Līdz šim izmantoto tehnoloģiju un metožu priekšrocību un trūkumu novērtējums izmēģinājumu stādījumos un sējumos, kas ierīkoti marginālas platībās augsni ielabojot ar organiskas izcelsmes ielabošanas līdzekļiem

Evaluation of technologies and an assessment of the advantages and disadvantages of methods currently used in plantations on marginal lands where soil has been enriched with organic source amendments



2.1 Iepriekš ierīkotajos izmēģinājumu objektos ierīkoto koku stādījumu un sējumu biomasas un saglabāšanās uzmērījumi

2.1. Evaluation of tree and crop growth and survival in previously established experimental study sites

Salaspils 2023



Authors

Kristaps Makovskis – project leader, responsible for measurements, data analysis

Kārlis Dūmiņš – field works

Toms Arturs Štāls - field works

Dagnija Lazdiņa – idea and concept

**Materiāls angļu valodā sagatavots analizējot LVMI Silava 2011-2023.gadā ierīkotā izmēģinājumu objektā Skrīveru novadā , “Pardenči” iegūtos datus īstenojot pētījumu: Inovatīvu Baltā vītola-daudzgadīgo zālaugu agromežsaimniecības sistēmu ierīkošana ar koksnes pelnu un mazāk pieprasīto kūdras frakciju maisījumiem ielabotās marginālās minerālaugsnēs**

Programma "Izaugsme un nodarbinātība" specifiskais atbalsta mērķis 1.1.1. "Palielināt Latvijas zinātnisko institūciju pētniecisko un inovatīvo kapacitāti un spēju piesaistīt ārējo finansējumu, ieguldot cilvēkresursos un infrastruktūrā"  
pasākums 1.1.1.1. "Praktiskas ievirzes pētījumi", 3. kārta Nr. 1.1.1.1/19/A/112

Skriveri site description

Study site and measurements

Evaluation of tree survival and growth was done in Skriveri experimental site, where hybrid aspen (*Populus tremuloides* Michx. x *Populus tremula* L.), silver birch (*Betula pendula* Roth), grey alder (*Alnus incana* (L.)), black alder (*Alnus glutinosa* (L.)) and hybrid alder (*Alnus hybrida* A. Br) seedling were planted (Table 1). Site is located in Skriveri district in the eastern part of Latvia (56.6907511598531, 25.137236340170375). Site was established on 2011, where agroforestry management system was established on former agriculture land.

