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FOREST REGENERATION QUALITY ASSESSMENT BY ASTA SYSTEM

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In Latvia one third of the total forest area is regenerated by planting tree seedlings and therefore it is important to choose the appropriate soil preparation method and the right type of regeneration material for each forest type. Usually the success of afforestation is evaluated by how high is the average seedling survival rate and growth parameters like height, annual increment, diameter at breast height while the location of the seedling is disregarded. This may be of great importance since in such stands the environmental conditions typically are not entirely homogenous. Micro topography differences impact seedling growth, because it modifies water regime, temperature, micronutrient availability, sun radiation and other factors.
Therefore, aim of this work is to improve monitoring methods and determine the most efficient soil preparation and seedling preparation combination to improve the quality of forest regeneration. That could be done using ASTA documentation system originally developed to show seedling and mound location and density in planting area during mechanic planting. But it also allows to link the precise location of the seedling and growing conditions with its growing rate and survival and therefore it is easier to exclude seedlings that are affected by other factors than those that you are interested in, so you can gain more representative results. This also could be used in forest management. When using ASTA system it is also possible to display how different tree disease are distributed in the stand, if they have spread eventually or localized only in some parts of the stand, also it can be used for browsing and other tree damage monitoring in the stand.
In conclusion: in harsh environmental conditions on unprepared forest soil and soil prepared in furrows made by disc trench larger seedlings show better survival rate. Survival of seedlings is significantly impacted by micro topography, whereas mounded micro sites equalize local environmental conditions that reduce impact of micro topography.

Keywords: forest regeneration, ASTA system

INTRODUCTION

Proper forest regeneration is a key element for successful, sustainable and economically viable forest management and in boreal regions regeneration of coniferous species is crucial for sustainable forest management (Pouliot et al., 2002).

Forest regeneration methods over time have been changing. In Latvia natural regeneration generally was used before 20. century, but in 20's foresters came to conclusion that under certain circumstances natural regeneration is ineffective, and there is need to use artificial methods: sowing and planting, and one of the main precondition for successful forest regenerations is proper soil preparation (Kundziņš, 1939). Soil preparation is one of key elements in reforestation of clearcut areas, because it results in larger ecosystem C stocks than the control treatment due to the positive effects on the carbon storage by tree biomass. It has been found that tree C stock is the highest after ploughing, intermediate after mounding or disc trenching and the lowest in untreated control plots at all experimental sites. Finish forest scientists recommend mounding or disc trenching to promote C sequestration as they disturb sites' ecological, aesthetic and recreational values less than ploughing (Mjöfors et al., 2017).

Mounded planting spots are more fertile than untreated soil, because of double hummus layer, in previous seedling growing improvement project we found that even in mined areas by adding the lacking nutrients it is possible to successfully regenerate a forest (Lazdina et all., 2017. a, b).

Planting in furrows made by disc trenching nowadays is the main artificial forest regeneration method in Latvia (Research report, 2012). Site mounding method is effective and becomes more popular especially in *Myrtilloso – sphagnosa* and *Myrtillosa turf.me* forest type, where pit collects the excessive water (Lazdina et al., 2015). Service of mounding is new in Latvia and offered mostly by small and medium enterprises (SMEs), economists often remind that SMEs are the backbone of national economic, but they face many barriers and constraints towards innovations, particularly eco-innovations. In the European Union (EU) eco-innovations had been recognized as an important contributor for sustainable and green growth (Melece and Hazners, 2017).

The outlay of forest regeneration includes soil preparation, price of seedlings and labour force for planting and monitoring. One of the parameters assessing how successful forest regeneration has happened is the seedling survival rate that depends on various factors such as used soil preparation method, forest type, intensity of browsing, planting method, selected tree species, microrelief of planting pit, field vegetation, diseases and others (Klavina 2013., Hille and Den Ouden 2004., Kuuluvainen et al., 1993).

Coniferous forest regeneration in Latvia is accepted as successful if there is 2100* ha^{-1} *Picea abies* seedlings or 3200*ha^{-1} *Pinus sylvestris* seedlings. In case of significant amount of seedling dieback, there must be replenishment that causes additional costs. Relevant damage in early forest development stage leads to financial losses in future and therefore monitoring in the first years after planting is very important.

