 1980; II = March 31, 1980—June 8, 1982. Statistics as in Table 27.

Variable	Unit	Period	Number of observations				Values of statistics in different treatments																			
							min				m				x̄				s/x̄				max			
			a_M	b_M	c_M	d_M	a_M	b_M	c_M	d_M	a_M	b_M	c_M	d_M	a_M	b_M	c_M	d_M	a_M	b_M	c_M	d_M	a_M	b_M	c_M	d_M
Q	m^3	I	5	8	4	17	0.005	0.10	0.042	0.010	0.32	0.21	0.33	0.30	1.7	0.24	0.51	0.76	1.3	0.47	1.2	1.0	5.0	0.41	1.3	2.5
		II	13	22	12	35	0	0.007	0	0.010	0.11	0.46	0.33	0.96	1.7	1.9	2.5	2.0	1.9	2.0	1.5	1.7	11	14	11	14
N_{tot}	mg l^{-1}	I	4	8	4	12	7.0	3.5	5.5	5.6	9.8	15	10	16	10	14	11	17	0.34	0.37	0.51	0.43	14	20	19	29
		II	9	14	7	22	2.8	2.6	37	2.8	19	15	63	15	22	15	75	15	0.77	0.34	0.50	0.44	58	24	150	32
N_{NH_4}	mg l^{-1}	I	4	8	4	12	0.010	0.003	0.010	0.006	0.021	0.009	0.034	0.016	0.021	0.012	0.038	0.026	0.45	0.88	0.70	1.0	0.030	0.036	0.072	0.085
		II	7	16	8	26	0.006	0.003	0.005	0.005	0.010	0.008	0.009	0.011	0.010	0.014	0.019	0.018	0.37	1.1	0.99	1.2	0.016	0.057	0.061	0.11
N_{NO_2}	mg l^{-1}	I	3	7	2	10	0.002	0.001	0.002	0.001	0.002	0.002	.	0.002	0.002	0.002	.	0.003	0	0.34	.	0.93	0.002	0.002	0.005	0.008
		II	7	16	7	26	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.33	0.67	0.59	0.53	0.002	0.005	0.002	0.003
N_{NO_3}	mg l^{-1}	I	2	6	3	8	6.3	1.5	3.3	4.5	.	16	6.5	18	.	14	7.3	17	.	0.47	0.61	0.43	9.7	20	12	27
		II	7	13	8	20	12	0.63	7.8	0.38	19	12	56	12	18	13	80	13	0.23	0.42	0.92	0.52	24	22	250	25
P_{tot}	mg l^{-1}	I	4	8	4	12	0.036	0.018	0.046	0.017	0.050	0.033	0.11	0.041	0.051	0.040	0.098	0.053	0.26	0.59	0.37	0.75	0.069	0.085	0.13	0.14
		II	8	17	8	27	0.024	0.025	0.022	0.020	0.028	0.034	0.029	0.050	0.032	0.039	0.032	0.060	0.39	0.43	0.30	0.67	0.062	0.086	0.050	0.18
P_{PO_4}	mg l^{-1}	I	5	8	4	13	0.002	0.009	0.032	0.003	0.023	0.015	0.036	0.018	0.020	0.018	0.037	0.023	0.57	0.55	0.14	0.74	0.033	0.039	0.043	0.058
		II	7	16	7	25	0.002	0.004	0.	0.012	0.017	0.016	0.012	0.025	0.014	0.016	0.014	0.037	0.46	0.40	0.72	0.76	0.021	0.028	0.034	0.12
K	mg l^{-1}	I	2	2	3	4	7.0	3.8	6.3	5.0	.	.	8.8	7.4	.	.	9.0	8.0	.	.	0.32	0.38	13	11	12	12
		II	3	5	3	8	9.0	5.5	8.5	6.0	11	12	13	9.4	10	10	18	9.6	0.11	0.42	0.72	0.31	11	15	33	14
Ca	mg l^{-1}	I	2	2	3	4	11	5.1	11	9.0	.	.	20	19	.	.	17	18	.	.	0.32	0.38	18	28	21	25
		II	3	5	3	8	29	12	65	11	32	22	86	20	31	22	96	21	0.08	0.37	0.39	0.38	34	35	140	38
Mg	mg l^{-1}	I	2	2	3	4	3.3	1.5	3.7	3.5	.	.	5.0	8.4	.	.	4.6	7.4	.	.	0.17	0.36	4.4	13	5.1	9.2
		II	3	5	3	8	8.0	3.4	18	3.9	8.5	6.3	30	6.6	8.3	6.3	26	6.8	0.04	0.32	0.27	0.31	8.5	9.0	31	11
S_{SO_4}	mg l^{-1}	I	1	1	2	2	5.0	3.1	5.7	6.3	.	.	.	.	.	.	.	.	.	.	.	.	5.0	3.1	9.7	9.7
		II	4	5	5	5	6.3	7.3	12	7.7	8.7	8.7	16	7.7	8.7	10	17	9.0	0.25	0.36	0.31	0.21	11	16	22	12
Na	mg l^{-1}	I	2	2	3	4	1.6	1.0	1.7	1.5	.	.	2.6	2.3	.	.	2.5	2.1	.	.	0.30	0.22	2.2	6.0	3.2	2.6
		II	3	5	3	8	2.4	3.2	3.4	1.2	2.7	3.4	5.0	2.6	2.6	4.0	6.0	2.7	0.06	0.37	0.53	0.49	2.7	6.7	9.5	4.9
Cl	mg l^{-1}	I	4	8	4	11	6.4	3.5	6.2	5.4	12	26	10	10	11	23	13	10	0.30	0.41	0.66	0.42	13	32	26	18
		II	6	17	7	25	1.5	1.7	1.5	1.3	5.1	4.0	3.6	2.9	5.2	6.9	5.4	4.2	0.73	0.79	0.82	0.86	9.1	15	14	15
Fe	mg l^{-1}	I	1	2	2	2	0.41	0.18	1.7	0.066	.	.	.	.	.	.	.	.	.	.	.	.	0.41	0.56	2.2	3.1
		II	5	6	5	7	0.040	0.057	0.028	0.036	0.13	0.092	0.11	0.12	0.14	0.11	0.14	0.40	0.61	0.61	0.94	1.7	0.26	0.24	0.36	1.9
Mn	mg l^{-1}	I	1	2	2	2	0.027	0.018	0.056	0.008	.	.	.	.	.	.	.	.	.	.	.	.	0.027	0.038	0.066	0.095
		II	3	5	4	5	0.005	0.005	0.008	0.009	0.010	0.009	0.017	0.032	0.009	0.008	0.023	0.030	0.40	0.41	0.80	0.71	0.012	0.013	0.049	0.060
Zn	mg l^{-1}	I	1	1	2	2	0	0.013	0.004	0	.	.	.	.	.	.	.	.	.	.	.	.	0	0.013	0.030	0.002
		II	3	4	3	5	0.002	0	0.003	0.002	0.002	0.002	0.004	0.003	0.002	0.003	0.014	0.007	0.25	1.4	1.3	1.3	0.003	0.009	0.035	0.022

Table 29. Continued.

Variable	Unit	Period	Number of observations				Values of statistics in different treatments																			
							min				m				$\bar{x}$				$s/\bar{x}$				max			
			a_M	b_M	c_M	d_M	a_M	b_M	c_M	d_M	a_M	b_M	c_M	d_M	a_M	b_M	c_M	d_M	a_M	b_M	c_M	d_M	a_M	b_M	c_M	d_M
Cu	mg l^{-1}	I	1	1	2	2	0.010	0.038	0.012	0.010	.	.	.	.	.	.	.	.	.	.	.	.	0.010	0.038	0.034	0.014
		II	3	4	3	5	0.004	0.006	0.004	0.004	0.007	0.009	0.005	0.010	0.006	0.024	0.007	0.021	0.29	1.3	0.62	1.3	0.007	0.070	0.012	0.070
Ni	mg l^{-1}	I	1	1	2	2	0	0.003	0	0	.	.	.	.	.	.	.	.	.	.	.	.	0	0.003	0.003	0.004
		II	3	4	3	5	0	0	0.006	0.003	0	0.001	0.006	0.006	0	0.002	0.010	0.006	1.7	1.6	0.66	0.61	0	0.005	0.017	0.012
Cd	mg l^{-1}	I	1	1	2	2	0	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	0	0	0	0
		II	3	4	3	5	0	0	0	0	0	0.0001	0.0001	0	0	0.0001	0.0002	0.0001	1.7	1.5	1.3	2.2	0.0001	0.0004	0.0005	0.0004
Hg	mg l^{-1}	I	0	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	2	2	3	0	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	0	0	0	0
Pb	mg l^{-1}	I	1	1	2	2	0	0.002	0	0	.	.	.	.	.	.	.	.	.	.	.	.	0	0.002	0.002	0.002
		II	3	4	3	5	0	0	0	0	0	0	0	0	0	0	0	0	.	.	1.7	.	0	0	0.001	0
γ_{25}	mS m^{-1}	I	5	8	4	14	13	6.2	13	11	20	32	22	23	20	30	20	25	0.20	0.36	0.26	0.32	24	39	25	39
		II	6	17	8	26	20	20	25	12	30	25	66	22	29	26	67	22	0.16	0.15	0.40	0.27	33	34	120	34
pH		I	5	8	4	14	6.1	6.0	6.1	6.1	6.3	6.3	6.3	6.2	.	.	.	.	.	.	.	.	7.1	6.8	6.6	6.6
		II	6	17	8	26	5.6	5.7	5.5	5.6	5.8	6.2	5.6	6.1	.	.	.	.	.	.	.	.	6.1	6.5	6.7	6.6
COD_{Mn}	mg l^{-1} O_2	I	4	8	4	12	10	7.2	9.4	7.5	12	13	17	11	11	13	16	11	0.11	0.22	0.29	0.26	13	16	20	17
		II	6	14	7	22	7.2	7.3	4.3	8.1	9.1	16	11	11	12	15	9.2	13	0.59	0.25	0.48	0.41	26	21	15	27
SS	mg l^{-1}	I	1	4	1	4	5.0	0	0	0	.	0	.	0	.	0	.	5.0	.	.	.	1.2	5.0	0	0	9.6
		II	2	8	2	15	0	0	0	0	.	0	0	0	.	0	0	5.0	.	.	.	1.4	0	0	0	22
TS	mg l^{-1}	I	1	3	2	4	130	49	120	110	.	270	.	250	.	200	.	230	.	0.65	.	0.34	130	280	210	280
		II	3	8	2	14	14	20	39	100	260	210	.	230	190	330	.	220	0.81	1.2	0.27	0.31	290	1300	58	320
ASH	mg l^{-1}	I	1	3	2	4	43	29	76	78	.	150	.	110	.	110	.	110	.	0.66	.	0.26	43	170	110	130
		II	3	8	2	14	8	10	16	44	130	120	.	110	95	240	.	110	0.80	1.7	.	0.38	140	1200	27	210
TOCOL	counts/ 100 ml	I	0	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	4	3	5	1.0	0	0	0	.	2.5	1.0	230	.	11	2.0	580	.	1.7	1.3	1.5	2.0	39	5.0	2000
FECOL	counts/ 100 ml	I	1	1	0	4	0	0	.	0	.	.	.	.	.	.	.	.	.	.	.	.	0	0	.	0
		II	3	5	4	7	0	0	0	0	0	0	0	0	0	0	0	0.14	.	.	.	2.6	0	0	0	1.0
ENTCO	counts/ 100 ml	I	1	1	0	4	0	0	.	0	.	.	.	.	.	.	.	.	.	.	.	.	0	0	.	0
		II	3	5	4	7	0	0	0	0	0	2.0	0	0	5.0	48	4.5	20	1.7	2.1	2.0	2.2	15	230	18	120

Table 30. Properties of the distributions of surface-water quantity and quality variables in the Maaninka field. Legend as in Table 29. (No observations from treatment a_M.)

Variable	Unit	Period	Number of observations in treatment			Values of statistics in different treatments														
						min			m			$\bar{x}$			s/$\bar{x}$			max		
			b_M	c_M	d_M	b_M	c_M	d_M	b_M	c_M	d_M	b_M	c_M	d_M	b_M	c_M	d_M	b_M	c_M	d_M
Q	m^3	I	3	3	4	0.028	0.37	0.40	0.35	1.3	1.3	3.1	11	5.4	1.6	1.6	1.6	9.0	31	18
		II	12	14	12	0.008	0.005	0	0.46	0.40	0.98	1.6	1.1	2.4	1.6	1.8	1.4	7.9	7.7	11
N_{tot}	mg l^{-1}	I	2	3	4	3.3	4.9	1.0	.	8.7	3.1	.	7.8	3.2	.	0.33	0.62	3.4	9.8	5.6
		II	9	9	8	1.8	2.2	1.9	4.0	3.8	3.2	3.8	3.5	3.0	0.42	0.28	0.26	6.6	5.2	3.8
N_{NH_4}	mg l^{-1}	I	2	3	4	0.11	0.098	0.069	.	0.15	0.15	.	0.14	0.17	.	0.25	0.59	0.19	0.16	0.31
		II	10	10	8	0.008	0.003	0.024	0.036	0.048	0.073	0.051	0.065	0.081	0.80	0.82	0.51	0.15	0.16	0.15
N_{NO_2}	mg l^{-1}	I	1	1	3	0.003	0.007	0.003	.	.	0.003	.	.	0.003	.	.	0.17	0.003	0.007	0.004
		II	10	10	8	0.001	0.001	0.002	0.003	0.003	0.004	0.003	0.005	0.003	1.0	1.0	0.31	0.012	0.017	0.005
N_{NO_3}	mg l^{-1}	I	2	2	2	2.4	1.8	0.60	.	.	.	.	.	.	.	.	.	2.7	4.2	1.5
		II	8	8	6	0.36	0.22	0.44	2.3	2.5	1.9	2.6	2.3	2.0	0.63	0.52	0.61	5.4	3.7	3.5
P_{tot}	mg l^{-1}	I	2	3	4	0.16	0.095	0.066	.	0.21	0.12	.	0.17	0.12	.	0.40	0.39	0.24	0.22	0.17
		II	10	9	8	0.086	0.12	0.066	0.14	0.15	0.093	0.15	0.18	0.10	0.38	0.36	0.37	0.26	0.32	0.17
P_{PO_4}	mg l^{-1}	I	2	3	4	0.045	0.040	0.016	.	0.063	0.042	.	0.058	0.040	.	0.28	0.51	0.059	0.072	0.059
		II	10	9	8	0.059	0.068	0.029	0.084	0.087	0.042	0.086	0.096	0.043	0.27	0.31	0.23	0.12	0.17	0.062
K	mg l^{-1}	I	2	2	2	5.1	4.4	1.5	.	.	.	.	.	.	.	.	.	6.5	5.6	4.3
		II	3	2	2	3.5	3.3	3.8	3.6	.	.	8.0	.	.	0.96	.	.	17	4.0	3.8
Ca	mg l^{-1}	I	2	2	2	4.3	5.2	1.9	.	.	.	.	.	.	.	.	.	6.8	5.8	4.6
		II	3	2	2	6.6	7.9	7.9	13	.	.	13	.	.	0.46	.	.	18	9.0	8.6
Mg	mg l^{-1}	I	2	2	2	1.4	2.6	1.0	.	.	.	.	.	.	.	.	.	2.1	2.6	1.8
		II	3	2	2	2.4	2.5	2.2	3.1	.	.	3.7	.	.	0.44	.	.	5.5	2.9	2.3
S_{SO_4}	mg l^{-1}	I	2	2	2	1.7	1.9	0.50	.	.	.	.	.	.	.	.	.	3.2	2.7	2.2
		II	2	2	2	3.7	3.2	2.7	.	.	.	.	.	.	.	.	.	6.3	5.7	4.0
Na	mg l^{-1}	I	2	2	2	1.6	3.2	1.3	.	.	.	.	.	.	.	.	.	11	6.6	2.7
		II	3	2	2	1.5	2.3	1.3	3.3	.	.	3.1	.	.	0.50	.	.	4.6	2.8	1.5
Cl	mg l^{-}	I	2	3	4	2.8	2.7	1.4	.	3.7	4.9	.	6.8	5.6	.	0.92	0.78	5.5	14	11
		II	10	9	7	1.3	1.1	1.0	2.3	2.3	1.9	2.5	2.5	2.0	0.38	0.59	0.35	4.0	6.0	2.9
Fe	mg l^{-1}	I	2	2	2	4.1	9.3	2.1	.	.	.	.	.	.	.	.	.	9.9	40	7.2
		II	3	3	3	1.2	1.4	0.61	2.9	3.6	2.4	2.9	3.0	1.8	0.61	0.47	0.58	4.8	4.1	2.5
Mn	mg l^{-1}	I	2	2	2	0.089	0.11	0.052	.	.	.	.	.	.	.	.	.	0.12	0.26	0.071
		II	2	2	2	0.16	0.11	0.066	.	.	.	.	.	.	.	.	.	0.17	0.16	0.11
Zn	mg l^{-1}	I	2	2	2	0.004	0.010	0.002	.	.	.	.	.	.	.	.	.	0.011	0.017	0.004
		II	2	2	2	0.002	0.003	0.001	.	.	.	.	.	.	.	.	.	0.005	0.004	0.008

Table 30. Continued.

Variable	Unit	Period	Number of observations in treatment			Values of statistics in different treatments														
						min			m			$\bar{x}$			s/$\bar{x}$			max		
			b_M	c_M	d_M	b_M	c_M	d_M	b_M	c_M	d_M	b_M	c_M	d_M	b_M	c_M	d_M	b_M	c_M	d_M
Cu	mg l^{-1}	I	2	2	2	0.014	0.020	0.009	.	.	.	.	.	.	.	.	.	0.020	0.024	0.014
		II	2	2	2	0.008	0.008	0.006	.	.	.	.	.	.	.	.	.	0.016	0.010	0.016
Ni	mg l^{-1}	I	2	2	2	0.003	0.004	0.003	.	.	.	.	.	.	.	.	.	0.003	0.004	0.003
		II	2	2	2	0.001	0	0.003	.	.	.	.	.	.	.	.	.	0.005	0.003	0.005
Cd	mg l^{-1}	I	2	2	2	0	0	0	.	.	.	.	.	.	.	.	.	0	0	0
		II	2	2	2	0	0	0	.	.	.	.	.	.	.	.	.	0	0	0
Hg	mg l^{-1}	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	2	1	0	0	0	.	.	.	.	.	.	.	.	.	0.0001	0	0
Pb	mg l^{-1}	I	2	2	2	0.002	0.003	0.001	.	.	.	.	.	.	.	.	.	0.004	0.004	0.003
		II	2	2	2	0	0	0	.	.	.	.	.	.	.	.	.	0.001	0.001	0
γ_{25}	mS m^{-1}	I	2	3	4	8.5	6.8	2.8	.	9.2	8.4	.	12	9.1	.	3.7	0.66	9.6	19	17
		II	10	10	8	7.6	4.2	5.3	12	9.6	8.3	11	11	8.1	0.27	0.45	0.16	17	18	9.5
pH		I	2	3	4	6.3	6.4	6.4	.	6.6	6.6	.	.	.	.	.	.	6.8	6.6	7.0
		II	10	10	8	6.3	6.1	6.2	6.4	6.6	6.4	.	.	.	.	.	.	7.0	7.2	6.9
COD_{Mn}	mgl^{-1}O$_2$	I	2	3	4	9.9	7.5	9.8	.	11	12	.	10	12	.	0.27	0.23	13	13	16
		II	10	10	7	8.3	5.3	8.5	11	9.3	10	11	10	10	0.22	0.30	0.11	15	16	12
SS	mg l^{-1}	I	2	3	4	28	97	9.0	.	250	28	.	600	30	.	1.2	0.73	140	1400	57
		II	6	7	4	5.0	8.9	0	25	41	5.0	25	37	5.0	0.70	0.64	0.51	44	79	6.5
TS	mg l^{-1}	I	2	3	4	140	200	46	.	310	150	.	780	130	.	1.2	0.45	260	1800	180
		II	5	6	5	110	83	41	120	110	66	120	120	67	0.091	0.27	0.26	140	170	88
ASH	mg l^{-1}	I	2	3	4	99	180	26	.	270	91	.	720	86	.	1.2	0.53	210	1700	140
		II	6	6	5	74	56	37	92	81	41	96	90	49	0.28	0.31	0.31	140	140	75
TOCOL	counts/ 100 ml	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	3	2	3.0	47	510	.	1000	.	.	2100	.	.	1.3	.	470	5300	560
FECOL	counts/ 100 ml	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	3	4	3	0	0	0	0	0	0	0	18	0	.	2.0	.	0	73	0
ENTCO	counts/ 100 ml	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	3	4	3	1.0	0	0	4.0	17	3.0	48	48	17	1.6	1.6	1.6	140	160	49

Table 31. Flow-weighted mean concentrations of subdrainage water in the hydrological years (Nov. 1—Oct. 31) studied in the Liperi field.

Hydrological year	Treatment	Concentration (mg l^{-1})																					
		n[1]	N_{tot}	n	N_{NO_3}	n	P_{tot}	n	P_{PO_4}	n	K	n	Ca	n	Mg	n	S_{SO_4}	n	Na	n	Cl	n	Fe
1978—1979	a_L	59	7.8	55	6.5	63	0.058	63	0.017	46	5.3	46	58	46	19	8	37	20	8.7	63	32	8	1.0
	b_L	51	8.1	51	6.9	59	0.059	58	0.018	41	6.2	41	60	41	20	8	37	19	9.6	59	33	8	1.6
	c_L	58	8.0	54	6.9	62	0.058	62	0.018	44	7.6	44	59	44	19	8	31	20	9.8	62	33	8	0.72
	d_L	52	9.6	52	8.3	60	0.062	60	0.020	44	5.9	44	57	44	20	7	31	20	8.7	60	35	8	0.62
1979—1980	a_L	68	5.8	71	4.6	71	0.054	68	0.023	71	6.0	71	54	71	17	16	47	63	8.5	71	21	16	0.96
	b_L	69	11	73	7.5	73	0.084	68	0.028	72	7.4	72	63	72	22	16	50	64	9.8	73	24	16	1.4
	c_L	69	8.9	72	7.7	72	0.056	68	0.025	72	7.7	73	53	73	18	15	47	65	8.2	72	20	15	0.95
	d_L	69	7.1	73	5.6	73	0.056	69	0.027	73	5.6	73	49	73	18	16	43	65	8.0	73	20	16	0.84
1980—1981	a_L	136	9.1	72	9.4	136	0.091	72	0.037	118	6.6	118	53	118	16	36	29	118	8.0	72	8.7	36	3.0
	b_L	133	25	71	25	136	0.13	72	0.066	118	7.6	118	67	118	20	36	29	118	9.3	72	9.1	36	2.9
	c_L	133	33	72	32	136	0.11	72	0.048	120	8.9	120	64	120	20	36	30	120	9.6	72	9.0	36	2.3
	d_L	135	11	72	9.0	136	0.11	72	0.054	119	5.5	119	44	119	15	36	22	119	6.6	72	10	36	2.7
1981—1982	a_L	88	3.4	48	2.9	88	0.11	60	0.029	35	7.8	35	49	35	18	28	50	28	8.6	48	12	28	0.74
	b_L	88	6.8	48	6.4	88	0.13	60	0.056	36	9.0	36	48	36	18	28	50	28	8.8	48	14	28	0.63
	c_L	88	7.5	48	7.0	88	0.13	60	0.043	36	9.8	36	47	36	17	28	50	28	8.5	48	14	28	0.79
	d_L	88	4.4	48	4.2	88	0.13	60	0.048	36	6.7	36	43	36	17	28	43	28	7.2	48	13	28	2.0

1) n = number of observations

Hydrological year	Treatment	Concentration (mg l^{-1})															
		n	Mn	n	Zn	n	Cu	n	Ni	n	γ_{25}[2]	n	pH[3]	n	$COD_{Mn}(O_2)$	n	SS
1978—1979	a_L	8	0.074	8	0.002	8	0.014	8	0.020	63	63	63	6.5	63	11	4	<5
	b_L	8	0.090	8	0.001	8	0.012	8	0.015	59	65	59	6.5	59	11	4	<5
	c_L	8	0.053	8	0.004	8	0.013	8	0.021	62	59	62	6.4	62	11	4	<5
	d_L	8	0.054	8	0	8	0.010	8	0.016	60	60	59	6.5	60	12	4	<5
1979—1980	a_L	16	0.19	20	0.020	20	0.014	20	0.041	71	60	71	6.4	71	14	50	6.0
	b_L	16	0.27	20	0.017	20	0.013	20	0.042	73	69	73	6.5	73	15	51	6.4
	c_L	15	0.21	19	0.021	19	0.014	19	0.045	73	59	73	6.5	73	13	49	7.1
	d_L	16	0.12	20	0.026	20	0.036	20	0.034	73	59	73	6.5	73	14	50	7.4
1980—1981	a_L	36	0.22	36	0.018	36	0.012	36	0.032	136	59	136	6.2	72	13	135	21
	b_L	36	0.21	36	0.016	36	0.012	36	0.037	136	71	136	6.2	72	14	136	23
	c_L	36	0.18	36	0.016	36	0.011	36	0.041	136	66	136	6.2	72	13	136	17
	d_L	36	0.14	36	0.011	36	0.010	36	0.022	136	53	136	6.3	71	13	136	20
1981—1982	a_L	28	0.50	20	0.023	20	0.011	20	0.045	88	43	88	6.3	84	6.9	32	9.8
	b_L	28	0.47	20	0.020	20	0.009	20	0.038	88	49	88	6.4	84	7.3	32	5.7
	c_L	28	0.42	20	0.020	20	0.010	20	0.032	88	45	88	6.4	84	7.1	32	6.9
	d_L	28	0.66	20	0.014	20	0.009	20	0.032	88	39	88	6.4	84	7.4	31	11

2) In mS m^{-1} (median); 3) pH value (median)

Table 32. Flow-weighted mean concentrations of surface water in the hydrological years (Nov. 1—Oct. 31) studied in the Liperi field. Legend as in Table 31.

Hydrological year	Treatment	Concentration (mg l^{-1})																					
		n	N_{tot}	n	N_{NO_3}	n	P_{tot}	n	P_{PO_4}	n	K	n	Ca	n	Mg	n	S_{SO_4}	n	Na	n	Cl	n	Fe
1978—1979	a_L	9	3.8	11	3.4	12	0.065	12	0.014	8	5.8	8	50	8	19	2	22	4	12	12	33	2	3.8
	b_L	11	5.1	12	4.2	13	0.15	13	0.013	9	7.0	9	48	9	17	3	24	5	10	13	27	3	8.5
	c_L	10	3.6	11	2.8	12	0.056	12	0.011	7	6.7	7	53	7	19	1	12	3	14	12	38	1	7.9
	d_L	13	4.5	12	3.8	13	0.042	12	0.010	9	6.5	9	62	9	20	3	17	5	6.1	12	28	3	4.0
1979—1980	a_L	12	6.5	14	5.9	14	0.056	13	0.017	14	7.0	14	49	14	18	3	33	12	8.4	14	29	3	3.6
	b_L	13	6.4	14	4.2	14	0.10	13	0.040	14	7.9	14	54	14	18	3	30	12	8.1	14	34	3	7.6
	c_L	13	3.5	14	2.5	14	0.079	13	0.071	14	7.8	14	43	14	17	3	40	12	11	13	40	3	2.8
	d_L	13	3.7	14	2.5	14	0.11	13	0.048	14	11	14	40	14	14	3	37	12	7.0	14	26	3	5.0
1980—1981	a_L	32	8.5	16	6.3	31	0.18	16	0.047	27	5.3	27	32	27	12	8	19	27	5.1	16	9.9	8	9.2
	b_L	30	7.8	17	7.2	30	0.35	17	0.098	28	7.3	28	35	28	18	8	31	28	5.6	17	6.6	8	27
	c_L	30	5.9	16	5.3	30	0.25	16	0.065	26	6.5	26	17	26	6.6	7	10	26	4.2	16	4.2	7	15
	d_L	23	6.1	14	5.2	23	0.43	14	0.12	22	14	22	31	22	17	7	11	22	4.3	14	4.3	7	30
1981—1982	a_L	20	5.1	10	7.6	20	0.20	13	0.044	6	5.7	6	30	6	12	6	21	4	4.9	10	11	6	2.3
	b_L	20	3.7	10	7.3	20	0.18	13	0.076	7	7.4	7	35	7	12	6	18	5	5.5	10	11	6	4.7
	c_L	20	2.9	10	1.5	20	0.17	13	0.051	7	5.8	7	15	7	6.5	6	18	5	2.6	10	3.8	6	2.9
	d_L	17	3.5	7	2.3	17	0.16	10	0.047	5	4.0	5	12	5	3.6	4	12	4	1.9	7	3.1	4	4.4

Hydrological year	Treatment	Concentration (mg l^{-1})															
		n	Mn	n	Zn	n	Cu	n	Ni	n	γ_{25}	n	pH	n	$COD_{Mn}(O_2)$	n	SS
1978—1979	a_L	2	0.076	1	0.005	1	0.013	1	0.014	12	56	12	7.3	12	7.2	8	58
	b_L	3	0.11	2	0.017	2	0.021	2	0.035	13	55	13	7.4	13	8.7	9	160
	c_L	1	0.11	1	0	1	0.008	1	0.008	12	55	12	7.4	11	5.2	7	39
	d_L	3	0.071	2	0.001	2	0.010	2	0.005	13	59	13	7.3	12	6.2	8	25
1979—1980	a_L	3	0.13	4	0.050	4	0.061	4	0.033	14	69	14	6.9	14	9.6	14	13
	b_L	3	0.30	4	0.075	4	0.019	4	0.039	14	75	14	7.1	14	11	14	16
	c_L	3	0.26	4	0.12	4	0.038	4	0.049	14	66	14	7.1	14	8.6	13	22
	d_L	3	0.10	4	0.046	4	0.028	4	0.028	14	83	14	7.4	14	12	14	25
1980—1981	a_L	8	0.22	7	0.017	7	0.014	7	0.017	32	52	32	7.2	17	13	31	90
	b_L	8	0.45	8	0.035	8	0.034	8	0.027	30	55	30	7.2	17	13	30	270
	c_L	7	0.26	7	0.015	7	0.012	7	0.013	30	54	30	7.2	16	9.7	28	160
	d_L	7	0.53	7	0.050	7	0.026	7	0.027	23	63	23	7.5	14	13	22	180
1981—1982	a_L	6	0.27	3	0.010	3	0.010	3	0.020	20	26	20	7.2	19	8.1	10	56
	b_L	6	0.34	4	0.027	4	0.008	4	0.021	20	26	20	7.3	19	6.8	11	85
	c_L	6	0.17	4	0.019	4	0.017	4	0.014	20	19	20	7.3	19	6.8	11	70
	d_L	4	0.15	3	0.017	3	0.012	3	0.013	17	16	17	7.4	16	6.8	9	57

Table 33. Flow-weighted monthly concentrations of nitrogen and phosphorus of subdrainage water in the various treatments in the hydrological years studied in the Liperi field. The number of monthly observations ranges from 4 to 44 by quality variable and treatment.

Month, year	Concentration (mg l^{-1})																			
	N_{tot}				N_{NH_4}				N_{NO_3}				P_{tot}				P_{PO_4}			
	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L
Nov., 1978	10	12	12	15	0.013	0.004	0.010	0.013	7.6	8.3	8.4	10	0.054	0.044	0.048	0.056	0.030	0.028	0.031	0.034
Dec., 1978	3.7	7.0	2.9	5.2	..	..	..	..	3.3	3.4	2.5	3.4	0.047	0.031	0.046	0.045	0.039	0.005	0.041	0.032
Jan., 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Febr., 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
March, 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
April, 1979	9.1	..	6.1	..	0.004	..	0.004	..	8.7	..	5.4	..	0.050	..	0.072	..	0.035	..	0.053	..
May, 1979	7.8	8.1	8.0	9.5	0.036	0.037	0.039	0.042	6.5	6.9	7.0	8.3	0.059	0.060	0.058	0.062	0.016	0.017	0.017	0.019
June, 1979	1.7	2.0	1.8	2.7	0.004	0.005	0.005	0.006	1.5	1.6	1.5	2.5	0.028	0.025	0.032	0.044	0.020	0.020	0.023	0.030
July, 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Aug., 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sept., 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Oct., 1979	6.5	4.8	5.1	5.5	0.005	0.004	0.005	0.005	5.4	3.9	4.1	4.4	0.060	0.048	0.059	0.056	0.046	0.036	0.039	0.041
Nov., 1979	7.5	7.4	7.4	8.4	0.003	0.003	0.003	0.003	6.2	5.6	6.0	6.9	0.049	0.047	0.046	0.045	0.018	0.017	0.017	0.019
Dec., 1979	4.9	4.2	3.4	5.1	0.004	0.004	0.003	0.004	3.7	2.9	2.9	3.6	0.039	0.029	0.029	0.038	0.026	0.021	0.022	0.026
Jan., 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Febr., 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
March, 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
April, 1980	5.6	8.6	5.3	6.5	0.030	1.7	0.061	0.075	4.3	4.3	4.0	4.7	0.066	0.14	0.072	0.071	0.025	0.039	0.031	0.031
May, 1980	2.1	3.1	3.2	3.3	0.024	0.56	0.040	0.037	1.5	1.8	1.6	2.1	0.030	0.045	0.039	0.035	0.018	0.026	0.018	0.022
June, 1980	0.84	1.8	0.86	1.2	0.004	0.13	0.009	0.004	0.62	1.4	0.69	0.97	0.029	0.037	0.028	0.033	0.025	0.027	0.021	0.027
July, 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Aug., 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sept., 1980	12	16	28	7.3	0.006	0.13	0.010	0.008	11	15	27	6.5	0.072	0.058	0.056	0.053	0.061	0.045	0.042	0.040
Oct., 1980	11	53	67	15	0.003	0.004	0.004	0.004	10	48	65	14	0.032	0.035	0.034	..	0.023	0.023	0.022	..
Nov., 1980	3.0	19	22	6.3	0.003	0.004	0.004	0.003	2.6	17	21	6.1	0.025	0.025	0.021	0.026	0.019	0.020	0.017	0.021
Dec., 1980	1.7	9.9	12	3.3	0.003	0.003	0.003	0.003	1.4	9.4	11	3.0	0.020	0.022	0.018	0.021	0.017	0.019	0.016	0.018
Jan., 1981	1.1	7.3	9.1	2.2	0.011	0.008	0.006	0.003	0.95	7.2	9.0	2.1	0.018	0.022	0.017	0.020	0.019	0.021	0.018	0.019
Febr., 1981	1.6	9.0	11	2.6	0.002	0.002	0.002	0.002	1.2	7.4	9.9	2.0	0.017	0.020	0.017	0.020	0.015	0.019	0.015	0.016
March, 1981	1.5	8.3	11	2.5	..	..	..	..	..	..	..	..	0.023	0.024	0.021	0.025	..	..	..	..
April, 1981	27	74	89	34	0.007	0.006	0.010	0.009	30	85	92	29	0.043	0.047	0.055	0.057	0.019	0.023	0.024	0.029
May, 1981	8.5	18	22	8.9	0.041	0.032	0.025	0.033	7.2	15	19	7.6	0.12	0.18	0.13	0.15	0.047	0.088	0.060	0.071
June, 1981	10	28	33	16	0.019	0.015	0.018	0.009	11	33	31	16	0.036	0.044	0.036	0.046	0.025	0.033	0.025	0.034
July, 1981	2.9	12	12	4.5	..	..	..	..	..	..	..	..	0.069	0.077	0.072	0.078	..	..	..	..
Aug., 1981	2.1	9.9	11	2.8	..	..	..	..	0.57	7.8	9.8	1.2	0.046	0.056	0.063	0.058	0.027	0.036	0.031	0.034
Sept., 1981	2.0	8.1	9.7	3.7	..	..	..	..	..	..	..	..	0.18	0.12	0.15	0.13	..	..	..	..
Oct., 1981	1.8	5.1	6.8	2.8	..	..	..	..	0.24	3.1	3.9	0.75	0.15	0.23	0.22	0.20	0.042	0.068	0.074	0.053

Table 33. Continued.

Month, year	Concentration (mg l^{-1})																			
	N_{tot}				N_{NH_4}				N_{NO_3}				P_{tot}				P_{PO_4}			
	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L
Nov., 1981	0.93	6.2	8.2	1.9	0.031	0.057	0.053	0.037	0.40	4.4	6.3	1.1	0.042	0.069	0.065	0.084	0.017	0.043	0.026	0.026
Dec., 1981	0.83	5.6	7.8	1.2	0.047	0.036	0.019	0.033	0.22	4.6	7.0	0.69	0.038	0.033	0.023	0.030	0.019	0.020	0.016	0.016
Jan., 1982	0.45	4.9	6.7	0.82	0.019	0.007	0.007	0.006	0.24	4.5	6.3	0.65	0.013	0.022	0.012	0.014	0.007	0.016	0.010	0.010
Febr., 1982	0.41	4.2	5.8	0.79	0.008	0.003	0.003	0.003	0.23	3.8	5.5	0.56	0.017	0.018	0.013	0.015	0.008	0.015	0.010	0.010
March, 1982	0.41	4.0	5.5	0.74	0.040	0.004	0.004	0.004	0.16	3.4	4.9	0.48	0.014	0.020	0.013	0.017	0.007	0.015	0.012	0.013
April, 1982	4.4	6.5	7.2	5.0	0.032	0.043	0.035	0.039	4.0	6.1	6.8	4.5	0.16	0.17	0.17	0.17	0.042	0.072	0.060	0.066
May, 1982	3.4	6.9	7.0	6.1	0.12	0.31	0.11	0.33	2.7	5.7	6.1	4.8	0.087	0.17	0.11	0.12	0.031	0.099	0.053	0.065
June, 1982	4.7	9.6	8.7	8.0	0.015	0.010	0.014	0.016	4.4	9.0	8.6	7.5	0.031	0.043	0.040	0.048	0.024	0.036	0.033	0.038
July, 1982	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Aug., 1982	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sept., 1982	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Oct., 1982	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table 34. Flow-weighted monthly concentrations of nitrogen and phosphorus of surface water in the various treatments in the hydrological years studied in the Liperi field. The number of monthly observations ranges from 1 to 6 by quality variable and treatment.

Month, year	Concentration (mg l^{-1})																			
	N_{tot}				N_{NH_4}				N_{NO_3}				P_{tot}				P_{PO_4}			
	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L
Nov., 1978	14	11	8.0	10	0.010	0.006	0.002	0.003	12	9.1	6.4	8.7	0.029	0.024	0.036	0.023	0.010	0.009	0.008	0.007
Dec., 1978	10	..	..	..	..	..	..	..	9.4	..	..	..	0.021	..	..	..	0	..	..	..
Jan., 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Febr., 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
March, 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
April, 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
May, 1979	2.9	4.9	3.4	3.8	0.11	0.065	0.060	0.071	2.3	4.0	2.6	3.2	0.071	0.15	0.057	0.045	0.014	0.013	0.011	0.010
June, 1979	3.6	4.4	2.2	2.6	0.005	0.011	0.007	0.005	3.3	3.6	1.9	2.1	0.034	0.038	0.028	0.051	0.007	0.017	0.010	..
July, 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Aug., 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sept., 1979	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Oct., 1979	..	5.6	4.0	1.9	..	0.002	0.002	0.002	..	5.1	3.4	1.4	..	0.072	0.15	0.095	..	0.048	0.097	0.072
Nov., 1979	10	7.5	6.0	7.0	0.006	0.028	0.012	0.015	9.0	6.2	4.9	6.1	0.020	0.050	0.029	0.027	0.005	0.019	0.007	0.005
Dec., 1979	5.0	7.9	3.3	6.5	0.002	0.035	0.003	0.017	7.0	5.1	3.0	5.0	0.013	0.038	0.018	0.026	0	0.017	0.006	0.007
Jan., 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Febr., 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
March, 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
April, 1980	5.5	4.3	3.4	3.5	0.052	1.0	0.047	0.039	4.8	2.3	2.3	2.3	0.076	0.13	0.081	0.11	0.025	0.048	0.081	0.050
May, 1980	5.7	3.8	3.2	3.4	0.041	1.2	0.069	0.067	4.8	1.3	2.4	2.3	0.082	0.11	0.18	0.22	0.017	0.042	0.027	0.038
June, 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
July, 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Aug., 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sept., 1980	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Oct., 1980	5.7	22	3.2	8.1	0.006	0.017	0.007	0.006	5.2	20	2.7	7.0	0.020	0.028	0.018	0.083	0.011	0.011	0.008	0.067
Nov., 1980	7.2	11	3.4	11	0.002	0.013	0.004	0.001	6.6	9.9	2.9	10	0.015	0.020	0.015	0.069	0.009	0.012	0.010	0.063
Dec., 1980	4.2	6.8	2.3	9.5	0.005	0.010	0.005	0.002	3.6	6.2	1.9	9.0	0.010	0.020	0.011	0.10	0.005	0.010	0.005	0.083
Jan., 1981	2.6	3.8	1.5	9.3	0.005	0.007	0.003	0.006	2.5	3.7	1.2	8.5	0.006	0.023	0.007	0.017	0.005	0.021	0.005	0.015
Febr., 1981	2.6	5.9	2.1	6.2	0.013	0	0.012	0.011	2.4	0	1.8	5.7	0.007	0.018	0.014	0.15	0.005	0	0.009	0.15
March, 1981	2.6	3.8	1.9	..	..	..	..	..	..	..	..	..	0.021	0.030	0.017	..	..	..	..	..
April, 1981	23	22	17	23	0.030	0.039	0.064	0.027	13	23	18	23	0.043	0.077	0.069	0.052	0.010	0.031	0.022	0.011
May, 1981	7.6	5.8	5.8	5.9	0.059	0.050	0.054	0.057	6.2	5.1	5.2	4.9	0.21	0.44	0.26	0.49	0.051	0.11	0.066	0.12
June, 1981	10	6.2	6.8	9.8	0.070	0.024	0.054	0.11	9.2	5.0	6.2	8.7	0.093	0.37	0.14	0.074	0.025	0.064	0.033	0.028
July, 1981	3.8	3.7	3.8	2.1	..	..	..	..	..	..	..	..	0.068	0.11	0.097	0.063	..	..	..	..
Aug., 1981	1.8	1.8	1.4	1.5	..	..	..	..	0.14	0.073	0.031	0.033	0.056	0.11	0.070	0.046	0.031	0.034	0.017	0.020
Sept., 1981	1.2	1.5	1.3	0	..	..	..	..	..	..	..	..	0.032	0.053	0.070	0	..	..	..	..
Oct., 1981	2.2	1.2	1.7	1.6	..	..	..	..	0.19	0.18	0.043	0.38	0.19	0.11	0.41	0.24	0.056	0.026	0.056	0.072

Table 34. Continued.

Month, year	Concentration (mg l^{-1})																			
	N_{tot}				N_{NH_4}				N_{NO_3}				P_{tot}				P_{PO_4}			
	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L	a_L	b_L	c_L	d_L
Nov., 1981	1.4	1.1	0.90	1.2	0.024	0.014	0.012	0.013	0.37	0.35	0.28	0.83	0.17	0.15	0.19	0.18	0.017	0.029	0.049	0.070
Dec., 1981	0.94	1.0	0.85	1.2	0.024	0.004	0.015	0.033	0.47	0.36	0.37	0.64	0.036	0.060	0.052	0.069	0.010	0.022	0.019	0.036
Jan., 1982	0	0.98	0.96	..	0	0.005	0.009	..	0	0.38	0.57	..	0	0.047	0.047	..	0	0.013	0.020	..
Febr., 1982	0.87	1.2	0.95	..	..	0.010	0.006	..	0.45	0.59	0.50	..	0.037	0.060	0.074	..	0.011	0.016	0.025	..
March, 1982	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
April, 1982	4.4	3.5	2.9	3.3	0.040	0.028	0.058	0.070	2.1	1.6	0.55	0.44	0.21	0.18	0.16	0.16	0.054	0.079	0.047	0.044
May, 1982	2.5	3.6	1.9	1.9	0.031	0.16	0.010	0.014	1.6	2.7	0.55	1.4	0.19	0.13	0.46	0.14	0.061	0.050	0.099	0.057
June, 1982	23	14	13	12	0.29	0.26	0.10	0.039	22	13	13	12	0.11	0.34	0.25	0.18	0.026	0.087	0.071	0.054
July, 1982	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Aug., 1982	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sept., 1982	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Oct., 1982	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table 35. Flow-weighted mean concentrations of subdrainage and surface waters in the hydrological years 1978—1981 (Nov. 1—Oct. 31) in the Maaninka field. Combined observations (treatments combined).