**Table 1 Tree species planted in Skriveri site in 2011**

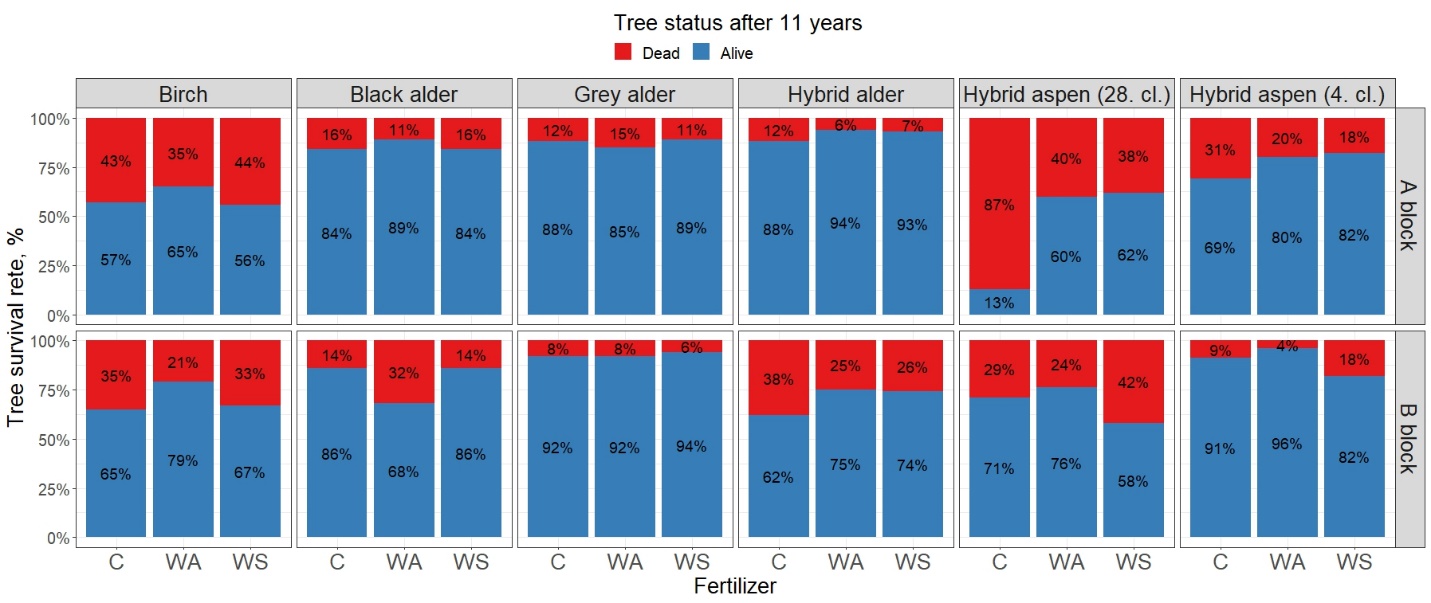
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| **Tree species in Skriveri site** | **Trees in one subplot (planted in 2011)** | **Planting density, (planted in 2011), trees ha-1** | **Planting scheme (m)** |
| Hybrid alder (*Alnus hybrida* A. Br) | 72 trees (8 lines with 9 trees in every line) | 1600 | 2.5 x 2.5 m |
| Black alder (*Alnus glutinosa* (L.)) |
| Grey alder (*Alnus incana* (L.)) |
| Silver birch (*Betula pendula* Roth.) |
| Hybrid aspen clone no. 28 (*Populus* *tremuloides* Michx. x *Populus tremula* L.) | 55 trees (5 lines with 11 trees in every line) | 2500 | 2.0 x 2.0 m |
| Hybrid aspen clone no. 4 (*Populus tremuloides* Michx. x *Populus tremula* L.) |

Three distinct soil fertilization techniques were examined and contrasted. The first technique involved no fertilization, serving as a control. The second technique used wood ash for initial fertilization, which is rich in various minerals. The third technique used wastewater sludge for initial fertilization, which is abundant in organic nitrogen, phosphorus, and carbon, along with a range of other elements. The soil was only fertilized once in 2011, with no subsequent fertilization. Tractors and agricultural spreaders were used to mechanically apply the fertilizers. Wood ash dosage was 6 t DM ha-1 and wastewater sludge 10 t DM ha-1. Each tree species and each fertilizer had two repetitions, and each subplot spanned an area of 0.044 ha (20 x 22 m).

In 2022 trees were measured used a tree caliper to measure the diameter of tree trunks at breast height (referred to as DBH). Each tree trunk was measured in two directions, both north-south and east-west, and the average value of these measurements was used in calculations. Trees with a DBH less than 6.00 cm were categorized as shoots. In the same year, we determined the height of the trees using a DBH-height curve that was specifically fitted for each subplot, based on measurements of the height of five sample trees within each subplot. All measured trees were planted in 2 repetitions – A and B block.

