HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Usability of stem pricing and fractional stem pricing in roundwood trade – reliability of pre-harvest stand value estimations between alternative pricing methods

Department of Forest Sciences
Forest Economics and Marketing
Master's thesis

Jori Rautalin

May 2020

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Tiedekunta – Fakultet – Faculty	Koulutusohjelma – Utbildingsprogram – Degree Programme
Faculty of Agriculture and Forestry	Forest Economics and Marketing

Tekijä – Författare – Author
Jori Rautalin

Työn nimi – Arbetets titel – Title
Usability of stem pricing and fractional stem pricing in roundwood trade – reliability of pre-harvest stand value estimations between alternative pricing methods

Oppiaine/Opintosuunta – Läroämne/Studieinriktning – Subject/Study track
Forest resource and environmental economics

Työn laji – Arbetets art – Level	Aika – Datum – Month and year	Sivumäärä – Sidoantal – Number of pages
Master's Thesis	May 2020	71

Tiivistelmä – Referat – Abstract

The usage of assortment pricing in roundwood trade creates a clear conflict of financial interests between the buyer and the seller, since sellers only get about a quarter of their total stumpage earnings from pulpwood, while its demand is likely to stay high or to increase. This thesis studies two possible alternatives to assortment pricing, stem and fractional stem pricing. In both methods, the buyer's bucking decision and the pricing are separated from each other. This study aims to assess the usability of the alternative pricing methods by comparing how actual stand values differ between assortment, stem and fractional stem pricing when they are equally valued in pre-harvest trade offers. The premise of this study is that the smaller the actual stand value difference between assortment pricing and the alternative pricing methods, the more usable they are in the roundwood trade. This is because neither side wants to take the possible monetary risk affiliated with switching away from assortment pricing.

The comparison was conducted by determining equally valued assortment pricing, stem pricing and fractional stem pricing (according to Luke's 2016 method proposition) for 27 study stands, on the basis of Trestima-based pre-harvest data and well-known taper curve and stem length models. With the resulting unit prices, all three pricings were again conducted for the same stands, this time constructed from harvester data by using the same taper curve and stem length models.

Based on the results, switching to stem pricing or fractional stem pricing creates on average from one to three percent higher stand values than assortment pricing. Stem pricing however deviated more than fractional stem pricing, so it could be considered to be slightly riskier method. Overall, both alternative pricing methods are usable in roundwood trade, and their usage should be encouraged.

Avainsanat – Nyckelord – Keywords
Assortment pricing, stem pricing, fractional stem pricing, stand value estimation

Ohjaaja tai ohjaajat – Handledare – Supervisor or supervisors
Markku Ollikainen

Säilytyspaikka – Förvaringställe – Where deposited
E-thesis

Muita tietoja – Övriga uppgifter – Additional information

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Tiedekunta – Fakultet – Faculty		Koulutusohjelma – Utbildingsprogram – Degree Programme
Maatalous-metsätieteellinen tiedekunta		Metsäekonomia ja markkinointi

Tekijä – Författare – Author
Jori Rautalin

Työn nimi – Arbetets titel – Title
Runkohinnoittelun ja rungonosahinnoittelun käytettävyys puukaupassa – leimikon arvon ennustamisen luotettavuus vaihtoehtoisilla hinnoittelumenetelmillä

Oppiaine/Opintosuunta – Läroämne/Studieinriktning – Subject/Study track
Metsien luonnonvara- ja ympäristötaloustiede

Työn laji – Arbetets art – Level	Aika – Datum – Month and year	Sivumäärä – Sidoantal – Number of pages
Pro gradu -tutkielma	Toukokuu 2020	71

Tiivistelmä – Referat – Abstract

Puutavaralajihinnoittelun käyttö puukaupassa luo selkeän ristiriidan ostajan ja myyjän taloudellisten intressien välille, sillä myyjät saavat vain noin neljänneksen puunmyyntituloistaan kuitupuusta, samalla kun sen kysyntä todennäköisesti pysyttelee korkella tai kasvaa. Tässä tutkimuksessa tarkastellaan vaihtoehtoisina hinnoittelumenetelminä runko- ja rungonosahinnoittelua, joissa ostajan runkojen katkonta ja puukaupan hinnoittelu on erotettu toisistaan. Tutkimuksen tarkoituksena on arvioida runko- ja rungonosahinnoittelun käyttökelpoisuutta puukaupassa vertailemalla millaisia eroja puukaupan lopullisiin arvoihin syntyy kun ne on pystykaupan ostotarjouksissa hinnoiteltu samanarvoisiksi ptl-, runko-, ja rungonosahinnoittelulla. Tutkimuksen lähtökohtana on oletus, että vaihtoehtoiset hinnoittelumenetelmät ovat sitä käyttökelpoisempia mitä lähemmäs ptl-hinnoittelun arvoa päästään, sillä kumpikaan puukaupan osapuolista ei halua hinnoittelumenetelmää vaihtamalla ottaa suurta taloudellista riskiä.

Vertailu toteutettiin johtamalla Trestima-ennakkotietojen sekä tunnettujen puun pituus- ja runkokäyrämallien avulla arvoiltaan yhtäläiset ptl-hinnoittelu, runkohinnoittelu sekä Luken vuoden 2016 menetelmäehdotukseen perustuva rungonosahinnoittelu 27:lle leimikolle. Saaduilla yksikköhinnoilla johdettiin kaikki kolme hinnoittelua toteutuneisiin leimikoihin, jotka koottiin takaisin pystyyn hakkuukonedatan ja samojen puun pituus- ja runkokäyrämallien avulla.

Tulosten perusteella runko- ja rungonosahinnoitteluun siirtyminen tuottaa molemmilla menetelmillä keskimäärin yhdestä kolmeen prosenttia korkeampia puuston arvoja kuin ptl-hinnoittelu, mutta runkohinnoittelun arvo vaihteli enemmän, joten sitä voidaan pitää hiukan riskialttiimpana menetelmänä. Kaiken kaikkiaan molemmat vaihtoehtoiset hinnoittelumenetelmät ovat käyttökelpoisia puukaupassa, ja niiden käyttöä tulisi edistää.

Avainsanat – Nyckelord – Keywords
Puutavaralajihinnoittelu, runkohinnoittelu, rungonosahinnoittelu, leimikon arvon ennustaminen

Ohjaaja tai ohjaajat – Handledare – Supervisor or supervisors
Markku Ollikainen

Säilytyspaikka – Förvaringställe – Where deposited
E-thesis

Muita tietoja – Övriga uppgifter – Additional information

Acknowledgements

I would like to thank the Ministry of Agriculture and Forestry and the Metsämiesten Säätiö Foundation for funding this thesis. I would also like to thank Metsä Group for providing the data without which this thesis would not have been possible to carry out. Special thanks to Professor Markku Ollikainen for valuable feedback during the writing process and to Jori Uusitalo (Luke) and Heikki Korpunen (Luke) for introducing me to the topic and the calculation models used in this thesis.

Contents

1. Introduction

1.1 The Finnish roundwood market

The Finnish forest industry is dependent on the raw material supply from private forest owners, since the trade between Finnish forest owners and the forest industry accounts for about 80 % of the roundwood supply needed by the industry (Luke 2019). In 2018, the industry purchased 51.5 million cubic meters of roundwood from private forest owners, 50 % of it being pulpwood, 46 % logs and 4 % small-sized logs and specialty woods (Luke statistics database 2019a). Total stumpage earnings of private forest owners were 2.3 billion euros in 2018 (Luke 2019). There are over 600,000 private forest owners in Finland, and they own about 60 % of the total forest area in Finland (Leppänen & Torvelainen 2015). In contrast, the industry is very concentrated, since the three biggest companies (UPM, Stora Enso and Metsä Group) usually account for approximately 80 % of the total roundwood procurement in the market (Finnish Competition and Consumer Authority 2006). The "big three" purchase practically all pulpwood in the market, either directly from forest owners or from smaller roundwood purchasers. These practically oligopsonistic circumstances and the forest industry's dependence on the supply from forest owners highlights the importance of a well-functioning roundwood market. About two thirds of Finnish roundwood sales are from clearcuts, and about 85 % of the roundwood sales are standing sales (Luke 2019). Forestry management associations have a big role in the roundwood market, as they conduct about 40 % of total the roundwood sales from private forest owners via proxy (Maaseudun Tulevaisuus 2017).

In the dominant Nordic harvesting system, where stems are cut to final lengths in the forest, the price of timber in the Finnish market is based on timber assortment volumes (logs, small-sized logs and pulpwood). Assortment pricing has a long history in the Finnish roundwood trade, and discussions regarding pricing and unit prices (€/m³) for each assortment have traditionally been sensitive matters to both, the industry and the forest owners. Therefore, efficient and fair pricing of roundwood is required to maintain a sustainable raw material supply for the forest industry.

1.2 Premise of the study

Assortment unit prices and measurement and quality requirements (minimum diameter and length of the logs) are agreed upon between the buyer and the seller before the felling. Because the final assortment recovery is clear only after the felling, the value of timber sales is uncertain when the sales agreements are made. Therefore, the timber sales agreements and trade offers are based on the estimated/forecasted final assortment recovery and monetary value of the stand marked for harvesting.

In the prevailing sales practices, the standing sale contract restricts (assortment dimensions) the buyer’s bucking decisions to a certain degree, and often the largest forest industry companies are accused of cutting/allocating some log-requirements fulfilling raw material to pulpwood, in order to match their current pulpwood demand and reduce procurement costs. This scenario is unfavorable to the seller and may lead to substantial financial losses per each sold forest stand, since logs are significantly (about three times) more valuable. Because of these accusations, forest owners often like to make sure that the allocation of the assortments is in line with the agreement and measurement requirements by monitoring the fellings e.g. via forestry management associations. The buyers are obligated to compensate the financial losses to the seller if the agreement violations are clear enough, but this kind of negotiations are time consuming and frustrating to both parties. A good example of such a process is the court case between UPM and a private forest owner, in which the felling of the stand in question happened in 2016 and the case was closed in the court of appeal in 2019 (Maaseudun Tulevaisuus 2019). Small-scale forest owners cannot usually sell timber every year, so the decisions to sell are not taken lightly. Therefore, forest owners often compare multiple trade offers (from multiple buyers) before selling. On the other hand, when selling, an unexperienced forest owner might overlook the importance of bucking and only focus on the offered unit prices.

The fundamental flaw in assortment pricing is that the buyers would like to have more flexibility in their harvesting processes (to further optimize the bucking and their own supply chain), and the forest owners naturally seek to maximize the value of their forest stands. In other words, the conflict of interest creates mistrust between the forest industry and the private forest owners, which may hinder the efficiency of the roundwood market.

Due to recent and possibly forthcoming large investments in pulp manufacturing facilities by the large forest industry companies, the demand for pulpwood is expected to stay high or increase further in the near future. As roughly half of the raw material goes to highly profitable pulp, and the forest owners get the majority of their stumpage earnings from log sells, more and more conflicts regarding log and pulpwood allocation and bucking seem inevitable. The “big three” keeps getting high profits in the pulp market and while pulpwood’s value recovery for the industry has lately significantly increased, at the same time only about 25 % of the sellers’ stumpage earnings come from pulpwood (Luke statistics database 2019b). The industry has managed to keep the price of pulpwood quite stagnant and increase the log prices instead (Helsingin Sanomat 2018). In the process, the independent sawmills are at times in trouble due to high log prices.

As the demand for pulpwood remains high, new pricing methods could relieve the stress in the roundwood market, and in order to keep the market competitive and fair for all stakeholders, the cutting and pricing of timber should be separated on as large scale as possible. This would decrease the disputes about the assortment allocation, because the cutting/bucking of the stems would not directly affect the stumpage earnings anymore and the buyers would be free to optimize their raw material usage.

Because of the shortcomings of assortment pricing, there has been a growing interest in the governmental level (Ministry of Agriculture and Forestry 2014) to find alternative and improved ways to conduct the pricing of roundwood. The Finnish Ministry of Agriculture and Forestry has been trying to alleviate the problems affiliated with assortment pricing by encouraging and funding research and development of alternative pricing methods.

The industry and the forest owners both have shown some interest in renewing the pricing mechanism from time to time, but so far only stem pricing, where roundwood has single unit price regardless of the assortments bucked from the stems, has gained some foothold in the market. Some other alternative pricing methods are, or have been, in marginal use by some independent sawmills (Malinen et al. 2010). These alternatives are price list pricing (dominant pricing method in Sweden and Norway) where each log diameter and length class has its own price, quality-based assortment pricing where unit prices are weighted by estimated log dimensions or quality, and fractional stem pricing where stems are divided into diameter-based value fractions (Malinen et al. 2010). Lately, as the industry has been evolving due to changes in the global end product markets, and the industry's inner technological development (e.g. digitalization), interest in alternative pricing methods have sparked again. With the current pulpwood demand, forest owners have also realized the possible need for renewing the pricing mechanism.

This study focuses on two alternatives; fractional stem pricing and stem pricing. In both alternatives, the bucked timber assortments are separated from the pricing of the timber (Figure 1), and the pricing is based on stem/stem part volumes computed by the harvester. The premise of this study is that alternative pricing methods become realistic options only if the difference between the estimated/forecasted and actual timber sales values (stand values) do not significantly exceed or undermine the same difference achieved via assortment pricing. The smaller the actual stand value difference between assortment pricing and the alternative pricing methods, the better their usage in the roundwood market.

To increase the popularity of the alternative pricing methods, reliable ways to compare timber trade offers between different pricing methods are a necessity. Pre-harvest estimation of the value of a forest stand is crucial in both formulating the purchase offers and in comparing the different trade offers. As comparing different offers can be confusing enough with just assortment pricing, comparing trade offers between different pricing methods can further increase the seller's confusion. The buyers also need to assess the reliability of their pre-harvest estimations, while deciding whether to use less familiar pricing methods in different kinds of forest stands or not.

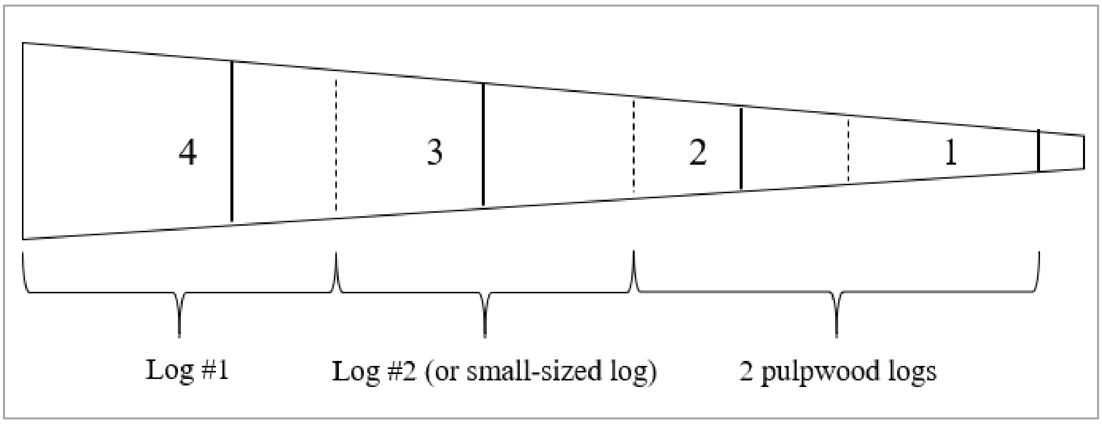

Figure 1. Example on separated pricing and bucking. Solid lines mark the limits of diameter-based value fractions of fractional stem pricing (four grades). Dashed lines mark the buyer's bucking decision and assortment recovery for assortment pricing. In stem pricing, commercial wood (diameter over 6 cm) has one unit price (€/m3). In this study, treetop (diameter under 6 cm) is priced identically in all three pricing methods.

1.3 Previous studies

Assortment pricing's dominant status has remained, but within the last decade some studies have highlighted its shortcomings and alternative pricing methods have been studied e.g. by Luke and its predecessor Metla. Malinen et al. (2010) discuss the qualities of theoretically optimal roundwood pricing method(s) in Nordic roundwood markets. The authors studied whether assortment pricing, weighted assortment pricing, price list pricing, stem pricing and fractional stem pricing fulfill their optimality conditions. They concluded that stem and fractional stem pricing could be viable options. Malinen et al. (2015) studied in their market simulations if changing the used pricing method would affect roundwood's market price level. They concluded that with a short time horizon, market price level does not change as long as every buyer is using the same pricing method. Malinen & Kilpeläinen (2013) studied the relationship of timber sale values and buyer's wood paying capability between different pricing methods, and the elasticity of the pricing methods with changing log dimension demand.

In Luke's study by Korpunen et al. (2016), the authors compared assortment pricing and fractional stem pricing in seven pine and spruce dominant clearcut stands. They used laser scanning, Trestima application and actual harvester stm-data with bucking simulator as they studied the usability of fractional stem pricing. They determined the forest owner's risk associated with the possible increase in the fractional stem pricing's popularity by comparing aggregate sums of the standwise stumpage earnings with both pricing methods. Korpunen et al. (2016) found the monetary risk to be two percent with their seven clearcut study stands, by comparing aggregate value of the best actual stand values (optimal combination of either assortment or fractional stem pricing) to the aggregate value of the worst actual stand values. Based on their results, actual aggregate stand value comparison purely between the pricing methods yielded 0.6 percent higher value with fractional stem pricing. Korpunen et al. (2016) conclude that risks associated with fractional stem pricing lie mostly with the industry.

This study uses a similar method to determine the relative monetary risks associated with alternative pricing methods as Korpunen et al. (2016). However, instead of comparing the aggregate value of the optimal stand value combination to the worst combination, the aggregate stand value comparisons are done between the pricing methods, not between any combinations of them.

1.4 Aim of the study

This study aims to determine the reliability of pre-harvest estimations of stand values between assortment pricing, stem pricing and fractional stem pricing, by comparing the pre-harvest estimated/forecasted study stands' stumpage earnings to the actual stumpage earnings of the same study stands, with each pricing method. The goal is to assess the relative monetary risks associated with switching to an alternative pricing method from assortment pricing, in terms of the reliability of the pre-harvest stand value estimations. The relative monetary risks are derived directly from the timber sales values. E.g. two percent higher timber sales value via fractional stem pricing as opposed to via assortment pricing implies that the two percent risk falls on the buyer, and two percent lower sales value in turn means that the risk falls on the seller. Relative monetary risks between the pricing methods are considered through the average stand value ratios, standard deviations and stand value ranges of 27 study stands used in this study.

All in all, this study tries to answer the following questions: how close with each other the actual stand values of the three pricing methods will end up if they were set equal in the pre-harvest estimations, and do the resulting differences justify the usage of stem and fractional stem pricing in roundwood trade? Previous studies have shown that stem and fractional stem pricing could be viable pricing alternatives, and this study hopes to further asses the possible monetary risks that roundwood market players would face if the usage of the alternative pricing methods would gain popularity alongside assortment pricing. As a generation change is going on among forest owners and the industry is renewing itself, now could be the time to change the pricing methods as well.

2. Choice between the pricing methods

2.1 Theoretically optimal roundwood pricing and flaws in assortment pricing

The principles of stem pricing are quite old. A basic form of the method was used quite commonly as early as in the 19th century (Heikkilä 2012). Besides the independent sawmills, larger roundwood buyers are also recently increasing the usage of the method in their trade offers. For example, approximately one third of clearcuts via sales by proxy are already conducted using stem pricing in the Päijät-Häme region (Metsälehti 2018). The usage of stem pricing varies throughout the country, and it is difficult to project (percentagewise) exactly how much the method is used, since no public price statistics exists yet. Overall, its usage is still low. Stem pricing is quite dependent on highly accurate estimates of stand characteristics, and this can create problems since large estimation errors are still quite common with the current estimation methods. Nevertheless, stem pricing has proven to be a viable option in coniferous tree species clearcuts, and it has also been used in first thinnigs (Heikkilä 2012). The formulation of stem pricing regarding this study is explained in Chapter 3.6.

Fractional stem pricing has been suggested to be the optimal roundwood pricing solution by Malinen et al. (2010), who argues that the method should be used in standing sales. In addition, the Finnish Ministry of Agriculture and Forestry (2014) has recommended fractional stem pricing to be used in roundwood trade. Thanks to modern harvester technology, the industry could be able to begin using fractional stem pricing in a relatively short amount of time. Fractional stem pricing should lower the monetary risk for both sales partners as compared to stem pricing, since the multiple price grades should take the qualities of the stems better into account. This hypothesis is also tested in this study, as the resulting stand values should support the such claim. Additional advantage of fractional stem pricing is that the need for high accuracy stand characteristics estimations is not as imperative as with stem pricing. The theory behind fractional stem pricing and the method for determining stand values with it, are explained in Chapters 3.5 and 3.6. Fractional stem pricing can naturally be carried out in multiple ways, but since practically no one is using the method, Luke’s proposition from 2016 was selected to represent the method in this study.

When looking at the attributes of theoretically optimal roundwood pricing mechanism (Figure 2) set by Malinen et al. (2010), it seems that stem pricing and fractional stem pricing could be considered as viable options. Both are applicable on standing sales, transparent and relatively easy to understand, pricing and bucking decisions are separated from each other, and at least fractional stem pricing has potential to offer a greater incentive to grow higher quality timber, and grant the seller a compensation that accurately reflects the characteristics and quality of the sold stand. Therefore, from a purely theoretical point of view, fractional stem pricing fulfills the optimal solution criteria better than stem pricing.

The needed attributes of optimal pricing method for roundwood trade:

1. Pricing method needs to be transparent and easily understandable
2. Pricing method should encourage growing higher quality timber
3. Pricing method should allow value optimization of purchased/sold raw material

Figure 2. Basic optimality conditions for roundwood pricing mechanisms (Malinen et al. 2010).

The first attribute in Figure 2 stems from an asymmetric information that currently hinders the efficiency of the roundwood market, because the industry, i.e. the buyers, have inside information on e.g. processing values of the sold timber (Malinen et al. 2010). In other words, the forest owner does not always know how well the cut assortment volumes reflect the qualities of the stand, or how valuable the sold timber assortments actually are to the buyer. One may argue that fractional stem pricing is difficult to understand, but the counter argument is that as the method only relies on value grade volumes computed by the harvester, it is not complicated compared to assortment pricing where the buyers bucking decisions potentially create confusion for the seller.

According to (Malinen et al. 2010) the asymmetric information has possibly led the market into another problem: the compensation for the most valuable logs is too low and the compensation for the lower value logs is too high in relation to the actual processing values, since the value recovery per m^3 in sawing varies greatly between quality and log dimensions and the seller rarely has knowledge of these value variations. This averaging of the compensation might in some cases shorten the rotation period of the forest stands and cause the sturdiness of the stems to decrease, since there are no clear economic incentives to grow higher quality timber (Malinen et al. 2010). The second attribute in Figure 2 is also closely linked to the current climate goals which encourage growing sturdier stands, due to better carbon sequestrating capabilities bearing end products. Although stem pricing can at best slightly increase the price variation between lower and higher quality stands (compared to assortment pricing), it is prone to some level of price averaging, meaning that the price difference between higher and lower quality stands might still not truthfully reflect their processing values (Malinen et al. 2010). This is shown in study by Malinen et al. (2010), where the correlation between processing and sale value of the stems was weaker with stem pricing than with fractional stem pricing. Therefore, it can be argued that stem pricing might not give enough incentive to grow higher quality timber, since it lacks clear ways to indicate how the quality of the stems actually affects the price. As already stated, with fractional stem pricing the incentives to grow higher quality timber is easily achievable through correctly set price levels of the diameter dimension-based grades.

The third attribute in Figure 2 naturally stems from the conflicting interests of the two parties of roundwood trade. Modern harvesters are capable of calculating the optimal bucking solution according to the current demand of timber assortments and log dimensions, with the assortment and log dimensions stated in the timber sales agreement acting as a constraint in the calculation process (Malinen et al 2010). However, situations when the agreed assortment minimum requirements/dimensions are no longer optimal can easily arise because standing sale contracts are possibly made as early as two years before the felling (Malinen et al. 2010). Market demands for the company's products or raw material supply may change significantly between the time of the sales contract and the time of the felling and bucking, and this can lead to a situation where the buyer is forced to harvest "unwanted" raw material (Malinen et al. 2010). According to Malinen et al. (2011), a drop in the value recovery of a raw material is usually larger than the affiliated drop in the price of the end product, and respectively an increase in the value recovery of a raw material is usually larger than the affiliated increase in the price of the end product. Therefore, further optimization of the companies' raw material supply chain (bucking and assortment allocations to the production facilities or to customers) can lead to substantial improvements in net profits. Uusitalo et al. (2011) suggest, that at least 50 percent improvements per cut forest stand are theoretically possible. For example, the buyer could allocate larger volumes of pulpwood from a stand to a nearby pulp mill (if it is the current optimal solution) than what was previously possible or reasonable with assortment pricing. The bucking decision of the buyer may very well remain unchanged when switching to some alternative pricing method, but with freed bucking, the buyer has more options.