Hydrological year	Runoff component	Concentration (mg l^{-1})													
		n[1]	N_{tot}	n	N_{NO_3}	n	P_{tot}	n	P_{PO_4}	n	K	n	Ca	n	Mg
1978—1979	Subdrainage	25	12	16	11	25	0.060	25	0.028	11	9.7	11	17	11	5.1
	Surface	9	5.7	6	1.8	9	0.19	9	0.058	6	3.7	6	4.7	6	1.9
1979—1980	Subdrainage	13	9.7	9	8.3	21	0.069	23	0.042	2	10	2	37	2	11
	Surface	6	3.0	2	1.4	7	0.17	7	0.066	0	.	0	.	0	.
1980—1981	Subdrainage	19	36	19	48	19	0.053	19	0.030	12	13	12	39	12	11
	Surface	8	3.5	8	2.5	8	0.14	8	0.071	4	4.1	4	7.9	4	2.6

1) n = number of observations

Hydrological year	Runoff component	Concentration (mg l^{-1})																	
		n	S_{SO_4}	n	Na	n	Cl	n	Fe	n	Mn	n	Zn	n	Cu	n	Ni	n	$COD_{Mn}(O_2)$	n	SS
1978—1979	Subdrainage	6	6.9	11	2.1	25	9.4	7	0.89	7	0.035	6	0.002	6	0.013	6	0.001	25	12	8	<5
	Surface	6	2.1	6	2.5	9	3.9	6	8.4	6	0.17	6	0.007	6	0.018	6	0.004	9	11	9	83
1979—1980	Subdrainage	2	13	2	5.2	18	7.6	2	0.088	2	0.028	2	0.003	2	0.070	2	0.011	18	13	16	<5
	Surface	0	.	0	.	8	3.0	0	.	0	.	0	.	0	.	0	.	7	9.5	6	28
1980—1981	Subdrainage	9	11	12	3.0	19	4.6	9	0.47	9	0.020	9	0.007	9	0.009	9	0.005	19	13	7	<5
	Surface	3	3.2	4	1.8	8	1.8	3	2.9	3	0.14	3	0.006	3	0.014	3	0.004	8	11	5	27

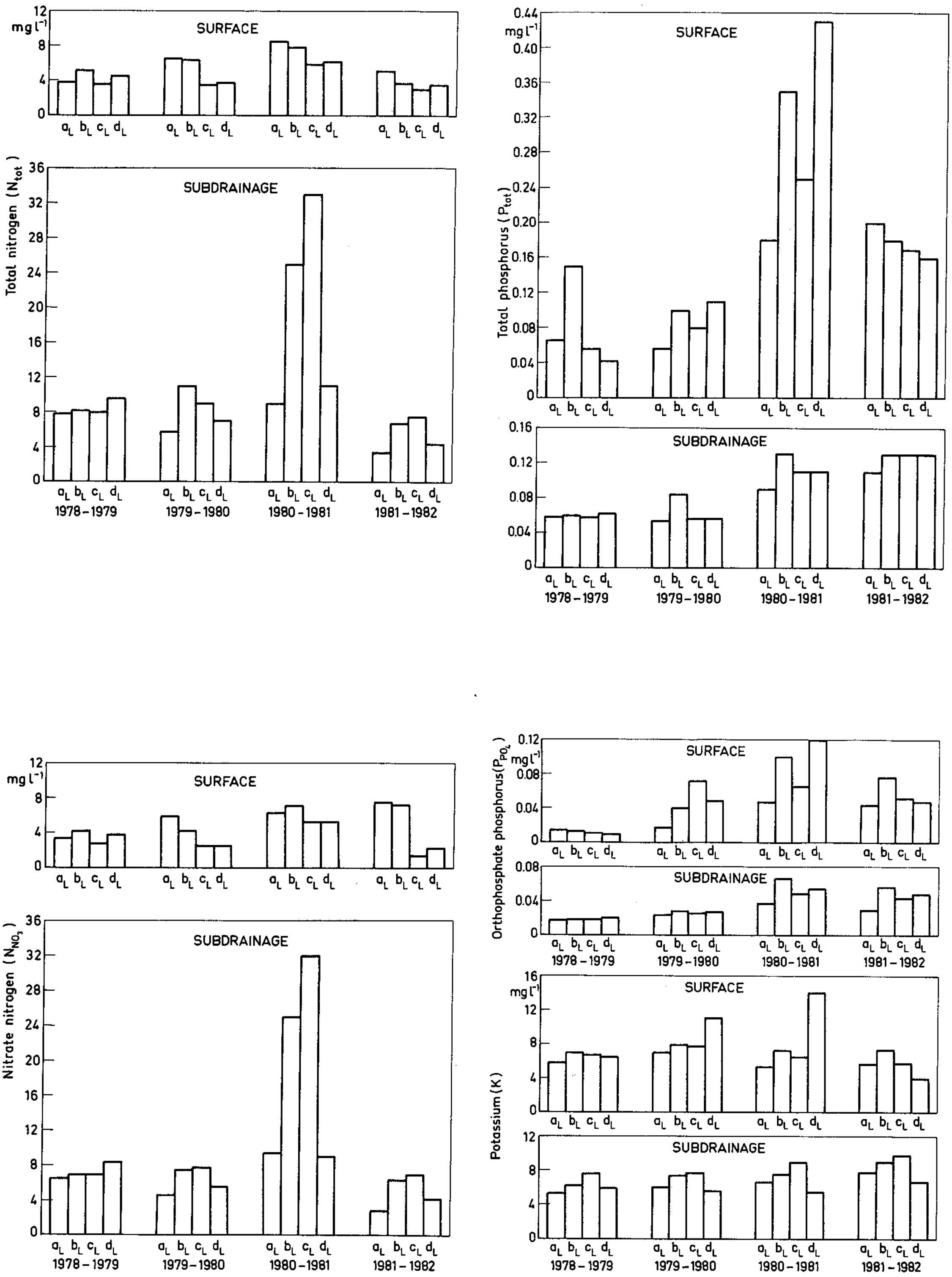


Fig. 13. Flow-weighted mean concentrations in surface and subdrainage waters in the hydrological years studied in the Liperi field.

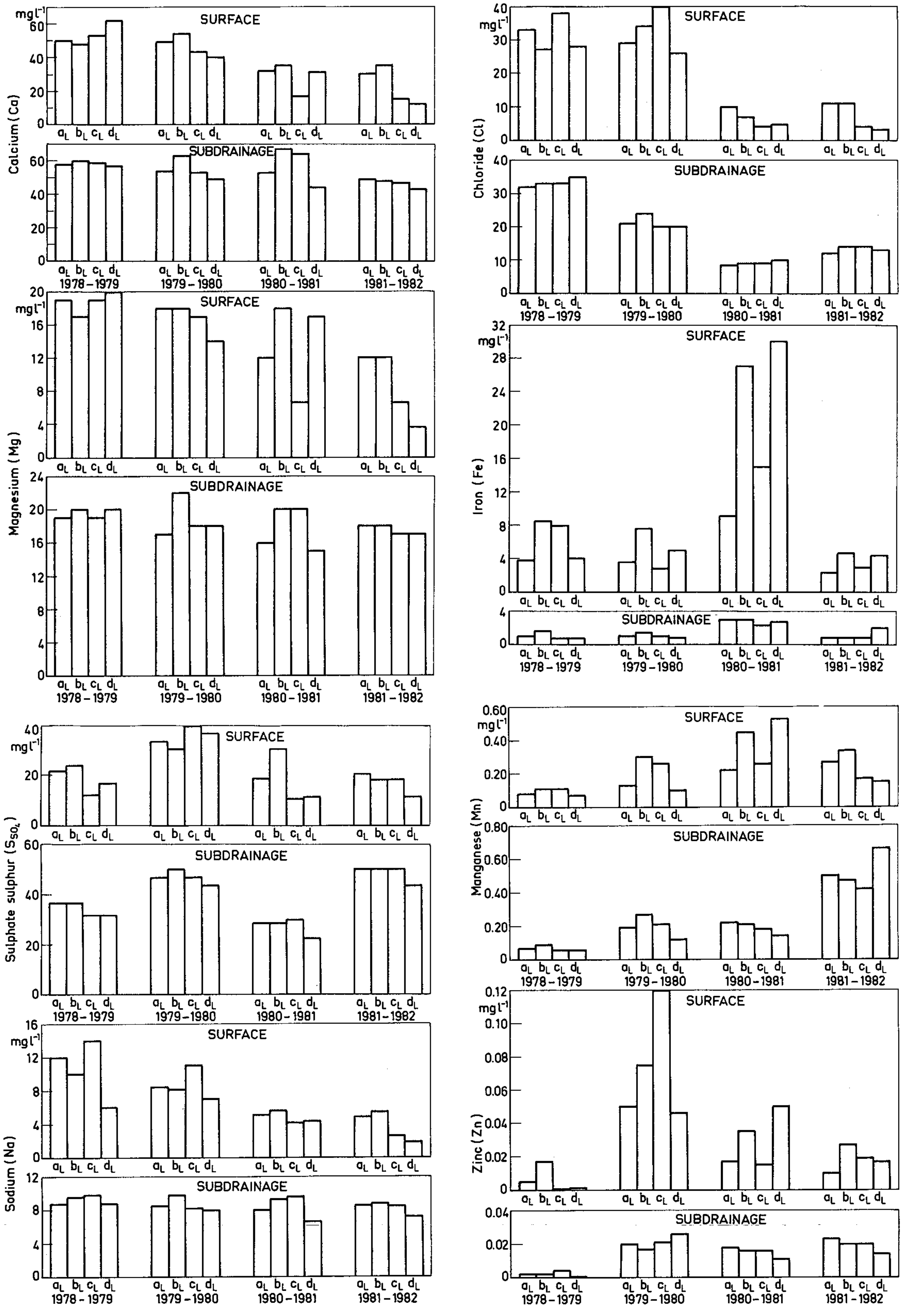
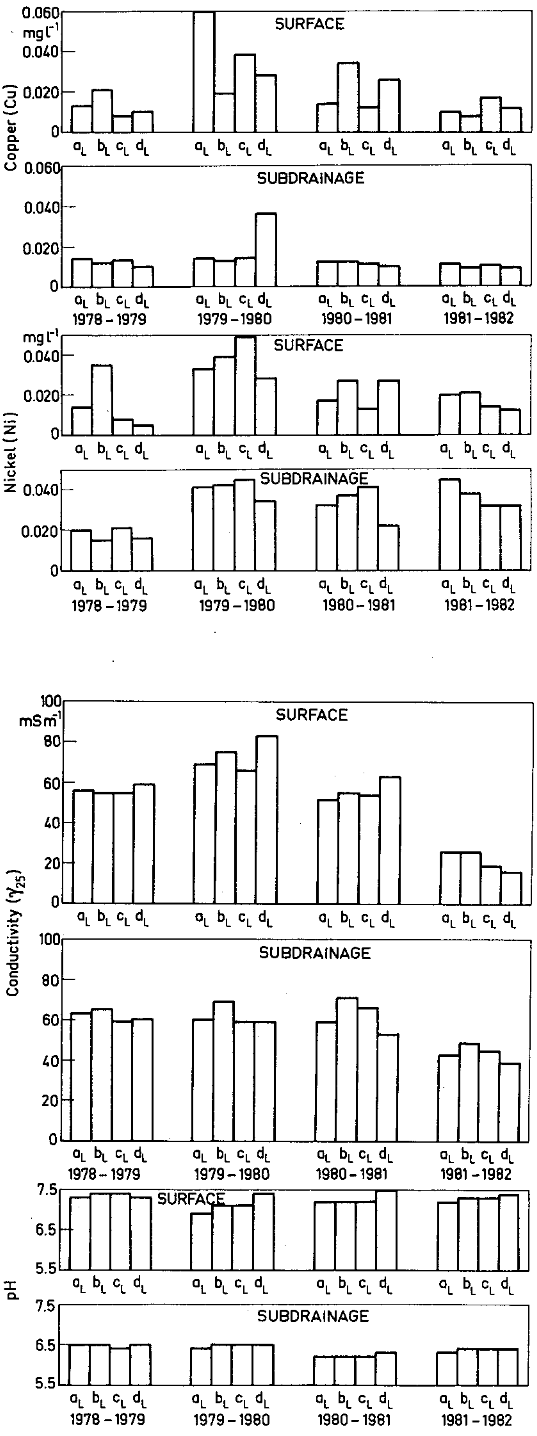


Fig. 13. Continued.



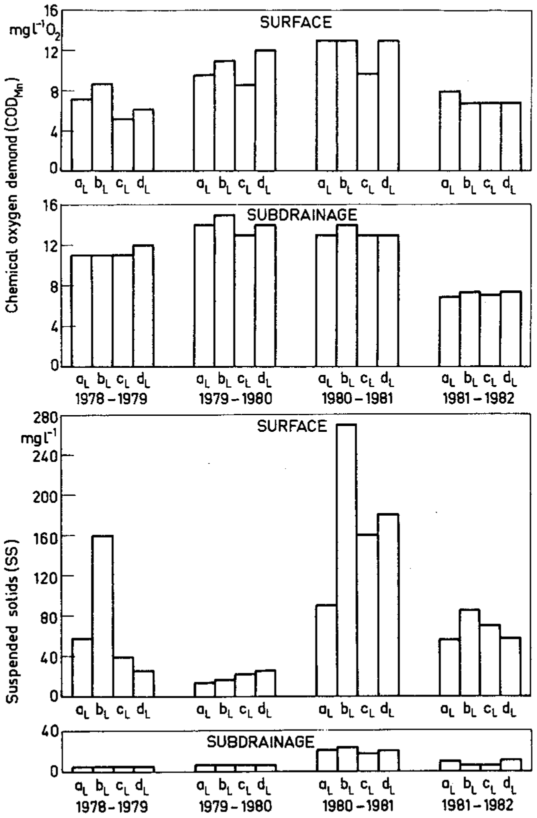


Fig. 13. Continued.

this increase was, however, caused by increased runoff.) The nitrogen content of subdrainage water was higher than that of surface water. High contents of ammonium nitrogen were observed in both subdrainage and surface waters immediately after the treatments in the Liperi field (Tables 33—34, Fig. 14): the sewage sludge, spread on snow (treatment b_L) in March 1980, yielded a monthly flow-weighted mean of 1.7 mg l^{-1} N_{NH_4} in the subdrainage water in April and 1.0—1.2 mg l^{-1} N_{NH_4} in the surface water in April—May.

In the order of 30—50 per cent of phosphorus was in phosphate form (Tables 31—32, 35). The total phosphorus content of subdrainage water in Liperi grew from about 0.06 mg l^{-1} in 1978—1979 to 0.10—0.13 mg l^{-1} in 1980—1981 and 1981—

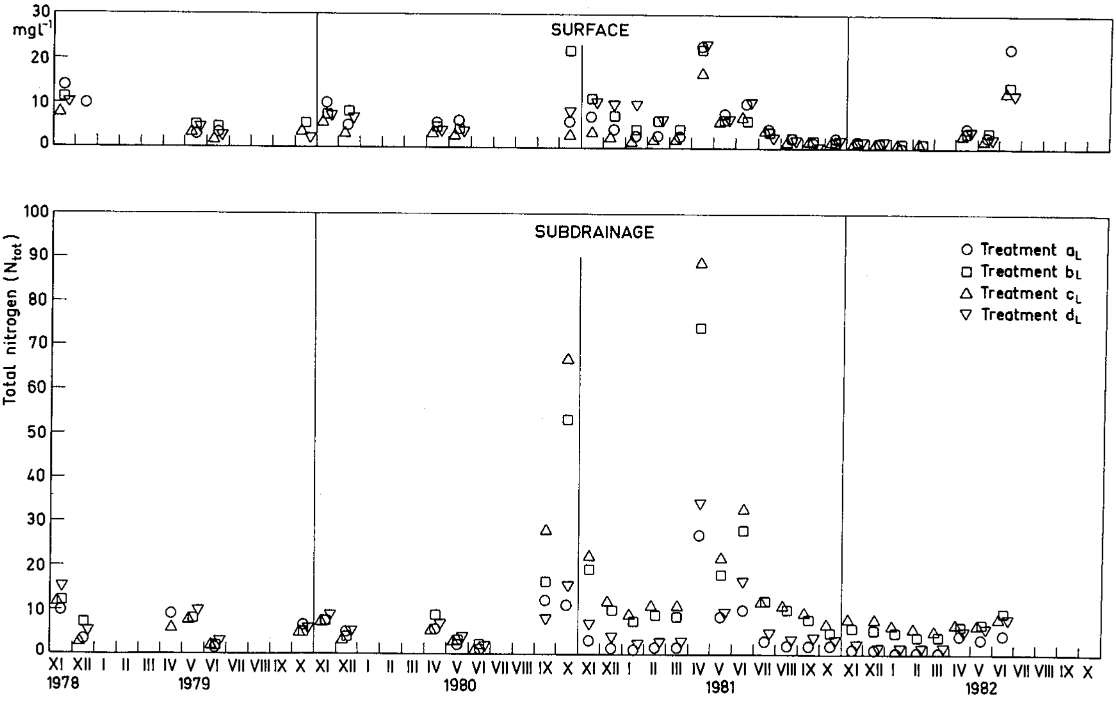


Fig. 14. Flow-weighted monthly mean concentrations of nitrogen and phosphorus in surface and subdrainage waters in the Liperi field.

1982. (Because this increase was also observed in the reference plots, it is obvious that it was mostly caused by increased runoff.) The phosphorus content was generally higher in the surface water than in the subdrainage water.

Only a slight increase could be observed in the flow-weighted means of potassium after the treatments (Tables 31—32, 35) and this growth is, obviously, mostly explained by runoff. Mean concentrations were on the order of 5—10 mg l^{-1} K in both subdrainage and surface waters.

The small increase in organic matter contents (COD_{Mn}) was obviously also mostly explained by increased runoff. The mean COD_{Mn} value in the subdrainage waters was 10—15 mg l^{-1} O_2 and slightly lower in the surface waters (Tables 31—32, 35).

Median concentrations of heavy metals remained at the detection limit of analysis (0.003 mg l^{-1} Cr, 0.0001 mg l^{-1} Cd, 0.0001 mg l^{-1} Hg, 0.001 mg l^{-1} Pb) in both subdrainage and surface waters in the both fields (Tables 27—30). Land application with normal sludge, performed according to the present guidelines, thus does not seem to cause any harmful runoff of heavy metals with subdrainage and surface waters. This is in accordance with the results of most foreign studies, e.g. de Haan (1981), Larsen (1983), Grant and Olesen (1983) (see Ch. 1.32).

A statistical evaluation of bacteria runoff was not possible because of too few samples (Tables 27—30). Presence of fecal streptococci and clostridia, also in the reference plots, further hampered conclusions. Fecal coliforms seemed, however, to disappear in a short time after the applications. Some other studies, e.g. Brink (1971), Grant and Olesen (1983), Korkman (1971) (see Ch. 1.34), show that high rates of application raise pathogen contents in runoff water or soil for some time.

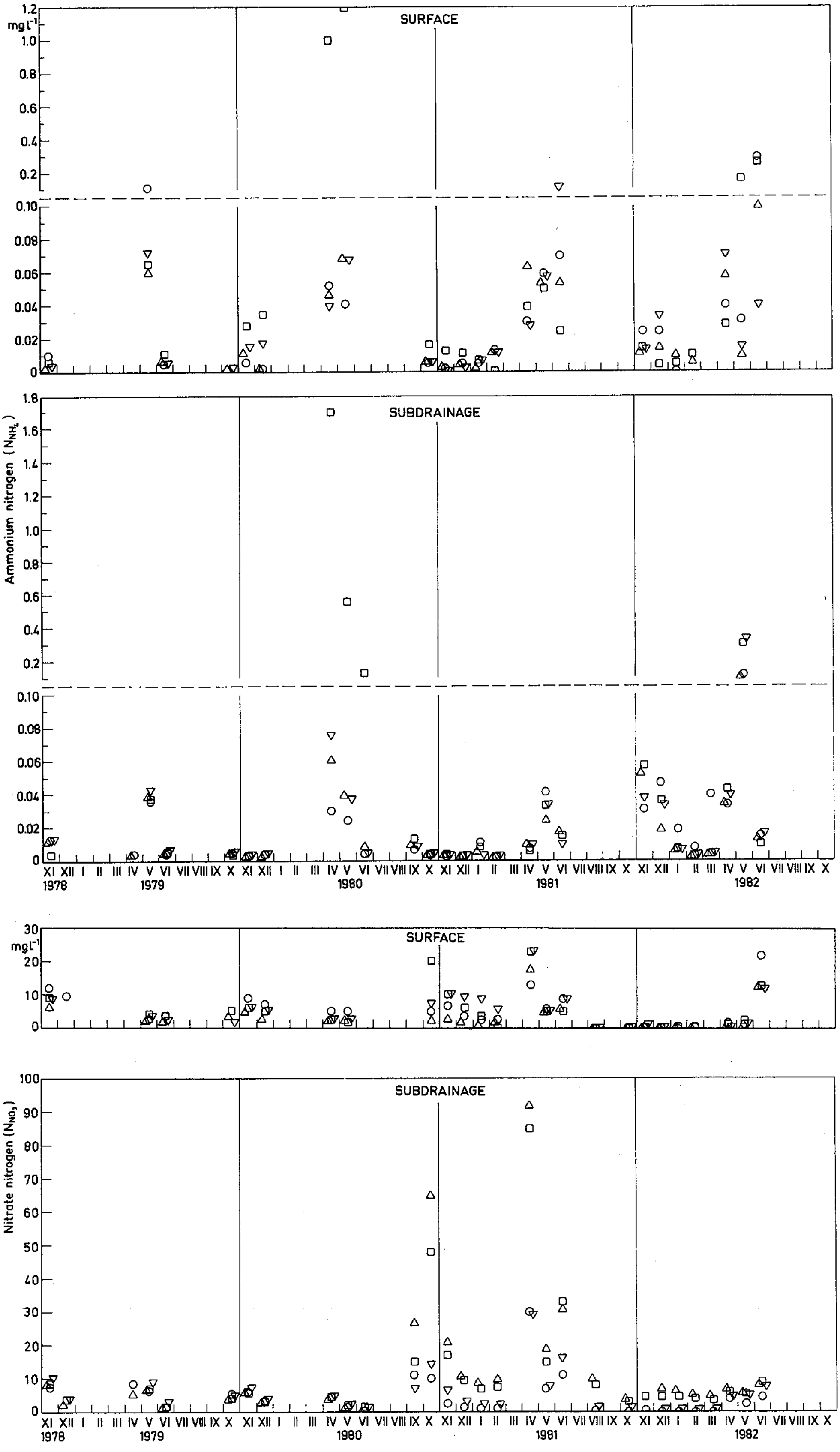


Fig. 14. Continued.

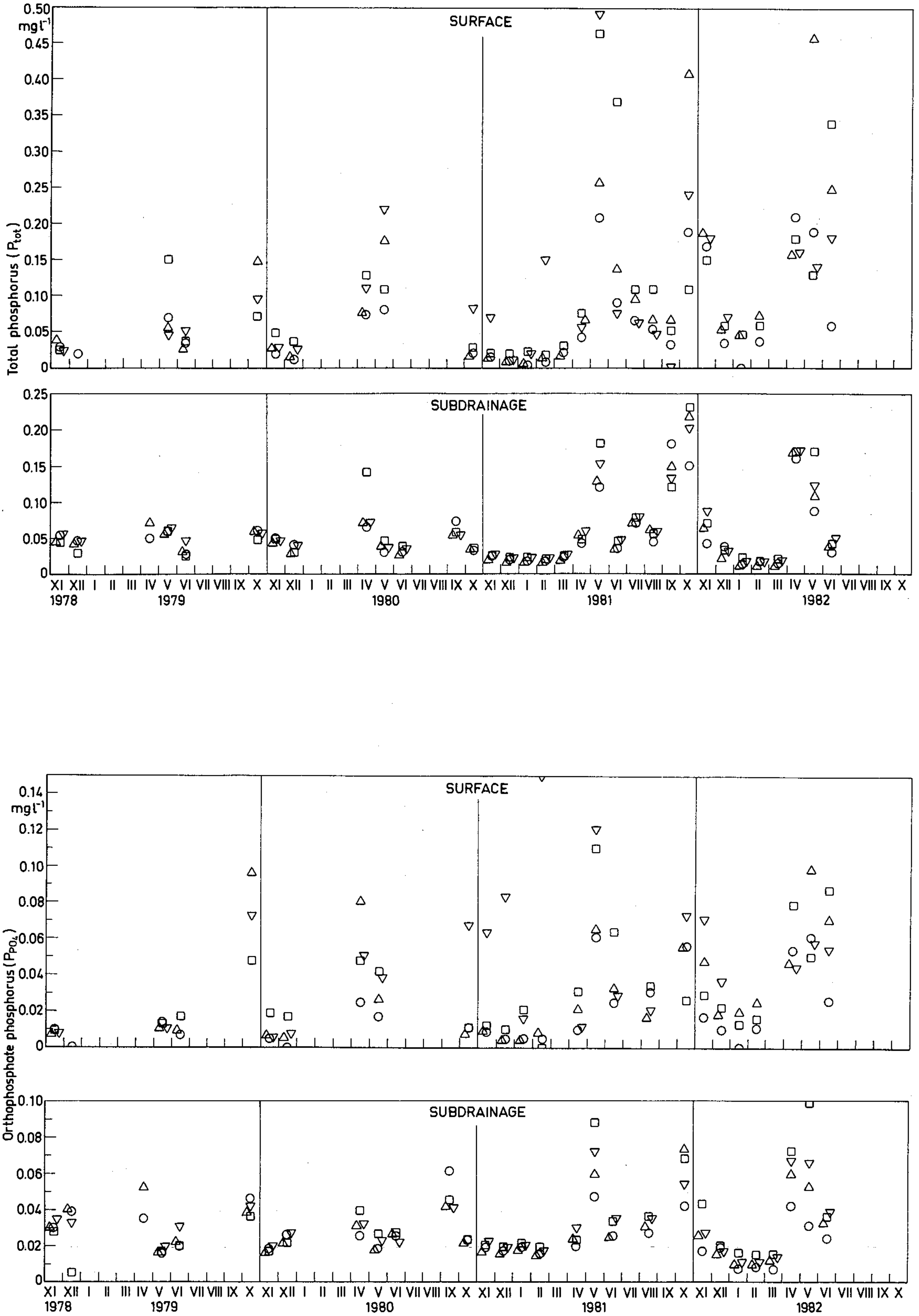


Fig. 14. Continued.

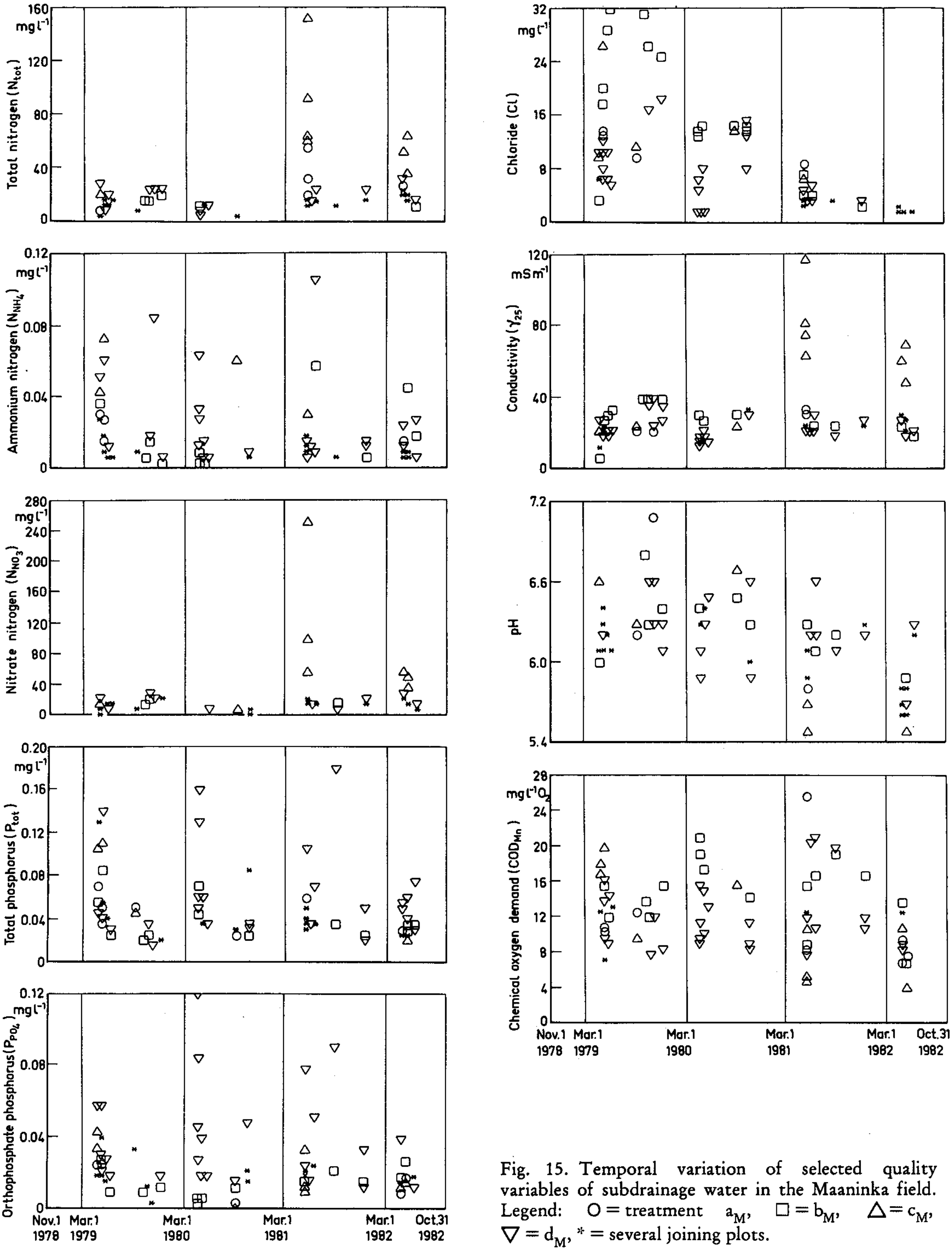


Fig. 15. Temporal variation of selected quality variables of subdrainage water in the Maaninka field. Legend: ○ = treatment a_M, □ = b_M, △ = c_M, ▽ = d_M, * = several joining plots.

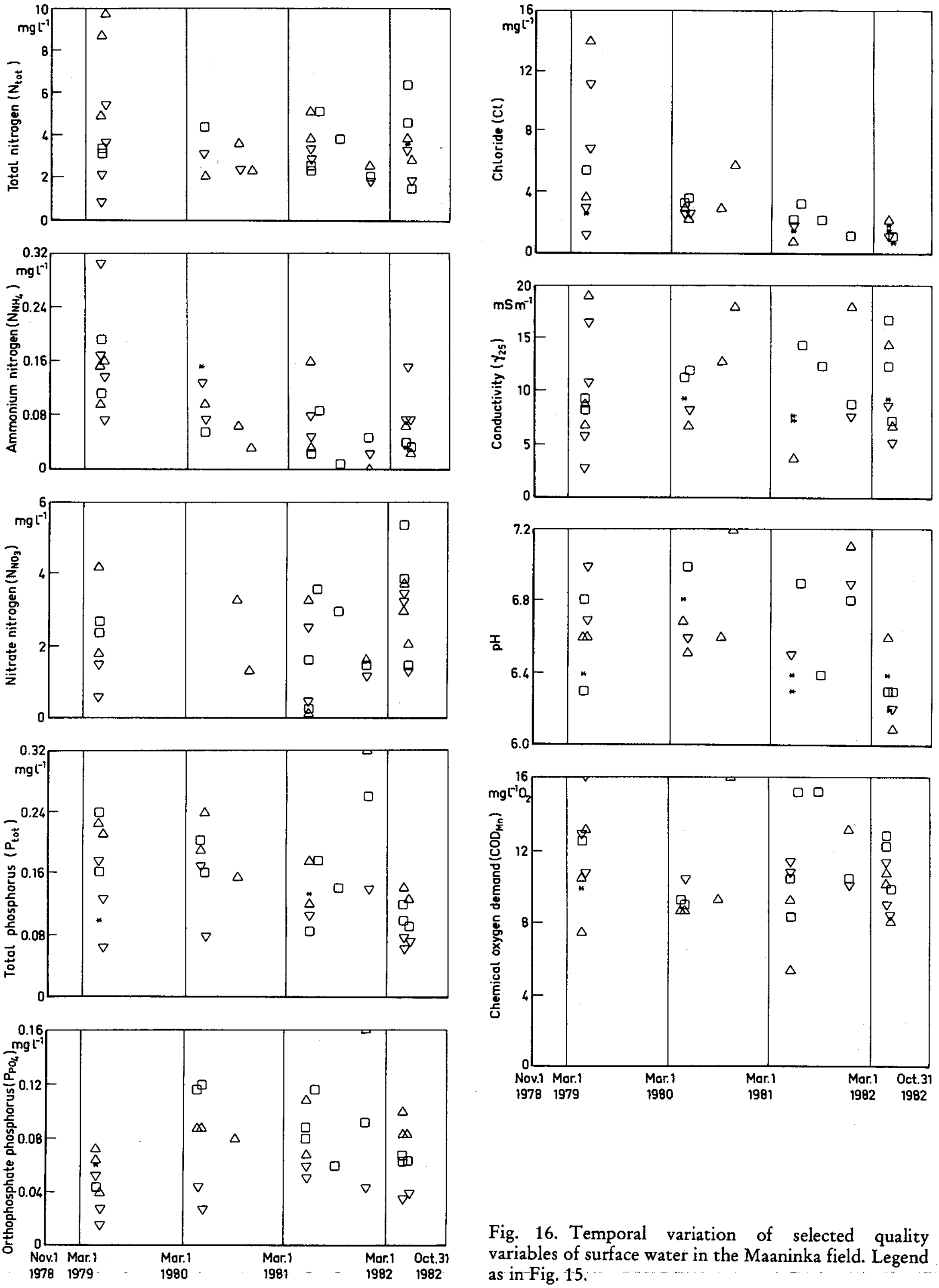


Fig. 16. Temporal variation of selected quality variables of surface water in the Maaninka field. Legend as in Fig. 15.

3.42 Leaching rates

Maximum rates of leaching were, in general, observed in the hydrological year 1980—1981 when runoff had its peak (Fig. 11).

In the Liperi field, leaching of total nitrogen through subdrainage rose from about 1 800 kg $km^{-2}a^{-1}$ in 1978—1979 to about 20 000 kg $km^{-2}a^{-1}$ in treatments b_L (sewage sludge on snow) and c_L (sludge on nonfrozen soil) (Table 36). At the same time, leaching through surface increased from 200—500 kg km^{-2} a^{-1} to 1 200—1 800 kg km^{-2} a^{-1} (Table 37). These rates of leaching, in 1980—1981, were roughly 40-fold (subdrainage) and 20-fold (surface) compared with those in Maaninka (Table 38) (reflecting mostly the difference in soil type between the two test fields but also the problems in runoff measurement in the Maaninka field). The leaching through subdrainage in 1980—1981 in Liperi was exceptionally high because of exceptional runoff and large amount of nitrogen in soil storage; similar rates were not reported in the literature surveyed. Isotalo (1979) (Ch. 1.31) gives, however, a higher leaching loss of nitrogen through surface when 25 t ha^{-1} DM of sludge was spread on snow-covered clay soil.

The leaching of total phosphorus through subdrainage in the Liperi field grew from 12—13 kg km^{-2} a^{-1} in 1978—1979 to about 80 kg km^{-2} a^{-1} in 1980—1981 in the sludge treatments (b_L—d_L); leaching with surface runoff increased from about 5 kg km^{-2} a^{-1} P to 50—75 kg km^{-2} a^{-1} P, respectively. These rates were roughly 100- and 20-fold compared with the Maaninka figures (Table 36—38). Isotalo (1979) (Ch. 1.31) reports on a leaching loss of phosphorus on the surface, which was on the same order of magnitude as the ones observed in Liperi in 1980—1981.

The rate of leaching of potassium through subdrainage in the Liperi field was in the order of 1 000—1 500 kg km^{-2} a^{-1} in 1978—1979 (Table 36); this rate grew to 4 000—6 000 kg km^{-2} a^{-1} in 1980—1981. At the same time, leaching through surface increased from about 400 kg km^{-2} a^{-1} K to 1 000—2 000 kg km^{-2} a^{-1} K (Table 37). These 1980—1981 rates were 25-fold (subdrainage) and 20-fold (surface) compared with the figures in Maaninka (Table 38).

The leaching of organic matter, measured as COD_{Mn}, through subdrainage in the Liperi field increased from 2 000—2 500 kg km^{-2} a^{-1} 0_2 in 1978—1979 to 9 000—10 000 kg km^{-2} a^{-1} 0_2 in 1980—1981 (Table 36). Leaching with surface runoff grew from about 400 kg km^{-2} a^{-1} 0_2 to 2 000—3 000 kg km^{-2} a^{-1} 0_2, respectively (Table 37). These rates were 50- and 10-fold compared with those in Maaninka (Table 38). The rates of leaching, in 1980—1981 in Liperi, were high compared with the few figures found in the literature, e.g. Brink (1972, 1973) (Ch. 1.33); this is, obviously, explained by the high runoff rates.

Distribution of the total (subdrainage plus surface) leaching was studied in Liperi in the test plots where both subdrainage and surface runoff were measured (Table 39). The proportion of subdrainage leaching of the total was as follows, regarding major nutrients and organic matter (figures in per cent):

Year	$L_{N_{tot}}$	$L_{P_{tot}}$	L_K	$L_{COD_{Mn}}$
1978—1979	80—90	60—85	75—80	75—90
1979—1980	85—95	70—90	65—90	85—90
1980—1981	90	50—85	60—90	75—90
1981—1982	90—95	80—90	90—95	90

The above figures clearly show the dominant role of subdrainage in a flat clay field. In sandy soil the situation is different: in the Maaninka field, the level of leaching through the surface was higher than that through subdrainage in the case of such constituents as phosphorus, iron, manganese, copper and solids (Table 38).

The snow-melting period plays a crucial role as regards annual leaching (Tables 40—41, App. 2—4).

The spring period (March 1—May 31) accounted for the following percentages of the annual leaching through subdrainage in the Liperi field (Table 40):

Year	$L_{N_{tot}}$	$L_{P_{tot}}$	L_K	$L_{COD_{Mn}}$
1978—1979	95	95	90—95	95
1979—1980	40—60	80—95	60—75	70—80
1980—1981	70—75	45—55	35—45	45—50
1981—1982	60—75	85—90	55—65	70—75

The percentages in the case of surface runoff were (Table 41):

Year	$L_{N_{tot}}$	$L_{P_{tot}}$	L_K	$L_{COD_{Mn}}$
1978—1979	75—95	~100	80—95	95
1979—1980	55—95	95	70—95	85—95
1980—1981	80—95	80—95	70—95	75—95
1981—1982	80—90	85—95	70—85	85—90

The impact of the exceptionally wet years 1980—1981 and 1981—1982 can be seen in the decreased proportion of the spring leaching through subdrainage in those years, as compared with the previous years. (The figures also reflect dry conditions in the years 1978—1979 and 1979—1980.)

Table 36. Annual subdrainage leaching in the hydrological years studied in the Liperi field. Amount of leaching computed by the total amount of runoff and the flow-weighted mean concentration of a quality variable. Four replicates per treatment. (For the number of observations, see Table 31.)

Hydrological year	Treatment	Leaching (kg km^{-2} a^{-1})																
		$L_{N_{tot}}$	$L_{N_{NO_3}}$	$L_{P_{tot}}$	$L_{P_{PO_4}}$	L_K	L_{Ca}	L_{Mg}	$L_{S_{SO_4}}$	L_{Na}	L_{Cl}	L_{Fe}	L_{Mn}	L_{Zn}	L_{Cu}	L_{Ni}	$L_{COD_{Mn}(O_2)}$	L_{SS}
1978—1979	a_L	1600	1300	12	3.5	1100	12000	3800	7300	1700	6300	210	15	0.44	3.0	4.0	2100	180
	b_L	1800	1600	13	4.0	1400	14000	4600	8700	2200	7500	350	20	0.32	2.7	3.4	2500	390
	c_L	1800	1500	13	4.0	1700	13000	4300	6700	2200	7300	160	12	0.89	2.9	4.7	2500	330
	d_L	2000	1800	13	4.3	1300	12000	4400	6700	1900	7500	130	12	0.078	2.1	3.3	2600	330
1979—1980	a_L	1200	930	11	4.6	1200	11000	3500	9700	1700	4300	200	39	4.0	2.9	8.2	2700	1200
	b_L	1900	1400	15	5.2	1300	11000	4000	9300	1800	4400	250	49	3.2	2.3	7.7	2800	1200
	c_L	1900	1700	12	5.4	1700	11000	3900	10000	1800	4200	200	45	4.5	3.1	9.7	2900	1600
	d_L	1300	1100	11	5.0	1100	9200	3400	8000	1500	3900	160	23	5.0	6.8	6.4	2700	1400
1980—1981	a_L	5500	5700	55	22	4000	32000	10000	17000	4800	5200	1800	130	11	7.1	19	7800	13000
	b_L	16000	16000	83	41	4800	42000	13000	18000	5800	5700	1800	130	10	7.9	24	8800	15000
	c_L	24000	23000	79	35	6400	46000	15000	22000	6900	6500	1700	130	11	8.2	29	9400	12000
	d_L	7900	6600	83	40	4000	32000	11000	16000	4800	7400	2000	110	7.7	7.4	16	9800	15000
1981—1982	a_L	1700	1400	54	15	3900	25000	8800	25000	4300	6100	370	250	12	5.4	23	3500	4900
	b_L	4000	3800	74	33	5300	28000	10000	30000	5200	8400	370	280	12	5.3	23	4300	3300
	c_L	4900	4600	82	29	6400	31000	11000	32000	5600	8900	520	270	13	6.7	21	4700	4600
	d_L	2700	2500	81	29	4000	26000	10000	27000	4300	8000	1200	400	8.6	5.6	19	4500	6500

Table 37. Annual surface runoff leaching in the hydrological years studied in the Liperi field. Amount of leaching computed by the total amount of runoff and the flow-weighted mean concentration of a quality variable. One replicate per treatment. (For the number of observations, see Table 32.)

Hydrological year	Treatment	Leaching (kg km^{-2} a^{-1})																
		$L_{N_{tot}}$	$L_{N_{NO_3}}$	$L_{P_{tot}}$	$L_{P_{PO_4}}$	L_K	L_{Ca}	L_{Mg}	$L_{S_{SO_4}}$	L_{Na}	L_{Cl}	L_{Fe}	L_{Mn}	L_{Zn}	L_{Cu}	L_{Ni}	$L_{COD_{Mn}(O_2)}$	L_{SS}
1978—1979	a_L	140	120	2.4	0.50	210	1800	690	800	420	1200	140	2.8	0.18	0.48	0.51	260	2100
	b_L	500	420	14	1.2	700	4700	1700	2300	990	2700	840	11	1.7	2.1	3.4	860	16000
	c_L	190	150	3.0	0.60	360	2800	1000	630	750	2000	420	5.9	0	0.43	0.43	280	2100
	d_L	260	220	2.4	0.56	370	3500	1200	970	350	1600	230	4.0	0.065	0.57	0.29	360	1400
1979—1980	a_L	150	130	1.3	0.39	160	1100	410	800	190	660	81	3.0	1.1	1.4	0.76	220	280
	b_L	190	130	3.2	1.2	240	1600	560	930	250	1000	230	9.2	2.3	0.58	1.2	350	500
	c_L	65	46	1.5	1.3	150	800	310	770	200	770	52	4.8	2.4	0.71	0.92	160	410
	d_L	180	120	5.3	2.4	530	2000	710	1800	350	1300	250	5.0	2.2	1.4	1.4	580	1200
1980—1981	a_L	660	490	14	3.7	420	2500	940	1500	400	780	730	17	1.3	1.1	1.3	990	7100
	b_L	1200	1100	54	15	1100	5200	2800	4700	850	990	4100	69	5.3	5.2	4.1	2000	41000
	c_L	1800	1600	74	19	1900	5200	2000	3100	1200	1200	4400	77	4.6	3.6	4.0	2900	48000
	d_L	680	580	48	13	1600	3400	1900	1300	470	470	3400	59	5.6	3.0	3.0	1400	20000
1981—1982	a_L	240	360	9.7	2.1	270	1400	580	1000	230	500	110	13	0.45	0.48	0.97	380	2600
	b_L	260	520	13	5.4	530	2500	870	1300	390	780	340	24	1.9	0.57	1.5	490	6000
	c_L	170	85	9.4	2.9	330	850	370	1100	150	220	170	9.7	1.1	0.99	0.83	390	4000
	d_L	190	120	8.7	2.5	210	620	190	600	99	170	230	7.7	0.92	0.62	0.67	360	3000

Table 38. Mean annual subdrainage and surface runoff and average annual leaching in the hydrological years 1978—1981 (Nov. 1—Oct. 31) in the Maaninka field. Combined observations (treatments combined). Amount of leaching computed by the total amount of runoff and the flow-weighted mean concentration of a quality variable. (For the number of observations, see Table 35.)

