Biomass Potential from Clear Fellings in Latvia

Biomasas potenciāls Latvijā no kailcirtēm

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Abstract

In recent years, the importance of renewable energy sources, including biomass, has considerably increased in EU and Nordic regions. The target level for EU is to reach 20% of total energy consumption. Latvia has to increase its share of renewables by 7% to reach its goal of 40% by 2020. The main, and still not fully used, renewable resource is biomass in Latvia.

The aim of this study is to evaluate available and potential resources of biomass from clear cuts now and in the future. Core data is taken from the National Forest Inventory (NFI), which is done for the first time in the history of Latvia. Availability of biomass is estimated at three levels and nine sublevels showing the change of available biomass today and in the future if harvest intensity and technologies of collecting energy wood in clear cuts are improved. Also, possible changes in the pulpwood market are reviewed. Level 1 expresses harvest intensity according to data from the State Forest Service. According to data from NFI level 2 shows the same pattern as level 1 and level 3 gives the maximum level of available biomass. Results are expressed in oven dry tones of energy wood.

Today the main limiting factor for the expansion of energy extraction from wood from clear cuts is the cost of energy wood. About 20% of all clear cuts are used for energy wood collection. The quantities that are produced today may be increased by about three times by optimizing the utilization of clear cuts used for energy wood extraction and slight improvements in methods and technologies. The main assortment of energy wood at the moment is logging residues and firewood. At level 1, biomass potential is 0.79 m odt (oven dry tons) annually. If, at the same level, stump lifting would be introduced, available biomass would be 0.98 m odt (level 1.1). With improved technologies and optimal land use, biomass for energy would reach 2.54 m odt. If in the market situation price for pulpwood is too low and it is used as energy wood, available biomass would be 3.66 m odt. At the base of level 2, available biomass is 1.06 m odt annually. With the stump lifting at level 2.1, the volume of energy wood is 1.30 m odt. Optimal land use and improved technologies at level 2.2 gives 3.40 m odt. By adding pulpwood biomass potential at the level 2.3, it is possible to reach 4.89 m odt. At the maximum harvest intensity at level 3 biomass potential is 2.21 m odt, level 3.1 gives 2.73 m odt, level 3.2 – 7.10 m odt, and the maximum annually available biomass potential at level 3.3 is 10.23 m odt.

It is rather hard to estimate biomass potential from the raw data of NFI, but the results look realistic when compared to other studies. Extra quantities of energy wood could be added from wood processing as a secondary source of biomass, which is not considered in this paper.

Keywords: biomass, potential, logging residues, stumps, firewood, pulpwood, Latvia

Anotācija

Pēdējos gados atjaunojamu energoresursu, ieskaitot biomasu, nozīmīgums ES un ziemeļu rajonos ir ievērojami pieaudzis. ES mērķis ir sasniegt 20% atjaunojamās enerģijas no kopējā enerģijas patēriņa, tas nozīmē, Latvijai ir jāpalielina atjaunojamo energoresursu īpatsvars par 7%, lai sasniegtu 40% mērķi 2020. gadā. Galvenais un joprojām pilnīgi neizmantotais atjaunojamais resurss Latvijā ir biomasa.

Šī pētījuma mērķis bija biomasas pieejamā un potenciālā apjoma noteikšana no kailcirtēm šobrīd un nākotnē. Pamata informācija ir ņemta no nacionālās meža inventarizācijas, kas Latvijas vēsturē ir veikta pirmo reizi. Biomasas pieejamība ir novērtēta trīs pakāpēs un kopā deviņās apakšpakāpēs, uzrādot pieejamās biomasas izmaiņas šodien un nākotnē, ja mežistrādes intensitāte un energokoksnes savākšanas tehnoloģijas kailcirtēs tiek uzlabotas. Arī iespējamās izmaiņas papīrmalkas tirgū ir virspusēji apskatītas. Pirmais līmenis izsaka ciršanas intensitāti saskaņā ar Valsts meža dienesta datiem. Otrais līmenis parāda to pašu, ko pirmais, bet saskaņā ar NMI. Trešais līmenis uzrāda maksimālo pieejamās biomasas apjomu saskaņā ar NMI. Rezultāti ir izteikti energokoksnes tonnās sausnas.

