Nitrogen runoff in a potato-dominated watershed area of Prince Edward Island, Canada

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Abstract The upper reaches of an arable watershed area in central Prince Edward Island, Canada, commercially-farmed and potato-dominated, has been monitored for nitrates year-round since 1991. Together with this, an inventory of field practices has been taken in the autumn and spring of each year. Recorded nitrate-N data from 1991 to 1993 for two instrumented sub-watersheds, mainly under potato rotations or under pasture, show a dominance of dormant-season nitrate-N outflow. Application of the Soil and Water Assessment Tool (SWAT) computer model indicates, further, that most of the nitrate-N loss comes from surface flow.

INTRODUCTION

The Wilmot River, situated in central Prince Edward Island (PEI), Canada, comprises mostly potato lands. It is an intensively farmed area in which the main economic crop is potatoes, rotated with grain (mainly barley) and forages for hay. Some of these potato lands may sojourn as cattle pasture. The soils are fine sandy loam in texture with a naturally-occurring compact layer at a depth of about 0.60 m over a subsurface of soft sandstone bedrock. Isolated patches of regrowth softwood forest exist, mainly as windbreak belts between fields.

The watershed of the Wilmot River is 81.2 km^2 and, as shown in Fig. 1, flows in a westerly direction emptying through a long estuary into Bedeque Bay on the Northumberland Strait. The upper 45.2 km^2 of the watershed has been monitored for discharge and suspended sediment since 1972 by Environment Canada (Pol, 1988).

In 1987, three of the most intensely commercial sub-watersheds in the eastern, upper reaches of the Wilmot River were selected for study and instrumented for year-round discharge recording using Parshall flumes and automated flow sampling

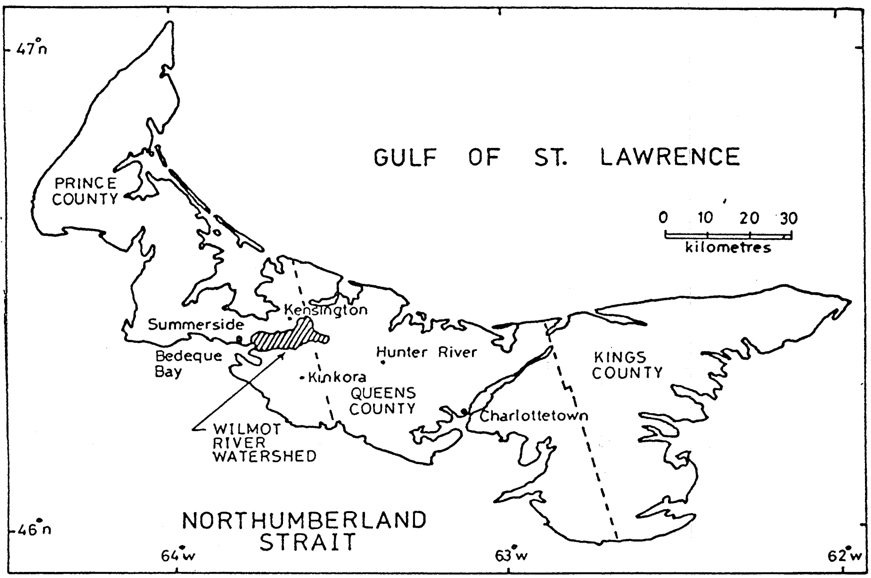

Fig. 1 Map of Prince Edward Island showing monitored watershed.

(Burney & Edwards, 1994). These three sub-watersheds comprise a 140-ha area (Curley's), mainly under potatoes in a two-year rotation with barley; a 203-ha area (Murphy's), mainly under three-year potato rotations with barley and forages; and a 416-ha area (Mayne's), mostly under pasture for summer, dairy grazing. An inventory of land use has been taken every spring and autumn on each of the sub-watersheds. Unfortunately, however, recurring failures in the sampling system at the outflow of the 203-ha watershed (Murphy's) rendered the data quality unacceptable; therefore, this is not presented. Discharge from each sub-watershed was recorded at 10-min intervals, and full profile streamflow samples were taken from a vertical slit mounted at the exit to each Parshall flume at periods varying from 10 min (with frequently varying flow) to 17 h (under steady, baseflow-only, supplied conditions). The flow samples were analysed for sediment content; and, since 1991, have also been analysed for nitrate-N (NO_3-N).

