Collection: Cost Action E29 Meeting 2008 – Istanbul (Turkey)
Future Monitoring and Research Needs for Forest Ecosystems
Guest Editor: Marcus Schaub (WSL, Birmensdorf, CH)

Hydrology, element budgets, acidification, nutrient N in a climate change perspective for the northern forest region

Lundin L

The aim of this paper is to discuss the potential impact of climate change on element budgets and acidity in northern forest ecosystems. A catchment approach should provide the most appropriate unit and to be investigated in several spatial scales. Future monitoring has also to address tree composition, forestry activities, follow the soil organic matter storage and include changes in hydrology with episodic extremes.

Keywords: Acidification, Forest land, Hydrology, Nitrogen, Organic substances

Introduction

Climate change targeting precipitation and temperature will affect forest ecosystem conditions. This will have impacts on hydrology, organic matter, acidity and nitrogen. Turnover of elements is to a large extent dependent on hydrological conditions. In a climate change perspective, it is foreseen frequently more extreme variations, *e.g.*, regarding wetness and drought. In a northern climate, the historically ordinary hydrological pattern includes a dormant period often being snow covered and a vegetation period in summer with relatively high temperature and evapotranspiration. This pattern already has changed to mild winters including snow melt during the whole period, resulting in the absence of a high snow melt spring flood. Instead, high element runoffs occur during the dormant period meaning a rather high flow to surface waters and the sea. In summer, variations between high precipitation and periods of drought occur at different geographical locations and in time. The consequences for element turnover could be drastic.

Effects of atmospheric deposition and climate conditions are studied in the UN ECE International Cooperative Programme on Integrated Effects of Air Pollution on Ecosystems (ICP IM). This programme is included in the content of the Working Group on Effects (WGE) in the Convention on Long-Range Transboundary Air Pollution (CLRTAP - Sliggers & Kakebeeke 2004, CLRTAP 2007). The focus of the programme is on total ecosystem monitoring for revealing cause-effect connections and to give causative explanations to identified changes and effects. The programme considers among other items acidification and eutrophication, in the present situation being highly dependent on climate change. Included concepts relate to water balances and chemical budgets for defined compartments such as catchments where also effects on the biological system should be identified. Sweden is one country included and results from three of the Swedish IM sites and some research project sites have been used for special investigations on discharge patterns, element flows and relations between hydrology and organic matter transport. Special attention has been placed on organic matter as bearing agent for many other chemical elements. The aim of this paper is to discuss the potential impact of climate change on element budgets and acidity in northern forest ecosystems.

Department of Aquatic Sciences and Assessment, Swedish University of Agricultural Sciences, P.O. Box 7050, SE-750 07 Uppsala, Sweden

@ Lars Lundin (Lars.Lundin@ma.slu.se)

Received: Mar 13, 2008 - Accepted: Dec 09, 2008

Citation: Lundin L, 2009. Hydrology, element budgets, acidification, nutrient N in a climate change perspective for the northern forest region. iForest 2: 23-25 [online: 2009-01-22] URL: http://www.sisef.it/iforest/show.php?id=479

Methods

In five small forested catchments of which three are included in the ICP IM programme (IM 2007), the input and output conditions have been monitored over many years. The catchments embraces areas of 20 to 45 ha and are located on till soils with mainly drained upland soils but close to streams higher soil organic storage exist. To achieve long term data series, also hydrological modelling using the Q-model (Lundin & Kvarnäs 2002) has been included.

