Modelling the consequences of increased use of forest harvest residues for bioenergy production

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Background

There is an increasing demand for biomass energy as substitute to fossil fuels. The Norwegian government plans to double the production of bioenergy from 14 TWh (2009) to 28 TWh by 2020. A large part of this increase must come from the forest, which has the greatest potential in respect to biomass supply. The annual increment in Norwegian forests is increasing, whereas the harvest intensity has remained stable over hundred years (**Fig. 1**). It is economically feasible to utilize all the tree parts except stumps, the whole tree harvest (**WTH**), instead of conventional harvest (**CH**) where tree crowns, branches, leaves and needles are left on the ground. However, as these parts contain a large share of the tree's nutrients (**Fig. 2**), WTH may reduce the supply of nutrients and organic matter to the soil.

The Norwegian research project "Ecological consequences of increased biomass removal" **ECOBREM** (2008-2012) is investigating the ecological consequences of WTH compared to CH.

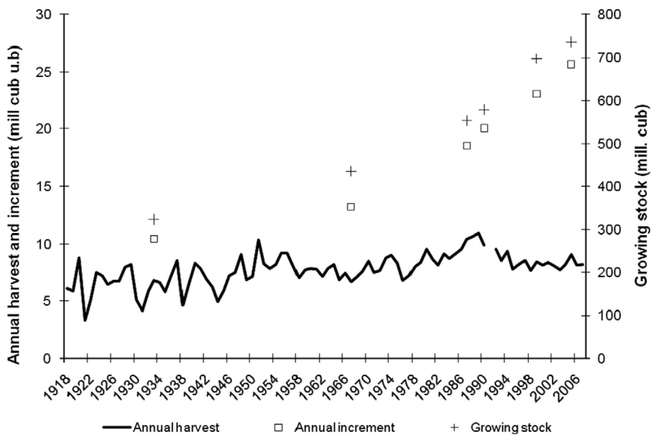


FIGURE 1 *Growing stock, annual harvest and increment in Norwegian forests* (Source: *Sjølie, H. K. et al. 2010*).

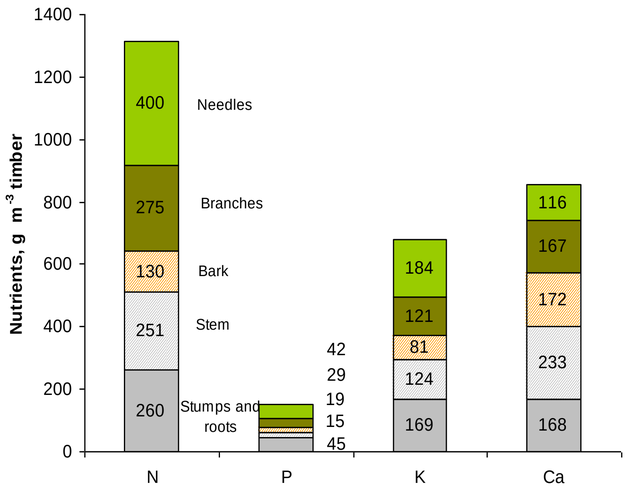


FIGURE 2 *Nutrient distribution in 45 year old Scots pine (Pinus sylvestris) stand* (Source: *Mälkönen 1976*).

Aims

To model the system behaviour under WTH, trying to identify key factors driving soil organic matter, nutrients, biomass, biodiversity of ground vegetation and others. Simulate the effect of WTH on the carbon and nitrogen budget in particular, compared to CH. The approach comprises statistical and time series analysis and process-oriented models.

Give recommendations for appropriate strategies, such as the percentage of residues that should be left in the system, and suitable regions (in Norway) where WTH may be sustainably performed.

Study sites and treatments

Two research sites were selected which represent two distinct landscape types with either Norway spruce (*Picea abies*) or Scots pine (*Pinus sylvestris*) stands. Two different treatment were used at each stand, CH or WTH, in addition to control plots without harvest.