Hydrological year	Runoff component	Runoff (l s^{-1} km^{-2})	Leaching (kg km^{-2} a^{-1})															
		Mq	$L_{N_{tot}}$	$L_{N_{NO_3}}$	$L_{P_{tot}}$	$L_{P_{PO_4}}$	L_K	L_{Ca}	L_{Mg}	$L_{S_{SO_4}}$	L_{Na}	L_{Cl}	L_{Fe}	L_{Mn}	L_{Zn}	L_{Cu}	L_{Ni}	$L_{COD_{Mn}(O_2)}$	L_{SS}
1978—1979	Subdrainage	0.17	68	60	0.33	0.15	53	93	28	38	12	51	4.8	0.19	0.0088	0.068	0.0057	66	21
	Surface	1.3	240	76	8.1	2.5	150	200	81	88	100	170	360	7.3	0.29	0.75	0.15	460	3500
1979—1980	Subdrainage	0.12	37	32	0.26	0.16	40	140	41	49	20	29	0.34	0.11	0.011	0.27	0.041	49	11
	Surface	0.18	17	8.3	0.96	0.38	.	.	.	.	.	17	.	.	.	.	.	55	160
1980—1981	Subdrainage	0.49	540	730	0.81	0.46	200	610	160	170	46	70	7.2	0.31	0.10	0.14	0.078	200	67
	Surface	0.61	67	47	2.7	1.4	79	150	50	61	34	35	55	2.7	0.11	0.27	0.067	200	520

Table 39. Annual total leaching (subdrainage plus surface) and percentage subdrainage leaching of the total in the Liperi field in the four test plots having both subdrainage and surface runoff measured. Principle of calculation as in Table 36.

Hydrological year	Treatment	Total leaching (kg km^{-2} a^{-1}) and percentage subdrainage leaching (%)																			
		$L_{N_{tot}}$		$L_{N_{NO_3}}$		$L_{P_{tot}}$		$L_{P_{PO_4}}$		L_K		L_{Ca}		L_{Mg}		$L_{S_{SO_4}}$		L_{Na}		L_{Cl}	
		kg km^{-2}a^{-1}	%	kg km^{-2}a^{-1}	%	kg km^{-2}a^{-1}	%	kg km^{-2}a^{-1}	%	kg km^{-2}a^{-1}	%	kg km^{-2}a^{-1}	%	kg km^{-2}a^{-1}	%	kg km^{-2}a^{-1}	%	kg km^{-2}a^{-1}	%	kg km^{-2}a^{-1}	%
1978—1979	a_L	1800	92	1500	92	15	84	4.5	89	920	77	14000	87	5200	87	8000	90	2200	81	8100	85
	b_L	2300	78	1900	78	36	61	6.5	82	2600	73	20000	76	7700	78	12000	81	3400	71	10000	73
	c_L	1500	87	1300	88	16	81	4.4	86	1800	80	14000	80	5400	81	4000	84	2500	69	7200	72
	d_L	2700	90	2500	91	12	81	4.2	87	1400	73	13000	73	4800	75	7000	86	1700	79	7000	77
1979—1980	a_L	960	84	700	81	9.6	86	3.9	90	1300	87	8900	88	3300	88	7000	89	1400	86	3500	81
	b_L	2500	92	1700	92	33	90	11	89	1900	88	16000	90	5700	90	11000	92	2300	89	5400	81
	c_L	2000	97	1700	97	19	92	7.5	83	1900	92	14000	94	5500	94	12000	94	2100	90	5000	85
	d_L	1700	89	1200	90	18	71	9.0	73	1500	65	10000	81	4000	82	9000	79	1700	79	4200	69
1980—1981	a_L	6200	89	5700	91	80	83	27	86	5300	92	36000	93	13000	93	21000	93	5000	92	5900	87
	b_L	13000	91	14000	92	140	60	53	72	5500	80	43000	88	14000	80	19000	76	6200	86	4000	75
	c_L	24000	92	23000	93	150	51	46	59	7500	75	49000	89	19000	89	26000	88	6800	82	5900	80
	d_L	6400	89	4200	86	99	52	39	67	5400	70	34000	90	14000	86	20000	94	5200	91	12000	92
1981—1982	a_L	2000	88	1900	81	100	90	23	91	4700	94	27000	95	13000	95	31000	97	4400	95	5500	91
	b_L	3900	93	3800	86	74	82	28	81	4400	88	25000	90	9200	91	23000	94	3800	90	4200	81
	c_L	5700	97	5500	98	110	91	24	88	6000	95	31000	97	14000	97	32000	97	5000	97	4800	95
	d_L	2600	93	2300	95	65	87	17	85	3400	94	22000	97	9900	98	21000	97	3500	97	3400	95

Hydrological year	Treatment	Total leaching (kg km^{-2} a^{-1}) and percentage subdrainage leaching (%)													
		L_{Fe}		L_{Mn}		L_{Zn}		L_{Cu}		L_{Ni}		$L_{COD_{Mn}(O_2)}$		L_{SS}	
		kg km^{-2} a^{-1}	%	kg km^{-2} a^{-1}	%	kg km^{-2} a^{-1}	%	kg km^{-2} a^{-1}	%	kg km^{-2} a^{-1}	%	kg km^{-2} a^{-1}	%	kg km^{-2} a^{-1}	%
1978—1979	a_L	350	60	22	87	1.2	85	3.2	85	5.2	90	2700	90	2300	9
	b_L	1700	50	33	67	2.0	16	4.9	57	6.5	48	3500	75	17000	5
	c_L	600	30	14	58	1.4	100	5.2	92	3.8	89	2000	86	2500	14
	d_L	320	28	9.7	59	0.084	23	2.4	76	3.1	91	2700	86	1700	17
1979—1980	a_L	250	68	37	92	5.8	81	4.6	70	12	94	2200	90	1200	76
	b_L	670	66	59	84	3.8	39	3.4	83	7.7	84	4200	92	3400	85
	c_L	310	83	26	81	6.4	63	4.0	82	8.8	90	3900	93	4500	53
	d_L	430	42	14	65	2.6	16	3.2	56	4.9	71	3700	84	2300	48
1980—1981	a_L	2500	71	180	90	21	93	9.4	88	27	95	8800	89	19000	63
	b_L	7200	43	160	57	14	62	12	58	19	79	9200	78	61000	33
	c_L	7100	38	170	54	22	79	13	73	30	87	11000	73	67000	28
	d_L	4900	31	110	45	11	50	11	71	17	82	11000	87	24000	15
1981—1982	a_L	450	76	240	95	17	99	6.3	92	39	98	4900	92	7500	65
	b_L	720	53	84	71	6.6	71	4.3	87	9.5	84	4300	89	8900	33
	c_L	700	76	140	93	18	94	8.6	88	24	97	5000	93	8400	64
	d_L	430	47	48	84	5.0	82	3.5	82	7.8	91	4200	91	7200	58

Table 40. Percentage spring (March 1—May 31) subdrainage-runoff leaching of the annual subdrainage-runoff leaching in the hydrological years studied in the Liperi field. Four replicates per treatment.

Hydrological year	Treatment	Percentage spring runoff leaching (%)																
		$L_{N_{tot}}$	$L_{N_{NO_3}}$	$L_{P_{tot}}$	$L_{P_{PO_4}}$	L_K	L_{Ca}	L_{Mg}	$L_{S_{SO_4}}$	L_{Na}	L_{Cl}	L_{Fe}	L_{Mn}	L_{Zn}	L_{Cu}	L_{Ni}	$L_{COD_{Mn}(O_2)}$	L_{SS}
1978—1979	a_L	94	92	92	89	88	92	95	91	94	94	95	93	93	93	93	100	.
	b_L	94	94	100	93	93	93	93	88	91	95	100	95	78	93	94	96	.
	c_L	94	100	92	90	94	92	93	95	95	96	100	92	93	93	96	96	.
	d_L	95	94	100	91	92	92	93	95	95	92	100	92	81	95	94	96	.
1979—1980	a_L	60	58	78	76	68	55	57	66	71	56	75	79	48	66	51	70	74
	b_L	49	34	100	87	73	60	55	61	78	64	84	84	56	70	51	79	63
	c_L	39	32	83	81	65	51	51	63	67	57	80	78	49	68	45	69	69
	d_L	60	52	78	78	59	53	53	63	67	54	75	83	40	25	38	70	71
1980—1981	a_L	73	61	45	50	35	38	37	35	33	37	56	28	39	41	36	46	60
	b_L	69	59	53	59	44	50	45	42	47	40	61	35	43	47	41	50	59
	c_L	75	65	48	54	41	54	49	45	48	42	59	36	44	49	48	50	58
	d_L	73	65	53	58	40	41	40	37	38	28	65	35	48	47	41	49	66
1981—1982	a_L	76	79	89	80	54	52	44	34	60	49	84	34	47	70	48	74	57
	b_L	60	58	85	85	53	61	52	30	60	50	100	39	60	77	52	72	100
	c_L	63	63	88	86	64	58	50	31	59	53	100	33	63	81	52	74	80
	d_L	74	72	84	90	58	58	52	27	58	46	100	100	53	95	47	73	92

Table 41. Percentage spring (March 1—May 31) surface-runoff leaching of the annual surface-runoff leaching in the hydrological years studied in the Liperi field. One replicate per treatment.

Hydrological year	Treatment	Percentage spring runoff leaching (%)																
		$L_{N_{tot}}$	$L_{N_{NO_3}}$	$L_{P_{tot}}$	$L_{P_{PO_4}}$	L_K	L_{Ca}	L_{Mg}	$L_{S_{SO_4}}$	L_{Na}	L_{Cl}	L_{Fe}	L_{Mn}	L_{Zn}	L_{Cu}	L_{Ni}	$L_{COD_{Mn}(O_2)}$	L_{SS}
1978—1979	a_L	71	68	100	100	81	89	91	88	81	92	100	89	100	96	96	99	100
	b_L	94	93	100	100	96	98	94	84	95	93	100	100	94	95	97	98	100
	c_L	95	93	100	98	97	100	100	100	97	100	100	98	.	98	98	96	100
	d_L	81	82	100	100	89	97	92	83	89	94	100	95	85	96	97	97	100
1979—1980	a_L	60	61	100	100	69	50	54	50	63	68	81	50	21	23	45	82	100
	b_L	53	41	94	92	75	61	66	75	76	75	83	79	65	91	50	83	96
	c_L	86	85	93	100	87	84	84	70	90	94	94	79	63	44	71	94	98
	d_L	94	92	100	96	96	85	87	95	91	92	96	94	50	93	86	97	100
1980—1981	a_L	82	78	79	76	69	64	68	70	65	73	77	76	67	73	71	75	80
	b_L	83	82	87	80	80	73	82	79	75	80	80	81	81	81	80	85	90
	c_L	94	94	96	95	95	85	85	92	92	92	93	92	91	92	93	93	96
	d_L	91	86	94	85	88	74	84	82	77	85	85	86	86	83	87	86	95
1981—1982	a_L	79	24	93	100	85	69	64	83	87	32	50	23	64	88	94	89	42
	b_L	88	19	92	96	87	64	66	92	87	28	29	28	41	100	87	90	55
	c_L	88	33	87	86	70	65	49	59	87	50	42	63	100	100	100	87	85
	d_L	84	18	93	88	76	74	58	100	93	31	30	29	92	97	100	92	63

3.43 Treatment effects

The Mann-Whitney rank-sum test and latin-square procedure of the analysis of variance were used to test differences in concentrations and leaching rates caused by the various treatments (Tables 42—50, App. 5—8).

3.431 Liperi field

An analysis of the mean (median) concentrations of subdrainage water in the period after land applications gave the following results (Table 42):

1. A statistically significant difference was found between the reference treatment (a_L) and all three sludge treatments (b_L—d_L), as regards total nitrogen, nitrate nitrogen and magnesium. In addition, total phosphorus, orthophosphate phosphorus, potassium, calcium, sodium and conductivity had raised levels in at least two sludge treatments. Treatment with the limed sludge (d_L) had some influence on hydrogen-ion concentrations.
2. Application of sludge on nonfrozen soil (c_L) yielded a higher total nitrogen content than sludge on snow (b_L). The latter treatment (b_L) gave, instead, higher contents of total and phosphate phosphorus and manganese.
3. Application of sludge on nonfrozen soil (c_L) yielded higher concentrations than limed sludge (d_L), regarding several constituents: total nitrogen, nitrate nitrogen, potassium, calcium, magnesium, sodium, zinc and conductivity. Limed sludge, however, gave higher contents of total and phosphate phosphorus.
4. Application of limed sludge on nonfrozen soil (d_L) yielded the lowest contents for several constituents: total and nitrate nitrogen, potassium, calcium, magnesium, sodium and conductivity. Sludge on nonfrozen soil (c_L) gave the highest total and nitrate nitrogen contents. Sludge on snow (b_L) generated the highest contents of total and phosphate phosphorus.

An analysis of the mean concentrations of surface water gave contradictory results: the reference treatment (a_L) could yield higher contents than did the sludge treatments, etc. (Tables 43 and 28). This was a result of the small number of observations on one hand; on the other hand, a certain amount of mixing could not be avoided between the test plots. Because the contribution of surface water was found to be minor as regards total leaching, conclusions on the effects of treatment may be based on subdrainage water. (No further statistical tests were thus made for surface water.)

When subdrainage leaching was studied on a yearly basis, the following results were obtained (Table 44):

1. The effect of sludge treatments is the most profound with regard to nitrogen and conductivity. Duration of the effect is (at least) two years for nitrogen.
2. The differences between the application of sludge on snow (b_L) and sludge on nonfrozen soil (c_L) are not statistically significant.
3. The differences between the application of unlimed (c_L) and limed (d_L) sludge are not statistically significant as regards phosphorus, magnesium and sodium.

Analysis of the treatment effects on subdrainage water was continued on a calendar-year basis by the latin-square procedure which also revealed and eliminated possible row and column effects in the field; several row and column effects could actually be found (Tables 45—48).

Analysis with the flow-weighted annual mean concentrations yielded the following results (Tables 45 and 47):

1. In 1980, the application of sludge on snow (b_L) and on nonfrozen soil (c_L) gave the highest contents of total and nitrate nitrogen (the mutual differences were statistically insignificant). In addition, sludge on snow (b_L) gave the highest concentration of calcium, magnesium and sodium.
2. In 1981, raised levels persisted in the treatments with sludge on snow (b_L) and on nonfrozen soil (c_L) as regards total and nitrate nitrogen, calcium and magnesium (the mutual differences were statistically insignificant).
3. In 1982, raised levels were still found in the two treatments, referred to above, regarding total nitrogen. Nitrate nitrogen contents were also raised compared with those observed in the reference plots.

Analysis with the annual leaching rates gave the following results (Tables 46 and 48):

1. In 1980, the application of sludge on snow (b_L) and on nonfrozen soil (c_L) yielded the highest leaching of total and nitrate nitrogen (the mutual differences were statistically insignificant).
2. In 1981, raised levels of leaching persisted in the two treatments, referred to above, regarding total and nitrate nitrogen and calcium; the highest leaching was caused by the treatment with sludge on nonfrozen soil (c_L). The highest leaching of phosphate phosphorus was observed in treatments with sludge on snow (b_L) and limed sludge on nonfrozen soil (d_L).
3. In 1982, raised levels were still found in

Table 42. Test of the hypothesis on identical locations of the subdrainage-water quantity and quality variable distributions (defined in Table 27) in the Liperi field. Two-sided testing by the Mann-Whitney rank-sum test. Periods (I = before the application of sludge, II = after the application) studied as in Table 26. Four replicates per treatment. Comparison between treatments a_L and b_L.

Variable	Period I				Period II			
	Number of observations		Level of significance$^{1)}$	Conclusion$^{2)}$	Number of observations		Level of significance$^{1)}$	Conclusion$^{2)}$
	a_L	b_L			a_L	b_L		
Q	138	141	0.89	N.S.	631	622	0.97	N.S.
t	138	141	0.96	N.S.	631	622	0.80	N.S.
N_{tot}	79	72	0.86	N.S.	296	293	0.0000	b_L
N_{NO_3}	78	76	0.96	N.S.	192	191	0.0000	b_L
P_{tot}	86	84	0.0058	a_L	296	296	0.0006	b_L
P_{PO_4}	83	79	0.040	a_L	204	203	0.0000	b_L
K	69	66	0.95	N.S.	209	209	0.0002	b_L
Ca	69	66	0.76	N.S.	209	209	0.0001	b_L
Mg	69	66	0.065	N.S.	209	209	0.0000	b_L
S_{SO_4}	12	12	0.71	N.S.	84	84	0.18	N.S.
Na	43	44	0.80	N.S.	194	193	0.0003	b_L
Cl	86	84	0.91	N.S.	192	192	0.94	N.S.
Fe	12	12	0.84	N.S.	84	84	0.35	N.S.
Mn	12	12	0.47	N.S.	84	84	0.38	N.S.
Zn	12	12	0.77	N.S.	80	80	0.16	N.S.
Cu	12	12	0.23	N.S.	80	80	0.84	N.S.
Ni	12	12	0.45	N.S.	80	80	0.94	N.S.
Y_{25}	86	84	0.50	N.S.	296	296	0.0000	b_L
$H^{+3)}$	86	84	0.96	N.S.	296	296	0.56	N.S.
COD_{Mn}	86	84	0.83	N.S.	228	228	0.27	N.S.
SS	8	8	.	.	221	223	0.92	N.S.

1) The probability of committing an error if the hypothesis on identical locations is rejected. The highest permitted risk is 0.05; 2) Notations used: N.S. = the hypothesis on identical locations cannot be rejected, a_L = treatment a_L generates higher values; 3) $H^+ = 10^{-pH}$

Table 42. Continued. Comparison between treatments a_L and c_L.

Variable	Period I				Period II			
	Number of observations		Level of significance$^{1)}$	Conclusion$^{2)}$	Number of observations		Level of significance$^{1)}$	Conclusion$^{2)}$
	a_L	c_L			a_L	c_L		
Q	138	173	0.090	N.S.	631	591	0.97	N.S.
t	138	173	0.30	N.S.	631	591	0.88	N.S.
N_{tot}	79	96	0.57	N.S.	296	276	0.0000	c_L
N_{NO_3}	78	95	0.41	N.S.	192	175	0.0000	c_L
P_{tot}	86	103	0.24	N.S.	296	279	0.95	N.S.
P_{PO_4}	83	99	0.35	N.S.	204	187	0.41	N.S.
K	69	85	0.52	N.S.	209	195	0.0014	c_L
Ca	69	86	0.0023	a_L	209	195	0.46	c_L
Mg	69	86	0.59	N.S.	209	195	0.0000	c_L
S_{SO_4}	12	20	0.71	N.S.	84	75	0.79	N.S.
Na	43	62	0.28	N.S.	194	179	0.025	c_L
Cl	86	103	0.17	N.S.	192	175	0.24	N.S.
Fe	12	20	0.45	N.S.	84	75	0.81	N.S.
Mn	12	20	0.55	N.S.	84	75	0.17	N.S.
Zn	12	20	0.52	N.S.	80	71	0.53	N.S.
Cu	12	20	0.24	N.S.	80	71	0.14	N.S.
Ni	12	20	0.86	N.S.	80	71	0.94	N.S.
Y_{25}	86	104	0.066	N.S.	296	279	0.0004	c_L
H^+	86	104	0.50	N.S.	296	279	0.23	N.S.
COD_{Mn}	86	104	0.99	N.S.	228	211	0.98	N.S.
SS	8	24	.	.	221	205	0.64	N.S.

Table 42. Continued. Comparison between treatments a_L and d_L.

Variable	Period I				Period II			
	Number of observations		Level of significance[1]	Conclusion[2]	Number of observations		Level of significance[1]	Conclusion[2]
	a_L	d_L			a_L	d_L		
Q	138	179	0.26	N.S.	631	594	0.40	N.S.
t	138	179	0.55	N.S.	631	594	0.98	N.S.
N_{tot}	79	89	0.54	N.S.	296	279	0.0000	d_L
N_{NO_3}	78	93	0.58	N.S.	192	176	0.0001	d_L
P_{tot}	86	101	0.90	N.S.	296	280	0.017	d_L
P_{PO_4}	83	97	0.39	N.S.	204	188	0.0007	d_L
K	69	85	0.0027	a_L	209	195	0.0028	a_L
Ca	69	85	0.0041	a_L	209	195	0.10	N.S.
Mg	69	85	0.61	N.S.	209	195	0.0017	d_L
S_{SO_4}	12	19	0.63	N.S.	84	76	0.32	N.S.
Na	43	61	0.19	N.S.	194	179	0.14	N.S.
Cl	86	101	0.46	N.S.	192	176	0.25	N.S.
Fe	12	20	0.76	N.S.	84	76	0.34	N.S.
Mn	12	20	0.91	N.S.	84	76	0.059	N.S.
Zn	12	20	0.46	N.S.	80	72	0.0002	a_L
Cu	12	20	0.010	a_L	80	72	0.0012	a_L
Ni	12	20	0.28	N.S.	80	72	0.098	N.S.
γ_{25}	86	101	0.093	N.S.	296	280	0.12	N.S.
H^+	86	100	0.99	N.S.	296	280	0.0016	a_L
COD_{Mn}	86	101	0.32	N.S.	228	211	0.55	N.S.
SS	8	24	.	.	221	205	0.51	N.S.

Table 42. Continued. Comparison between treatments b_L and c_L.

Variable	Period I				Period II			
	Number of observations		Level of significance[1]	Conclusion[2]	Number of observations		Level of significance[1]	Conclusion[2]
	b_L	c_L			b_L	c_L		
Q	141	173	0.064	N.S.	622	591	0.96	N.S.
t	141	173	0.27	N.S.	622	591	0.93	N.S.
N_{tot}	72	96	0.45	N.S.	293	276	0.018	c_L
N_{NO_3}	76	95	0.48	N.S.	191	175	0.069	N.S.
P_{tot}	84	103	0.10	N.S.	296	279	0.0038	b_L
P_{PO_4}	79	99	0.28	N.S.	203	187	0.0003	b_L
K	66	85	0.69	N.S.	209	195	0.66	N.S.
Ca	66	86	0.014	b_L	209	195	0.14	N.S.
Mg	66	86	0.052	N.S.	209	195	0.69	N.S.
S_{SO_4}	12	20	0.65	N.S.	84	75	0.30	N.S.
Na	44	62	0.18	N.S.	193	179	0.25	N.S.
Cl	84	103	0.13	N.S.	192	175	0.23	N.S.
Fe	12	20	0.68	N.S.	84	75	0.54	N.S.
Mn	12	20	0.92	N.S.	84	75	0.028	b_L
Zn	12	20	0.36	N.S.	80	71	0.47	N.S.
Cu	12	20	0.75	N.S.	80	71	0.22	N.S.
Ni	12	20	0.74	N.S.	80	71	0.97	N.S.
γ_{25}	84	104	0.024	b_L	296	279	0.41	N.S.
H^+	84	104	0.39	N.S.	296	279	0.068	N.S.
COD_{Mn}	84	104	0.86	N.S.	228	211	0.26	N.S.
SS	8	24	.	.	223	205	0.55	N.S.

Table 42. Continued. Comparison between treatments d_L and c_L.

Variable	Period I				Period II			
	Number of observations		Level of significance[1)]	Conclusion[2)]	Number of observations		Level of significance[1)]	Conclusion[2)]
	d_L	c_L			d_L	c_L		
Q	179	173	0.50	N.S.	594	591	0.38	N.S.
t	179	173	0.63	N.S.	594	591	0.86	N.S.
N_{tot}	89	96	0.23	N.S.	279	276	0.0000	c_L
N_{NO_3}	93	95	0.16	N.S.	176	175	0.0000	c_L
P_{tot}	101	103	0.16	N.S.	280	279	0.042	d_L
P_{PO_4}	97	99	0.052	N.S.	188	187	0.031	d_L
K	85	85	0.020	c_L	195	195	0.0000	c_L
Ca	85	86	0.84	N.S.	195	195	0.0008	c_L
Mg	85	86	0.47	N.S.	195	195	0.0037	c_L
S_{SO_4}	19	20	0.82	N.S.	76	75	0.23	N.S.
Na	61	62	0.77	N.S.	179	179	0.0006	c_L
Cl	101	103	0.42	N.S.	176	175	0.95	N.S.
Fe	20	20	0.50	N.S.	76	75	0.42	N.S.
Mn	20	20	0.52	N.S.	76	75	0.63	N.S.
Zn	20	20	0.25	N.S.	72	71	0.0033	c_L
Cu	20	20	0.20	N.S.	72	71	0.077	N.S.
Ni	20	20	0.52	N.S.	72	71	0.11	N.S.
γ_{25}	101	104	0.89	N.S.	280	279	0.0000	c_L
H^+	100	104	0.50	N.S.	280	279	0.0000	c_L
COD_{Mn}	101	104	0.25	N.S.	211	211	0.53	N.S.
SS	24	24	0.59	N.S.	205	205	0.27	N.S.

Table 43. Test of the hypothesis on identical locations of the surface-water quantity and quality variable distributions (defined in Table 28) in the Liperi field. Comparison between treatments a_L and $b_L - d_L$ (b_L, c_L and d_L as a group). One replicate per treatment. Otherwise, legend as in Table 42.

Variable	Period I				Period II			
	Number of observations		Level of significance[1)]	Conclusion[2)]	Number of observations		Level of significance[1)]	Conclusion[2)]
	a_L	$b_L - d_L$			a_L	$b_L - d_L$		
Q	32	109	0.97	N.S.	136	384	0.017	a_L
t	32	109	0.55	N.S.	136	384	0.92	N.S.
N_{tot}	13	57	0.32	N.S.	66	174	0.42	N.S.
N_{NO_3}	17	61	0.023	a_L	40	108	0.88	N.S.
P_{tot}	18	64	0.11	N.S.	65	174	0.014	$b_L - d_L$
P_{PO_4}	17	60	0.012	$b_L - d_L$	43	117	0.0003	$b_L - d_L$
K	14	51	0.22	N.S.	43	117	0.0003	$b_L - d_L$
Ca	14	51	0.65	N.S.	43	117	0.068	N.S.
Mg	14	51	0.50	N.S.	43	117	0.36	N.S.
S_{SO_4}	3	14	.	.	18	46	0.35	N.S.
Na	10	39	0.84	N.S.	39	106	0.22	N.S.
Cl	18	63	0.52	N.S.	40	107	0.94	N.S.
Fe	3	14	.	.	18	46	0.63	N.S.
Mn	3	14	.	.	18	46	0.029	a_L
Zn	2	12	.	.	15	44	0.47	N.S.
Cu	2	12	.	.	15	44	0.76	N.S.
Ni	2	12	.	.	15	44	0.53	N.S.
γ_{25}	18	64	0.85	N.S.	66	174	0.52	N.S.
H^+	18	64	0.16	N.S.	66	174	0.0030	a_L
COD_{Mn}	18	62	0.97	N.S.	50	135	0.16	N.S.
SS	14	50	0.19	N.S.	55	144	0.10	N.S.
TS	14	50	0.81	N.S.	39	106	0.034	$b_L - d_L$
ASH	14	50	0.66	N.S.	39	106	0.011	$b_L - d_L$

Table 43. Continued. Comparison between treatments b_L and c_L.

Variable	Period I				Period II			
	Number of observations		Level of significance[1]	Conclusion[2]	Number of observations		Level of significance[1]	Conclusion[2]
	b_L	c_L			b_L	c_L		
Q	35	38	0.97	N.S.	141	130	0.45	N.S.
t	35	38	0.58	N.S.	141	130	0.75	N.S.
N_{tot}	16	19	0.0046	b_L	64	60	0.0033	b_L
N_{NO_3}	18	21	0.010	b_L	41	36	0.084	N.S.
P_{tot}	19	22	0.57	N.S.	64	60	0.48	N.S.
P_{PO_4}	18	21	0.30	N.S.	44	39	0.41	N.S.
K	15	17	0.97	N.S.	45	39	0.034	b_L
Ca	15	17	0.37	N.S.	45	39	0.033	b_L
Mg	15	17	0.62	N.S.	45	39	0.30	N.S.
S_{SO_4}	4	4	.	.	18	15	0.041	b_L
Na	11	13	0.28	N.S.	41	35	0.026	c_L
Cl	19	22	0.27	N.S.	41	35	0.73	N.S.
Fe	4	4	.	.	18	15	0.87	N.S.
Mn	4	4	.	.	18	15	0.13	N.S.
Zn	3	4	.	.	17	14	0.18	N.S.
Cu	3	4	.	.	17	14	0.75	N.S.
Ni	3	4	.	.	17	14	0.18	N.S.
γ_{25}	19	22	0.37	N.S.	64	60	0.086	N.S.
H^+	19	22	0.35	N.S.	64	60	0.14	N.S.
COD_{Mn}	19	21	0.0012	b_L	50	45	0.0023	b_L
SS	15	17	0.43	N.S.	55	48	0.53	N.S.
TS	15	17	0.47	N.S.	41	34	0.0076	b_L
ASH	15	17	0.56	N.S.	41	34	0.013	b_L

Table 43. Continued. Comparison between treatments d_L and c_L.

Variable	Period I				Period II			
	Number of observations		Level of significance[1]	Conclusion[2]	Number of observations		Level of significance[1]	Conclusion[2]
	d_L	c_L			d_L	c_L		
Q	36	38	0.50	N.S.	113	130	0.032	c_L
t	36	38	0.91	N.S.	113	130	0.97	N.S.
N_{tot}	22	19	0.14	N.S.	50	60	0.0014	d_L
N_{NO_3}	22	21	0.27	N.S.	31	36	0.0031	d_L
P_{tot}	23	22	0.72	N.S.	50	60	0.078	N.S.
P_{PO_4}	21	21	0.54	N.S.	34	39	0.0011	d_L
K	19	17	0.19	N.S.	33	39	0.024	d_L
Ca	19	17	0.090	N.S.	33	39	0.0083	d_L
Mg	19	17	0.44	N.S.	33	39	0.14	N.S.
S_{SO_4}	6	4	.	.	13	15	0.60	N.S.
Na	15	13	0.024	c_L	30	35	0.045	c_L
Cl	22	22	0.57	N.S.	31	35	0.25	N.S.
Fe	6	4	.	.	13	15	0.46	N.S.
Mn	6	4	.	.	13	15	0.45	N.S.
Zn	5	4	.	.	13	14	0.41	N.S.
Cu	5	4	.	.	13	14	0.27	N.S.
Ni	5	4	.	.	13	14	0.72	N.S.
γ_{25}	23	22	0.20	N.S.	50	60	0.32	N.S.
H^+	23	22	0.96	N.S.	50	60	0.024	c_L
COD_{Mn}	22	21	0.19	N.S.	40	45	0.085	N.S.
SS	18	17	0.40	N.S.	41	48	0.61	N.S.
TS	18	17	0.29	N.S.	31	34	0.098	N.S.
ASH	18	17	0.28	N.S.	31	34	0.093	N.S.

Table 44. Test of the hypothesis on identical locations of the subdrainage runoff and leaching distributions in the hydrological years studied in the Liperi field. Two-sided testing by the Mann — Whitney rank-sum test. Otherwise, legend as in Table 42.

Hydrological year	Treatments tested	Test for variable											
		Mq				$L_{N_{tot}}$				$L_{N_{NO_3}}$			
		Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion
1978—1979	a_L vs. b_L	103	106	0.82	N.S.	59	51	0.69	N.S.	55	51	0.79	N.S.
	a_L vs. c_L	103	102	0.87	N.S.	59	58	0.81	N.S.	55	54	0.77	N.S.
	a_L vs. d_L	103	105	0.50	N.S.	59	52	0.96	N.S.	55	52	0.98	N.S.
	b_L vs. c_L	106	102	1.00	N.S.	51	58	0.58	N.S.	51	54	0.66	N.S.
	d_L vs. c_L	105	102	0.56	N.S.	52	58	0.82	N.S.	52	54	0.75	N.S.
1979—1980	a_L vs. b_L	138	130	0.65	N.S.	68	69	0.21	N.S.	71	73	0.43	N.S.
	a_L vs. c_L	138	137	0.97	N.S.	68	69	0.46	N.S.	71	72	0.66	N.S.
	a_L vs. d_L	138	141	0.74	N.S.	68	69	0.88	N.S.	71	73	0.91	N.S.
	b_L vs. c_L	130	137	0.71	N.S.	69	69	0.66	N.S.	73	72	0.84	N.S.
	d_L vs. c_L	141	137	0.70	N.S.	69	69	0.54	N.S.	73	72	0.68	N.S.
1980—1981	a_L vs. b_L	296	296	0.32	N.S.	136	133	0.0000	b_L	72	71	0.0000	b_L
	a_L vs. c_L	296	295	0.61	N.S.	136	133	0.0000	c_L	72	72	0.0000	c_L
	a_L vs. d_L	296	295	0.43	N.S.	136	135	0.032	d_L	72	72	0.0018	d_L
	b_L vs. c_L	296	295	0.72	N.S.	133	133	0.18	N.S.	71	72	0.10	N.S.
	d_L vs. c_L	295	295	0.75	N.S.	135	133	0.0000	c_L	72	72	0.0000	c_L
1981—1982	a_L vs. b_L	200	199	0.84	N.S.	88	88	0.0026	b_L	48	48	0.0000	b_L
	a_L vs. c_L	200	198	0.27	N.S.	88	88	0.0003	c_L	48	48	0.0000	c_L
	a_L vs. d_L	200	200	0.97	N.S.	88	88	0.23	N.S.	48	48	0.080	N.S.
	b_L vs. c_L	199	198	0.42	N.S.	88	88	0.38	N.S.	48	38	0.36	N.S.
	d_L vs. c_L	200	198	0.34	N.S.	88	88	0.016	c_L	48	48	0.0009	c_L
Summer 1980—spring 1982[1]	a_L vs. b_L	536	531	0.70	N.S.	240	237	0.0000	b_L	136	135	0.0000	b_L
	a_L vs. c_L	536	533	0.85	N.S.	240	236	0.0000	c_L	136	135	0.0000	c_L
	a_L vs. d_L	536	534	0.71	N.S.	240	239	0.039	d_L	136	136	0.0048	d_L
	b_L vs. c_L	531	533	0.64	N.S.	237	236	0.13	N.S.	135	135	0.092	N.S.
	d_L vs. c_L	534	533	0.60	N.S.	239	236	0.0000	c_L	136	135	0.0000	c_L

[1] June 1, 1980—May 31, 1982

Table 44. Continued.

Hydrological year	Treatments tested	Test for variable											
		$L_{P_{tot}}$				$L_{P_{PO4}}$				L_K			
		Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion
1978—1979	a_L vs. b_L	63	59	0.82	N.S.	63	58	0.78	N.S.	46	41	0.97	N.S.
	a_L vs. c_L	63	62	0.57	N.S.	63	62	0.37	N.S.	46	44	0.86	N.S.
	a_L vs. d_L	63	60	0.97	N.S.	63	60	0.98	N.S.	46	44	0.36	N.S.
	b_L vs. c_L	59	62	0.73	N.S.	58	62	0.48	N.S.	41	44	0.86	N.S.
	d_L vs. c_L	60	62	0.60	N.S.	60	62	0.39	N.S.	44	44	0.49	N.S.
1979—1980	a_L vs. b_L	71	73	0.97	N.S.	68	68	0.92	N.S.	71	72	0.99	N.S.
	a_L vs. c_L	71	72	0.65	N.S.	68	68	0.66	N.S.	71	72	0.71	N.S.
	a_L vs. d_L	71	73	0.64	N.S.	68	69	0.78	N.S.	71	73	0.28	N.S.
	b_L vs. c_L	73	72	0.68	N.S.	68	68	0.73	N.S.	72	72	0.66	N.S.
	d_L vs. c_L	73	72	0.97	N.S.	69	68	0.87	N.S.	73	72	0.18	N.S.
1980—1981	a_L vs. b_L	136	136	0.84	N.S.	72	72	0.94	N.S.	118	118	0.73	N.S.
	a_L vs. c_L	136	136	0.50	N.S.	72	72	0.38	N.S.	118	120	0.30	N.S.
	a_L vs. d_L	136	136	0.89	N.S.	72	72	0.99	N.S.	118	119	0.095	N.S.
	b_L vs. c_L	136	136	0.42	N.S.	72	72	0.30	N.S.	118	120	0.26	N.S.
	d_L vs. c_L	136	136	0.44	N.S.	72	72	0.35	N.S.	119	120	0.024	c_L
1981—1982	a_L vs. b_L	88	88	0.27	N.S.	60	60	0.11	N.S.	35	36	0.60	N.S.
	a_L vs. c_L	88	88	0.43	N.S.	60	60	0.31	N.S.	35	36	0.25	N.S.
	a_L vs. d_L	88	88	0.43	N.S.	60	60	0.35	N.S.	35	36	0.69	N.S.
	b_L vs. c_L	88	88	0.81	N.S.	60	60	0.50	N.S.	36	36	0.58	N.S.
	d_L vs. c_L	88	88	0.96	N.S.	60	60	0.85	N.S.	36	36	0.14	N.S.
Summer 1980—spring 1982	a_L vs. b_L	240	240	0.48	N.S.	148	147	0.27	N.S.	173	174	0.89	N.S.
	a_L vs. c_L	240	239	0.95	N.S.	148	147	0.97	N.S.	173	175	0.13	N.S.
	a_L vs. d_L	240	240	0.71	N.S.	148	148	0.61	N.S.	173	175	0.20	N.S.
	b_L vs. c_L	240	239	0.47	N.S.	147	147	0.28	N.S.	174	175	0.24	N.S.
	d_L vs. c_L	240	239	0.67	N.S.	148	147	0.61	N.S.	175	175	0.013	c_L

Table 44. Continued.

Hydrological year	Treatments tested	Test for variable											
		L_{Ca}				L_{Mg}				$L_{S_{SO4}}$			
		Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion
1978—1979	a_L vs. b_L	46	41	0.96	N.S.	46	41	0.77	N.S.	8	8	.	.
	a_L vs. c_L	46	44	0.58	N.S.	46	44	0.90	N.S.	8	8	.	.
	a_L vs. d_L	46	44	0.35	N.S.	46	44	0.62	N.S.	8	7	.	.
	b_L vs. c_L	41	44	0.54	N.S.	41	44	0.64	N.S.	8	8	.	.
	d_L vs. c_L	44	44	0.75	N.S.	44	44	0.80	N.S.	7	8	.	.
1979—1980	a_L vs. b_L	71	72	0.96	N.S.	71	72	0.81	N.S.	16	16	0.76	N.S.
	a_L vs. c_L	71	73	0.93	N.S.	71	73	0.87	N.S.	16	15	0.87	N.S.
	a_L vs. d_L	71	73	0.33	N.S.	71	73	0.71	N.S.	16	16	0.73	N.S.
	b_L vs. c_L	72	73	0.94	N.S.	72	73	0.96	N.S.	16	15	0.94	N.S.
	d_L vs. c_L	73	73	0.43	N.S.	73	73	0.57	N.S.	16	15	0.55	N.S.
1980—1981	a_L vs. b_L	118	118	0.80	N.S.	118	118	0.48	N.S.	36	36	0.92	N.S.
	a_L vs. c_L	118	120	0.83	N.S.	118	120	0.21	N.S.	36	36	0.68	N.S.
	a_L vs. d_L	118	119	0.24	N.S.	118	119	0.83	N.S.	36	36	0.83	N.S.
	b_L vs. c_L	118	120	0.95	N.S.	118	120	0.52	N.S.	36	36	0.75	N.S.
	d_L vs. c_L	119	120	0.16	N.S.	119	120	0.26	N.S.	36	36	0.54	N.S.
1981—1982	a_L vs. b_L	35	36	0.72	N.S.	35	36	0.63	N.S.	28	28	0.74	N.S.
	a_L vs. c_L	35	36	0.56	N.S.	35	36	0.35	N.S.	28	28	0.65	N.S.
	a_L vs. d_L	35	36	0.86	N.S.	35	36	0.65	N.S.	28	28	0.90	N.S.
	b_L vs. c_L	36	36	0.94	N.S.	36	36	0.71	N.S.	28	28	0.87	N.S.
	d_L vs. c_L	36	36	0.42	N.S.	36	36	0.57	N.S.	28	28	0.65	N.S.
Summer 1980—spring 1982	a_L vs. b_L	173	174	0.56	N.S.	173	174	0.32	N.S.	64	64	0.99	N.S.
	a_L vs. c_L	173	175	0.44	N.S.	173	175	0.10	N.S.	64	63	0.69	N.S.
	a_L vs. d_L	173	175	0.40	N.S.	173	175	0.66	N.S.	64	64	0.70	N.S.
	b_L vs. c_L	174	175	0.80	N.S.	174	175	0.48	N.S.	64	63	0.62	N.S.
	d_L vs. c_L	175	175	0.12	N.S.	175	175	0.26	N.S.	64	63	0.40	N.S.

Table 44. Continued.

Hydrological year	Treatments tested	Test for variable											
		L_{Na}				L_{Cl}				L_{Fe}			
		Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion
1978—1979	a_L vs. b_L	20	19	0.52	N.S.	63	59	0.93	N.S.	8	8	.	.
	a_L vs. c_L	20	20	0.98	N.S.	63	62	0.67	N.S.	8	8	.	.
	a_L vs. d_L	20	20	0.83	N.S.	63	60	0.90	N.S.	8	8	.	.
	b_L vs. c_L	19	20	0.50	N.S.	59	62	0.58	N.S.	8	8	.	.
	d_L vs. c_L	20	20	0.81	N.S.	60	62	0.87	N.S.	8	8	.	.
1979—1980	a_L vs. b_L	63	64	0.72	N.S.	71	73	0.92	N.S.	16	16	1.00	N.S.
	a_L vs. c_L	63	65	0.75	N.S.	71	72	0.86	N.S.	16	15	0.64	N.S.
	a_L vs. d_L	63	65	0.28	N.S.	71	73	0.47	N.S.	16	16	0.91	N.S.
	b_L vs. c_L	64	65	0.95	N.S.	73	72	0.97	N.S.	16	15	0.64	N.S.
	d_L vs. c_L	65	65	0.47	N.S.	73	72	0.59	N.S.	16	15	0.64	N.S.
1980—1981	a_L vs. b_L	118	118	0.74	N.S.	72	72	0.65	N.S.	36	36	0.95	N.S.
	a_L vs. c_L	118	120	0.72	N.S.	72	72	0.63	N.S.	36	36	0.73	N.S.
	a_L vs. d_L	118	119	0.35	N.S.	72	72	0.48	N.S.	36	36	0.96	N.S.
	b_L vs. c_L	118	120	0.55	N.S.	72	72	0.99	N.S.	36	36	0.59	N.S.
	d_L vs. c_L	119	120	0.25	N.S.	72	72	0.84	N.S.	36	36	0.74	N.S.
1981—1982	a_L vs. b_L	28	28	0.92	N.S.	48	48	0.80	N.S.	28	28	0.29	N.S.
	a_L vs. c_L	28	28	0.54	N.S.	48	48	0.78	N.S.	28	28	0.81	N.S.
	a_L vs. d_L	28	28	0.73	N.S.	48	48	0.87	N.S.	28	28	0.50	N.S.
	b_L vs. c_L	28	28	0.74	N.S.	48	48	0.92	N.S.	28	28	0.54	N.S.
	d_L vs. c_L	28	28	0.35	N.S.	48	48	0.66	N.S.	28	28	0.76	N.S.
Summer 1980— spring 1982	a_L vs. b_L	158	158	0.79	N.S.	136	136	0.90	N.S.	64	64	0.42	N.S.
	a_L vs. c_L	158	159	0.60	N.S.	136	135	0.98	N.S.	64	63	0.98	N.S.
	a_L vs. d_L	158	159	0.34	N.S.	136	136	0.56	N.S.	64	64	0.69	N.S.
	b_L vs. c_L	158	159	0.49	N.S.	136	135	0.93	N.S.	64	63	0.43	N.S.
	d_L vs. c_L	159	159	0.18	N.S.	136	135	0.61	N.S.	64	63	0.62	N.S.