Tree survival

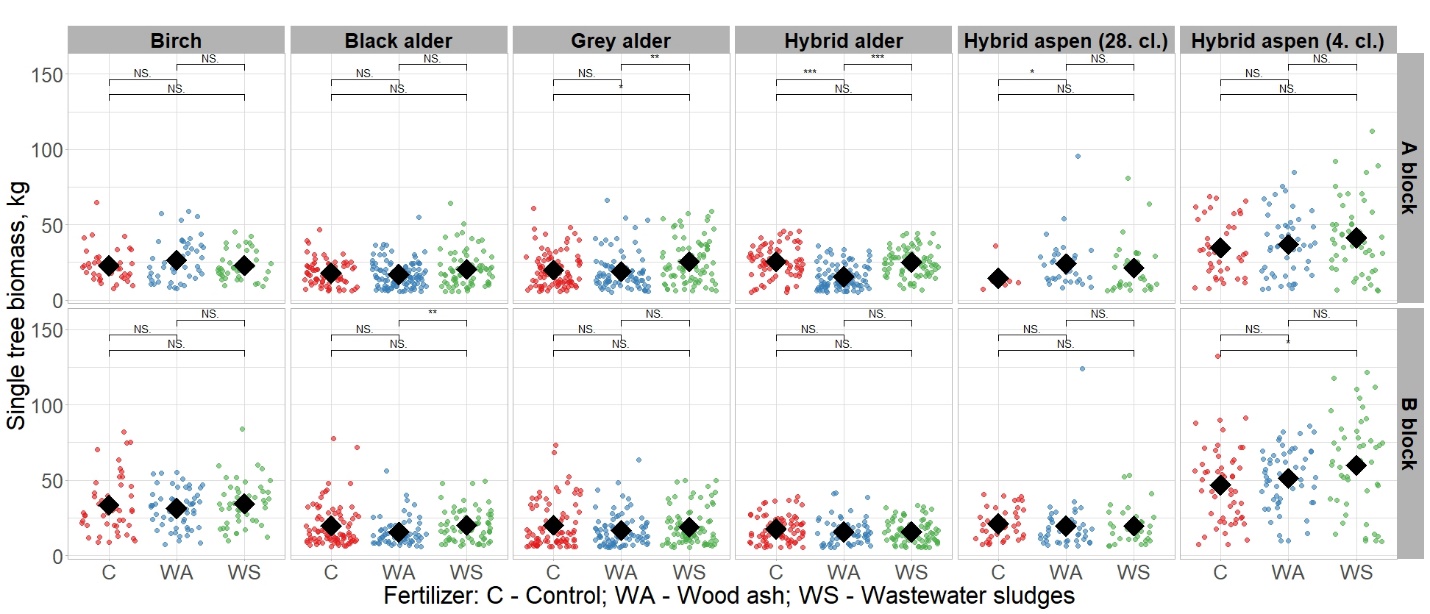
In 2011, all trees were planted and then assessed 11 years later. A single tree seedling was placed in each planting location. Trees were counted as alive if their diameter at breast height (DBH) exceeded 5.99 cm, otherwise, they were categorized as shoots and omitted from the dataset. Notably, the most favorable survival rates were observed in grey alders, ranging from 88% to 94% (Figure 1). Conversely, the tree survival rate was lowest in hybrid aspen no. 28 clone sampling plots, where it ranged from 13% to 76%. Across all tree species, the average survival rate in control plots was 72% (ranging from 13% to 92%) in wood ash plots was 80% (ranging from 60% to 99%) in wastewater sludge plots was 77% (ranging from 56% to 94%). Remarkably, the lowest survival rate was identified in the control plots for hybrid aspen no. 28 clone at 13%, while the highest was observed in the wood ash plots for hybrid alder, reaching 94%.



**Figure 1.** The survival rate of different tree species in 11-year-old plantations. Fertilizers: C=control; WA=wood ash; WS=wastewater sludge. Trees with DBH< 6 cm were excluded from the dataset.