The classical method for estimating the quality of regeneration is to use a 25 m^2 dimensional sample plots and then extrapolate obtained results for the entire stand (Cabinet Regulation No. 152). Although this method saves time thus financial resources, it is not as precise since the selected plots may not be representative for the whole stand. Only the approximate number of damaged or drop out trees in the stand or in one hectare can be calculated and this method does not provide information about the damage distribution in the stand. Other alternative is to observe every seedling in the regenerated stand, so you gain precise result of the drop out and damaged trees. That could be done by using ASTA documentation system originally developed to show seedling and mound location and density in planting area during mechanic planting. It also allows to link the precise location of the seedling and growing conditions with its growing and survival rate. Using ASTA system it is also possible to display how different tree diseases are distributed in stand, if it is spread eventually or only locally in some spots in the stand, also it can be used for browsing and other tree damage monitoring in the stand for better assessment of forest regeneration quality.

The aim of this study was to analyse the difference between sample plot and ASTA system methods in assessment of forest regeneration.

MATERIAL AND METHODS

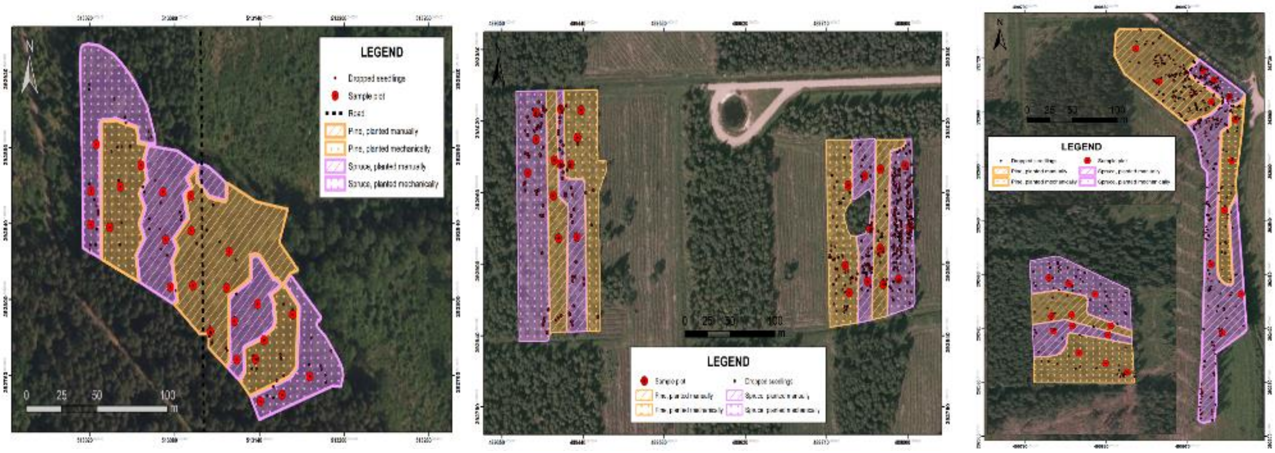
Study site

The study was done at six young stand sites, which were reforested in the spring of 2017 at central part of Latvia. Due to the difference between locations and planting conditions: soil fertility and water regimes, young stands were combined into three groups – with natural water regime Katrīnmuiža, drained stands – Uzvaras Līdums 1 and Uzvaras Līdums 2.

Both young stands at Katrīnmuiža near parish Ķekava have natural water regime on mineral soil (*Myrtiltoso-sphagnosa* forest type) with total area of 1.53 ha, located at 56.778349, 24.214402 decimal degrees coordinates (Figure 1).

Young stands near parish Olaine at Uzvaras līdums 1 both are drained, section 176-5 is on mineral soil (*Mercurialosa mel*.) and 177-21 on peat soil (*Oxalidosa turf. Met*.). Total area of Uzvaras Līdums 1 is 3.14 ha, located at 56.781206, 23.827135 and 56.780784, 23.831711 decimal degrees coordinates (Figure 1). Peat soils peat layer is deeper than 20 cm (Zālītis 2006., Berķis 2013).

Soil at Uzvaras Līdums 2 is more fertile and wet than at Uzvaras līdums 1. Both young stand sites are drained, and one forest section 178-10 is on mineral soil (*Myrtillosa mel*.) and other 189-9 on peat soil (*Myrtillosa turf. Mel*.). Total area at Uzvaras līdums 2 is 3.38 ha, located at 56.776281, 23.841026 and 56.777830, 23.852595 decimal degrees coordinates (Figure 1).



168-9 / 169-3-Myrtiltoso-sphagnosa   *176-5 Mercurialosa mel.* 177-21 *Oxalidosa turf. Met*   178-10 *Myrtillosa mel.* 189-9 *Myrtillosa turf. Mel.*

Figure 1. Study sites with distribution of the sample plots and drop out seedlings, from left Katrīnmuiža, Uzvaras līdums 1., Uzvaras līdums 2.