2.2 Skepticism towards the alternative pricing methods

Forest owners and the forest industry have used assortment pricing for so long, that in such a traditional setting as timber trade where changes happen slowly, alternative pricing methods have quite a hurdle to clear if the goal is to overthrow assortment pricing. A much more realistic first goal for the methods is to become better known and established as coexisting alternatives to assortment pricing.

Forest owners have grown accustomed to monitoring the cutting of their sold forest stands, since with assortment pricing, the seller is forced to either trust the bucking to be fair or monitor the fellings. When conducting timber trade through the alternative pricing methods, the seller practically only needs to worry about the functioning of the harvesters' volume calculations. In the end, the issue of trust remains, but it is more focused on technology, rather than bucking decisions or the harvester operator. Forest owners might also have suspicions about fractional stem pricing because it is not as simple as stem pricing and it must be said that some forest owners barely understand how assortment pricing works. Naturally, both the industry and forest owners want the other party to take on the possible monetary risk of using the alternative pricing methods. Therefore, assortment pricing is not going to disappear even if the alternatives gain popularity.

Stem pricing can bear quite a high risk to both parties in uneven stands (quality- and size-wise), which is why it cannot and will not be used as a sole pricing method in the market. Some other pricing method, e.g. assortment pricing or fractional stem pricing, should be used alongside stem pricing, to fairly valuate challenging and uneven stands. So far, the dilemma with stem pricing is that while assortment market prices and roundwood demand are high, stem pricing can potentially be used as a market pressure valve, by offering high stem prices instead of high assortment pricing to keep the price statistics of assortment prices from rising to their potential maximum (Metsälehti 2018).

Even though researchers and the industry have studied fractional stem pricing, the method has not made a breakthrough to the market. This is probably largely due to assortment pricing’s long traditions and fractional stem pricing’s fairly complex functioning compared to stem pricing. The industry quite often blames forest owners for stubbornness to accept changes in pricing and claims that forest owners might conceive suggestions for changes to be the industry’s plan to swindle them. On the other hand, forest owners claim that the current market situation, where industry can purchase pulpwood cheaply, prevents changes in pricing (Heikkilä 2012). Current assortment pricing levels are a good way for large forest industry integrates to practice cost control, because it allows them to purchase cheap pulpwood from forest owners, and from other wood procurement companies which only use the saw logs from their own timber purchases. The topic of pulpwood demand and bucking solutions is a hot one, and the great emotions involved also slow the progression of alternative pricing methods, since spreading wider usage of the methods would need immense cooperation between forest owners and the forest industry.

3. Data and methods

3.1 Data and the premise of the stand value calculations

To conduct a comparison between the pricing methods, both pre- and post-harvest data were needed. A data set of 33 mainly pine and spruce dominant study stands, which were clearcut during 2017-2018 in Southeastern Finland, was provided by Metsä Group. In this study, study stands include only clearcuts. Additionally, all stands are assumed to be sold via standing sales, since in the pricing methods studied, buyer fells and bucks the trees.

The needed pre-harvest determined mean stand characteristics (Table 1), and stem number distribution (Appendix 1) were measured with the Trestima application, which takes the measurements from methodically taken photographs of the stands. Trestima-based data needed by the models used in this study included standwise tree species-specific mean diameter, height, stem number distribution and the total land area of each stand. Post-harvest data was measured by the harvester machine as it was cutting the stands. Post-harvest data (Table 2) required for the models included standwise tree species-specific mean diameter, volume, stem number distribution (Appendix 2) and the total land area of each stand. Tree species taken into calculations were pine, spruce and birch.

Volume estimations and calculations were conducted on the 33 forest stands, and further inspection of the data and the calculated results revealed that pre-harvest estimated (and Trestima-forecasted) volumes of five stands were so significantly overestimated (80–160 percent overestimations) that corrupted harvester data or inconceivable Trestima data due to possible measurement errors became obvious. After this, the remaining 28 study stands included only one birch-dominant stand, and it was therefore also removed from the data set. In the end, stand value calculations were conducted using a dataset of 27 stands ranging from 0.5 to 10.1 hectares, which included 23 stands containing pine, 23 stands containing spruce and 12 containing birch (Table 1). In some stands a small amount (in total 432 m^3 over the 27 stands) of other wood than pine, spruce or birch was harvested, which Trestima did not find or which was misidentified. Additionally, over the 27 stands in total 312 m^3 of wood (usually birch) was harvested but not priced. This combined amount (744 m^3) of misidentified wood was not included in the stand volume or value calculations, because although including this “extra” amount of wood would have slightly shrunk the volume over-estimation in some stands, the lack of Trestima-data entries prevents forming pre-harvest stem and fractional stem pricing value estimates (note that Table 2 has more entries than Table 1). In other words, the “extra” wood could not be a part of the comparison between the pricing methods. It should be noted that this excluded amount would not have had a significant effect on the average stand value ratio results between pricing methods, as in total the excluded amount accounts for only about four percent of the combined volume of excluded and included wood (16740 m^3).

To compare the value of the estimated and actual study stands between the three pricing methods, national averages of assortment unit prices from 2018 in Luke’s public statistics database were used as a benchmark in the calculations (Chapter 3.6). Since neither a generalized way to conduct the pricing nor actual price statistics for fractional stem pricing exist, Luke’s (2016) proposal to conduct the pricing (Chapter 3.5) was chosen to represent the method, and the value grade (diameter-based value fractions) prices were determined by using the value grade relationships from the fractional stem pricing solutions by Korpunen et al. (2016) and Luke’s proposal (2016) as a benchmark for the price ranges of the value grades (detailed explanation in chapter 3.6).

As laid out in the aim of the study, while conducting the stand value comparison between the three pricing methods, they are set to yield equal pre-harvest stand value estimates. The assumption that assortment pricing and the alternative pricing methods would yield equal pre-harvest stand value estimates in a ”real life” timber sales situation would naturally be unrealistic, since trade offers usually come from multiple different buyers, or an individual buyer probably does not have any incentives to form multiple identically valued offers for a single stand (buyer might include the perceived pricing method related risks into the unit prices). Furthermore, the seller might consider that timber sales with freed bucking should yield higher stand value than with assortment pricing. After all, pricing in timber sales is always a negotiation process. Setting the preharvest estimated stand values equal however enables finding out if the alternative pricing methods per se would contain inherent or built-in attributes that increase financial risks compared to assortment pricing, which is exactly what the aim of this study is. Additionally, the assumption that switching from assortment pricing to some other method per se will not affect stand values, is backed up by the findings of Malinen et .al (2015), who argue that changing pricing method per se will not affect the prevalent market price level, while the allocations of bought timber between different buyers might change.

Table 1. Stand characteristics (per hectare) measured by Trestima. Mean diameter and height are basal area weighted.

Stand	Area (ha)	Species	Mean diameter (cm)	Mean height (m)
1	2.4	Pine	31.9	21.85
1	2.4	Spruce	25.5	19.40
2	4.9	Pine	28.7	20.90
2	4.9	Spruce	27.2	22.01
3	2.6	Spruce	27.0	22.87
3	2.6	Birch	21.1	20.34
4	2.9	Pine	33.6	25.61
4	2.9	Spruce	32.8	25.05
5	3.7	Pine	25.6	18.70
6	3.7	Pine	24.8	19.33
6	3.7	Spruce	27.9	21.26
6	3.7	Birch	18.5	16.55
7	10.1	Pine	24.6	19.00
7	10.1	Spruce	24.4	19.21
7	10.1	Birch	11.9	11.59
8	3.1	Pine	35.1	24.17
8	3.1	Spruce	30.3	22.60
8	3.1	Birch	17.8	15.33
9	1.6	Spruce	26.2	19.70
9	1.6	Birch	23.2	18.47
10	0.8	Pine	27.1	19.23
10	0.8	Spruce	23.0	18.50
11	0.7	Spruce	24.5	20.20
12	2.1	Pine	24.1	20.32
12	2.1	Spruce	22.9	19.90
12	2.1	Birch	20.6	17.29
13	1.5	Pine	26.2	19.40
13	1.5	Spruce	22.2	18.75
14	4.1	Pine	22.9	19.00
14	4.1	Spruce	23.6	20.49
14	4.1	Birch	24.9	21.51
15	3.5	Pine	32.0	22.19
15	3.5	Spruce	31.1	22.63
16	2.6	Pine	20.6	17.60
17	2.4	Pine	25.8	21.37
17	2.4	Spruce	23.0	19.48
17	2.4	Birch	19.7	18.70
18	3.9	Pine	20.9	16.00
19	1.8	Pine	24.6	22.34
19	1.8	Spruce	23.4	22.00
19	1.8	Birch	20.1	20.84

Stand	Area (ha)	Species	Mean diameter (cm)	Mean height (m)
20	1.9	Pine	22.8	18.97
20	1.9	Spruce	24.6	20.10
21	2.1	Pine	28.0	20.88
21	2.1	Spruce	25.3	19.17
22	1.1	Spruce	22.6	18.23
23	1.5	Pine	25.1	18.50
24	0.5	Pine	26.9	20.94
24	0.5	Spruce	24.3	19.90
25	1.7	Pine	21.9	15.97
25	1.7	Spruce	24.0	17.20
25	1.7	Birch	21.4	16.66
26	0.8	Pine	23.8	21.10
26	0.8	Spruce	28.0	24.59
26	0.8	Birch	19.9	20.29
27	1.5	Pine	29.3	21.57
27	1.5	Spruce	27.0	20.84
27	1.5	Birch	21.6	18.28

Table 2. Stand characteristics (per hectare) measured by the harvester. Mean diameter and height are basal area weighted.

Stand	Area (ha)	Species	Mean diameter (cm)	Volume (m3)
1	2.4	Pine	27.8	51.9
1	2.4	Spruce	24.1	246.7
1	2.4	Birch	21.2	8.9
2	4.9	Pine	25.7	106.0
2	4.9	Spruce	24.9	75.7
2	4.9	Birch	16.5	3.0
3	2.6	Pine	33.3	4.6
3	2.6	Spruce	25.1	175.3
3	2.6	Birch	20.3	31.6
4	2.9	Pine	34.8	74.7
4	2.9	Spruce	37.0	426.2
4	2.9	Birch	21.2	14.9
5	3.7	Pine	22.6	172.6
5	3.7	Spruce	15.1	0.7
5	3.7	Birch	16.8	3.2
6	3.7	Pine	34.0	64.3
6	3.7	Spruce	30.1	315.7
6	3.7	Birch	20.0	17.0
7	10.1	Pine	22.4	144.0
7	10.1	Spruce	16.8	9.9
7	10.1	Birch	13.0	15.7
8	3.1	Pine	30.3	27.9
8	3.1	Spruce	28.1	231.4
8	3.1	Birch	18.3	28.7
9	1.6	Pine	23.9	2.8
9	1.6	Spruce	23.9	204.9
9	1.6	Birch	19.4	15.9
10	0.8	Pine	27.9	85.6
10	0.8	Spruce	21.6	204.6
10	0.8	Birch	19.5	3.3

Stand	Area (ha)	Species	Mean diameter (cm)	Volume (m3)
11	0.7	Pine	29.0	2.1
11	0.7	Spruce	32.7	198.4
11	0.7	Birch	21.3	9.2
12	2.1	Pine	27.0	24.5
12	2.1	Spruce	24.9	143.7
12	2.1	Birch	18.2	29.7
13	1.5	Pine	29.1	144.0
13	1.5	Spruce	21.8	33.3
13	1.5	Birch	20.7	5.6
14	4.1	Pine	29.1	82.3
14	4.1	Spruce	25.1	65.6
14	4.1	Birch	22.9	18.9
15	3.5	Pine	29.1	175.9
15	3.5	Spruce	28.9	59.1
15	3.5	Birch	14.7	4.1
16	2.6	Pine	19.3	137.3
16	2.6	Spruce	22.1	4.2
16	2.6	Birch	19.3	3.4
17	2.4	Pine	22.7	71.8
17	2.4	Spruce	22.3	126.2
17	2.4	Birch	17.4	37.1
18	3.9	Pine	19.1	99.6
18	3.9	Spruce	29.8	0.1
18	3.9	Birch	14.1	7.9
19	1.8	Pine	29.0	51.7
19	1.8	Spruce	29.4	130.6
19	1.8	Birch	24.2	6.0
20	1.9	Pine	24.1	24.0
20	1.9	Spruce	26.4	174.6
20	1.9	Birch	19.4	4.2
21	2.1	Pine	29.5	181.2
21	2.1	Spruce	29.8	65.3
21	2.1	Birch	29.3	2.1
22	1.1	Pine	27.0	38.8
22	1.1	Spruce	21.7	256.8
22	1.1	Birch	18.7	42.0
23	1.5	Pine	23.7	102.7
23	1.5	Spruce	21.2	3.4
23	1.5	Birch	20.8	7.5
24	0.5	Pine	26.5	61.0
24	0.5	Spruce	25.0	112.5
24	0.5	Birch	21.2	1.3
25	1.7	Pine	23.4	107.0
25	1.7	Spruce	23.5	133.4
25	1.7	Birch	17.7	95.4
26	0.8	Pine	28.5	67.8
26	0.8	Spruce	23.4	75.5
26	0.8	Birch	20.1	11.3
27	1.5	Pine	32.3	327.3
27	1.5	Spruce	27.0	163.1
27	1.5	Birch	20.1	22.0

3.2 Estimation and computing models

In order to conduct the volume and pricing calculations in chapters 3.4.-3.6, height of each stem (diameter classes) and profiles (taper curves) of each stem in the study stands were solved. The first step of the pricing method comparison was to reconstruct the cut study stands from the harvester data and similarly construct the pre-harvest estimated forest stands from the Trestima data. This had to be done in order to conduct the fractional stem pricing in the study stands, because fractional stem pricing can practically only be determined for whole/uncut stems.

A simple combination of well-known models was used to reconstruct the study stands and to estimate and compute the profiles and volumes of each stem (diameter classes) in the Trestima- and harvester-based stem number distribution of the study stands. The harvester data-based stand calculations were considered as a true or factual representation of the study stands. Trestima-based calculations were naturally used as pre-harvest estimations of the study stands. Both pre-harvest estimations and harvester data-based calculations were conducted using same models and methods.

Stem number distribution reveals how many stems are in each diameter class (example in Figure 3). This means that if the height of each stem (diameter classes) can be determined, the profiles of each stem in the study stands can be calculated with Laasasenaho's (1982) taper curve equations, and the volume of each stem with a volume formula for a cylinder (in this study by summarizing the volumes of 10-centimeter vertical pieces). The needed stem heights for each diameter class was solved by utilizing Siipilehto's regression models (1999) for Näslund's height curve model (1936). Siipilehto's model was chosen because of its simplicity due to only requiring two stand characteristics. Finally, the actual pricing of the study stands, and price method comparisons were conducted after the Trestima- and harvester data-based stands were constructed.

As mentioned in chapter 3.1, in this study the breast height diameter (height of 1,3 m) distribution was given in the dataset (stem number distribution). In a situation where there is no access to this kind of specific data, it is also possible to estimate the diameter distribution of the study stands by using e.g. Weibull distribution with parameter recovery method by Siipilehto & Mehtätalo (2013) or general regression models for pine and spruce by Mykkänen (1986) and Kilkki et al (1989).

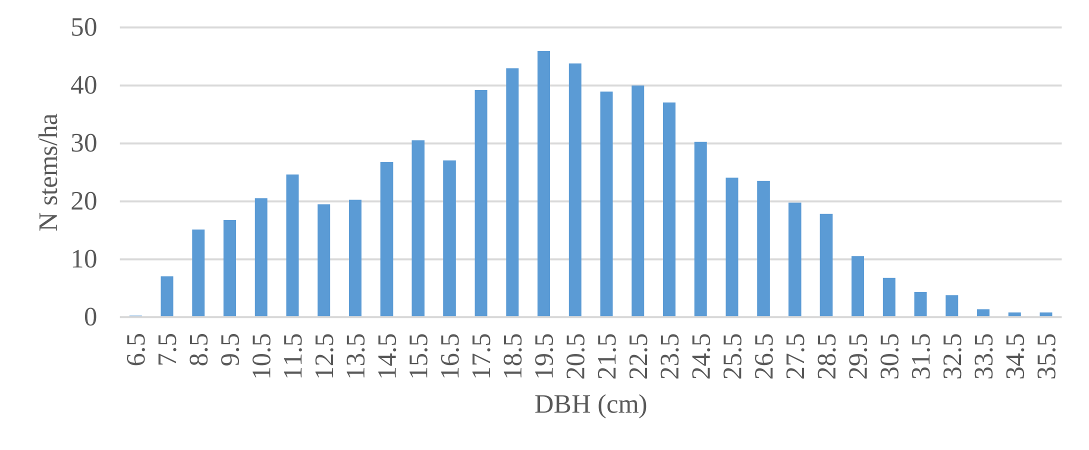

Figure 3. Stem number distribution (number of stems per hectare in breast height diameter classes), harvester data, pine, stand five.

3.3 Stem heights

As the tree species-specific stem number per hectare per each one-centimeter breast height diameter class is known, the first part of the calculations is to compute the stem height in each diameter class. This is done by using Näslund's (1936) height curve model (1).

$$h = \frac{d^m}{(b_0 + b_1 d)^m} + 1.3 \quad (1)$$

$where\ d = diameter\ class,$

$m = 2\ for\ pine\ and\ birch,\ 3\ for\ spruce\ (Siipilehto\ 1999),$

$b_0\ and\ b_1 = parameters\ to\ be\ estimated$

In order to determine parameters b_0 and b_1, a method introduced by Siipilehto (1999) was used. Parameter b_0 is deduced by forcing it through one known point in the height curve (2), and b_1 is solved using Siipilehto's regression models (Table 3). Both b_0 and b_1 are solved by utilizing the tree species-specific mean diameter and height (i.e. average stem per tree species in a stand) and are kept constant for all diameter classes of the tree species and stand in question. Both of these mean stand characteristics are provided by Trestima data, whereas the harvester data provides the mean diameter but not the mean height of the logged stems. This means that pre-harvest estimations and harvester-based factual calculations are both conducted with the same method, except that the harvester data-based mean heights of the study stands needed to be solved by utilizing the actual stand volumes (detailed explanation in the next section).

$$b_0 = d_g/\left(h_g - 1.3\right)^{(1/m)} - b_1 d_g \quad (2)$$

$$where\ d_g\ and\ h_g\ are\ basal\ area\ weighted\ mean\ diameter\ and\ height$$

Table 3. Parameter b_1 regression models for Näslund's height curve model (1936) by Siipilehto (1999). *Parameter coefficients d_{gM} and h_{gM} (basal area weighted median diameter and height) are replaced by basal area weighted mean diameter (d_g) and height (h_g).

	Pine: b_1	Spruce: b_1	Birch: b_1
Constant	0.2908	0.3834	0.2754
d_{gM*}	0.00134	0.00299	0
h_{gM*}	-0.00634	-0.00807	-0.00418
r^2	0.61	0.75	0.64
s_e	0.011	0.012	0.011

Solving stem heights from harvester data by utilizing actual stand volumes

Since harvester data and calculations based on it are considered factual, and everything else except the mean heights were known (the actual tree species-specific volumes of the study stands are given by the data), the correct mean heights were solved by iterating until the stand volume calculations matched the known stand volumes from the harvester data. This was done by combining stem height, taper curve and volume calculations (all the steps in chapters 3.3–3.4) into an Excel computing-module, with standwise tree species-specific mean diameter, mean height, total volume and the number of stems in diameter classes as possible input variables. Hence, this iterating process means that the mean height was being guessed until the calculation process unveiled the right (same) stand volume given by the harvester data.

The tree species specific stand volumes provided by the harvester data exclude the volume of treetops. Since the purpose of reconstructing the stands was to simulate the original stands as closely as possible and every m^3 in the harvester data is commercial wood (pulp logs, small-sized logs and logs), tops' volumes were added by iterating the mean height until the commercial wood's share of the total stand volume matched the harvester data-based volume (the used Excel computing-module calculates whole stem's volume, not just the share of commercial wood).

3.4 Stem profiles and volume calculation of the stands

In order to estimate or compute the volume of a study stand in a similar way with commercial harvesters, stem profiles were formulated for each diameter class. This was achieved by using Laasasenaho's (1982) taper curve model (3). Combining the taper curve model and general parameter values for pine, spruce and birch (Table 4) reveals the local diameter of a stem in chosen vertical intervals. In this case the intervals were set to 10 cm since the stem volumes were later calculated by summarizing 10 cm vertical pieces of the stem.

$$\frac{d_l}{d_{20\%h}} = b_1x + b_2x^2 + b_3x^3 + b_4x^5 + b_5x^8 + b_6x^{13} + b_7x^{21} + b_8x^{34} \quad (3)$$

$where\ d_{20\%h} = diameter\ at\ 20\ \%\ height, h = total\ height,$

$d_l = diameter\ at\ a\ height\ of\ l\ from\ the\ ground,$

$x = 1 - \frac{l}{h}$

Table 4. Laasasenaho's general parameter values for taper curve model (1982).

	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
Pine	2.123	-0.632	-1.608	2.489	-2.415	2.362	-1.754	1.082
Spruce	2.337	-3.268	3.651	-2.261	0.0	2.15	-2.741	1.888
Birch	0.938	4.106	-7.852	7.899	-7.502	6.386	-4.392	2.16

At this point the local diameters (in 10 cm intervals) of each stem, the height of each stem and the number of the stems in the chosen stand are known. By using the volume formula of a cylinder (4), we can compute the volume of each 10 cm piece and sum them up for the total volume of a model stem. This method is comparable with commercial harvesters, since during the harvesting process, the volume of the stems is computed in short (e.g. 10 cm) intervals.

Because the number of each model tree in the stand is known (stem number distribution), the total volume of a stand can easily be determined through a simple multiplication and summarizing the volumes of each diameter class into the total volume of a stand. Similarly, the stem number of each diameter class in the stands need to be multiplied by the actual land area of the stands, since stem number distribution describes amount per hectare. As noted, calculations were conducted separately for each tree species and the final aggregate stand volumes are presented in the results chapter.

$$V = \pi/4((d_0 + d_1)/2)^2 h \quad (4)$$

$where\ d_0 = lower\ diameter\ of\ the\ piece,$

$d_1 = top\ diameter\ of\ the\ piece,$

$h = height\ of\ the\ piece$

3.5 Determining the value grade volumes and assortment recovery for pricing

As mentioned, this study utilizes Luke's fractional stem pricing solution proposal by retaining the same four progressively valued stem part grades, and similar unit price ratios between the grades. Progress through the grades happens as diameter grows, so stem parts with greater diameter are naturally in the more valuable grades. In order to reach any of the price grades, individual stems need to yield at least one 2.7-meter long stem part with at least a 6 cm lower diameter. If a stem fails to reach this minimum requirement, it is left out from the stand value calculations. In order to reach grades three or four, individual stem needs to yield at least one 3.7-meter long stem part, which fulfills the diameter requirements of those grades. Grade four can be reached only if the 3.7-meter condition is met and grade four diameter requirement is met by at least 0.7-meter long stem part.

The diameter and length minimum requirements of all four grades in Luke's proposal are presented in Table 5. The two solutions are quite similar, only the diameter limit between grades two and three is different and the grade prices are determined a bit differently (Chapter 3.6). This study uses only the length and diameter requirements suggested by Luke, and timber quality requirements were not considered as a factor in the stand value calculations. In this study, fractional stem pricing was determined independently with both solutions, and grade requirements are set identically for all tree species. Grade volumes per each stem are calculated from the solved 10-centimeter vertical pieces' volumes by checking how many pieces fulfill each of the grade requirements and summarizing the corresponding volumes.

Table 5. Luke's fractional stem pricing proposal (2016). Value grade requirements are in centimeters. Applied for pine, spruce and birch.

