Project no: 118

Nordic Forest Research
Co-operation Committee (SNS)

Send the report to SNS-secretaries Jonas Rönnberg 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**

1. Projekt titel	Ekologiska effekter av intensiv biomassehösting i de nordiska och baltiska länderna
2. Project title	Ecological effects of intensive biomass harvesting in the Nordic and Baltic countries
3. Coordinator (name, address, telephone, e-mail)	Nicholas Clarke Norwegian Institute of Bioeconomy Research P.O. Box 115, N-1431 Ås, Norway Tel. +47-97480327, e-mail: nicholas.clarke@nibio.no
4. Duration	January 1 2013 to December 31 2014
5. Cost	SNS funding: 500 000 DKK. Other funding: 2 883 800 NOK SNS funding was used primarily for employing staff to gather metadata and data in order to build a database.
6. The purpose of the project / main problems / hypotheses addressed)	The objectives of this study were to evaluate the effects of forest biomass harvesting on soil nutrient stores, soil carbon stocks, surface and ground water quality, and biodiversity. Furthermore, we wished to explore the possible influence of factors such as harvesting type (stem-only, whole-tree etc.), site quality, and impact of the harvesting on productivity. The objectives were to be reached by building a Nordic-Baltic database including results from relevant field experiments, which could be used, if enough data should be found, for doing a meta-analysis in order to quantify if possible the ecological effects of intensified forest biomass harvesting in the Nordic and Baltic countries.

7. Brief description of the research plan and of possible larger deviations from the plan	According to the original research plan, the first year should be used to do a thorough literature search and to design a meta-database with information about all experiments carried out in the Nordic and Baltic countries. Then we had planned in the second year to construct a real database and finally to carry out a meta-analysis of its results, providing there were sufficient data. Three project meetings have been held, at Hverageröi, Iceland (May 2013), Birštonas, Lithuania (March 2014) and Vantaa, Finland (October 2014). During these meetings participants from Norway, Sweden, Denmark, Finland, Iceland, Latvia and Lithuania actively participated in the development of the databases and helped with getting access to all relevant data from their respective countries between meetings. We have followed the above research plan. In the project's first year, the main activity was to do a literature search and to start to compile data about relevant experiments. For this we hired a graduate student, Thorveig Johannsdottir, who was based at Copenhagen University during her work. We have, however, extended the scope somewhat. We decided to include not only the Nordic and Baltic countries, but also other countries in NW Europe in the boreal and north temperate zones (above 45˚N latitude) and we also included all published stump harvesting studies in this region. In the second year, a new real database in Access format was constructed. A researcher at the Agricultural University of Iceland, Helena M. Stefansdottir, was hired for doing this part. She and other project members were in direct contact with many authors to get additional data for the database. A part of this database (on soil chemical parameters) was then selected for making a further meta-analysis. For that work, the statistician Lars Pødenphant Kiær from Copenhagen University and Teresa G. Barcena from Bioforsk (Norway) joined the group. This part is still ongoing. Funding from SNS has been used as follows (NOK): From SNS 536 520 Work on the database/meta-database 459 674 Project coordination and administration 68 241 Travel costs (SNS meeting, Rønne, May 2013) 8 606
8. Results (max 2 pages)	See Appendix 1.
9. What advantages have been gained by the Nordic collaboration	The Nordic-Baltic collaboration has enabled the construction of a database in Access format covering ecological effects of intensified forest harvesting for the entire Nordic-Baltic-UK-Ireland region. Many authors sent in raw data used in earlier publications and the project also facilitated access to otherwise easily missed sources in reports etc., as well as unpublished data, which enabled inclusion of results in the meta-database and meta-analysis that otherwise might have been excluded.This has made the database much stronger and will enable us to study not only similarities between effects observed in diverse field experiments but also differences, which could aid in the identification of critical factors affecting the observed effects. The project has promoted interdisciplinary collaboration (e.g. statistics, forestry and soil science) and data sharing, consolidating the positive cooperation that exists among the project participants.
10. Publications and other communication activities (International scientific peer reviewed journals,	The primary product of the project is the database, which is currently being used for meta-analysis. Results will be published in a peer-reviewed journal. **The following papers linked to the project have been/are being published:** Clarke N et al. 2015. Influence of different tree-harvesting intensities on forest soil carbon stocks in boreal and northern temperate forest ecosystems.