Table 44. Continued.

Hydrological year	Treatments tested	Test for variable											
		L_{Mn}				L_{Zn}				L_{Cu}			
		Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion
1978—1979	a_L vs. b_L	8	8	.	.	8	8	.	.	8	8	.	.
	a_L vs. c_L	8	8	.	.	8	8	.	.	8	8	.	.
	a_L vs. d_L	8	8	.	.	8	8	.	.	8	8	.	.
	b_L vs. c_L	8	8	.	.	8	8	.	.	8	8	.	.
	d_L vs. c_L	8	8	.	.	8	8	.	.	8	8	.	.
1979—1980	a_L vs. b_L	16	16	0.62	N.S.	20	20	0.45	N.S.	20	20	0.57	N.S.
	a_L vs. c_L	16	15	0.87	N.S.	20	19	0.87	N.S.	20	19	0.74	N.S.
	a_L vs. d_L	16	16	0.76	N.S.	20	20	0.34	N.S.	20	20	0.50	N.S.
	b_L vs. c_L	16	15	0.66	N.S.	20	19	0.61	N.S.	20	19	0.71	N.S.
	d_L vs. c_L	16	15	0.64	N.S.	20	19	0.45	N.S.	20	19	0.80	N.S.
1980—1981	a_L vs. b_L	36	36	0.76	N.S.	36	36	0.57	N.S.	36	36	0.84	N.S.
	a_L vs. c_L	36	36	0.90	N.S.	36	36	0.90	N.S.	36	36	0.96	N.S.
	a_L vs. d_L	36	36	0.39	N.S.	36	36	0.059	N.S.	36	36	0.53	N.S.
	b_L vs. c_L	36	36	0.65	N.S.	36	36	0.44	N.S.	36	36	0.80	N.S.
	d_L vs. c_L	36	36	0.59	N.S.	36	36	0.057	N.S.	36	36	0.52	N.S.
1981—1982	a_L vs. b_L	28	28	0.90	N.S.	20	20	0.83	N.S.	20	20	0.94	N.S.
	a_L vs. c_L	28	28	0.74	N.S.	20	20	0.98	N.S.	20	20	0.87	N.S.
	a_L vs. d_L	28	28	0.54	N.S.	20	20	0.27	N.S.	20	20	0.50	N.S.
	b_L vs. c_L	28	28	0.58	N.S.	20	20	0.87	N.S.	20	20	0.87	N.S.
	d_L vs. c_L	28	28	0.90	N.S.	20	20	0.30	N.S.	20	20	0.56	N.S.
Summer 1980— spring 1982	a_L vs. b_L	64	64	0.84	N.S.	64	64	0.65	N.S.	64	64	0.72	N.S.
	a_L vs. c_L	64	63	0.89	N.S.	64	63	0.82	N.S.	64	63	0.97	N.S.
	a_L vs. d_L	64	64	0.31	N.S.	64	64	0.028	a_L	64	64	0.25	N.S.
	b_L vs. c_L	64	63	0.65	N.S.	64	63	0.39	N.S.	64	63	0.71	N.S.
	d_L vs. c_L	64	63	0.55	N.S.	64	63	0.030	c_L	64	63	0.32	N.S.

Table 44. Continued.

Hydrological year	Treatments tested	Test for variable											
		L_{Ni}				γ_{25}				H^+			
		Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion
1978—1979	a_L vs. b_L	8	8	.	.	63	59	0.51	N.S.	63	59	0.98	N.S.
	a_L vs. c_L	8	8	.	.	63	62	0.48	N.S.	63	62	0.67	N.S.
	a_L vs. d_L	8	8	.	.	63	60	0.78	N.S.	63	59	0.98	N.S.
	b_L vs. c_L	8	8	.	.	59	62	0.22	N.S.	59	62	0.64	N.S.
	d_L vs. c_L	8	8	.	.	60	62	0.72	N.S.	59	62	0.69	N.S.
1979—1980	a_L vs. b_L	20	20	0.89	N.S.	71	73	0.081	N.S.	71	73	0.66	N.S.
	a_L vs. c_L	20	19	0.98	N.S.	71	73	0.87	N.S.	71	73	0.59	N.S.
	a_L vs. d_L	20	20	0.47	N.S.	71	73	0.28	N.S.	71	73	0.20	N.S.
	b_L vs. c_L	20	19	0.96	N.S.	73	73	0.28	N.S.	73	73	0.83	N.S.
	d_L vs. c_L	20	19	0.47	N.S.	73	73	0.21	N.S.	73	73	0.097	N.S.
1980—1981	a_L vs. b_L	36	36	0.90	N.S.	136	136	0.0000	b_L	136	136	0.31	N.S.
	a_L vs. c_L	36	36	0.70	N.S.	136	136	0.0000	c_L	136	136	0.47	N.S.
	a_L vs. d_L	36	36	0.58	N.S.	136	136	0.13	N.S.	136	136	0.0017	a_L
	b_L vs. c_L	36	36	0.77	N.S.	136	136	0.69	N.S.	136	136	0.084	N.S.
	d_L vs. c_L	36	36	0.30	N.S.	136	136	0.0000	c_L	136	136	0.0001	c_L
1981—1982	a_L vs. b_L	20	20	0.68	N.S.	88	88	0.10	N.S.	88	88	0.70	N.S.
	a_L vs. c_L	20	20	0.98	N.S.	88	88	0.38	N.S.	88	88	0.89	N.S.
	a_L vs. d_L	20	20	0.39	N.S.	88	88	0.18	N.S.	88	88	0.23	N.S.
	b_L vs. c_L	20	20	0.62	N.S.	88	88	0.43	N.S.	88	88	0.75	N.S.
	d_L vs. c_L	20	20	0.53	N.S.	88	88	0.089	N.S.	88	88	0.21	N.S.
Summer 1980—spring 1982	a_L vs. b_L	64	64	0.88	N.S.	240	240	0.0000	b_L	240	240	0.55	N.S.
	a_L vs. c_L	64	63	0.75	N.S.	240	239	0.0002	c_L	240	239	0.54	N.S.
	a_L vs. d_L	64	64	0.31	N.S.	240	240	0.14	N.S.	240	240	0.0035	a_L
	b_L vs. c_L	64	63	0.86	N.S.	240	239	0.55	N.S.	240	239	0.21	N.S.
	d_L vs. c_L	64	63	0.21	N.S.	240	239	0.0000	c_L	240	239	0.0004	c_L

Table 44. Continued.

Hydrological year	Treatments tested	Test for variable							
		$L_{COD_{Mn}}$				L_{SS}			
		Number of observations		Level of significance	Conclusion	Number of observations		Level of significance	Conclusion
1978—1979	a_L vs. b_L	63	59	0.95	N.S.	4	4	.	.
	a_L vs. c_L	63	62	0.65	N.S.	4	4	.	.
	a_L vs. d_L	63	60	0.93	N.S.	4	4	.	.
	b_L vs. c_L	59	62	0.62	N.S.	4	4	.	.
	d_L vs. c_L	60	62	0.69	N.S.	4	4	.	.
1979—1980	a_L vs. b_L	71	73	0.85	N.S.	50	51	0.67	N.S.
	a_L vs. c_L	71	73	0.70	N.S.	50	49	0.35	N.S.
	a_L vs. d_L	71	73	0.68	N.S.	50	50	0.95	N.S.
	b_L vs. c_L	73	73	0.87	N.S.	51	49	0.59	N.S.
	d_L vs. c_L	73	73	0.99	N.S.	50	49	0.27	N.S.
1980—1981	a_L vs. b_L	72	72	0.55	N.S.	135	136	0.98	N.S.
	a_L vs. c_L	72	72	0.53	N.S.	135	136	0.52	N.S.
	a_L vs. d_L	72	71	0.96	N.S.	135	136	0.87	N.S.
	b_L vs. c_L	72	72	0.93	N.S.	136	136	0.53	N.S.
	d_L vs. c_L	71	72	0.55	N.S.	136	136	0.43	N.S.
1981—1982	a_L vs. b_L	84	84	0.58	N.S.	32	32	0.48	N.S.
	a_L vs. c_L	84	84	0.48	N.S.	32	32	0.77	N.S.
	a_L vs. d_L	84	84	0.72	N.S.	32	31	0.66	N.S.
	b_L vs. c_L	84	84	0.80	N.S.	32	32	0.58	N.S.
	d_L vs. c_L	84	84	0.72	N.S.	31	32	0.73	N.S.
Summer 1980—spring 1982	a_L vs. b_L	172	172	0.99	N.S.	187	188	0.96	N.S.
	a_L vs. c_L	172	171	0.83	N.S.	187	187	0.45	N.S.
	a_L vs. d_L	172	171	0.83	N.S.	187	187	0.72	N.S.
	b_L vs. c_L	172	171	0.84	N.S.	188	187	0.36	N.S.
	d_L vs. c_L	171	171	0.99	N.S.	187	187	0.25	N.S.

Table 45. Analysis of variance (latin square) for the flow-weighted annual (Jan. 1—Dec. 31) mean concentrations of subdrainage water in the Liperi field. Sources of variation: C = column factor, R = row factor, T = treatment. Degrees of freedom: 3 for C, R and T, and 6 for the residual (error). Level of significance = tail probability of the F distribution (the probability of committing an error if the hypothesis on non-significant effect is rejected). Value underlined indicates a significant effect of a factor (the highest risk allowed is 0.05). Concentrations given in App. 5.

Variable	Analysis of variance statistics																							
	Year 1979						Year 1980						Year 1981						Year 1982					
	F ratio			Level of significance			F ratio			Level of significance			F ratio			Level of significance			F ratio			Level of significance		
	C	R	T	C	R	T	C	R	T	C	R	T	C	R	T	C	R	T	C	R	T	C	R	T
N_{tot}	1.46	0.45	0.75	0.32	0.73	0.56	0.96	1.14	15.05	0.47	0.41	0.0034	1.24	1.29	23.97	0.37	0.36	0.0010	0.77	0.63	9.66	0.55	0.62	0.010
N_{NO_3}	1.70	0.37	0.76	0.27	0.78	0.55	1.10	1.14	15.56	0.42	0.41	0.0031	1.19	1.38	24.41	0.39	0.34	0.0009	0.03	0.49	6.34	0.99	0.70	0.027
P_{tot}	0.52	0.23	0.24	0.68	0.87	0.86	1.24	1.59	2.71	0.38	0.29	0.14	3.41	0.65	1.29	0.094	0.61	0.36	13.26	1.73	1.84	0.0047	0.26	0.24
P_{PO_4}	1.41	0.47	0.44	0.33	0.71	0.73	2.98	2.54	0.81	0.12	0.15	0.54	2.32	0.95	3.34	0.18	0.47	0.097	8.68	1.23	3.19	0.013	0.38	0.11
K	2.77	6.74	1.46	0.13	0.024	0.32	0.63	3.10	1.14	0.62	0.11	0.41	1.43	3.59	2.93	0.32	0.086	0.12	0.78	4.58	1.30	0.55	0.054	0.36
Ca	2.37	38.31	1.58	0.17	0.0003	0.29	0.95	11.50	7.12	0.47	0.0067	0.021	11.15	35.65	50.62	0.0072	0.0003	0.0001	1.20	40.74	5.30	0.39	0.0002	0.040
Mg	1.02	9.08	0.47	0.45	0.012	0.72	0.70	3.61	8.34	0.58	0.085	0.015	1.59	0.88	9.47	0.29	0.50	0.011	0.18	2.26	1.60	0.91	0.18	0.29
S_{SO_4}	4.78	16.68	1.73	0.049	0.0026	0.26	0.73	8.04	0.61	0.57	0.016	0.63	1.92	7.72	3.79	0.23	0.018	0.078	0.33	24.07	2.16	0.80	0.0010	0.19
Na	1.24	105.11	1.90	0.38	0.0000	0.23	0.47	57.60	4.79	0.72	0.0001	0.049	3.30	28.99	5.57	0.099	0.0006	0.036	0.96	37.58	2.05	0.47	0.0003	0.21
Cl	0.18	75.94	0.19	0.91	0.0000	0.90	1.04	86.72	2.46	0.44	0.0000	0.16	0.66	14.51	0.11	0.61	0.0037	0.95	0.45	101.51	1.15	0.73	0.0000	0.40
Fe	0.40	1.20	0.43	0.76	0.39	0.74	1.12	0.18	0.96	0.41	0.91	0.47	2.11	0.85	0.37	0.20	0.52	0.78	1.21	1.33	1.06	0.38	0.35	0.43
Mn	0.63	7.35	1.10	0.62	0.020	0.42	0.54	10.23	0.95	0.67	0.0090	0.47	1.26	73.24	2.41	0.37	0.0000	0.17	4.85	56.07	1.25	0.048	0.0001	0.37
Zn	0.62	0.45	0.29	0.63	0.73	0.83	0.40	1.21	0.04	0.76	0.38	0.99	0.25	1.76	1.24	0.86	0.26	0.38	0.27	2.03	0.67	0.84	0.21	0.60
Cu	1.80	1.53	0.36	0.25	0.30	0.78	0.30	1.28	0.30	0.83	0.36	0.83	3.30	13.87	3.99	0.099	0.0042	0.070	0.51	7.05	0.07	0.69	0.022	0.97
Ni	1.53	5.10	0.83	0.30	0.043	0.52	0.40	1.95	0.09	0.76	0.22	0.96	0.48	5.19	2.45	0.71	0.042	0.16	0.13	3.06	0.36	0.94	0.11	0.78
COD_{Mn}	0.50	3.80	0.89	0.70	0.077	0.50	0.20	0.66	2.27	0.89	0.61	0.18	4.45	19.23	1.03	0.057	0.0018	0.44	1.80	4.12	0.70	0.25	0.066	0.59
SS	3.52	4.03	0.27	0.089	0.069	0.85	2.22	0.59	0.81	0.19	0.64	0.53	1.61	0.11	0.46	0.28	0.95	0.72	3.21	1.55	0.31	0.10	0.30	0.82

Table 46. Analysis of variance (latin square) for the mean annual (Jan. 1—Dec. 31) subdrainage runoff and leaching in the Liperi field. Legend as in Table 45. Rates of runoff and leaching given in App. 7.

Variable	Analysis of variance statistics																							
	Year 1979						Year 1980						Year 1981						Year 1982					
	F ratio			Level of significance			F ratio			Level of significance			F ratio			Level of significance			F ratio			Level of significance		
	C	R	T	C	R	T	C	R	T	C	R	T	C	R	T	C	R	T	C	R	T	C	R	T
Mq	1.82	2.01	0.36	0.24	0.21	0.78	1.24	1.71	0.48	0.37	0.26	0.71	4.71	2.12	1.50	0.051	0.20	0.31	5.57	8.11	4.09	0.036	0.016	0.067
$L_{N_{tot}}$	0.72	1.18	0.64	0.58	0.39	0.62	0.45	0.42	6.60	0.73	0.75	0.025	0.83	4.45	137.86	0.52	0.057	0.0000	1.74	7.51	43.31	0.26	0.019	0.0002
$L_{N_{NO_3}}$	0.52	1.28	0.83	0.68	0.36	0.52	0.66	0.32	6.73	0.61	0.81	0.024	1.58	4.14	139.90	0.29	0.066	0.0000	1.12	3.27	14.23	0.41	0.10	0.0039
$L_{P_{tot}}$	1.21	0.87	0.07	0.38	0.51	0.97	0.75	1.85	0.98	0.56	0.24	0.46	11.04	0.60	3.23	0.0074	0.64	0.10	22.07	7.64	4.52	0.0012	0.018	0.055
$L_{P_{PO_4}}$	2.08	1.17	0.21	0.20	0.40	0.89	1.13	2.45	0.20	0.41	0.16	0.90	8.48	2.00	4.97	0.014	0.22	0.046	20.27	2.83	6.56	0.0015	0.13	0.025
L_K	0.41	1.56	1.01	0.75	0.29	0.45	0.89	2.22	1.57	0.50	0.19	0.29	1.12	0.76	2.58	0.41	0.55	0.15	0.35	1.48	1.72	0.79	0.31	0.26
L_{Ca}	0.74	1.83	0.55	0.56	0.24	0.67	1.56	1.72	2.12	0.29	0.26	0.20	2.72	1.33	8.06	0.14	0.35	0.016	2.16	2.28	2.33	0.19	0.18	0.17
L_{Mg}	1.70	1.15	0.86	0.27	0.40	0.51	1.28	0.87	1.18	0.36	0.51	0.39	6.47	1.50	4.99	0.026	0.31	0.045	2.83	2.47	2.45	0.13	0.16	0.16
$L_{S_{SO_4}}$	1.29	6.82	1.85	0.36	0.023	0.24	2.07	2.69	0.40	0.21	0.14	0.76	1.71	1.05	1.43	0.26	0.44	0.32	1.44	3.32	1.89	0.32	0.098	0.23
L_{Na}	0.68	7.39	0.69	0.60	0.019	0.59	4.04	34.10	2.45	0.069	0.0004	0.16	0.40	7.84	3.43	0.76	0.017	0.093	0.46	5.50	1.33	0.72	0.037	0.35
L_{Cl}	1.52	7.75	0.30	0.30	0.017	0.82	2.53	46.06	0.71	0.15	0.0002	0.58	0.72	6.69	0.71	0.58	0.024	0.58	1.74	45.89	1.45	0.26	0.0002	0.32
L_{Fe}	0.52	1.21	0.50	0.68	0.38	0.70	1.71	0.59	0.63	0.26	0.65	0.62	1.81	1.93	0.14	0.25	0.23	0.93	1.46	1.08	1.12	0.32	0.43	0.41
L_{Mn}	0.18	3.72	1.01	0.91	0.080	0.45	0.56	11.98	1.15	0.66	0.0060	0.40	30.70	160.64	1.02	0.0005	0.0000	0.45	9.59	34.52	2.27	0.011	0.0004	0.18
L_{Zn}	0.67	0.33	0.30	0.60	0.80	0.83	0.55	0.92	0.06	0.67	0.49	0.98	0.90	1.49	0.82	0.49	0.31	0.53	1.02	1.23	0.78	0.45	0.38	0.55
L_{Cu}	1.51	1.40	0.33	0.30	0.33	0.80	0.40	0.93	0.62	0.76	0.48	0.63	2.94	3.23	1.26	0.12	0.10	0.37	4.83	4.00	1.19	0.049	0.070	0.39
L_{Ni}	0.41	3.00	0.94	0.75	0.12	0.48	0.35	1.68	0.10	0.79	0.27	0.95	0.49	2.77	2.80	0.70	0.13	0.13	0.16	1.46	0.17	0.92	0.32	0.91
$L_{COD_{Mn}}$	2.60	0.93	0.56	0.15	0.48	0.66	0.29	0.41	0.09	0.83	0.75	0.97	4.29	2.19	1.74	0.061	0.19	0.26	10.85	5.55	10.85	0.0078	0.036	0.0077
L_{SS}	2.17	3.17	0.53	0.19	0.11	0.68	2.05	1.07	0.60	0.21	0.43	0.64	2.53	0.83	0.34	0.15	0.52	0.80	3.36	0.71	0.45	0.096	0.58	0.73

Table 47. Significant differences caused by treatments in the flow-weighted annual (Jan. 1—Dec. 31) mean concentrations of subdrainage water in the Liperi field. t values (two — sided testing) for 6 degrees of freedom: at 5 % level 2.447, at 1 % level 3.707, at 0.1 % level 5.959. (See Table 45.)

Year	Variable	Treatment mean (mg l^{-1})				Standard error of mean (mg l^{-1})	Significant difference (mg l^{-1}) between two means at level			Conclusion1)
		a_L	b_L	c_L	d_L		0.05	0.01	0.001	
1980	N_{tot}	5.0	13	11	6.6	1.0	3.4	5.2	8.4	$b_L>a_L$ (0.01); $c_L>a_L$(0.01); $b_L>d_L$ (0.01); $c_L>d_L$ (0.05)
	N_{NO_3}	3.9	9.8	9.8	5.3	0.81	2.8	4.2	6.8	$b_L>a_L$ (0.01); $c_L>a_L$ (0.01); $b_L>d_L$ (0.01); $c_L>d_L$ (0.01)
	Ca	49	66	51	47	3.0	10	16	25	$b_L>a_L$ (0.01); $b_L>c_L$ (0.05); $b_L>d_L$ (0.01)
	Mg	16	22	17	17	0.94	3.3	4.9	7.9	$b_L>a_L$ (0.01); $b_L>c_L$ (0.01); $b_L>d_L$ (0.01)
	Na	8.6	11	8.4	8.3	0.50	1.7	2.6	4.2	$b_L>a_L$ (0.05); $b_L>c_L$ (0.05); $b_L>d_L$ (0.01)
1981	N_{tot}	7.6	22	29	9.2	2.1	7.3	11	18	$b_L>a_L$ (0.01); $c_L>a_L$ (0.001); $b_L>d_L$ (0.01); $c_L>d_L$ (0.001)
	N_{NO_3}	8.5	22	29	8.3	2.1	7.3	11	18	$b_L>a_L$ (0.01); $c_L>a_L$ (0.001); $b_L>d_L$ (0.01); $c_L>d_L$ (0.001)
	Ca	52	62	61	44	1.3	4.6	7.0	11	$b_L>a_L$ (0.01); $c_L>a_L$ (0.01); $a_L>d_L$ (0.01); $b_L>d_L$ (0.001); $c_L>d_L$ (0.001)
	Mg	17	20	20	16	0.72	2.5	3.8	6.1	$b_L>a_L$ (0.05); $c_L>a_L$ (0.05); $b_L>d_L$ (0.01); $c_L>d_L$ (0.01)
	Na	7.8	9.2	9.5	6.6	0.67	2.3	3.5	5.7	$b_L>d_L$ (0.05); $c_L>d_L$ (0.05)
1982	N_{tot}	3.5	6.1	6.5	4.5	0.47	1.6	2.5	4.0	$b_L>a_L$ (0.01); $c_L>a_L$ (0.01); $b_L>d_L$ (0.05); $c_L>d_L$ (0.05)
	N_{NO_3}	2.3	5.1	5.2	3.4	0.57	2.0	3.0	4.8	$b_L>a_L$ (0.05); $c_L>a_L$ (0.05)
	Ca	48	51	46	44	1.6	5.5	8.3	13	$b_L>d_L$ (0.05)

1) Notation $b_L>a_L$ (0.01) shows that treatment mean b_L is bigger than mean a_L at the level of significance of 0.01 (1 %)

Table 48. Significant differences caused by treatments in the annual (Jan. 1—Dec. 31) subdrainage leaching in the Liperi field. Legend as in Table 47. (See Table 46.)

Year	Variable	Treatment mean (kg km^{-2} a^{-1})				Standard error of mean (kg km^{-2} a^{-1})	Significant difference (kg km^{-2} a^{-1}) between two means at level			Conclusion
		a_L	b_L	c_L	d_L		0.05	0.01	0.001	
1980	$L_{N_{tot}}$	910	2 100	2 000	1 100	240	830	1 300	2 000	$b_L>a_L$ (0.05); $c_L>a_L$ (0.05); $b_L>d_L$ (0.05); $c_L>d_L$ (0.05)
	$L_{N_{NO_3}}$	710	1 600	1 800	900	200	710	1 200	1 700	$b_L>a_L$ (0.05); $c_L>a_L$ (0.05); $c_L>d_L$ (0.05)
1981	$L_{N_{tot}}$	5 500	16 000	25 000	8 000	730	2 500	3 900	6 200	$b_L>a_L$ (0.001); $c_L>a_L$ (0.001); $d_L>a_L$ (0.05); $c_L>b_L$ (0.001); $b_L>d_L$ (0.001); $c_L>d_L$ (0.001)
	$L_{N_{NO_3}}$	6 100	17 000	25 000	7 100	730	2 500	3 900	6 200	$b_L>a_L$ (0.001); $c_L>a_L$ (0.001); $c_L>b_L$ (0.001); $b_L>d_L$ (0.001); $c_L>d_L$ (0.001)
	$L_{P_{PO_4}}$	25	49	40	45	4.8	17	25	40	$b_L>a_L$ (0.05); $d_L>a_L$ (0.05)
	L_{Ca}	37 000	47 000	53 000	38 000	2 600	9 100	14 000	22 000	$b_L>a_L$ (0.05); $c_L>a_L$ (0.01); $c_L>d_L$ (0.01)
	L_{Mg}	12 000	15 000	17 000	14 000	970	3 400	5 100	8 200	$c_L>a_L$ (0.05)
1982	$L_{N_{tot}}$	1 600	3 300	4 000	2 500	150	530	810	1 300	$b_L>a_L$ (0.001); $c_L>a_L$ (0.001); $d_L>a_L$ (0.01); $c_L>b_L$ (0.05); $b_L>d_L$ (0.05); $c_L>d_L$ (0.001)
	$L_{N_{NO_3}}$	1 100	2 800	3 200	1 900	250	860	1 300	2 100	$b_L>a_L$ (0.01); $c_L>a_L$ (0.01); $b_L>d_L$ (0.05); $c_L>d_L$ (0.01)
	$L_{P_{PO_4}}$	13	27	26	25	2.5	8.7	13	21	$b_L>a_L$ (0.01); $c_L>a_L$ (0.05); $d_L>a_L$ (0.05)
	$L_{COD_{Mn}}$	3 600	4 400	5 000	4 700	180	640	960	1 500	$b_L>a_L$ (0.05); $c_L>a_L$ (0.01); $d_L>a_L$ (0.01)

Table 49. Test of the hypothesis on identical locations of selected subdrainage-water quantity and quality variable distributions (Table 29) in the period of March 31, 1980—June 8, 1982 in the Maaninka field. Two-sided testing by the Mann-Whitney rank-sum test. (Treatments b_M, c_M and d_M as a group in the test versus treatment a_M.)

Variable	Treatments tested		Number of observations		Level of significance	Conclusion[1]
Q	a_M	$b_M - d_M$	13	69	0.16	N.S.
	b_M	d_M	22	35	0.37	N.S.
	c_M	d_M	12	35	0.49	N.S.
N_{tot}	a_M	$b_M - d_M$	9	43	0.64	N.S.
	b_M	d_M	14	22	0.82	N.S.
	c_M	d_M	7	22	0.0001	c_M
N_{NH_4}	a_M	$b_M - d_M$	7	50	0.73	N.S.
	b_M	d_M	16	26	0.29	N.S.
	c_M	d_M	8	26	0.87	N.S.
N_{NO_3}	a_M	$b_M - d_M$	7	41	0.30	N.S.
	b_M	d_M	13	20	0.90	N.S.
	c_M	d_M	8	20	0.0014	c_M
P_{tot}	a_M	$b_M - d_M$	8	52	0.033	$b_M - d_M$
	b_M	d_M	17	27	0.039	d_M
	c_M	d_M	8	27	0.014	d_M
P_{PO_4}	a_M	$b_M - d_M$	7	48	0.22	N.S.
	b_M	d_M	16	25	0.0017	d_M
	c_M	d_M	7	25	0.0058	d_M
Cl	a_M	$b_M - d_M$	6	49	0.91	N.S.
	b_M	d_M	17	25	0.10	N.S.
	c_M	d_M	7	25	0.57	N.S.
γ_{25}	a_M	$b_M - d_M$	6	51	0.22	N.S.
	b_M	d_M	17	26	0.022	b_M
	c_M	d_M	8	26	0.0001	c_M
$H^{+2)}$	a_M	$b_M - d_M$	6	51	0.069	N.S.
	b_M	d_M	17	26	0.71	N.S.
	c_M	d_M	8	26	0.013	c_M
COD_{Mn}	a_M	$b_M - d_M$	6	43	0.23	N.S.
	b_M	d_M	14	22	0.060	N.S.
	c_M	d_M	7	22	0.15	N.S.

1) As in Table 42; 2) $H^+ = 10^{-pH}$

Table 50. Test of the hypothesis on identical locations of selected surface-water quantity and quality variable distributions (Table 30) in the period of March 31, 1980—June 8, 1982 in the Maaninka field. Two-sided testing by the Mann-Whitney rank-sum test. Legend as in Table 49.

Variable	Treatments tested		Number of observations		Level of significance	Conclusion
Q	b_M	d_M	12	12	0.53	N.S.
	c_M	d_M	14	12	0.33	N.S.
N_{tot}	b_M	d_M	9	8	0.29	N.S.
	c_M	d_M	9	8	0.21	N.S.
N_{NH_4}	b_M	d_M	10	8	0.13	N.S.
	c_M	d_M	10	8	0.37	N.S.
P_{tot}	b_M	d_M	10	8	0.083	N.S.
	c_M	d_M	9	8	0.012	c_M
P_{PO_4}	b_M	d_M	10	8	0.0005	b_M
	c_M	d_M	9	8	0.0005	c_M
Cl	b_M	d_M	10	7	0.28	N.S.
	c_M	d_M	9	7	0.37	N.S.
γ_{25}	b_M	d_M	10	8	0.083	N.S.
	c_M	d_M	10	8	0.25	N.S.
H^+	b_M	d_M	10	8	0.56	N.S.
	c_M	d_M	10	8	0.62	N.S.
COD_{Mn}	b_M	d_M	10	7	0.56	N.S.
	c_M	d_M	10	7	0.38	N.S.

treatments with sludge on snow (b_L) and sludge on nonfrozen soil (c_L) in the case of total and nitrate nitrogen. Raised levels of leaching were observed in all sludge treatments (b_L—d_L) as regards total (and nitrate) nitrogen, phosphate phosphorus and organic matter, compared with reference treatment (a_L).

The various analyses of the effects of the different sludge treatments in the Liperi field can be summarized as the following main findings:

1. The treatments had the most profound effect on nitrogen leaching and on the conductivity of runoff waters.
2. The duration of treatment effects was (at least) two years for nitrogen. (Brink (1971) (Ch. 1.31) states two years for nitrogen and one year for phosphorus.)
3. The application of limed sludge on nonfrozen soil caused, in general, the lowest leaching among the three studied sludge treatments.
4. Application of sludge on snow raised the content of ammonium nitrogen in runoff waters for some period. In the long run, applications on snow and on nonfrozen soil yielded equal nitrogen leaching.

Because of varying sludge characteristics the amounts of some constituents, spread in the various treatments, differed to some extent (Table 7); especially, a smaller amount of nitrogen, potassium, copper and nickel was applied in the treatment d_L (limed sludge on nonfrozen soil).

The smaller amount of nitrogen contained in the limed sludge may have corresponded to plant needs better than the amount in the other treatments, resulting in low leaching. The amount of nitrogen has however been adequate and the time of application favourable because the crop yield was as good as in the other treatments.

Leaching of nitrogen corresponds to the storage of mineral nitrogen in soil especially well (Table 18).

3.432 Maaninka field

The small number of observations hampered the analysis of the effects of treatment in the Maaninka field. Thus, only those constituents were statistically studied for which there were at least about ten observations per treatment; the conclusions are nevertheless preliminary.

In subdrainage water (Tables 49 and 29), sewage sludge applied on nonfrozen soil (c_M) generated the highest content for total and nitrate nitrogen and conductivity (also calcium, magnesium, sulphate sulphur and sodium). Cow slurry on nonfrozen soil (d_M) seemed to cause the highest phosphorus contents; one explanation is, however, a variation in soil properties between the test plots in analysis and not an effect of treatment.

In surface water (Tables 50 and 30), cow slurry spread on nonfrozen soil (d_M) caused the lowest phosphorus contents. (It also gave the lowest figures for nitrogen, chloride and conductivity, although the differences were not statistically significant.)

The amount of nitrogen, spread in treatment with sewage sludge (c_M), was much higher than in the other treatments (Table 8); this explains the highest crop yield in the first year in this treatment (Table 16).

3.44 Correlations

Spearman's rank correlation coefficients were computed to analyse the dependence of various constituent concentrations on runoff volume (Q) and suspended solids content (SS) (Tables 51—54).

A growing runoff volume was, in general, found to increase the concentration of a constituent in the following cases: total phosphorus, iron, organic matter and suspended solids. A decrease was observed in the following concentrations: calcium, sulphate, sodium, chloride, conductivity, total solids and ash.

The positive correlation of phosphorus, iron and organic matter (COD_{Mn}) with suspended solids refers to their attachment to solids.

3.5 Quality of ground water

Because of the varying properties of soil in the Maaninka field, ground water was not detected in all installed pipes (see Fig. 5). The pipes under analysis here are G 3 (treatment a_M), G 9 (a_M), G 2 (b_M), G 10 (b_M) and G 4 (c_M). Handling of samples was changed during the test; the figures from the calibration period and the period after treatments are thus not directly comparable. An improperly installed slurry store in the immediate vicinity of the field probably had an effect on ground-water quality during the experiment (Fig. 17); also, the variation in the calibration period between the sampling points was wide. Thus the impact of the treatments cannot be analysed accurately. A further problem was the small number of observations (Tables 55—56) which allows only preliminary conclusions.

In the period after the treatments (Table 55), the median concentrations of nitrate nitrogen ranged from 0.031 to 6.3 mg $l^{-1}N_{NO_3}$ (0.14 to 28

Table 51. Correlation of the water volume (Q) with quality variable contents (concentrations) in the Liperi field. Spearman's rank correlation coefficient. Combined observations during the periods defined in Table 26. Notations: * = 0.05 level of significance; ** = 0.01 level of significance; *** = 0.001 level of significance. Two-sided test.

Variable	Period	Number of observations (n) and value of Spearman's coefficient (ρ) in			
		Subdrainage water		Surface water	
		n	ρ	n	ρ
N_{tot}	I	336	0.306***	70	0.060
	II	1 144	0.031	240	0.046
N_{NO_3}	I	342	0.417***	78	0.033
	II	734	- 0.045	148	0.049
P_{tot}	I	374	0.192***	82	0.287**
	II	1 151	0.539***	239	0.404***
P_{PO_4}	I	358	- 0.474***	77	0.032
	II	782	0.211***	160	0.144
K	I	305	- 0.399***	65	- 0.170
	II	808	- 0.238***	160	- 0.027
Ca	I	306	- 0.162**	65	- 0.238
	II	808	- 0.360***	160	- 0.421***
Mg	I	306	- 0.318***	65	- 0.175
	II	808	- 0.561***	160	- 0.497***
S_{SO_4}	I	63	- 0.800***	17	- 0.637**
	II	319	- 0.678***	64	- 0.254*
Na	I	210	- 0.486***	49	- 0.492***
	II	745	- 0.402***	145	- 0.336***
Cl	I	374	0.053	81	- 0.013
	II	735	- 0.303***	147	-0.164*
Fe	I	64	0.858***	17	0.559*
	II	319	0.735***	64	0.341**
Mn	I	64	- 0.111	17	- 0.222
	II	319	- 0.067	64	0.102
Zn	I	64	- 0.442***	14	- 0.506
	II	303	- 0.323***	59	- 0.392**
Cu	I	64	- 0.133	14	0.157
	II	303	0.170**	59	0.322*
Ni	I	64	-0.532***	14	-0.267
	II	303	-0.431***	59	-0.113
γ_{25}	I	375	- 0.320***	82	- 0.351**
	II	1 151	- 0.493***	240	- 0.394***
H^{+} 1)	I	374	0.411***	82	0.293**
	II	1 151	- 0.259***	240	0.679***
COD_{Mn}	I	375	0.510***	80	0.190
	II	878	0.607***	185	0.471***
SS	I	64	0.483***	64	0.276*
	II	854	0.575***	199	0.447***
TS	I	0	.	64	- 0.297**
	II	0	.	145	- 0.214**
ASH	I	0	.	64	- 0.349**
	II	0	.	145	- 0.287***

1) $H^{+} = 10^{-pH}$

Table 52. Correlation of the water volume (Q) with quality variable contents (concentrations) in the Maaninka field. Combined observations during the periods defined in Table 29. Otherwise, legend as in Table 51.

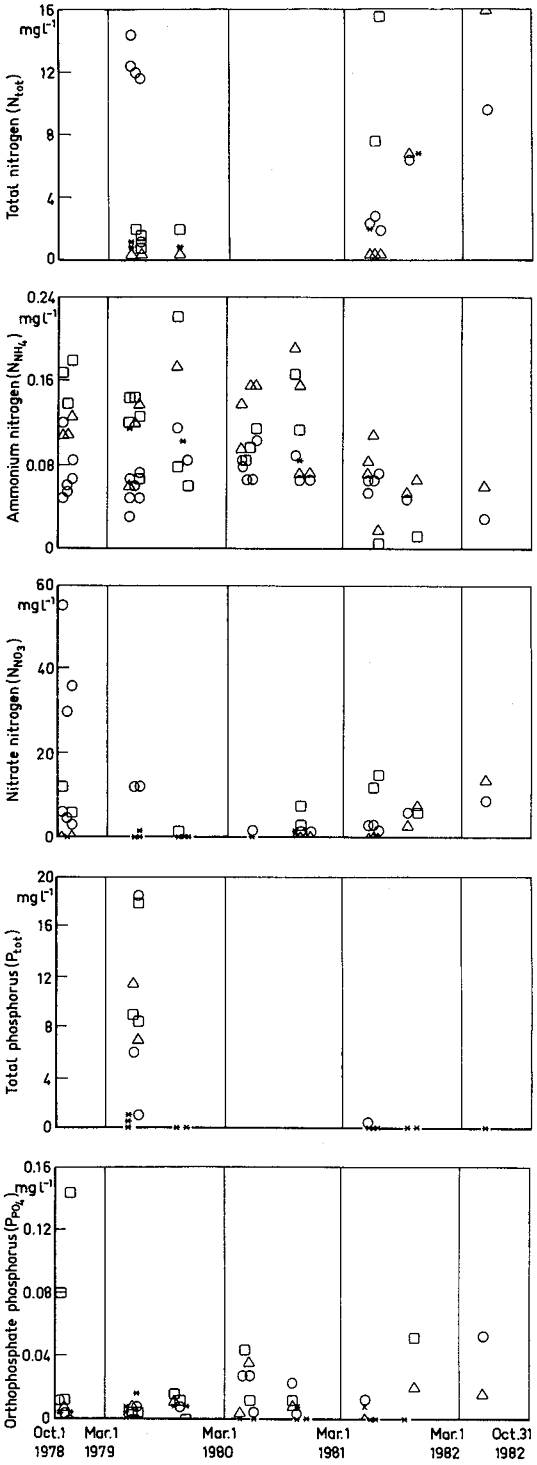
Variable	Period	Number of observations (n) and value of Spearman's coefficient (ρ) in			
		Subdrainage water		Surface water	
		n	ρ	n	ρ
N_{tot}	I	28	- 0.187	9	- 0.050
	II	48	0.216	26	- 0.101
N_{NO_3}	I	19	- 0.337	6	- 0.257
	II	44	0.217	22	0.175
P_{tot}	I	28	0.234	9	0.033
	II	56	0.125	27	- 0.306
P_{PO_4}	I	30	0.405*	9	0.427
	II	51	0.347*	27	- 0.488**
K	I	11	0.351	6	- 0.543
	II	18	0.083	7	- 0.595
Ca	I	11	- 0.018	6	0.314
	II	18	0.031	7	- 0.829*
Mg	I	11	- 0.296	6	0.290
	II	18	0.020	7	- 0.536
S_{SO_4}	I	6	0.203	6	0.257
	II	19	- 0.252	6	- 0.886*
Na	I	11	- 0.347	6	- 0.543
	II	18	- 0.156	7	- 0.829*
Cl	I	27	- 0.635***	9	- 0.083
	II	51	- 0.488***	26	- 0.452*
Fe	I	7	- 0.250	6	- 0.086
	II	23	- 0.095	9	- 0.300
Mn	I	7	- 0.250	6	0.200
	II	17	- 0.076	6	- 0.086
Zn	I	6	- 0.986***	6	- 0.377
	II	15	- 0.097	6	0.771
Cu	I	6	- 0.870*	6	0.029
	II	15	- 0.124	6	0.795
Ni	I	6	- 0.185	6	0.414
	II	15	- 0.049	6	0.530
γ_{25}	I	31	- 0.402*	9	- 0.583
	II	53	- 0.240	28	- 0.422*
H^+	I	31	0.557**	9	0.673*
	II	53	0.513***	28	0.630***
COD_{Mn}	I	28	- 0.067	9	- 0.167
	II	48	- 0.158	27	- 0.068
SS	I	10	0.413	9	- 0.167
	II	27	- 0.029	17	- 0.596*
TS	I	10	- 0.382	9	- 0.367
	II	26	- 0.507**	16	- 0.727**
ASH	I	10	-0.442	9	- 0.383
	II	26	- 0.142***	17	- 0.731***

Table 53. Correlation of the suspended solids (SS) content (concentration) with other quality variable contents in the Liperi field. Legend as in Table 51.

Variable	Period	Number of observations (n) and value of Spearman's coefficient (ρ) in			
		Subdrainage water		Surface water	
		n	ρ	n	ρ
N_{tot}	I	64	0.656***	58	-0.351**
	II	847	0.138***	199	-0.177*
N_{NO_3}	I	63	0.633***	64	-0.344**
	II	581	0.129**	141	-0.191*
P_{tot}	I	64	0.342**	64	0.635***
	II	854	0.709***	199	0.858***
P_{PO_4}	I	64	-0.379**	60	0.353**
	II	581	0.454***	145	0.685***
K	I	63	-0.307*	56	-0.185
	II	719	-0.009	154	0.189*
Ca	I	64	-0.171	56	-0.292*
	II	719	-0.282***	154	-0.600***
Mg	I	64	-0.058	56	-0.212
	II	719	-0.450***	154	-0.554***
S_{SO_4}	I	47	-0.321*	17	-0.520*
	II	318	-0.618***	61	-0.470***
Na	I	64	-0.398**	49	-0.309*
	II	672	-0.241***	142	-0.529***
Cl	I	64	0.074	64	-0.314*
	II	582	-0.059	141	-0.453***
Fe	I	48	0.785***	17	0.856***
	II	318	0.859***	61	0.867***
Mn	I	48	-0.159	17	0.095
	II	318	-0.074	61	0.210
Zn	I	48	-0.466***	14	-0.158
	II	286	-0.236***	58	-0.075
Cu	I	48	0.147	14	0.172
	II	286	0.383***	58	0.709***
Ni	I	48	-0.503***	14	0.191
	II	302	-0.456***	58	-0.122
γ_{25}	I	64	-0.255*	64	-0.526***
	II	854	-0.296***	199	-0.663***
H^+	I	63	-0.061	64	0.223
	II	854	-0.346***	199	0.229**
COD_{Mn}	I	64	0.729***	64	0.112
	II	581	0.748***	145	0.702***
TS	I	0	.	64	-0.238
	II	0	.	141	-0.331***
ASH	I	0	.	64	-0.264*
	II	0	.	141	-0.330***

Table 54. Correlation of the suspended solids (SS) content (concentration) with other quality variable contents in the Maaninka field. Legend as in Table 52.

Variable	Period	Number of observations (n) and value of Spearman's coefficient (ρ) in			
		Subdrainage water		Surface water	
		n	ρ	n	ρ
N_{tot}	I	10	- 0.353	9	0.400
	II	19	- 0.238	15	- 0.050
N_{NO_3}	I	10	- 0.365	6	0.829*
	II	18	- 0.501*	13	- 0.423
P_{tot}	I	10	0.845**	9	0.550
	II	27	0.535**	16	0.715**
P_{PO_4}	I	10	0.735*	9	0.226
	II	27	0.475*	16	0.806***
K	I	5	- 0.200	6	0.657
	II	8	- 0.277	4	0.400
Ca	I	5	- 0.400	6	- 0.086
	II	8	0.347	4	1.000***
Mg	I	5	- 0.300	6	0.319
	II	8	0.419	4	1.000***
S_{SO_4}	I	5	- 0.205	6	- 0.371
	II	1	.	0	.
Na	I	5	0.300	6	0.714
	II	8	0.386	4	1.000***
Cl	I	10	- 0.693*	9	- 0.017
	II	27	0.310	17	0.474
Fe	I	5	0.900*	6	1.000***
	II	5	0.400	3	0.500
Mn	I	5	0.900*	6	0.714
	II	1	.	0	.
Zn	I	5	- 0.051	6	0.812*
	II	5	0.949*	3	0.500
Cu	I	5	0.154	6	0.618
	II	5	- 0.205	3	0.866
Ni	I	5	0.527	6	0.621
	II	5	0.580	3	- 0.866
γ_{25}	I	10	- 0.777**	9	0.267
	II	27	- 0.068	17	- 0.047
H^+	I	10	0.475	9	- 0.060
	II	27	0.068	17	- 0.511*
COD_{Mn}	I	10	- 0.183	9	- 0.283
	II	27	- 0.373	17	- 0.267
TS	I	0	.	0	.
	II	0	.	0	.
ASH	I	0	.	0	.
	II	0	.	0	.