Solution 1			
Value grade	Lower diameter	Upper diameter	Minimum length
4	25	-	70
3	20	25	370
2	13	20	-
1	6	13	270
Treetop	> 0	6	-
Solution 2			
Value grade	Lower diameter	Upper diameter	Minimum length
4	25	-	70
3	18	25	370
2	13	18	-
1	6	13	270
Treetop	> 0	6	-

Assortment volumes were determined in a similar fashion as fractional stem pricing's value grade volumes, but with the dimension requirements shown in Table 6. Lower diameter for logs was set to 15 centimeters for pine, 16 centimeters for Spruce and 18 centimeters for birch. It is essential to remember that assortment recovery is dependent on the buyer's bucking decisions, and assortment volume calculations done using this kind of method describe the theoretical optimal assortment recovery for the seller, since every centimeter of log requirements fulfilling wood ends up in log assortment, while realistic bucking always leads to some of it becoming pulpwood. This is because even if the harvester does the bucking as close to the seller's optimal solutions as possible, the log length requirements alternate usually in 30 cm intervals starting often either from 370 cm, 410 cm or 430 cm. This in turn means that short sections of log requirements fulfilling wood end up becoming parts of pulpwood logs.

An example: Log diameter requirement fulfilling section of a stem is exactly 10 meters long and the log lengths stated in the sales agreement are 430, 460, 490, 520, 550 and 370 (as aid dimension) centimeters. None of the possible bucking combinations can allocate the whole 10-meter section to logs, but the assortment recovery calculation method of this study will allocate the whole 10-meter section to logs.

Because in all likelihood, the log volumes calculated using the assortment recovery method of this study would otherwise be slightly overestimated, a three percent subtraction was done to every stem's log recovery and was reallocated to pulpwood recovery. Korpunen et al. (2016) also used 3 % subtraction on log recovery in their 2016 study, although it was used to account log defects, which are excluded from consideration in this study's calculations.

Stem pricing differs from the other two pricing methods since it does not include price grades or assortments (except for the top section of a stem with a diameter smaller than 6 cm, which is priced separately). Stems are therefore ready for pricing after volume calculations without further processing.

Table 6. Used dimension requirements for assortment pricing in centimeters.

	Pine		
Assortment	Lower diameter	Upper diameter	Minimum length
Logs	15	-	370
Small-sized logs	11	15	310
Pulpwood	6	11	270
Treetop	> 0	6	-
	Spruce		
Assortment	Lower diameter	Upper diameter	Minimum length
Logs	16	-	370
Small-sized logs	11	16	310
Pulpwood	6	11	270
Treetop	> 0	6	-
	Birch		
Assortment	Lower diameter	Upper diameter	Minimum length
Logs	18	-	330
Small-sized logs	-	-	-
Pulpwood	6	18	270
Treetop	> 0	6	-

3.6 Pricing of the study stands

Assortment pricing

After all the calculations described in Chapters 3.3–3.5, the pre-harvest estimated study stands were assigned assortment pricing by using the 2018 national averages of the assortment unit prices in Luke's statistics database (Table 7). Assortment prices were kept constant with every stand of the data set. The top section of the stems (diameter under 6 cm) was priced at 1 € per m^3 for every tree species and stand. After this, stem pricing and fractional stem pricing were set to yield equal monetary stand value as assortment pricing. The resulting prices where then transferred to the actual stands, to simulate the value differences forming between the pricing methods in a timber sales situation.

Table 7. Clearcut stumpage prices (€). 2018 Finland's national average (Luke statistics database 2019c)

	Logs	Small-sized logs	Pulpwood
Pine	63	28	20
Spruce	65	29	21
Birch	48	-	19

Fractional stem pricing

For fractional stem pricing, the pre-harvest estimated stand values were set to be equal with stand values via assortment pricing by giving price ranges to the value grades, inside which each grade's price could move freely to reach a suitable combination. The value grade prices were determined using Korpunen et al. (2016) and Luke's fractional stem pricing solution's value grade price ratios as a basis for the chosen ranges. Korpunen et al. (2016) in turn derived the value grade price ratios from the study by Uusitalo et al. (2011) about value added of pine assortments.

The most valuable of the grades, grade four was set as a function of assortment log price and the other grades were set as a function of the previous grade with ranges shown in Table 8. Pricing was conducted independently for the two different solutions (Table 5). Contrary to assortment pricing where unit prices were the same in every stand, fractional stem pricing was solved individually per stand (the ranges of the value grade prices were kept constant). This way every stand could be considered as an individual timber sale.

Table 8. Chosen price ranges for the value grades of fractional stem pricing solutions presented in table 5. If a feasible solution (equal stand value with assortment pricing) is not found, the price of either grade four or three is fixed freely until a solution is reached.

	Solution 1	
Value grade	Lower bound	Upper bound
4	Log price (€) ÷ 0.95	Log price (€) ÷ 0.85
3	0.80 × price of grade 4	0.85 × price of grade 4
2	0.775 × price of grade 3	0.825 × price of grade 3
1	0.40 × price of grade 2	0.50 × price of grade 2
Treetop	always 1 € per m^3	
	Solution 2	
Value grade	Lower bound	Upper bound
4	Log price (€) ÷ 0.93	Log price (€) ÷ 0.85
3	0.80 × price of grade 4	0.85 × price of grade 4
2	0.55 × price of grade 3	0.60 × price of grade 3
1	0.50 × price of grade 2	0.55 × price of grade 2
Treetop	always 1 € per m^3	

Stem pricing

Like fractional stem pricing, pre-harvest estimated stem pricing was solved per stand and per tree species. As with the other pricing methods, the treetop of the stems (diameter under 6 cm) was always priced at 1 € per m^3. Since only the volumes of the stems affect the pricing, the stand values were set to equal the values via assortment pricing by using a simple formula (5), where everything except the stem price are known. This is, of course, only a theoretical way to determine stem pricing, since in a timber sales situation it can be very challenging to the buyer to determine what the maximum affordable price would be and to the seller to determine what the lowest acceptable price would be. If the volume estimations are significantly incorrect, the final stand value might be an unpleasant surprise to either the buyer or seller, depending on how sturdy the stems really were.

$$stem\ price\ \times\ stand\ volume\ (commercial\ wood) + treetop\ price\ of\ 1€\ \times\ treetop\ volumes\ of\ a\ stand = value\ of\ a\ stand\ via\ assortment\ pricing \quad (5)$$

3.7 Risk assessment

The relative monetary risks associated with switching from assortment pricing to an alternative pricing method are in this study derived directly from the calculated (actual) standwise timber sales values. This means that *x* percent higher timber sales value via fractional stem pricing than via assortment pricing implies that the relative monetary risk of *x* percent falls on the buyer, and *x* percent lower sales value in turn means that the relative monetary risk falls on the seller.

Relative stand value differences between the pricing methods are studied from the 27 study stands to determine the average relative monetary risks of switching away from assortment pricing. Aggregate stand value differences (over the 27 stands) between the pricing methods are also calculated for comparison. Relying only on average risk can at worst be quite misleading and therefore the ranges and standard deviations of the relative standwise value differences between the pricing methods were also considered.

Stand value ranges are not a very efficient way to evaluate overall monetary risks but are still somewhat useful information as they give an expectation on what might happen in the best/worst-case scenarios. Average risk and standard deviations, on the other hand, offer valuable information about overall monetary risk to both sales parties because they give an expectation on how the alternative pricing methods would behave in an individual/typical timber sales situation compared to assortment pricing.

4. Results

4.1. Stand volume results

The 27 study stands yielded the Trestima data-based volume estimates and harvester data-based actual stand volumes presented in Table 9. In total the 27 stands yielded 16804 m^3 in pre-harvest estimation and 15996 m^3 in actual stand volumes, but this difference is mostly due to the 744 m^3 of wood which was excluded from the calculations (explained in Chapter 3.1). In the actual stand volumes used in the stand value calculations, the tree species' shares of the total volume in the 27 stands were almost unchanged from estimations, both pine and spruce giving about one percentage away to birch. 50.6 percent (8100 m^3) of the actual total volume was spruce, 43.8 percent (7002 m^3) was pine and 5.6 percent (893 m^3) was birch.

Table 9. Estimated and actual stand volumes (m^3). Figures in parentheses are not counted into totals and are excluded from stand value calculations.

	Pre-harvest estimated volumes				Actual volumes					
Stand	Pine	Spruce	Birch	Total	Pine	Spruce	Birch	Other	Total	Excluded
1	166	515	-	681	126	601	(21)	-	727	(21)
2	754	241	-	995	524	375	(15)	-	899	(15)
3	-	561	65	626	(12)	460	84	(17)	544	(29)
4	95	1265	-	1361	218	1246	(43)	(51)	1464	(94)
5	672	-	-	672	646	(3)	(12)	-	646	(15)
6	93	1181	34	1308	241	1192	65	(11)	1499	(11)
7	1949	311	20	2279	1480	104	171	-	1755	-
8	150	817	62	1028	88	738	93	(97)	919	(97)
9	-	358	9	367	(4)	327	26	(41)	353	(45)
10	31	190	-	221	70	168	(3)	-	238	(3)
11	-	177	-	177	(2)	146	(7)	-	146	(9)
12	55	371	59	485	52	308	64	(206)	425	(206)
13	223	81	-	304	214	50	(8)	-	264	(8)
14	347	324	62	733	336	269	78	(1)	682	(1)
15	772	277	-	1049	620	210	(15)	(3)	830	(18)
16	400	-	-	400	358	(11)	(9)	(1)	358	(21)
17	139	427	53	619	172	303	91	-	566	-
18	496	-	-	496	400	(1)	(31)	-	400	(32)
19	115	327	24	465	94	242	11	-	347	-
20	63	379	-	442	46	340	(8)	-	386	(8)
21	397	46	-	442	382	139	(4)	-	521	(4)
22	-	305	-	305	(41)	277	(44)	(3)	277	(88)
23	198	-	-	198	160	(5)	(12)	-	160	(17)
24	38	55	-	92	33	60	(1)	-	93	(1)
25	49	182	146	377	183	228	165	-	576	-
26	71	80	11	163	57	63	10	-	130	-
27	253	236	28	518	503	252	36	(1)	790	(1)
Total	**7524**	**8708**	**572**	**16804**	**7002**	**8100**	**893**		**15996**	
Excluded					(59)	(20)	(233)	(432)		(744)

Even though the aim of the study was not to focus on the reliability of the Trestima data-based stand volume estimations themselves, it is useful to review how well the used model estimates the stand volumes. This simultaneously indicates whether the data itself is reliable and whether the model constructed works properly, as seen when five stands had to be discarded due to suspicious data (Chapter 3.1). When comparing the stand volumes (all tree species combined) estimated by the constructed model and the stand volume forecast given in the Trestima dataset, on average the Trestima forecast volumes were five percent lower than the volumes estimated by the model, and 1.7 percent higher than the actual stand volumes (Trestima-given volumes were not utilized in the pre-harvest estimation process, only mean characteristics and stemcount distribution series were). With total volume over all 27 stands, Trestima forecast volume (15957 m^3) was 5.0 percent lower than the estimated volume (16804 m^3), 0.2 percent lower than the actual volume used in stand value calculations (15996 m^3) and 4.7 percent lower than the combined volume of excluded and included wood (16740 m^3). The estimated stand volumes in turn were on average 7.2 percent higher than the actual stand volumes used in stand value calculations. It is however to be noted that with total volume over all 27 stands, the pre-harvest estimated volume was only 5.1 percent higher than the actual used volume, and if the excluded wood is taken into account, only 0.4 percent higher (Table 10).

All in all, Trestima measurements appear to describe stand volumes quite accurately, but misidentification of the tree species seems to be quite common, at least among this study's data set. Trestima forecast's ratio to aggregate estimated and actual stand volumes, however, indicates that in relation to this study's objectives, the model performs well enough to justify its use as a basis in the stand value calculations, since the differences between the Trestima-forecast and estimated and actual total volume over all 27 stands is relatively small. The same ratios also indicate that the pre-harvest data in the final dataset of 27 study stands describes the stands well enough to conduct the stand value comparisons.

Table 10. Ratios of estimated and actual stand volumes (pine, spruce and birch combined). *Estimated volumes divided by actual stand volumes

Stand	Estimated / Actual used stand volume(s)*	Estimated / Actual stand volume(s) with excluded wood*
1	0.937	0.910
2	1.106	1.088
3	1.151	1.093
4	0.929	0.873
5	1.040	1.017
6	0.873	0.866
7	1.299	1.299
8	1.119	1.012
9	1.040	0.920
10	0.929	0.919
11	1.210	1.145
12	1.140	0.767
13	1.152	1.116
14	1.075	1.074
15	1.264	1.238
16	1.116	1.058
17	1.093	1.093
18	1.240	1.148
19	1.340	1.340
20	1.143	1.119
21	0.849	0.842
22	1.104	0.836
23	1.242	1.123
24	0.991	0.984
25	0.654	0.654
26	1.249	1.249
27	0.655	0.655
On average	1.072	1.016
Total volume over all 27 stands	1.051	1.004

4.2 Stand value results

The actual stand values with the three pricing methods, and the mutual estimated stand values are presented in Tables 11 and 12. Spruce yielded the highest aggregate value over the 27 stands with all pricing methods, as it should as about a half of the harvested wood was spruce and it had the highest log price. Over the whole dataset of 27 stands, estimated aggregate value of the stands via assortment pricing was ten percent higher than actual aggregate value of the stands via assortment pricing, which is partly due to the 744 m^3 of excluded wood but also because the average mean diameter (unweighted) is about 2 centimeters sturdier in the Trestima-data than in the harvester-data, and therefore stem profiles in estimated stands tend to yield slightly larger volumes and monetary values than in actual stands. Actual aggregated stand values over the 27 stands yielded 844109 euros with assortment pricing, 871274 euros with stem pricing, 860303 euros with fractional stem pricing solution 1 and 852107 euros with fractional stem pricing solution 2. Assortment pricing does not yield the highest value in any of the study stands with either of the fractional stem pricing solutions, while stem pricing yields the highest value in most of the study stands (Table 13). Solved standwise and tree species-specific stem and fractional stem prices are shown in Table 14. Mean stem price was 55.9 euros for pine, 56.2 euros for spruce and 30 euros for birch. Mean for grade 4 with fractional stem pricing solution 1 was 71.5 euros for pine, 70.8 euros for spruce and 50.6 euros for birch. Respectively, mean for grade 4 with fractional stem pricing solution 2 was 74.3 euros for pine, 73.5 euros for spruce and 51.7 euros for birch.

Table 11. Stand values (€).

Stand	Tree Species	Pre-harvest estimation	Assortment pricing	Fractional stem pricing 1	Fractional stem pricing 2	Stem pricing
1	Pine	9752	7065	6806	6690	7391
1	Spruce	28762	31903	32008	31409	33423
2	Pine	43615	28615	27825	27305	30230
2	Spruce	14062	20524	20571	20327	21797
3	Spruce	32226	25108	24988	24723	26341
3	Birch	1863	2385	2274	2312	2382
4	Pine	5674	12925	12879	12865	12977
4	Spruce	76678	75932	77546	77862	75523
5	Pine	37610	33032	32835	31350	35968
6	Pine	5175	14126	15947	16446	13409
6	Spruce	68244	69228	70537	70646	68882
6	Birch	939	1908	1956	1974	1819
7	Pine	107509	72601	74068	70703	81011
7	Spruce	16642	3956	4193	3868	5397
7	Birch	334	3285	3313	3322	3026
8	Pine	8912	5007	4856	4742	5235
8	Spruce	48225	41046	41198	40368	43434
8	Birch	1708	2531	2544	2561	2546
9	Spruce	20361	17320	17275	16890	18511
9	Birch	333	754	802	754	950
10	Pine	1795	3855	3984	3885	4005
10	Spruce	10153	8116	8590	8332	8931
11	Spruce	9990	8690	9489	9647	8279
12	Pine	2992	2910	3083	3126	2871

Stand	Tree Species	Pre-harvest estimation	Assortment pricing	Fractional stem pricing 1	Fractional stem pricing 2	Stem pricing
12	Spruce	19615	15946	16965	16634	16261
12	Birch	1871	1639	1803	1674	2029
13	Pine	12649	12218	12763	12854	12146
13	Spruce	4366	2415	2624	2619	2673
14	Pine	18655	19289	20852	21929	18073
14	Spruce	17536	14503	15101	15260	14533
14	Birch	2203	2597	2495	2522	2746
15	Pine	45259	35828	34696	34540	36271
15	Spruce	16745	11755	11934	11709	12644
16	Pine	19083	15832	16371	15831	17036
17	Pine	7642	8724	9014	8543	9399
17	Spruce	21632	15131	15900	16186	15305
17	Birch	1145	2354	2111	2254	1940
18	Pine	24712	17565	18664	17929	19928
19	Pine	6320	5389	5698	5813	5191
19	Spruce	17266	14120	14425	15037	12847
19	Birch	706	410	397	409	328
20	Pine	3263	2434	2491	2565	2412
20	Spruce	21028	19024	19570	19685	18854
21	Pine	22777	22192	22260	22266	21954
21	Spruce	2643	8229	8742	8702	8028
22	Spruce	15205	13329	13338	13230	13731
23	Pine	10960	8647	8466	8530	8813
24	Pine	2131	1856	1822	1830	1867
24	Spruce	3057	3329	3373	3325	3359
25	Pine	2538	9450	9927	9843	9460
25	Spruce	9947	11904	12184	11938	12407
25	Birch	4461	4024	4096	3943	5011
26	Pine	3878	3303	3570	3626	3118
26	Spruce	4617	3245	3238	3107	3636
26	Birch	320	301	275	296	272
27	Pine	14607	29611	30283	30348	29002
27	Spruce	13551	13678	14188	13984	14394
27	Birch	1025	1013	1098	1037	1272

Table 12. Aggregate stand values (€).

Stand	Pre-harvest estimation	Assortment pricing	Fractional stem pricing 1	Fractional stem pricing 2	Stem pricing
1	38514	38968	38814	38099	40814
2	57677	49139	48395	47632	52027
3	34089	27493	27262	27035	28722
4	82352	88857	90426	90727	88500
5	37610	33032	32835	31350	35968
6	74358	85262	88441	89066	84110
7	124484	79842	81573	77894	89433
8	58846	48584	48598	47670	51215
9	20694	18074	18077	17644	19461
10	11948	11971	12574	12217	12937
11	9990	8690	9489	9647	8279
12	24478	20496	21851	21435	21161
13	17015	14633	15387	15473	14819
14	38394	36389	38448	39712	35352
15	62004	47583	46631	46249	48915
16	19083	15832	16371	15831	17036
17	30419	26209	27025	26984	26643
18	24712	17565	18664	17929	19928
19	24292	19920	20519	21260	18366
20	24291	21459	22061	22250	21265
21	25419	30422	31002	30969	29981
22	15205	13329	13338	13230	13731
23	10960	8647	8466	8530	8813
24	5188	5185	5194	5156	5226
25	16946	25378	26207	25724	26878
26	8814	6849	7083	7029	7026
27	29183	44302	45569	45368	44668
Total	926968	844109	860303	852107	871274

Table 13. Stand value rankings between the pricing methods.

Pricing method	Number of stands with the highest value	Number of stands with the lowest value
With fractional stem pricing solution 1		
Assortment pricing	0	14
Fractional stem pricing	12	6
Stem pricing	15	7
With fractional stem pricing solution 2		
Assortment pricing	0	8
Fractional stem pricing	12	12
Stem pricing	15	7

Table 14. Solved stem prices and fractional stem price grades (€).

		Fractional stem pricing solution 1 grades				Fractional stem pricing solution 2 grades				Stem price
Stand	Species	4	3	2	1	4	3	2	1	-
1	Pine	67.2	57.1	46.5	20.9	67.7	57.5	33.0	18.2	59.1
1	Spruce	70.3	59.8	48.8	21.8	73.1	62.2	35.4	17.7	56.2
2	Pine	69.2	58.8	47.4	21.1	70.6	60.0	33.8	16.9	58.1
2	Spruce	71.5	60.8	47.1	20.5	72.3	61.5	34.8	19.2	58.6
3	Spruce	70.9	60.3	46.7	20.5	72.2	61.4	34.9	17.4	57.8
3	Birch	50.5	35.5	27.5	11.0	51.6	41.4	22.8	11.7	29.0
4	Pine	66.3	54.6	44.8	20.2	67.7	54.0	29.7	14.9	59.6
4	Spruce	68.4	56.7	44.0	19.8	69.9	55.4	30.5	15.2	60.8
5	Pine	71.5	60.8	50.2	21.5	74.1	63.0	36.5	20.1	56.3
6	Pine	74.1	63.0	52.0	22.0	77.3	65.7	39.4	21.7	55.8
6	Spruce	69.1	58.8	48.0	21.6	71.0	60.3	34.5	19.0	58.1
6	Birch	50.5	40.6	31.5	12.8	51.6	43.9	25.5	14.0	28.6
7	Pine	72.1	61.3	50.6	21.6	74.5	63.4	38.0	20.9	55.5
7	Spruce	72.1	61.3	47.5	20.8	72.8	61.9	35.6	19.6	53.9
7	Birch	50.5	40.3	31.3	12.5	52.8	44.9	26.9	14.8	19.0
8	Pine	66.3	53.8	44.2	19.9	67.0	54.5	30.0	15.0	59.6
8	Spruce	68.4	57.0	46.8	21.1	69.9	57.8	33.3	16.6	59.3
8	Birch	50.5	39.8	30.8	12.3	51.6	43.6	25.1	13.8	28.2
9	Spruce	70.1	59.6	48.6	21.7	72.5	61.6	35.0	17.5	57.2
9	Birch	50.5	41.2	33.8	15.2	51.6	43.8	25.2	12.6	37.7
10	Pine	71.6	60.9	47.2	20.0	71.2	60.5	34.0	18.7	57.7
10	Spruce	72.2	61.3	50.6	22.2	75.7	64.3	37.9	20.8	53.9
11	Spruce	72.8	61.8	50.9	22.2	75.4	64.1	36.4	18.2	56.9
12	Pine	74.1	63.0	51.0	25.5	77.6	65.9	39.6	21.8	55.2
12	Spruce	71.8	61.0	50.4	22.2	75.0	63.8	37.2	18.6	53.4
12	Birch	50.5	40.5	31.4	14.4	51.6	43.7	25.1	12.6	32.2

		Fractional stem pricing solution 1 grades				Fractional stem pricing solution 2 grades				Stem price
Stand	Species	4	3	2	1	4	3	2	1	-
13	Pine	70.9	60.3	49.4	21.4	73.2	62.2	35.2	19.3	57.0
13	Spruce	72.5	61.6	50.9	22.4	76.7	65.2	39.1	21.5	54.3
14	Pine	74.1	63.0	52.0	23.9	79.2	67.3	40.4	22.2	54.1
14	Spruce	71.4	60.7	50.1	22.0	75.7	64.3	37.5	18.8	54.5
14	Birch	50.5	36.7	28.5	11.4	51.1	40.9	22.5	11.2	35.8
15	Pine	67.0	56.9	46.4	20.9	67.9	57.8	33.1	16.6	58.8
15	Spruce	68.4	56.0	46.0	20.7	69.9	56.1	30.8	15.5	60.6
16	Pine	72.7	61.8	51.0	22.9	81.2	69.0	41.4	22.8	48.4
17	Pine	74.1	63.0	52.0	22.7	75.5	64.2	38.5	21.2	55.5
17	Spruce	72.4	61.6	50.8	22.5	78.0	66.3	39.8	21.9	51.3
17	Birch	50.5	35.1	27.2	10.9	51.6	42.3	23.3	12.8	22.2
18	Pine	74.1	63.0	51.9	25.9	83.8	71.2	42.7	23.5	50.8
19	Pine	73.1	62.1	51.3	21.7	75.6	64.2	38.5	21.2	55.5
19	Spruce	70.4	59.8	49.3	21.9	75.0	63.8	37.5	18.7	53.3
19	Birch	50.5	39.7	30.8	12.3	51.6	42.4	24.4	13.4	30.1
20	Pine	74.1	63.0	50.9	25.4	80.5	68.4	41.1	20.5	52.6
20	Spruce	71.2	60.5	49.8	22.0	74.6	63.4	36.3	18.1	55.8
21	Pine	70.3	59.8	46.3	19.9	70.7	60.1	33.9	18.6	57.7
21	Spruce	73.0	62.1	50.7	22.1	74.2	63.0	35.4	17.7	58.0
22	Spruce	68.5	58.2	47.8	21.5	74.0	62.9	36.6	18.6	50.5
23	Pine	72.8	61.9	51.1	21.6	75.9	64.5	38.7	21.3	55.6
24	Pine	71.2	60.5	46.9	20.1	72.0	61.2	34.5	19.0	57.1
24	Spruce	72.2	61.3	50.5	22.2	74.5	63.3	35.9	18.0	56.3
25	Pine	74.5	63.4	52.3	26.1	79.6	67.7	40.6	22.3	52.3
25	Spruce	71.2	60.5	49.7	22.1	74.5	63.3	35.8	17.9	55.0
25	Birch	50.5	37.7	29.2	11.7	51.6	42.2	23.2	12.8	31.1
26	Pine	74.1	63.0	52.0	23.1	76.5	65.1	38.8	21.4	54.7
26	Spruce	69.0	58.6	47.9	21.6	70.7	60.1	34.3	17.2	58.0
26	Birch	50.5	38.5	29.8	11.9	51.6	42.8	24.6	12.3	28.9
27	Pine	69.2	58.8	45.6	19.9	69.7	59.2	33.6	18.5	57.9
27	Spruce	70.2	59.6	48.6	21.7	72.5	61.6	35.0	17.5	57.7
27	Birch	50.9	43.3	33.6	15.1	52.1	44.3	25.4	14.0	37.0
Mean	Pine	71.5	60.6	49.3	22.1	74.3	62.9	36.7	19.8	55.9
Mean	Spruce	70.8	60.0	48.8	21.6	73.5	62.1	35.6	18.3	56.2
Mean	Birch	50.6	39.1	30.4	12.6	51.7	43.0	24.5	13.0	30.0

4.3 Risk assessment of the pricing methods

Table 15 shows the relative standwise value differences when comparing fractional stem pricing to assortment pricing and stem pricing to assortment pricing. Over the whole dataset of 27 stands fractional stem pricing yields 1.9 percent higher stand values with solution 1 and 0.9 percent higher stand values with solution 2 than assortment pricing. On average fractional stem pricing yields 2.3 percent higher stand values with solution 1 and 1.4 percent higher stand values with solution 2 than assortment pricing. Stem pricing in turn yields over all the stands 3.2 percent higher stand values and on average 3.1 percent higher stand values than assortment pricing. Based only on the figures above, it seems that on average, switching from assortment pricing to the presented alternative pricing methods yields slightly higher stand values, and the relative monetary risk lies with the buyer.

