**Project no: 110**

*Send the report to SNS-secretaries Jonas Rönneberg and Inga Bödeker (bodeker.sns@slu.se)*

## FINAL REPORT for PROJECT

Please notice that the size of text sections in the form can be adjusted if needed. The length of the final report should not exceed 3 pages. **Supplementary information can be attached**

<table>
<thead>
<tr>
<th>1. Projekt titel</th>
<th>Export av kol, kväve och fosfor från skogsmark i Norden och Baltikum</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Project title</td>
<td>Leaching of carbon, nitrogen and phosphorus from forest land in the Nordic and Baltic countries</td>
</tr>
</tbody>
</table>
| 3. Coordinator (name, address, telephone, e-mail) | Lars Högbom  
Skogforsk  
Uppsala Science Park  
751 83 Uppsala, Sweden  
+46 18 18 85 49, +46 705 17 85 46  
lars.hogbom@skogforsk.se |
| 4. Duration | from January 1 2011 to December 12 2013 |
| 5. Cost | SNS-funding: 1,095,067 DKK Other funding: 2,951,367 DKK |
6. The purpose of the project / main problems / hypotheses addressed

The overall goal of this project was to build a meta-database which identifies and documents forest research sites in Fennoscandia and the Baltic states where water chemistry has been analyzed.

In the application we formulated two specific objectives:
- to summarize available data as regards concentrations and export of C, N, and P following forestry operations
- to document the level of background leaching (C, N, and P) from forest land and to evaluate the possible influence of factors determining the differences in C, N, and P leaching.

and four hypotheses:
1 – N and P leaching on an area basis decrease and the relative importance of organic N increases with increasing latitude.
2 – C, N and P leaching increase with increasing peat-land coverage.
3 – Nutrient-rich sites show higher rates of N and P leaching than nutrient-poor sites.
4 – N leaching is primarily related to the N deposition rate and, of secondarily to site quality.

7. Brief description of the research plan and of possible larger deviations from the plan

The plan was to construct a meta-database of forest experiments and monitoring sites which included water-related measurements, in Fennoscandia and the Baltic states. We have also been able to include Estonia in the project, although it wasn’t included in the original application. The meta-database has been constructed and will be published in detail in a Skogforsk Working Report (in English). In the application we presented an ambitious publication plan, which we haven’t been able to meet. However, the content of the planned publications outlined in the proposal will be included in the above-mentioned Skogforsk report. Within the framework of the SNS funded CAR-ES network we also aim to publish selected results and evaluations in peer-reviewed journals. A major research proposal (Finer et al. 2013) was a spin-off from the project, which despite the substantial effort unfortunately was not funded.

8. Results (max 2 pages)

Please see Appendix 1 – Results

9. What advantages have been gained by the Nordic collaboration

As a result of the collaboration within the project we have gained information about ongoing activities within the participating countries and deepened the collaboration between Nordic and Baltic scientists. We have learned from each other’s experiences regarding scientific methods and strategies for water protection. In addition, we have broadened our perspective and understanding of both regional differences and similarities. Furthermore, the meta-database offers an overview of the existing
10. Publications and other communication activities
(International scientific peer reviewed journals, other scientific publications, short communications, web etc.)

**External presentations including the project** (project meetings excluded)

**Written output as a direct or indirect result of the project**
Excessive inputs of N and P to the Baltic Sea cause eutrophication, leading to algal blooms, oxygen depletion and other harmful effects. While most of the nutrients entering the Baltic Sea come from agricultural and urban lands, the input from forest land should be investigated further. Over the years, the impact of forest and forestry on water quantity and quality has been a major interest. A lot of this research and monitoring has been conducted in order to address specific questions and to follow up on various environmental issues. Further, over the years a large number of experimental and measurement approaches have been applied. Therefore, we felt a need to summarise past and present results more comprehensively.