Šodien galvenais limitējošais energokoksnes savākšanas izplatības faktors no kailcirtēm ir cena un izmaksas par energokoksni. Apmēram 20% no visām kailcirtēm ir izmantotas energokoksnes savākšanai. Izstrādātie apjomi šodien var tikt palielināti apmēram 3 reizes optimizējot kailciršu izmantošanu energokoksnes savākšanai, un nedaudz uzlabojot metodes un tehnoloģijas biomasas izstrādē. Galvenais energokoksnes sortiments šobrīd ir mežistrādes atliekas un malka. Pirmajā līmenī biomasas potenciāls ir 0,79 milj. sausnas gadā. Ja tādā pašā pakāpē tiktu ieviesta celmu izstrāde, pieejamais biomasas daudzums būtu 0,98 milj. sausnas (1.1 līmenis). Ar uzlabotām tehnoloģijām un optimālu zemes izmantošanu, biomasa enerģijas ražošanas nolūkiem sasniegtu 2,54 milj. sausnas (1.2 līmenis). Un pie nosacījuma, ka papīrmalkas cena ir pārāk zema, un tā tiek izmantota kā energokoksne, pieejamais biomasas daudzums būtu 3.66 milj. sausnas (1.3 līmenis). Otrajā pamatlīmenī, pieejamais biomasas apjoms ir 1,06 milj. sausnas. Ar celmu izstrādi 2.1 līmenī energokoksnes apjomi ir 1,30 milj. sausnas. Optimāla zemes izmantošana un uzlabotas tehnoloģijas 2.2 līmenī dod 3,40 milj. sausnas. Un pievienojot papīrmalku, biomasas potenciāls 2.3 līmenī sasniedz 4,89 milj. sausnas. Pie maksimālas ciršanas intensitātes 3. līmenī biomasas potenciāls ir 2,21 milj. sausnas, 3.1 līmenis dod 2,73 milj. sausnas, 3.2 līmenis 3.2 – 7,10 milj. sausnas, un maksimālais pieejamais biomasas potenciāls 3.3 līmenī ir 10,23 milj. sausnas.

Ir diez gan sarežģīti novērtēt biomasu potenciālu no NMI pamatdatiem, bet salīdzinātie rezultāti ar citiem autoriem izskatās ticami. Papildus energokoksne var tikt pievienota no kokapstrādes kā sekundārs biomasas avots, kas nav iekļauts šai darbā.

Atslēgas vārdi: biomasa, potenciāls, ciršanas atliekas, celmi, malka, papīrmalka, Latvija

Table of Content

1. Introduction

According to the directive 2009/28/EC of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Energy Sources, the proportion of renewable sources in Latvia at the year 2020 must reach 40% of the total energy consumption. Today the share of renewables is 32.6% (The European Parliament and The Council of the European Union, 2009). In the European Union context, biomass is the only renewable source, which, in the short term, can ensure the sustainability of the power industry. In 2004, 4.13% of the total Gross Inland Consumption in the EU, came from biomass resources (Ragossnig, 2007). The EU target for the year 2020 is to reach 20% share of renewables (The European Parliament and The Council of the European Union, 2009). The forest is one of the most important resources in Latvia. With an increasing global demand for biomass, forest resources will play an important role in the fulfillment of economic, social, environmental and national energy requirements in a new market situation.

1.1. Energy Sector and Primary Energy Sources

The total consumption of primary energy resources in Latvia was 204.6 PJ (Peta – Joule) or 56.8 TWh (terawatt hour) in 2007 (Ministry of Economics of the Republic of Latvia, 2009). Due to climatic conditions, the heating season in Latvia is 200 – 210 days. 44% of the energy generated in Latvia is used for thermal heating (Figure 1) (Latvia Distric Heating Association, 2009).