If the results regarding the relative monetary risk between alternative pricing methods and assortment pricing were to be generalized to help decision-making in an isolated timber sales situation, relying solely on average risk can, at worst, be quite misleading and therefore the ranges and standard deviations of the aggregated relative standwise value differences between pricing methods were also viewed. When changing from assortment pricing to stem pricing, the range of the relative monetary risk on the 27 study stands was 21.3 percent points (from -7.8 percent to 13.5 percent), and the standard deviation was 4.8 percent points. In turn, when switching from assortment pricing to fractional stem pricing, the range of the relative monetary risk was 11.3 percent points (from -2.1 percent to 9.2 percent) with solution 1 and 16.1 percent points (from -5.1 percent to 11 percent) with solution 2. The standard deviation was 2.8 percent points with solution 1 and 3.8 percent points with solution 2.

Table 15. Relative stand value differences (actual stand value ratios to assortment pricing).

Stand	Fractional stem pricing 1	Fractional stem pricing 2	Stem pricing
1	0.996	0.978	1.047
2	0.985	0.969	1.059
3	0.992	0.983	1.045
4	1.018	1.021	0.996
5	0.994	0.949	1.089
6	1.037	1.045	0.986
7	1.022	0.976	1.120
8	1.000	0.981	1.054
9	1.000	0.976	1.077
10	1.050	1.020	1.081
11	1.092	1.110	0.953
12	1.066	1.046	1.032
13	1.052	1.057	1.013
14	1.057	1.091	0.972
15	0.980	0.972	1.028
16	1.034	1.000	1.076
17	1.031	1.030	1.017
18	1.063	1.021	1.135
19	1.030	1.067	0.922
20	1.028	1.037	0.991
21	1.019	1.018	0.986
22	1.001	0.993	1.030
23	0.979	0.986	1.019
24	1.002	0.994	1.008
25	1.033	1.014	1.059
26	1.034	1.026	1.026
27	1.029	1.024	1.008
Average	**1.023**	**1.014**	**1.031**
Min	0.979	0.949	0.922
Max	1.092	1.110	1.135
Range	0.113	0.161	0.213
Standard deviation	0.028	0.038	0.048

Aggregated (actual) stand values' ratios to assortment pricing			
Pre-harvest estimation	Fractional stem pricing 1	Fractional stem pricing 2	Stem pricing
1.098	**1.019**	**1.009**	**1.032**

Tree species-specific average value ratios, ranges and standard deviations between pricing methods shown in Table 16 are in line with aggregated results described in Table 15. Spruce's stem pricing ratio to assortment pricing ranges up to 45 percent points (from -9 percent to 36 percent) with average ratio being 4.5 percent higher values via stem pricing than assortment pricing, and standard deviation being 8.4

percent points. Corresponding figures with pine are only 20 percent points (from -6 percent to 14 percent), 2.0 percent and 5.3 percent points.

Fractional stem pricing for solution 1 yielded ratios (to assortment pricing) of 2.4 percent for pine and 3.0 percent for spruce, with pine’s range and standard deviation being 17 percent points (from -4 percent to 13 percent) and 4.2 percent points, and spruce’s 9.7 percent points (from -0.5 percent to 9.2 percent) and 2.9 percent points. Solution 2 yielded practically the same average price ratio to assortment pricing for pine and spruce, varying from 1.9 to 2.0 percent. Pine has larger price ratio range and standard deviation with 21.7 percent points (from -5.3 percent to 16.4 percent) and 5.9 percent points, while Spruce’s corresponding figures are 15 percent points (from -4 to 11 percent) and 3.9 percent points.

Stem pricing’s average ratio to assortment pricing with birch was 3.9 percent, and price ratio range and standard deviation were 46 percent points (from -20 percent to 26 percent) and 16.4 percent points. Fractional stem pricing yielded value ratio range of 20 percent points (from -10 percent to 10 percent) and standard deviation of 6.1 percent points with solution 1. Solution 2 yielded value ratio range of 8 percent points (from -4 percent to 4 percent) and standard deviation of 2.3 percent points. On average birch’s fractional stem pricing (both solutions) yielded practically the same stand values as with assortment pricing.

If fractional stem pricing’s aggregate relative stand value difference to assortment pricing (1.9 and 0.9 percent higher stand values via fractional stem pricing solutions 1 and 2) is compared with the corresponding figure of the study by Korpunen et al. (2016), the results are quite similar. As mentioned in Chapter 1, based on their results, aggregate stand value comparison yielded 0.6 percent higher value with fractional stem pricing than with assortment pricing. The similarity between the results is to be expected as both studies utilize Luke’s fractional stem pricing proposition and this study’s value grade prices were determined by using Korpunen et al. (2016) and Luke’s fractional stem pricing solution’s value grade price ratios as a basis for the chosen ranges in Table 8.

Table 16. Tree species specific relative stand value differences (actual stand value average ratios to assortment pricing).

	Pine			Spruce			Birch		
Stand	Frac. stem pricing 1	Frac. stem pricing 2	Stem pricing	Frac. stem pricing 1	Frac. stem pricing 2	Stem pricing	Frac. stem pricing 1	Frac. stem pricing 2	stem pricing
1	0.963	0.947	1.046	1.003	0.985	1.048	-	-	-
2	0.972	0.954	1.056	1.002	0.990	1.062	-	-	-
3	-	-	-	0.995	0.985	1.049	0.953	0.969	0.999
4	0.996	0.995	1.004	1.021	1.025	0.995	-	-	-
5	0.994	0.949	1.089	-	-	-	-	-	-
6	1.129	1.164	0.949	1.019	1.020	0.995	1.025	1.035	0.953
7	1.020	0.974	1.116	1.060	0.978	1.364	1.008	1.011	0.921
8	0.970	0.947	1.046	1.004	0.983	1.058	1.005	1.012	1.006
9	-	-	-	0.997	0.975	1.069	1.064	1.000	1.260
10	1.033	1.008	1.039	1.058	1.027	1.100	-	-	-
11	-	-	-	1.092	1.110	0.953	-	-	-
12	1.059	1.074	0.987	1.064	1.043	1.020	1.100	1.021	1.237
13	1.045	1.052	0.994	1.087	1.085	1.107	-	-	-
14	1.081	1.137	0.937	1.041	1.052	1.002	0.961	0.971	1.057
15	0.968	0.964	1.012	1.015	0.996	1.076	-	-	-
16	1.034	1.000	1.076	-	-	-	-	-	-
17	1.033	0.979	1.077	1.051	1.070	1.012	0.897	0.958	0.824
18	1.063	1.021	1.135	-	-	-	-	-	-
19	1.057	1.079	0.963	1.022	1.065	0.910	0.967	0.997	0.799
20	1.023	1.054	0.991	1.029	1.035	0.991	-	-	-
21	1.003	1.003	0.989	1.062	1.057	0.975	-	-	-
22	-	-	-	1.001	0.993	1.030	-	-	-
23	0.979	0.986	1.019	-	-	-	-	-	-
24	0.982	0.986	1.006	1.013	0.999	1.009	-	-	-
25	1.051	1.042	1.001	1.024	1.003	1.042	1.018	0.980	1.245
26	1.081	1.098	0.944	0.998	0.958	1.120	0.914	0.982	0.904
27	1.023	1.025	0.979	1.037	1.022	1.052	1.084	1.024	1.256
Average	1.024	1.019	1.020	1.030	1.020	1.045	1.000	0.997	1.039
Min	0.963	0.947	0.937	0.995	0.958	0.910	0.897	0.958	0.799
Max	1.129	1.164	1.135	1.092	1.110	1.364	1.100	1.035	1.260
Range	0.166	0.217	0.198	0.097	0.153	0.455	0.203	0.077	0.461
Standard deviation	0.042	0.059	0.053	0.029	0.039	0.084	0.061	0.023	0.164

5. Analysis of the results

This chapter aims to explain what leads to the results that were obtained in the previous chapter. The analysis focuses on how stand characteristics (mainly log percentage) can be used to explain how the stand values form between the different pricing methods, and how the results could be generalized and utilized in timber sales related decision-making situations.

5.1 Stand volumes

Even though including the excluded wood would practically eliminate the total volume estimation error over the 27 stands, standwise errors still vary as seen in Table 10. Based on the used stand characteristics and computing models, the number of factors to consider when discussing the reasons for volume and stem profile estimation errors is quite limited. Either the stem number, stand evenness (diameter deviation), the overall sturdiness of the stand or their combination must be the causes for volume estimation errors.

Stem number estimation errors alone is an inefficient way to explain volume estimation errors since stem number does not give any information about stem volumes. Only about a half of study stands' (all tree species combined) standwise stem numbers follow a trend where an under-estimated stem number would consistently lead to underestimated volume and overestimated stem number to over-estimated volume.

In contrast, comparing estimated and actual stem number distribution is extremely useful because it simultaneously indicates how well the number of stems and their placement to diameter classes is estimated. This comparison reveals whether the stand evenness and/or the overall sturdiness of the stand explains the estimation errors in the study stands. One way of trying to explain volume estimation errors is to study the stem number distribution's changes (from estimations) via standwise mean diameter's standard deviations. In this context stand evenness means that while volume estimation error exists, either the estimated or the actual stands have higher mean diameter's standard deviation and/or higher number of diameter classes than the other. If overall sturdiness (the size of the stems) estimation is off by far, it suggests that Trestima data-based diameter class distribution is severely incorrect.

Both the estimated and actual stands were quite even, which is to be expected as all stands were clearcut. Based on the Trestima-measured stem number distributions over the 27 stands, mean diameters' standard deviation was on average 4.7 centimeters. Mean diameters' standard deviation over the actual 27 stands was on average 6.5 centimeters. Even though this average difference of about 2 centimeters exists, mean diameters' standard deviation over the 27 stands does not seem to explain the difference between the estimated and realized stand volumes, since as seen in Figure 4, no linear relation between tree species-specific standwise mean diameters' standard deviation differences and volume estimation errors exists (weak R^2 and regression line has wrong sign). Using real values instead of absolute values or using second order fit in the regression analysis does not improve R^2 significantly, as the datapoints in Figure 4 seem to be placed almost randomly. In other words, the volume estimation error does not seem to increase when mean diameter's standard deviation does so.

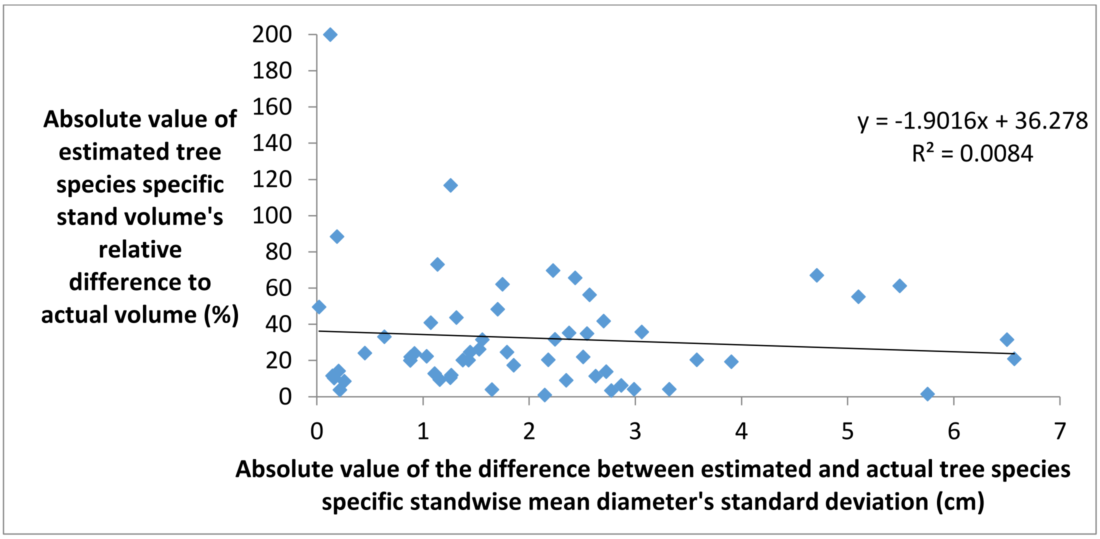

Figure 4. Linear regression between tree species-specific standwise mean diameters' standard deviation and volume estimation errors.

The actual stands' slightly higher average mean diameter's standard deviation is a result of every stand having more diameter classes in the harvester-data based stem number distribution than its counterpart in the pre-harvest data. In other words, Trestima seems to centralize diameter distribution. Harvester-based diameter distribution had consistently more stems in smaller and sturdier diameter classes than Trestima-based diameter distribution. Essentially, this means that unevenness of either the estimated or the actual stands did not directly cause the volume estimation errors, but diameter distribution was sometimes poorly described by Trestima, and therefore the overall sturdiness of the estimated stands were sometimes a bit off compared to the actual stands. This is also visible when looking at the stem number distribution of the stands with the highest volume estimation errors: the overall sturdiness (and therefore mean diameter) and in some cases the total stem number was poorly measured by Trestima, but the stand unevenness was hardly ever to blame for the volume estimation errors.

Tree species-specific volume estimation errors were quite large in some stands because Trestima had apparently misidentified and allocated some of the volume to another tree species. These errors were evened out and diminished quite much when aggregated volumes and estimation errors were calculated. This is quite visible when looking at the tree species' shares of the total volume in the 27 stands, which were almost unchanged from the estimations. As noted in chapter 4.2, on average the stems are larger/sturdier in the Trestima-data than in the harvester-data, and with the excluded wood, they seem to be the reasons for that estimated stands tend to yield slightly larger volumes than actual stands.

5.2 Stand values

The difference between estimated and actual stand volumes itself does not lead to differences in stand values between pricing methods, but it is inevitable that the value grade and assortment recovery will also change when the stand volume is over- or underestimated because the stem profiles behind the calculations have also been changed. Because pre-harvest stand values between the pricing methods were set to be equal, the actual stand values between the pricing methods change in relation to each other as standwise assortment and value grade recovery changes from estimated recovery to actual recovery and the unit prices are kept constant. As these allocation changes create the stand value differences between pricing methods, it is useful to study how the stem profiles change from estimated to actual.

The effects of stem profile changes can be compared e.g. via stand log percentage (log recovery divided by total volume). Log percentage is a simple and effective way to describe an individual stand's value potential because log unit prices are usually about three times the value of pulpwood unit prices, and therefore log percentage simultaneously indicates how stem profiles (sturdiness) and stand value compare to the corresponding pre-harvest estimates. Mean diameters are also good indicators of the overall sturdiness but do not explain stand values as unambiguously and easily as log recovery. Table 17 shows the difference between estimated and actual stand log percentages and assortment allocation in general (all tree species aggregated). Average estimated log percentage was 76 and average actual log percentage was 72.

When the log percentage of assortment pricing changes, it is practically certain that the value grade allocation of fractional stem pricing also changes, and that the direction of value changes in relation to stand sturdiness changes is the same in both pricing methods. Therefore, log percentage can be used to describe stand structure or sturdiness changes in all three pricing methods. Using the log percentage simplifies the pricing method comparisons as only a single indicator is used.

Table 17. Standwise log percentages and assortment allocation. Percentages of total standwise wood yield.

	Pre-harvest estimation			Actual		
Stand	Logs	Small-sized logs	Pulpwood	Logs	Small-sized logs	Pulpwood
1	80.2	10.8	8.3	72.2	17.2	9.6
2	86.6	4.7	8.3	76.9	12.7	9.6
3	76.0	10.6	12.7	67.6	13.9	17.4
4	89.4	4.9	5.4	90.1	4.6	5.0
5	82.7	6.5	10.2	70.2	14.6	14.1
6	80.5	10.2	8.7	81.7	8.6	9.2
7	78.5	9.9	10.9	57.2	17.2	23.4
8	83.0	6.2	10.4	72.7	10.8	15.5
9	79.1	11.9	8.4	67.1	18.1	13.6
10	72.9	16.6	9.6	64.4	21.4	12.9
11	78.5	14.0	6.9	86.5	6.2	6.9
12	67.3	16.7	14.9	62.1	15.3	21.3
13	81.1	8.7	9.6	80.5	7.2	11.5
14	72.9	14.5	11.8	76.9	8.0	14.3
15	89.3	3.2	7.2	84.9	6.1	8.4
16	60.6	24.6	13.5	51.6	29.2	17.4
17	62.7	19.0	17.0	58.9	15.5	23.7
18	66.9	18.1	13.1	51.3	28.2	18.7
19	69.8	18.4	10.9	83.3	8.6	7.6

	Pre-harvest estimation			Actual		
Stand	Logs	Small-sized logs	Pulpwood	Logs	Small-sized logs	Pulpwood
20	75.2	16.2	7.9	76.7	14.3	8.2
21	86.0	4.8	8.8	87.2	5.9	6.5
22	61.9	23.1	13.6	58.0	25.3	15.0
23	80.7	8.9	9.8	77.4	12.9	8.8
24	80.2	10.9	8.3	78.5	12.5	8.3
25	61.0	8.8	29.1	55.2	13.1	30.3
26	76.7	10.8	11.8	73.6	10.3	15.1
27	82.8	6.7	9.8	82.2	6.9	10.2
Average	76.4	11.8	11.0	72.0	13.5	13.4

Figure 5 shows that when the log percentage estimation error increases, stand value difference between stem pricing and assortment pricing also increases. When actual log recovery decreased from the estimated log recovery, stem pricing was more profitable than assortment pricing every time (Figure 6), and 15 out of 20 times more profitable than fractional stem pricing (both solutions). When log recovery increased from the estimated log recovery, stem pricing was always the least profitable of all pricing methods.

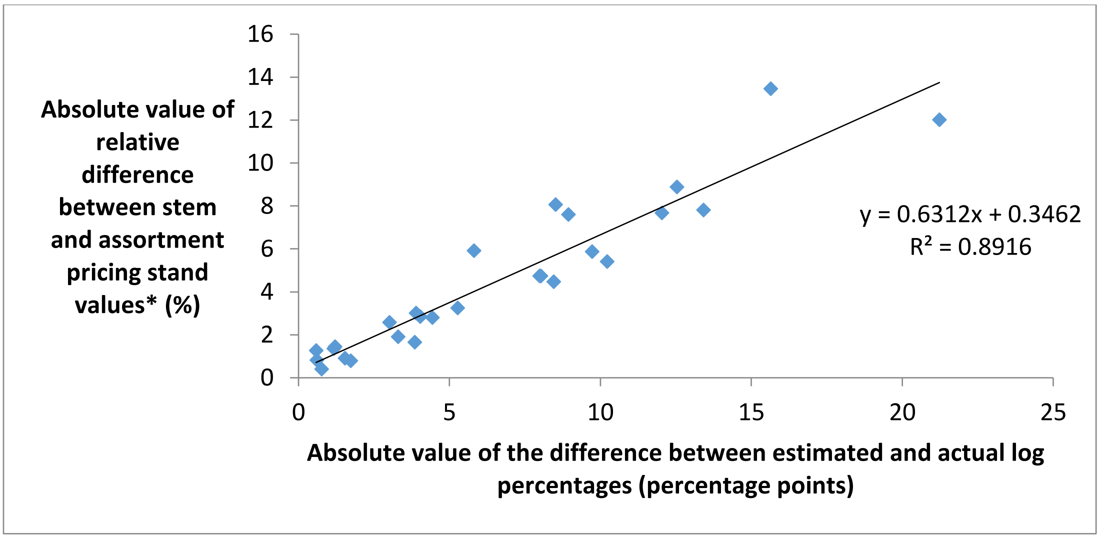

Figure 5. Linear regression between log percentage estimation error and stand value differences of stem and assortment pricing (absolute values). *Stand values with stem pricing divided by stand values with assortment pricing (absolute value).

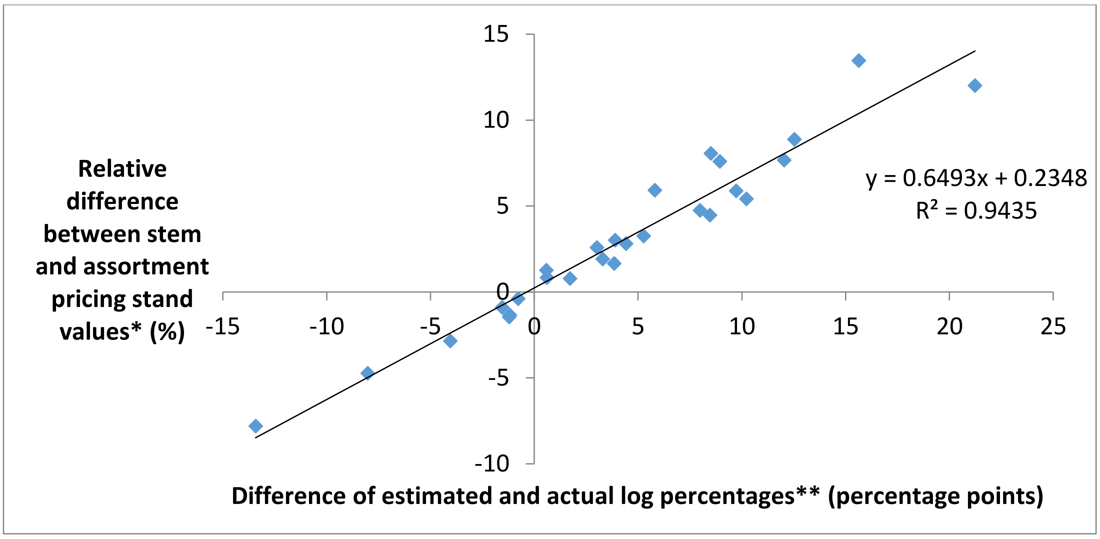

Figure 6. Linear regression between log percentage differences (estimated and actual) and relative stand value differences of stem and assortment pricing. *Stand values with stem pricing divided by stand values with assortment pricing. **Actual log percentages subtracted from estimated log percentages.