In order to meet this objective, we set up a number of specific goals for the project:

- To get an up-to-date overview of both previous and present field experiments and monitoring sites in the participating countries.
- To collect and assemble meta-data from both previous and ongoing measurements concerning forests, forestry and water from Nordic and the Baltic countries.
- To facilitate information exchange between the countries and to learn from each other.
- To identify important research gaps, particularly forestry measures for which experimental evidence of the effects on water quality are lacking.
- Propose a plan for future work on how to effectively utilize the data collected in the experiments and monitoring programmes included in the meta-database.

Within this project we have constructed a meta-database covering forest experiments and monitoring sites where data on soil-, ground- and surface water nutrient chemistry have been collected. The meta-database locates and catalogues studies where nitrogen (N), phosphorus (P) and organic carbon (DOC) have been measured in water from intact and conventional and whole-tree harvested forests.

The meta-database is up to date and in total 443 entries have been included (630 entries if individual treatments on plot scale are included). All entries represent studies or environmental monitoring which encompass chemical analysis of soil-, ground- or stream water (Table 1). The entries have been divided in the first instance into catchment- (n=261) or plot-scale studies (n=182). (Please note that exact numbers change as new experiments are established.) Within each scale level the entries have been divided into closed forest (background) and a number of forestry operations, like final felling, whole tree harvesting, ditching and ditch cleaning, liming, wood-ash recycling, N-fertilization and afforestation. We have found that that there might not be enough sites with treatments where data have been collected to facilitate the analysis we had originally proposed. However, this is in itself an important result as it shows the need for more long-term experiments and the importance of publicizing experimental results.

<table>
<thead>
<tr>
<th>11. Project summary (about 1/3 page) for possible use in the News &amp; Views section of Scandinavian Journal of Forest Research</th>
</tr>
</thead>
<tbody>
<tr>
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<table>
<thead>
<tr>
<th>12. Date and signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date: Uppsala, 30 August, 2014</td>
</tr>
<tr>
<td>Signature of project leader/coordinator: Lars Högbom</td>
</tr>
</tbody>
</table>
Appendix 1 – Results

Nitrogen (N), carbon (C), and phosphorus (P) are all essential for life. With the exception of N these elements are available in global reservoirs. Nitrogen, having the greatest total abundance in the Earth’s atmosphere, is also the least readily availability to sustain life. Apart from being essential nutrients these elements are also key factors in many of the environmental issues we are facing today, this is in particular true for reactive N (eutrophication, greenhouse gases), P (eutrophication) and C (greenhouse gases). In surface waters, excess N and P cause eutrophication, C has an impact on water colour, temperature, oxygen, energy supply, availability of toxic elements and heavy metals. Further, high N and DOC concentrations have adverse effects on drinking water quality. While concentrations are often low, the large forest area in Fennoscandia and the Baltic States means that leaching of N and P from forests can have large effects on the eutrophication situation in the Baltic Sea.

The Nordic-Baltic region (including Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, Norway and Sweden) constitutes a rather small region from an international perspective, but includes some very strong gradients both as regards climate, N-deposition, forest production and population pressures. The climatic gradient from north to south is probably the most pronounced, ranging from almost Arctic conditions in northern Finland and Norway down to the temperate forest in southern Denmark. Superimposed on the north-south main gradient there are east-west climatic gradients ranging from inland climate along the border to Russia to marine climate along the Atlantic coast. Iceland should in this context be treated as a special entity, with a climate distinctively different from the other parts of the region, but very important since Icelandic data on young soil important for process understanding.

The impact of forest and forestry on water has over the years been a major interest. A lot of this research and monitoring has been conducted in order to address specific questions and to follow up on various environmental issues. Further, over the years a large number of approaches have been applied. Therefore, we felt a need to summarise past and present results more comprehensively.

Table 1. Number of entries in each country divided into different types of water.