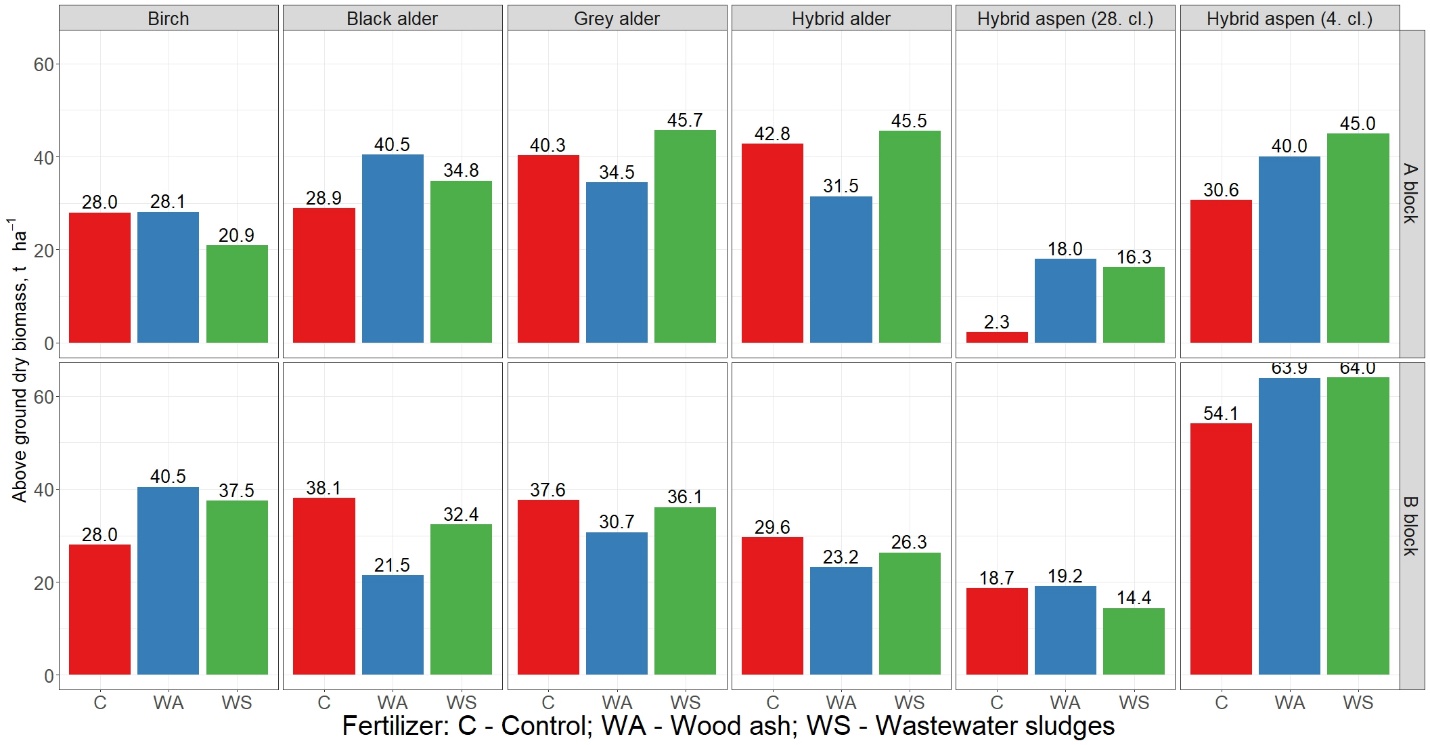
Tree biomass

The data reveals variations in the average above-ground biomass (AGB) of individual trees among different tree species and treatments (Figure 2). At the age of 11 years, there were no statistically significant differences observed between birch trees in control and fertilized plots. Specifically, the mean tree biomass under the control treatment was 28.49kg, under the wood ash treatment, it was 29.03kg, and under the wastewater sludge treatment, it was 29.19 kg. For black alder, no significant differences were found between the control and fertilized plots. The mean tree biomass under the control treatment was 18.89 kg, while under the wood ash treatment, it was 16.42 kg, and under the wastewater sludge treatment, it was 20.11 kg. Similarly, in the case of grey alder, there were no significant differences between the control and fertilized plots. The mean tree biomass under the control treatment was 20.06 kg, under the wood ash treatment, it was 17.82 kg, and under the wastewater sludge treatment, it was 22.09 kg. For hybrid alder, there was no significant difference between the mean tree biomass under the control treatment with 21.52 kg and the wastewater sludge treatment with 20.54 kg. However, a highly significant difference was observed between the control treatment and the wood ash treatment, with a mean biomass of 15.52 kg. In the case of hybrid aspen clone no. 28, no significant difference was found between the mean biomass of trees in the control and fertilized plots. The mean tree biomass under the control treatment was 20.07 kg, under the wood ash treatment, it was 21.55 kg and under the wastewater sludge treatment, it was 20.42 kg. For hybrid aspen clone no. 4, no significant difference was observed between the mean tree biomass under the control treatment was 41.43 kg and the wood ash treatment it was 44.42 kg. However, there was a significant difference between the mean biomass under the control treatment and the wastewater sludge treatment, with a mean of 50.50 kg.



**Figure 2.** Single tree AGB in 11-year-old plantations of birch, hybrid aspen, hybrid alder, black alder, and grey alder with different fertilizers. Fertilizers: C=control; WA=wood ash; WS=wastewater sludge. Significance levels \*\*\* (<0.001), \*\* (0.001–0.01), \* (0.01-0.05), and NS (Not Significant) show the results of the Wilcoxon test between fertilizers. Trees with DBH< 6 cm were excluded from dataset.