Figure 7 shows that when the log percentage estimation error increases, the actual stand value difference between fractional stem pricing and assortment pricing does not necessarily increase (R^2 = only 0.0007, and second using order fit does not improve the situation significantly), meaning that the relationship between log recovery and stand value differences between fractional stem pricing and assortment pricing is not as straightforward as with stem pricing. However, clear relationship is found when comparison is performed with real values instead of absolute values (Figure 8). When log recovery increased from the estimated log recovery, fractional stem pricing was more profitable than assortment pricing (Figure 8) or stem pricing every time. When log recovery decreased, assortment pricing was more profitable than fractional stem pricing 6 (solution 1) and 12 (solution 2) out of 20 times.

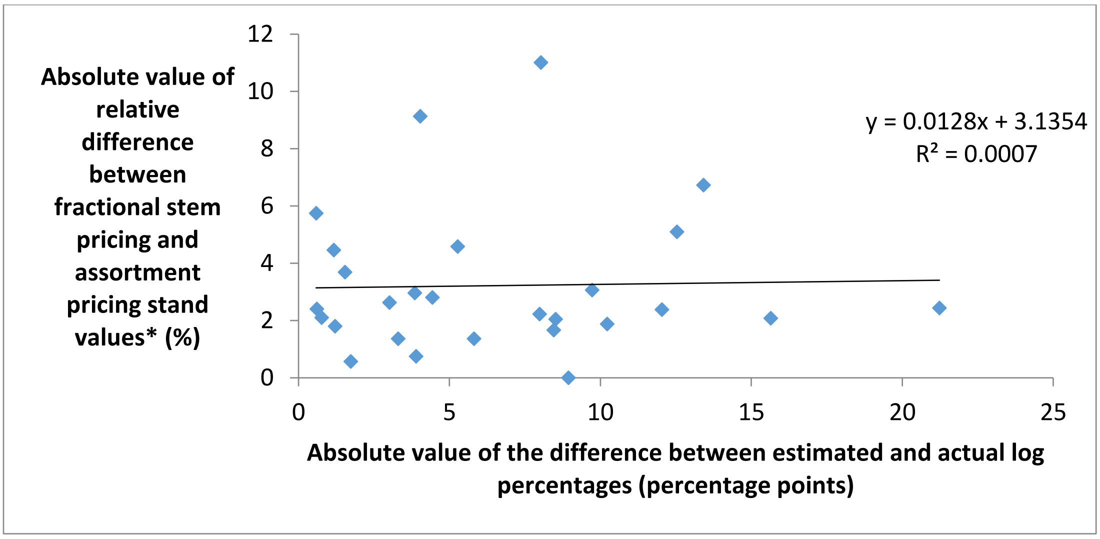

Figure 7. Linear regression between log percentage estimation error and stand value differences of fractional stem pricing (solution 2) and assortment pricing (absolute values). *Stand values with fractional stem pricing (solution 2) divided by stand values with assortment pricing (absolute value).

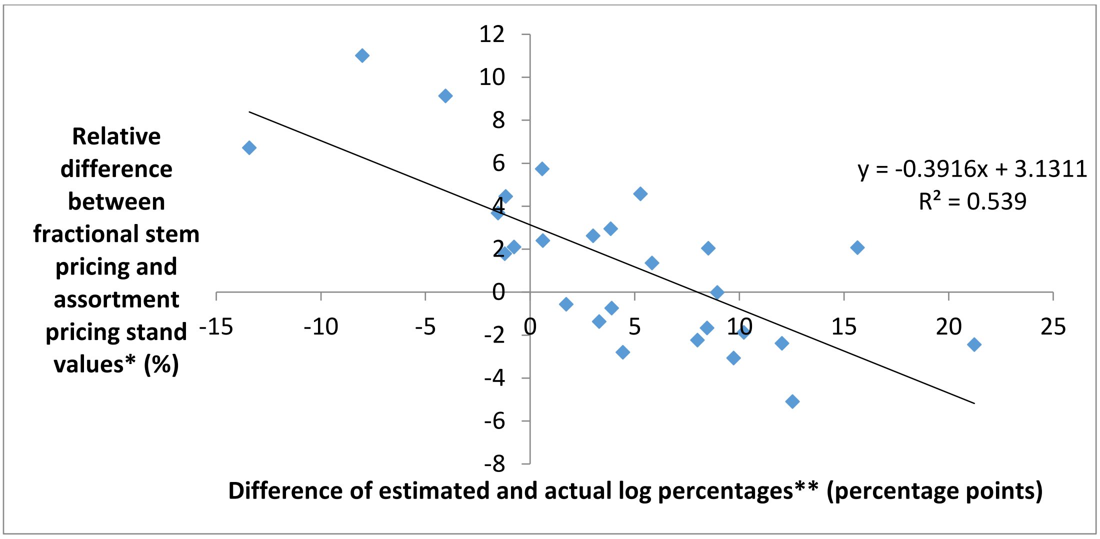

Figure 8. Linear regression between log percentage differences (estimated and actual) and relative stand value differences of fractional stem pricing (solution 2) and assortment pricing. *Stand values with fractional stem pricing (solution 2) divided by stand values with assortment pricing. **Actual log percentages subtracted from estimated log percentages.

Log percentage changes from estimated and stand value relationships between pricing methods are presented in Table 18 (with fractional stem pricing solution 2). Notably, there are a couple of stands where log recovery decreased from the estimated log recovery and stem pricing was not more profitable than fractional stem pricing (stands 12, 13, 17, 26 and 27). This probably means that in such a stand, the estimated and actual stand differ from each other so much that the stand valuation does not form as expected. Figure 9 shows an example from stand 12 (spruce), where it is clearly visible that the estimated and actual stand are quite different.

Table 18. Effect of log percentage changes (from estimation) on pricing method stand value ratios. *Highest value = 1, Lowest value = 3. Rankings with fractional stem pricing solution 2.

	Log percentage			Actual stand value rankings*		
Stand	Pre-harvest	Actual	Direction	Fractional stem pricing	Stem pricing	Assortment pricing
1	80.2	72.2	Drop	3	1	2
2	86.6	76.9	Drop	3	1	2
3	76.0	67.6	Drop	3	1	2
4	89.4	90.1	Rise	1	3	2
5	82.7	70.2	Drop	3	1	2
6	80.5	81.7	Rise	1	3	2
7	78.5	57.2	Drop	3	1	2
8	83.0	72.7	Drop	3	1	2
9	79.1	67.1	Drop	3	1	2
10	72.9	64.4	Drop	2	1	3
11	78.5	86.5	Rise	1	3	2
12	67.3	62.1	Drop	1	2	3
13	81.1	80.5	Drop	1	2	3
14	72.9	76.9	Rise	1	3	2
15	89.3	84.9	Drop	3	1	2
16	60.6	51.6	Drop	3	1	2
17	62.7	58.9	Drop	1	2	3
18	66.9	51.3	Drop	2	1	3
19	69.8	83.3	Rise	1	3	2
20	75.2	76.7	Rise	1	3	2
21	86.0	87.2	Rise	1	3	2
22	61.9	58.0	Drop	3	1	2
23	80.7	77.4	Drop	3	1	2
24	80.2	78.5	Drop	3	1	2
25	61.0	55.2	Drop	2	1	3
26	76.7	73.6	Drop	1	2	3
27	82.8	82.2	Drop	1	2	3

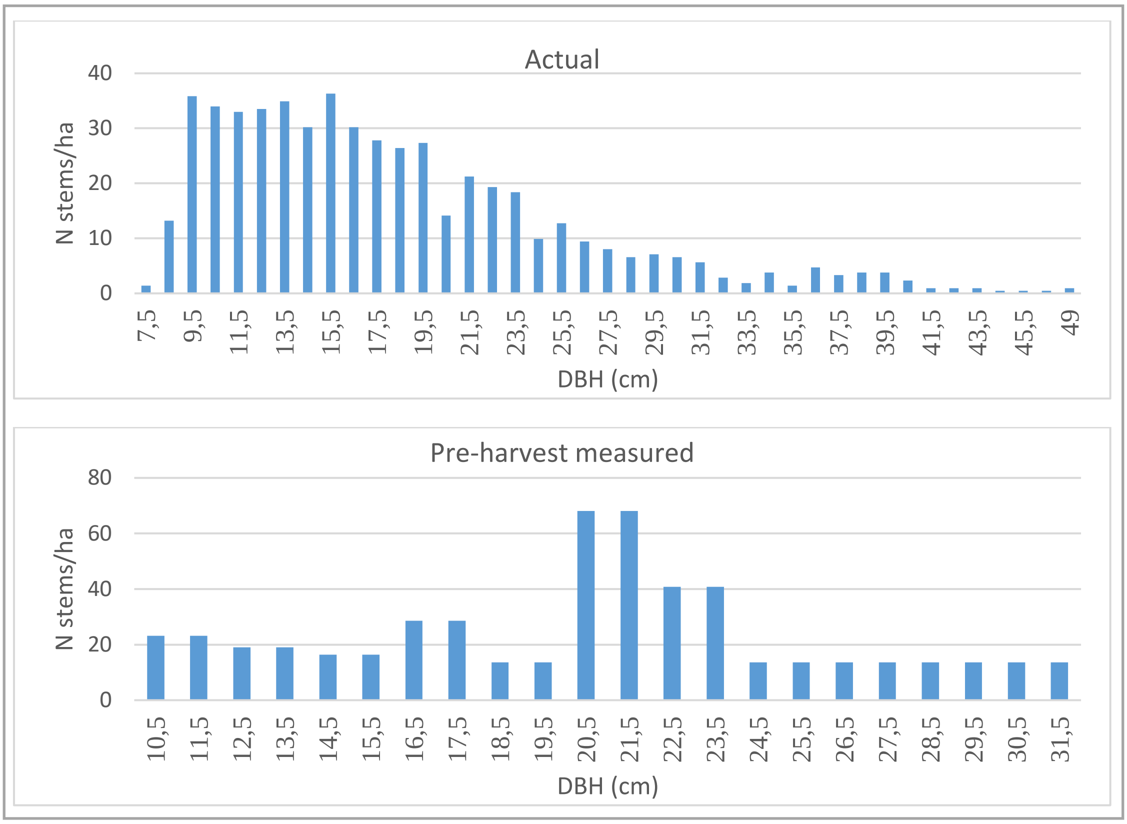

Figure 9. Stand 12 (spruce), stem number distribution. Actual log percentage is 67 %, d_g is 24.9 cm and diameter's standard deviation is 7.6 cm. Pre-harvest measured counterparts are 69 %, 22.9 cm and 5.4 cm.

When viewing how the stand structure/sturdiness changes between estimated and actual stands, and how stand values differ between the three pricing methods, based on Table 18 and Figures 6 and 8, the following four conditions can be derived from seller's point of view (opposite profitability aspect from the buyer's perspective):

1. If the share of pulp wood increases in comparison to pre-harvest estimates, the share of the more valuable grades decreases, and fractional stem pricing's profitability is likely to drop (solution 2) compared to assortment pricing. This is because some volume from grades where the price is higher or close to the log price has moved to cheaper grades where the price is lower than the log price. In other words, fractional stem pricing usually benefits from overall sturdiness more than assortment pricing, and as the log percentage drops, the value of fractional stem pricing is likely to drop relatively more (solution 2) than the value of assortment pricing.

2. If the share of pulp wood increases in comparison to pre-harvest estimates, the share of the more valuable assortments decreases, and stem pricing's profitability rises compared to assortment pricing. This is because the assortment allocation changes do not affect (negatively or positively) the value of stem pricing (only volume matters), but naturally the value of assortment pricing moves in the same direction as the log percentage.

3. If the share of logs increases in comparison to pre-harvest estimates, the share of the more valuable grades increases, and fractional stem pricing's profitability rises compared to assortment pricing. This is because some volume from grades where the price is lower than the log price has moved to the more valuable grades where the price is higher or close to the log price. In other word, fractional stem pricing benefits from overall sturdiness more than assortment pricing, and as the log percentage rises, the value of fractional stem pricing rises relatively more than the value of assortment pricing.

4. If the share of logs increases in comparison to pre-harvest estimates, the share of the more valuable assortments increases, and stem pricing's profitability drops compared to assortment pricing. This is because the assortment allocation changes do not affect (negatively or positively) the value of stem pricing (only volume matters), but naturally the value of assortment pricing moves in the same direction as the log percentage. In other words, because the stem price is lower than the log price, the seller has sold more wood with a lower price than intended based on the pre-harvest estimates.

Overall, the stand value results show that as expected, the changes from estimations to actual log recovery explain most of the stand value differences between pricing methods. The log recovery changes satisfactorily explain the difference between assortment pricing and stem pricing, and between fractional stem pricing and stem pricing. Furthermore, log recovery changes strongly direct the value relationship between assortment and fractional stem pricing. It also seems that as expected, the more accurately the log percentage (overall sturdiness) is estimated, the smaller the stand value range between the three pricing methods (Figure 10).

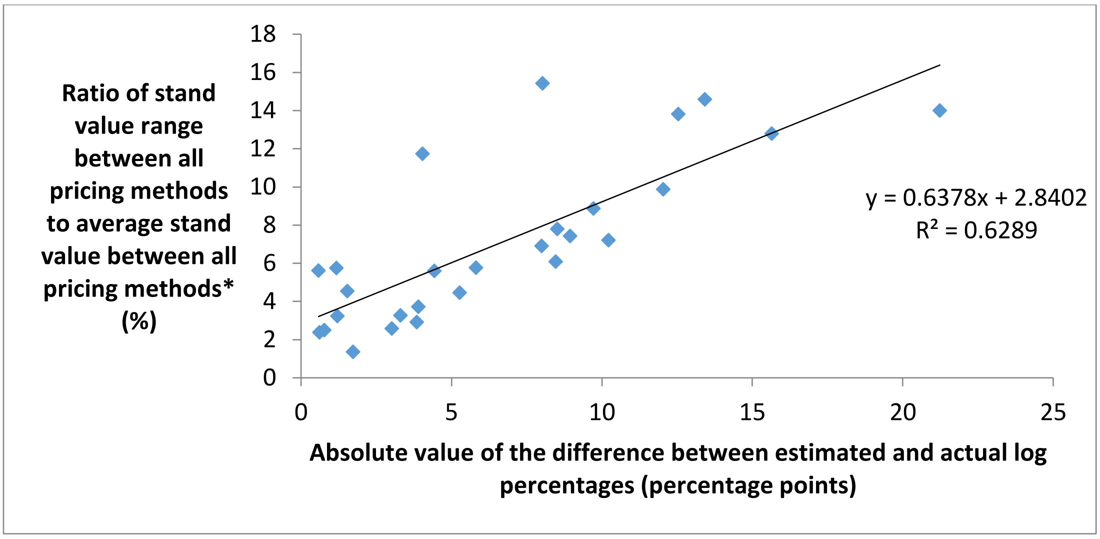

Figure 10. Linear regression between log percentage estimation error and stand value variation between the three pricing methods. *Stand value ranges between the three pricing methods divided by average stand values between the three pricing methods. (With fractional stem pricing solution 2).

5.3 Risk assessment

Based on the results in Chapter 5.2, the relative risks between pricing methods is strongly linked to log percentage estimation errors, and therefore a successfully made overall stand sturdiness estimation is extremely important. The stands with high volume-estimation errors did not have a significant effect on the average value ratios (between pricing methods) or standard deviations, but instead increased the stand value ranges. Because the mean diameters' standard deviation differences between estimated and actual stands did not directly affect the volume estimation errors, they cannot be used to explain stand value differences and thus not the monetary risks between the pricing methods either.

Tree species-specific relative risk results between pricing methods presented in Table 16 (Chapter 4.3) indicate that estimating spruce's log or value grade recovery is slightly more challenging than with pine, at least with this study's dataset and the models used. Fractional stem pricing's value ratio to assortment pricing was practically the same for pine and spruce, while spruce's stem pricing yielded a slightly higher relative monetary risk than for pine.

As only about six percent of the actual volume was birch, its significance to stand values is quite limited. It is still to be noted that as birch's log percentage estimation was at times significantly off the mark, using stem pricing can yield high risk situations. Even though on average the risks are low (similar with pine and spruce), value ratio to assortment pricing can vary dangerously, as value ratio's standard deviation was very high at 16 percent points. This is not surprising since stem pricing is typically used only with coniferous trees (Heikkilä 2012). Fractional stem pricing, on the other hand, does not have these problems with birch.

Straightforward standwise risk analysis in stem pricing versus assortment pricing indicates that the buyer takes on average a monetary risk of three percent when using stem pricing. The three percent only describes the average risk, and therefore the range and deviations of the possible risk levels should be viewed as factors when contemplating on the usability of pricing methods. Stem pricing ranges from 0.92 to 1.135 -fold stand values comparing to assortment pricing, resulting in over 21 percent point range and 4.8 percent point standard deviation. So, even though on average the risk is relatively low, in an individual timber sales situation results can vary quite considerably. This is particularly important information to sellers, since they conduct timber sales usually quite rarely, whereas buyers have massive timber sales quotas and the average risk represent the true risks much better. In other words, if the buyer knows that his bucking optimization benefits exceed the three percent higher procurement cost, they should consider using stem pricing.

Fractional stem pricing solutions yielded on average about two percent (solution 1) and one percent (solution 2) higher stand values than assortment pricing, which are good result for both parties of timber sales, since on average the relative risk between the two methods seems manageable and relatively small. With solution 1 fractional stem pricing ranges from 0.98 to 1.09 -fold stand values compared to assortment pricing, resulting in 11 percent point range and 2.8 percent point standard deviation. With solution two stand values range from 0.95 to 1.11 -fold stand values resulting in 16 percent point range and 3.8 percent point standard deviation. 11 and 16 percent point ranges and about three to four percent point standard deviation can still raise suspicion towards the method, even though on average fractional stem pricing is very safe for even the smallest forest owners. When using the same logic as with stem pricing, buyers should consider using fractional stem pricing if they can exceed the one to two percent higher procurement costs with the optimization benefits.

5.4 Alternative calculation scenarios

Fractional stem pricing without the length requirements

As mentioned, fractional stem pricing is sometimes criticized about its perceived complexity. However, fractional stem pricing could easily be simplified for sellers if the value grade related stem-part length requirements were left out entirely. The length requirements can cause confusion as the requirements practically mirror assortments pricing's minimum log and pulp log lengths, and the big selling point of fractional stem pricing is separated bucking and pricing. More importantly, the length requirements have no practical effect on the stand values and therefore on the risk between fractional stem pricing and assortment pricing. When the lack of length requirements regarding fractional stem pricing was inserted into pre-harvest and actual stand value calculations, fractional stem pricing solution 2 stand values on average increased 0.2 percent and the average risk (fractional stem pricing to assortment pricing ratio) increased only 0.2 percent points. With solution 1 the effect was even smaller and practically non-existing. The only logical explanation is that the stems in clearcut-ready stands usually fulfill the length requirements, and therefore their contractual enforcements is not really necessary. Quite the opposite, they make the method harder to comprehend for the average forest owner.

Adding artificial stands where log percentage rose from pre-harvest estimation

The significance of successful log percentage estimation leads to an unavoidable conclusion regarding the used study stands and the average relative monetary risk when switching away from assortment pricing. As the log percentage rose from the pre-harvest estimation in only seven stands (dropped in 20 stands), it greatly affects the average relative stand value differences between the pricing methods. This is evident when comparing stem and fractional stem pricing results in Table 15 (page 37). Because stand values usually move into opposite directions between stem and fractional stem pricing, depending on whether the log percentage is over-/under-estimated, stem pricing ended up with higher average relative monetary risk. If it is assumed that over- and under-estimating the log percentage are equally probable, the average results between stem and fractional stem pricing are clearly biased. In order to see what would happen if the stands were more even regarding over-/underestimated log percentages, an alternative setup for the calculations was created by adding more stands with over-estimated log percentage. This was done by taking the average stem and fractional pricing stand value ratios to assortment pricing of the seven stands where log percentage was over-estimated, and thus creating an artificial average stand where log percentage rose from pre-harvest estimation. This artificial stand was then added 13 times to the standwise relative stand value difference results (from Table 15), and the averages over the setup of 40 stands was recalculated. The average results turned around (compared to results in Table 15), as the average relative monetary risk when switching from assortment pricing to stem pricing became now only about one percent and with switching to fractional stem pricing (both solutions) the corresponding figure was about three percent. In practice this information reinforces the implication that if pre-harvest valuation of a stand is equal between assortment pricing and the used alternative pricing methods, switching away from assortment pricing poses in general a monetary risk of one to three percent to the buyer.

Significance of small-sized logs

As said on page one, small-sized logs account for less than five percent of purchased roundwood. With this study's setup the actual small-sized log percentage was about 13, so it could be argued that its share of the assortment allocation might have been over-estimated. To see whether including small-sized logs into the stand value calculations had any significance on the average stand value ratios between the pricing methods, the calculations were re-run without small-sized logs. With this scenario, fractional stem pricing's average ratio to assortment pricing increased 0.4 percent points (with both solutions) compared to the original setup with small-sized logs. Stem pricing's average ratio to assortment pricing also increased 0.4 percent points. As, expected stem pricing's standwise ratios to assortment pricing deviated slightly more than while including small-sized log. Fractional stem pricing on the other hand deviated less without small-sized logs. When the 13 extra stands were added into this scenario with the same logic as in the previous scenario, the average results were practically the same whether small-sized logs were included or not. Overall, small-sized logs do not significantly affect the average results.

5.5 Generalizing the results

The value ratio averages between the three pricing methods reveal the expected level of monetary risk of switching away from assortment pricing. This information is useful when either the seller or the buyer does not trust that the pre-harvest determined stand value is estimated correctly. For example, if the seller believes that the stand's log percentage will increase from the estimation, the seller should not opt for trade using stem pricing when a similarly valued offer via assortment or fractional stem pricing is also available. Similarly, the buyer might not want to offer stem pricing (or acceptable unit price for the seller) if the possibility of poor stand estimates is likely. By following the four conditions presented in Chapter 5.2, the seller can try to gain more profitable timber sales, assuming that trade offers with different pricing methods are valued closely to each other. Overall, if the log/value grade recovery estimation is expected to be reliable, both forest owners and roundwood buyers should favor stem or fractional stem pricing because of separated pricing and bucking.

Stands with challenging pre-harvest estimation are in general perhaps best to be left for assortment pricing, as this study's results indicate, it tends to be valued between stem and fractional stem pricing. Hence assortment pricing could in this case represent a shared risk between buyer and seller. Assortment pricing did not yield the highest stand value in any of the study stands, because of the nature of the stand valuation logic behind the studied pricing alternatives. In this study's setup, when log percentage increases from the estimated, fractional stem pricing always yields higher stand value than assortment pricing, and when the log percentage decreases, stem pricing always yields higher stand value than assortment pricing. In a situation where assortment pricing is compared with only one of the alternatives, it can easily yield the highest value. Furthermore, if the hypothesis of identically valued trade offers from all three methods is excluded, assortment pricing can naturally be the most valuable alternative.

The tradeoffs between stem and fractional stem pricing are that fractional stem pricing protects the buyer and seller from poor pre-harvest estimations and therefore from monetary risks better than stem pricing, but stem pricing's one unit price makes it simple and easily understandable and it requires none of the technology/software implementation into harvesters that fractional stem pricing would likely require. The value relationship between stem and fractional stem pricing is quite straightforward, since when the log percentage increases from the estimated, with equally valued trade offers, fractional stem pricing should yield higher stand values in relation to stem pricing, and when the log percentage decreases, stem pricing usually yields higher stand values.

Fractional stem pricing solutions 1 and 2 yielded very similar average stand value ratios to assortment pricing. Solution 1 however had smaller value range and standard deviation (in stand value ratios to assortment pricing). The drawback in solution 1 is that because of the setup of the price ranges between the grades (e.g. the range between grades one and four is smaller than in solution 2), the incentive to grow sturdier stands is not as clear as with solution 2. However, solution 1 still offers the incentive to grow sturdier stands far more efficiently and clearly than stem and assortment pricing, which is one of the most fundamental advantages of fractional stem pricing as a pricing method. The results show that while stand value estimation errors exist, a smaller price range between value grades shields both parties of timber sales from high stand value deviations between assortment and fractional stem pricing. Correctly set value grade price levels are extremely important regarding the usability of the method, and they should be set to simultaneously reflect the real processing values of different stem parts, reward sturdiness through adequate price progression, and offer a realistically valued alternative for assortment pricing.