Soil preparation, seedlings and planting methods were the same for all stands. Soil was prepared mechanically by mounding method. As planting material Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) container seedlings were used. All seedlings were planted mechanically with M-Planter Oy planting device that has already once been tested in Latvia (Liepins et al., 2011) and manually with seedling planting tube. Soil was papered with LSFRI elaborated planting device MPV600 having a similarly shaped blade as M-planter (Lazdina et al., 2015). At every stand we established both manually planted and mechanically planted spruce and pine seedlings (Figure 1).

Sampling design

Survival rate of the seedlings was inspected on October 2017 with ASTA documentation system and by sample plot method.

With ASTA documentation system every spot where a tree should be in stand site was inspected and dropped seedling marked out with coordinates in a. gpx file (± 1 meter after ASTA technical specifications). Sampling plots were established randomly in every planting area at every stand. We collected data a total of 6 sites × 4 planting methods × 3 study plots = 72 sampling plots and 24 per young stand (Figure 1 - red dots). Each plot has an area of 25 m^2 (r = 2.82 m), which makes 1800 m^2 in total and 300 m^2 per stand. In sampling plots dropped seedlings and animal damage was detected. The total amount of the area coincides with the Cabinet of the Minister minimum sampling plot size.

Method evaluation

To compare ASTA system and sampling method, gained results from each site with different establishment variant in each stand was calculated for one hectare of forest land. Then, assuming that the planting density for Norway spruce was 2400 seedlings ha^{-1} and Scots pine 3200 seedlings ha^{-1}, the percentage of how many seedlings would drop out in one hectare and the standard error was calculated. The Wilcoxon sign rank test (α=0.95) was used to examine the difference between results of ASTA system and sampling plot method.

Time and cost study

To calculate the difference of the costs for young stand renewal we multiplied the difference between dropped seedling count by both sampling methods with a price of one containerized seedling (pine = 0.164 EUR and spruce = 0.172 EUR) and results calculated to average costs per hectare for every pair (Katrīnmuiža and both Uzvaras Līdums sites) of young stands, by applying the following formula (Equations 1):

$$\text{COSTS} = (\text{ASTA} - \text{SP}) * \text{seedling price} / \text{area} \quad (1)$$

where: ASTA = dropped seedling count by ASTA documentation system, SP = dropped seedling count by sample plot method

To calculate the difference between sampling methods we multiplied the difference between spent time by both sampling methods with average gross wage in forestry sector in Latvia of 2016 (hourly rate = 5.87 EUR) (Central statistics department 2017) and results calculated to average costs per hectare for every pair of young stands (Equation 2):

$$\text{TIME COSTS} = (\text{ASTA}_T - \text{SP}_T) * \text{hourly rate} / \text{area} \quad (2)$$

where: ASTA_T = time spent by ASTA documentation system, SP_T = time spent by sample plot method

For final results we used the difference between costs of seedlings for young stand renewal per hectare and labour costs per hectare (Equation 3):

$$\text{TOTAL COSTS} = \text{COSTS} - \text{TIME COSTS} \quad (3)$$

RESULTS

Evaluation of methods

Overall Scots pine seedlings had higher surviving rate than Norway spruce in all six stands and in all variants, average drop out seedlings for Scots pine was 62 ± SE 16 seedlings ha^{-1} and for Norway spruce 136 ± SE 21 seedlings ha^{-1}. The largest amount of drop out seedlings were in mechanically planted variant with Norway spruce in Uzvaras līdums 1. and 2. (192 and 168 seedlings ha^{-1}) (Table 1.). In nine of eleven variants plot method showed higher count of drop out seedlings, the difference was not significant ($p>0.05$) but it shows high trend that plot method reflects lover surviving rate ($p=0.0537$), and the average difference between both method was 5.53% ± SE 1.86. The difference between both methods was more significant when overall drop out seedling count was higher, for example, residual for Scots pine was 1.94% ± SE 0.95 (ASTA 1.94% ± SE 0.51, Plot 3.13 ± SE 1.04), but for Norway spruce difference between methods was 9.83% ± SE 3.05 (ASTA 6.48% ± SE 1.02, Plot 15.26 ± SE 4.53) and in total the highest difference – 19.44% between both methods was observed in mechanically planted Norway spruce Uzvaras līdums 1. variant, where ASTA system reflected 192 drop out seedlings ha^{-1} but plot method 600 drop out seedlings ha^{-1}.