other scientific publications, short communications, web etc.)	For Ecol Manage 351:9-19. Ring E et al. 2015. Soil and soil-water chemistry below different amounts of logging residues at two harvested forest sites in Sweden. Silva Fennica. 49:1265. Piirainen S et al. 2015. Changes in forest floor and mineral soil carbon and nitrogen stocks in a boreal forest after clear-cutting and mechanical site preparation. European Journal of Soil Science doi: 10.1111/ejss.12264. Bardule A et al. 2015. Evaluation of properties of soils solution during a 2-years period after stump removal in fertile forest sites in Latvia. *Proceedings of Adaptation and mitigation: strategies for management of forest ecosystems*, Airport hotel ABC, 2015. pp 61–62. Airport hotel ABC. Varnagirytė-Kabašinskienė I et al. 2014. Kelmų medienos panaudojimo kurui Lietuvoje ekologinis, ekonominis ir technologinis vertinimas (*Ecological, economic and technological assessment of stump wood use in Lithuania*). *Miškininkystė* 2 (76):7-20 (in Lithuanian). Jacobson S et al. 2015. The distribution of harvest residues and its impact on seedling establishment and growth in two Norway spruce stands. Submitted. **External presentations (project meetings excluded):** Vesterdal et al. (2013). *Soil carbon sequestration in forestry: influences of changed land use and management.* Keynote talk. Soil carbon sequestration for climate, food security and ecosystem services. International conference, Reykjavik, Iceland, May 26-29, 2013 Vesterdal et al. (2014). Hugst af træ – påvirkes jordens kulstoflager? [Does wood harvesting affect the soil carbon stock?]. Talk in Danish Energy Agency, 4 December 2014. Sigurdsson (2015). Effects of forest management on C-sequestration in soils. The Annual Icelandic Forestry Conference, Hotel Borgarnes, Iceland, 12 March 2015. **Other dissemination:** The project was presented at the SNS network meeting in Rønne on 16 May 2013 by the project co-ordinator. A policy brief, "*Ecological effects of intensive biomass harvesting in the Nordic and Baltic countries*", was written at the end of the first project year.
11. Project summary (about 1/3 page) for possible use in the News & Views section of Scandinavian Journal of Forest Research	In conventional timber harvesting, branches, tops and stumps are left in the forests. Removal of these parts for bioenergy may have ecological consequences. As a large part of the nutrients in trees are located in the needles and branches, removing these will reduce the input of nutrients and organic matter to the soil. In the long term, this might both increase the risk for nutrient imbalance and reduced forest production and affect biodiversity by changing species composition. However, field experiments have found contrasting results for both soil chemistry and ground vegetation. There is a need for more knowledge about which factors determine these differences, and of how variation in these factors affects long-term site sustainability. In the Nordic and Baltic countries, much work has already been done on these problems, and further integration of the knowledge obtained in the countries has the potential for greatly increasing our understanding of the mechanisms responsible. We have constructed a database with results from field experiments on effects of intensified biomass harvesting, enabling us to carry out an ongoing meta-analysis on these effects. In the long term, the results will contribute to sustainable forestry and thus assist in protection of the environment where forest is harvested for bioenergy production.
12. Date and signature	Date: 29.09.2015 Signature of project leader/coordinator: Nicholas Clarke

Appendix 1: Main results from project SNS-118

In conventional timber harvesting, branches, tops and stumps are left in the forests. Removal of these parts for bioenergy may have ecological consequences. As a large part of the nutrients in trees are located in the needles and branches, removing these during whole-tree harvesting (WTH) will reduce the carbon and nutrient supply to the soil. In the long term, this might both increase the risk for nutrient imbalance and reduced forest production and affect biodiversity by changing species composition. However, field experiments have found contrasting results for both soil chemistry and ground vegetation. There is a need for more knowledge about which factors determine these differences, and of how variation in these factors affects long-term site sustainability.