Even though the average monetary risks compared to assortment pricing are low in both stem and fractional stem pricing, in an individual timber sales stand values can vary quite much and the stand value range in both methods shows that the buyer has a greater chance of worse trade value (higher stand value) than the seller. However, as mentioned, when timber sales/procurement quantities increase, the risks affiliated with large stand value ranges between pricing methods diminishes, and average risks describe the true monetary risks much better than with smaller quantities. Therefore, stem and fractional stem pricing are safe alternatives especially for large scale forest owners and for most roundwood buyers. Finland is full of small-scale forest owners who conduct timber sales rarely and appreciate simple and low risk trade practices, and therefore might have a higher threshold to switch away from assortment pricing. Delving into new methods takes effort, and the possibility of a worse stand value with the alternative pricing methods compared to assortment pricing still exists.

6. Conclusions

This study attempted to determine how closely assortment pricing, stem pricing and fractional stem pricing would end up being valued if they were valued equally in standwise pre-harvest trade offers, and whether the resulting differences justify the usage of stem and fractional stem pricing in roundwood trade. With this study's setup, when switching from assortment pricing to stem or fractional stem pricing, the average relative monetary risk lies with the buyer and settles between one and three percent with both alternative pricing methods. However, as stand values with stem pricing deviate more and have wider range, fractional stem pricing could be considered to be safer for both parties of timber sales. Even though on average both methods yielded slightly higher stand values than assortment pricing, the average difference should be small enough to satisfy buyers also, as with raw material supply and production chains optimization benefits of freed bucking, it should be possible to overcome the slightly higher average raw material procurement costs. Using alternative pricing methods would be a win-win situation for all, as the buyers would get the advantages of freed bucking, and the disputes about bucking decisions could practically be eliminated. Overall, stem and fractional stem pricing seem to reach reasonable enough actual stand values in relation to assortment pricing to justify their usage in roundwood trade.

Assortment or value grade allocation changes from pre-harvest estimates explain the stand value differences between the pricing methods, and the better the log percentage (overall sturdiness) is estimated, the smaller the stand value range (and therefore monetary risk) between the three pricing methods. Stem and fractional stem pricing are suitable to use in both pine- and spruce-dominant stands. Unsurprisingly, fractional stem pricing seems to suit birch much better than stem pricing. Using stem pricing with birch should be done with caution, at least in pine- or spruce-dominant stands where it might be challenging to correctly estimate log recovery for birch.

All in all, fractional stem pricing implemented as proposed by Luke (both solution 1 and 2) seems like a viable and functioning solution to update the pricing of roundwood and to coexist with assortment pricing. It is however to be noted that the length requirements included in Luke's proposal likely have no practical effect on stand values/procurement costs and could therefore be removed. With correctly set value grade prices, fractional stem pricing would likely improve the functioning of the roundwood market. Likewise, if implemented correctly, stem pricing seems like a viable alternative for assortment pricing. The usage of both methods should be encouraged and promoted. As stem pricing is already in use, the right price levels for wider usage are easy to be set by the market itself. Fractional stem pricing however is a totally different case, and it needs to be set up correctly from the get-go, in order to establish its wider usage. Roundwood purchasers will learn from possibly suboptimal timber sales, but if forest owners gain negative experiences right from the start, they might not opt to use fractional stem pricing again.

Probably the main reason for the slow increase in the usage rate of the alternative pricing methods is the risk factor affiliated with changes and possible financial losses. Neither side is willing to bear the risks alone, so a compromise is clearly needed. Since assortment pricing and stem pricing are neither perfect, fractional stem pricing might be the solution, since it reduces the industry's risk compared to stem pricing while enabling fair pricing for the sellers. Other possible reason for why roundwood pricing has remained unchanged is that just with assortment pricing, forest owners already have challenges in comparing trade offers from multiple buyers, as the varying and buyer-specific estimated stand values and assortment allocations (and their significance to the final stand value) can be confusing. If even more possible timber sales outcomes are added through the alternative pricing methods, for some forest owners a basic timber sales situation can suddenly look more complicated than it needs to be. With a theoretical popularity increase of the alternative pricing methods, forestry management associations' role would likely change at least in some degree from monitoring the fellings to offering guidance and expertise on the pricing methods. As before, they would still have a big role in conducting roundwood sales via proxy and making trade offer comparisons for their members. Demand for their services could even peak due to a lack of knowledge about the alternative pricing methods among forest owners.

Launching price statistics of stem prices (e.g. by Luke) as soon as possible could hinder the possible usage of stem pricing as a market pressure valve and simultaneously promote its usage as more forest owners would become aware of a different pricing option in timber sales. As log prices have for long remained quite constant as about three times the value of pulp logs, and demand for pulpwood will remain high in the near future due to recent and upcoming investments to pulp manufacturing facilities, roundwood pricing should be updated to remove the conflicting interest of sellers and buyers regarding the bucking solutions. Furthermore, as forests are an important part of ambitious climate goals, fractional stem pricing offers a greater incentive to grow sturdier stands than assortment pricing, and the resulting end products (possibly less pulp-based products) might be more environmentally sustainable and release carbon slower.

This thesis focused on pine and spruce-dominant stands, and the small amount of birch seemed to cause difficulties to Trestima application. Therefore, similar calculations with birch-dominant forest stands would give more specific information whether the alternative pricing methods would be worthwhile to apply with birch or not (currently stem pricing is not typically used with birch). All study stands used in this study were clearcut, and a study regarding continuous cover forestry or thinnings, and implementing the alternative pricing methods to such harvesting alternatives would be needed in order to see how the alternative pricing methods would behave in timber sales scenarios other than clearcuts. This would particularly concern fractional stem pricing since stem pricing is already in use at least with first thinnings.

As the stand value calculations via assortment pricing were conducted with theoretically optimal assortment recovery for the seller (with three percent log recovery subtraction), more authentic assortment recovery could be achieved by using a bucking simulator for the pre-harvest estimations and actual bucking data from the harvester for the actual stand value calculations. The stands where log percentage dropped from the pre-harvest estimation were over-represented in the dataset, so calculations with more even data regarding log percentage over-/under estimation would be needed to further asses the results of this thesis.

References

Finnish Competition and Consumer Authority. 2006. Esitys kilpailunrajoituslain 6 §:n ja Euroopan yhteisön perustamissopimuksen 81 artiklan mukaisen kilpailunrajoituksen toteamisesta ja kilpailunrikkomusmaksun määräämisestä Stora Enso Oyj:lle ja Metsäliitto Osuuskunnalle. [Referred 26.4.2020] Available: https://www.kkv.fi/globalassets/kkv-suomi/ratkaisut-aloitteet-lausunnot/ratkaisut/kilpailuasiat/2006/esitykset-markkinaoikeudelle/r-2004-61-0416.pdf

Heikkilä, J. 2012. Runkohinnoitteluselvitys. Puumarkkinoille toimivuutta- hanke, Metsänomistajien liitto Länsi-Suomi. [Referred 26.4.2020] Available: https://www.mhy.fi/sites/default/files/liitto-lansi-suomi/loppuraportti_runkohinta.pdf

Helsingin Sanomat 14.5.2018. Sahoilta kuuluu hätähuuto samaan aikaan kuin metsä-jätit tekevät huippu-tulosta – ”Sahojen toiminta-ympäristö on Suomessa tuhottu”. [Referred 26.4.2020] Available: https://www.hs.fi/talous/art-2000005678682.html

Kilkki, P., Maltamo, M., Mykkänen, R. & Päivinen, R. 1989. Use of the Weibull function in the estimation the basal area dbh-distribution. Silva Fennica 23(4): 311–318.

Korpunen, H., Vastaranta, M., Siipilehto, J. & Uusitalo, J. 2016. Lentolaserkeilaukseen ja Trestima-menetelmään perustuvien puusto-tunnusten hyödyntäminen puutavara-laji- ja rungonosahinnoittelu-menetelmien vertailussa. Luonnonvara- ja biotalouden tutkimus 75/2016. Luonnonvarakeskus (Luke). 23 p. [Referred 26.4.2020] Available: https://jukuri.luke.fi/handle/10024/537752

Laasasenaho, J. 1982. Taper curve and volume functions for pine, spruce and birch. Communicationes Instituti Forestalis Fenniae 108. 74 p.

Leppänen, J. & Torvelainen, J. 2015. Tilasto: Metsämaan omistus 2013. Luonnonvara- ja biotalouden tutkimus 5/2015. Luonnonvarakeskus (Luke). [Referred 26.4.2020] Available: https://jukuri.luke.fi/bitstream/handle/10024/485473/luke-luobio_5_2015.pdf?sequence=4&isAllowed=y

Luke. 2019. Ruoka- ja luonnonvaratilastojen e-vuosikirja 2019. Luonnonvara- ja biotalouden tutkimus 86/2019. Luonnonvarakeskus (Luke). [Referred 26.4.2020] Available: https://jukuri.luke.fi/handle/10024/545183

Luke statistics database. 2019a. Roundwood trade 2018. [Referred 26.4.2020] Available: http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE__04%20Metsa__04%20Talous__02%20Teollisuuspuun%20kauppa__04%20Vuositilastot/05b_Puukauppamaarat_v.px/?rxid=8b285ea4-5224-49e8-a147-4a782a9e2e43

Luke statistics database. 2019b. Gross stumpage earnings 2018. [Referred 26.4.2020] Available: http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE__04%20Metsa__04%20Talous__16%20Kantorahatulot/01_Bruttokantorahat_v_omistajaryhma.px/?rxid=046b14c9-7f10-4fab-bb0e-313c81c27e24

Luke statistics database. 2019c. Stumpage prices of roundwood 2018. [Referred 26.4.2020] Available: http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE__04%20Metsa__04%20Talous__02%20Teollisuuspuun%20kauppa__04%20Vuositilastot/01b_Kantohinnat_v.px/?rxid=29f02aba-bd74-4f12-9114-6acc340e72a6

Luke. Fractional stem pricing proposal (in Finnish). 2016. [Referred 26.4.2020] Available: https://docplayer.fi/58639023-Rungonosahinnoittelu-jori-uusitalo-luke-mmm-puukauppatyoryhma.html

Maaseudun Tulevaisuus 16.10.2017. MTK:n Tiirola: "Metsäteollisuus näkee mhy:n kilpailuttaman puun kivenä kengässä". [Referred 26.4.2020] Available: https://www.maaseuduntulevaisuus.fi/metsa/artikkeli-1.209765

Maaseudun Tulevaisuus 30.8.2019. UPM jatkaa katkontakiistaa pirkanmaalaisen metsänomistajan kanssa – ei tyydy hovioikeuden ratkaisuun. [Referred 26.4.2020] Available: https://www.maaseuduntulevaisuus.fi/metsa/artikkeli-1.498856

Malinen, J., Berg, V. & Kilpeläinen, H. 2010. Roundwood pricing mechanisms and their performance in Scots pine roundwood markets. Working Papers of the Finnish Forest Research Institute 174. 35 p.

Malinen, J., Haring, M., Kilpeläinen, H. & Verkasalo, E. 2015. Comparison of alternative roundwood pricing systems -a simulation approach. Silva Fennica vol 49 no. 3 article id 1293. 14 p.

Malinen, J. & Kilpeläinen, H., 2013. Price Systems for Standing Sales of Industrial Roundwood in Finland. Baltic Forestry 19(2): 307–315.

Malinen, J., Wall, T., Kilpeläinen, H. & Verkasalo, E. 2011. Leimikon arvonmuodostus vaihtoehtoisissa loppukäyttökohteissa. Working Papers of the Finnish Forest Research Institute 206. 45 p.

Metsälehti 2018. Huippuhinnat voi piilottaa runkohintaan. [Referred 26.4.2020] Available: https://www.metsalehti.fi/artikkelit/huippuhinnat-voi-piilottaa-runkohintaan/

Ministry of Agriculture and Forestry 2014. Uusia toimintatapoja puukauppaan. [Referred 26.4.2020] Available: http://mmm.fi/artikkeli/-/asset_publisher/nya-instrument-for-utveckling-av-virkeshandeln

Mykkänen, R. 1986. Weibull-funktion käyttö puuston läpimittajakauman estimoinnissa. Metsätalouden syventävien opintojen tutkielma. Joensuu. 80 p.

Näslund, M. 1936. Skogsförsöksanstaltens gallringsförsök i tallskog. Meddelanden från Statens Skogsförsöksanstalt 29. 169 p.

Siipilehto, J. 1999. Improving the accuracy of predicted basal-area diameter distribution in advanced stands by determining stem number. Silva Fennica 33(4): 281-301.

Siipilehto J. & Mehtätalo L. (2013). Parameter recovery vs. parameter prediction for the Weibull distribution validated for Scots pine stands in Finland. Silva Fennica vol. 47 no. 4 article id 1057. 22 p.

Uusitalo, J., Kivinen, V.-P. & Korpunen, H. 2011. A step towards optimal wood supply chain: A case study on optimal treebucking in Central Finland: Formec Austria 2011. Pushing the boundaries with research and innovation in forest engineering. 11 p.

Appendices

Appendix 1. Stem number distribution measured by Trestima application. Species: Pine =1, Spruce =2, Birch =3

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
1	1	1	2	2	1	2	2	3	2	3	3	4	1	4	2	5	1	6	1	6	2	6	3	7	1	7	2	7	3
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
22.5	7.9	8.5	17.3	18.5	9.2	18.5	4.1	8.5	3.7	12.5	4.6	24.5	4.3	20.5	5.3	12.5	3.7	18.5	4.5	10.5	6.3	12.5	7.3	14.5	9.7	14.5	4.7	6.5	8.1
23.5	7.9	9.5	17.3	19.5	9.2	19.5	4.1	9.5	3.7	13.5	4.6	25.5	4.3	21.5	5.3	13.5	3.7	19.5	4.5	11.5	6.3	13.5	7.3	15.5	9.7	15.5	4.7	7.5	8.1
24.5	0.0	10.5	16.6	20.5	9.2	20.5	4.1	10.5	5.7	14.5	11.5	26.5	0.0	22.5	10.6	14.5	0.0	20.5	9.0	12.5	4.5	14.5	12.7	16.5	16.8	16.5	8.4	8.5	0.0
25.5	0.0	11.5	16.6	21.5	9.2	21.5	4.1	11.5	5.7	15.5	11.5	27.5	0.0	23.5	10.6	15.5	0.0	21.5	9.0	13.5	4.5	15.5	12.7	17.5	16.8	17.5	8.4	9.5	0.0
26.5	14.7	12.5	9.0	22.5	13.8	22.5	12.2	12.5	7.2	16.5	7.7	28.5	0.0	24.5	26.6	16.5	14.0	22.5	9.0	14.5	20.4	16.5	0.0	18.5	18.0	18.5	0.0	10.5	4.4
27.5	14.7	13.5	9.0	23.5	13.8	23.5	12.2	13.5	7.2	17.5	7.7	29.5	0.0	25.5	26.6	17.5	14.0	23.5	9.0	15.5	20.4	17.5	0.0	19.5	18.0	19.5	0.0	11.5	4.4
28.5	5.1	14.5	16.9	24.5	22.9	24.5	4.1	14.5	6.0	18.5	11.5	30.5	4.3	26.5	47.8	18.5	13.2	24.5	4.5	16.5	11.2	18.5	0.0	20.5	33.5	20.5	12.7	12.5	3.5
29.5	5.1	15.5	16.9	25.5	22.9	25.5	4.1	15.5	6.0	19.5	11.5	31.5	4.3	27.5	47.8	19.5	13.2	25.5	4.5	17.5	11.2	19.5	0.0	21.5	33.5	21.5	12.7	13.5	3.5
30.5	6.8	16.5	17.3	26.5	27.5	26.5	4.1	16.5	9.3	20.5	3.9	32.5	0.0	28.5	42.5	20.5	33.6	26.5	0.0	18.5	29.7	20.5	0.0	22.5	50.3	22.5	4.2	14.5	2.7
31.5	6.8	17.5	17.3	27.5	27.5	27.5	4.1	17.5	9.3	21.5	3.9	33.5	0.0	29.5	42.5	21.5	33.6	27.5	0.0	19.5	29.7	21.5	0.0	23.5	50.3	23.5	4.2	15.5	2.7
32.5	3.4	18.5	24.2	28.5	22.9	28.5	4.1	18.5	19.4	22.5	3.9	34.5	4.3	30.5	31.9	22.5	41.9	28.5	0.0	20.5	40.8	22.5	6.1	24.5	58.7	24.5	0.0		
33.5	3.4	19.5	24.2	29.5	22.9	29.5	4.1	19.5	19.4	23.5	3.9	35.5	4.3	31.5	31.9	23.5	41.9	29.5	0.0	21.5	40.8	23.5	6.1	25.5	58.7	25.5	0.0		
34.5	3.4	20.5	28.7	30.5	4.6	30.5	12.2	20.5	19.4	24.5	0.0	36.5	0.0	32.5	21.3	24.5	33.6	30.5	4.5	22.5	48.2			26.5	20.6	26.5	8.4		
35.5	3.4	21.5	28.7	31.5	4.6	31.5	12.2	21.5	19.4	25.5	0.0	37.5	0.0	33.5	21.3	25.5	33.6	31.5	4.5	23.5	48.2			27.5	20.6	27.5	8.4		
36.5	3.4	22.5	34.5	32.5	6.0			22.5	21.0	26.5	0.0	38.5	4.3	34.5	21.3	26.5	41.9			24.5	11.2			28.5	18.9	28.5	0.0		
37.5	3.4	23.5	34.5	33.5	6.0			23.5	21.0	27.5	0.0	39.5	4.3	35.5	21.3	27.5	41.9			25.5	11.2			29.5	18.9	29.5	0.0		
38.5	0.0	24.5	44.9	34.5	12.9			24.5	29.0	28.5	0.0			36.5	10.6	28.5	19.6			26.5	26.0			30.5	14.7	30.5	4.2		
39.5	0.0	25.5	44.9	35.5	12.9			25.5	29.0	29.5	0.0			37.5	10.6	29.5	19.6			27.5	26.0			31.5	14.7	31.5	4.2		
40.5	3.4	26.5	35.6	36.5	4.6			26.5	25.1	30.5	3.9			38.5	10.6	30.5	8.4			28.5	39.0								
41.5	3.4	27.5	35.6	37.5	4.6			27.5	25.1	31.5	3.9			39.5	10.6	31.5	8.4			29.5	39.0								
		28.5	13.8					28.5	27.8					40.5	10.6	32.5	7.0			30.5	24.1								
		29.5	13.8					29.5	27.8					41.5	10.6	33.5	7.0			31.5	24.1								
		30.5	11.4					30.5	16.1					42.5	5.3					32.5	14.5								
		31.5	11.4					31.5	16.1					43.5	5.3					33.5	14.5								
		32.5	6.9					32.5	8.0					44.5	5.3					34.5	14.1								
		33.5	6.9					33.5	8.0					45.5	5.3					35.5	14.1								
		34.5	3.5					34.5	7.4											36.5	16.7								
		35.5	3.5					35.5	7.4											37.5	16.7								
		36.5	0.0					36.5	2.9																				
		37.5	0.0					37.5	2.9																				
		38.5	0.0																										
		39.5	0.0																										
		40.5	3.5																										
		41.5	3.5																										

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
8	1	8	2	8	3	9	2	9	3
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
20.5	3.7	8.5	9.3	10.5	23.8	10.5	6.0	16.5	2.0
21.5	3.7	9.5	9.3	11.5	23.8	11.5	6.0	17.5	2.0
22.5	0.0	10.5	0.0	12.5	0.0	12.5	14.6	18.5	0.0
23.5	0.0	11.5	0.0	13.5	0.0	13.5	14.6	19.5	0.0
24.5	0.0	12.5	5.9	14.5	14.5	14.5	8.6	20.5	0.0
25.5	0.0	13.5	5.9	15.5	14.5	15.5	8.6	21.5	0.0
26.5	3.7	14.5	19.4	16.5	13.2	16.5	14.9	22.5	2.0
27.5	3.7	15.5	19.4	17.5	13.2	17.5	14.9	23.5	2.0
28.5	0.0	16.5	0.0	18.5	0.0	18.5	22.4	24.5	4.0
29.5	0.0	17.5	0.0	19.5	0.0	19.5	22.4	25.5	4.0
30.5	7.4	18.5	8.5	20.5	0.0	20.5	26.1		
31.5	7.4	19.5	8.5	21.5	0.0	21.5	26.1		
32.5	0.0	20.5	16.9	22.5	13.2	22.5	37.3		
33.5	0.0	21.5	16.9	23.5	13.2	23.5	37.3		
34.5	0.0	22.5	21.1			24.5	37.3		
35.5	0.0	23.5	21.1			25.5	37.3		
36.5	3.7	24.5	21.1			26.5	44.8		
37.5	3.7	25.5	21.1			27.5	44.8		
38.5	3.7	26.5	12.7			28.5	14.6		
39.5	3.7	27.5	12.7			29.5	14.6		
40.5	3.7	28.5	25.4			30.5	11.6		
41.5	3.7	29.5	25.4			31.5	11.6		
		30.5	16.1			32.5	6.4		
		31.5	16.1			33.5	6.4		
		32.5	21.1			34.5	8.6		
		33.5	21.1			35.5	8.6		
		34.5	16.1			36.5	5.6		
		35.5	16.1			37.5	5.6		
		36.5	10.6						
		37.5	10.6						
		38.5	0.0						
		39.5	0.0						
		40.5	8.5						
		41.5	8.5						

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
10	1	10	2	11	2	12	1	12	2
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
22.5	12.7	10.5	33.4	16.5	10.4	18.5	10.7	10.5	23.2
23.5	12.7	11.5	33.4	17.5	10.4	19.5	10.7	11.5	23.2
24.5	8.3	12.5	34.1	18.5	20.8	20.5	0.0	12.5	19.1
25.5	8.3	13.5	34.1	19.5	20.8	21.5	0.0	13.5	19.1
26.5	8.3	14.5	0.0	20.5	41.6	22.5	10.7	14.5	16.4
27.5	8.3	15.5	0.0	21.5	41.6	23.5	10.7	15.5	16.4
28.5	0.0	16.5	36.6	22.5	62.3	24.5	0.0	16.5	28.6
29.5	0.0	17.5	36.6	23.5	62.3	25.5	0.0	17.5	28.6
30.5	9.5	18.5	51.7	24.5	83.1	26.5	10.7	18.5	13.6
31.5	9.5	19.5	51.7	25.5	83.1	27.5	10.7	19.5	13.6
		20.5	75.7	26.5	38.1			20.5	68.1
		21.5	75.7	27.5	38.1			21.5	68.1
		22.5	51.7	28.5	20.8			22.5	40.9
		23.5	51.7	29.5	20.8			23.5	40.9
		24.5	32.8					24.5	13.6
		25.5	32.8					25.5	13.6
		26.5	25.9					26.5	13.6
		27.5	25.9					27.5	13.6
		28.5	15.8					28.5	13.6
		29.5	15.8					29.5	13.6
		30.5	15.8					30.5	13.6
		31.5	15.8					31.5	13.6

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
12	3	13	1	13	2	14	1	14	2
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
12.5	16.5	18.5	6.3	12.5	22.5	16.5	11.4	14.5	5.4
13.5	16.5	19.5	6.3	13.5	22.5	17.5	11.4	15.5	5.4
14.5	13.2			14.5	0.0	18.5	28.5	16.5	14.0
15.5	13.2			15.5	0.0	19.5	28.5	17.5	14.0
16.5	11.0			16.5	0.0	20.5	17.1	18.5	13.5
17.5	11.0			17.5	0.0	21.5	17.1	19.5	13.5
18.5	0.0			18.5	16.1	22.5	29.6	20.5	9.0
19.5	0.0			19.5	16.1	23.5	29.6	21.5	9.0
20.5	5.5			20.5	0.0	24.5	12.6	22.5	22.1
21.5	5.5			21.5	0.0	25.5	12.6	23.5	22.1
22.5	5.5			22.5	32.1	26.5	21.7	24.5	19.8
23.5	5.5			23.5	32.1	27.5	21.7	25.5	19.8
24.5	5.5			24.5	0.0			26.5	11.3
25.5	5.5			25.5	0.0			27.5	11.3
26.5	5.5			26.5	16.1			28.5	6.8
27.5	5.5			27.5	16.1			29.5	6.8