Results and Discussion

Long-term determination of discharge patterns has been ongoing and a model study on long-term runoff from the Swedish IM site Kindla (Lundin & Kvarnäs 2002) together with recent measurements during 12 years showed for the period before 1987, the traditional low discharges in winter, followed by a spring discharge peak flow, low summer runoff and again a small autumn peak (Fig. 1). In later years a new pattern developed with high flows during the dormant winter period followed by a smaller spring peak as compared to earlier years, summer low flow but a more or less constant increase in autumn flow to again high winter flows (Fig. 1). The connection to element transport is obvious and the pattern for organic substances (DOC) in relation to discharge shows the high transport during early stages in discharge increase (Fig. 1). With DOC, many elements are associated and transported to surface waters. High discharges in spring with somewhat raised DOC concentrations furnish rather high flow of DOC (c. 1200 kg DOC ha^{-1} yr^{-1}). However, higher DOC concentrations in beginning of autumn contribute to even higher flows in this period (c. 2000 kg DOC ha^{-1} yr^{-1}). There are also strong connections to acidification processes and leaching of nutrient nitrogen.

Acidification depends on deposition of sulphur and nitrogen acids but also on biological production where growth means release of protons to the soil system. The chemical conditions in the soil changes, related to BC/Al ratio, base saturation and pH decline and have adverse effects on biological processes. Changes may be site specific and proton budgets have revealed processes influencing the acidity conditions (Forsius et al. 2005). Deposition of S and N contributes to the acidification but at present the S deposition has decreased to levels being lower compared to leaching from the soils with a net release of stored S (Wright et al. 2005). Nitrogen deposition has a strong impact on acidification and with higher input of N the acidity increases. Other such conditions influencing acidity are sea salts, changed water runoff, weathering and organic acids. All these are dependent on the climate and changes in storm events and discharge conditions, as mentioned above, contribute in the processes.

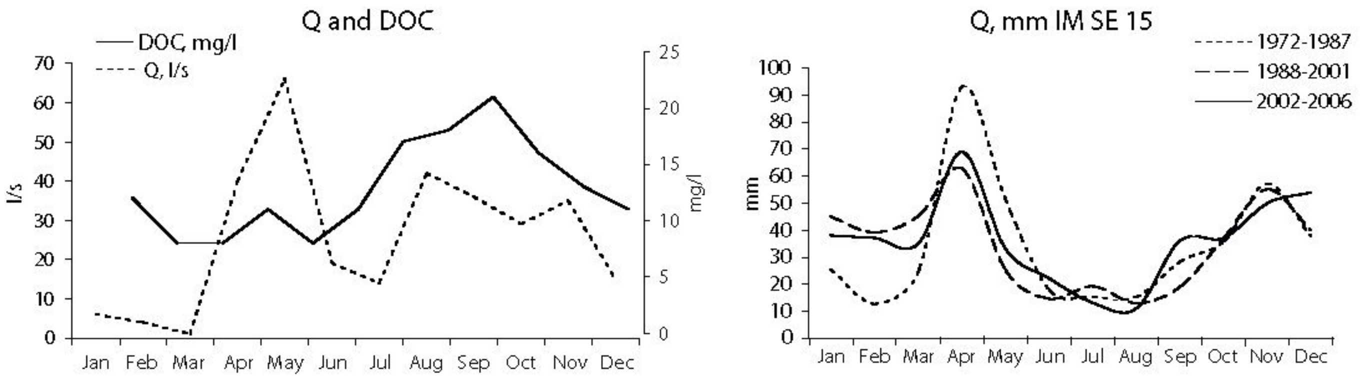

Fig. 1 - Monthly discharge (Q) together with DOC concentrations at site Buskbäcken (BB) in 1985-1988 (left) and annual discharge patterns during three periods at the IM site Kindla (SE 15 - right).

Nutrient nitrogen is closely related to eutrophication processes and deposition of N remains on elevated levels with no clear trend on changes (Kleemola & Forsius 2006). Leaching from catchments is well below deposition amounts and reaches only 10% of the input. At N-deposition values over about 10 kg ha^{-1} yr^{-1} increased leaching may occur (Kleemola & Forsius 2007). An ongoing accumulation in the soil exists and it has been shown the relation between high nitrogen storage in soils and low CN-ratios. With such low C/N, the risk for enhanced leaching increases and below C/N of about 25, leaching are higher (Gundersen et al. 2006). Climate influences on the N-processes are related, among other things, to temperature and deposition conditions.