Average AGB for birch was 30.5 t ha-1, where in control it was 28.0 t ha-1, in wood ash 34.3 t ha-1 and in wastewater sludge 29.2 t ha-1 (Figure 3). Average AGB for black alder was 32.7 t ha-1, where in control it was 33.5 t ha-1, in wood ash 31.0 t ha-1 and in wastewater sludge 33.6 t ha-1. Average AGB for grey alder was 37.5 t ha-1, where in control it was 39.0 t ha-1, in wood ash 32.6 t ha-1 and in wastewater sludge 40.9 t ha-1. Average AGB for hybrid alder was 33.2 t ha-1, where in control it was 36.2 t ha-1, in wood ash 27.3 t ha-1 and in wastewater sludge 35.9 t ha-1. Average AGB for hybrid alder (28. Clone) was 14.8 t ha-1, where in control it was 10.5 t ha-1, in wood ash 18.6 t ha-1 and in wastewater sludge 15.3 t ha-1. Average AGB for hybrid alder (4. Clone) was 49.6 t ha-1, where in control it was 42.4 t ha-1, in wood ash 52.0 t ha-1 and in wastewater sludge 54.5 t ha-1. The biggest calculated AGB was in hybrid aspen (clone 4) B block sampling plot with wastewater sludge fertilization with 64.0 t ha-1 and the lowest in hybrid aspen (clone 28) A block sampling plot in control with 2.3 t ha-1



**Figure 3.** The total above-ground biomass of different tree species per hectare in 11-year-old plantations. Fertilizers: C=control; WA=wood ash; WS=wastewater sludge. Trees with DBH< 6 cm were excluded from the dataset.

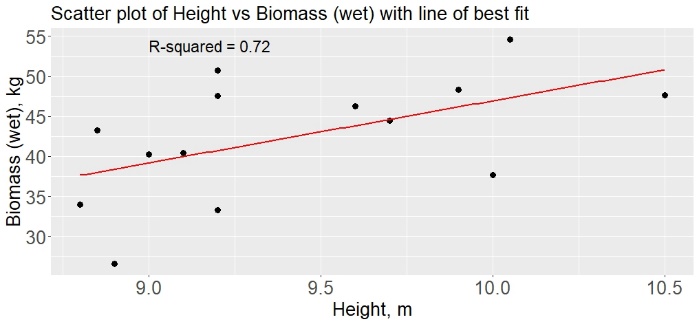
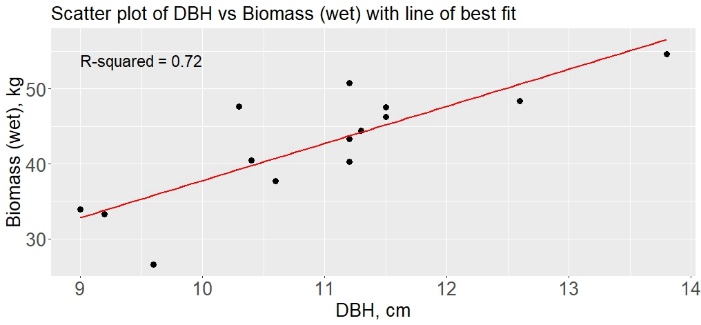
Hybrid alder above ground biomass calculations based on DBH and height

