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Hydrological pathways and nitrogen runoff in agricultural dominated catchments in Nordic and Baltic countries

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ABSTRACT

Nitrogen (N) transport and retention in streams are largely determined by hydrological characteristics (e.g. water runoff, baseflow index (BFI) and flashiness index (FI)) in the catchment. It is important to know the impact of catchment characteristics such as land use, subsurface drainage intensity, elevation difference and catchment size on the hydrological properties and N loss. This paper presents a comparison of the magnitude and variation of the baseflow and flashiness in streams in relation to the selected geographical and drainage characteristics for thirty studied agriculture dominated catchments in the Nordic and Baltic countries and the effects it can have on N loss. The analysis included measured data from the total discharge and nitrogen loss at the catchment outlets for the period from the beginning of 1993 to 2011, although there is variation in the length of periods among catchments and countries. The study revealed that the rate of subsurface drainage systems and drainage intensity (given as lateral tile drainage spacing) were statistically significant explanatory variables in explaining differences in hydrological characteristics between catchments. There is a considerable increase in the FI, almost by a factor of three, when using hourly discharge values instead of average daily values, indicating that large diurnal variation in discharge can occur, especially at higher FI values. The analysis also showed that there is a negative relation between FI and the BFI, i.e. a high BFI corresponding to a low FI and vice versa. In general, there seems to be a positive relationship between long-term average runoff and N loss, with the highest runoff and N loss occurring in the Norwegian catchments. However, flow path can have a significant influence on the N loss.

1. Introduction

Agriculture contributes nutrients to the environment, and is to a large degree responsible for the eutrophication of inland waters and coastal zones. In the Baltic Sea catchment area, the major anthropogenic source of waterborne nitrogen is diffuse inputs which constitute around 70% of the total load into surface waters within the catchment area. Agriculture alone contributes approximately 80% of the total reported diffuse load (Stålnacke, 1996; HELCOM, 2009). Several authors (e.g. Kauppi, 1979; Rekolainen, 1989; Zabłocki and Pieńkowski, 1999; De Wit, 2000; Mander et al., 2000; Vagstad et al., 2004; Iital et al., 2005) have described the relative importance of different factors, e.g. land use, fertilization rate, livestock density, topography and soil type, influencing the loss of nitrogen. Nutrient losses, especially nitrogen, are well correlated with variations in discharge (Stålnacke and Grimvall, 2000). However, when comparing the results of different water quality monitoring programmes in catchments with a relative high agricultural share, large differences in nutrient losses can be observed under otherwise almost similar climatological conditions and agricultural practices (Vagstad et al., 2004). Also, catchment scale can play a role in the nutrient loss processes. Deelstra et al.

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(2005) and Lagzdins et al. (2012) found a decrease in nitrogen concentration in Latvian catchments with an increase in catchment scale. In addition to a decrease in area-specific fertiliser application rates, it was concluded that flow processes also had an important impact on water chemistry. Similar findings were made by Tiemeyer et al. (2006) when studying nutrient losses in artificially drained catchments in north-east Germany. When comparing nutrient losses from small agricultural catchments in the Baltic and Nordic countries, Vagstad et al. (2004) found that high groundwater contributions, e.g. a higher share of the baseflow in the catchment discharge, might lead to lower nitrogen loss. Hydrological pathways are of great importance not only for the transport of nitrogen but also for nitrogen transformation processes in soils and the buffering capacities of the catchment area. Thus, a good understanding of the hydrology is necessary to understand the processes leading to nitrogen loss and retention. Besides surface and groundwater flow, subsurface drainage systems are also an important pathway for both water and transport of nitrogen in agricultural dominated catchments (Deelstra 2013; Kværnø 2013). However, its magnitude is very much influenced by soil type and drainage systems, (for example Skaggs et al., 1994; Gilliam and Skaggs, 1986). Kladivko et al. (2004) and Nangia et al. (2009) showed the importance of drain spacing on the magnitude of these losses, indicating greater N loss with narrower drain spacing. A study carried out by Paasonen-Kivekàs et al. (1999) also showed the importance of subsurface drainage systems on transport of nitrogen in Finland, especially highlighting the effects of the macropore system on this transport. In the

Table 1
Catchment characteristics.

