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Modelling of water balance and nitrogen cycle in vegetative filter strips

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Abstract

The retention of nutrients by 10-m-wide grass buffers and buffers under natural vegetation has been studied over 10 years in Jokioinen in southwestern Finland. The results have been compared with those from 70-m-long plots without buffers. Grass was sown on the adjacent field and plots without buffers in 2002, and the field plots and these were grazed for 12 and 24 days in summer 2003 and 2004, respectively. The COUP model was applied both to the field and to vegetative filter strips to model water balance and nitrogen dynamics. Modelling was based on measured surface runoff, soil moisture, and physical, chemical and microbiological properties of soil. Simulated cumulative evapotranspiration from grass buffer was higher than from field during this period due to dense vegetation with well-developed roots. Simulated nitrogen leaching from the fertilized pasture was 22–23, and from the unfertilized grass buffer 7 and from the unfertilized buffer under natural vegetation 5 kg ha^{-1} a^{-1}. Grazing with short duration did not seem to increase leaching of inorganic nitrogen.

1. Introduction

A vegetative buffer zone is a vegetated area designed into the downhill edge of a field slope to filter suspended material from surface runoff water. In several studies buffer zones have been able to reduce erosion load effectively, and also total N load in runoff water (e.g. Uusi-Kämppä &Kilpinen 2000). In this study the main aim was to model hydrology and nitrogen cycles to find out the processes behind reduced N load from fields with buffer zones. Coupled heat and mass transfer model for soil-plant-atmosphere system (COUP) model is a dynamic, process based model which calculates water and heat fluxes and nitrogen (N) and carbon (C) cycles in a soil profile (Jansson & Karlberg 2001). The COUP model is commonly applied to agricultural areas in Nordic countries to model hydrological processes and N leaching (e.g. Arheimer 1998, Granlund *et al*. 2000).

2. Material and methods

The retention of nutrients by 10-m-wide grass buffers (GBS) and buffers under natural vegetation (VBS) has been studied over 10 years in Jokioinen in southwestern Finland. The results have been compared with those from 70-m-long plots without buffers (NBS). Grass was sown on the adjacent field and NBS in 2002, and the field plots and NBS were grazed for 12 and 24 days on three experimental plots in summer 2003 and 2004, respectively.

The COUP model was applied both to the field and to vegetative filter strips to model water balance and nitrogen dynamics. Modelling was based on measured surface runoff, soil moisture, and physical and chemical properties of soil. Fluxes of nitrous oxide were measured from the buffer zones and the pasture every second week, and soil microbial biomass and potential activity of microbial mediated processes of nitrogen cycle were studied once a year in the autumn. Meteorological input data was available from Jokioinen Observatory of Finnish Meteorological Institute.

3. Results and discussion

The COUP model was calibrated against observed soil moisture, surface runoff, inorganic N content of soil and vegetation N uptake. The effect of grazing was included by adding constant amount of organic fertilizer daily. The year 2003 was calibration period and the year 2004 validation period.

Annual precipitation was 478 mm in 2003 and 726 mm in 2004. Simulated cumulative evapotranspiration from GBS was 130 mm higher than from field during this period (Figure 1). Observed average soil moisture in 0–60 cm soil profile were between modelled soil moisture in layers 0–10 cm, 10–20 cm, 20–40 cm and 40–60 cm (Figure 2).

