Airborne Laser Scanning and Gamma Ray Data in Wood Procurement Planning of Peatlands

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Forwarder week ago at work

Class 1 ≤ 50 kPa **Class 2 ≤ 40 kPa** **Class 3 ≤ 30 kPa**

Introduction

Class 1	Class 2	Class 3
• 12 t: in front the chains and in rear ≥700 mm wide tracks. • 17 t: in front and in rear ≥700 mm wide tracks.	• 12 t: in front the chains and in rear ≥750 mm wide tracks. • 17 t: in front and in rear ≥870 mm wide tracks.	• 12 t: in front ≥700 mm wide tracks and in rear ≥700 mm wide tracks with extra axle. • 17 t: in front ≥820 mm wide tracks and in rear ≥820 mm wide tracks with extra axle.

Initial tree volume, $m^3\ ha^{-1}$	Estimated load on strip road network based on the storage, shape and size of harvesting site *), **)		
	Low	Moderate	High
	Carrying capacity class of forwarder		
>170	1	2	3
170–120	2	3	WINTER
<120	3	WINTER	WINTER

Patches for the classes:

- Depth to the groundwater table:

• If the groundwater table is less than 25 cm depth in the swamp's surface, the carrying capacity will decrease by one grade.

• If the harvesting operation has been preceded by a dry season which has lasted for more than 4 weeks, the carrying capacity will increase by one grade.

- If the thickness of peat layer is less than 75 cm, the carrying capacity will increase by one grade.

- Timber haulage in forest

*) Average forest haulage distance on peatland: low <100 m, moderate 100–200 m, and high > 200 m.

* *) It is assumed that logging residues are cut to strip roads and small-sized and critical points on strip road network shall be reinforced by logging residues or in any other way.

Introduction

- The rut formation was interpreted as more than 10 cm deep and more than 50 cm long ruts if it was on one of tracks.
- The percentage of rut formation was calculated by means of the length of rut formation according to the guidelines of harvesting result in thinnings (2003) drawn up Metsäteho.
- The deepest rut point (i.e. maximum rut depth) on the tracks in the study stand was measured.

Aim of the study

Since an operational impact of GIS applications depends finally on their reliability to describe harvesting conditions for peatland thinnings, our study examined what factors contributed to rut formation and could be modelled to support wood procurement planning. When planning wood harvesting operations, it is crucial to know should a stand be selected for summertime or wintertime harvesting. For this purpose, we evaluated one explanatory regression model of rut formation in summertime thinnings. During this process we analyzed the benefits that the ALS and Gamma Ray Data may offer in wood procurement planning, highlighting their potential to replace field measurements.

The number of the study plots (N) of geographical information.

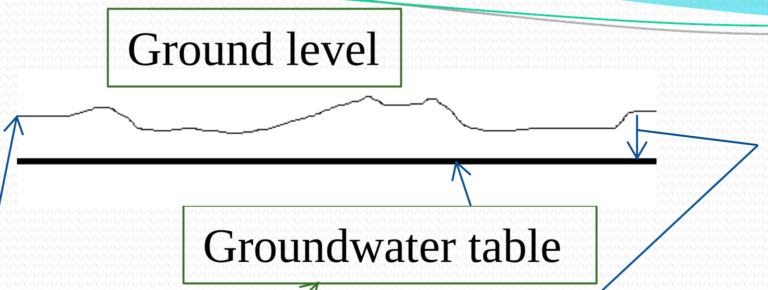
Data source	N
Raster of the length of the stand	96
Density raster	85
Potassium raster	179
General soil map (1:200,000)	240
Height raster (2×2 m)	96
Height raster (25×25 m)	144

Machinery

Table 3. The model and the number of wheels used in harvesting machinery of the study, as wells as the number of plots in the study. Type: H = Harvester; F = Forwarder; HF = Two-machine system.

Machine unit	Type	Wheel, N	Plot, N
John Deere 1070D	H	6	77
Ponsse Beaver	H	6	14
Ponsse HS10	H	8	124
John Deere 1010D	F	8	14
John Deere 810D	F	8	57
Ponsse Elk	F	8	6
Ponsse S10	F	8	100
Ponsse Wisent	F	8	14
Ponsse Gazelle	HF	8	62
Valmet 840 + pulling trailer	F	12	24

Results



The correlations (C) between the rut formation and independent variables. (* = statistically almost meaningful ($p \leq 0.05$), (** = statistically meaningful ($p \leq 0.01$), (*** = statistically very meaningful ($p \leq 0.001$), Rmax = maximum rut depth, R% = rut formation percentage, N= number of observations.