Soil organic matter would play a key role in the turnover of elements. Increased growth would furnish more litterfall and root production. A higher temperature could change the stand tree composition and in case of a change from pine to spruce increase the soil organic matter storage. In moist and wet areas this would mean enhanced accumulation of organic carbon. A high nitrogen input furnishes additional organic matter storage possibilities. Under a stable moist or wet condition more organic matter would influence water quality with higher colour, lower pH and hazardous conditions for metals. In case of changes in soil moisture conditions, *i.e.*, drier periods, the decomposition of stored organic matter will start and could be considerable. This would release stored elements, increase nitrate production and leakage. After the drier period, again precipitation will eventually fall and flush out the released elements with strong effects on e.g. pH, N and metal flows.

For Swedish IM sites recent changes in acidic, nitrogen and organic carbon leaching have occurred. The earlier (1970-1990's) fairly strong relation between acidity and

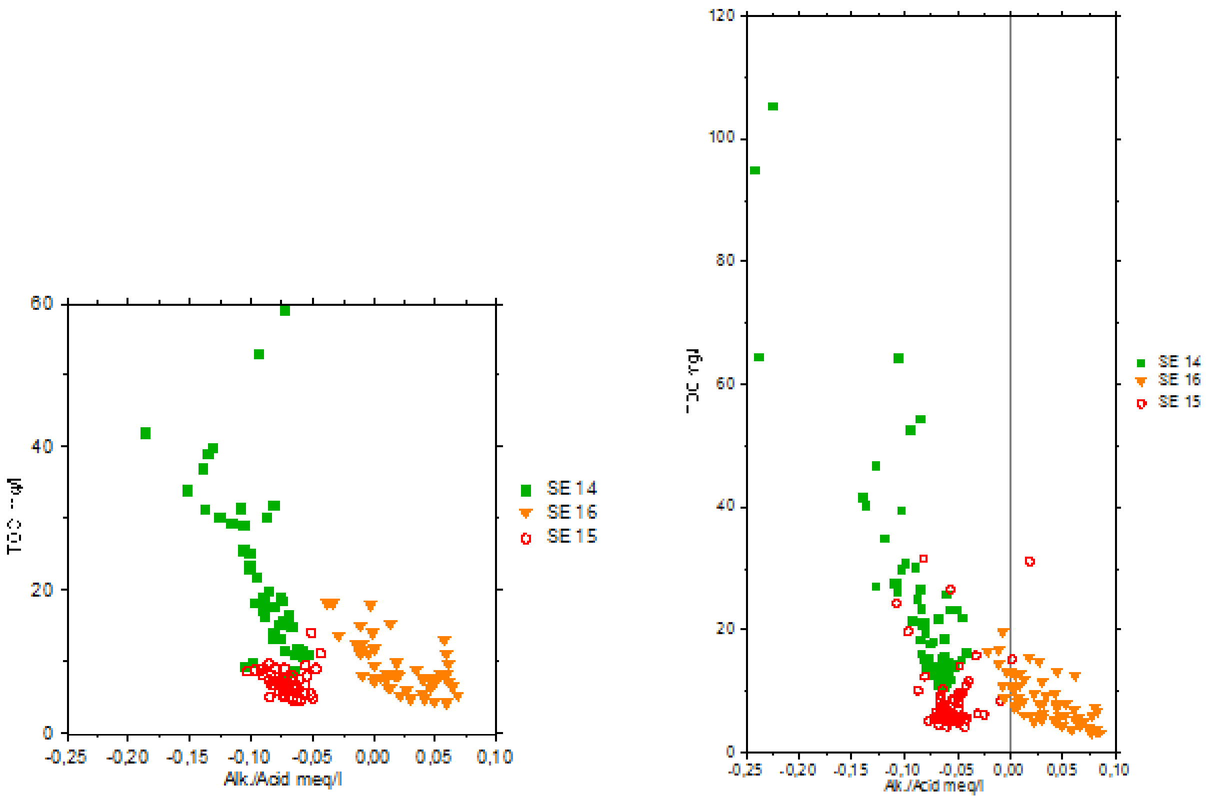

Fig. 2 - Alkalinity (positive) or acidity (negative) in relation to total organic carbon during the two periods 1998-1999 (left) and 2002-2004 (right) at three Swedish IM sites; Aneboda (SE 14) green squares, Kindla (SE 15) red circles and Gammtratten (SE 16) orange triangles.

sulphuric compounds has changed to stronger influences from organic substances and acids with also higher TOC contents in runoff waters as could be seen for periods 1998-1999 in comparison to 2002-2004 (Fig. 2).