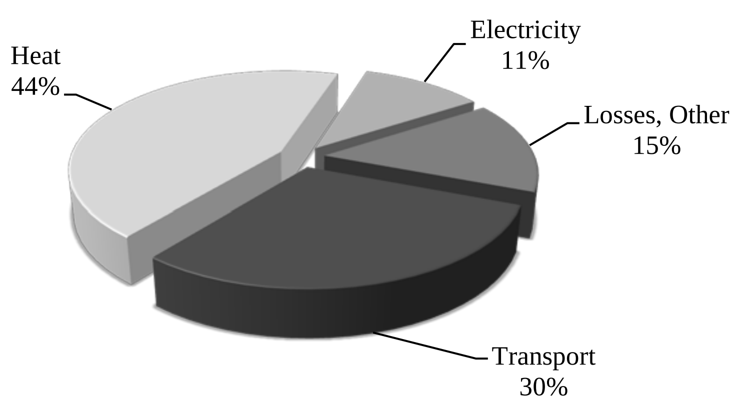

Figure 1. Energy balance in Latvia, year 2007

Attēls 1. *Energo bilance Latvijā 2007 gadā.*

Of the total final energy consumed in Latvia, 25.5% comes from biomass, the second highest figure in EU 27 (European Biomass Association, 2009). However, this figure is likely higher since the use of firewood is likely not accounted for in the statistics. The final energy consumption includes 100% of biomass used in households, industry, and transport.

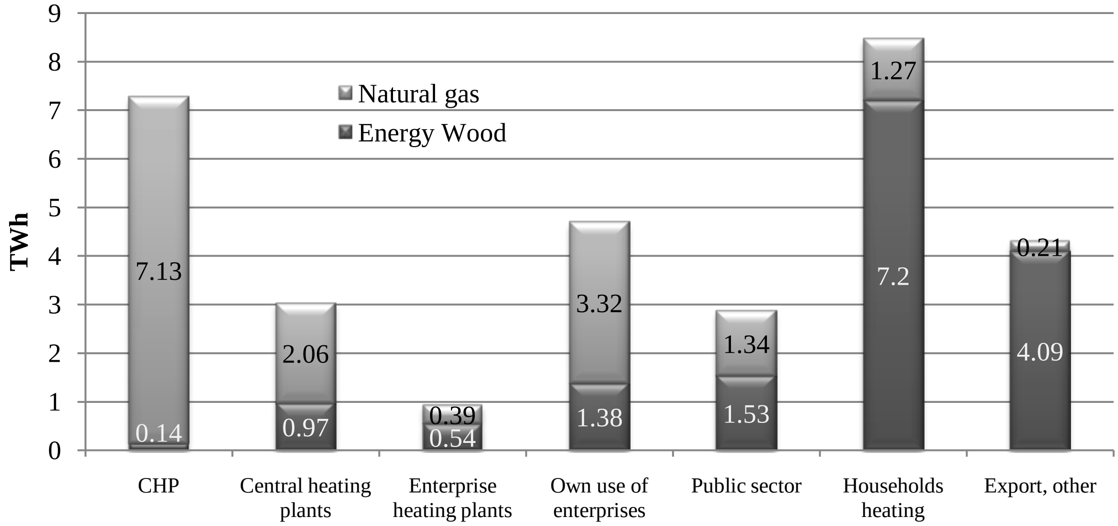

Figure 2. The annual use of natural gas and energy wood in Latvia, year 2007

Attēls 2. *Dabas gāzes un enerģētiskās koksnes vietēja ikgadējā izmantošana Latvijā, 2007 gadā*

If comparing the two main competing resources in production of thermal energy; natural gas and energy wood, it's apparent that user groups are split in two main groups: big scale energy producers and small scale energy producers or households (Figure 2). In general, big scale energy producers i.e. combined heat and power plants (CHP), central heating plants and enterprises produced heat and electricity by utilizing natural gas. The local use of biomass has been quite stable from 2004 to 2008, while biomass export has been fluctuating more relative to local use. As figure 3 shows, export of biomass dominates over local use when biomass for technological processes and production of heat and electricity is used. Export of biomass is fourth greatest use of all forestry goods in Latvia, and, expressed in monetary value, is just behind sawn goods, roundwood and plywood (Lazdiņa, 2008).

