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Electronic Supplementary Material
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Title:**Intensive land use in the Swedish mountains between AD 800 and 1200 led to deforestation and ecosystem transformation with long-lasting effects**

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Material and Methods

Scenario design and evaluation

Fuel-wood cutting was simulated as repeated selective cutting in forest patches, with a varying return interval of ten to forty years in any given patch. To mimic scenarios with harvesting starting near the settlements and subsequently spreading out as trees and wood became scarce, the first cutting in any patch was allowed to occur at different times (see Shackleton and Prins 1992 for a description of a conceptual model of pre-historical resource use). In this manner, patches where simulated cutting first occurs represent stands close to the settlement, and patches where the first cutting is postponed represent more remote stands. The management regimes for each patch were defined to mimic continuous selection cuttings by simulating consecutive series of thinning starting with the largest trees. For each treatment unit several management regimes were generated by varying the thinning grade, minimum cutting interval, and first period for cutting.The model also takes changes in regrowth of small trees into account (as a result of altered forest caused by tree cutting). The ingrowth function has three components; presence and density of small trees, and the possibility for a small tree to grow into the stand(see Wikberg 2004).

Heureka PlanWise software was also used to evaluate each of the scenarios (see Anon 2010). The growth-and-yield model was calibrated using inventory data from 2001 and 2009 collected in natural mountain birch stands (since the growth functions were based on tree growth observed in productive, mostly evenly aged forests, and thus were not suitable without calibration). To minimize effects of tree age, which had not been measured, the aging of trees was to some extent ignored by increasing tree age by just 0.5 years per five-year period. Subsequently, different growth functions were tested and the function presented by Söderberg (1986) was found to give the smallest residuals between observed and calculated growth data. The basal area growth, as predicted by Söderberg (1986), was reduced by 70 %.

An optimization problem was formulated and run for each scenario separately. Each scenario was set with individual targets for volume cut per time unit, and the optimization problem was formulated as a linear goal programming model as follows. The overall goal was to meet the harvest level in each time period. If a specified harvest level was not reached in all time periods, higher penalty weights were applied to deviations in early time periods than in later periods, thereby meeting the set targets for as long as possible. The penalty weight was increased by 10 percent for each five-year period, i.e. it was formulated as a discounting factor. In addition to the individual targets, we constrained fluctuations in cut volume between consecutive time periods by setting 10% limits for increases and 50% limits for reductions in cut volume between any time period and the following period.

References

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