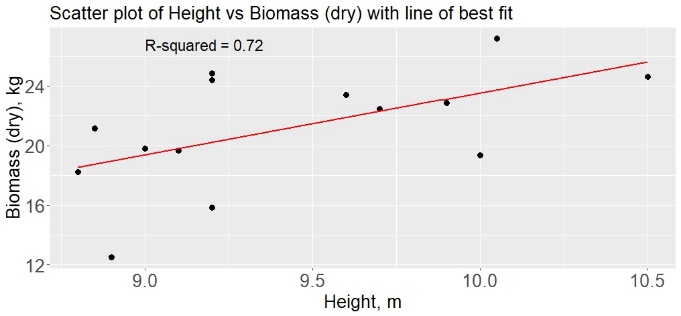
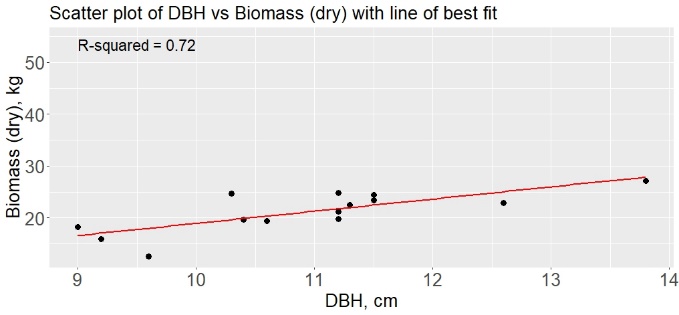
In this study, a linear regression model was developed to predict the above ground biomass of hybrid alder trees based on two independent variables: the diameter at breast height (DBH) and the height of the tree. In Latvia biomass yield models for other tree species like birch, aspen, black alder and grey alder was done before by other authors (Liepiņš et al., 2018, 2021). However, hybrid alder biomass models from DBH and tree height was firstly done in this project. Biomass was determinated for planted and not for naturally ingrown hybrid alder trees, because, all tress in the site were planted and natural ingrown was not observed in the site. In the study 14 hybrid alder trees were cut down and dry branches, green branches and tree trunk were weighted for biomass and later dried to determine moisture. Moisture levels were on average 50.2% (46.3-52.9%) (Figure 4)



**Figure 5.** Hybrid alder plantation and drying of wooden logs to determine moisture.

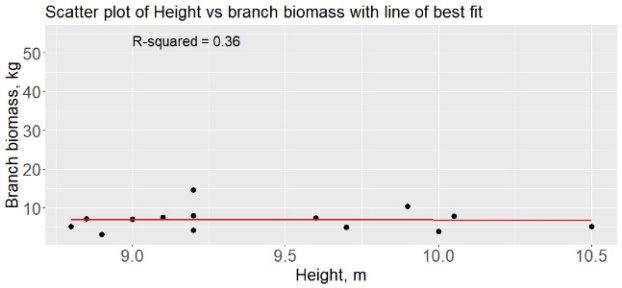
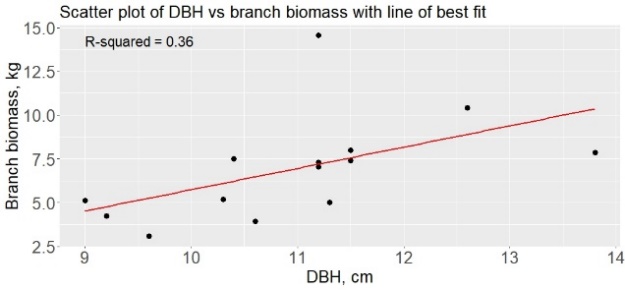
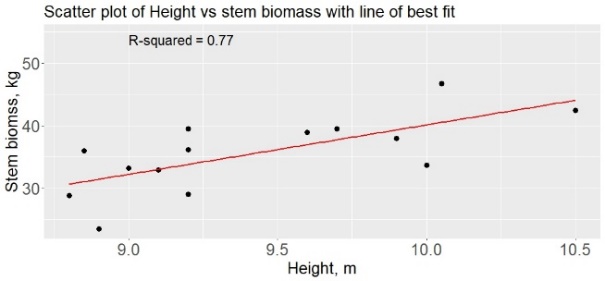
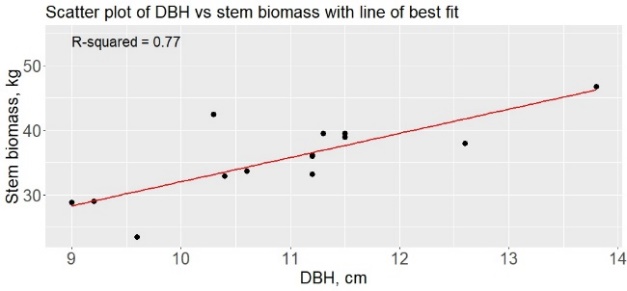
The linear regression model was fitted using the lm() function, with Biomass as the dependent variable and DBH and Height as independent variables. The R-squared value obtained from the model summary is a measure of how well the model fits the data. It represents the proportion of variance in the dependent variable (Biomass) that can be explained by the independent variables (DBH and Height). Scatter plots were created to visualize the relationship between Biomass and each of the independent variables (DBH and Height) (Figure 5).