	Thickness of peat layer		Height raster (2×2 m)		Depth to groundwater table		Density of tree volume		Height of stand		Forest haulage distance		Potassium	
	Rmax	R%	Rmax	R%	Rmax	R%	Rmax	R%	Rmax	R%	Rmax	R%	Rmax	R%
C	.32 (***	.40 (***	-.34 (**	-.28 (**	-.44 (***	-.33 (***	-.26 (*	-.29 (**	.32 (**	.29 (**	.30 (**	.28 (**	-.20	-.29 (*
N	115	115	96	96	113	113	85	85	96	96	115	115	54	54

-From GIS variables, The height raster, The height of stand, Potassium and The density value of laser scanner that reflected back from vegetation were statistically significant variables.
-On the basis of the findings measured, the height raster correlated with the groundwater table and was combined with it (new variable is The depth to groundwater table).
-The variables in blue boxes were statistically selected for the maximum rut depth model.

Results

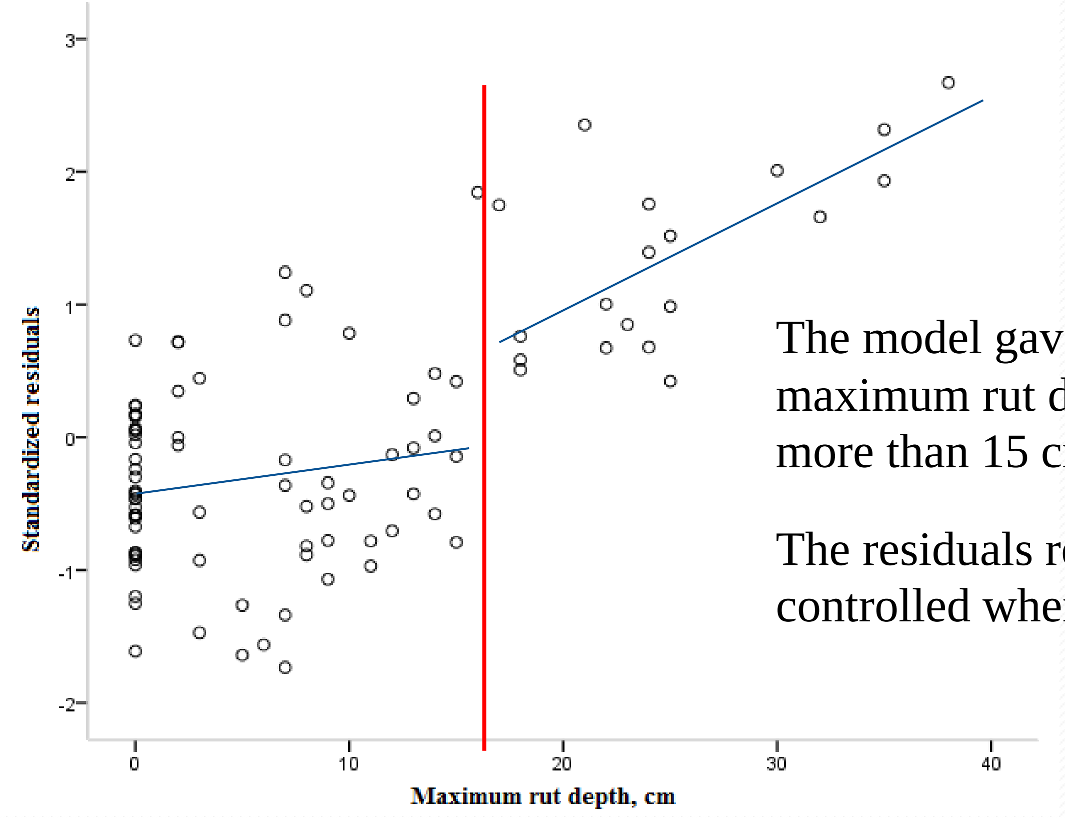
An explanatory model for the maximum rut depth of strip road network.

$y = a + b_1k_1 + b_2x_1 + b_3x_2 + b_4x_3$

where
y = maximum rut depth, cm
k_1 = dummy variable: 1 = harwarder, 2 = two-machine system (i.e. harvester & forwarder)
x_1 = thickness of peat layer, cm
x_2 = forest haulage distance, m
x_3 = depth to the groundwater table, cm
a = constant
b_1, b_2, b_3, b_4 = coefficients of the variables

Variable	Parameter estimate	Standard error	Standardized regression coefficient	t value	p value
a	-10.047	3.252		-3.089	.003
b_1	9.250	1.690	0.472	5.474	.000
b_2	0.121	0.029	0.306	4.212	.000
b_3	0.031	0.015	0.156	2.046	.044
b_4	-3.040	1.553	-0.166	-1.958	.053
N	R	R^2	Adjusted R^2	Mean error of estimate	Kolmogorov-Smirnov
95	.731	.535	.514	6.863	.049
	Sum of squares	Degree of freedom	Mean square	F value	p value
Regression	4866.911	4	1216.728	25.836	.000
Residual	4238.520	90	47.095		
Total	9105.432	94			

Results



The model gave too high values, while the maximum rut depth of strip road network was more than 15 cm.