Table 1. Count and percentage of drop out seedlings

Location Forest sites	Variant	ASTA	ASTA (%)	Plot	Plot (%)	Difference (%)
Katrīnmuiža *Myrtiltoso-sphagnosa*	*P. sylvestris* manually	28	0.87	67	2.09	1.22
	P. *sylvestris* mechanically	53	1.65	67	2.09	0.44
	P. abies mechanically	66	3.14	200	9.52	6.38
Uzvaras līdums 1. *Mercurialosa mel. Oxalidosa turf. Met*	*P. sylvestris* manually	32	1	67	2.09	1.09
	P. sylvestris mechanically	60	1.87	267	8.34	6.47
	P. abies manually	132	6.29	267	12.71	6.42
	P. abies mechanically	192	9.13	600	28.57	19.44
Uzvaras līdums 2. *Myrtillosa mel. Myrtillosa turf. Mel.*	*P. sylvestris* manually	139	4.35	67	2.09	2.26
	P. sylvestris mechanically	61	1.91	67	2.09	0.18
	P. abies manually	124	5.89	67	3.19	2.7
	P. abies mechanically	168	7.99	467	22.24	14.25

*All values have been estimated for one hectare assuming planting density for Scots pine 3200 ha^{-1} and Norway spruce 2100 ha^{-1}.

Browsing was only observed in Scots pine variants with plot method and proportion of browsed seedlings varied from 2% to 4% of seedlings ha^{-1}. Sample plot method allows to record more detailed survey as single button ASTA system.

Cost difference between sampling methods

The total amount of consumed time with ASTA documentation system to mark out dropped seedlings for all three locations is similar – about 40 minutes per hectare, whereas the spent time with sample plot method gradually increases and the difference of a coasts for hourly rate proportionally decreases with the size of site. Negative value of seedling costs in Table 2 difference column shows how much money per hectare we would spend for unnecessary seedlings of young stand renewal, whereas the positive value would mean that we would buy less seedlings than needed, but empty mounds would be left out (Table 2).

Total economy of cost in favour of the ASTA documentation system are 21.68 EUR at Katrīnmuiža, 130.49 EUR at Uzvaras Līdums 1 and 28.33 EUR at Uzvaras līdums 2.

Table 2. Time and cost study results.

Location	Area (ha)	Time spent by ASTA (per ha)	Time spent by sample plots (per ha)	Labour costs difference	Seedling costs difference
Katrīnmuiža	1.53	40.5	7.5	3.23	-24.91
Uzvaras Līdums 1	3.14	39.8	13.1	2.61	-133.10
Uzvaras Līdums 2	3.38	40.5	15.0	2.50	-30.82

DISCUSSION

In early forest regeneration stage ASTA system provides more precise results of seedlings survival rate in comparison with the sample plot method, because with ASTA system every tree is observed, and the difference between both methods is higher with increment of drop out trees in the area, and in result of that it provides opportunity to make the right decision, if there is need to compliment the stand with new seedlings.

Browsing was observed only in Scots pine variants and it has been shown previously, that large herbivores prefer pine seedlings more than spruce (Bergstrom and Bergqvist 1997., Hjeljord and Langen 2017), but overall Scots pine seedlings showed higher survival rate than Norway spruce that has been observed previously (Mäkitalo 1999).

Results of ASTA documentation system are easy to display on a map. The difference of labour costs between both methods is not significant. If more precise amount of dropped out seedling is known, the lower the costs for stand renewal may be, especially in sites where dropped out seedling placement isn't evenly spaced.

Data from ASTA system shows where geographically the problematic areas in the regenerated forest are located. In this case it is in sparse mounds and in some compartments (figure 1. black dots). In such places with less favourable growth conditions, it is possible to do additional activities or to plant different species. A lot of research projects have sought to evaluate whether mixed forests are more stable or provide more goods and services than monocultures, there is still little information on the underlying mechanisms and trade-offs behind these effects. Important role of mixtures for the stability of forests faced with environmental changes and the provision of ecosystem services to society (Coll et al., 2017). But current scientific knowledge about mixstand forestry is variable and the problems related to the economically effective management of mixed forests could be solved by using mixed species compartments like in our experimental stands or mixed species in the stand, which could be done by replanting more suitable species where main species have not survived.

Growing conditions may become unfavourable for trees because of the machinery used for logging and forest regeneration. When mounding was done, excavator had left tracks, but it did not compact the soil as much as machines with tires. Soil compaction is one of the most important issues in agriculture and in forestry. It is estimated that if soil is compacted, it leads to yield losses between 15 % and 35 % in agriculture. Deep loosening aims to achieve a radical change of soil structure in the compacted, settled and impermeable layer, thus increasing the capacity of water storage, creating conditions for normal aeration and heating of soil and for the activation of biological processes in the soil. Deep loosening can be done by making a deep pit thus increases the volume of soil pores and the lacuna space allows quick drainage of water and accelerates the flow of surface water, which helps the soil to dry faster in the spring (Laurentiu et al., 2017). Soil compaction is not reason for seedling dieback in this case.

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