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**Figure 5.** Linear regression model for predicting hybrid alder above ground biomass green and dried

Each plot includes a line of best fit based on the linear regression model, as well as an annotation displaying the R-squared value. The plots show that there is a positive relationship between both DBH and Height and Biomass, as indicated by the upward slope of the lines of best fit. This model can be used to estimate the biomass of hybrid alder trees based on measurements of DBH and Height. By inputting these measurements into the model, one can obtain an estimate of Biomass. This can be particularly useful in forestry management practices where accurate estimates of tree biomass are needed. When stem (wet) and branch (wet) biomass prediction was done, better results showed stem biomass and weaker branch biomass (Figure 6).



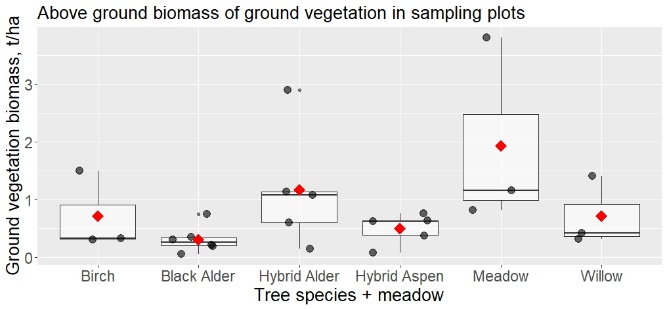
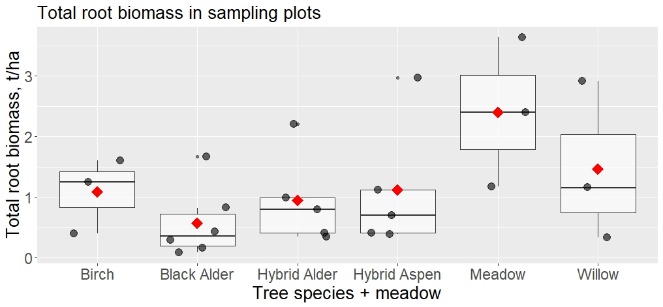
**Figure 6.** Linear regression model for predicting hybrid alder stem and branch biomass.

Total root biomass, above ground biomass of vegetation and above ground tree litter

Single tree roots were not measured, because the plantation will be harvested in 2025 and then all trees will be cut down. Instead of single tree root biomass measurements, total root biomass, above-ground biomass of ground vegetation and tree above-ground litter was measured. In addition to previously reported tree species, data were collected also in willow stand (13 000 stems per ha-1) and in meadow, where in the first-year reed canary grass was grown.

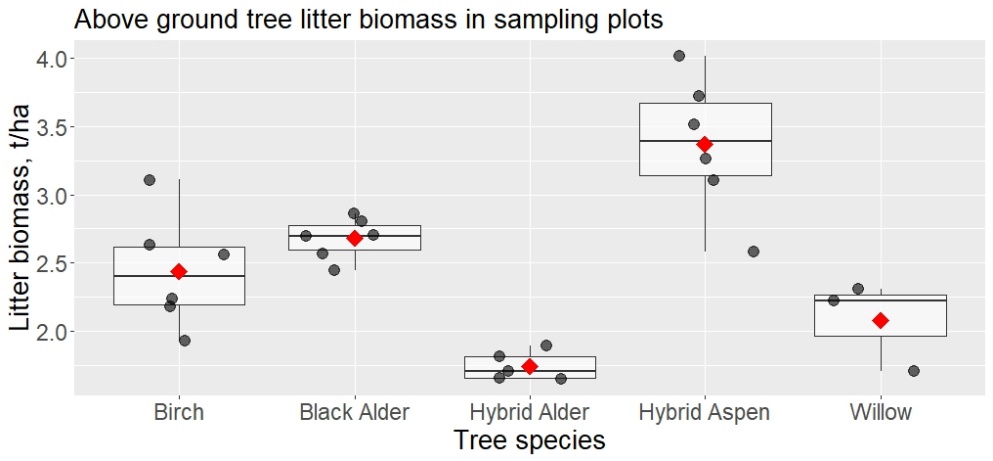
In each of the research subplots, with birch, black alder, hybrid alder, hybrid aspen, willows and meadow (in 1st. Year Reed Canary grass was grown) we conducted assessments of both the above-ground biomass of ground vegetation and the total root biomass. Within each 25 × 25 cm square sample plot, all above-ground components of ground vegetation were systematically removed using a sharp knife and placed into sealed plastic bags. Furthermore, all the roots within the same 25 × 25 cm sample plots were excavated to a depth of 30 cm, cleaned of soil, and stored in sealed plastic bags. These samples were then transported to the laboratory at LSFRI Silava for further analysis. To determine their dried mass, the vegetation biomass and roots underwent a drying process in drying chambers set at 105 °C.