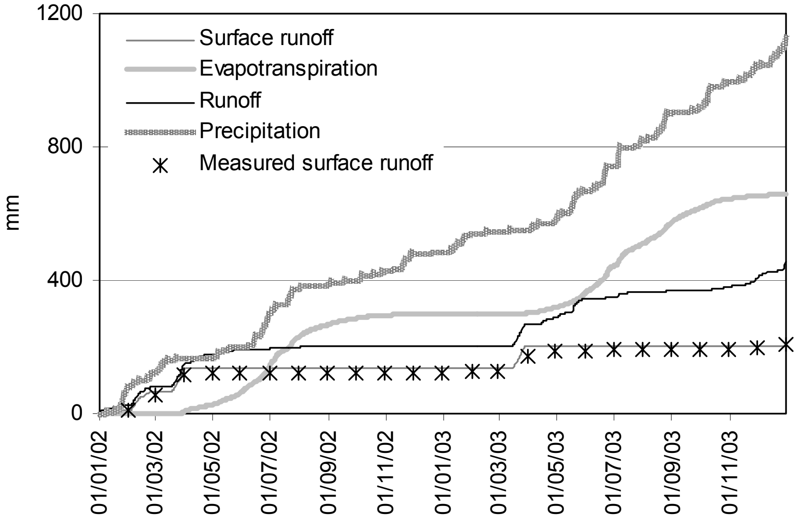

Figure 1. Simulated and measured water balance components in pasture

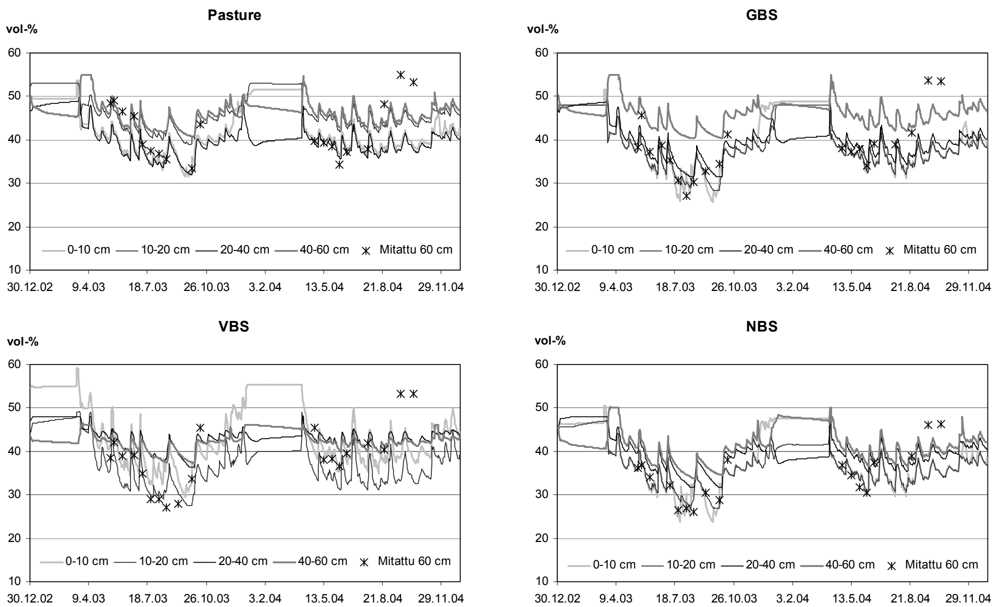

Figure 2. Simulated and measured soil moisture in different field parcels

Modelled main inputs and outputs of inorganic N are presented in Table 1. Modelled N in harvest of grass was lower than estimated 106 kg ha^{-1} a^{-1} based on mass balance studies (Marttila *et al*. 2005). On the other hand Jaakkola (1984) estimated in lysimeter studies that N uptake of grass was 56 kg ha^{-1} a^{-1} when fertilization level was

100 kg N ha^{-1} a^{-1} and 112 kg ha^{-1} a^{-1} when fertilization level was 200 kg N ha^{-1} a^{-1}. Modelled denitrification was low but in the same range with measured values.

Table 1. Main inputs and outputs of inorganic N on pasture and buffer zones (kg N ha^{-1} a^{-1})

Field parcel	Mineral fertilizer	Organic fertilizer	Harvest	Denitrification	Leaching
Pasture	150	10	64–73	0.2–1.5	22–24
VBS	–	–	–	0.8	5
GBS	–	–	17	0.15	7
NBS	150	10	57	0.3	22

Modelled inorganic N leaching from the fertilized pasture was 23 kg ha^{-1} a^{-1}. Marttila *et al*. (2005) estimated that N balance of grass was 22 kg ha^{-1} a^{-1} positive during six years long study period, which value corresponds well with the simulated leaching. Simulated inorganic N leaching from the unfertilized GBS and from the unfertilized and uncut VBS was clearly lower because they were not fertilized but also because the microbiological activity was lower than on pasture. Measured surface leaching of N was less than 2 kg ha^{-1} a^{-1} in years 2003 and 2004. Grazing did not seem to increase inorganic N leaching considerably during study period.

4. Conclusions

Most of the inorganic N was washed through soil profile to subsurface drains. Vegetative buffer zones decrease the cultivated area and thus inorganic N leaching. Further, vegetation in buffer zones takes up water and probably also N effectively. This may be one of the processes by which buffer zones decrease inorganic N leaching. Periodical short-term grazing did not seem to increase inorganic N leaching.

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