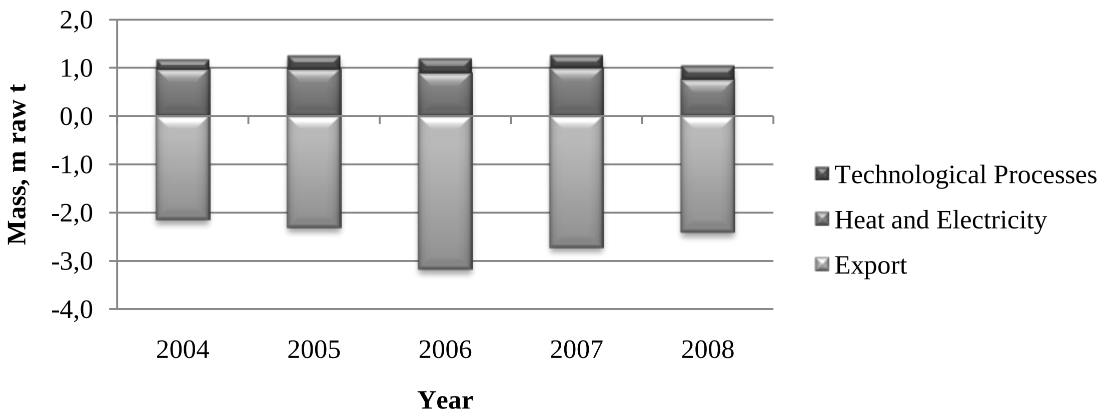

Figure 3. Use of biomass for technological processes, heat and electricity and export in Latvia (Latvijas republikas Zemkopības ministrija, 1993-2009), (Latvian Environment Geology and Meteorology Centre, n.d.).

Attēls 3. *Biomasas izmantošana Latvijā tehnoloģiskajiem procesiem, siltuma un elektroenerģijas ražošanai un eksportam.*

Figure 4 shows that gas price index has increased by 170 index points, from 2004 to 2009 (CSB of Latvia, n.d.). Together with the financial crisis, the increase in gas price has dramatically increased the heating bills to a level that many people are no longer capable of paying for delivered heat.

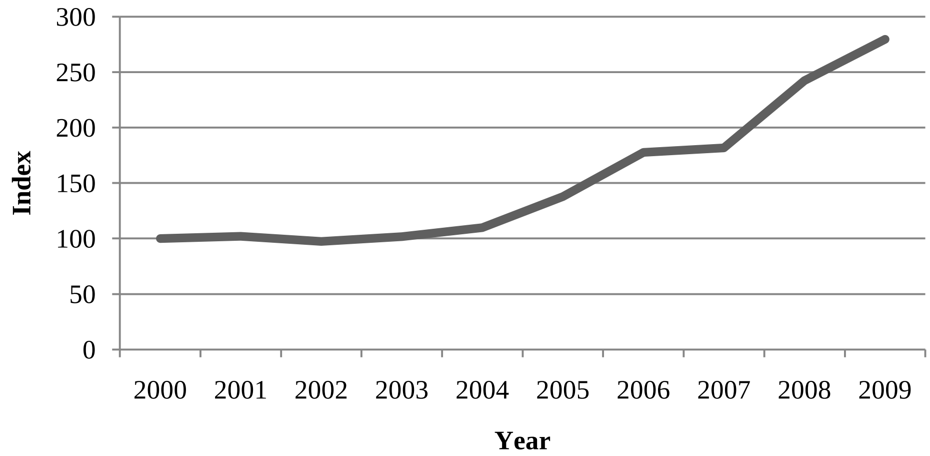

Figure 4. Index of gas price in Latvia from year 2000 to 2009. Index at year 2000 is assumed to be 100.

Attēls 4. *Gāzes cenu indekss Latvijā no 2004 līdz 2009 gadam. Indekss 2000 gadā ir pieņemts kā 100.*

As figure 1, 2 and 3 show, to produce the thermal energy at needed level in Latvia, instead of importing increasingly expensive gas, local resources could be used, mainly biomass from forestry.

1.2. Forest coverage and ownership structure in Latvia

According to data from the National Forest Inventory (NFI), forest coverage in Latvia has increased to 50% compared to 23% in 1923 according to State Forest Service (SFS) (Valsts meža dienests, n.d.;Latvijas republikas Zemkopības ministrija, 2004). Afforestation has occurred on abandoned agricultural land, and in the future, further increase of forest area is expected. Forest coverage over the whole country is not evenly distributed and varies from 29.9% to 64.3% (Figure 5).

In Latvia, 47% of the total forest land is owned by the state and is managed by joint stock company Latvijas valsts meži (LVM). The rest of the forest is privately owned and accounts for the remaining 53% (Latvijas republikas Zemkopības ministrija, n.d.-a).