The aim of the project was to compile available experimental data and published results from our biomes in northern Europe on the effects of intensive forest biomass harvesting on soil nutrient stores, soil carbon stocks, soil structure, surface and ground water, and biodiversity. The main achievement in the first year was the construction of the meta-database containing data on relevant experiments. It consisted of the following spreadsheets in Excel format:

1. Variable names and descriptions
2. Codes for variables used
3. Cross-links between plots/sites and source papers
4. References and contact information
5. Overview of information about the experiments (two spreadsheets)
6. Biodiversity information (two spreadsheets)
7. Soil property information (two spreadsheets)

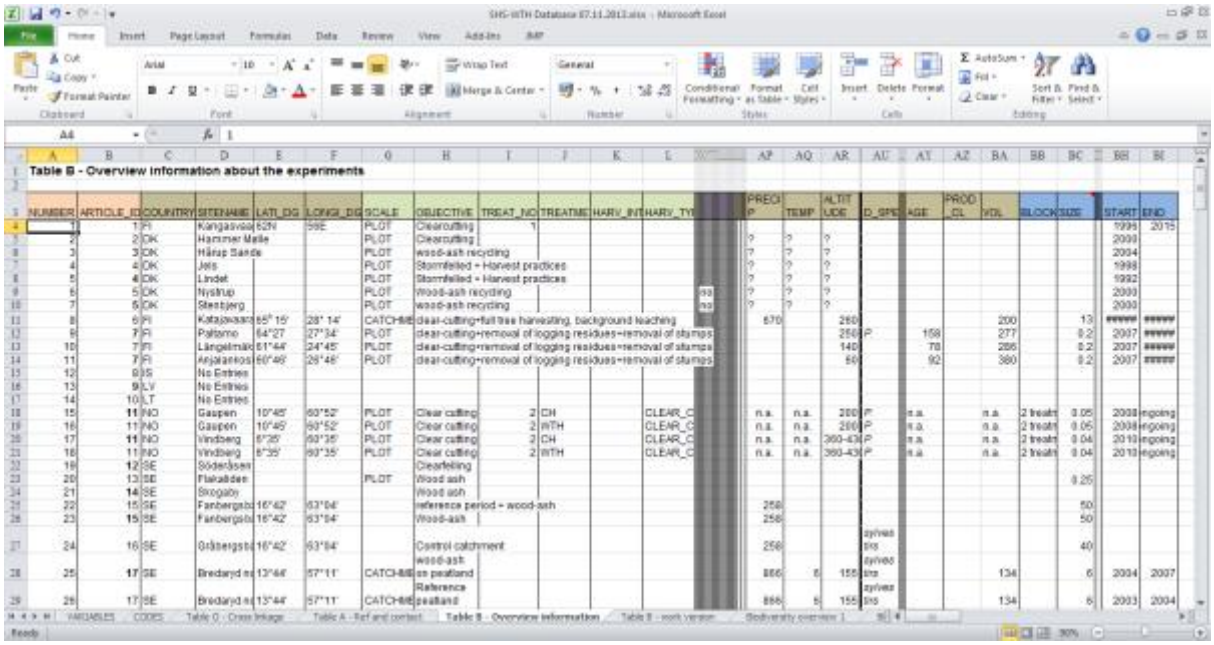

Figure 1. An example from the meta-database showing "Overview information".

In the second year, the database was extended and populated with all available and published data from our region and transferred into Microsoft Access format (Figure 2). Figure 3 shows the locations of all the field studies on the effects of intensive forest biomass harvesting on different biological and chemical parameters that are included in the final database.