The residuals reveal that the rut depth can be controlled when it is under 15 cm.

Figure 2. The residuals of the regression model of maximum rut depth.

Discussion

The best explanation degree of the regression model was $\boxed{51.4\%.}$

From the perspective of operational planning of harvesting operations, the model was able to describe the rut formation up to the maximum depth of 15 cm with a sufficient degree of certainty, even if the residuals of the model range were quite large.

The linearity of the residual variation can contribute to be due to this reason, although the most likely reason is the difficulty of measuring the maximum rut depth in deep ruts.

In deep ruts the results exceeds the criterion value (<10 cm) permitted by law. Hence the model works with a sufficient degree of certainty in an acceptable operating range of harvesting on peatlands.

Conclusions

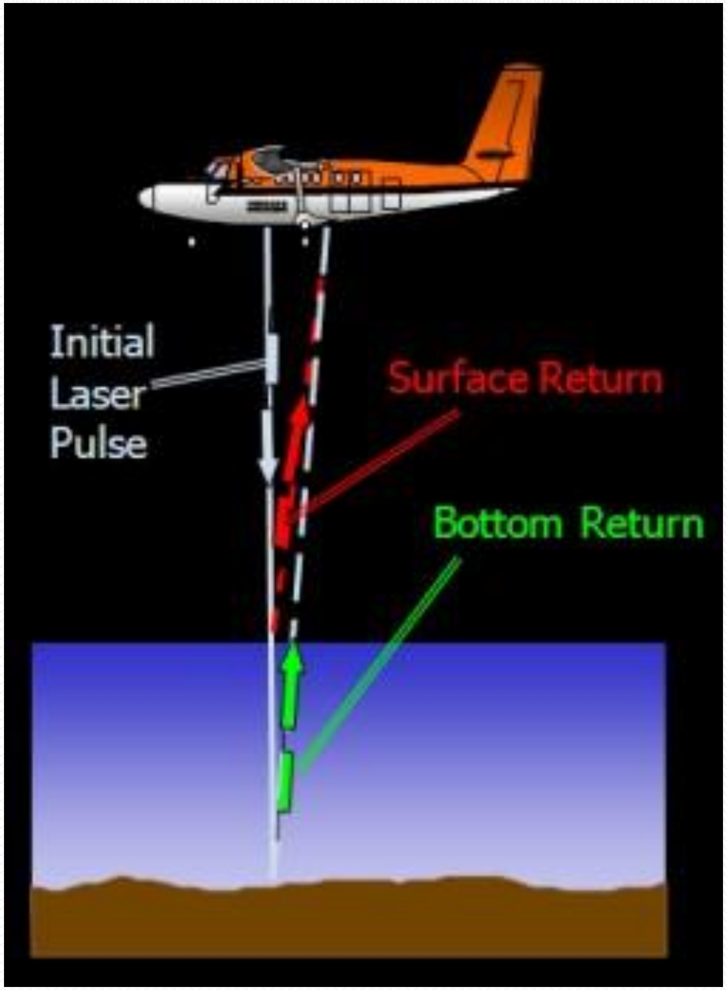
Little statistical evidence has so far emerged to show that the GIS can be used in operational planning of peatland thinnings. In this study, the variables that described a spatial variation in the stands, were tried to include the rut depth model. On the basis of the correlation analysis, The tree height raster, The ground height raster, Potassium and Density value of ALS that reflected back from vegetation would have been statistically significant variables. However, on the basis of the findings measured in regression analysis, the model drawn up from these variables had a lower explanation degree than that of the model presented in this study. Our model can be used for selection of stands for summertime wood harvesting, in which the maximum rut depth is less than or equal to 10 cm. On the basis of this criterion, 33 study plots located in such stands, which should have been harvested during wintertime.

In presented model the ground height raster was combined with the groundwater variable.

Suggestions for future research

Bathymetric LiDAR

Bathymetric LiDAR needs more explanation. This hybrid LiDAR system uses both green and infra-red laser. While the infra-red beam reflects from the water, the green penetrates through the bottom of the ditch. As a result, the topography of the ditch network and the water level can be mapped from the same measurement. Bathymetric LiDAR is capable of measuring a parameter for modelling a groundwater table. Then ALS (ground height model) can be used automatically for calculating depth to the groundwater table.



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Many Thanks!