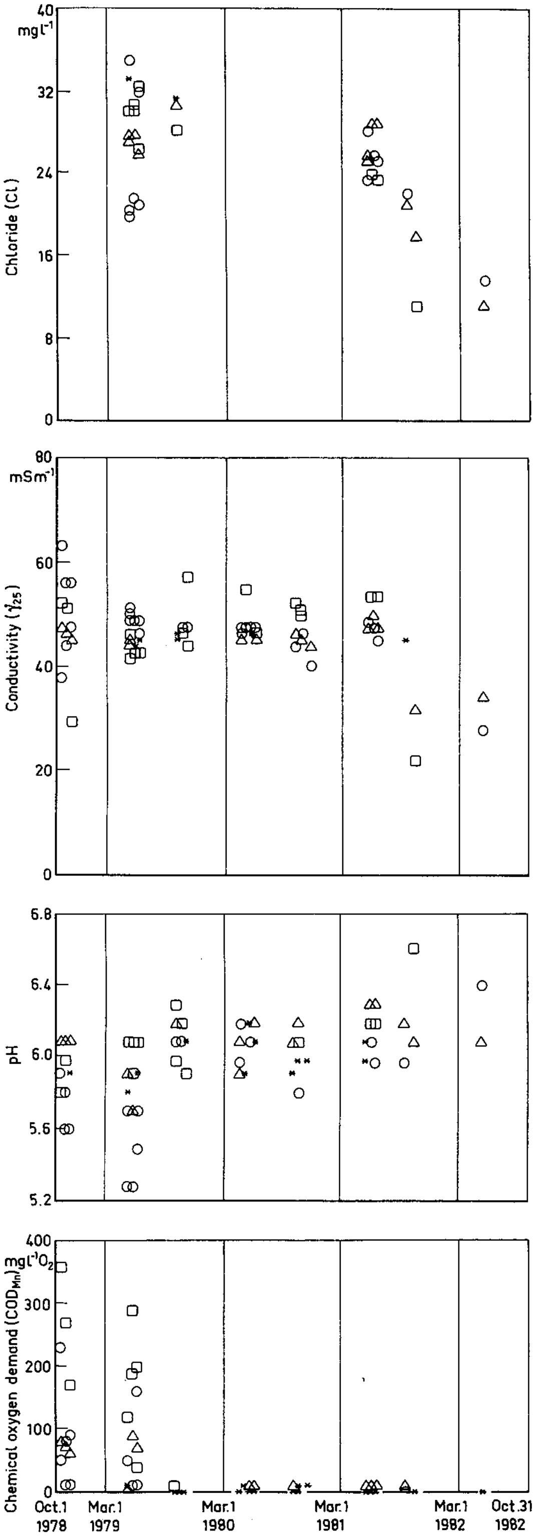


Fig. 17. Temporal variation of selected quality variables of ground water in the Maaninka field. Legend as in Fig. 15.

Table 55. Properties of the distributions of ground-water quality variables in the Maaninka field. Legend as in Table 29. (No observations for treatment d_M.)

Variable	Unit	Period	Number of observations in treatment			Values of statistics in different treatments														
						min			m			$\bar{x}$			$s/\bar{x}$			max		
			a_M	b_M	c_M	a_M	b_M	c_M	a_M	b_M	c_M	a_M	b_M	c_M	a_M	b_M	c_M	a_M	b_M	c_M
N_{tot}	mg l^{-1}	I	8	9	5	0.65	0.41	0.29	6.3	1.0	0.34	6.8	1.1	0.39	0.93	0.50	0.27	14	1.8	0.56
		II	6	3	7	2.0	6.8	0.27	2.6	7.5	2.0	4.2	9.9	2.0	0.72	0.49	1.2	9.5	15	16
N_{NH_4}	mg l^{-1}	I	16	14	8	0.030	0.061	0.059	0.065	0.13	0.12	0.073	0.13	0.12	0.37	0.35	0.28	0.12	0.22	0.18
		II	15	8	15	0.033	0.007	0.016	0.067	0.090	0.085	0.069	0.085	0.10	0.25	0.64	0.48	0.099	0.17	0.19
N_{NO_2}	mg l^{-1}	I	16	14	8	0.005	0.002	0.002	0.010	0.011	0.005	0.010	0.012	0.005	0.47	0.52	0.50	0.019	0.026	0.010
		II	15	9	15	0.003	0.002	0	0.010	0.008	0.002	0.010	0.012	0.005	0.55	0.82	1.2	0.026	0.029	0.018
N_{NO_3}	mg l^{-1}	I	12	11	6	0.24	0.012	0.006	5.3	0.52	0.048	13	2.1	0.097	1.3	1.7	1.3	56	12	0.35
		II	11	7	12	1.1	0.41	0	1.8	6.3	0.031	2.9	6.7	2.2	0.93	0.82	2.0	9.5	15	14
P_{tot}	mg l^{-1}	I	9	9	5	0.011	0.010	0.017	0.42	0.14	0.54	3.0	4.1	3.9	2.0	1.6	1.3	18	18	12
		II	6	3	7	0	0.004	0	0.024	0.015	0.040	0.064	0.047	0.044	1.5	1.4	0.84	0.25	0.12	0.090
P_{PO_4}	mg l^{-1}	I	16	15	8	0	0	0	0.005	0.008	0.006	0.005	0.022	0.007	0.77	1.7	0.73	0.014	0.15	0.015
		II	15	9	15	0	0	0	0.005	0.006	0.005	0.012	0.015	0.007	1.3	1.4	1.4	0.054	0.054	0.035
K	mg l^{-1}	I	1	2	1	15	70	63	.	.	.	.	.	.	.	.	.	15	180	63
		II	5	3	5	7.4	7.2	6.5	7.9	7.6	7.3	8.4	8.8	7.3	0.17	0.28	0.079	11	12	8.1
Ca	mg l^{-1}	I	1	2	1	43	75	53	.	.	.	.	.	.	.	.	.	43	460	53
		II	5	3	5	24	24	24	27	38	27	28	33	27	0.14	0.24	0.13	33	38	33
Mg	mg l^{-1}	I	1	2	1	38	110	94	.	.	.	.	.	.	.	.	.	38	370	94
		II	5	3	5	17	17	15	20	20	17	19	22	16	0.069	0.29	0.050	20	29	17
S_{SO_4}	mg l^{-1}	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	1	2	50	53	50	.	.	.	.	.	.	.	.	.	53	53	53
Na	mg l^{-1}	I	1	2	1	15	38	51	.	.	.	.	.	.	.	.	.	15	120	51
		II	5	3	5	13	14	13	15	17	14	15	17	14	0.093	0.19	0.068	17	21	15
Cl	mg l^{-1}	I	8	8	5	20	27	26	26	31	28	27	30	28	0.24	0.070	0.061	35	33	31
		II	6	3	7	14	11	12	24	24	25	23	20	23	0.22	0.37	0.28	28	24	29
Fe	mg l^{-1}	I	2	2	1	12	51	34	.	.	.	.	.	.	.	.	.	53	52	34
		II	3	1	3	3.0	17	1.8	21	.	38	20	.	30	0.81	.	0.84	35	17	51
Mn	mg l^{-1}	I	2	2	1	1.2	1.4	2.0	.	.	.	.	.	.	.	.	.	1.8	1.6	2.0
		II	3	1	3	0.25	1.7	0.48	0.38	.	0.51	0.83	.	1.0	1.1	.	0.90	1.9	1.7	2.1

Table 55. Continued.

Variable	Unit	Period	Number of observations in treatment			Values of statistics in different treatments														
						min			m			$\bar{x}$			$s/\bar{x}$			max		
			a_M	b_M	c_M	a_M	b_M	c_M	a_M	b_M	c_M	a_M	b_M	c_M	a_M	b_M	c_M	a_M	b_M	c_M
Zn	mg l^{-1}	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	2	2	0.005	0.010	0.004	.	.	.	.	.	.	.	.	.	0.010	0.017	0.008
Cu	mg l^{-1}	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	2	2	0.009	0.003	0.003	.	.	.	.	.	.	.	.	.	0.065	0.060	0.065
Ni	mg l^{-1}	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	2	2	0.020	0.040	0	.	.	.	.	.	.	.	.	.	0.050	0.067	0.047
Cd	mg l^{-1}	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	3	2	2	0.0002	0	0.0001	0.0004	.	.	0.0004	.	.	0.61	.	.	0.0005	0.0002	0.0001
Hg	mg l^{-1}	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	2	2	0	0	0	.	.	.	.	.	.	.	.	.	0	0	0
Pb	mg l^{-1}	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	2	2	0	0	0	.	.	.	.	.	.	.	.	.	0.002	0.001	0.002
γ_{25}	mS m^{-1}	I	16	15	8	39	30	45	49	46	46	50	46	46	0.12	0.13	0.022	64	58	48
		II	15	9	15	28	22	33	47	52	46	46	48	45	0.12	0.21	0.11	49	55	50
pH		I	16	15	8	5.3	5.8	5.7	5.8	6.0	6.0	.	.	.	.	.	.	6.1	6.3	6.2
		II	15	9	15	5.8	5.9	5.9	6.0	6.1	6.1	.	.	.	.	.	.	6.4	6.6	6.3
COD_{Mn}	mg l^{-1} O_2	I	16	14	8	3.0	3.7	4.6	9.3	82	62	45	120	48	1.5	1.0	0.74	230	360	94
		II	15	9	15	2.5	2.0	1.6	3.7	3.5	5.3	4.2	4.5	5.5	0.31	0.59	0.47	7.2	10	12
TOCOL	counts/ 100 ml	I	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		II	2	1	2	0	1.0	0	.	.	.	.	.	.	.	.	.	2.0	1.0	300
FECOL	counts/ 100 ml	I	1	2	0	0	0	.	.	.	.	.	.	.	.	.	.	0	0	.
		II	3	2	3	0	0	0	0	.	0	0	.	0	.	.	.	0	0	0
ENTCO	counts/ 100 ml	I	1	2	0	0	0	.	.	.	.	.	.	.	.	.	.	0	0	.
		II	3	2	3	0	0	0	0	.	0	0	.	0	.	.	.	0	2.0	0

Table 56. Test of the hypothesis on identical locations of selected ground-water quality variable distributions (Table 55) in the period of March 31, 1980—June 8, 1982 in the Maaninka field. Two-sided testing by the Mann-Whitney rank-sum test. Otherwise, legend as in Table 42.

Variable	Treatments tested	Number of observations		Level of significance	Conclusion
N_{NH_4}	a_M b_M	15	8	0.14	N.S.
	a_M c_M	15	15	0.046	c_M
	b_M c_M	8	15	0.82	N.S.
N_{NO_3}	a_M b_M	11	7	0.094	N.S.
	a_M c_M	11	12	0.042	a_M
	b_M c_M	7	12	0.018	b_M
P_{PO_4}	a_M b_M	15	9	0.86	N.S.
	a_M c_M	15	15	0.25	N.S.
	b_M c_M	9	15	0.45	N.S.
γ_{25}	a_M b_M	15	9	0.032	b_M
	a_M c_M	15	15	0.38	N.S.
	b_M c_M	9	15	0.011	b_M
H^+	a_M b_M	15	9	0.22	N.S.
	a_M c_M	15	15	0.027	a_M
	b_M c_M	9	15	0.67	N.S.
COD_{Mn}	a_M b_M	15	9	0.65	N.S.
	a_M c_M	15	15	0.074	N.S.
	b_M c_M	9	15	0.23	N.S.

mg l^{-1} as NO_3), the arithmetic means from 2.2 to 6.7 mg l^{-1} N_{NO_3} (9.7 to 30 mg $l^{-1} NO_3$) and the observed maxima from 9.5 to 15 mg l^{-1} N_{NO_3} (42 to 66 mg l^{-1} NO_3). The Finnish guidelines on drinking water (Lääkintöhallitus 1980, 1983) put upper limits of 30 and 50 mg l^{-1} NO_3 for acceptable water. Contents of over 50 mg l^{-1} but under 100 mg l^{-1} may exceptionally be accepted in drinking water used by adults. As regards nitrate, the Maaninka ground water would thus violate the Finnish drinking-water standard. Observed nitrite-nitrogen contents remained below the limits given in the standard (0.2 and 1.0 mg l^{-1} NO_2).

The few observations on toxic heavy metals do not indicate any contamination. In the drinking-water standard, the following highest acceptable limits are given: 0.002 mg l^{-1} Hg, 0.005 mg l^{-1} Cd and 0.05 mg l^{-1} Pb.

There are too few observations on bacteria for reliable conclusions to be drawn. Absence of fecal coliforms would, however, suggest that no bacteriological contamination has occurred.

It is uncertain how well observations on individual ground-water pipes reflect the treatment which the plot in question received. Cow slurry applied on snow (treatment b_M), however, may have caused higher concentrations than the other treatments (Tables 55—56): a statistically significant difference was found in nitrate nitrogen and conductivity.

The results from the Maaninka field can be summarized as the following (preliminary) conclusions, regarding situation in a sandy soil:

1. There is a risk of increase of the nitrate content of ground water. This is in accordance with most results found in the literature, e.g. Huylebroeck (1981) (Ch. 1.31), Vainio (1984) (Chs. 1.23 and 1.31), Seppänen and Kuukka (1982) (Ch. 1.23), Vetter and Steffens (1981) (Ch. 1.31).
2. Contamination of ground water by toxic heavy metals or (indicator) micro-organisms is not probable. Results of foreign studies generally support this conclusion, see e.g. Huylebroeck (1981) (Chs. 1.32, 1.34) and Larsen (1983) (Ch. 1.32).
3. Application of slurry (or sludge) on snow should be allowed only exceptionally. This conclusion was also drawn in an earlier study by the National Board of Waters (Vesihallitus 1974) (Ch. 1.31).

The measured crop yields (Table 16) support the conclusion on the application of slurry on snow: this treatment distinctly gave the lowest yield in the first year 1980; it also gave the lowest three-year average crop yield.

3.6 Concluding remarks

A major contribution of the Liperi and Maaninka experiments is in simultaneous monitoring of four different land applications, which allows a statistical analysis to evaluate their effects.

The two years, 1981 and 1982, following the treatments in 1980 were hydrologically exceptional: the 1981 annual runoffs have a return period of 30 years or more; the spring runoffs 1982 are exceeded only once in 20 to 30 years, on the average. The leaching rates, observed in these years, are thus not directly comparable with those measured in normal years. The period 1981—1982 gives however an excellent opportunity to analyse differences in the effects of various treatments in exceptional conditions. In the application year 1980 two special features have to be emphasized: first, snow melting was a slow process, secondly, the summer was dry and warm and precipitation was concentrated in few heavy periods of rain. These two factors were one cause of relatively small leaching in the first year (App. 7); under different circumstances different leaching results would have been obtained.

In the Liperi field, some influence of the surroundings and, possibly, of ground-water leakage to the drains could be observed. This was obviously one of the reasons for contradictory results regarding surface runoff. Measurement of the surface runoff was inaccurate also in other respects. The main conclusions of the study can, however, be considered reliable.

In the Maaninka field, the number of observations was small. Varying soil properties also caused problems in the sense that runoff — or ground water — could not be detected in all test plots. The Maaninka results and conclusions are thus preliminary.

Several experimental problems occurred. The small size of the test plots caused a sharp variation in results, thus making statistical analysis cumbersome. Because of high costs, not all constituents could be measured on a continuous basis. Leaching rates of many of them thus show an order of magnitude in the first place; mutual comparisons can, however, be regarded as reliable.

4. CONCLUSIONS

Application of sewage sludges on flat clay soil according to the present guidelines yielded the following main conclusions:

1. Climatic and weather conditions (total precipitation, snow accumulation, soil frost penetration, etc.) have a strong effect on leaching (two of the years studied were hydrologically exceptional).
2. Most of the total leaching, generally over 80—90 per cent, is through subdrainage. The snowmelting period has a dominant role with regard to annual leaching.
3. No harmful leaching of heavy metals or (indicator) micro-organisms, through subdrainage or surface, can be expected when normal sludge is applied in favourable conditions according to the present guidelines.
4. The treatments have the most profound effect on nitrogen leaching and on the conductivity of runoff waters.
5. The duration of treatment effect is at least two years for nitrogen.
6. Application on snow can for some time raise the content of ammonium nitrogen in runoff water. In the long run, applications on snow and on nonfrozen soil yield equal nitrogen leaching.
7. No major changes are needed in the present guidelines regulating land application of sewage sludges.

The experiment on sandy soil gave the following preliminary conclusions:

1. There is a risk of increase of the nitrate content of ground water. Application of slurry (or sludge) on snow should be allowed only exceptionally.
2. Contamination of ground water by heavy metals or (indicator) micro-organisms is not probable when the present guidelines of land application are followed.

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LOPPUTIIVISTELMÄ

Jätevesilietteestä, lietelannasta ja väkilannoitteesta aiheutuvaa huuhtoutumista tutkittiin Liperissä ja Maaningalla sijaitsevilla koekentillä vuosina 1979—1982 vesihallinnon ja Maatalouden tutkimuskeskuksen yhteisprojektissa. Tutkimusta on jatkettu vuoden 1982 jälkeen; tässä raportissa esitetään nelivuotiskauden 1979—1982 huuhtoutumistulokset, satotuloksista laaditaan erillinen julkaisu.

Vuosi 1979 oli kummallakin koekentällä kalibrointijakso, jolloin ei suoritettu lannoituksia. Tarkastellut käsittelyt tehtiin keväällä 1980.

Koekentät oli järjestetty siten, että voitiin samanaikaisesti tutkia neljää eri käsittelyä, joissa kussakin oli kolme tai neljä toistoa. Kentällä oli yhteensä 15 tai 16 koeruutua à 500 tai 600 m^2. Liperin savimaalla tutkittiin erilaisten lietekäsittelyjen (16—20 t ha^{-1} kuiva-aineena) — kuivattu liete lumelle, kuivattu liete sulaan maahan sekä kuivattu ja kalkittu liete sulaan maahan — vaikutusta salaoja- ja pintavesiin. Vertailukohteena oli käsittely, jossa vuonna 1980 ei ollut lainkaan lannoitusta. Maaningan karkealla kivennäismaalla tutkittiin pinta-, salaoja- ja pohjavesivaikutuksia, kun käsittelyinä olivat kuivattu jätevesiliete sulaan maahan (20 t ha^{-1} kuiva-aineena), naudan lietelanta sulaan maahan (50 m^3 ha^{-1}), naudan lietelanta lumelle (45—48 m^3 ha^{-1}) ja normaali lannoitus väkilannoitteella (400 kg ha^{-1}). Vesistä määritettiin tärkeimmät ravinteet, raskasmetalleja, orgaaninen aine ja eräitä indikaattorimikro-organismeja. Viljelykasvina kokeissa oli ohra.

Vuodet 1981 ja 1982 olivat hydrologisesti poikkeuksellisia: vuoden 1981 runsailla keskivalumilla on yli 30 vuoden keskimääräinen toistumisaika; vuoden 1982 kevätvalunta ylitetään puolestaan keskimäärin vain kerran 20—30 vuodessa.

Poikkeuksellisen sateiset vuodet osoittivat selvästi kuinka suuri vaikutus valuman suuruudella on huuhtoutumiin. Liperissä kasvoi typpihuuhtouma salaojien kautta arvosta 1 800 kg km^{-2} a^{-1} N hydrologisena vuotena (marraskuu—lokakuu) 1978—1979 (kalibrointijakso) arvoon 20 000 kg km^{-2} a^{-1} N vuotena 1980—1981 (kuivattu liete lumelle ja sulaan maahan); fosforihuuhtouma kohosi vastaavasti tasolta 12—13 kg km^{-2} a^{-1} P tasolle 80 kg km^{-2} a^{-1} P ja kaliumhuuhtouma arvoista 1 000—1 500 kg km^{-2} a^{-1} K arvoihin 4 000—6 000 kg km^{-2} a^{-1} K. Huuhtoutumien kasvuun vaikuttivat sekä valuma että lietekäsittelyt.

Liperin savimaalla havaittiin salaojavalunnan edustavan 75—90 % kokonaisvalunnasta. Ainehuuhtoutumista tuli useimmiten yli 80—90 % salaojien kautta. Maaningan kivennäismaalla ainehuuhtoumien jakautuminen oli toisenlainen: fosforia, rautaa, mangaania, kuparia ja kiintoainetta huuhtoutui enemmän pintavalunnan kuin salaojavalunnan mukana. Kevään sulamiskaudella on ratkaiseva osuus vuotuishuuhtoutumia ajatellen: Liperin kentän salaojista huuhtoutuneesta typestä tuli 1.3.—31.5. välisenä aikana 95 % hydrologisena vuotena 1978—1979, 40—60 % vuotena 1979—1980, 70—75 % vuotena 1980—1981 ja 60—75 % vuotena 1981—1982; vastaavat fosforin huuhtoutumisen osuudet olivat 95, 80—95, 45—55 ja 85—90 %.

Liperin kentältä kerätyt havainnot johtavat seuraaviin pääjohtopäätöksiin, jotka koskevat jätevesilietteen levittämistä savimaalle noudattaen nykyisiä määräyksiä:

1. Käsittelyistä ei ole odotettavissa haitallista raskasmetallien tai (indikaattori)mikro-organismien huuhtoutumista, kun liete levitetään suotuisissa olosuhteissa.
2. Jätevesiliete lisää selvimmin typen huuhtoutumista. Käsittelyn vaikutus kestää (ainakin) kaksi vuotta.
3. Lietteen levitys lumelle nostaa ammoniumtypen pitoisuuksia valumavesissä lumen sulamisvaiheessa; pitkällä aikavälillä typpihuuhtoutumat lumelle ja sulaan maahan levitetyistä lietteistä ovat tämän kokeen perusteella samansuuruisia. Maaperään varastoitunut typpi ja poikkeukselliset hydrologiset olosuhteet yhdessä voivat aiheuttaa korkeita typpihuuhtoutumia.
4. Jätevesilietteen levitystä koskeviin määräyksiin ei ole tarpeen tehdä periaatteellisia muutoksia.

Maaningan koekentältä kerätyistä havainnoista voidaan tehdä seuraavat alustavat karkeata kivennäismaata koskevat johtopäätökset:

1. Pohjaveden nitraattipitoisuuden kasvu on mahdollista. Lietelannan (tai jätevesilietteen) levitys lumelle tulisi sallia — nykyisten määräysten mukaisesti — vain poikkeustapauksissa.
2. Pohjaveden pilaantuminen raskasmetallien tai (indikaattori)mikro-organismien vaikutuksesta ei ole todennäköistä.

LIST OF SYMBOLS

DM	dry matter
n	number of observations
min	minimum observed
m	median
$\bar{x}$	arithmetic mean
s	standard deviation

max	maximum observed
ρ	Spearman's rank correlation coefficient
Mq	mean annual runoff
q	runoff rate
Q	runoff volume between recordings
t	time interval between recordings
N_{tot}	total nitrogen content
N_{NH_4}	ammonium nitrogen content
N_{NO_2}	nitrite nitrogen content
N_{NO_3}	nitrate nitrogen content
P_{tot}	total phosphorus content
P_{PO_4}	orthophosphate phosphorus content
K	potassium content
Ca	calcium content
Mg	magnesium content
S_{SO_4}	sulphate sulphur content
Na	sodium content
Cl	chloride content
Fe	iron content
Mn	manganese content
Zn	zinc content
Cu	copper content
Cr	chromium content
Ni	nickel content
Cd	cadmium content
Hg	mercury content
Pb	lead content
γ_{25}	conductivity
pH	pH value
COD_{Mn}	chemical oxygen demand (oxidation with permanganate)
SS	suspended solids content
TS	total solids content
ASH	inorganic solids content
TOCOL	total coliform bacteria (35 °C)
FECOL	fecal coliform bacteria (44 °C)
ENTCO	enterococcus bacteria
$L_{N_{tot}}$	total nitrogen leaching
$L_{N_{NO_3}}$	nitrate nitrogen leaching
$L_{P_{tot}}$	total phosphorus leaching
$L_{P_{PO_4}}$	orthophosphate phosphorus leaching
L_K	potassium leaching
L_{Ca}	calcium leaching
L_{Mg}	magnesium leaching
$L_{S_{SO_4}}$	sulphate sulphur leaching
L_{Na}	sodium leaching
L_{Cl}	chloride leaching
L_{Fe}	iron leaching
L_{Mn}	manganese leaching
L_{Zn}	zinc leaching
L_{Cu}	copper leaching
L_{Ni}	nickel leaching
$L_{COD_{Mn}}$	organic matter leaching (measured as COD_{Mn})
L_{SS}	suspended solids leaching

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Appendix 1. Basic principles of the statistical methods used

Mann-Whitney rank-sum test

The Mann-Whitney (Wilcoxon) rank-sum test is the nonparametric version of the two-sample t test for independent samples.

In the method, observations of the two samples, with sample sizes n_1 and n_2, are combined and arranged according to size. The smallest observation is given the rank 1 and the largest the rank $n_1 + n_2$. (Ties are taken care of by giving them the average of the ranks that would have been assigned if no ties were present.)

The test statistic is

$$U = R_1 - \frac{n_1\,(n_1 + 1)}{2} \tag{1}$$

where R_1 is the sum of the ranks for the sample of size n_1.

For large values of n_1 and n_2, U is approximately normally distributed with

$$\text{mean} = \frac{n_1 n_2}{2} \tag{2}$$

and

$$\text{variance} = n_1 n_2 (n_1 + n_2 + 1)/12 \tag{3}$$

Thus,

$$Z = \frac{U - n_1 n_2/2}{\sqrt{n_1 n_2 (n_1 + n_2 + 1)/12}} \tag{4}$$

is approximately normal with mean zero and unit variance.

Latin square procedure[1]

In the latin square the treatments are grouped into replicates in two different ways. Every row and every column of any latin square is a complete replication. The effect of the double grouping is to eliminate from the errors all differences among rows and equally all differences among columns.

Suppose that we have the following 6 × 6 latin square with six treatments A, B, C, D, E, F, and yields starting with +3.5 in Column 1 & Row 1 and ending with +8.6 in Column 6 & Row 6:

Row	Column						Totals
	1	2	3	4	5	6	
1	F +3.5	B +4.2	A +6.7	D +6.6	C +4.1	E +3.8	+28.9
2	B +8.9	F +1.9	D +5.8	A +4.5	E +2.4	C +5.8	+29.3
3	C +9.6	E +3.7	F −2.7	B +3.7	D +6.0	A +7.0	+27.3
4	D +10.5	C +10.2	B +4.6	E +3.7	A +5.1	F +3.8	+37.9
5	E +3.1	A +7.2	C +4.0	F −3.3	B +3.5	D +5.0	+19.5
6	A +5.9	D +7.6	E −0.7	C +3.0	F +4.0	B +8.6	+28.4
Totals	+41.5	+34.8	+17.7	+18.2	+25.1	+34.0	+171.3 = G

Totals for treatments

A	B	C	D	E	F
+36.4	+33.5	+36.7	+41.5	+16.0	+7.2

The following sums of squares are calculated in the analysis of variance:

$$\text{Correction factor: } C = \frac{G^2}{r^2} = \frac{(171.3)^2}{6^2} = 815.10$$

$$\text{Total: } (3.5)^2 + (4.2)^2 + \ldots + (8.6)^2 - C =$$
$$1144.73 - 815.10 = 329.63$$

$$\text{Rows: } \frac{1}{6}\,[(28.9)^2 + \ldots + (28.4)^2] - C =$$
$$843.70 - 815.10 = 28.60$$

$$\text{Columns: } \frac{1}{6}\,[(41.5)^2 + \ldots + (34.0)^2] - C =$$
$$893.97 - 815.10 = 78.87$$

$$\text{Treatments: } \frac{1}{6}\,[(36.4)^2 + \ldots + (7.2)^2] - C =$$
$$970.70 - 815.10 = 155.60$$

These sums of squares are entered in the analysis of variance (the error s.s. is found by subtraction):

Source of variation	d.f.	s.s.	m.s.	F
Rows	(r−1) = 5	28.60	5.720	1.72
Columns	(r−1) = 5	78.87	15.774	4.74**
Treatments	(r−1) = 5	155.60	31.120	9.35**
Error	(r−1) (r−2) = 20	66.56	3.328	
Total	(r^2−1) = 35	329.63		

The F value for the treatments (31.120/3.328 = 9.35) is well beyond the 1 % level, which is 4.10 for 5 and 20 d.f. This shows that the yield varies from one treatment to another as the means below indicate:

A	B	C	D	E	F
+6.07	+5.58	+6.12	+6.92	+2.67	+1.20

The formula

$$\sqrt{2\,s^2/r} \tag{5}$$

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[1] According to Cochran, W.G. & Cox, G.M. 1957. Experimental designs. 2nd ed. New York. P. 117—127.

gives the estimated standard error of the difference between two treatment means, where s^2 is the mean square per unit and r the number of replicates. Here the standard error is $\sqrt{2\,(3.328)/6} = 1.053$. Since the 5 % t value for 20 d.f. is 2.086, the difference between two means must be at least (2.086)(1.053), or 2.20, in order to attain significance at this level. It appears that the treatments fall into two sets — A, B, C, D and E, F.

According to the analysis of variance table above, no significant row effect was established (further, the row totals do not suggest any consistent trend). On the other, the F value for the columns m.s., 4.74, is significant at the 1 % level, indicating a bias depending on the column.

Spearman's rank correlation coefficient

Spearman's rank correlation coefficient is defined as

$$\rho = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n^3 - n} \qquad (6)$$

where d_i is the difference between the ranks of the ith pair of the group of n pairs of items, each member of a pair having been ranked among the like members of the other pairs.

Critical values of ρ have been tabulated in handbooks for small values of n. For $n > 10$, a test statistic (t distribution)

$$t = \frac{\rho\sqrt{n-2}}{\sqrt{1-\rho^2}}$$

with $f = n - 2$ degrees of freedom can be used to test the significance of the rank correlation coefficient ρ.

When rankings are tied, ρ is modified. In this work, a procedure adopted in the BMDP3S program has been utilized.

Appendix 2. Average rates of subdrainage runoff and leaching during sampling intervals in different seasons of the hydrological years studied in the Liperi field. Leaching averages computed by cumulative amounts over sampling intervals. Four replicates per treatment (Diagrams in App. 4). Winter = Nov. 1—Febr. 28; spring = March 1—May 31; summer = June 1—Oct. 31.)

Season	Treatment	Runoff ($l\ s^{-1}\ km^{-2}$)		Leaching ($kg\ km^{-2}\ a^{-1}$)							
		n[1)]	q	n	$L_{N_{tot}}$	n	$L_{N_{NO_3}}$	n	$L_{P_{tot}}$	n	$L_{P_{PO_4}}$
Winter 1978—79	a_L	38	0.87	22	320	18	590	26	2.0	26	1.2
	b_L	40	0.90	15	300	15	540	23	1.3	22	0.91
	c_L	36	0.77	20	310	16	530	24	1.4	24	0.91
	d_L	40	0.94	16	390	16	990	24	2.3	24	1.4
Spring 1979	a_L	37	17	21	11 000	21	9 300	21	84	21	23
	b_L	37	18	20	14 000	20	12 000	20	100	20	29
	c_L	38	18	22	10 000	22	8 900	22	74	22	22
	d_L	35	19	20	16 000	20	14 000	20	110	20	32
Summer 1979	a_L	28	0.19	16	55	16	47	16	0.64	16	0.48
	b_L	29	0.26	16	75	16	61	16	0.80	16	0.61
	c_L	28	0.23	16	58	16	47	16	0.79	16	0.54
	d_L	30	0.21	16	65	16	54	16	0.78	16	0.56
Winter 1979—80	a_L	32	5.9	20	2 900	23	1 900	23	16	20	8.3
	b_L	31	6.7	21	2 600	25	1 500	25	13	21	7.3
	c_L	34	7.0	22	3 000	26	1 900	25	16	21	8.9
	d_L	37	4.1	21	2 800	25	1 700	25	13	21	7.6
Spring 1980	a_L	46	13	24	4 800	24	3 600	24	58	24	23
	b_L	44	11	24	4 600	24	2 300	24	75	24	22
	c_L	45	14	24	4 700	23	3 400	24	64	24	28
	d_L	45	15	24	4 600	24	3 400	24	51	24	23
Summer 1980	a_L	60	1.1	24	970	24	900	24	3.1	24	2.3
	b_L	55	1.1	24	4 800	24	4 300	24	3.6	23	2.6
	c_L	58	1.1	23	6 500	23	6 300	23	3.5	23	2.3
	d_L	59	1.4	24	1 600	24	1 500	24	4.2	24	3.0
Winter 1980—81	a_L	116	3.6	52	250	44	220	52	2.5	44	2.1
	b_L	116	3.3	51	1 400	44	1 300	52	2.5	44	2.1
	c_L	115	3.2	51	1 600	44	1 600	52	2.0	44	1.7
	d_L	115	3.4	52	480	44	470	52	2.6	44	2.2
Spring 1981	a_L	84	36	40	19 000	12	53 000	40	120	12	170
	b_L	84	42	40	55 000	12	160 000	40	220	12	390
	c_L	84	49	40	85 000	12	240 000	40	180	12	310
	d_L	84	48	40	29 000	12	77 000	40	220	12	410
Summer 1981	a_L	96	22	44	2 100	16	2 500	44	68	16	29
	b_L	96	21	42	5 800	15	8 300	44	85	16	39
	c_L	96	23	42	7 500	16	11 000	44	96	16	47
	d_L	96	25	43	3 200	16	4 200	44	94	16	57
Winter 1981—82	a_L	64	15	24	470	20	110	24	21	20	5.0
	b_L	64	16	24	3 700	20	1 600	24	39	20	13
	c_L	64	17	24	5 100	20	2 500	24	37	20	8.6
	d_L	64	17	24	1 100	20	330	24	49	20	7.9
Spring 1982	a_L	116	36	56	7 800	20	2 800	56	280	32	33
	b_L	116	43	56	14 000	20	5 600	56	380	32	78
	c_L	116	50	56	19 000	20	6 600	56	430	32	65
	d_L	116	45	56	12 000	20	4 000	56	410	32	64
Summer 1982	a_L	20	3.5	8	2 400	8	2 200	8	16	8	13
	b_L	19	4.4	8	6 400	8	6 000	8	29	8	24
	c_L	18	4.3	8	5 600	8	5 500	8	26	8	21
	d_L	20	3.5	8	4 200	8	3 900	8	25	8	20

1) n = number of observations

Appendix 2. Continued.

Season	Treatment	Leaching (kg km^{-2} a^{-1})									
		n	L_K	n	L_{Ca}	n	L_{Mg}	n	$L_{S_{SO_4}}$	n	L_{Na}
Winter 1978—79	a_L	18	200	18	1 800	18	600	0	.	4	64
	b_L	13	110	13	1 100	13	390	0	.	3	77
	c_L	16	150	16	1 200	16	470	0	.	4	53
	d_L	16	210	16	2 200	16	800	0	.	4	68
Spring 1979	a_L	12	10 000	12	110 000	12	37 000	4	73 000	12	17 000
	b_L	12	13 000	12	130 000	12	43 000	4	90 000	12	20 000
	c_L	12	14 000	12	110 000	12	36 000	4	77 000	12	18 000
	d_L	12	13 000	12	120 000	12	45 000	4	67 000	12	19 000
Summer 1979	a_L	16	170	16	1 200	16	350	4	2 200	4	320
	b_L	16	220	16	1 700	16	540	4	4 700	4	600
	c_L	16	230	16	1 200	16	410	4	3 200	4	420
	d_L	16	110	16	960	16	350	3	2 500	4	420
Winter 1979—80	a_L	23	2 100	23	26 000	23	8 100	4	11 000	23	3 300
	b_L	25	2 000	25	20 000	25	7 300	4	16 000	25	2 600
	c_L	26	2 900	26	24 000	26	9 000	4	13 000	26	3 300
	d_L	25	1 800	25	18 000	25	7 000	4	12 000	25	2 500
Spring 1980	a_L	24	5 500	24	41 000	24	13 000	8	32 000	24	7 800
	b_L	23	4 700	23	33 000	23	11 000	8	26 000	23	6 800
	c_L	23	7 000	24	36 000	24	13 000	8	26 000	24	7 600
	d_L	24	3 800	24	29 000	24	11 000	8	22 000	24	6 100
Summer 1980	a_L	24	920	24	8 600	24	2 600	4	670	16	790
	b_L	24	1 100	24	13 000	24	4 000	4	970	16	740
	c_L	23	1 400	23	16 000	24	4 100	3	800	15	720
	d_L	24	930	24	9 800	24	3 300	4	870	16	640
Winter 1980—81	a_L	44	1 000	44	8 500	44	2 900	8	13 000	44	1 400
	b_L	44	830	44	8 700	44	3 200	8	13 000	44	1 200
	c_L	44	1 100	44	8 000	44	3 100	8	13 000	44	1 300
	d_L	44	780	44	7 500	44	3 100	8	13 000	44	1 200
Spring 1981	a_L	32	11 000	32	93 000	32	28 000	12	90 000	32	12 000
	b_L	32	17 000	32	170 000	32	48 000	12	130 000	32	22 000
	c_L	32	22 000	32	210 000	32	60 000	12	160 000	32	27 000
	d_L	32	14 000	32	110 000	32	36 000	12	110 000	32	15 000
Summer 1981	a_L	42	5 400	42	40 000	42	13 000	16	37 000	42	6 700
	b_L	42	5 800	42	40 000	42	13 000	16	33 000	42	6 300
	c_L	44	8 500	44	41 000	44	15 000	16	40 000	44	7 500
	d_L	43	5 800	43	44 000	43	16 000	16	50 000	43	7 400
Winter 1981—82	a_L	15	4 700	15	30 000	15	12 000	16	33 000	8	6 200
	b_L	16	6 600	16	32 000	16	13 000	16	37 000	8	8 200
	c_L	16	6 500	16	35 000	16	14 000	16	37 000	8	9 100
	d_L	16	5 000	16	32 000	16	13 000	16	33 000	8	7 600
Spring 1982	a_L	16	8 200	16	50 000	16	15 000	8	19 000	16	9 900
	b_L	16	11 000	16	68 000	16	21 000	8	21 000	16	13 000
	c_L	16	15 000	16	65 000	16	20 000	8	21 000	16	12 000
	d_L	16	8 400	16	55 000	16	19 000	8	17 000	16	9 300
Summer 1982	a_L	4	980	4	5 700	4	1 900	4	57 000	4	1 300
	b_L	4	1 000	4	5 500	4	2 000	4	80 000	4	1 200
	c_L	4	2 000	4	6 200	4	2 400	4	73 000	4	1 500
	d_L	4	540	4	4 200	4	1 800	4	57 000	4	940

Appendix 2. Continued.

Season	Treatment	Leaching (kg km^{-2}a^{-1})											
		n	L_{Cl}	n	L_{Fe}	n	L_{Mn}	n	L_{Zn}	n	L_{Cu}	n	L_{Ni}
Winter 1978—79	a_L	26	1 400	0	.	0	.	0	.	0	.	0	.
	b_L	23	1 100	0	.	0	.	0	.	0	.	0	.
	c_L	24	1 100	0	.	0	.	0	.	0	.	0	.
	d_L	24	2 200	0	.	0	.	0	.	0	.	0	.
Spring 1979	a_L	21	45 000	4	2 200	4	150	4	6.8	4	47	4	62
	b_L	20	56 000	4	4 100	4	230	4	3.6	4	36	4	46
	c_L	22	42 000	4	1 900	4	130	4	10	4	34	4	55
	d_L	20	58 000	4	1 400	4	120	4	1.1	4	35	4	55
Summer 1979	a_L	16	420	4	3.5	4	1.6	4	0.47	4	0.53	4	1.1
	b_L	16	710	4	8.8	4	6.3	4	1.3	4	1.1	4	2.4
	c_L	16	480	4	5.3	4	3.2	4	0.61	4	0.60	4	1.3
	d_L	16	350	4	6.3	4	1.7	4	0.35	4	0.43	4	1.1
Winter 1979—80	a_L	23	11 000	4	75	4	8.8	4	0.62	4	2.2	4	3.2
	b_L	25	8 800	4	150	4	20	4	0.85	4	2.8	4	4.9
	c_L	25	10 000	4	110	4	16	4	1.7	4	2.5	4	5.1
	d_L	25	8 500	4	93	4	9.0	4	13	4	33	4	2.8
Spring 1980	a_L	24	16 000	8	770	8	160	8	9.5	8	9.7	8	21
	b_L	24	14 000	8	900	8	180	8	7.7	8	7.2	8	17
	c_L	24	15 000	8	640	8	140	8	9.1	8	8.6	8	18
	d_L	24	13 000	8	550	8	84	8	9.0	8	7.7	8	11
Summer 1980	a_L	24	1 700	4	1.7	4	0.60	8	10	8	3.2	8	19
	b_L	24	2 200	4	0.99	4	1.1	8	7.1	8	1.8	8	17
	c_L	23	2 200	3	2.0	3	0.37	7	10	7	3.0	7	23
	d_L	24	2 200	4	1.5	4	0.59	8	6.2	8	1.2	8	19
Winter 1980—81	a_L	44	1 900	8	8.9	8	94	8	10	8	2.9	8	17
	b_L	44	1 800	8	7.4	8	100	8	8.3	8	1.9	8	19
	c_L	44	1 800	8	13	8	81	8	8.5	8	2.5	8	16
	d_L	44	1 700	8	18	8	64	8	6.2	8	1.4	8	14
Spring 1981	a_L	12	28 000	12	16 000	12	550	12	65	12	45	12	100
	b_L	12	37 000	12	18 000	12	750	12	71	12	61	12	160
	c_L	12	44 000	12	17 000	12	760	12	78	12	65	12	230
	d_L	12	37 000	12	23 000	12	680	12	65	12	62	12	110
Summer 1981	a_L	16	9 600	16	840	16	370	16	19	16	12	16	38
	b_L	16	11 000	16	620	16	320	16	18	16	13	16	43
	c_L	16	13 000	16	950	16	350	16	23	16	13	16	46
	d_L	16	30 000	16	680	16	340	16	16	16	17	16	42
Winter 1981—82	a_L	20	3 900	16	720	16	330	8	20	8	6.5	8	39
	b_L	20	5 400	16	490	16	360	8	18	8	6.6	8	39
	c_L	20	5 300	16	710	16	330	8	19	8	7.4	8	37
	d_L	20	5 400	16	530	16	400	8	14	8	4.4	8	35
Spring 1982	a_L	20	7 300	8	680	8	180	12	12	12	8.5	12	24
	b_L	20	10 000	8	1 100	8	240	12	16	12	9.2	12	27
	c_L	20	11 000	8	1 100	8	190	12	17	12	11	12	23
	d_L	20	8 500	8	6 300	8	950	12	10	12	12	12	19
Summer 1982	a_L	8	8 800	4	180	4	540	0	.	0	.	0	.
	b_L	8	12 000	4	280	4	660	0	.	0	.	0	.
	c_L	8	12 000	4	470	4	600	0	.	0	.	0	.
	d_L	8	10 000	4	260	4	520	0	.	0	.	0	.

Appendix 2. Continued.

