Agriculture, Ecosystems and Environment 198 (2014) 25–35

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Small agricultural monitoring catchments in Sweden representing environmental impact

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ARTICLE INFO

Article history:
Received 31 January 2014
Received in revised form 20 May 2014
Accepted 23 May 2014
Available online 6 June 2014

Keywords:
Nitrogen
Leaching
Losses
Crop
Scaling

ABSTRACT

Nutrient losses to surface waters have been monitored at the small agricultural catchment scale (2–35 km^2) for 20 years in Sweden. Eight of the 21 catchments have been more intensively monitored, with flow-proportional stream water sampling, analysis of groundwater quality, yearly crop management surveys and soil characterisation. Annual losses of total nitrogen (N) at catchment stream outlet vary from 6 to 32 kg ha^{-1}, with the largest losses from sandy loam soils in south-west Sweden, where precipitation is high. Losses of total phosphorus (P) vary from 0.1 to 2.0 kg ha^{-1} $year^{-1}$ and are largest in catchments with clay soils. Compared with surrounding agricultural areas, crop production is more intensive in most of the monitoring catchments, e.g. the production of annual crops for the market constitutes a larger share of arable land than production of ley in 15 out of 21 monitoring catchments. A more intensive crop production is a consequence of a preference for a high proportion of arable land in the monitoring area which coincides with more productive agricultural areas in the regions. Knowing how the catchments relate to other agricultural areas is important when the catchments are used as indicators of agricultural impacts on surface waters. For detection of the success of implemented mitigation measures, small monitoring catchments are suitable since the response on stream water quality is faster than in larger river catchments where the contribution from other sources is larger and retention in streams and lakes occurs to a larger extent. The catchment information also enhances validation of models used for estimating losses of nutrients from other agricultural areas where information on crops, soils and climate exist but data on agricultural management and water quality is scarce.

1. Introduction

Eutrophication of inland waters and surrounding seas is a severe problem in the Baltic Sea region. Several agreements with the aim of reducing eutrophication have been made in the past decade. The most recent of these, the HELCOM Baltic Sea Action Plan, aims to restore good ecological status of the Baltic marine environment by 2021 (HELCOM, 2007). To meet the requirements specified in international agreements and EU directives, e.g. the Nitrate Directive (EC, 1991), Sweden has set up a number of national environmental quality objectives (Swedish Environmental Protection Agency, 2012). One of these objectives is 'Zero eutrophication', which is followed up by e.g. national calculations of N load from the whole of Sweden to the surrounding seas (Brandt et al., 2009) which are based on modelled data, but validated to monitoring data. One such monitoring programme is the *Agricultural Monitoring Programme*, which consists of 21 small agricultural catchments where stream water has been monitored for approximately 20 years (Kyllmar et al., 2006). In these catchments, agricultural land is the main source to losses of nitrogen and phosphorus at catchment stream outlet. The measurements started within a regional programme run by the County Administration Boards, but in 2002 the programme was reorganised and eight of the regional catchments were transferred to a national programme under the Swedish Environmental Protection Agency (EPA), with the Swedish University of Agricultural Sciences (SLU) delegated to carry out the monitoring work. The national monitoring programme was established to secure long-term monitoring and to intensify monitoring in these eight catchments. The catchments in the monitoring programme altogether represent a large variation in climate, soil types and crops grown which enhances a thorough evaluation of the impact of agriculture on water quality in recipient waters. Compared to the surrounding agricultural areas, such detailed information on agriculture and water quality is not available. Similar agricultural monitoring programmes exist in other Nordic and Baltic countries

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http://dx.doi.org/10.1016/j.agee.2014.05.016
0167-8809/

as described by Vagstad et al. (2004). The monitoring approach is almost the same among these national programmes including water sampling at stream outlet, continuous water flow measurements and yearly crop management surveys (e.g. Bechmann et al., 2008; Blicher-Mathiesen et al., 2013; Granlund et al., 2005; Iital et al., 2014; Jansons et al., 2013; Povilaitis et al., 2014).

Monitoring at the catchment scale imply that many systems and processes need to be measured or estimated, e.g. water flow pathways and dynamics in surface waters and groundwater, nutrient cycling including decomposition in soil and waters, the information from farmers on management of crops and soil, land management on other areas than agriculture, influences from point sources. Each of these data is associated with uncertainties that need to be considered. Another factor that also has to be considered is the representativity of the monitoring catchments compared to the regions where they are situated. The usefulness of monitoring data is dependent on how they relate to other agricultural areas where information on agricultural impact on water quality is limited.