Conclusions

These conditions need to be followed for the total ecosystem where a catchment approach should provide the most appropriate unit and perhaps to be investigated in several spatial scales. In the Integrated monitoring (IM) approach for natural forests, this is ongoing but for the majority of land, where ongoing land-use such as forestry exists, the monitoring is on a low level and needs development. Future monitoring has to include these facts and address tree composition, forestry activities, especially in a higher biofuel use perspective, and follow the soil organic matter storage in a climate change perspective. Specially, included are changes in hydrology with episodic extremes and in relation to climate gas emissions.

Acknowledgements

The presentation was made possible by support from the Swedish University of Agricultural Sciences, Swedish Environmental Protection Agency and the International Cooperative Programme on Integrated Monitoring.

References

CLRTAP (2007). Convention on Long-range Transboundary Air Pollution. UNECE Web Site. [online] URL:http://www.unece.org/env/lrtap

Forsius M, Kleemola S, Starr M (2005). Proton budgets for a monitoring network of European forested catchments: impacts of nitrogen and sulphur deposition. Ecological Indicators 5: 73-83. - doi: 10.1016/j.ecolind.2004.05.001

IM (2007). International Cooperative Programme (ICP) on Integrated Monitoring of Air Pollution Effects on Ecosystems. www.environment.fi web site. [online] URL:http://www.environment.fi/default.asp?contentid=17110&lan=EN

Gundersen P, Berg B, Currie WS, Dise NB, Emmett BA, Gauci V, Holmberg M, Kjønaas OJ, Mol-Dijkstra J, van der Salm C, Schmidt IK, Tietema A, Wessel WW, Vestgardem LS, Akselsson C, Van der Vries W, Forsius M, Kros H, Matzner E, Moldan F, Nadelhoffer KJ, Nilsson L-O, Reinds GJ, Rosengren U, Stuanes AO, Wright RF (2006). Carbon-nitrogen interactions in forest ecosystems: final report. Danish Centre for Forest, Landscape and Planning, Hørsholm, Denmark, pp. 61.

Kleemola S, Forsius M (2006). Trend assessment of bulk deposition, throughfall and runoff water/soil water chemistry at ICP im sites. In: "International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems" (Kleemola S, Forsius M eds). 15th Annual Report 2006, Helsinki, Finland. The Finnish Environment 30: 22-48.

Kleemola S, Forsius M (2007). International cooperative programme on integrated monitoring of air pollution effects on ecosystems. 16th Annual Report 2007. The Finnish Environment 26, Helsinki, Finland, pp. 100.

Lundin L, Kvarnäs H (2002). Long-term effects of forestry on runoff determined by modelled reference time series. Proceedings of the XXII Nordic Hydrological Conference (Röros, Norway, 4-7 August 2002). Nordic Hydrological Programme Report No. 47, pp. 239-247.

Sliggers J, Kakebeeke W (2004). Clearing the air: 25 years of the Convention on long-range transboundary air pollution. ECE/EB.AIR/84, UN/ECE, Geneva, Switzerland, pp. 167.

Wright RF, Camarero L, Cosby BJ, Ferrier RC, Forsius M, Helliwell R, Jenkins A, Kopáček J, Larssen T, Majer V, Moldan F, Posch M, Rogora M, Schöpp W (2005). Recovery of acidified European surface waters. Environmental Science and Technology 39: 64A-72A. - doi: 10.1021/es0531778