Season	Treatment	Leaching (kg km^{-2}a^{-1})							
		n	γ_{25}[2)]	n	pH[3)]	n	$L_{COD_{Mn}}(O_2)$	n	L_{SS}
Winter 1978—79	a_L	26	66	26	6.4	26	320	0	.
	b_L	23	73	23	6.4	23	230	0	.
	c_L	24	64	24	6.3	24	240	0	.
	d_L	24	66	24	6.3	24	400	0	.
Spring 1979	a_L	21	50	21	6.4	21	15 000	0	.
	b_L	20	51	20	6.4	20	19 000	0	.
	c_L	22	49	22	6.4	22	15 000	0	.
	d_L	20	50	20	6.4	20	21 000	0	.
Summer 1979	a_L	16	73	16	6.8	16	91	4	27
	b_L	16	68	16	6.8	16	150	4	92
	c_L	16	67	16	6.8	16	120	4	63
	d_L	16	65	15	6.7	16	100	4	63
Winter 1979—80	a_L	23	63	23	6.5	23	5 500	4	3 300
	b_L	25	59	25	6.5	25	4 500	4	5 800
	c_L	26	59	26	6.5	26	5 600	4	4 400
	d_L	25	61	25	6.5	25	4 600	4	4 100
Spring 1980	a_L	24	53	24	6.4	24	13 000	22	6 400
	b_L	24	54	24	6.5	24	11 000	23	3 900
	c_L	24	47	24	6.5	24	13 000	22	7 500
	d_L	24	47	24	6.6	24	11 000	22	6 500
Summer 1980	a_L	24	64	24	6.2	24	690	24	81
	b_L	24	89	24	6.1	24	630	24	79
	c_L	23	97	23	6.1	23	720	23	220
	d_L	24	68	24	6.4	24	890	24	100
Winter 1980—81	a_L	52	63	52	6.1	44	190	51	27
	b_L	52	78	52	6.1	44	180	52	28
	c_L	52	72	52	6.1	44	180	52	52
	d_L	52	62	52	6.2	44	240	52	39
Spring 1981	a_L	40	59	40	6.2	12	55 000	40	36 000
	b_L	40	82	40	6.1	12	73 000	40	44 000
	c_L	40	81	40	6.1	12	77 000	40	33 000
	d_L	40	56	40	6.3	11	91 000	40	49 000
Summer 1981	a_L	44	51	44	6.3	16	14 000	44	10 000
	b_L	44	58	44	6.3	16	14 000	44	12 000
	c_L	44	57	44	6.3	16	17 000	44	12 000
	d_L	44	48	44	6.4	16	24 000	44	10 000
Winter 1981—82	a_L	24	50	24	6.1	20	1 600	20	11 000
	b_L	24	56	24	6.2	20	2 400	20	5 400
	c_L	24	52	24	6.2	20	2 300	20	8 900
	d_L	24	46	24	6.2	20	2 400	20	14 000
Spring 1982	a_L	56	31	56	6.6	56	15 000	8	6 200
	b_L	56	34	56	6.5	56	18 000	8	14 000
	c_L	56	31	56	6.5	56	21 000	8	7 700
	d_L	56	27	56	6.6	56	20 000	7	12 000
Summer 1982	a_L	8	52	8	6.1	8	1 200	4	3 100
	b_L	8	62	8	6.3	8	2 000	4	1 700
	c_L	8	55	8	6.1	8	1 700	4	3 200
	d_L	8	55	8	6.3	8	1 300	4	2 800

2) In mS m^{-1} (median); 3) pH value (median)

Appendix 3. Average rates of surface runoff and leaching during sampling intervals in different seasons of the hydrological years studied in the Liperi field. Leaching averages computed by cumulative amounts over sampling intervals. One replicate per treatment (Diagrams in App. 4). Legend as in App. 2.

Season	Treatment	Runoff ($l\ s^{-1}\ km^{-2}$)		Leaching ($kg\ km^{-2}a^{-1}$)							
		n1)	q	n	$L_{N_{tot}}$	n	$L_{N_{NO_3}}$	n	$L_{P_{tot}}$	n	$L_{P_{PO_4}}$
Winter 1978—79	a_L	9	0.15	3	150	5	58	6	0.17	6	0.060
	b_L	8	0.26	3	120	4	84	5	0.30	5	0.11
	c_L	8	0.093	3	140	4	87	5	0.52	5	0.11
	d_L	8	0.20	6	120	5	95	6	0.28	6	0.081
Spring 1979	a_L	9	3.4	5	260	5	200	5	6.2	5	1.2
	b_L	9	9.2	5	2 400	5	2 000	5	74	5	6.1
	c_L	9	5.1	5	670	5	520	5	11	5	2.2
	d_L	9	5.3	5	730	5	620	5	8.7	5	2.0
Summer 1979	a_L	4	0.0077	1	4.5	1	4.2	1	0.043	1	0.0089
	b_L	7	0.040	3	11	3	9.7	3	0.13	3	0.087
	c_L	6	0.0078	2	2.8	2	2.4	2	0.076	2	0.045
	d_L	4	0.0026	2	2.1	2	1.6	2	0.097	1	0.19
Winter 1979—80	a_L	9	0.49	4	640	6	430	6	0.93	5	0.22
	b_L	10	0.35	5	310	6	170	6	1.4	5	0.73
	c_L	7	0.21	5	74	6	46	6	0.27	5	0.10
	d_L	7	0.31	5	160	6	98	6	0.45	5	0.13
Spring 1980	a_L	9	1.9	5	690	5	600	5	9.6	5	3.1
	b_L	10	2.7	5	870	5	440	5	25	5	9.6
	c_L	9	1.3	5	530	5	360	5	13	5	12
	d_L	9	3.7	5	1 400	5	920	5	44	5	20
Summer 1980	a_L	7	0.055	3	64	3	59	3	0.23	3	0.13
	b_L	10	0.23	3	890	3	770	3	1.1	3	0.45
	c_L	11	0.057	3	29	3	24	3	0.17	3	0.072
	d_L	9	0.025	3	49	3	43	3	0.51	3	0.41
Winter 1980—81	a_L	29	0.21	13	37	11	36	13	0.082	11	0.045
	b_L	27	0.20	12	49	11	45	12	0.10	11	0.059
	c_L	28	0.089	13	9.0	11	7.8	13	0.045	11	0.026
	d_L	24	0.033	10	13	9	11	10	0.11	9	0.075
Spring 1981	a_L	17	8.3	9	3 400	2	12 000	9	70	2	89
	b_L	18	15	8	8 500	2	30 000	8	390	2	410
	c_L	17	40	9	12 000	2	54 000	9	490	2	660
	d_L	12	13	5	9 200	2	16 000	5	670	2	360
Summer 1981	a_L	22	1.3	10	90	3	85	9	3.9	3	1.7
	b_L	24	2.0	10	200	4	45	10	7.7	4	1.5
	c_L	19	1.4	8	270	3	39	8	11	3	0.88
	d_L	19	1.1	8	120	3	28	8	4.2	3	0.86
Winter 1981—82	a_L	14	0.37	6	18	5	1.9	6	2.2	5	0.080
	b_L	14	0.32	6	14	5	1.4	6	1.9	5	0.11
	c_L	14	0.58	6	20	5	2.8	6	4.1	5	0.46
	d_L	9	0.31	3	24	2	7.5	3	3.5	2	0.63
Spring 1982	a_L	27	4.4	13	1 600	4	110	13	77	7	3.0
	b_L	27	6.9	13	2 300	4	26	13	120	7	1.4
	c_L	28	5.3	13	1 200	4	72	13	68	7	6.5
	d_L	27	3.8	13	1 500	4	48	13	73	7	4.6
Summer 1982	a_L	4	0.15	1	1 100	1	1 000	1	5.1	1	1.2
	b_L	4	0.16	1	720	1	650	1	17	1	4.4
	c_L	4	0.080	1	330	1	320	1	6.3	1	1.8
	d_L	4	0.13	1	510	1	510	1	7.6	1	2.3

1) n = number of observations

Appendix 3. Continued.

Season	Treatment	Leaching (kg km^{-2}a^{-1})									
		n	L_K	n	L_{Ca}	n	L_{Mg}	n	$L_{S_{SO_4}}$	n	L_{Na}
Winter 1978—79	a_L	4	30	4	210	4	72	1	130	1	76
	b_L	3	42	3	220	3	160	1	140	1	71
	c_L	3	150	3	680	3	190	0	.	0	.
	d_L	4	74	4	450	4	140	1	100	1	51
Spring 1979	a_L	3	190	3	1 800	3	690	1	12 000	3	370
	b_L	3	4 500	3	31 000	3	11 000	1	11 000	3	6 400
	c_L	3	1 400	3	11 000	3	4 100	1	6 300	3	3 000
	d_L	3	1 200	3	13 000	3	4 100	1	7 700	3	1 100
Summer 1979	a_L	1	8.3	1	60	1	19	0	.	0	.
	b_L	3	26	3	120	3	28	1	220	1	140
	c_L	1	7.7	1	48	1	15	0	.	0	.
	d_L	2	25	2	59	2	13	1	100	1	120
Winter 1979—80	a_L	6	400	6	4 000	6	1 400	1	15 000	6	530
	b_L	6	240	6	2 400	6	810	1	1 200	6	280
	c_L	6	81	6	800	6	280	1	2 000	6	120
	d_L	6	160	6	1 800	6	580	1	1 400	6	160
Spring 1980	a_L	5	820	5	4 200	5	1 700	2	2 200	5	940
	b_L	5	1 500	5	8 200	5	3 100	2	2 500	5	1 600
	c_L	5	1 200	5	6 300	5	2 500	2	600	5	1 700
	d_L	5	4 300	5	14 000	5	5 300	2	5 000	5	2 700
Summer 1980	a_L	3	100	3	1 000	3	270	0	.	1	72
	b_L	3	410	3	4 800	3	1 200	0	.	1	340
	c_L	3	120	3	540	3	250	0	.	1	33
	d_L	3	67	3	700	3	170	0	.	1	40
Winter 1980—81	a_L	11	49	11	540	11	180	2	630	11	70
	b_L	11	38	11	510	11	140	2	530	11	50
	c_L	11	23	11	270	11	88	2	530	11	43
	d_L	9	9.7	9	140	9	41	2	260	9	13
Spring 1981	a_L	7	3 300	7	18 000	7	7 100	2	33 000	7	3 000
	b_L	7	10 000	7	44 000	7	26 000	2	130 000	7	7 300
	c_L	7	22 000	7	54 000	7	21 000	2	100 000	7	13 000
	d_L	5	21 000	5	37 000	5	24 000	2	33 000	5	5 400
Summer 1981	a_L	9	270	9	1 800	9	600	4	930	9	290
	b_L	10	530	10	3 800	10	1 000	4	1 000	10	540
	c_L	8	660	8	3 900	8	1 300	3	500	8	770
	d_L	8	540	8	4 300	8	1 000	3	900	8	470
Winter 1981—82	a_L	3	99	3	700	3	300	4	370	1	180
	b_L	4	110	4	610	4	210	4	240	2	78
	c_L	4	230	4	650	4	360	4	210	2	130
	d_L	2	200	2	620	2	270	2	53	1	35
Spring 1982	a_L	3	590	3	2 500	3	940	1	2 600	3	500
	b_L	3	250	3	850	3	310	1	830	3	190
	c_L	3	1 300	3	3 000	3	990	1	1 900	3	690
	d_L	3	770	3	2 100	3	530	1	700	3	430
Summer 1982	a_L	0	.	0	.	0	.	1	770	0	.
	b_L	0	.	0	.	0	.	1	800	0	.
	c_L	0	.	0	.	0	.	1	930	0	.
	d_L	0	.	0	.	0	.	1	530	0	.

Appendix 3. Continued.

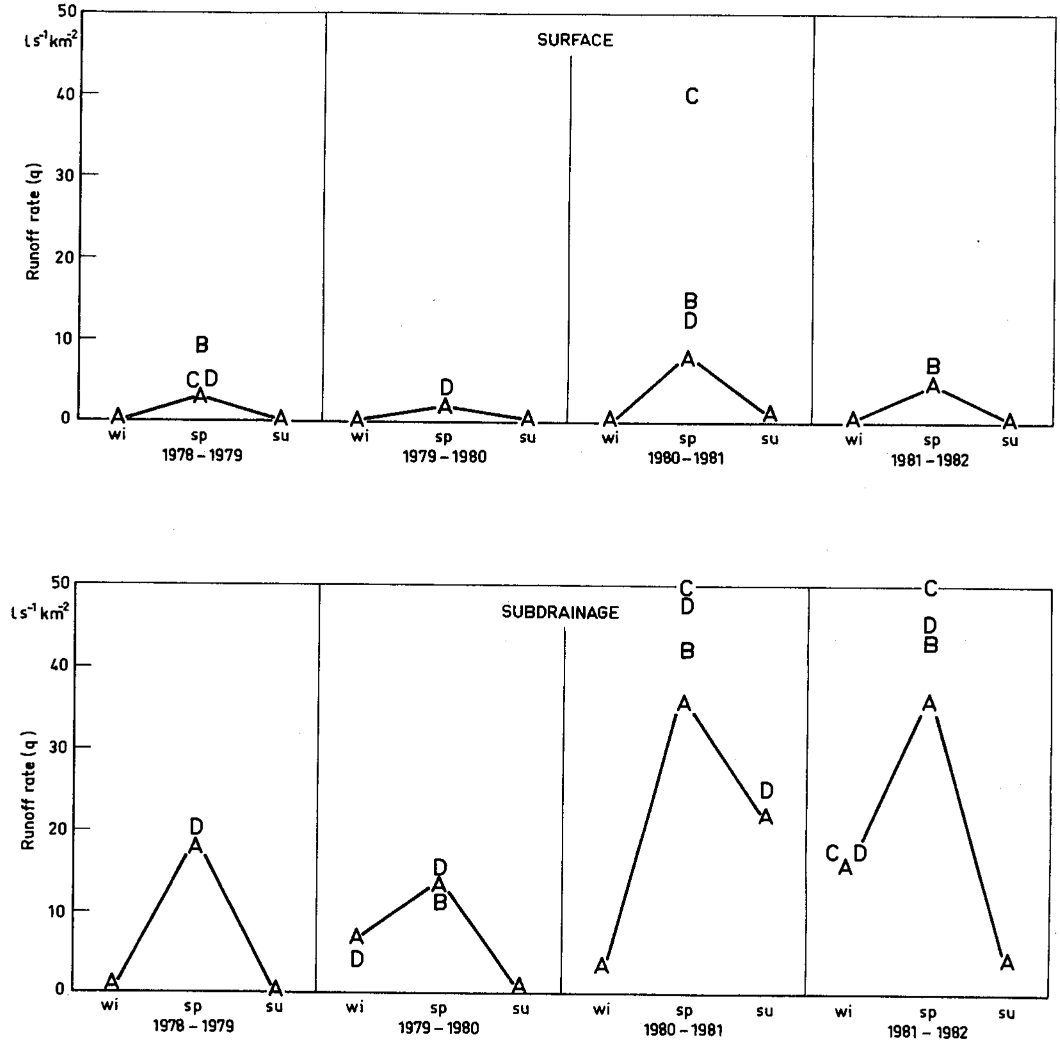
Season	Treatment	Leaching (kg km^{-2}a^{-1})											
		n	L_{Cl}	n	L_{Fe}	n	L_{Mn}	n	L_{Zn}	n	L_{Cu}	n	L_{Ni}
Winter 1978—79	a_L	6	280	1	1.8	1	0.37	0	.	0	.	0	.
	b_L	5	550	1	0.48	1	0.089	0	.	0	.	0	.
	c_L	5	610	0	.	0	.	0	.	0	.	0	.
	d_L	6	460	1	0.47	1	0.23	0	.	0	.	0	.
Spring 1979	a_L	5	2 700	1	2 500	1	44	1	0.40	1	1.0	1	1.1
	b_L	5	13 000	1	5 000	1	64	1	18	1	22	1	37
	c_L	5	7 300	1	4 200	1	59	1	0	1	2.2	1	2.2
	d_L	5	5 200	1	2 300	1	36	1	0.26	1	2.6	1	1.3
Summer 1979	a_L	1	19	0	.	0	.	0	.	0	.	0	.
	b_L	3	48	1	1.9	1	0.18	1	0.11	1	0.054	1	0.045
	c_L	2	22	0	.	0	.	0	.	0	.	0	.
	d_L	1	34	1	0.12	1	0.16	1	0.065	1	0.036	1	0.016
Winter 1979—80	a_L	6	1 800	1	67	1	57	1	29	1	52	1	15
	b_L	6	1 600	1	25	1	3.8	1	0.57	1	0.13	1	0.82
	c_L	6	330	1	2.0	1	8.8	1	5.4	1	5.2	1	1.9
	d_L	6	620	1	1.4	1	4.4	1	1.7	1	0.042	1	1.3
Spring 1980	a_L	5	3 400	2	360	2	8.4	2	1.2	2	1.8	2	1.9
	b_L	5	6 300	2	650	2	25	2	5.4	2	1.9	2	2.1
	c_L	4	8 900	2	53	2	4.1	2	1.6	2	0.33	2	0.70
	d_L	5	10 000	2	690	2	14	2	3.2	2	3.9	2	3.6
Summer 1980	a_L	3	240	0	.	0	.	1	2.6	1	0.048	1	0.63
	b_L	3	1 100	0	.	0	.	1	5.4	1	0.47	1	4.0
	c_L	3	230	0	.	0	.	1	1.3	1	0.022	1	0.34
	d_L	3	160	0	.	0	.	1	5.7	1	0.074	1	0.48
Winter 1980—81	a_L	11	150	2	0.87	2	5.4	2	2.8	2	0.094	2	0.55
	b_L	11	120	2	2.7	2	2.9	2	1.9	2	0.093	2	0.39
	c_L	11	93	2	0.34	2	3.0	2	2.8	2	0.061	2	0.48
	d_L	9	29	2	0.063	2	0.42	2	3.2	2	0.037	2	0.17
Spring 1981	a_L	2	18 000	2	18 000	2	400	2	28	2	25	2	29
	b_L	2	26 000	2	110 000	2	1 800	2	140	2	140	2	110
	c_L	2	40 000	2	150 000	2	2 600	2	150	2	120	2	130
	d_L	2	13 000	2	96 000	2	1 700	2	150	2	83	2	83
Summer 1981	a_L	3	320	4	110	4	7.9	3	0.73	3	0.85	3	1.5
	b_L	4	230	4	260	4	14	4	1.5	4	0.96	4	1.2
	c_L	3	200	3	190	3	8.0	3	0.60	3	0.57	3	0.83
	d_L	3	140	3	62	3	6.9	3	0.41	3	0.59	3	0.76
Winter 1981—82	a_L	5	41	4	31	4	6.4	1	0.41	1	0.25	1	0.46
	b_L	5	30	4	31	4	1.5	2	0.48	2	0.083	2	0.26
	c_L	5	49	4	95	4	2.0	2	0.51	2	0.34	2	0.27
	d_L	2	26	2	40	2	0.48	1	0.25	1	0.15	1	0.11
Spring 1982	a_L	4	200	1	170	1	8.9	2	0.48	2	0.71	2	1.5
	b_L	4	55	1	68	1	4.5	2	0.27	2	0.21	2	0.47
	c_L	4	290	1	210	1	18	2	2.3	2	2.3	2	2.0
	d_L	4	110	1	80	1	2.5	2	0.50	2	0.36	2	0.44
Summer 1982	a_L	1	1 200	1	130	1	13	0	.	0	.	0	.
	b_L	1	860	1	290	1	22	0	.	0	.	0	.
	c_L	1	450	1	71	1	8.3	0	.	0	.	0	.
	d_L	1	590	1	220	1	8.1	0	.	0	.	0	.

Appendix 3. Continued.

Season	Treatment	Leaching (kg km^{-2}a^{-1})							
		n	$\gamma_{25}^{2)}$	n	pH$^{3)}$	n	$L_{COD_{Mn}}(O_2)$	n	L_{SS}
Winter 1978—79	a_L	6	66	6	7.4	6	40	3	12
	b_L	5	65	5	7.3	5	96	2	25
	c_L	5	53	5	7.5	5	85	2	91
	d_L	6	62	6	7.3	6	71	3	24
Spring 1979	a_L	5	46	5	6.8	5	640	4	6 600
	b_L	5	46	5	7.0	5	4 200	4	100 000
	c_L	5	53	5	7.1	5	1 000	4	10 000
	d_L	5	58	5	7.0	5	1 200	4	6 500
Summer 1979	a_L	1	43	1	7.7	1	7.4	1	9.3
	b_L	3	67	3	7.9	3	20	3	5.4
	c_L	2	61	2	8.0	1	3.8	1	7.6
	d_L	2	63	2	7.5	1	26	1	3.4
Winter 1979—80	a_L	6	73	6	6.4	6	370	6	140
	b_L	6	73	6	7.3	6	330	6	140
	c_L	6	70	6	7.1	6	54	6	64
	d_L	6	86	6	7.3	6	120	6	73
Spring 1980	a_L	5	49	5	7.1	5	1 400	5	2 300
	b_L	5	53	5	7.2	5	2 400	5	4 100
	c_L	5	51	5	7.1	5	1 400	4	5 000
	d_L	5	51	5	7.4	5	4 700	5	10 000
Summer 1980	a_L	3	67	3	7.2	3	50	3	20
	b_L	3	87	3	7.0	3	360	3	96
	c_L	3	72	3	7.3	3	40	3	32
	d_L	3	85	3	7.6	3	44	3	180
Winter 1980—81	a_L	13	61	13	7.2	11	29	13	4.4
	b_L	12	74	12	7.6	11	31	12	7.3
	c_L	13	69	13	7.6	11	13	12	1.4
	d_L	10	91	10	7.8	9	7.1	9	1.6
Spring 1981	a_L	9	53	9	7.2	2	23 000	9	36 000
	b_L	8	48	8	7.0	2	55 000	8	300 000
	c_L	9	52	9	7.1	2	98 000	8	410 000
	d_L	5	52	5	7.2	2	40 000	5	290 000
Summer 1981	a_L	10	40	10	7.1	4	460	9	1 700
	b_L	10	47	10	6.9	4	640	10	3 700
	c_L	8	36	8	7.1	3	370	8	4 500
	d_L	8	53	8	7.1	3	510	8	760
Winter 1981—82	a_L	6	39	6	7.4	5	33	4	3 200
	b_L	6	43	6	7.4	5	29	5	650
	c_L	6	23	6	7.5	5	70	5	2 600
	d_L	3	16	3	7.3	2	76	3	3 000
Spring 1982	a_L	13	19	13	7.2	13	2 900	5	1 500
	b_L	13	15	13	7.3	13	4 500	5	910
	c_L	13	15	13	7.2	13	2 800	5	9 000
	d_L	13	15	13	7.4	13	3 000	5	4 200
Summer 1982	a_L	1	50	1	6.9	1	380	1	2 500
	b_L	1	35	1	7.3	1	550	1	9 100
	c_L	1	35	1	7.0	1	280	1	2 800
	d_L	1	33	1	7.3	1	370	1	3 100

2) In mS m^{-1} (median); 3) pH value (median)

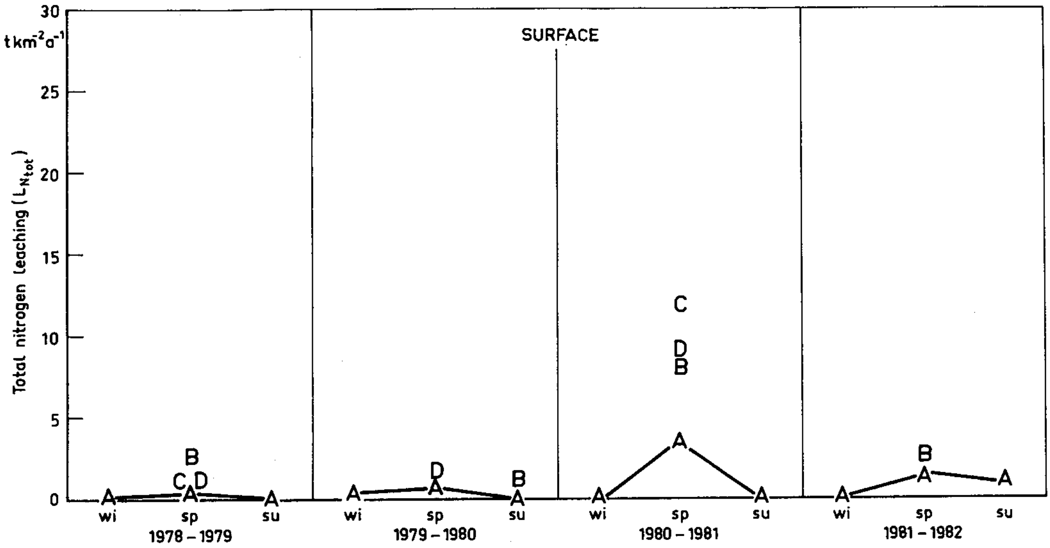
Appendix 4. Average rates of runoff and leaching during sampling intervals in different seasons of the hydrological years studied in the Liperi field. Number of observations in App. 2 and 3. (Diagrams of $L_{S_{SO_4}}$, L_{Fe}, L_{Mn}, L_{Zn}, L_{Cu} and L_{Ni} for surface runoff omitted because of low number of observations.)

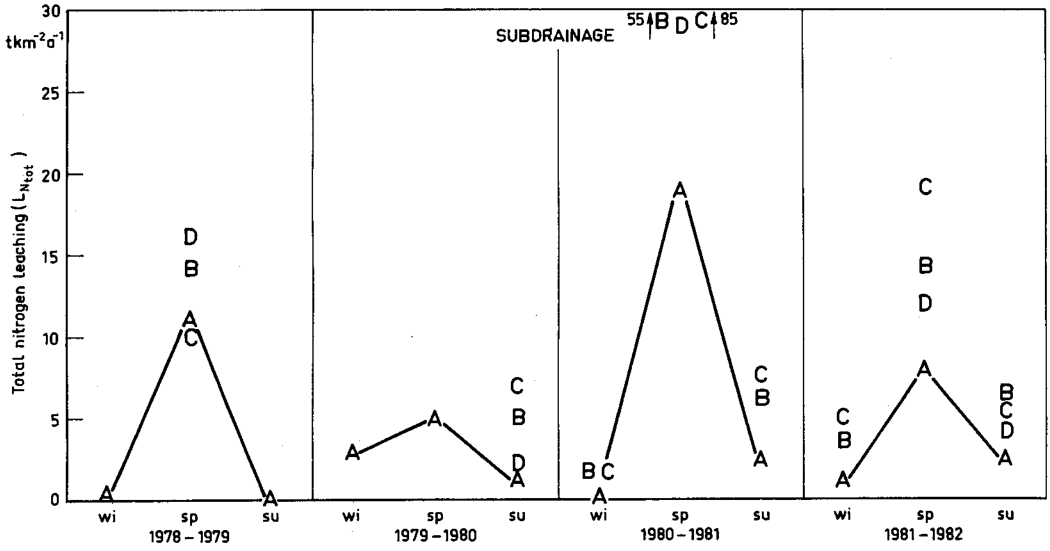


Legend:
A Treatment a_L
B Treatment b_L
C Treatment c_L
D Treatment d_L

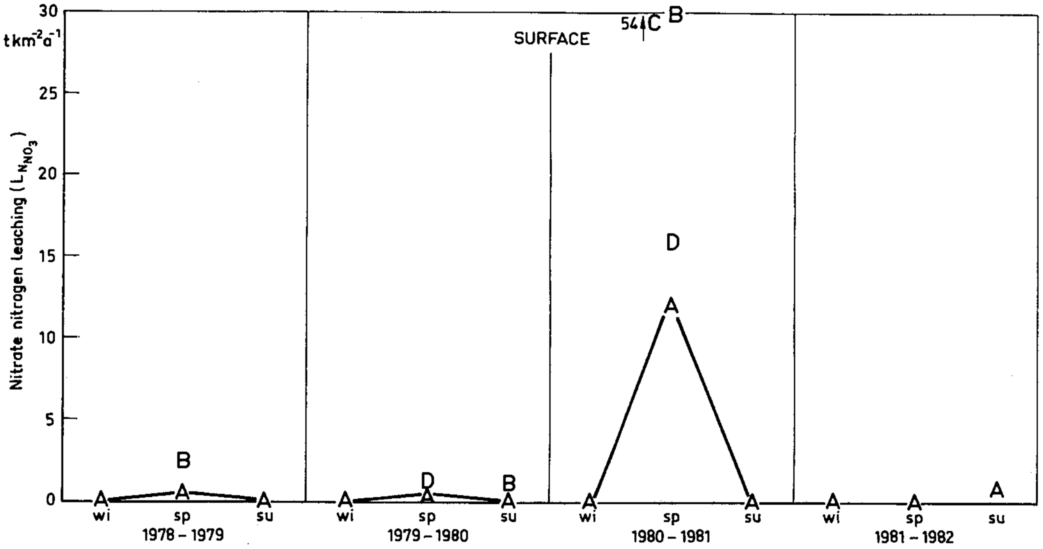
1978—1979	Hydrological year
wi	Winter (Nov. 1—Febr. 28)
sp	Spring (March 1—May 31)
su	Summer (June 1—Oct. 31)

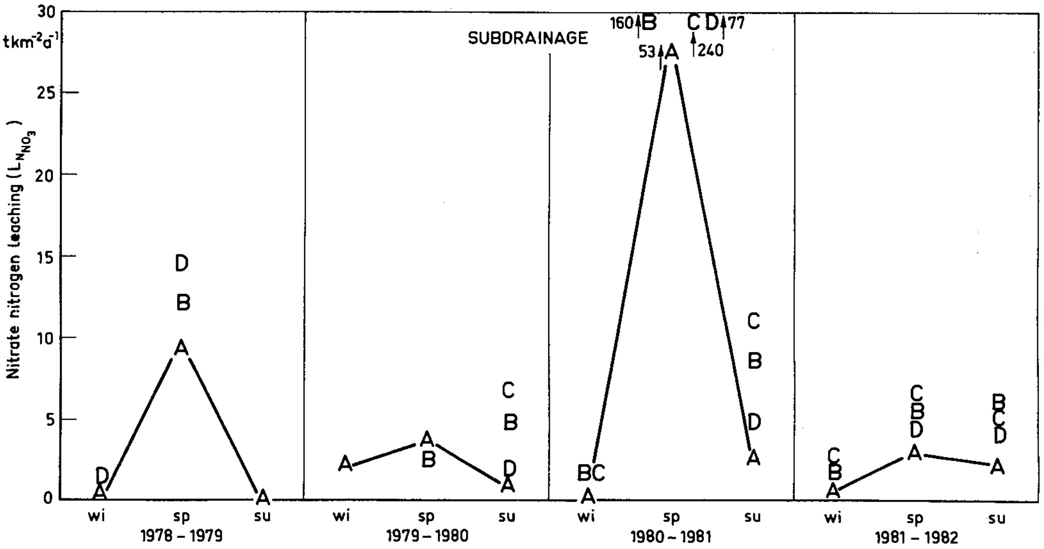
Appendix 4. Continued.



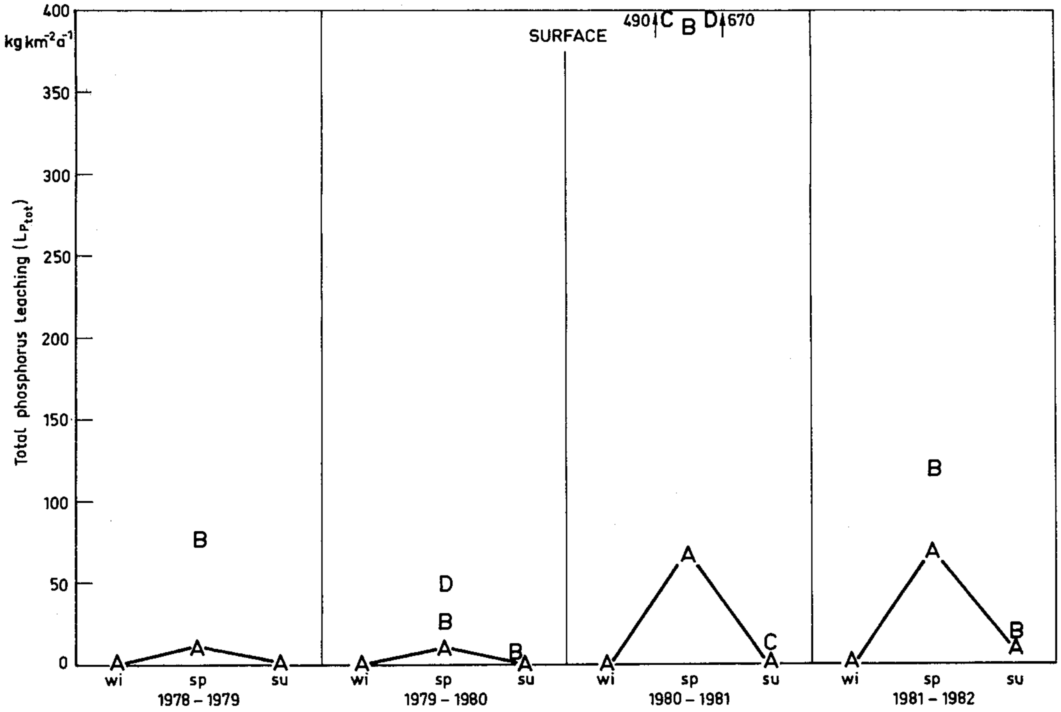


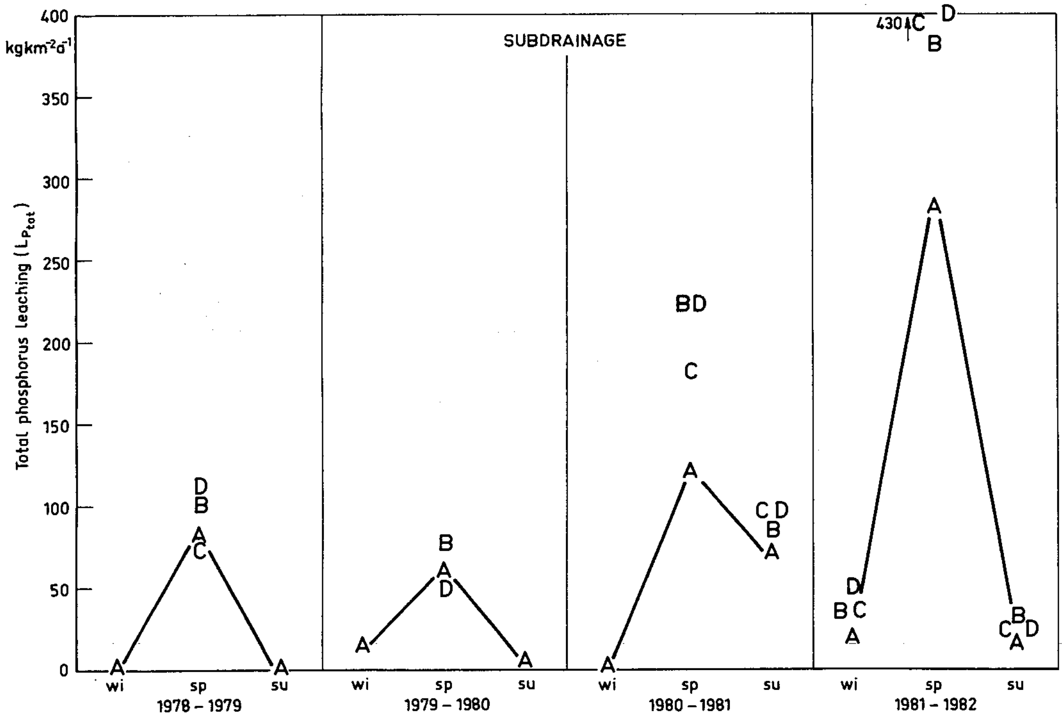
Appendix 4. Continued.



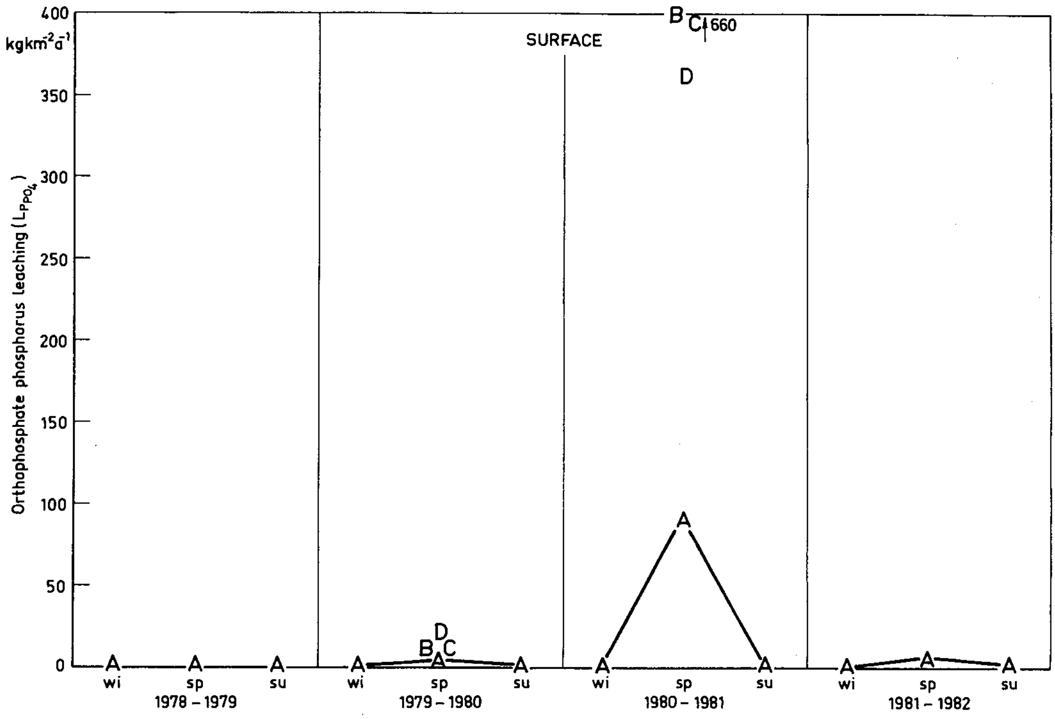


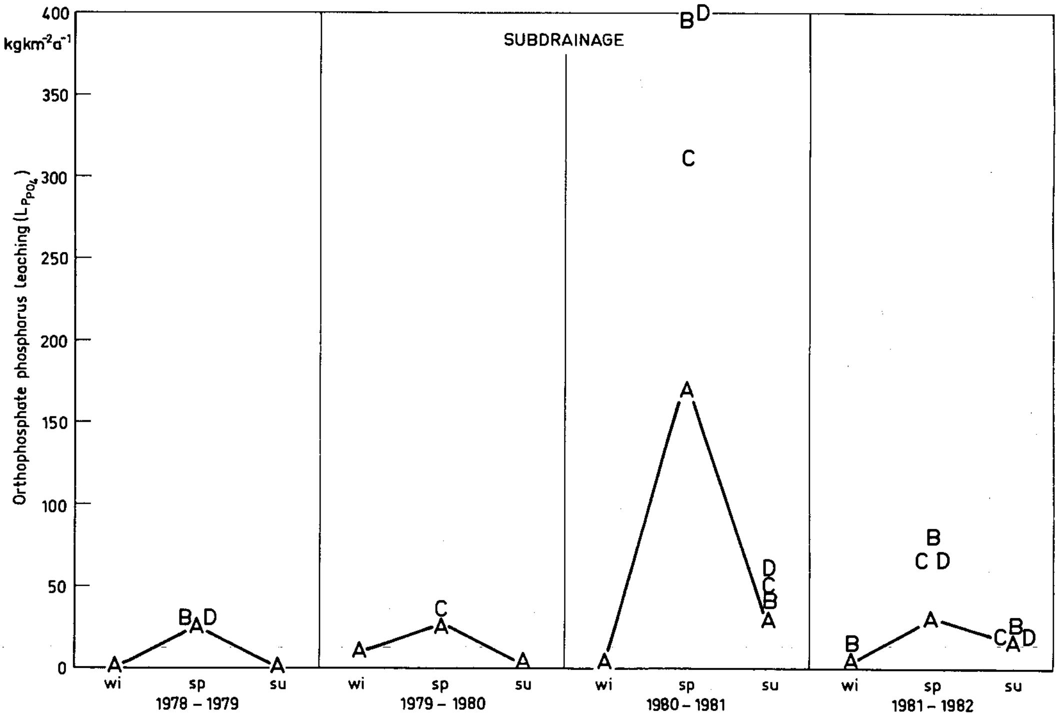
Appendix 4. Continued.



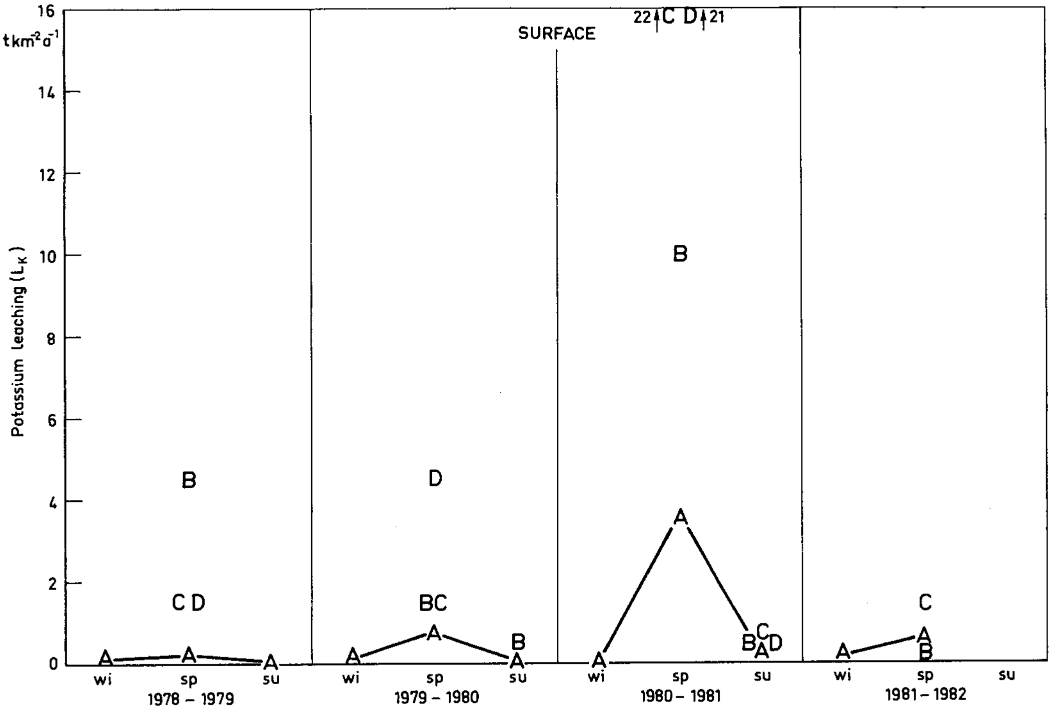


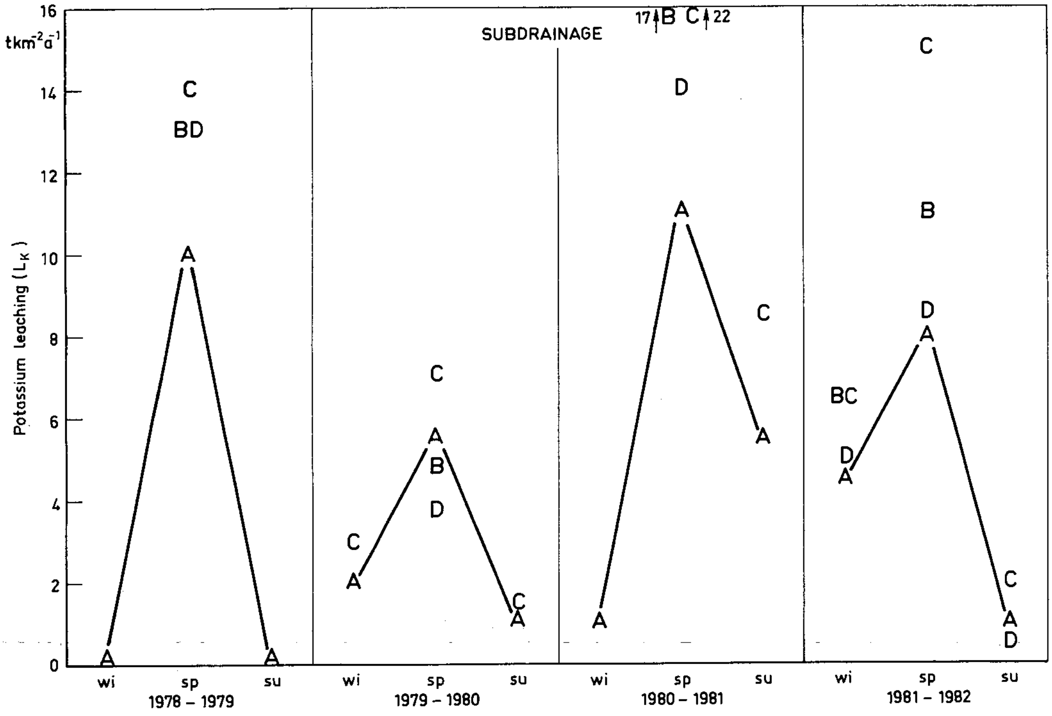
Appendix 4. Continued.