In this study, one of the objectives is to investigate the conditions in the monitoring catchments in relation to the agricultural areas in the regions where they are situated. Another is to evaluate whether the monitoring catchments can be used as indicators of changes in agriculture, and thus, its effect on water quality. A third objective is to describe the agricultural monitoring programme. The description is distinguished from that in a former publication (Kyllmar et al., 2006) where the monitoring programme as it was before the reorganisation in 2002 was described. The present paper include new data on such as groundwater quality, crop management and water quality based on flow-proportional water sampling.

2. Materials and methods

2.1. Monitoring catchments

The monitoring catchments are located in the main agricultural areas in Sweden (Fig. 1). The catchments are small, approximately 10 km^2, and are mostly dominated by arable land (Table 1). Catchments included in the national part of the monitoring programme generally have more intensive crop production than those in the regional part of the programme. Intensive crop production is here defined as production systems with high input levels of fertiliser, high yields and often a large proportion of annual crops. Altogether this means that nutrient circulation is high which increases the risk for leaching, of nitrogen especially. A perennial crop as ley that covers the soil for several years has a lower area-specific leaching (16 kg ha^{-1} year^{-1}) than e.g. winter wheat (34 kg ha^{-1} year^{-1}), according to national load calculations for leaching region 1a (Blombäck et al., 2011). Most of those catchments with intensive crop production also have a high proportion of arable land in the catchment area. Among the eight national catchments, three are situated in coastal areas in the most south-westerly part of Sweden, where the climate is characterised by mild winters and high precipitation. The soils in these catchments are mostly sandy loam and the crop production is intensive, with crops such as winter wheat, oilseeds, sugar beet and potato. Not far from these catchments, but in more forested areas, there is a national catchment with high livestock density and mainly ley production which has the highest annual precipitation (more than 900 mm as

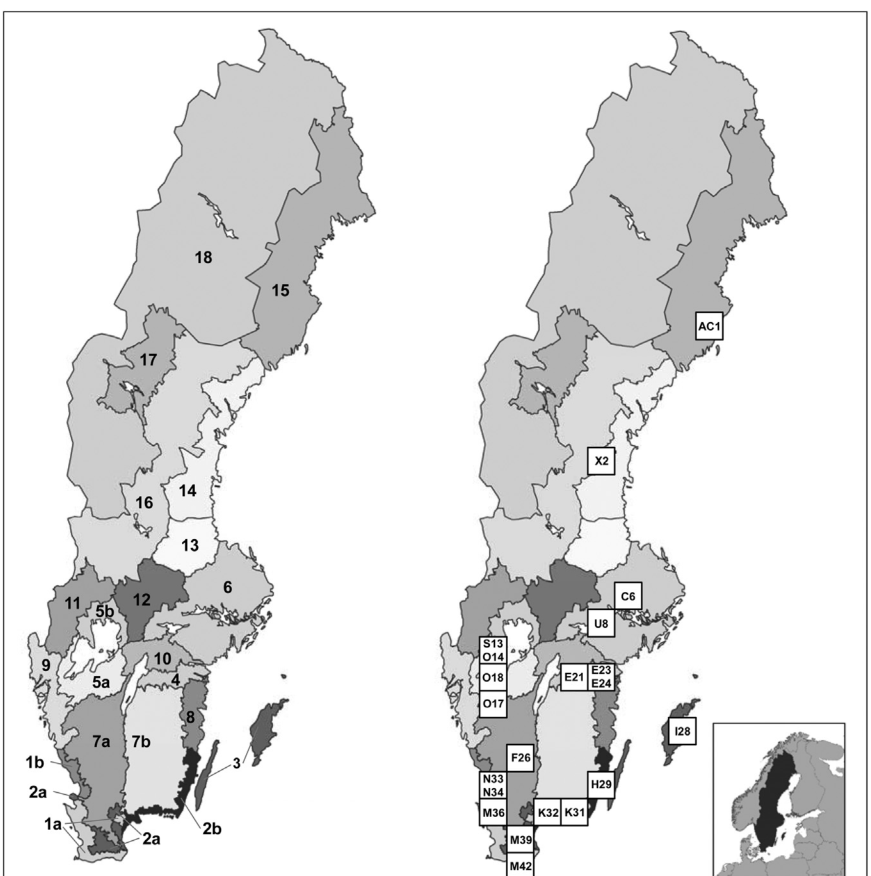

Fig. 1. Agricultural leaching regions and agricultural monitoring catchments (squares). Catchments are located somewhere within the marked 50 × 50 km^2 square.