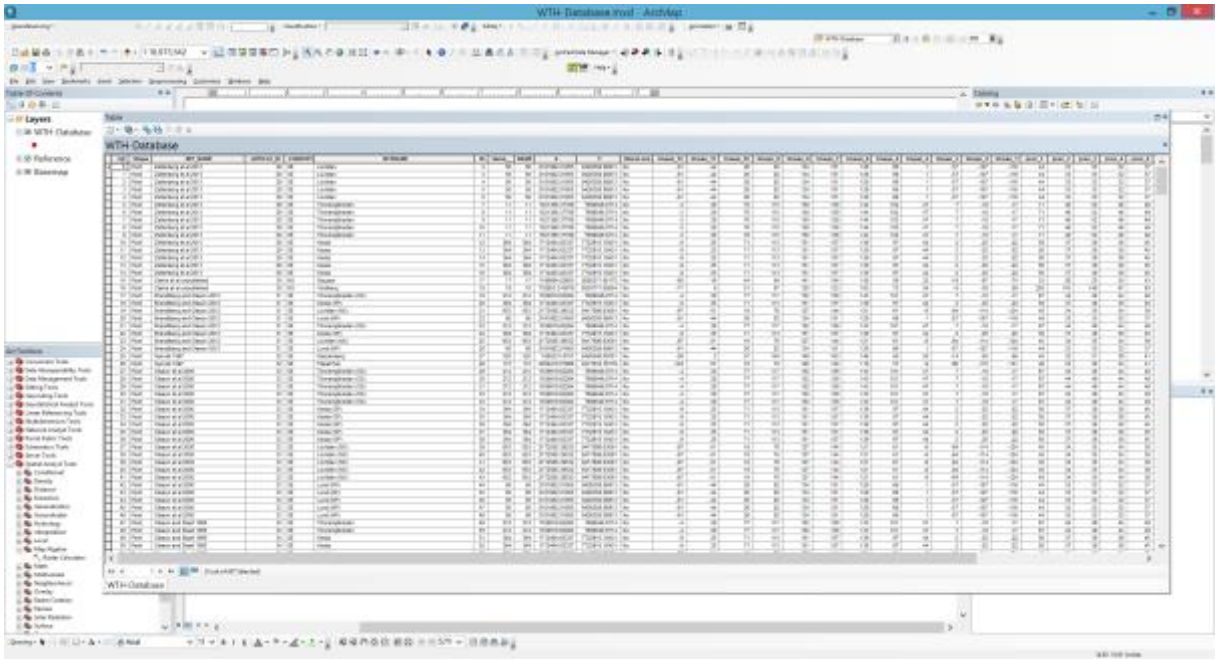

Figure 2. The WTH database.