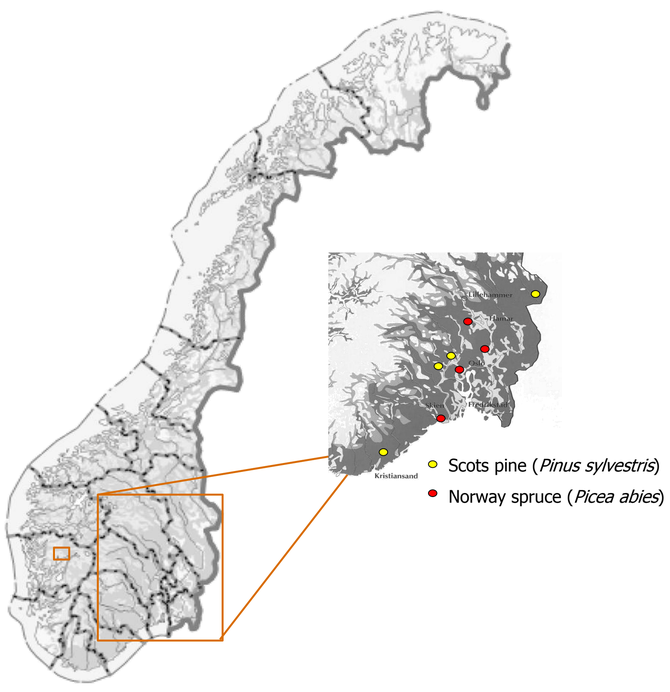


Figure 3 *Site in SE Norway established in 1972-1977 and site in SW Norway established in 2010.*

FIGURE 4 *Two different treatments, CH (left) and WTH (right)* (Photos: *Kjersti Holt-Hanssen*).

Methods

Generalized Additive Models (GAM) are flexible tools to relate a response variable to several predictors (continuous or categorical). The canonical equation is

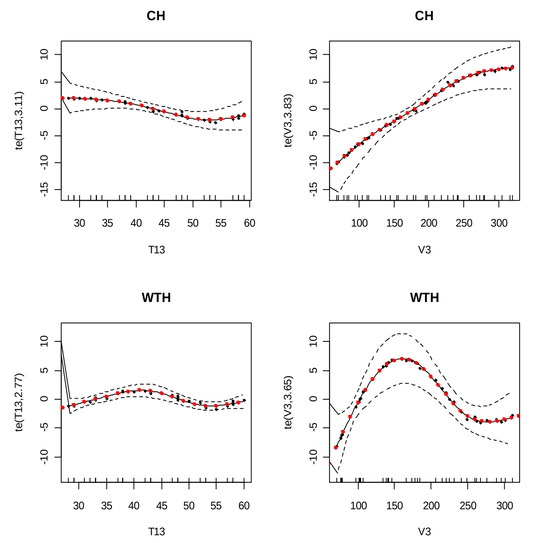
$$y = \beta_0 + \sum_{i=1}^{n} f_i(x_i) + \varepsilon$$

where $f_i(x_i)$ are response functions (piecewise smooth interpolation objects) optimized by the model itself.
In this work, we are relating volume increment to stand variables such as breast height, diameter or basal area

Results

Table 1 *Volume increment modelled by a GAM. * indicates response variables included in the model for CH and WTH. Number of * represent strength of significance.*

Treatment	Year	T13	HO	H1	D1	G1	VT	V3
CH	*	*	*	-	-	**	-	***
WTH	**	**	**	-	-	-	-	**



T13: Breast height (130 cm)

V3: Standing living volume

Figure 4 *Two of the response functions for the two treatments CH and WTH. Red dots are smoothing points.*

Conclusions

Drivers for volume increment over 30 years were determined. The preliminary study shows that there are differences between CH and WTH in two directions: both the significance of drivers and the shapes of the response functions are different. GAM turns out to be a flexible tool superior to multivariate linear regression. Further investigations will include nutrient concentrations and other response variables as well.

References:

Mälkönen, E. 1976. Effect of whole-tree harvesting on soil fertility. Silva Fenn. 10:157–164.

Sjølie, H. K. et al. (2010) Effects and costs of policies to increase bioenergy use and reduce GHG emissions from heating in Norway. Forest Policy and Economics 12, 57–66.