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
14	3	15	1	15	2	16	1	17	1
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
16.5	4.7	16.5	5.6	24.5	5.1	8.5	17.9	16.5	6.0
17.5	4.7	17.5	5.6	25.5	5.1	9.5	17.9	17.5	6.0
18.5	4.7	18.5	4.7	26.5	10.2	10.5	13.2	18.5	0.0
19.5	4.7	19.5	4.7	27.5	10.2	11.5	13.2	19.5	0.0
20.5	0.0	20.5	4.7	28.5	5.1	12.5	23.4	20.5	15.2
21.5	0.0	21.5	4.7	29.5	5.1	13.5	23.4	21.5	15.2
22.5	4.7	22.5	9.3	30.5	20.3	14.5	24.9	22.5	17.5
23.5	4.7	23.5	9.3	31.5	20.3	15.5	24.9	23.5	17.5
24.5	0.0	24.5	28.0	32.5	0.0	16.5	74.7	24.5	22.2
25.5	0.0	25.5	28.0	33.5	0.0	17.5	74.7	25.5	22.2
26.5	0.0	26.5	28.0	34.5	5.1	18.5	56.0	26.5	4.6
27.5	0.0	27.5	28.0	35.5	5.1	19.5	56.0	27.5	4.6
28.5	0.0	28.5	18.7	36.5	5.1	20.5	30.4	28.5	4.6
29.5	0.0	29.5	18.7	37.5	5.1	21.5	30.4	29.5	4.6
30.5	4.7	30.5	14.0			22.5	56.8		
31.5	4.7	31.5	14.0			23.5	56.8		
		32.5	10.3			24.5	17.9		
		33.5	10.3			25.5	17.9		
		34.5	5.6			26.5	12.5		
		35.5	5.6			27.5	12.5		
		36.5	6.5						
		37.5	6.5						
		38.5	8.4						
		39.5	8.4						
		40.5	0.0						
		41.5	0.0						
		42.5	7.0						
		43.5	7.0						
		44.5	4.7						
		45.5	4.7						

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
17	2	17	3	18	1	19	1	19	2
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
8.5	83.6	12.5	9.4	6.5	44.0	16.5	2.9	14.5	31.4
9.5	83.6	13.5	9.4	7.5	44.0	17.5	2.9	15.5	31.4
10.5	0.0	14.5	23.9	8.5	0.0	18.5	11.5	16.5	37.1
11.5	0.0	15.5	23.9	9.5	0.0	19.5	11.5	17.5	37.1
12.5	9.3	16.5	14.5	10.5	0.0	20.5	7.5	18.5	28.9
13.5	9.3	17.5	14.5	11.5	0.0	21.5	7.5	19.5	28.9
14.5	33.9	18.5	7.3	12.5	19.8	22.5	16.7	20.5	20.6
15.5	33.9	19.5	7.3	13.5	19.8	23.5	16.7	21.5	20.6
16.5	27.9	20.5	7.3	14.5	24.2	24.5	15.2	22.5	34.7
17.5	27.9	21.5	7.3	15.5	24.2	25.5	15.2	23.5	34.7
18.5	71.7			16.5	16.7	26.5	8.1	24.5	33.4
19.5	71.7			17.5	16.7	27.5	8.1	25.5	33.4
20.5	53.1			18.5	71.9	28.5	3.8	26.5	23.5
21.5	53.1			19.5	71.9	29.5	3.8	27.5	23.5
22.5	35.2			20.5	55.8	30.5	4.3	28.5	14.5
23.5	35.2			21.5	55.8	31.5	4.3	29.5	14.5
24.5	35.8			22.5	28.5			30.5	6.2
25.5	35.8			23.5	28.5			31.5	6.2
26.5	5.3			24.5	18.0				
27.5	5.3			25.5	18.0				
28.5	6.7			26.5	5.0				
29.5	6.7			27.5	5.0				
30.5	6.7			28.5	3.1				
31.5	6.7			29.5	3.1				
				30.5	3.1				
				31.5	3.1				

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
19	3	20	1	20	2	21	1	21	2
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
14.5	5.1	16.5	12.3	12.5	4.7	14.5	3.3	20.5	6.9
15.5	5.1	17.5	12.3	13.5	4.7	15.5	3.3	21.5	6.9
16.5	9.3	18.5	0.0	14.5	17.1	16.5	5.6	22.5	0.0
17.5	9.3	19.5	0.0	15.5	17.1	17.5	5.6	23.5	0.0
18.5	0.0	20.5	21.5	16.5	18.2	18.5	5.6	24.5	6.9
19.5	0.0	21.5	21.5	17.5	18.2	19.5	5.6	25.5	6.9
20.5	4.6	22.5	0.0	18.5	25.0	20.5	3.6	26.5	10.4
21.5	4.6	23.5	0.0	19.5	25.0	21.5	3.6	27.5	10.4
22.5	0.0	24.5	9.2	20.5	28.5	22.5	27.7		
23.5	0.0	25.5	9.2	21.5	28.5	23.5	27.7		
24.5	4.6	26.5	6.2	22.5	57.1	24.5	47.0		
25.5	4.6	27.5	6.2	23.5	57.1	25.5	47.0		
				24.5	39.2	26.5	22.1		
				25.5	39.2	27.5	22.1		
				26.5	19.6	28.5	19.4		
				27.5	19.6	29.5	19.4		
				28.5	14.3	30.5	11.1		
				29.5	14.3	31.5	11.1		
				30.5	16.1	32.5	17.4		
				31.5	16.1	33.5	17.4		
				32.5	3.6	34.5	6.9		
				33.5	3.6	35.5	6.9		
						36.5	0.0		
						37.5	0.0		
						38.5	2.8		
						39.5	2.8		

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
22	2	23	1	24	1	24	2	25	1	25	2	25	3	26	1	26	2	26	3	27	1	27	2	27	3
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
8.5	60.7	16.5	10.6	16.5	5.0	14.5	7.7	10.5	10.0	10.5	15.7	8.5	39.7	16.5	12.4	10.5	21.6	14.5	10.2	14.5	6.9	12.5	11.0	8.5	17.9
9.5	60.7	17.5	10.6	17.5	5.0	15.5	7.7	11.5	10.0	11.5	15.7	9.5	39.7	17.5	12.4	11.5	21.6	15.5	10.2	15.5	6.9	13.5	11.0	9.5	17.9
10.5	90.2	18.5	19.3	18.5	5.0	16.5	7.1	12.5	0.0	12.5	13.8	10.5	0.0	18.5	5.9	12.5	0.0	16.5	8.5	16.5	0.0	14.5	9.5	10.5	11.3
11.5	90.2	19.5	19.3	19.5	5.0	17.5	7.1	13.5	0.0	13.5	13.8	11.5	0.0	19.5	5.9	13.5	0.0	17.5	8.5	17.5	0.0	15.5	9.5	11.5	11.3
12.5	122.3	20.5	48.2	20.5	0.0	18.5	0.0	14.5	0.0	14.5	12.0	12.5	0.0	20.5	23.6	14.5	7.0	18.5	0.0	18.5	6.3	16.5	0.0	12.5	9.3
13.5	122.3	21.5	48.2	21.5	0.0	19.5	0.0	15.5	0.0	15.5	12.0	13.5	0.0	21.5	23.6	15.5	7.0	19.5	0.0	19.5	6.3	17.5	0.0	13.5	9.3
14.5	36.6	22.5	48.2	22.5	9.9	20.5	19.2	16.5	5.9	16.5	10.1	14.5	19.1	22.5	23.6	16.5	0.0	20.5	0.0	20.5	12.5	18.5	23.6	14.5	0.0
15.5	36.6	23.5	48.2	23.5	9.9	21.5	19.2	17.5	5.9	17.5	10.1	15.5	19.1	23.5	23.6	17.5	0.0	21.5	0.0	21.5	12.5	19.5	23.6	15.5	0.0
16.5	69.7	24.5	0.0	24.5	9.9	22.5	38.4	18.5	5.9	18.5	9.2	16.5	33.8	24.5	35.3	18.5	5.9	22.5	8.5	22.5	6.3	20.5	23.6	16.5	0.0
17.5	69.7	25.5	0.0	25.5	9.9	23.5	38.4	19.5	5.9	19.5	9.2	17.5	33.8	25.5	35.3	19.5	5.9	23.5	8.5	23.5	6.3	21.5	23.6	17.5	0.0
18.5	66.1	26.5	9.7	26.5	19.8	24.5	25.6	20.5	11.8	20.5	18.4	18.5	44.1	26.5	0.0	20.5	11.7			24.5	37.5	22.5	15.7	18.5	0.0
19.5	66.1	27.5	9.7	27.5	19.8	25.5	25.6	21.5	11.8	21.5	18.4	19.5	44.1	27.5	0.0	21.5	11.7			25.5	37.5	23.5	15.7	19.5	0.0
20.5	42.9	28.5	9.7	28.5	9.9	26.5	12.8	22.5	14.7	22.5	23.0	20.5	14.7	28.5	0.0	22.5	0.0			26.5	13.1	24.5	15.7	20.5	0.0
21.5	42.9	29.5	9.7	29.5	9.9	27.5	12.8	23.5	14.7	23.5	23.0	21.5	14.7	29.5	0.0	23.5	0.0			27.5	13.1	25.5	15.7	21.5	0.0
22.5	42.9	30.5	9.7	30.5	9.9	28.5	12.8	24.5	8.8	24.5	50.6	22.5	14.7	30.5	5.9	24.5	5.9			28.5	25.6	26.5	18.1	22.5	0.0
23.5	42.9	31.5	9.7	31.5	9.9	29.5	12.8	25.5	8.8	25.5	50.6	23.5	14.7	31.5	5.9	25.5	5.9			29.5	25.6	27.5	18.1	23.5	0.0
24.5	29.5	32.5	0.0							26.5	9.2	24.5	11.8			26.5	14.0			30.5	6.9	28.5	26.0	24.5	0.0
25.5	29.5	33.5	0.0							27.5	9.2	25.5	11.8			27.5	14.0			31.5	6.9	29.5	26.0	25.5	0.0
26.5	14.3	34.5	9.7							28.5	0.0	26.5	11.8			28.5	0.0			32.5	0.0	30.5	0.0	26.5	13.3
27.5	14.3	35.5	9.7							29.5	0.0	27.5	11.8			29.5	0.0			33.5	0.0	31.5	0.0	27.5	13.3
28.5	22.3									30.5	0.0	28.5	7.4			30.5	16.4			34.5	7.5	32.5	0.0		
29.5	22.3									31.5	0.0	29.5	7.4			31.5	16.4			35.5	7.5	33.5	0.0		
30.5	13.4									32.5	9.2					32.5	0.0			36.5	17.5	34.5	19.7		
31.5	13.4									33.5	9.2					33.5	0.0			37.5	17.5	35.5	19.7		
32.5	0.0															34.5	11.7								
33.5	0.0															35.5	11.7								
34.5	0.0																								
35.5	0.0																								
36.5	17.9																								
37.5	17.9																								

Appendix 2. Stem number distribution measured by the harvester. Species: Pine =1, Spruce =2, Birch =3

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
1	1	1	2	2	1	2	2	3	2
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
6.0	0.4	6.5	2.1	7.5	1.6	6.5	0.2	7.5	2.7
8.0	0.8	7.5	10.8	8.5	1.6	7.5	3.9	8.5	11.5
9.5	0.8	8.5	16.6	9.5	1.6	8.5	8.4	9.5	18.1
10.5	0.4	9.5	26.1	10.5	1.8	9.5	10.0	10.5	21.2
11.5	0.4	10.5	32.0	11.5	3.9	10.5	10.2	11.5	18.8
12.5	1.7	11.5	31.5	12.5	3.5	11.5	7.7	12.5	15.8
13.5	2.5	12.5	28.2	13.5	5.7	12.5	6.7	13.5	16.5
14.5	0.8	13.5	35.7	14.5	7.1	13.5	6.7	14.5	13.1
15.5	4.6	14.5	34.0	15.5	10.4	14.5	6.9	15.5	20.8
16.5	1.7	15.5	33.6	16.5	9.6	15.5	7.5	16.5	21.2
17.5	0.8	16.5	32.4	17.5	8.1	16.5	6.9	17.5	16.5
18.5	2.9	17.5	30.7	18.5	11.0	17.5	8.6	18.5	20.0
19.5	4.1	18.5	34.9	19.5	13.8	18.5	8.6	19.5	25.0
20.5	5.4	19.5	37.8	20.5	18.3	19.5	7.7	20.5	27.3
21.5	5.4	20.5	30.3	21.5	12.8	20.5	10.6	21.5	27.3
22.5	7.5	21.5	36.5	22.5	15.7	21.5	10.6	22.5	23.1
23.5	3.7	22.5	34.9	23.5	18.1	22.5	13.8	23.5	24.2
24.5	6.2	23.5	33.6	24.5	18.9	23.5	16.5	24.5	21.2
25.5	2.5	24.5	31.1	25.5	18.9	24.5	11.0	25.5	18.5
26.5	3.3	25.5	27.0	26.5	11.4	25.5	10.6	26.5	21.9
27.5	7.5	26.5	24.9	27.5	14.1	26.5	11.6	27.5	14.6
28.5	7.9	27.5	26.1	28.5	12.2	27.5	8.8	28.5	13.5
29.5	6.2	28.5	21.6	29.5	7.5	28.5	6.3	29.5	14.2
30.5	5.0	29.5	14.9	30.5	6.9	29.5	5.9	30.5	10.8
31.5	2.9	30.5	13.7	31.5	4.7	30.5	5.3	31.5	7.7
32.5	2.9	31.5	10.0	32.5	4.9	31.5	2.6	32.5	9.2
33.5	1.2	32.5	5.8	33.5	3.3	32.5	1.6	33.5	5.8
34.5	2.9	33.5	3.7	34.5	2.0	33.5	2.0	34.5	6.5
35.5	1.2	34.5	5.0	35.5	1.8	34.5	2.0	35.5	2.3
36.5	0.4	35.5	3.3	36.5	1.6	35.5	1.0	36.5	3.5
38.5	0.8	36.5	1.2	37.5	0.8	36.5	1.0	37.5	1.5
41.0	0.8	37.5	2.9	39.5	0.2	38.0	0.8	38.5	1.2
43.0	0.4	38.5	1.7	42.5	0.2	39.5	0.6	40.5	0.4
		39.5	0.8	44.5	0.2	40.5	0.2	43.5	0.4
		40.5	0.4	45.5	0.2	41.5	0.4		
		41.5	0.8						
		42.5	0.4						

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
3	3	4	1	4	2	4	2	5	1
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
7.5	2.7	7.0	0.3	7.5	2.4	47.5	3.1	6.5	0.3
8.5	9.2	8.5	1.0	8.5	10.7	48.5	3.4	7.5	7.0
9.5	13.5	10.0	0.3	9.5	12.1	49.5	3.8	8.5	15.1
10.5	11.5	13.0	0.3	10.5	9.0	50.5	2.4	9.5	16.8
11.5	13.8	15.5	0.3	11.5	5.2	51.5	1.4	10.5	20.5
12.5	11.9	16.5	0.3	12.5	8.6	52.5	1.0	11.5	24.6
13.5	10.0	17.5	0.3	13.5	7.6	53.5	2.1	12.5	19.5
14.5	14.6	18.5	0.7	14.5	4.5	54.5	0.7	13.5	20.3
15.5	15.4	19.5	0.7	15.5	5.9	55.5	1.0	14.5	26.8
16.5	7.3	20.5	0.7	16.5	2.8	56.5	0.3	15.5	30.5
17.5	10.0	21.5	1.7	17.5	4.5	57.5	0.3	16.5	27.0
18.5	6.9	22.5	3.4	18.5	5.5	58.5	0.7	17.5	39.2
19.5	12.7	23.5	2.8	19.5	5.9			18.5	43.0
20.5	6.5	24.5	2.8	20.5	6.2			19.5	45.9
21.5	4.6	25.5	2.1	21.5	5.9			20.5	43.8
22.5	4.2	26.5	3.4	22.5	9.7			21.5	38.9
23.5	3.8	27.5	3.4	23.5	8.3			22.5	40.0
24.5	1.9	28.5	3.4	24.5	8.3			23.5	37.0
25.5	1.9	29.5	3.1	25.5	11.7			24.5	30.3
26.5	1.5	30.5	2.8	26.5	14.8			25.5	24.1
27.5	0.8	31.5	5.2	27.5	15.5			26.5	23.5
28.5	1.2	32.5	3.8	28.5	13.4			27.5	19.7
29.5	2.3	33.5	4.5	29.5	17.6			28.5	17.8
30.5	0.8	34.5	5.9	30.5	13.1			29.5	10.5
31.5	0.8	35.5	2.1	31.5	13.8			30.5	6.8
33.0	0.4	36.5	3.1	32.5	14.1			31.5	4.3
38.0	0.4	37.5	4.1	33.5	13.8			32.5	3.8
44.0	0.4	38.5	2.1	34.5	14.5			33.5	1.4
48.0	0.4	39.5	3.1	35.5	17.6			34.5	0.8
		40.5	2.1	36.5	13.1			35.5	0.8
		41.5	0.7	37.5	16.2				
		42.5	0.7	38.5	12.8				
		43.5	1.7	39.5	12.4				
		44.5	1.7	40.5	5.5				
		45.5	0.3	41.5	7.6				
		46.5	0.3	42.5	12.4				
		47.5	0.3	43.5	9.7				
		48.5	0.3	44.5	8.3				
		49.5	0.7	45.5	6.9				
				46.5	3.1				

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
6	1	6	1	6	2	6	2	6	3
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
7.5	1.1	50.5	0.3	7.5	1.9	48.0	0.8	7.5	2.1
8.5	0.8			8.5	8.6	49.5	1.1	8.5	3.5
9.5	0.5			9.5	9.9	50.5	1.1	9.5	7.0
10.5	1.6			10.5	12.0	51.5	0.5	10.5	5.6
11.5	0.8			11.5	14.7	52.5	0.5	11.5	8.8
13.0	0.5			12.5	15.2			12.5	6.4
14.5	1.3			13.5	12.6			13.5	7.0
15.5	1.6			14.5	16.6			14.5	5.6
16.5	1.6			15.5	15.2			15.5	5.9
17.5	2.1			16.5	19.5			16.5	8.0
18.5	1.3			17.5	23.0			17.5	7.2
19.5	2.1			18.5	18.4			18.5	2.9
20.5	2.9			19.5	20.1			19.5	5.1
21.5	2.1			20.5	20.6			20.5	6.7
22.5	1.1			21.5	22.7			21.5	5.1
23.5	2.1			22.5	23.5			22.5	1.9
24.5	4.0			23.5	22.2			23.5	0.8
25.5	2.7			24.5	20.1			24.5	2.7
26.5	4.8			25.5	27.5			25.5	1.3
27.5	1.6			26.5	20.9			26.5	0.8
28.5	2.9			27.5	20.3			27.5	1.3
29.5	2.1			28.5	25.9			28.5	0.3
30.5	5.3			29.5	22.7			30.0	1.1
31.5	2.9			30.5	22.7			31.5	1.1
32.5	4.8			31.5	20.6			32.5	0.3
33.5	4.0			32.5	18.2			34.5	0.3
34.5	3.2			33.5	15.0			37.5	0.3
35.5	2.4			34.5	13.4				
36.5	4.5			35.5	12.6				
37.5	4.3			36.5	10.2				
38.5	3.5			37.5	9.6				
39.5	1.1			38.5	6.4				
40.5	1.6			39.5	5.3				
41.5	1.6			40.5	2.9				
42.5	1.1			41.5	2.7				
43.5	0.8			42.5	2.7				
44.5	1.1			43.5	2.1				
46.0	0.8			44.5	1.6				
48.0	0.8			45.5	1.3				
49.5	0.3			46.5	1.9				

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
7	1	7	2	7	3	8	1	8	2	8	2	8	3	9	2	9	3	10	1	10	2	11	2	12	1	12	2	12	3
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
6.5	3.5	6.5	0.5	6.5	21.4	7.5	1.0	5.5	0.6	45.5	2.9	5.0	0.3	5.5	0.6	7.5	4.4	6.5	1.2	6.5	8.6	8.5	1.4	9.0	1.4	7.5	1.4	6.5	0.5
7.5	13.2	7.5	6.7	7.5	43.3	8.5	1.0	6.5	4.8	46.5	1.9	6.5	1.3	6.5	5.7	8.5	7.0	7.5	2.5	7.5	40.7	9.5	4.1	10.5	0.9	8.5	13.2	7.5	3.3
8.5	20.2	8.5	13.8	8.5	43.8	9.5	0.3	7.5	17.8	47.5	1.0	7.5	8.6	7.5	13.9	9.5	8.9	8.5	6.2	8.5	51.9	10.5	5.5	11.5	1.4	9.5	35.8	8.5	6.6
9.5	19.1	9.5	15.5	9.5	45.9	10.5	1.0	8.5	30.6	48.5	1.0	8.5	13.7	8.5	32.9	10.5	10.1	9.5	3.7	9.5	50.6	11.5	12.3	12.5	1.4	10.5	34.0	9.5	7.5
10.5	20.6	10.5	16.1	10.5	41.9	11.5	0.6	9.5	34.4	50.0	0.3	9.5	14.0	9.5	16.5	11.5	6.3	10.5	4.9	10.5	55.6	12.5	6.8	14.0	0.5	11.5	33.0	10.5	14.6
11.5	24.9	11.5	9.9	11.5	29.1	12.5	1.6	10.5	31.8	51.5	0.3	10.5	11.1	10.5	24.7	12.5	5.7	11.5	3.7	11.5	60.5	13.5	11.0	15.5	1.4	12.5	33.5	11.5	17.0
12.5	29.7	12.5	9.7	12.5	22.9	13.5	1.9	11.5	33.1	52.5	0.3	11.5	19.1	11.5	25.3	13.5	7.0	12.5	4.9	12.5	48.1	14.5	12.3	16.5	1.4	13.5	34.9	12.5	22.6
13.5	29.4	13.5	8.1	13.5	18.9	14.5	1.9	12.5	28.0	53.5	0.3	12.5	22.0	12.5	23.4	14.5	3.8	13.5	8.6	13.5	42.0	15.5	5.5	17.5	2.4	14.5	30.2	13.5	20.3
14.5	31.3	14.5	5.2	14.5	12.7	15.5	1.6	13.5	21.3			13.5	19.1	13.5	22.8	15.5	2.5	14.5	4.9	14.5	63.0	16.5	5.5	18.5	1.9	15.5	36.3	14.5	21.2
15.5	35.1	15.5	4.7	15.5	9.6	16.5	1.0	14.5	28.3			14.5	13.4	14.5	28.5	16.5	4.4	15.5	7.4	15.5	72.8	17.5	6.8	19.5	1.9	16.5	30.2	15.5	22.2
16.5	36.4	16.5	5.3	16.5	6.6	17.5	1.0	15.5	28.7			15.5	17.5	15.5	33.5	17.5	3.8	16.5	7.4	16.5	69.1	18.5	6.8	20.5	3.8	17.5	27.8	16.5	9.0
17.5	37.6	17.5	2.1	17.5	5.7	18.5	2.2	16.5	28.3			16.5	9.6	16.5	24.7	18.5	3.2	17.5	8.6	17.5	53.1	19.5	6.8	21.5	1.4	18.5	26.4	17.5	15.1
18.5	34.5	18.5	2.0	18.5	4.0	19.5	2.5	17.5	23.2			17.5	12.1	17.5	27.8	19.5	4.4	18.5	7.4	18.5	49.4	20.5	5.5	22.5	3.8	19.5	27.4	18.5	6.6
19.5	35.3	19.5	2.2	19.5	2.5	20.5	2.9	18.5	23.9			18.5	8.3	18.5	31.6	20.5	3.8	19.5	6.2	19.5	34.6	21.5	2.7	23.5	2.8	20.5	14.2	19.5	14.6
20.5	35.0	20.5	1.7	20.5	1.2	21.5	3.2	19.5	29.6			19.5	4.8	19.5	24.1	21.5	3.2	20.5	11.1	20.5	46.9	22.5	2.7	24.5	4.2	21.5	21.2	20.5	4.2
21.5	28.7	21.5	1.8	21.5	0.4	22.5	2.5	20.5	20.7			20.5	8.9	20.5	44.9	22.5	2.5	21.5	3.7	21.5	30.9	23.5	4.1	25.5	5.2	22.5	19.3	21.5	3.8
22.5	27.7	22.5	0.6	22.5	0.5	23.5	1.6	21.5	29.3			21.5	5.1	21.5	30.4	23.5	2.5	22.5	4.9	22.5	38.3	24.5	6.8	26.5	4.2	23.5	18.4	22.5	5.2
23.5	28.9	23.5	0.9	23.5	0.2	24.5	1.9	22.5	20.4			22.5	7.0	22.5	34.8	24.5	1.9	23.5	6.2	23.5	25.9	25.5	12.3	27.5	3.3	24.5	9.9	23.5	5.2
24.5	20.4	24.5	0.6	24.5	0.4	25.5	1.6	23.5	22.3			23.5	5.4	23.5	24.1	25.5	2.5	24.5	6.2	24.5	23.5	26.5	15.1	28.5	2.4	25.5	12.7	24.5	1.9
25.5	16.7	25.5	0.9	25.5	0.2	26.5	1.3	24.5	16.9			24.5	1.6	24.5	31.0	26.5	1.3	25.5	8.6	25.5	19.8	27.5	5.5	29.5	1.4	26.5	9.4	25.5	1.4
26.5	13.0	26.5	0.7	26.5	0.1	27.5	1.3	25.5	13.1			25.5	2.2	25.5	23.4	27.5	0.6	26.5	9.9	26.5	11.1	28.5	16.4	30.5	0.9	27.5	8.0	26.5	1.9
27.5	10.5	27.5	0.4	27.5	0.1	28.5	1.3	26.5	15.9			26.5	1.3	26.5	20.3	28.5	0.6	27.5	8.6	27.5	11.1	29.5	17.8	31.5	1.9	28.5	6.6	27.5	1.4
28.5	7.4	28.5	0.4	29.0	0.2	29.5	2.5	27.5	15.6			28.0	1.9	27.5	14.6	30.0	0.6	28.5	7.4	28.5	14.8	30.5	15.1	32.5	1.9	29.5	7.1	29.5	0.5
29.5	6.0	29.5	0.3	31.0	0.1	30.5	1.0	28.5	12.1			29.5	0.3	28.5	17.1	32.0	0.6	29.5	8.6	29.5	13.6	31.5	15.1	33.5	1.4	30.5	6.6	33.5	0.9
30.5	6.7	30.5	0.7	32.5	0.1	31.5	1.9	29.5	16.2			30.5	1.3	29.5	12.0			30.5	14.8	30.5	11.1	32.5	12.3	35.0	0.5	31.5	5.7	38.5	0.5
31.5	3.9	32.5	0.3	34.5	0.1	32.5	1.6	30.5	15.0			31.5	0.6	30.5	8.2			31.5	3.7	31.5	4.9	33.5	8.2	40.0	0.5	32.5	2.8		
32.5	3.8	35.5	0.2	37.5	0.1	33.5	3.2	31.5	15.0			32.5	0.6	31.5	9.5			32.5	6.2	32.5	2.5	34.5	13.7	48.0	0.5	33.5	1.9		
33.5	3.7					34.5	1.6	32.5	14.3					32.5	8.9			33.5	7.4	33.5	1.2	35.5	9.6			34.5	3.8		
34.5	2.7					35.5	1.3	33.5	9.9					33.5	3.2			34.5	2.5	34.5	2.5	36.5	11.0			35.5	1.4		
35.5	1.2					36.5	2.5	34.5	7.6					34.5	3.2			35.5	1.2	35.5	2.5	37.5	8.2			36.5	4.7		
36.5	0.8					37.5	1.3	35.5	4.8					35.5	1.3			36.5	1.2	36.5	2.5	38.5	2.7			37.5	3.3		
37.5	0.9					38.5	0.6	36.5	4.1					36.5	1.3			37.5	1.2	38.0	2.5	39.5	2.7			38.5	3.8		
38.5	0.4					39.5	0.3	37.5	4.1					37.5	1.9			40.5	1.2	40.5	2.5	40.5	2.7			39.5	3.8		
39.5	0.1					40.5	1.3	38.5	6.4					38.5	1.9			45.5	2.5	43.5	1.2	41.5	2.7			40.5	2.4		
40.5	0.1					42.5	0.3	39.5	2.9					39.5	0.6							42.5	1.4			41.5	0.9		
42.0	0.3					45.5	0.3	40.5	3.8					43.0	0.6							43.5	8.2			42.5	0.9		
44.5	0.1							41.5	1.9					49.0	0.6							44.5	4.1			43.5	0.9		
53.5	0.1							42.5	3.8													46.5	2.7			44.5	0.5		
68.5	0.1							43.5	1.9													49.5	1.4			45.5	0.5		
								44.5	1.3																	47.0	0.5		
																										49.0	0.9		