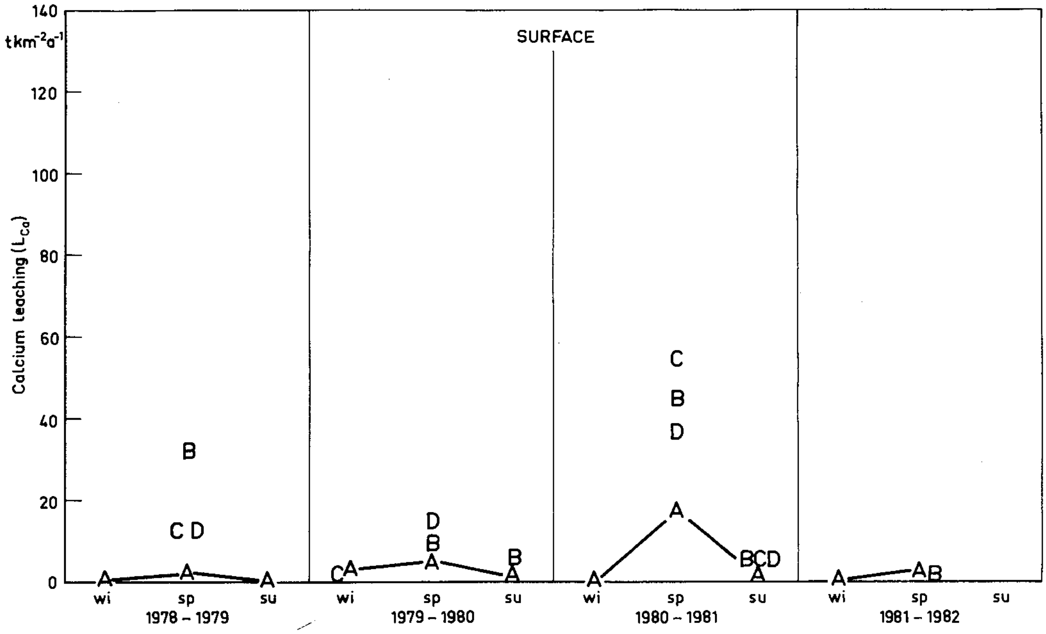


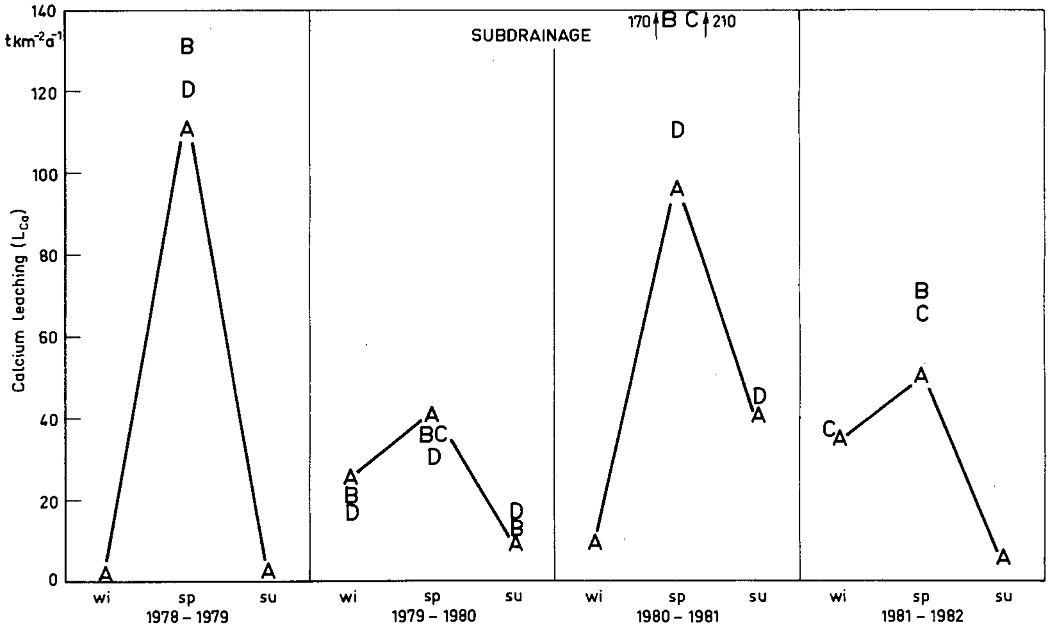
Appendix 4. Continued.



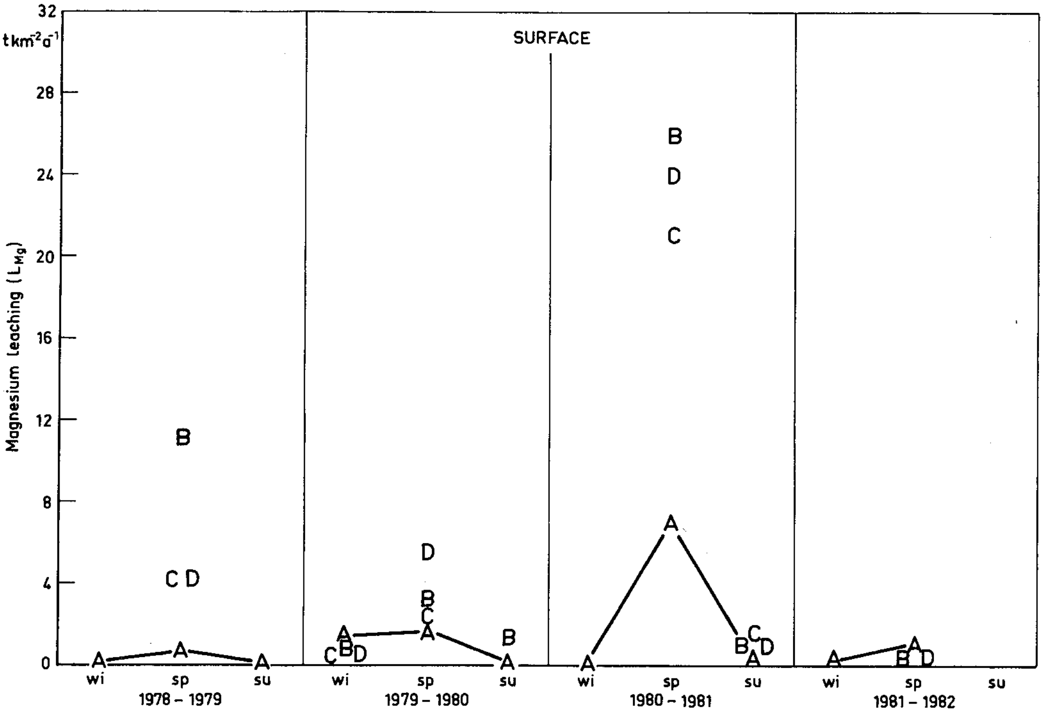


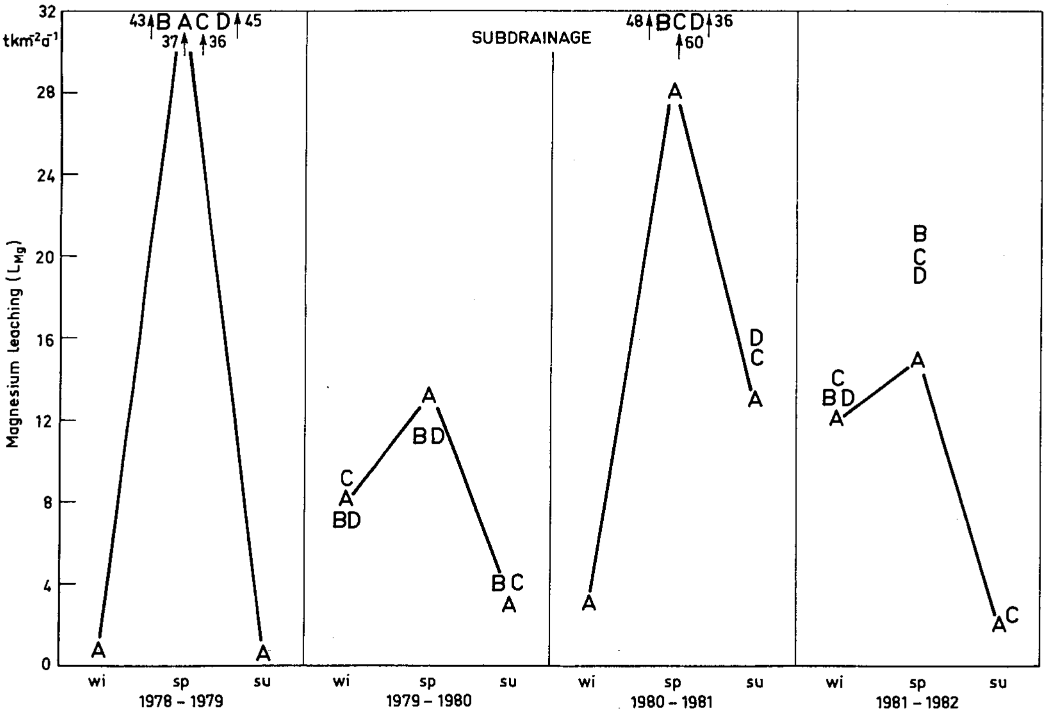
Appendix 4. Continued.



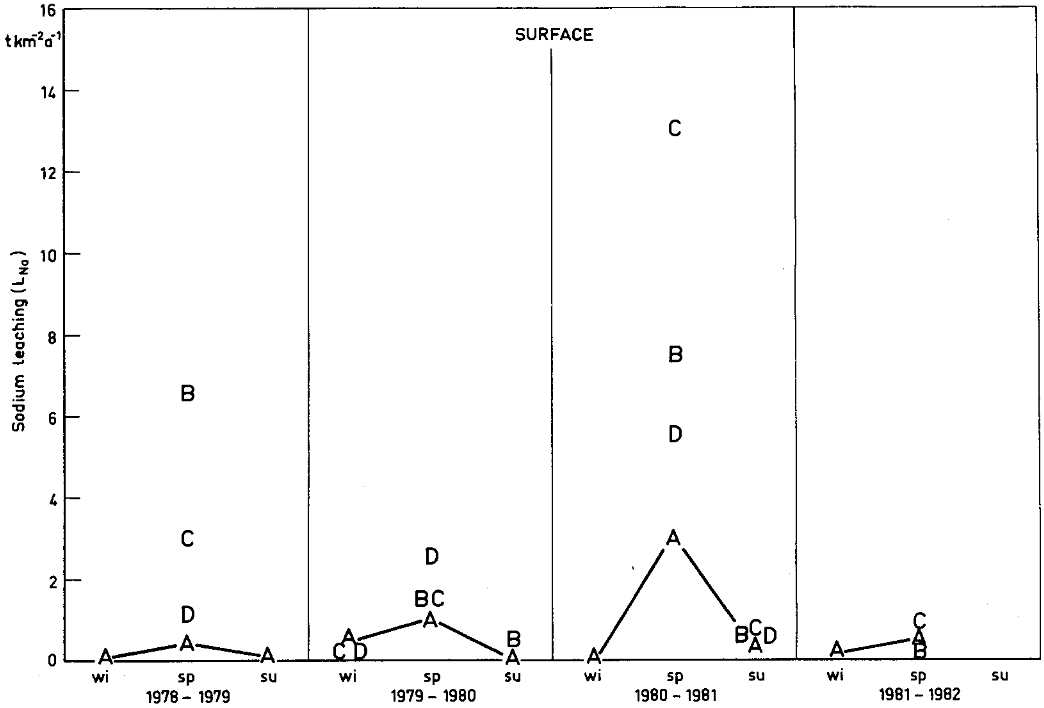


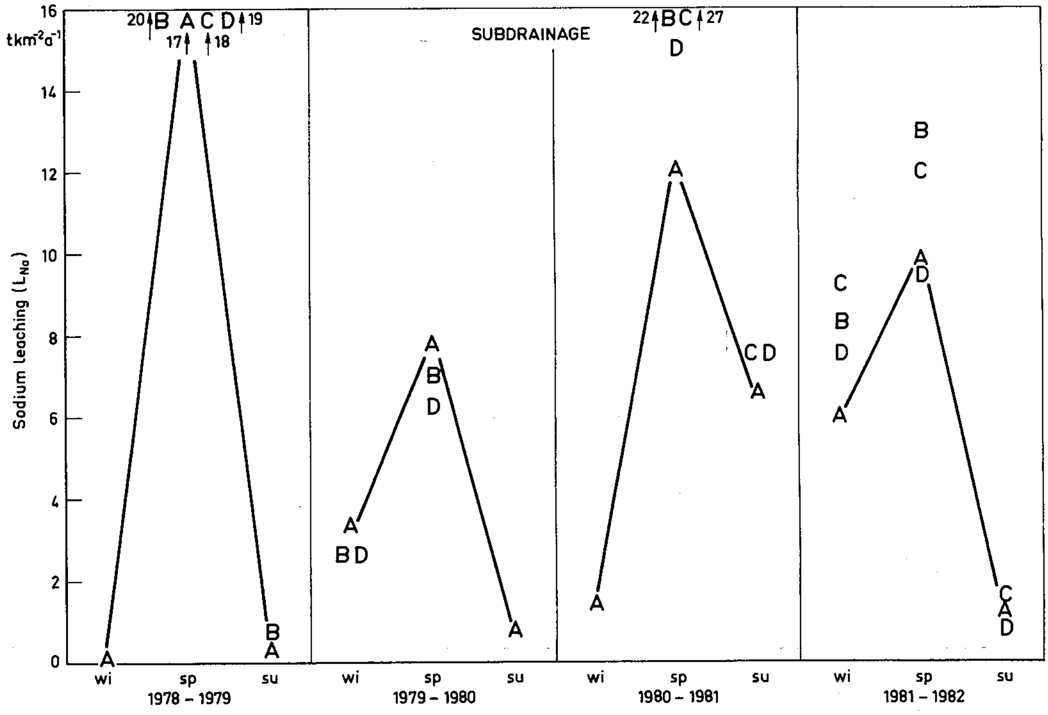
Appendix 4. Continued.

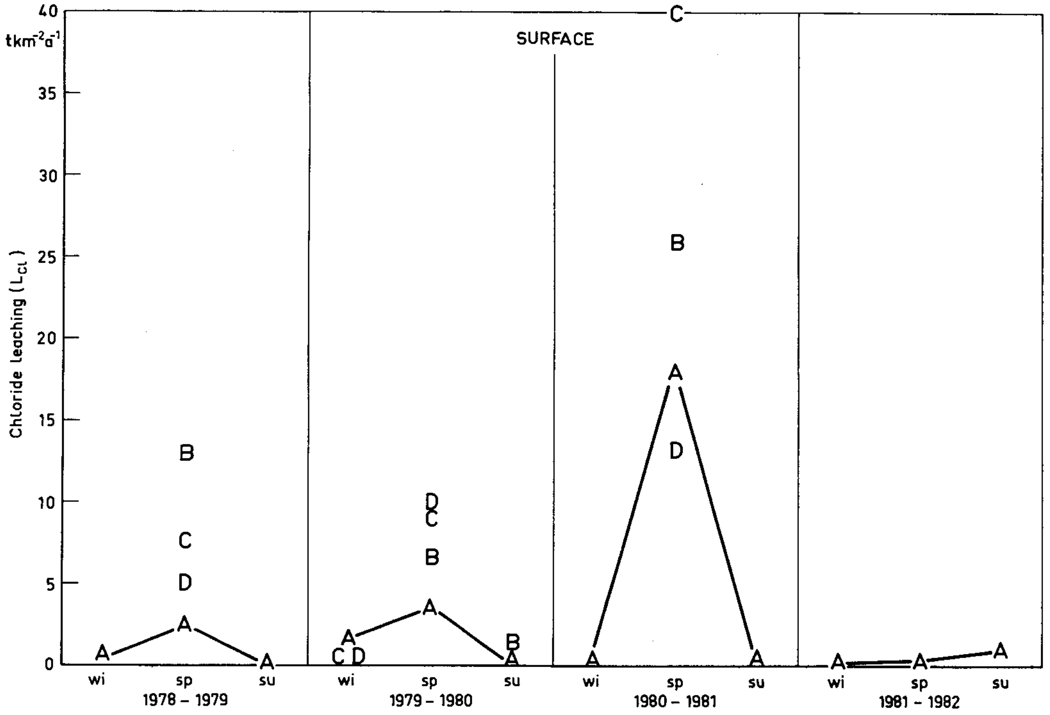


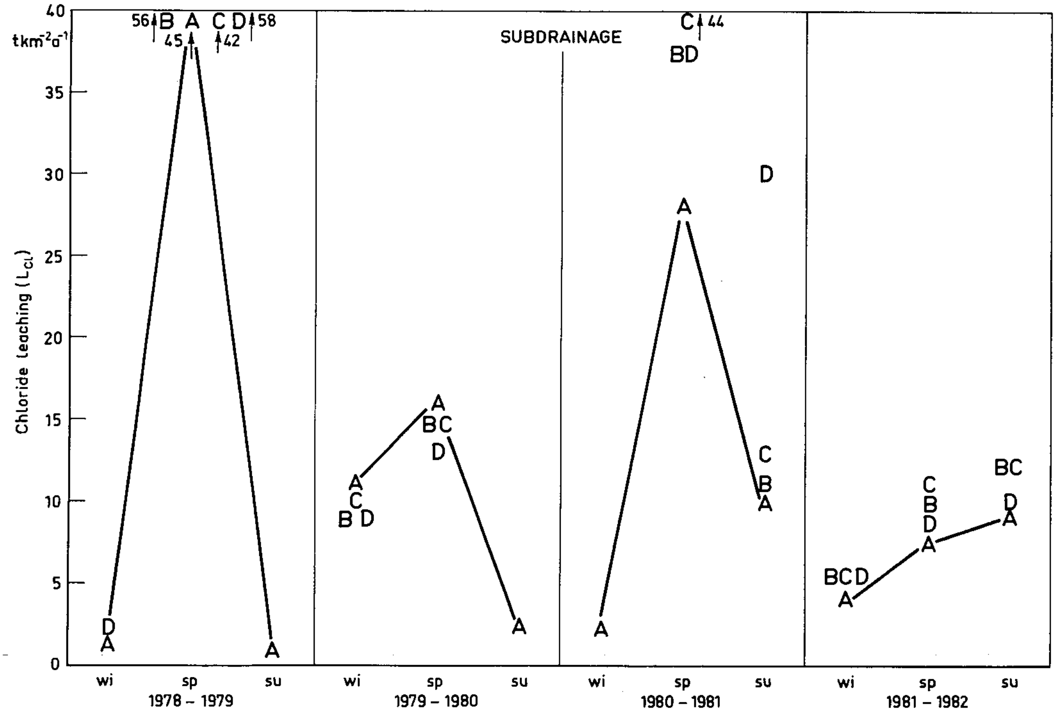


Appendix 4. Continued.

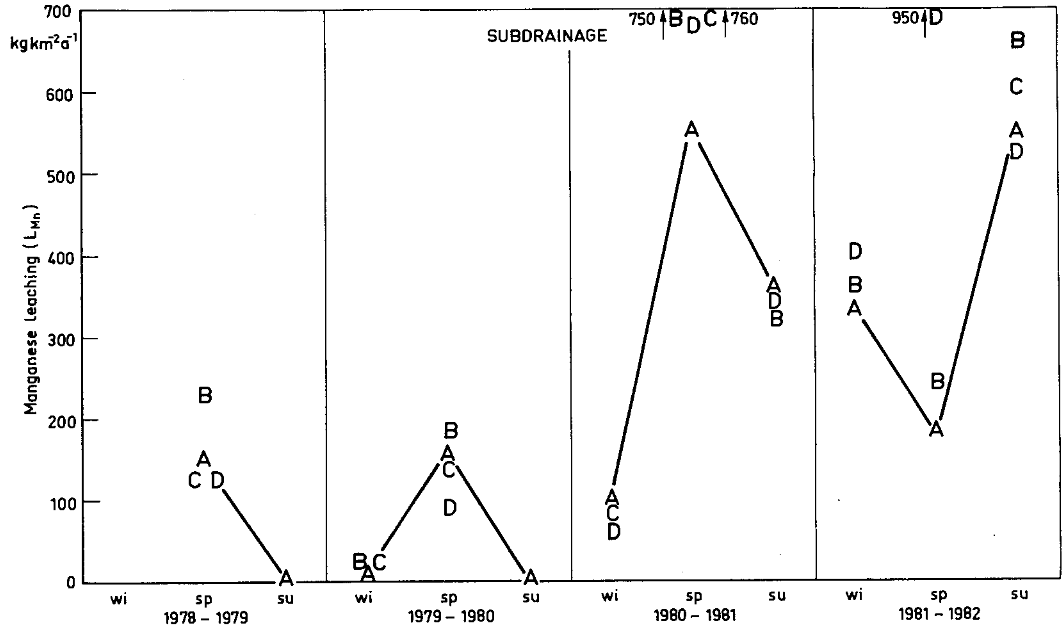


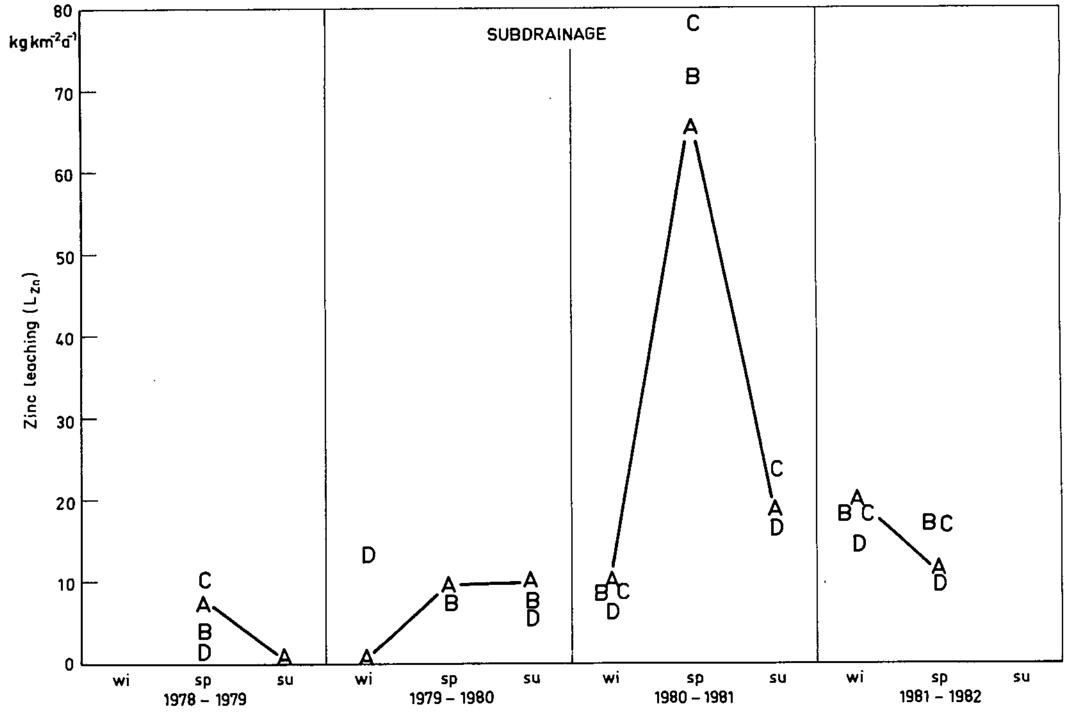



SURFACE
Chloride leaching (L_{Cl})
tkm⁻²a⁻¹
0
5
10
15
20
25
30
35
40
A
B
C
D
wi
sp
su
1978 – 1979
1979 – 1980
1980 – 1981
1981 – 1982

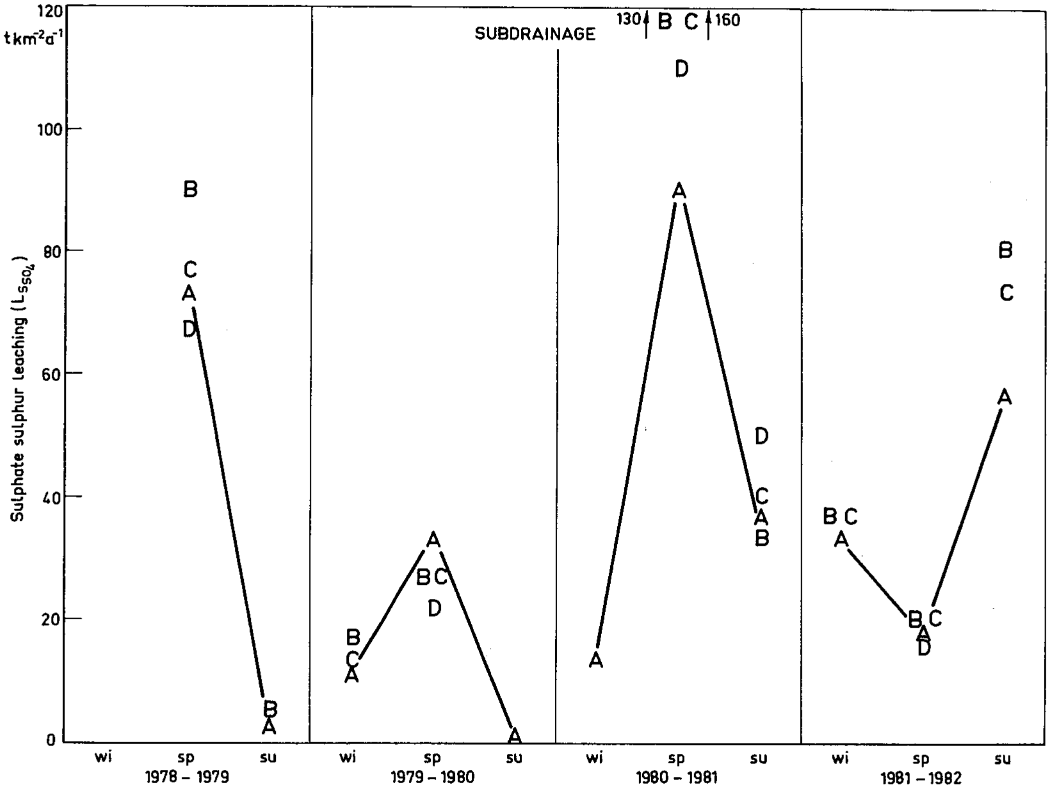

SUBDRAINAGE
Chloride leaching (L_{Cl})
tkm⁻²a⁻¹
0
5
10
15
20
25
30
35
40
56
45
42
58
44
A
B
C
D
BC
BD
BCD
wi
sp
su
1978 – 1979
1979 – 1980
1980 – 1981
1981 – 1982

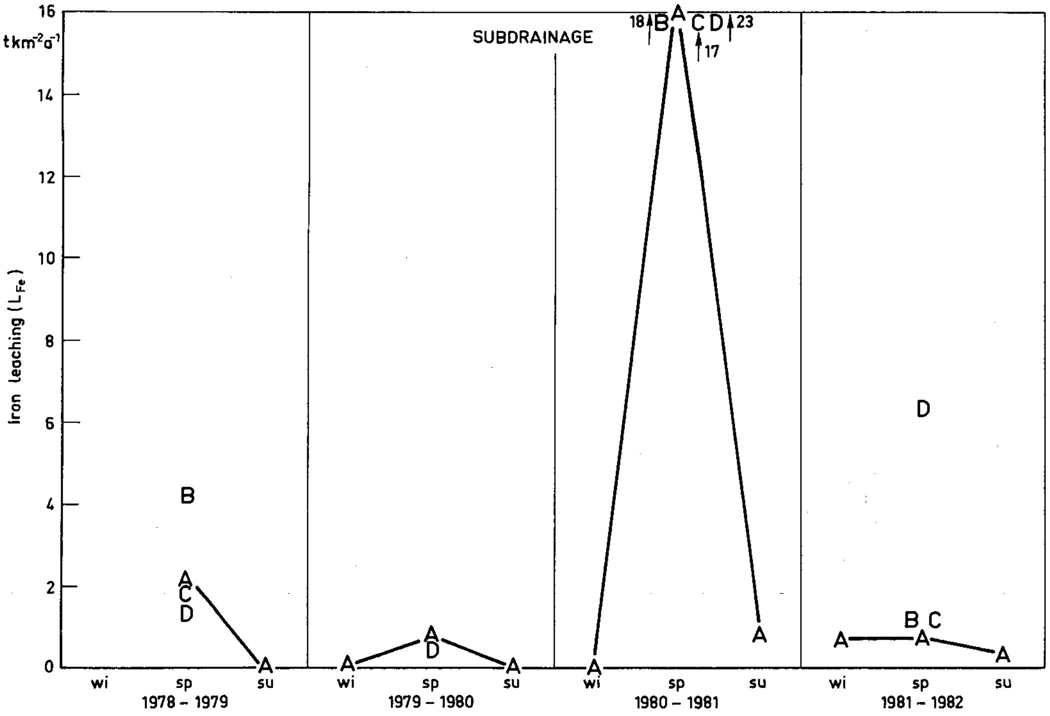
Appendix 4. Continued.



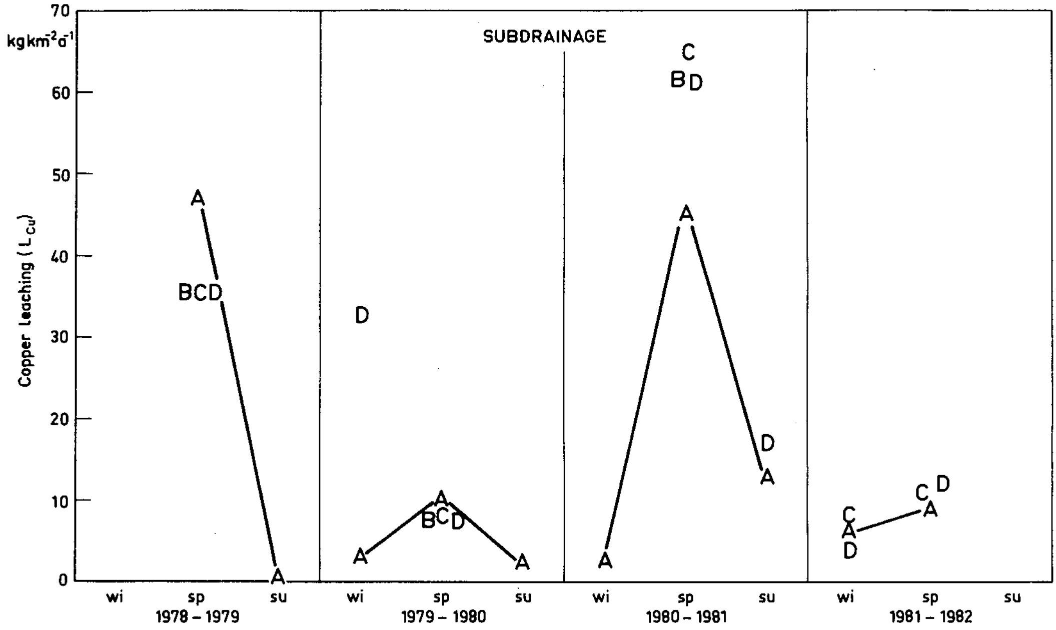


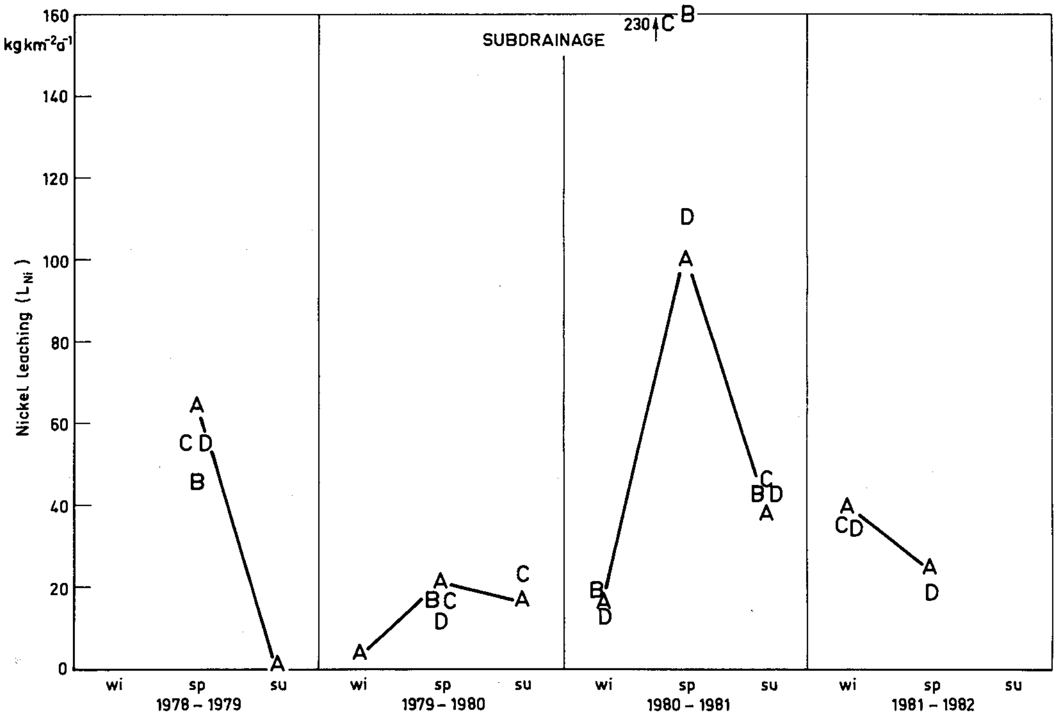
Appendix 4. Continued.



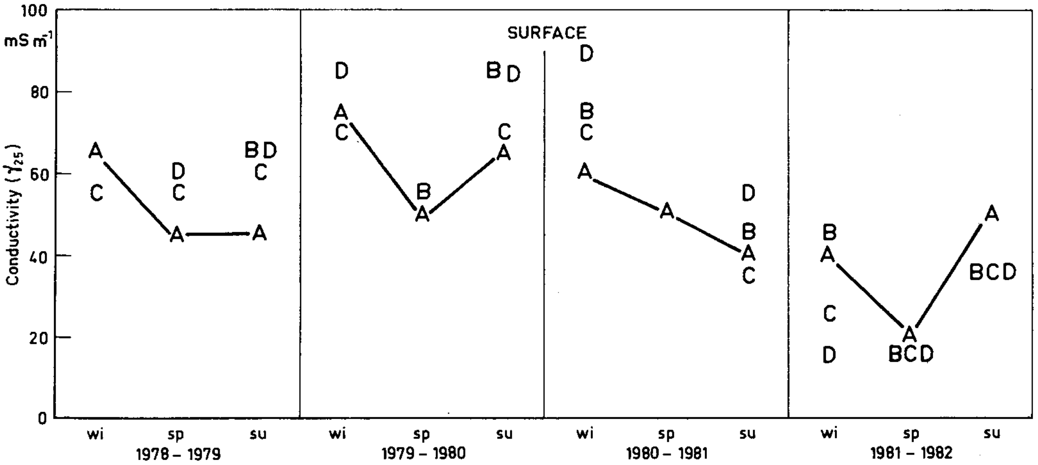


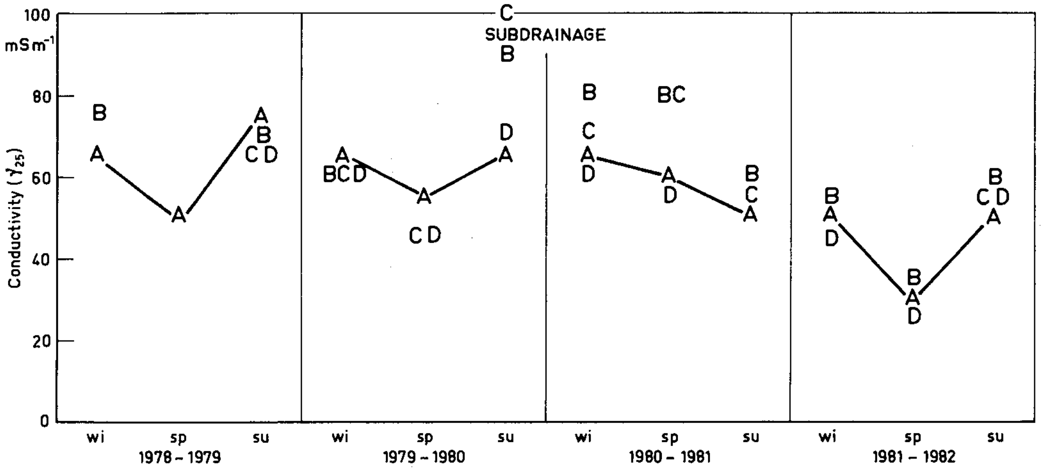
Appendix 4. Continued.

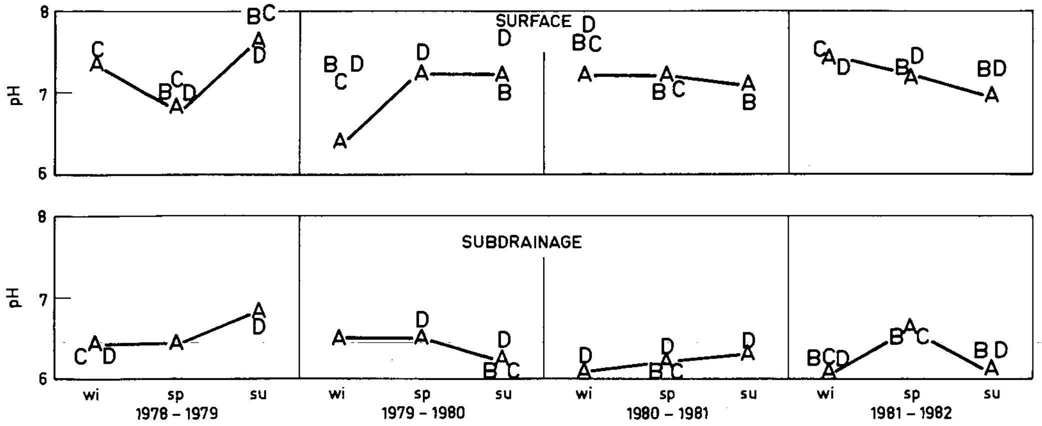




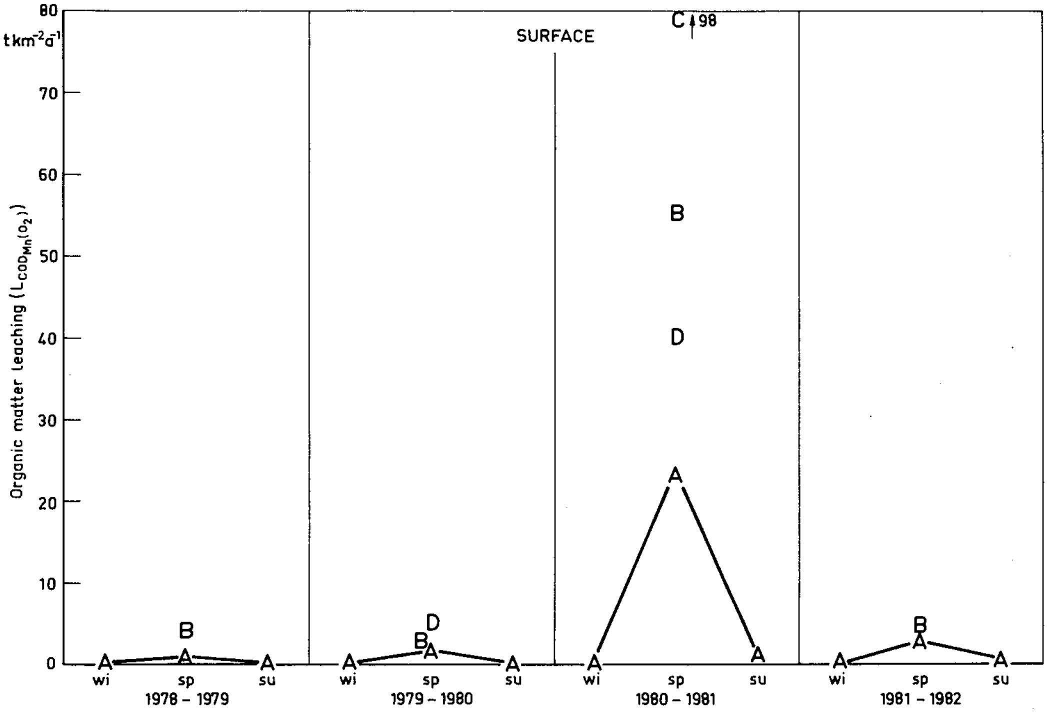
Appendix 4. Continued.

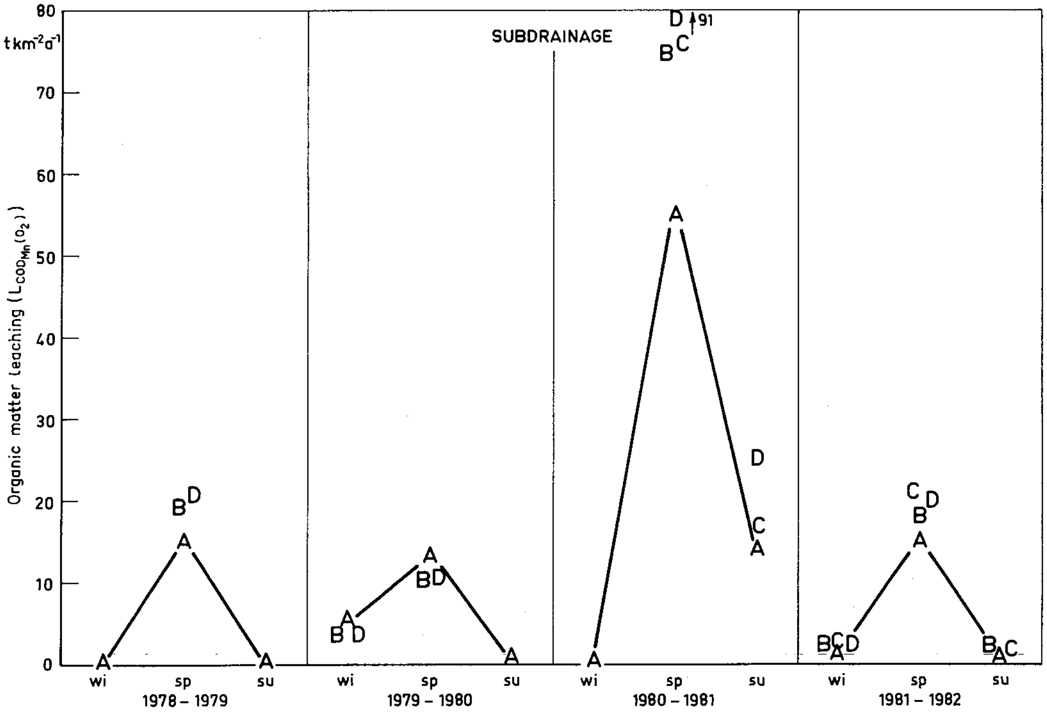




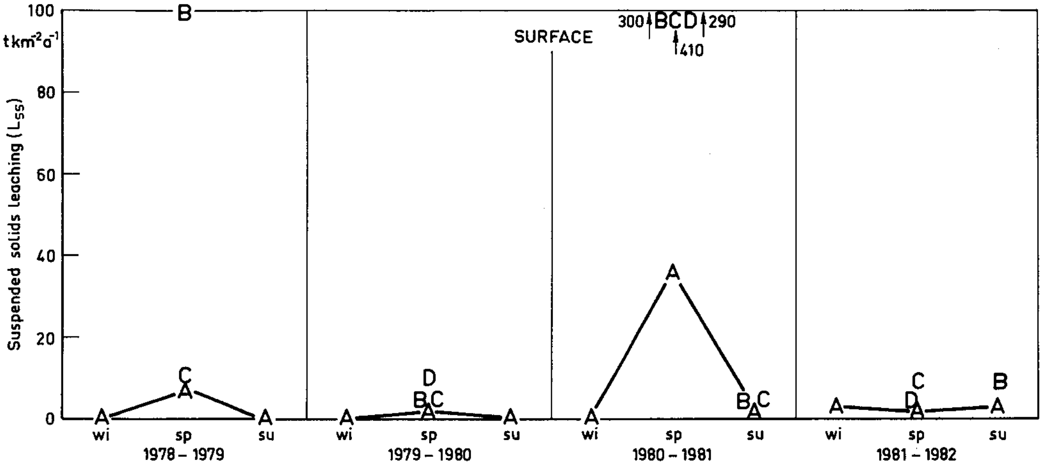


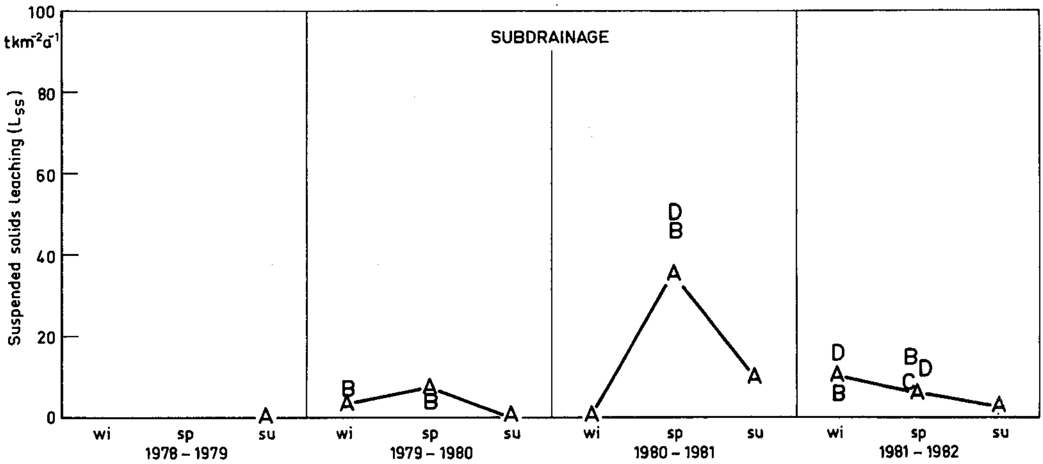
Appendix 4. Continued.