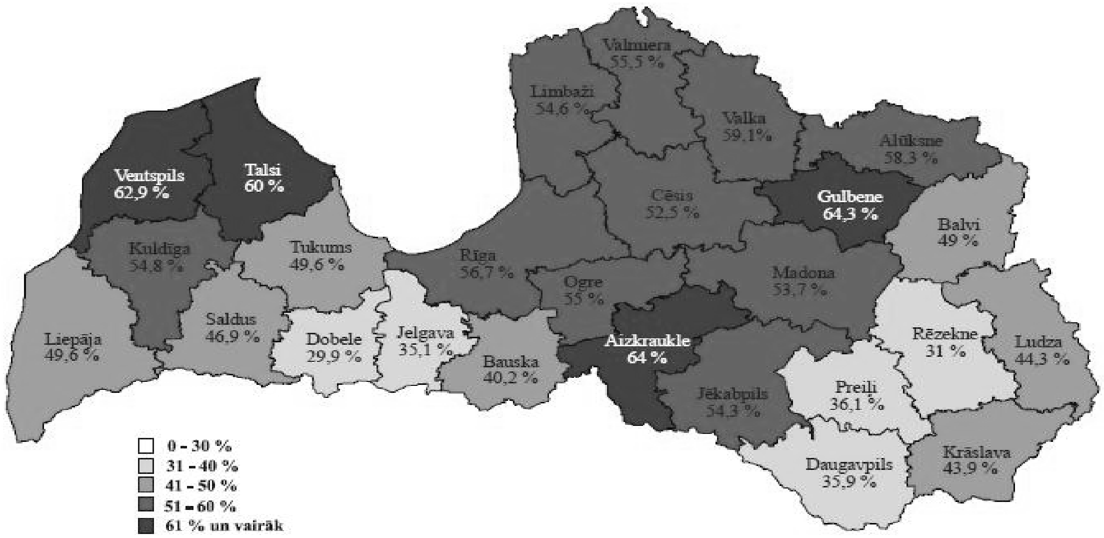

Figure 5. Forest coverage by districts in Latvia (Latvijas republikas Zemkopības ministrija, n.d.-b)

Attēls 5. Mežainums Latvijā pa rajoniem.

The trees species distribution varies between the state–owned and private–owned forests. State–owned forests are comprised of 58% conifers compared with 29% of private–owned forest (Latvijas republikas Zemkopības ministrija, n.d.-a). Deciduous trees, especially grey alder which is mostly used for firewood, dominate the private–owned forests (Figure 6).

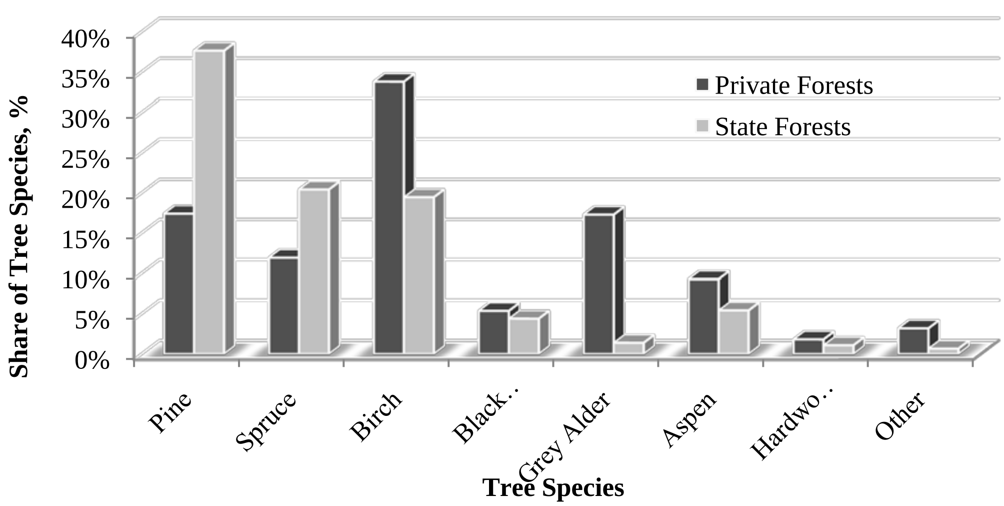

Figure 6. Tree species distribution in private and state forests in Latvia.