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
13	1	13	2	14	1	14	2	14	3	15	1	15	2	16	1	17	1	17	2	17	3	18	1	19	1	19	2	19	3
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
7.5	2.0	8.5	12.8	8.5	0.2	8.5	3.4	6.5	0.2	7.5	0.6	7.5	2.6	6.5	7.8	5.5	1.3	5.5	0.4	5.5	3.0	6.5	2.3	10.0	0.6	8.5	1.1	12.5	1.1
8.5	0.7	9.5	20.9	9.5	1.5	9.5	15.5	7.5	2.0	8.5	0.9	8.5	15.4	7.5	11.8	6.5	9.4	6.5	1.3	6.5	11.1	7.5	17.0	11.5	1.1	9.5	2.8	14.5	0.6
9.5	0.7	10.5	26.4	10.5	0.7	10.5	13.1	8.5	5.2	9.5	1.1	9.5	20.0	8.5	14.9	7.5	21.7	7.5	23.4	7.5	26.0	8.5	17.3	12.5	1.7	10.5	0.6	15.5	0.6
10.5	3.4	11.5	21.6	11.5	0.2	11.5	11.8	9.5	5.2	10.5	0.3	10.5	15.7	9.5	15.7	8.5	11.1	8.5	53.6	8.5	29.8	9.5	22.3	13.5	0.6	11.5	2.8	16.5	0.6
11.5	3.4	12.5	16.2	12.5	0.7	12.5	11.6	10.5	5.7	11.5	0.6	11.5	14.6	10.5	23.9	9.5	10.2	9.5	56.2	9.5	31.5	10.5	22.3	14.5	0.6	12.5	1.1	17.5	1.1
12.5	3.4	13.5	10.8	13.5	0.5	13.5	11.8	11.5	3.2	12.5	0.3	12.5	11.4	11.5	29.0	10.5	7.2	10.5	45.1	10.5	32.8	11.5	25.9	15.5	0.6	13.5	5.5	18.5	0.6
13.5	2.7	14.5	12.2	14.5	1.5	14.5	10.3	12.5	2.2	13.5	0.3	13.5	10.0	12.5	47.1	11.5	8.5	11.5	51.9	11.5	20.9	12.5	36.5	17.0	1.1	14.5	1.7	19.5	1.1
14.5	4.1	15.5	9.5	15.5	2.2	15.5	10.8	13.5	2.2	14.5	0.9	14.5	7.1	13.5	51.0	12.5	8.9	12.5	33.6	12.5	23.0	13.5	35.3	18.5	1.1	15.5	2.8	20.5	0.6
15.5	10.1	16.5	8.8	16.5	1.0	16.5	7.9	14.5	4.4	15.5	0.3	15.5	6.3	14.5	71.4	13.5	11.1	13.5	33.2	13.5	12.3	14.5	46.2	19.5	1.1	16.5	7.7	21.5	1.1
16.5	5.4	17.5	5.4	17.5	1.5	17.5	9.4	15.5	4.7	16.5	1.7	16.5	4.9	15.5	67.5	14.5	8.5	14.5	29.8	14.5	17.9	15.5	43.9	20.5	4.4	17.5	5.5	22.5	1.1
17.5	13.5	18.5	2.0	18.5	3.0	18.5	8.4	16.5	3.0	17.5	1.4	17.5	2.6	16.5	62.0	15.5	10.6	15.5	30.2	15.5	15.7	16.5	43.9	21.5	6.1	18.5	5.0	23.5	2.2
18.5	6.8	19.5	5.4	19.5	3.4	19.5	9.1	17.5	8.6	18.5	4.6	18.5	2.3	17.5	66.3	16.5	12.8	16.5	18.3	16.5	14.9	17.5	35.8	22.5	6.1	19.5	7.2	24.5	1.1
19.5	8.8	20.5	2.7	20.5	4.7	20.5	6.7	18.5	5.7	19.5	6.3	19.5	1.7	18.5	56.9	17.5	15.3	17.5	20.0	17.5	17.4	18.5	47.0	23.5	6.1	20.5	12.2	25.5	2.2
20.5	6.8	21.5	3.4	21.5	6.7	21.5	8.6	19.5	4.4	20.5	6.0	20.5	2.9	19.5	50.6	18.5	17.4	18.5	18.3	18.5	12.3	19.5	42.4	24.5	3.3	21.5	12.7	26.5	0.6
21.5	14.2	22.5	0.7	22.5	8.4	22.5	13.8	20.5	4.9	21.5	8.6	21.5	2.6	20.5	45.1	19.5	17.9	19.5	28.1	19.5	8.5	20.5	37.8	25.5	6.1	22.5	7.2	27.5	1.1
22.5	18.9	23.5	3.4	23.5	10.6	23.5	9.4	21.5	3.2	22.5	13.7	22.5	3.1	21.5	38.0	20.5	21.7	20.5	22.6	20.5	12.3	21.5	23.9	26.5	4.4	23.5	15.5	29.0	0.6
23.5	17.6	24.5	2.7	24.5	10.6	24.5	12.3	22.5	5.4	23.5	12.6	23.5	1.1	22.5	25.5	21.5	16.6	21.5	19.6	21.5	8.1	22.5	18.0	27.5	5.0	24.5	11.6	31.0	1.1
24.5	15.5	25.5	4.7	25.5	6.9	25.5	5.7	23.5	3.2	24.5	18.6	24.5	2.9	23.5	15.3	22.5	17.0	22.5	18.7	22.5	6.4	23.5	13.7	28.5	4.4	25.5	15.5		
25.5	10.1	26.5	4.1	26.5	8.4	26.5	6.4	24.5	1.5	25.5	19.1	25.5	4.9	24.5	16.1	23.5	15.3	23.5	21.3	23.5	5.1	24.5	10.7	29.5	6.6	26.5	16.0		
26.5	13.5	27.5	2.7	27.5	10.3	27.5	8.9	25.5	2.0	26.5	27.4	26.5	1.4	25.5	14.5	24.5	11.9	24.5	16.6	24.5	3.0	25.5	7.6	30.5	2.8	27.5	11.6		
27.5	23.0	28.5	6.8	28.5	12.6	28.5	5.9	26.5	2.5	27.5	23.4	27.5	5.1	26.5	13.3	25.5	7.2	25.5	11.5	25.5	4.3	26.5	6.3	31.5	4.4	28.5	12.7		
28.5	17.6	29.5	2.7	29.5	8.1	29.5	4.7	27.5	0.7	28.5	18.3	28.5	3.1	27.5	3.9	26.5	8.9	26.5	13.6	26.5	2.1	27.5	3.0	32.5	6.6	29.5	8.8		
29.5	10.8	30.5	0.7	30.5	8.4	30.5	3.0	28.5	1.0	29.5	18.9	29.5	3.7	28.5	3.9	27.5	7.2	27.5	9.8	27.5	1.3	28.5	2.5	33.5	2.2	30.5	12.2		
30.5	11.5	31.5	1.4	31.5	4.9	31.5	4.2	29.5	1.0	30.5	17.7	30.5	2.3	29.5	1.6	28.5	3.0	28.5	9.4	28.5	0.9	29.5	3.0	34.5	0.6	31.5	7.7		
31.5	13.5	32.5	2.0	32.5	6.4	32.5	3.4	30.5	1.2	31.5	11.7	31.5	3.7	30.5	2.7	29.5	3.8	29.5	7.2	29.5	0.4	30.5	1.3	35.5	2.2	32.5	4.4		
32.5	15.5	33.5	2.7	33.5	4.4	33.5	3.2	31.5	0.7	32.5	13.1	32.5	4.0	31.5	0.8	30.5	3.0	30.5	3.4	30.5	0.4	32.5	0.8	36.5	1.7	33.5	6.1		
33.5	5.4	35.0	0.7	34.5	3.2	34.5	1.7	33.5	0.7	33.5	14.0	33.5	3.1	32.5	0.8	31.5	2.6	31.5	4.3			35.5	0.3	37.5	0.6	34.5	2.2		
34.5	12.8	37.0	0.7	35.5	2.7	35.5	2.5	35.5	0.7	34.5	9.4	34.5	3.7			32.5	0.4	32.5	3.8					38.5	0.6	35.5	6.6		
35.5	7.4			36.5	1.0	36.5	1.2	38.0	0.2	35.5	4.0	35.5	3.7			33.5	2.6	33.5	3.0					41.5	0.6	36.5	3.3		
36.5	2.7			37.5	2.2	37.5	1.2	40.5	0.2	36.5	2.9	36.5	2.6			34.5	0.4	34.5	3.0					46.5	0.6	37.5	1.1		
37.5	2.7			38.5	1.5	38.5	0.5	42.0	0.2	37.5	2.6	37.5	1.7			35.5	0.4	35.5	1.3							38.5	1.7		
38.5	1.4			39.5	1.0	39.5	0.2	44.0	0.2	38.5	1.1	38.5	1.4			36.5	0.9	36.5	1.7							39.5	0.6		
39.5	2.7			40.5	0.7	41.5	0.7			39.5	1.4	39.5	1.4			37.5	0.4	37.5	1.7							40.5	0.6		
40.5	2.0			41.5	0.2	44.5	0.5			41.5	0.6	40.5	0.9			38.5	0.9	38.5	0.4							41.5	1.1		
41.5	2.0			42.5	0.7					44.5	0.3	41.5	1.1					40.0	0.4							42.5	0.6		
42.5	2.0			43.5	0.2							42.5	0.9					41.5	0.4							43.5	1.1		
												43.5	0.6					43.0	0.4							44.5	0.6		
												44.5	0.3					46.0	0.4							46.5	0.6		
												45.5	0.3					50.0	0.4							49.5	0.6		
												48.5	0.3													53.0	0.6		
												53.5	0.3													57.0	0.6		

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
20	1	20	2	21	1	21	2	22	2
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
8.5	0.5	7.5	3.7	12.0	0.5	8.5	0.5	4.5	1.0
9.5	1.0	8.5	4.7	15.5	0.5	9.5	4.8	5.5	1.9
10.5	2.1	9.5	8.9	17.5	1.0	10.5	2.9	6.5	3.8
12.0	2.1	10.5	8.9	18.5	2.4	13.0	1.0	7.5	41.0
13.5	1.6	11.5	11.5	19.5	2.9	15.5	0.5	8.5	74.3
14.5	3.1	12.5	12.0	20.5	4.3	16.5	0.5	9.5	88.6
15.5	2.1	13.5	15.7	21.5	7.1	17.5	1.4	10.5	92.4
16.5	1.6	14.5	18.3	22.5	10.0	18.5	1.9	11.5	94.3
17.5	3.1	15.5	15.2	23.5	14.3	19.5	2.4	12.5	95.2
18.5	7.3	16.5	14.7	24.5	20.5	20.5	2.9	13.5	86.7
19.5	5.8	17.5	14.7	25.5	20.0	21.5	2.9	14.5	72.4
20.5	5.2	18.5	19.4	26.5	21.0	22.5	2.4	15.5	53.3
21.5	4.7	19.5	15.2	27.5	16.2	23.5	6.2	16.5	75.2
22.5	5.2	20.5	18.8	28.5	19.5	24.5	8.6	17.5	55.2
23.5	3.1	21.5	16.2	29.5	21.4	25.5	6.2	18.5	66.7
24.5	5.8	22.5	25.1	30.5	19.0	26.5	10.0	19.5	45.7
25.5	3.7	23.5	26.2	31.5	11.9	27.5	6.7	20.5	55.2
26.5	2.6	24.5	16.8	32.5	15.7	28.5	8.6	21.5	41.0
27.5	1.6	25.5	19.4	33.5	10.0	29.5	5.2	22.5	35.2
28.5	1.6	26.5	22.5	34.5	8.6	30.5	3.3	23.5	26.7
30.0	1.0	27.5	16.8	35.5	4.8	31.5	4.3	24.5	29.5
31.5	1.0	28.5	17.8	36.5	4.8	32.5	4.3	25.5	30.5
33.5	0.5	29.5	14.7	37.5	1.4	33.5	4.3	26.5	21.0
35.5	0.5	30.5	11.5	38.5	2.4	34.5	2.9	27.5	15.2
38.5	0.5	31.5	11.5	39.5	0.5	35.5	1.9	28.5	17.1
43.5	0.5	32.5	11.0	40.5	0.5	36.5	1.4	29.5	7.6
		33.5	6.8	42.0	0.5	37.5	1.0	30.5	7.6
		34.5	4.2	44.0	0.5	38.5	1.4	31.5	11.4
		35.5	3.7			39.5	1.0	32.5	5.7
		36.5	3.7			40.5	1.4	33.5	6.7
		37.5	3.7			41.5	0.5	34.5	3.8
		38.5	0.5			43.0	0.5	36.5	1.9
		40.0	1.0			45.0	0.5	38.5	2.9
		43.0	0.5					41.0	1.0
		46.0	0.5					43.5	1.0
		48.0	0.5					44.5	1.0
								45.5	1.0
								47.0	1.0
								49.0	1.0

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
23	1	24	1	24	2	25	1	25	2
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
4.0	0.6	7.5	7.5	8.5	1.9	6.5	0.6	7.5	4.7
8.5	0.6	9.5	5.7	9.5	7.5	7.5	2.4	8.5	15.4
10.0	3.2	11.5	1.9	10.5	3.8	8.5	4.7	9.5	16.6
11.5	1.3	13.0	1.9	11.5	5.7	9.5	4.7	10.5	18.9
12.5	2.6	15.5	1.9	12.5	5.7	10.5	4.7	11.5	20.1
13.5	3.2	18.5	3.8	13.5	5.7	11.5	12.4	12.5	22.5
14.5	1.3	20.5	3.8	14.5	11.3	12.5	10.1	13.5	20.7
15.5	3.9	21.5	13.2	15.5	3.8	13.5	14.8	14.5	27.8
16.5	5.2	22.5	3.8	16.5	5.7	14.5	10.1	15.5	24.9
17.5	8.4	23.5	11.3	17.5	9.4	15.5	12.4	16.5	27.2
18.5	8.4	24.5	5.7	18.5	11.3	16.5	19.5	17.5	21.3
19.5	18.8	25.5	15.1	19.5	17.0	17.5	18.9	18.5	22.5
20.5	30.5	26.5	5.7	20.5	17.0	18.5	20.7	19.5	18.3
21.5	30.5	27.5	9.4	21.5	18.9	19.5	18.3	20.5	23.1
22.5	26.6	28.5	13.2	22.5	17.0	20.5	27.2	21.5	21.9
23.5	19.5	30.0	9.4	23.5	18.9	21.5	12.4	22.5	17.8
24.5	28.6	31.5	5.7	24.5	17.0	22.5	23.1	23.5	29.0
25.5	22.1	32.5	5.7	25.5	22.6	23.5	24.9	24.5	20.1
26.5	15.6			26.5	15.1	24.5	20.1	25.5	16.6
27.5	11.0			27.5	17.0	25.5	14.2	26.5	19.5
28.5	7.8			28.5	9.4	26.5	11.8	27.5	11.8
29.5	4.5			29.5	5.7	27.5	9.5	28.5	9.5
30.5	2.6			30.5	5.7	28.5	9.5	29.5	8.3
31.5	1.3			31.5	3.8	29.5	5.9	30.5	7.1
32.5	0.6			32.5	1.9	30.5	7.1	31.5	8.3
				34.0	3.8	31.5	3.0	32.5	3.0
				36.5	1.9	32.5	1.2	33.5	1.2
				39.5	1.9	33.5	2.4	34.5	3.0
						34.5	1.8	35.5	1.8
						35.5	0.6	37.0	1.8
						36.5	0.6	39.0	1.2
								41.0	0.6

Stand	Species	Stand	Species	Stand	Species	Stand	Species	Stand	Species
25	3	26	1	26	2	26	3	27	1
DBH	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**	**DBH**	**n/ha**
5.5	0.6	10.5	1.2	7.5	1.2	8.5	3.6	7.5	0.7
6.5	4.1	11.5	1.2	8.5	2.4	9.5	2.4	8.5	1.3
7.5	18.3	14.0	1.2	9.5	16.9	10.5	4.8	9.5	0.7
8.5	33.1	16.5	1.2	10.5	24.1	11.5	4.8	11.0	1.3
9.5	31.4	17.5	1.2	11.5	33.7	12.5	3.6	12.5	3.9
10.5	37.3	19.0	2.4	12.5	26.5	13.5	6.0	13.5	0.7
11.5	52.7	20.5	4.8	13.5	25.3	14.5	1.2	14.5	0.7
12.5	46.2	21.5	4.8	14.5	20.5	15.5	6.0	16.0	0.7
13.5	49.7	22.5	4.8	15.5	9.6	16.5	3.6	17.5	1.3
14.5	49.7	23.5	14.5	16.5	18.1	17.5	1.2	18.5	2.6
15.5	53.8	24.5	14.5	17.5	7.2	18.5	4.8	19.5	2.0
16.5	47.9	25.5	9.6	18.5	10.8	19.5	1.2	20.5	3.9
17.5	56.2	26.5	8.4	19.5	19.3	20.5	9.6	21.5	2.6
18.5	42.6	27.5	9.6	20.5	15.7	21.5	2.4	22.5	3.9
19.5	37.3	28.5	10.8	21.5	16.9	22.5	4.8	23.5	7.8
20.5	25.4	29.5	6.0	22.5	7.2	23.5	3.6	24.5	11.1
21.5	20.7	30.5	6.0	23.5	6.0	24.5	1.2	25.5	17.6
22.5	7.7	31.5	6.0	24.5	7.2	26.0	1.2	26.5	17.0
23.5	10.1	32.5	7.2	25.5	14.5	28.0	1.2	27.5	19.0
24.5	10.1	33.5	7.2	26.5	7.2	30.0	1.2	28.5	20.3
25.5	5.3	34.5	2.4	27.5	7.2			29.5	31.4
26.5	4.1	36.0	1.2	28.5	7.2			30.5	30.7
28.0	1.2	38.0	3.6	29.5	4.8			31.5	30.1
30.0	0.6			30.5	4.8			32.5	27.5
31.5	0.6			31.5	2.4			33.5	33.3
32.5	0.6			32.5	3.6			34.5	21.6
				33.5	1.2			35.5	15.0
				34.5	2.4			36.5	16.3
				36.0	1.2			37.5	9.8
				41.5	1.2			38.5	4.6
				50.5	1.2			39.5	6.5
								40.5	2.0
								41.5	1.3
								42.5	0.7
								43.5	2.0
								44.5	0.7
								46.0	1.3
								48.0	0.7

Stand	Species	Stand	Species
27	2	27	3
DBH	**n/ha**	**DBH**	**n/ha**
6.5	6.5	6.5	2.6
7.5	23.5	7.5	7.2
8.5	34.0	8.5	22.9
9.5	29.4	9.5	23.5
10.5	35.9	10.5	17.0
11.5	30.7	11.5	15.0
12.5	29.4	12.5	15.0
13.5	28.1	13.5	17.0
14.5	19.6	14.5	7.8
15.5	17.6	15.5	6.5
16.5	20.9	16.5	9.8
17.5	17.0	17.5	2.6
18.5	17.6	18.5	3.9
19.5	19.0	19.5	3.3
20.5	12.4	20.5	1.3
21.5	7.8	21.5	2.0
22.5	9.8	22.5	1.3
23.5	17.0	23.5	2.0
24.5	6.5	24.5	0.7
25.5	9.2	25.5	2.6
26.5	11.8	26.5	2.0
27.5	9.8	27.5	2.0
28.5	9.8	28.5	0.7
29.5	5.2	30.5	1.3
30.5	4.6	39.0	1.3
31.5	7.2	53.0	0.7
32.5	5.9		
33.5	4.6		
34.5	5.2		
35.5	4.6		
36.5	5.9		
37.5	3.3		
38.5	2.0		
39.5	2.0		
40.5	2.0		
41.5	2.0		
42.5	2.6		
43.5	0.7		
44.5	1.3		
45.5	1.3		
47.0	1.3		
49.0	1.3		