Data for Curley's and Mayne's sub-watersheds for the calendar years 1991–1993 have been analysed and are presented herein.

RECORDED DATA

The percentage of each of the land-use practices in Curley's and Mayne's sub-watersheds in the years 1991–1993 are given in Table 1.

The concentration of each NO_3-N sample was multiplied by the streamflow rate at the time of sampling in order to evaluate the nitrate mass per unit time in the stream discharge. The average of the NO_3-N mass flow at the start and end of the period between samples multiplied by the time period, was summed over each month

Table 1 Cropping practices in the watersheds in percent area for the three years 1991–1993.

Crop	Curley's: 1991	1992	1993	Mayne's: 1991	1992	1993
Potatoes	47.1	19.6	21.0	10.0	3.4	11.1
Grain	4.6	50.1	20.9	15.8	27.2	8.1
Hay/pasture	19.1	1.1	32.3	57.3	52.5	63.9
Legumes	0.9	2.2	0.0	0.0	0.0	0.0
Forestry	27.2	25.9	24.8	12.5	12.5	12.5
Roads	0.4	0.4	0.4	1.1	1.1	1.1
Residences	0.7	0.7	0.7	3.3	3.3	3.3

on each sub-watershed and divided by the sub-watershed area. This then provided mass NO_3-N loss per ha per month.

The average monthly water yield from each of the sub-watersheds is shown in Fig. 2(a) and the NO_3-N monthly outflow in Fig. 2(b).

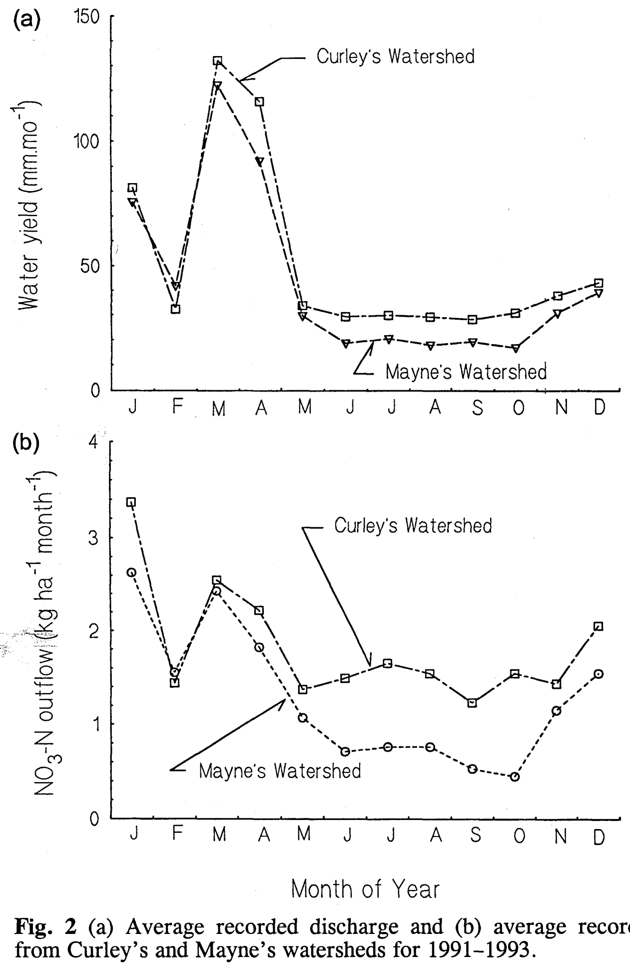

Fig. 2 (a) Average recorded discharge and (b) average recorded nitrate outflow, from Curley's and Mayne's watersheds for 1991–1993.

As may be noted in Fig. 2(a), the distribution of discharge over the year is dominated by two peaks: in January and in March–April. The first peak is a winter thaw which commonly lasts for about three days in late January, and the second is the spring snowmelt. These peaks indicate surface flow over a partially thawed surface underlain by a relatively impermeable frost layer. For the period of May–November, discharge in the streams is almost entirely from groundwater.