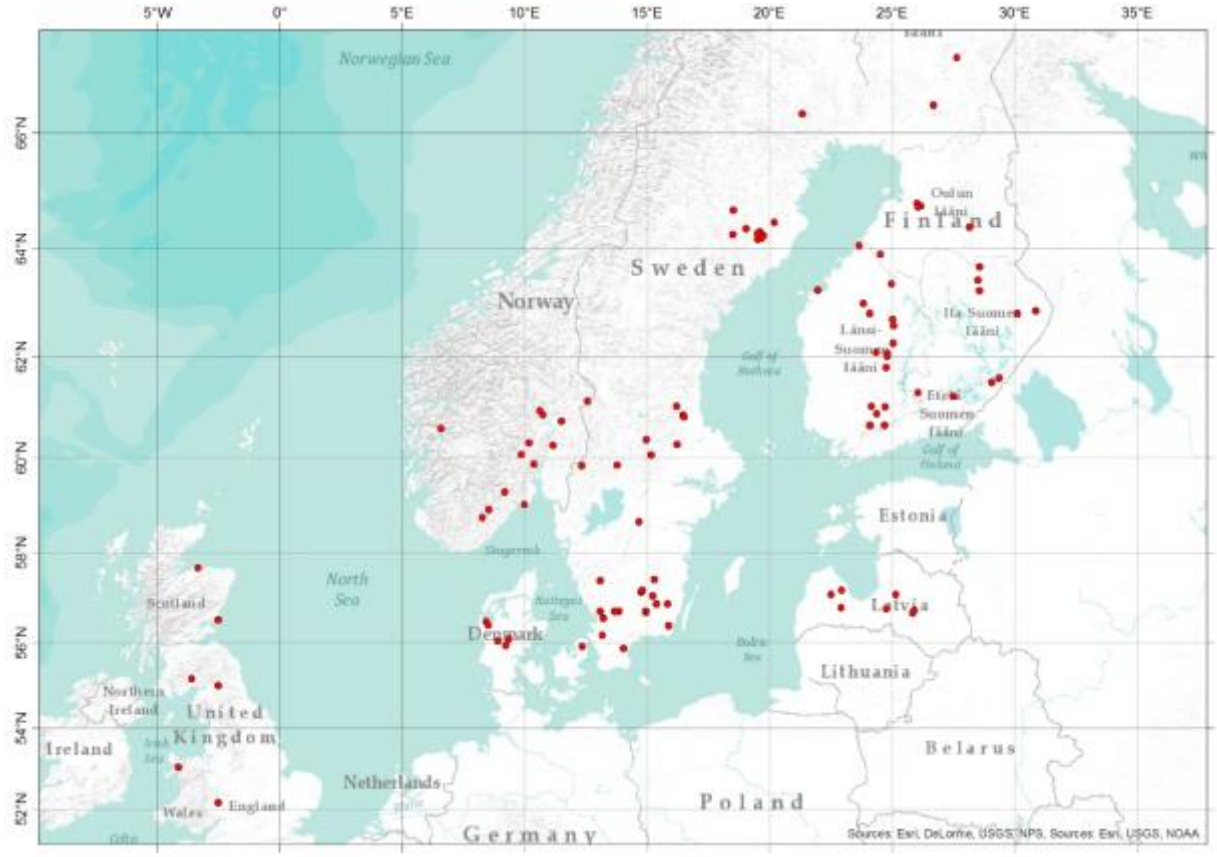

Figure 3. Locations of study sites included in the WTH database, including studies on effects on soil, tree growth, biodiversity etc. Map made by Sigmundur H. Brink., AUI.

It is evident from the database summary (Table 1) that only relatively few field studies have taken place in each country. Therefore such a joint SNS-funded collaboration, such as this WTH project, is of high importance. By combining results from the whole region we can reach new insight.

Table 1. Number of entries in each country in northern Europe divided into different types of more intensive harvesting. Studies on effects on soil, tree growth, biodiversity etc. are included. An "entry" can include information on different parameters and measurements from different times in the same area.

Country	Whole-tree thinning	Whole-tree harvesting	WTH + stump removal
Denmark	-	4	2
Estonia	-	-	-
Finland	50	13	4
Iceland	-	-	-
Ireland	-	-	-
Latvia	-	3	5
Lithuania	-	-	-
Norway	12	6	-
Sweden	15	51	9
United Kingdom	-	9	-
Total in N-Europe	**77**	**86**	**20**

When the database was ready it became clear that there were enough data about effects of intensified harvesting on soil organic carbon, pH and major nutrients (N and base cations) in soils so it would be possible to carry out meta-analyses. These analyses are ongoing (Figures 4-6).

In terms of soil nutrients, such as soil phosphorus (P), significant reductions can be seen in both forest floor and topsoil (0-10/15 cm depth into the mineral soil) following intensified extractions of biomass (Figure 4). Moreover, the negative effect was not significantly different following whole-tree thinning (WTT) than WTH. Deeper in the mineral soil the effects were not as clear, but still the reduction was found to be marginally significant in the WTT experiments ($p = 0.04$).

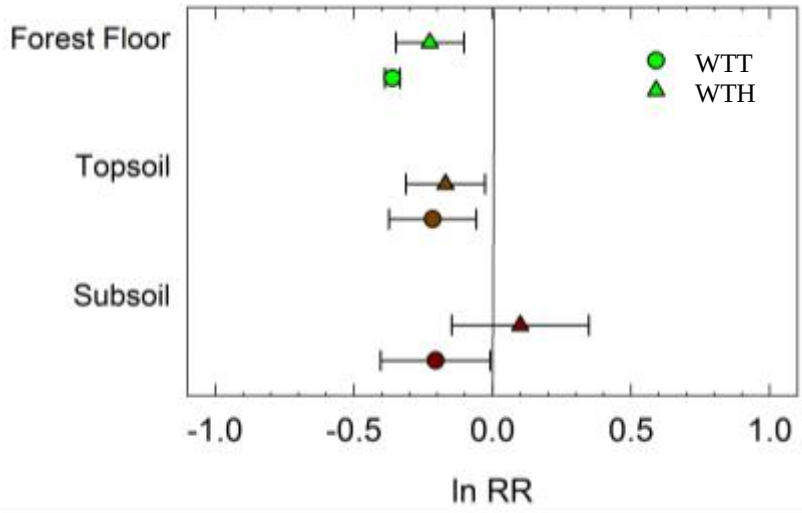

Figure 4. Preliminary results from the ongoing meta-analysis of the effects of intensified harvesting (WTT = whole-tree thinning and WTH = whole-tree (final) harvesting) on soil phosphorus (P) in three subsequent soil layers across all available studies within the region.