<table>
<thead>
<tr>
<th>Country</th>
<th>Soil solution</th>
<th>Groundwater</th>
<th>Stream water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>43</td>
<td></td>
<td>154</td>
</tr>
<tr>
<td>Finland</td>
<td>17</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Iceland</td>
<td>5</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Latvia</td>
<td>8</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Lithuania</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Norway</td>
<td>31</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Sweden</td>
<td>111</td>
<td>11</td>
<td>68</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>215</strong></td>
<td><strong>38</strong></td>
<td><strong>244</strong></td>
</tr>
</tbody>
</table>

Specific goals of the project were:

i) To get an up-to-date overview of both previous and present field experiments and monitoring sites in the participating countries.

ii) To collect and assemble meta-data from both previous and ongoing measurements concerning forest/forestry and water from Fennoscandia and the Baltic countries.

iii) To facilitate information exchange between the countries and to learn from each other.

iv) To identify important research gaps, particularly forestry measures for which no or few experiments have been carried out.
Propose a plan for future work on how to utilize the data collected in the experiments and monitoring programmes included in the meta-database.

So far, the project has been running more or less according to the plan in the application, except for publication where we are behind schedule.

The meta-database is up to date and in total 443 entries have been included (630 entries if individual treatments on plot scale are included). All entries represent studies or environmental monitoring which encompass chemical analysis of soil-, ground- or stream water (Table 1). The entries have been divided in the first instance into catchment- (n=261) or plot-scale studies (n=182). (Please note that exact numbers change as new experiments are established.) Within each scale level the entries have been divided into closed forest (background) and a number of forestry operations like; final felling, whole tree harvesting, ditching and ditch cleaning, liming, wood-ash recycling, N-fertilization and afforestation. We have found that that there might not be enough sites with treatments where data have been collected to facilitate the analysis we had originally proposed. However, this is in itself an important result. The number of entries differs between the participating countries and it isn’t surprising that Finland (n=173) and Sweden (n=171), the two countries with the largest shares of forest land (73% of the forest area in the entire region), host 75% of the forest research and monitoring sites. However, by adding results from the other countries a complementary and deepened insight in processes may be drawn. Further, with a close cooperation between the countries, data, results and knowledge will be exchanged between the countries in the region. Results from regions with different climate could help in predicting the effect of present models of climate change.

**Table 2.** Examples of entries in the meta-database separated into countries and reference and selected forestry operations.

<table>
<thead>
<tr>
<th>Country</th>
<th>Total number of entries</th>
<th>Final felling</th>
<th>Fertilisation</th>
<th>Ditch cleaning</th>
<th>Wood-ash return</th>
<th>Liming</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEN</td>
<td>43</td>
<td>4</td>
<td>3</td>
<td>.</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>FIN</td>
<td>173</td>
<td>17</td>
<td>4</td>
<td>46</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ICE</td>
<td>16</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LAT</td>
<td>9</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>LIT</td>
<td>7</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>NOR</td>
<td>37</td>
<td>7</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>SWE</td>
<td>171</td>
<td>87</td>
<td>25</td>
<td>6</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>443</strong></td>
<td><strong>120</strong></td>
<td><strong>39</strong></td>
<td><strong>54</strong></td>
<td><strong>28</strong></td>
<td><strong>28</strong></td>
</tr>
</tbody>
</table>

It is evident from the database summary (Table 2) that the main research issues differ between the countries. Therefore the joint Nordic/Baltic collaboration is of importance. By combining results from the whole region we can reach new insight in processes that control losses of N, P and C from forest land.

**New insight and preliminary results**

Nitrogen leaching from intact forests probably plays a minor role in Baltic Sea eutrophication. Intact forests in the northern part of the Baltic Sea catchment are generally N-limited and usually leach low amounts of dissolved inorganic N (DIN). A preliminary analysis of Swedish and Finnish data indicates that more productive sites (with a higher site index) generally leach more DIN, in accordance with our Hypothesis 3.
Productivity co-varies with N deposition: more productive sites in the south are subjected to higher N deposition. We hope that the data on site conditions, climate, N-deposition, soil and stand management assembled in the meta-database will help us to understand the site specific factors controlling N leaching from forest land in Nordic/Baltic conditions.

During the autumn the outcome from the project will be published in great detail and the results will be put into an international perspective in the first instance as a Skogforsk report (in English). Our aim for the future is to summarize our findings in articles in peer-reviewed journals. This will be done within the framework of SNS founded CAR-ES.