Catchment	Area (km^2)	Land use (%)			Precipitation ($mm\,y^{-1}$)	Temperature (°C)	Soil texture	Height difference (m, min/max)	Drain[a] spacing/depth (m)
		Agriculture	Forest	Other land use					
Norway									
Skuterud	4.5	61	28	12	930	6.3	Silty clay loam	91/146	8–10/0.8–1.0
Mørdre	6.8	62	28	10	762	5.3	Silt, silty clay loam	130/230	8–10/0.8–1.0
Kolstad	3.1	68	26	6	751	4.4	Loam	200/318	8–10/0.8–1.0
Hotran	20.0	58	31	11	997	6.1	Silty clay loam	10/282	8–10/0.8–1.0
Time	1.0	86	0	14	1278	8.5	Loamy sand	35/100	8–10/0.8–1.0
Naurstad	1.5	35	29	36	1258	5.2	Loamy sand, peat	4/91	8–10/0.8–1.0
Volbu	1.7	43	54	2	587	2.9	Loamy sand	440/863	8–10/0.8–1.0
Vasshaglona	0.7	60	35	5	1429	8.2	Sand, loam	5/40	8–10/0.8–1.0
Sweden									
M36	7.9	86	4	10	719	7.6	Clay, sandy loam	18/87	15/1.0
N34	13.9	85	5	10	886	7.2	Sandy loam, silt loam	4/72	20/1.0
F26	1.8	71	10	19	1066	6.2	Sandy loam	146/173	20/0.9
O18	7.7	92	2	7	655	6.1	Clay	64/86	10–12/1.0
E21	16.3	89	4	6	506	6	Sandy loam	102/130	20/1.0
I28	4.8	78	11	11	587	6.9	Sandy loam	32/43	20/1.0
C6	33.1	59	32	9	623	5.5	Clay loam	20/60	15/1.0
Finland									
Savijoki	15.4	39	57	4	644	5.8	Clay and moraine	50/75	20/1.0
Haapajyrä	6.1	58	26	16	545	4.5	Clay and peat	24/45	20/1.0
Löytäneenoja	5.6	77	20	3	604	5.1	Clay and sand	35/55	20/1.0
Estonia									
Räpu	24.9	61	29	10	716	6	Sandy clay loam	59/73	18–22/0.9
Rägina	21.1	53	47	0	656	6.3	Sandy clay loam	18/35	18–22/0.9
Latvia									
Berze	3.7	98	1	2	589	7.5	Silty clay loam	17/23	18–22/1.1
Mellupite	9.6	69	27	4	666	6.4	Loam	74/88	15–25/1.2
Lithuania									
Graisupis	14.2	69	29	2	716	5.7	Loam	60/70	16–20/0.9(78)
Vardas	7.5	73	25	2	561	7.3	Loamy sand	130/180	16–24/1.0(73)
Lyžena	1.7	97	2	1	661	7.2	Sandy loam	114/172	18–26/1.0
Denmark									
Højvads Rende	9.9	65	27	9	706	6.5	Loamy sand	2/24	12/1.0(72)
Odderbæk	11.4	98	2	0	732	9.4	Sand	11/58	12/1.0(10)
Horndrup bæk	5.5	82	18	0	949	8.4	Loamy sand	41/171	–/–
Lillebæk	4.7	89	2	9	921	8.5	Loamy sand	5/40	8/1.0(8)
Bolbro bæk	8.2	99	1	0	834	9.3	Sand	25/39	–/–

[a] In case <80% of agriculture area is artificial drained, information provided.