Nitrate-N outflow (Fig. 2(b)) also shows the same peaks, although the January peak is higher than the spring snowmelt peak, indicating that much of the residual nitrate from the previous summer's fertilizer applications is flushed out of the soil during the January thaw. The yearly average NO_3-N outflow for the three years on Curley's sub-watershed is 22 kg ha^{-1} $year^{-1}$, and on Mayne's sub-watershed is 15 kg ha^{-1} $year^{-1}$. This compares well with the findings of Milburn & Richards (1994), who measured year-round outflow of NO_3-N in tile drain discharge from a corn field in the neighbouring province of New Brunswick. They reported that 85% of the tile discharge occurred during the period of October–April and the mean annual NO_3-N losses ranged from 10 to 30 kg ha^{-1} $year^{-1}$.

MODELLING

The SWAT (Soil and Water Assessment Tool) computer model (Arnold *et al.*, 1994) was run in prediction mode for the whole of the 81.2 km^2 Wilmot River watershed in which the monitored watersheds were separately modelled as component sub-watersheds (Burney *et al.*, 1998).

The SWAT model is a comprehensive integrated mathematical (computer software) model aimed at rapidly and cheaply producing long-term hydrological, sediment, nutrient and pesticide predictions from ungauged watersheds subjected to varying exploitation and conservation ("what if") scenarios.

As the SWAT model required a uniform cropping practice over a defined area, Curley's watershed was modelled as having been under a two-year potato–barley rotation (the dominant cropping practice), and Mayne's watershed was modelled for continuous pasture. The simulated NO_3-N outflow for each of these watersheds is presented in Fig. 3.

It may be noted that the simulations indicated that almost all of the source of the NO_3-N loss was through surface flow, predominantly during the spring snowmelt period of March–April. The potato–barley rotation generated some surface loss of NO_3-N at the time of planting and fertilizer application in late May and in June.

The simulations also indicated that the peak outflow from the potato-barley rotation greatly exceeded that from pasture. This is to be expected, given the up-and-down-slope potato cultivation practices which provide efficient paths for the discharge of excess surface water.

CONCLUSIONS

1. Outflow of nitrate-N from fertilizer application to crops in PEI occurs primarily in the dormant season in surface flow during the January thaw and spring snowmelt.

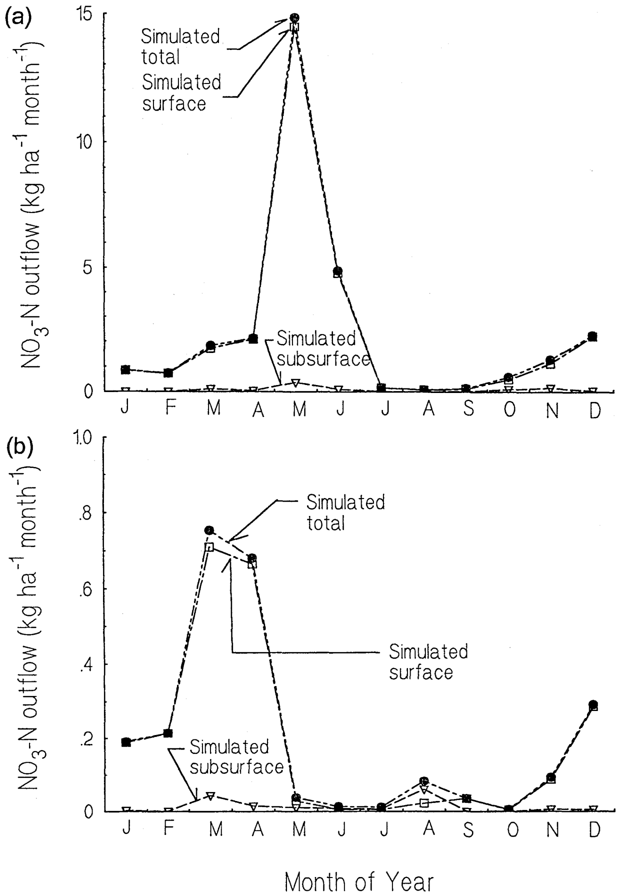

Fig. 3 (a) Simulated nitrate outflow (a) from Curley's watershed assuming entire area was in a 2-year potato-grain rotation, and (b) from Mayne's watershed assuming entire area was in continuous pasture.

2. Due to the presence of a naturally occurring compact layer in the soil, little of the nitrate-N percolates to the groundwater table.

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