Attēls 6. *Koku sugu sadalījums privātajos un valsts mežos Latvijā.*

Figure 7 shows the present age structure of all the main tree species in Latvia. In the next 30 years there will be an increase of mature birch stands with the area reaching 155 thousand hectares and a slight increase of area for spruce (Figure 7). In next 40 years an increase of pine stands is expected, but after that a rapid decrease will follow.

Figure 8 shows, a peak of mature grey alder stands which accounts for 83 thousand hectares. Grey alder is sometimes used for packaging and charcoal production, however, there is very little market for grey alder other than for biofuel. After 10 to 20 years, a rapid increase of aspen stands is predicted and area of aspen stands may reach 69 thousand hectares. (Latvijas republikas Zemkopības ministrija, 2004).

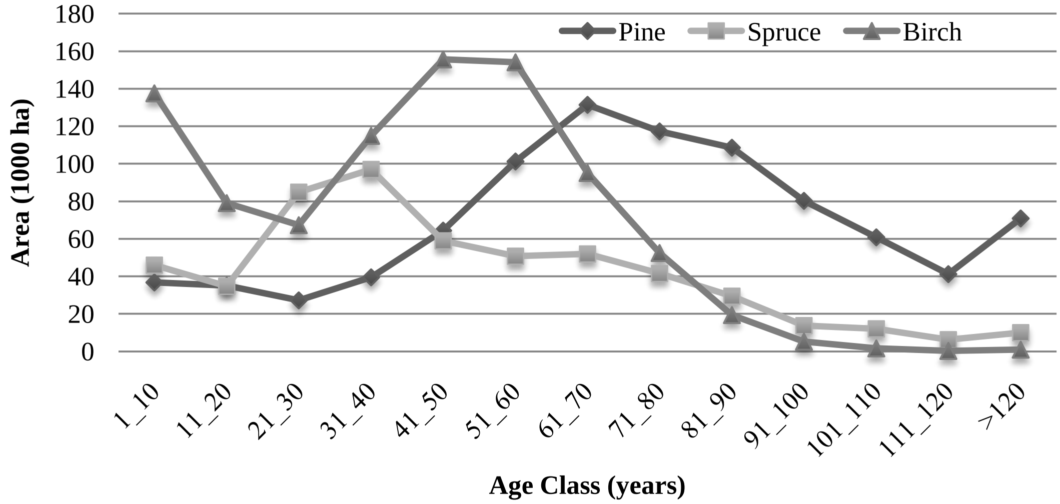

Figure 7. Age structure of pine, spruce and birch in Latvia.

Attēls 7. *Priedes, egles un bērza vecumstruktūra Latvijā.*

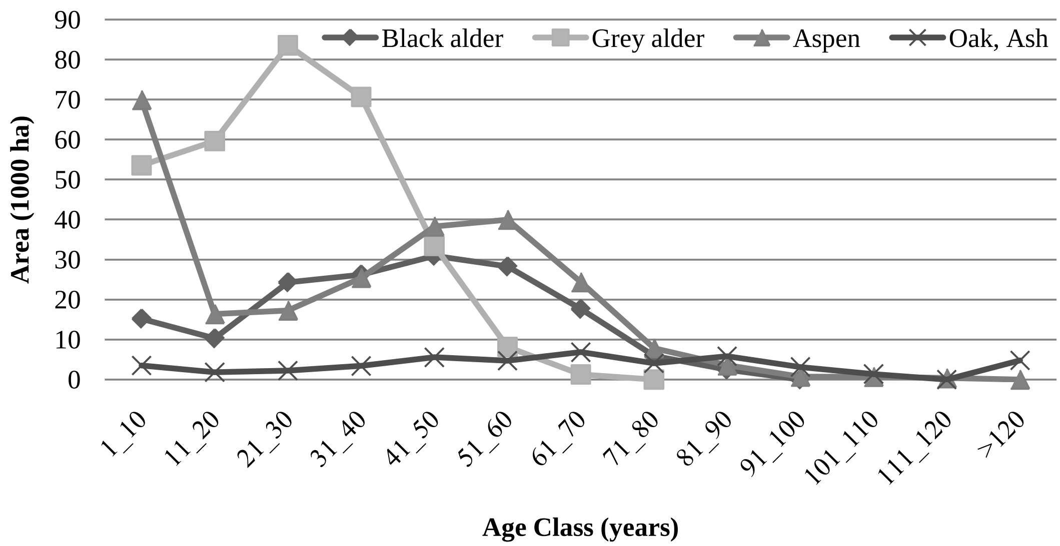

Figure 8. Age structure of black alder, grey alder, aspen, oak and ash-tree in Latvia.