Appendix 4. Continued.





Appendix 5. Annual (Jan. 1—Dec. 31) flow-weighted mean concentrations in the replicates of subdrainage water in the Liperi field. Year 1979. (For location of the replicates, see Fig. 3.)

		Concentration (mg l^{-1})																																	
Treatment	Replicate	n[1]	N_{tot}	n	N_{NO_3}	n	P_{tot}	n	P_{PO_4}	n	K	n	Ca	n	Mg	n	S_{SO_4}	n	Na	n	Cl	n	Fe	n	Mn	n	Zn	n	Cu	n	Ni	n	$COD_{Mn}(O_2)$	n	SS
a_L	5	15	6.6	16	5.5	16	0.051	15	0.016	13	3.7	13	49	13	19	3	34	10	7.5	16	27	3	0.84	3	0.077	3	0.004	3	0.011	3	0.019	16	11	2	23
	11	14	9.1	14	7.4	14	0.053	14	0.019	12	5.6	12	62	12	20	3	45	9	7.3	14	28	3	0.49	3	0.054	3	0	3	0.010	3	0.019	14	14	2	15
	14	14	6.9	15	5.9	15	0.068	14	0.018	13	6.0	13	54	13	19	3	34	10	7.6	15	26	3	1.7	3	0.055	3	0.001	3	0.030	3	0.013	15	11	2	17
	20	14	6.9	15	5.7	15	0.050	14	0.016	13	7.1	13	90	13	23	3	74	10	15	15	50	3	0.55	3	0.11	3	0.005	3	0.014	3	0.032	15	13	2	21
	$\bar{X}$[2]	57	7.5	60	6.2	60	0.055	57	0.017	51	5.5	51	63	51	20	12	45	39	9.0	60	32	12	0.93	12	0.071	12	0.002	12	0.015	12	0.020	60	12	8	20
b_L	6	14	8.3	15	6.7	15	0.057	14	0.020	13	3.8	13	50	13	19	3	34	10	7.0	15	24	3	0.81	3	0.034	3	0	3	0.010	3	0.008	15	13	2	20
	12	14	8.8	15	7.3	15	0.050	14	0.016	13	9.6	13	80	13	25	3	64	10	16	15	55	3	0.44	3	0.20	3	0.003	3	0.015	3	0.024	15	13	2	18
	15	14	9.4	15	8.4	15	0.045	14	0.017	13	6.2	13	72	13	23	3	66	10	7.5	15	31	3	0.35	3	0.069	3	0.003	3	0.014	3	0.022	15	13	2	16
	17	15	5.3	16	4.2	16	0.063	15	0.017	14	6.1	14	50	14	20	3	37	11	7.7	16	24	3	2.5	3	0.083	3	0	3	0.009	3	0.011	16	10	2	30
	$\bar{X}$	57	7.6	61	6.4	61	0.055	57	0.018	53	6.3	53	61	53	21	12	46	41	9.2	61	32	12	1.4	12	0.089	12	0.002	12	0.012	12	0.016	61	12	8	23
c_L	7	14	7.4	15	6.2	15	0.064	14	0.024	13	4.3	13	56	13	18	3	33	10	7.4	15	28	3	0.73	3	0.035	3	0	3	0.010	3	0.012	15	14	2	21
	9	15	5.7	16	4.8	16	0.054	15	0.018	13	6.3	13	54	13	23	3	26	10	7.6	16	21	3	0.82	3	0.048	3	0.006	3	0.020	3	0.016	16	11	2	26
	16	15	9.0	16	7.9	15	0.039	14	0.011	14	16	14	88	14	24	3	71	11	17	15	50	3	0.46	3	0.17	3	0.014	3	0.017	3	0.050	16	13	2	17
	18	16	7.8	17	6.9	17	0.048	16	0.015	14	5.5	14	50	14	20	3	39	11	6.9	17	28	3	0.70	3	0.023	3	0	3	0.009	3	0.011	17	12	2	19
	$\bar{X}$	60	7.4	64	6.3	63	0.053	59	0.018	54	7.7	54	61	54	21	12	39	42	9.5	63	31	12	0.70	12	0.060	12	0.004	12	0.013	12	0.022	64	13	8	21
d_L	8	14	6.4	15	5.0	15	0.066	14	0.022	13	7.5	13	72	13	24	3	46	10	13	15	50	3	0.50	3	0.078	3	0	3	0.010	3	0.016	15	14	2	20
	10	14	10	15	8.7	15	0.056	14	0.021	13	5.5	13	51	13	19	3	25	10	7.3	15	25	3	0.76	3	0.035	3	0.013	3	0.041	3	0.011	15	12	2	19
	13	15	11	16	10	16	0.050	15	0.020	14	5.4	14	51	14	20	2	40	11	6.8	16	27	3	0.49	3	0.036	3	0	3	0.010	3	0.015	16	14	2	19
	19	14	8.0	15	7.0	15	0.056	14	0.015	13	5.2	13	54	13	21	3	48	10	6.9	15	29	3	0.57	3	0.068	3	0.001	3	0.010	3	0.019	15	13	2	24
	$\bar{X}$	57	8.9	61	7.7	61	0.057	57	0.020	53	5.9	53	57	53	21	11	39	41	8.6	61	33	12	0.59	12	0.053	12	0.004	12	0.018	12	0.016	61	13	8	20

1) n = number of observations; 2) $\bar{X}$ = treatment average

Appendix 5. Continued. Year 1980.

		Concentration (mg l^{-1})																																	
Treatment	Replicate	n	N_{tot}	n	N_{NO_3}	n	P_{tot}	n	P_{PO_4}	n	K	n	Ca	n	Mg	n	S_{SO_4}	n	Na	n	Cl	n	Fe	n	Mn	n	Zn	n	Cu	n	Ni	n	$COD_{Mn}(O_2)$	n	SS
a_L	5	21	3.6	21	2.5	21	0.047	21	0.021	21	6.7	21	46	21	17	4	44	19	7.1	21	13	4	0.88	4	0.28	5	0.039	5	0.020	5	0.078	21	9.4	19	<5
	11	21	5.4	21	4.7	21	0.047	21	0.021	21	5.1	21	48	21	16	4	44	19	7.1	21	14	4	1.2	4	0.12	5	0.017	5	0.011	5	0.030	21	12	20	<5
	14	21	5.0	21	3.8	21	0.060	21	0.026	21	5.6	21	39	21	14	4	39	19	6.5	21	11	4	1.1	4	0.070	5	0.011	5	0.009	5	0.024	21	12	21	6.1
	20	21	5.9	21	4.5	21	0.052	21	0.023	21	8.4	21	70	21	17	4	70	19	15	21	33	4	0.31	4	0.65	5	0.045	5	0.022	5	0.082	21	11	21	<5
	$\bar{X}$	84	5.0	84	3.9	84	0.052	84	0.023	84	6.3	84	49	84	16	16	49	76	8.6	84	16	16	0.90	16	0.26	20	0.027	20	0.015	20	0.051	84	11	81	<5
b_L	6	21	12	21	9.1	21	0.090	20	0.039	21	7.3	21	53	21	21	4	44	19	8.6	21	12	4	0.80	4	0.12	5	0.006	5	0.011	5	0.029	21	13	20	<5
	12	21	11	21	8.8	21	0.057	21	0.015	21	10	21	71	21	23	4	66	19	17	21	45	4	2.2	4	0.79	5	0.048	5	0.014	5	0.086	21	14	21	<5
	15	21	15	21	11	21	0.060	21	0.020	20	7.0	20	77	20	24	4	66	18	9.2	21	18	4	0.65	4	0.49	5	0.050	5	0.018	5	0.10	21	13	21	<5
	17	21	14	21	11	21	0.16	21	0.050	21	7.4	21	63	21	21	4	43	19	8.6	21	11	4	1.5	4	0.21	5	0.007	5	0.010	5	0.031	21	14	21	7.8
	$\bar{X}$	84	13	84	9.8	84	0.095	83	0.032	83	8.0	83	66	83	22	16	54	75	11	84	21	16	1.3	16	0.38	20	0.025	20	0.013	20	0.058	84	14	83	<5
c_L	7	21	15	21	13	21	0.061	21	0.029	21	5.9	21	56	21	18	4	45	19	7.2	21	14	4	0.71	4	0.18	5	0.008	5	0.010	5	0.042	21	12	20	<5
	9	21	7.7	21	7.0	21	0.058	21	0.022	21	5.9	21	45	21	16	4	41	19	6.8	21	12	4	0.76	4	0.082	5	0.020	5	0.011	5	0.034	21	10	20	6.7
	16	20	9.6	20	8.7	20	0.038	20	0.014	20	17	20	70	20	19	3	71	18	16	20	36	3	0.81	3	0.88	4	0.077	4	0.033	4	0.13	20	12	20	5.7
	18	21	13	20	12	21	0.070	21	0.040	20	5.3	21	41	21	16	4	39	19	6.1	21	8.9	4	1.2	4	0.055	5	0.007	5	0.008	5	0.031	21	12	21	5.9
	$\bar{X}$	83	11	82	9.8	83	0.058	83	0.027	82	8.0	83	51	83	17	15	48	75	8.4	83	16	15	0.87	15	0.28	19	0.027	19	0.015	19	0.056	83	11	81	5.9
d_L	8	21	8.1	21	6.8	21	0.058	21	0.028	21	6.4	21	54	21	18	4	52	19	12	21	32	4	0.38	4	0.35	5	0.010	5	0.011	5	0.042	21	14	20	<5
	10	21	6.1	21	4.5	21	0.053	21	0.023	21	5.3	21	42	21	16	4	39	19	7.0	21	9.4	4	1.1	4	0.077	5	0.032	5	0.014	5	0.022	21	11	20	5.7
	13	21	6.3	21	4.8	21	0.065	21	0.034	21	4.8	21	39	21	14	4	32	19	6.4	21	9.4	4	0.83	4	0.045	5	0.003	5	0.008	5	0.018	21	13	21	<5
	19	21	5.8	21	5.0	21	0.046	21	0.026	21	5.8	21	56	21	23	4	64	19	7.5	21	14	4	0.66	4	0.35	5	0.046	5	0.012	5	0.11	21	9.5	21	13
	$\bar{X}$	84	6.6	84	5.3	84	0.056	84	0.028	84	5.6	84	47	84	17	16	45	76	8.3	84	16	16	0.76	16	0.18	20	0.022	20	0.011	20	0.044	84	12	82	5.8

Appendix 5. Continued. Year 1981.

		Concentration (mg l^{-1})																																	
Treatment	Replicate	n	N_{tot}	n	N_{NO_3}	n	P_{tot}	n	P_{PO_4}	n	K	n	Ca	n	Mg	n	S_{SO_4}	n	Na	n	Cl	n	Fe	n	Mn	n	Zn	n	Cu	n	Ni	n	$COD_{Mn}(O_2)$	n	SS
a_L	5	29	6.3	12	6.5	29	0.079	12	0.030	23	7.0	23	45	23	17	11	31	22	6.5	12	7.2	11	2.2	11	0.24	9	0.027	9	0.011	9	0.039	12	10	29	16
	11	29	6.5	12	7.2	29	0.070	12	0.027	22	6.4	22	51	22	17	11	31	21	6.4	12	6.6	11	3.0	11	0.16	9	0.015	9	0.011	9	0.025	12	12	29	21
	14	29	11	12	12	29	0.088	12	0.049	22	6.4	22	55	22	18	11	25	21	6.3	12	5.4	11	2.7	11	0.13	9	0.013	9	0.009	9	0.023	12	12	29	22
	20	29	8.1	12	9.5	29	0.11	12	0.040	22	7.9	22	64	22	16	11	37	22	14	12	17	11	3.1	11	0.59	9	0.020	9	0.016	9	0.046	12	18	29	24
	$\bar{X}$	116	7.6	48	8.5	116	0.083	48	0.035	89	6.8	89	52	89	17	44	31	86	7.8	48	8.5	44	2.7	44	0.26	36	0.019	36	0.011	36	0.032	48	13	116	20
b_L	6	29	17	11	17	29	0.13	12	0.071	23	6.9	23	52	23	18	11	25	22	6.0	12	5.3	11	2.0	11	0.14	9	0.009	9	0.009	9	0.022	12	12	29	16
	12	29	28	12	29	29	0.11	12	0.065	22	9.6	22	77	22	24	11	42	21	15	12	23	11	1.8	11	0.52	9	0.025	9	0.016	9	0.065	12	15	29	17
	15	28	27	12	27	29	0.097	12	0.053	22	9.4	22	71	22	19	11	37	21	9.0	12	7.4	11	2.1	11	0.23	9	0.020	9	0.013	9	0.047	12	15	29	20
	17	27	18	12	20	29	0.14	12	0.064	23	7.6	23	60	23	19	11	25	22	8.7	12	5.0	11	4.8	11	0.15	9	0.014	9	0.012	9	0.023	12	13	29	31
	$\bar{X}$	113	22	47	22	116	0.12	48	0.064	90	8.1	90	62	90	20	44	31	86	9.2	48	9.3	44	2.6	44	0.24	36	0.016	36	0.012	36	0.036	48	14	116	20
c_L	7	29	23	12	23	29	0.13	12	0.067	23	7.4	23	56	23	19	11	26	22	6.5	12	7.3	11	1.8	11	0.23	9	0.010	9	0.009	9	0.029	12	14	29	13
	9	28	26	12	26	29	0.096	12	0.035	23	7.8	23	56	23	22	11	32	22	7.4	12	6.2	11	3.2	11	0.14	9	0.023	9	0.012	9	0.035	12	10	29	23
	16	29	33	12	32	29	0.070	12	0.028	23	16	23	80	23	21	11	46	22	18	12	19	11	1.9	11	0.47	9	0.023	9	0.014	9	0.067	12	14	29	11
	18	27	36	12	36	29	0.10	12	0.048	23	6.2	23	59	23	20	11	27	22	8.2	12	6.7	11	1.8	11	0.072	9	0.011	9	0.010	9	0.035	12	12	29	15
	$\bar{X}$	113	29	48	29	116	0.10	48	0.046	92	8.9	92	61	92	20	44	32	88	9.5	48	9.1	44	2.2	44	0.21	36	0.016	36	0.031	36	0.039	48	13	116	16
d_L	8	29	10	12	10	29	0.18	12	0.076	23	6.9	23	50	23	16	11	27	22	9.0	12	15	11	2.0	11	0.49	9	0.012	9	0.010	9	0.029	12	16	29	22
	10	28	10	12	8.0	29	0.086	12	0.043	23	5.3	23	40	23	15	11	21	22	6.0	12	4.6	11	2.7	11	0.098	9	0.009	9	0.008	9	0.016	12	10	29	23
	13	29	6.6	12	4.3	29	0.064	12	0.033	22	5.1	22	40	22	16	11	25	21	6.1	12	14	11	1.8	11	0.065	9	0.007	9	0.009	9	0.018	11	12	29	5.6
	19	29	10	12	11	29	0.12	12	0.062	23	6.0	23	47	23	16	11	25	22	5.5	12	6.7	11	3.5	11	0.16	9	0.015	9	0.011	9	0.027	12	14	29	30
	$\bar{X}$	115	9.2	48	8.3	116	0.11	48	0.052	91	5.8	91	44	91	16	44	25	87	6.6	48	10	44	2.5	44	0.19	36	0.011	36	0.010	36	0.022	47	13	116	19

Appendix 5. Continued. Year 1982.

		Concentration (mg l^{-1})																																	
Treatment	Replicate	n	N_{tot}	n	N_{NO_3}	n	P_{tot}	n	P_{PO_4}	n	K	n	Ca	n	Mg	n	S_{SO_4}	n	Na	n	Cl	n	Fe	n	Mn	n	Zn	n	Cu	n	Ni	n	$COD_{Mn}(O_2)$	n	SS
a_L	5	24	3.0	15	2.0	24	0.15	18	0.032	9	6.4	9	39	9	14	6	43	8	6.1	15	8.3	6	0.36	6	0.32	6	0.026	6	0.011	6	0.051	24	7.8	6	<5
	11	24	3.8	15	2.8	24	0.092	18	0.025	9	5.5	9	51	9	16	6	54	8	7.4	15	8.6	6	0.24	6	0.23	6	0.011	6	0.007	6	0.028	24	7.1	6	<5
	14	24	4.0	15	2.6	24	0.096	18	0.029	9	5.6	9	41	9	13	6	39	8	5.8	15	5.7	6	0.40	6	0.097	6	0.014	6	0.009	6	0.016	24	7.4	6	<5
	20	24	3.2	15	2.0	24	0.072	18	0.025	9	11	9	63	9	15	6	67	8	15	15	29	6	0.72	6	1.1	6	0.024	6	0.019	6	0.048	24	9.1	6	6.7
	$\bar{X}$	96	3.5	60	2.3	96	0.11	72	0.028	36	6.7	36	48	36	15	24	50	32	8.2	60	12	24	0.41	24	0.41	24	0.019	24	0.011	24	0.037	96	7.7	24	<5
b_L	6	24	4.7	15	4.4	24	0.18	18	0.068	9	6.5	9	44	9	16	6	46	8	7.1	15	6.7	6	0.70	6	0.26	6	0.016	6	0.007	6	0.020	24	7.7	6	10
	12	24	7.0	15	5.3	24	0.10	18	0.055	9	12	9	63	9	18	6	69	8	15	15	38	6	0.42	6	1.1	6	0.030	6	0.017	6	0.061	24	8.9	6	<5
	15	24	8.2	15	6.7	24	0.10	18	0.031	9	6.3	9	59	9	17	6	64	8	6.6	15	11	6	0.30	6	0.49	6	0.030	6	0.012	6	0.059	24	8.9	6	<5
	17	24	5.6	15	4.5	24	0.11	18	0.042	9	6.0	9	43	9	14	6	41	8	6.1	15	6.0	6	0.50	6	0.098	6	0.006	6	0.007	6	0.013	24	7.7	6	<5
	$\bar{X}$	96	6.1	60	5.1	96	0.13	72	0.051	36	7.6	36	51	36	16	24	53	32	8.6	60	13	24	0.50	24	0.43	24	0.020	24	0.010	24	0.036	96	8.2	24	5.2
c_L	7	24	6.2	15	5.1	24	0.14	18	0.065	9	6.4	9	45	9	14	6	50	8	5.5	15	9.0	6	0.60	6	0.55	6	0.022	6	0.013	6	0.023	24	8.4	6	<5
	9	24	6.3	15	5.0	24	0.14	18	0.031	9	6.1	9	39	9	15	6	40	8	6.1	15	6.0	6	0.47	6	0.13	6	0.019	6	0.010	6	0.025	24	7.5	6	<5
	16	24	6.2	15	3.8	24	0.067	18	0.018	9	24	9	64	9	16	6	75	8	17	15	32	6	0.80	6	0.98	6	0.027	6	0.012	6	0.064	24	8.3	6	<5
	18	24	7.3	15	6.9	24	0.13	18	0.042	9	5.8	9	38	9	15	6	38	8	6.5	15	4.9	6	0.49	6	0.060	6	0.008	6	0.007	6	0.016	24	8.7	6	<5
	$\bar{X}$	96	6.5	60	5.2	96	0.13	72	0.042	36	9.9	36	46	36	15	24	50	32	8.2	60	12	24	0.58	24	0.42	24	0.019	24	0.012	24	0.031	96	8.2	24	<5
d_L	8	24	4.8	15	4.1	24	0.18	18	0.078	9	7.6	9	53	9	16	6	56	8	10	15	28	6	7.2	6	1.7	6	0.016	6	0.018	6	0.034	24	10	6	11
	10	24	4.6	15	3.3	24	0.13	18	0.038	9	5.2	9	41	9	14	6	36	8	5.7	15	5.5	6	0.38	6	0.10	6	0.004	6	0.007	6	0.012	24	7.0	6	<5
	13	24	4.1	15	3.0	24	0.095	18	0.024	9	4.6	9	33	9	14	6	33	8	5.3	15	5.3	6	0.35	6	0.061	6	0.004	6	0.006	6	0.012	24	7.9	5	<5
	19	24	4.5	15	3.1	24	0.12	18	0.035	9	5.3	9	48	9	17	6	56	8	5.9	15	10	6	0.63	6	0.49	6	0.024	6	0.011	6	0.045	24	9.0	6	5.2
	$\bar{X}$	96	4.5	60	3.4	96	0.13	72	0.044	36	5.7	36	44	36	15	24	45	32	6.8	60	12	24	2.2	24	0.60	24	0.012	24	0.011	24	0.026	96	8.4	23	5.6

Appendix 6. Annual (Jan. 1—Dec. 31) flow-weighted mean concentrations in the (replicates of) surface water in the Liperi field. (For location of the replicates, see Fig. 3)

Year	Treat-ment	Repli-cate	Concentration (mg l^{-1})																																	
			n[1)]	N_{tot}	n	N_{NO_3}	n	P_{tot}	n	P_{PO_4}	n	K	n	Ca	n	Mg	n	S_{SO_4}	n	Na	n	Cl	n	Fe	n	Mn	n	Zn	n	Cu	n	Ni	n	$COD_{Mn}(O_2)$	n	SS
1979	a_L	5	10	5.6	12	5.2	12	0.045	11	0.009	10	7.0	10	69	10	25	2	29	9	9.9	12	32	2	3.7	2	0.11	2	0.046	2	0.085	2	0.032	12	7.1	11	32
	b_L	17	13	5.1	14	4.2	14	0.14	13	0.013	12	7.1	12	51	12	18	3	22	10	9.8	14	29	3	9.0	3	0.12	3	0.017	3	0.021	3	0.035	14	9.0	13	150
	c_L	9	12	3.5	13	2.7	13	0.055	12	0.011	10	6.6	10	55	10	20	2	14	9	14	13	37	2	7.8	2	0.12	2	0.003	2	0.011	2	0.009	12	5.1	11	38
	d_L	13	12	4.1	13	3.5	13	0.043	11	0.010	11	6.6	11	69	11	23	3	16	10	6.4	12	28	3	4.2	3	0.071	3	0.002	3	0.010	3	0.006	12	6.4	11	24
1980	a_L	5	17	5.5	17	4.8	17	0.069	17	0.022	17	6.7	17	39	17	15	3	28	15	7.7	17	26	3	3.7	3	0.13	4	0.049	4	0.018	4	0.026	17	10	17	16
	b_L	17	17	6.3	17	4.2	17	0.11	17	0.043	17	7.8	17	51	17	17	3	31	15	8.0	17	30	3	7.5	3	0.30	4	0.079	4	0.019	4	0.039	17	11	17	18
	c_L	9	17	3.4	17	2.3	17	0.081	17	0.075	17	7.8	17	42	17	17	3	42	15	11	16	42	3	2.2	3	0.27	4	0.17	4	0.015	4	0.049	17	8.7	15	23
	d_L	13	15	3.6	15	2.4	15	0.11	15	0.050	15	11	15	37	15	13	3	38	13	6.9	15	25	3	4.9	3	0.10	4	0.064	4	0.028	4	0.028	15	12	15	26
1981	a_L	5	27	8.2	10	6.2	26	0.18	10	0.047	20	5.4	20	31	20	12	10	19	19	5.0	10	9.7	10	9.2	10	0.22	7	0.015	7	0.014	7	0.017	11	13	26	93
	b_L	17	25	7.6	11	7.2	25	0.35	11	0.099	21	7.3	21	34	21	18	10	31	20	5.5	11	6.4	10	27	10	0.45	8	0.035	8	0.034	8	0.027	11	13	25	270
	c_L	9	25	5.8	10	5.3	25	0.25	10	0.065	19	6.5	19	17	19	6.7	9	10	18	4.2	10	4.1	9	15	9	0.26	7	0.015	7	0.012	7	0.013	10	9.7	24	160
	d_L	13	19	6.0	9	5.2	19	0.43	9	0.12	17	14	17	31	17	17	8	11	16	4.2	9	4.2	8	30	8	0.53	7	0.049	7	0.026	7	0.027	9	13	18	180
1982	a_L	5	22	5.0	13	5.2	22	0.18	16	0.031	6	5.5	6	33	6	12	5	25	5	5.5	13	12	5	1.6	5	0.22	4	0.017	4	0.009	4	0.024	22	7.9	12	20
	b_L	17	22	3.7	13	4.5	22	0.17	16	0.047	7	6.5	7	45	7	13	5	29	6	6.3	13	11	5	3.5	5	0.31	5	0.023	5	0.009	5	0.024	22	6.9	13	100
	c_L	9	22	3.1	13	1.8	22	0.16	16	0.046	7	4.7	7	15	7	4.6	5	25	6	2.9	13	5.7	5	2.0	5	0.18	5	0.021	5	0.020	5	0.018	22	6.7	13	61
	d_L	13	20	3.6	11	2.4	20	0.16	14	0.042	5	3.4	5	12	5	3.0	4	16	5	2.0	11	4.1	4	4.0	4	0.14	4	0.021	4	0.011	4	0.016	20	6.8	12	40

1) n = number of observations

Appendix 7. Mean annual (Jan. 1—Dec. 31) subdrainage runoff and leaching in the various replicates of the Liperi field. Year 1979. Amount of leaching computed by the total amount of runoff and the flow-weighted mean concentration of a quality variable. (For location of the replicates, see Fig. 3.)

		Runoff ($ls^{-1} km^{-2}$)	Leaching ($kg km^{-2}a^{-1}$)																
Treatment	Replicate	Mq	$L_{N_{tot}}$	$L_{N_{NO_3}}$	$L_{P_{tot}}$	$L_{P_{PO_4}}$	L_K	L_{Ca}	L_{Mg}	$L_{S_{SO_4}}$	L_{Na}	L_{Cl}	L_{Fe}	L_{Mn}	L_{Zn}	L_{Cu}	L_{Ni}	$L_{COD_{Mn}}(O_2)$	L_{SS}
a_L	5	8.7	1 800	1 500	14	4.4	1 000	14 000	5 300	9 500	2 100	7 600	230	21	1.1	3.1	5.3	3 000	6 400
	11	8.7	2 500	2 000	15	5.1	1 500	17 000	5 400	12 000	2 000	7 700	130	15	0.010	2.7	5.2	3 800	4 200
	14	6.7	1 400	1 200	14	3.9	1 300	11 000	4 100	7 000	1 600	5 500	360	11	0.22	6.3	2.7	2 300	3 700
	20	5.4	1 200	970	8.6	2.8	1 200	15 000	4 000	13 000	2 500	8 500	94	18	0.77	2.5	5.4	2 300	3 700
	$\bar{X}$[1]	7.4	1 700	1 400	13	4.1	1 300	15 000	4 700	10 000	2 100	7 400	220	17	0.54	3.4	4.6	2 900	4 600
b_L	6	8.7	2 300	1 900	16	5.4	1 000	14 000	5 200	9 200	1 900	6 600	220	9.3	0.005	2.8	2.3	3 600	5 400
	12	6.4	1 800	1 500	10	3.3	1 900	16 000	5 000	13 000	3 200	11 000	89	40	0.58	3.0	4.8	2 600	3 700
	15	5.9	1 800	1 600	8.5	3.1	1 200	13 000	4 300	12 000	1 400	5 900	66	13	0.53	2.7	4.1	2 400	3 000
	17	12	2 000	1 600	23	6.5	2 300	19 000	7 300	14 000	2 800	8 800	910	31	0.35	3.4	3.9	3 700	11 000
	$\bar{X}$	8.2	2 000	1 600	14	4.6	1 600	16 000	5 500	12 000	2 400	8 200	350	23	0.40	3.1	4.1	3 100	5 800
c_L	7	10	2 300	2 000	20	7.5	1 300	17 000	5 800	10 000	2 300	8 900	230	11	0.018	3.2	3.8	4 400	6 500
	9	8.9	1 600	1 400	15	5.1	1 800	15 000	6 400	7 200	2 200	6 100	230	14	1.6	5.7	4.6	3 000	7 300
	16	6.5	1 800	1 600	8.1	2.2	3 400	18 000	5 000	15 000	3 500	10 000	94	35	3.0	3.5	10	2 700	3 600
	18	7.9	1 900	1 700	12	3.8	1 400	12 000	5 000	9 600	1 700	6 900	170	5.8	0	2.3	2.8	3 000	4 700
	$\bar{X}$	8.3	1 900	1 700	14	4.7	2 000	16 000	5 500	10 000	2 500	8 200	180	16	1.2	3.4	5.7	3 300	5 600
d_L	8	7.9	1 600	1 300	16	5.4	1 900	18 000	6 000	11 000	3 300	12 000	130	19	0.001	2.5	4.0	3 600	5 000
	10	8.6	2 800	2 400	15	5.8	1 500	14 000	5 200	6 700	2 000	6 800	210	9.6	3.6	11	2.9	3 300	5 300
	13	6.9	2 400	2 200	11	4.3	1 200	11 000	4 400	8 700	1 500	5 900	110	7.8	0.021	2.2	3.4	3 000	4 100
	19	7.3	1 800	1 600	13	3.5	1 200	12 000	4 900	11 000	1 600	6 700	130	16	0.25	2.3	4.4	3 000	5 500
	$\bar{X}$	7.7	2 200	1 900	14	4.7	1 400	14 000	5 100	9 400	2 100	8 000	140	13	0.89	4.4	3.8	3 200	4 900

[1] $\bar{X}$ = treatment average

Appendix 7. Continued. Year 1980.

		Runoff ($ls^{-1} km^{-2}$)	Leaching ($kg\ km^{-2}a^{-1}$)																
Treatment	Replicate	Mq	$L_{N_{tot}}$	$L_{N_{NO_3}}$	$L_{P_{tot}}$	$L_{P_{PO_4}}$	L_K	L_{Ca}	L_{Mg}	$L_{S_{SO_4}}$	L_{Na}	L_{Cl}	L_{Fe}	L_{Mn}	L_{Zn}	L_{Cu}	L_{Ni}	$L_{COD_{Mn}(O_2)}$	L_{SS}
a_L	5	4.9	560	400	7.3	3.3	1 000	7 200	2 700	6 800	1 100	2 000	140	44	6.2	3.1	12	1 500	620
	11	7.0	1 200	1 000	10	4.6	1 100	11 000	3 600	9 700	1 600	3 000	260	27	3.6	2.4	6.6	2 600	980
	14	6.8	1 100	830	13	5.6	1 200	8 400	3 000	8 400	1 400	2 300	240	15	2.3	1.9	5.1	2 500	1 300
	20	4.4	820	620	7.2	3.3	1 200	9 800	2 400	9 800	2 100	4 600	43	91	6.3	3.0	11	1 600	640
	$\bar{X}$	5.8	910	710	9.5	4.2	1 100	9 000	2 900	8 900	1 600	3 000	160	48	4.9	2.7	9.2	2 000	900
b_L	6	4.6	1 800	1 300	13	5.6	1 000	7 700	3 000	6 300	1 200	1 700	110	17	0.86	1.5	4.1	1 900	430
	12	4.7	1 700	1 300	8.4	2.2	1 500	10 000	3 500	9 800	2 500	6 600	330	120	7.1	2.0	13	2 100	400
	15	4.6	2 200	1 500	8.6	2.9	1 000	11 000	3 500	9 400	1 300	2 500	94	70	7.1	2.6	15	1 900	480
	17	6.5	2 800	2 200	32	10	1 500	13 000	4 400	8 800	1 800	2 200	310	42	1.5	2.1	6.4	2 900	1 600
	$\bar{X}$	5.1	2 100	1 600	15	5.1	1 300	11 000	3 600	8 600	1 700	3 400	210	61	4.1	2.1	9.4	2 200	710
c_L	7	4.7	2 200	1 900	9.0	4.2	870	8 200	2 600	6 600	1 100	2 100	100	26	1.2	1.4	6.2	1 800	660
	9	7.9	1 900	1 700	14	5.5	1 500	11 000	4 000	10 000	1 700	3 100	190	20	5.1	2.8	8.5	2 600	1 700
	16	4.6	1 400	1 300	5.6	2.0	2 500	10 000	2 800	10 000	2 300	5 300	120	130	11	4.7	19	1 700	820
	18	6.2	2 600	2 400	14	8.0	1 000	8 100	3 200	7 700	1 200	1 700	240	11	1.3	1.6	6.2	2 300	1 200
	$\bar{X}$	5.8	2 000	1 800	11	4.9	1 500	9 400	3 100	8 900	1 500	3 000	160	52	5.0	2.7	10	2 100	1 100
d_L	8	5.4	1 400	1 100	9.7	4.7	1 100	9 200	3 100	8 800	2 000	5 500	64	59	1.6	1.9	7.0	2 400	620
	10	5.6	1 100	790	9.3	4.0	940	7 400	2 700	6 800	1 200	1 600	190	14	5.6	2.4	4.0	1 900	1 000
	13	5.9	1 200	890	12	6.4	900	7 200	2 700	6 000	1 200	1 700	150	8.3	0.62	1.4	3.3	2 300	760
	19	4.8	880	770	7.0	3.9	880	8 600	3 500	9 800	1 100	2 200	100	53	7.0	1.9	17	1 500	2 000
	$\bar{X}$	5.4	1 100	900	9.7	4.8	950	8 000	3 000	7 700	1 400	2 800	130	31	3.7	1.9	7.6	2 000	1 000

Appendix 7. Continued. Year 1981.

Treatment	Replicate	Runoff ($ls^{-1} km^{-2}$)	Leaching ($kg\ km^{-2}a^{-1}$)																
		Mq	$L_{N_{tot}}$	$L_{N_{NO_3}}$	$L_{P_{tot}}$	$L_{P_{PO_4}}$	L_K	L_{Ca}	L_{Mg}	$L_{S_{SO_4}}$	L_{Na}	L_{Cl}	L_{Fe}	L_{Mn}	L_{Zn}	L_{Cu}	L_{Ni}	$L_{COD_{Mn}(O_2)}$	L_{SS}
a_L	5	27	5 400	5 600	68	26	6 000	39 000	15 000	27 000	5 500	6 200	1 900	210	24	9.3	33	8 800	14 000
	11	29	6 000	6 700	65	25	5 900	47 000	16 000	29 000	5 900	6 100	2 800	150	14	10	23	11 000	20 000
	14	17	6 100	6 700	47	26	3 400	29 000	9 600	14 000	3 400	2 900	1 500	70	7.0	4.8	12	6 400	12 000
	20	17	4 300	5 100	60	22	4 200	34 000	8 700	20 000	7 300	9 200	1 700	320	10	8.8	25	9 400	13 000
	$\bar{X}$	23	5 500	6 100	60	25	4 900	37 000	12 000	22 000	5 600	6 100	2 000	180	13	8.2	23	8 900	14 000
b_L	6	35	19 000	19 000	140	78	7 600	57 000	20 000	28 000	6 600	5 800	2 200	160	9.9	9.4	24	14 000	17 000
	12	20	18 000	19 000	71	42	6 200	50 000	15 000	27 000	10 000	15 000	1 100	340	16	10	42	9 700	11 000
	15	19	17 000	16 000	59	32	5 700	43 000	12 000	23 000	5 500	4 500	1 200	140	12	8.1	28	9 200	12 000
	17	22	12 000	14 000	92	43	5 200	41 000	13 000	17 000	5 900	3 400	3 200	100	9.7	7.9	16	8 700	21 000
	$\bar{X}$	24	16 000	17 000	92	49	6 100	47 000	15 000	24 000	6 900	7 000	2 000	180	12	9.0	27	10 000	15 000
c_L	7	35	25 000	25 000	140	73	8 100	61 000	21 000	28 000	7 000	7 900	1 900	250	11	9.9	32	16 000	14 000
	9	28	23 000	23 000	85	31	6 900	49 000	19 000	29 000	6 600	5 500	2 900	120	20	11	31	8 900	21 000
	16	22	23 000	22 000	49	19	11 000	55 000	14 000	32 000	13 000	13 000	1 300	330	16	9.8	46	10 000	7 700
	18	24	27 000	27 000	75	36	4 600	45 000	15 000	21 000	6 200	5 100	1 400	54	7.6	7.3	27	9 000	11 000
	$\bar{X}$	27	25 000	25 000	88	40	7 600	53 000	17 000	27 000	8 100	7 800	1 900	180	14	9.4	34	11 000	13 000
d_L	8	25	8 100	8 300	140	61	5 600	40 000	13 000	21 000	7 300	12 000	1 600	400	9.2	8.3	24	13 000	17 000
	10	29	9 300	7 400	79	40	4 900	37 000	14 000	19 000	5 500	4 200	2 400	89	8.4	7.7	15	9 200	21 000
	13	28	5 900	3 900	57	29	4 600	36 000	14 000	22 000	5 400	12 000	1 600	58	6.6	8.3	16	11 000	5 000
	19	27	8 900	9 500	100	53	5 100	40 000	13 000	22 000	4 600	5 700	2 900	130	13	9.0	23	12 000	25 000
	$\bar{X}$	27	8 000	7 100	94	45	5 000	38 000	14 000	21 000	5 700	8 900	2 100	160	9.3	8.3	19	11 000	17 000

Appendix 7. Continued. Year 1982.

Treatment	Replicate	Runoff (ls^{-1} km^{-2})	Leaching (kg $km^{-2}a^{-1}$)																
		Mq	$L_{N_{tot}}$	$L_{N_{NO_3}}$	$L_{P_{tot}}$	$L_{P_{PO_4}}$	L_K	L_{Ca}	L_{Mg}	$L_{S_{SO_4}}$	L_{Na}	L_{Cl}	L_{Fe}	L_{Mn}	L_{Zn}	L_{Cu}	L_{Ni}	$L_{COD_{Mn}}(O_2)$	L_{SS}
a_L	5	18	1 700	1 100	87	19	3 700	23 000	8 300	25 000	3 500	4 800	210	180	15	6.3	29	4 500	2 600
	11	19	2 200	1 600	54	15	3 200	30 000	9 300	32 000	4 400	5 100	140	140	6.4	4.1	17	4 200	1 500
	14	12	1 600	1 000	38	11	2 200	16 000	5 200	15 000	2 300	2 200	160	38	5.4	3.4	6.2	2 900	1 200
	20	10	1 000	640	23	8.1	3 400	21 000	4 800	22 000	5 000	9 400	230	350	7.7	6.0	16	3 000	2 200
	$\bar{X}$	15	1 600	1 100	51	13	3 200	22 000	6 900	24 000	3 900	5 600	190	190	8.9	5.2	17	3 600	2 000
b_L	6	24	3 500	3 300	130	51	4 900	33 000	12 000	34 000	5 300	5 000	530	200	12	5.4	15	5 800	7 700
	12	13	2 800	2 100	41	22	4 900	25 000	7 300	28 000	6 200	15 000	170	450	12	6.7	24	3 600	1 200
	15	15	3 800	3 100	46	14	2 900	27 000	7 900	29 000	3 000	5 100	140	220	14	5.7	27	4 100	1 400
	17	17	3 100	2 500	59	23	3 300	24 000	7 700	23 000	3 400	3 300	280	54	3.2	3.7	7.0	4 200	1 800
	$\bar{X}$	17	3 300	2 800	69	27	4 100	28 000	8 900	28 000	4 600	7 300	270	230	11	5.7	19	4 400	2 800
c_L	7	22	4 300	3 600	100	46	4 500	32 000	9 900	35 000	3 900	6 300	420	390	16	9.2	16	5 900	2 500
	9	22	4 400	3 400	97	22	4 200	27 000	10 000	28 000	4 200	4 200	330	89	13	7.0	18	5 200	2 900
	16	15	2 800	1 700	31	8.3	11 000	30 000	7 300	35 000	7 600	15 000	370	450	12	5.5	30	3 800	2 000
	18	19	4 400	4 200	80	26	3 500	23 000	9 400	23 000	3 900	3 000	300	36	4.6	4.1	9.7	5 300	2 400
	$\bar{X}$	20	4 000	3 200	78	26	6 100	28 000	9 200	31 000	5 000	7 600	360	260	12	6.6	19	5 000	2 400
d_L	8	16	2 400	2 000	90	38	3 700	26 000	8 100	27 000	5 100	14 000	3 500	840	8.0	8.7	17	4 900	5 300
	10	19	2 800	2 000	79	24	3 200	25 000	8 600	22 000	3 500	3 400	230	63	2.3	4.1	7.5	4 300	2 300
	13	18	2 300	1 700	53	13	2 500	19 000	7 900	18 000	3 000	2 900	190	34	2.4	3.6	6.6	4 400	830
	19	18	2 600	1 800	68	20	3 100	28 000	9 800	32 000	3 400	5 900	360	290	14	6.4	26	5 200	3 000
	$\bar{X}$	18	2 500	1 900	72	25	3 200	24 000	8 600	25 000	3 800	6 800	1 200	340	7.0	6.1	15	4 700	3 200

Appendix 8. Mean annual (Jan. 1—Dec. 31) surface runoff and leaching in the Liperi field. Legend as in App. 7.

Year	Treatment	Replicate	Runoff (ls^{-1} km^{-2})	Leaching (kg $km^{-2}a^{-1}$)															
			Mq	$L_{N_{tot}}$	$L_{N_{NO_3}}$	$L_{P_{tot}}$	$L_{P_{PO_4}}$	L_K	L_{Ca}	L_{Mg}	$L_{S_{SO_4}}$	L_{Na}	L_{Cl}	L_{Fe}	L_{Mn}	L_{Zn}	L_{Cu}	L_{Ni}	$L_{COD_{Mn}(O_2)}$	L_{SS}
1979	a_L	5	1.3	230	210	1.8	0.36	280	2 800	1 000	1 200	400	1 300	150	4.3	1.9	3.5	1.3	290	1 300
	b_L	17	3.1	510	420	14	1.3	710	5 100	1 800	1 200	980	2 800	900	12	1.7	2.1	3.5	890	15 000
	c_L	9	1.7	190	150	3.0	0.59	360	3 000	1 100	740	730	2 000	420	6.3	0.15	0.58	0.48	280	2 000
	d_L	13	1.8	240	200	2.4	0.55	380	3 900	1 300	900	360	1 600	240	4.1	0.12	0.57	0.32	360	1 400
1980	a_L	5	0.59	100	90	1.3	0.41	120	730	270	510	140	490	68	2.4	0.91	0.34	0.48	190	290
	b_L	17	0.91	180	120	3.2	1.2	230	1 500	500	880	230	880	210	8.7	2.3	0.55	1.1	330	510
	c_L	9	0.57	60	42	1.5	1.3	140	760	300	760	200	750	40	4.9	3.1	0.27	0.88	160	410
	d_L	13	1.5	170	110	5.3	2.4	520	1 800	640	1 800	330	1 200	240	4.8	3.1	1.3	1.3	570	1 200
1981	a_L	5	2.6	660	500	15	3.8	430	2 500	960	1 500	400	780	740	18	1.2	1.1	1.4	1 000	7 500
	b_L	17	4.9	1 200	1 100	54	15	1 100	5 200	2 800	4 700	850	990	4 100	69	5.4	5.2	4.1	2 100	41 000
	c_L	9	9.6	1 800	1 600	75	20	2 000	5 200	2 000	3 100	1 300	1 200	4 500	78	4.5	3.6	4.0	2 900	48 000
	d_L	13	3.6	680	590	49	13	1 600	3 500	1 900	1 300	480	470	3 400	60	5.5	3.0	3.0	1 500	21 000
1982	a_L	5	1.6	260	260	9.4	1.6	280	1 700	610	1 300	290	600	85	11	0.88	0.46	1.2	410	1 000
	b_L	17	2.3	280	330	13	3.5	480	3 300	1 000	2 100	460	840	260	23	1.7	0.66	1.8	510	7 600
	c_L	9	1.7	170	97	8.7	2.5	260	800	250	1 400	160	310	110	10	1.2	1.1	1.0	370	3 400
	d_L	13	1.7	190	130	8.5	2.3	180	620	160	850	110	220	210	7.7	1.1	0.60	0.85	370	2 200