Figure 5 shows how soil organic carbon (SOC) differs between the three more intensive harvesting methods included (WTT, WTH and WTH followed by a stump removal) in the three soil layers. The strongest negative effect was seen in the forest floor following WTH and stump removal, but WTH and WTT also reduced carbon significantly in that layer. In the subsoil, the SOC was however increased significantly by the stump removal, probably

indicating more mixing of surface layers and subsoil following the extraction of stumps and coarse roots (Figure 5).

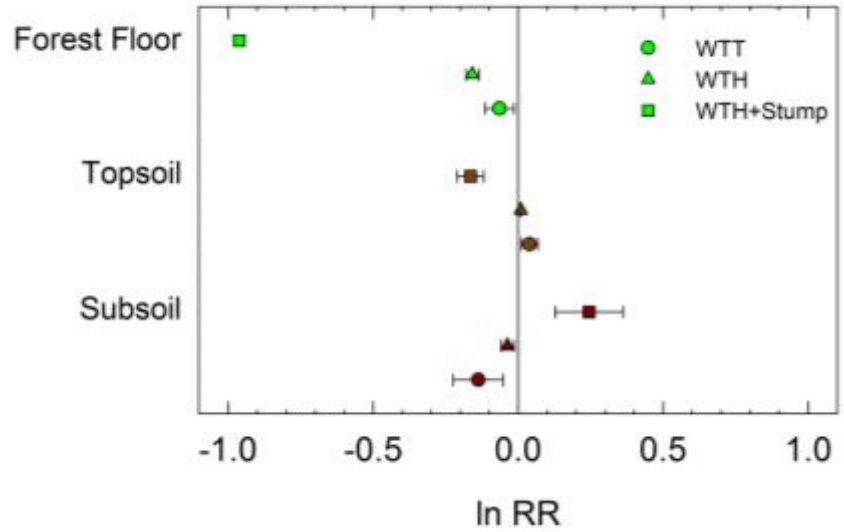

Figure 5. Preliminary results from the ongoing meta-analysis of the effects of intensified harvesting (WTT = whole tree thinning, WTH = whole tree (final) harvest, WTH+Stump = stump removal following whole tree thinning) on soil organic carbon (SOC) in three subsequent soil layers across all available studies within the region.

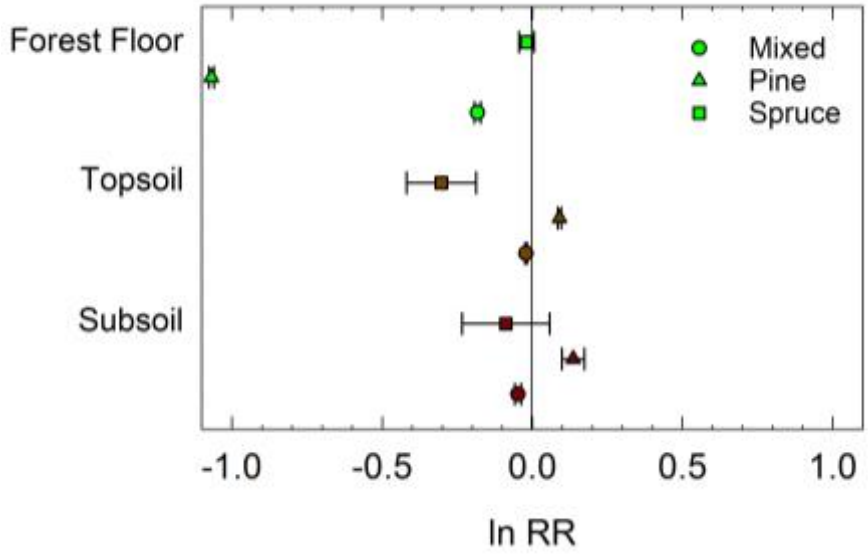

Figure 6. Preliminary results from the ongoing meta-analysis of the effects of intensified harvesting of different forest types (mixed coniferous stands, pine stands and spruce stands) on soil organic carbon (SOC) in three subsequent soil layers across all available studies within the region.

Figure 6 similarly shows how the SOC changes across all extraction methods differed between pure spruce and pine stands and mixed coniferous stands. The negative effects were strongest in the forest floor for the pine stands and in the topsoil mineral layer for spruce stands.

Unfortunately there were not enough data available in the WTH database to carry out meta-analysis for effects of intensified harvesting on biodiversity or soil water chemistry. This finding is, however, an important message in itself, pointing out where more studies are still needed.