Average total root biomass in birch stand was 1.08 t ha-1, in black alder stand 0.58 t ha-1, in hybrid alder 0.95 t ha-1, in hybrid aspen 1.11 t ha-1, in meadow 2.40 t ha-1 and in willow 1.46 t ha-1. Average above ground biomass of ground vegetation in birch stand was 0.71 t ha-1, in black alder stand 0.31 t ha-1, in hybrid alder 1.17 t ha-1, in hybrid aspen 0.50 t ha-1, in meadow 1.93 t ha-1 and in willow 0.71 t ha-1 (Figure 7).



**Figure 7.** Total root biomass and above-ground biomass of ground vegetation in sampling plots

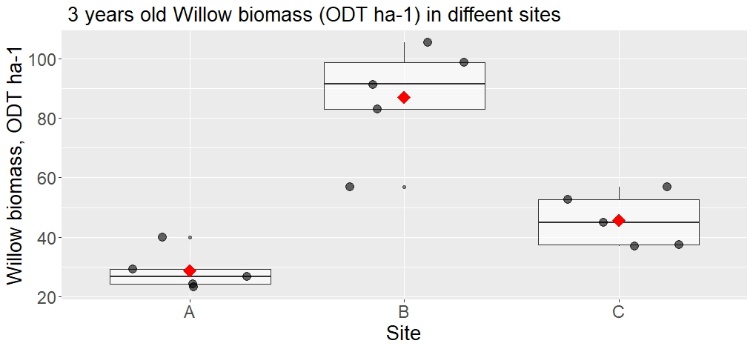
Between September and December in 2021 tree above-ground litter within each research subplot was collected. For this purpose, collectors were positioned beneath a uniform tree canopy at a height of 1.3 meters These collectors were constructed with a solid funnel extending to a depth of 0.5 meters, accompanied by a bag made of inert material (polyethylene) featuring a mesh size of 0.2 mm. The collecting area of each individual trap was 0.43 m². Average above ground tree lotter biomass in birch stand was 2.44 t ha-1, in black alder stand 2.68 t ha-1, in hybrid alder 1.74 t ha-1, in hybrid aspen 3.37 t ha-1 and in willow 2.08 t ha-1 (Figure 8).



**Figure 8.** Above-ground tree litter biomass in sampling plots

Willow biomass calculations

During the project, willow biomass parameters were measured in 3 different places in every place 5 sampling plots (size 25m2) were established. Willow plantation was 3 years old, Inger clone was planted and planting density was 13 000 seedlings ha-1. In every sampling plot willow DBH and height was measured. From the tree samples moisture and density was also measured. Willow plantation biomass (dry) measurement are in Figure 9.



**Figure 9.** Willow biomass in 3 years old plantation

Average biomass yields were highly variable in all sites. In site A the average calculated biomass yield was 28.57 ODT ha-1 (23.05 – 39.84 ODT ha-1), in site B 87.17 ODT ha-1 (56.96 – 105.53 ODT ha-1) and site C 45.73 ODT ha-1 (32.15 – 49,39 ODT ha-1).

References

Liepiņš, J., Lazdiņš, A., & Liepiņš, K. (2018). Equations for estimating above- and belowground biomass of Norway spruce, Scots pine, birch spp. and European aspen in Latvia. *Scandinavian Journal of Forest Research*, *33*(1), 58–70. https://doi.org/10.1080/02827581.2017.1337923

Liepiņš, J., Liepiņš, K., & Lazdiņš, A. (2021). Equations for estimating the above- and belowground biomass of grey alder (Alnus incana (L.) Moench.) and common alder (Alnus glutinosa L.) in Latvia. *Scandinavian Journal of Forest Research*, *36*(5), 389–400. https://doi.org/10.1080/02827581.2021.1937696