Attēls 8. *Melnalkšņa, baltalkšņa, apses, ozola un oša vecumstruktūra Latvijā.*

1.2.1. Study limitations

Current biomass use in Latvia could be divided into three main groups: agriculture byproducts, waste from landfills, and biomass from forestry.

Abandoned agriculture land has been the object of discussions for some time with regarding to biomass, however, this area of interest lacks data, to make a good overall estimation of biomass. Development and utilization of the waste from landfills is improving and today one of the main energy sources from the landfills is biogas.

Forest biomass is the most widely used type of biomass in Latvia today. It is divided into two major groups: direct biomass from forest (branches, tops, stumps and firewood) and forest industry by–products (woodchips, offcuts, sawdust, bark, etc.). Forest industry by–products are not considered in this paper as it is a secondary flow of biomass.

Although woody biomass for energy purposes can be produced in all types of wood harvesting this study will not consider biomass from selection fellings, thinnings and cleanings due to lack of reliable data and time restriction.

Removing undergrowth from road sides and cleaning ditches may give rather high volumes at a local level, but not at a state level. A lack of good data makes it difficult to estimate available biomass from these infrastructure objects.

Most of the volume of merchandisable timber is produced from clear cuts, which gives 83% of the total annual cut in 2009 (Valsts meža dienests, 2009b). The other 17% come from other types of harvest activities (e.g. selection fellings and thinnings). Because of this, the focus of this study is on clear cuts where most of the resources are located and where the development of applied technologies will be easier to implement in the near future.

This study includes biomass from three types of clear cuts; a) clear cuts where at least five ecological trees per ha are left (Anon., 2001), b) clear cuts where seed trees are left in order to promote natural regeneration and c) clear cut where cutting is done according to a target diameter (if stands of pine, spruce and birch reach target diameter before minimal acceptable felling age, they can be harvested).

There is no pulp industry in Latvia and that means almost all pulpwood is exported. Only a small share is processed locally to OSB boards (oriented strand boards). However small changes in market situations regarding the use of pulpwood may switch in favor to the energy industry. Because of this, pulpwood is partly included in biomass estimation. Today all available sources of biomass as energy wood from forestry are used, with the exception of pulpwood and stumps at the industrial scale.

The purpose of this paper is to estimate which biomass resources are available from clear cuts based on three different harvest levels and utilization practices and how the situation could change if harvest intensity and efficiency of collecting energy wood would change.

2. Materials and Methods

2.1. National Forest Inventory

The input data for calculating biomass potential comes from National Forest Inventory (NFI) carried out by the Latvian State Forest Research Institute Silava. NFI data was collected from year 2004 to 2008. It was the first time an NFI had been carried out in Latvia. An NFI is done at a three level sampling system: In the first level, an orthophoto map is used. In the second level, a network, entity, and temporary plots are set up. Entity plots are located 4 km from each other, while temporary plots are located 2 km from each other with the aim of increasing the credibility of the obtained results. In the third level, the trees are selected in each plot. During the rotation period of five years, each plot (entity and temporary) represents the total forest area of 300 ha (Latvijas republikas Zemkopības ministrija, 2004). All data representing forest stands are based on the dominant tree species in the stand.

As long as the second cycle of NFI is not finished, estimations of the annual increment may contain errors as the amount of dead wood is not clear.

2.2. Forest Typology

In Latvia almost all forestry activities are based on forest types and site index. That gives information about growing conditions such as moisture, drainage, nutrient content in the soil and other characteristics of the forest. The harvesting methods and time is decided by forest types. It gives information about which actions are allowed in the current locations. Each forest type may has seven site index classes, which show the productivity of the specific forest type (Appendix 1).

In total there are seven site index classes: Ia, I, II, III, IV, V, Va. The first four classes correspond to forest on rich soils while the last three correspond to forest on poor soils.

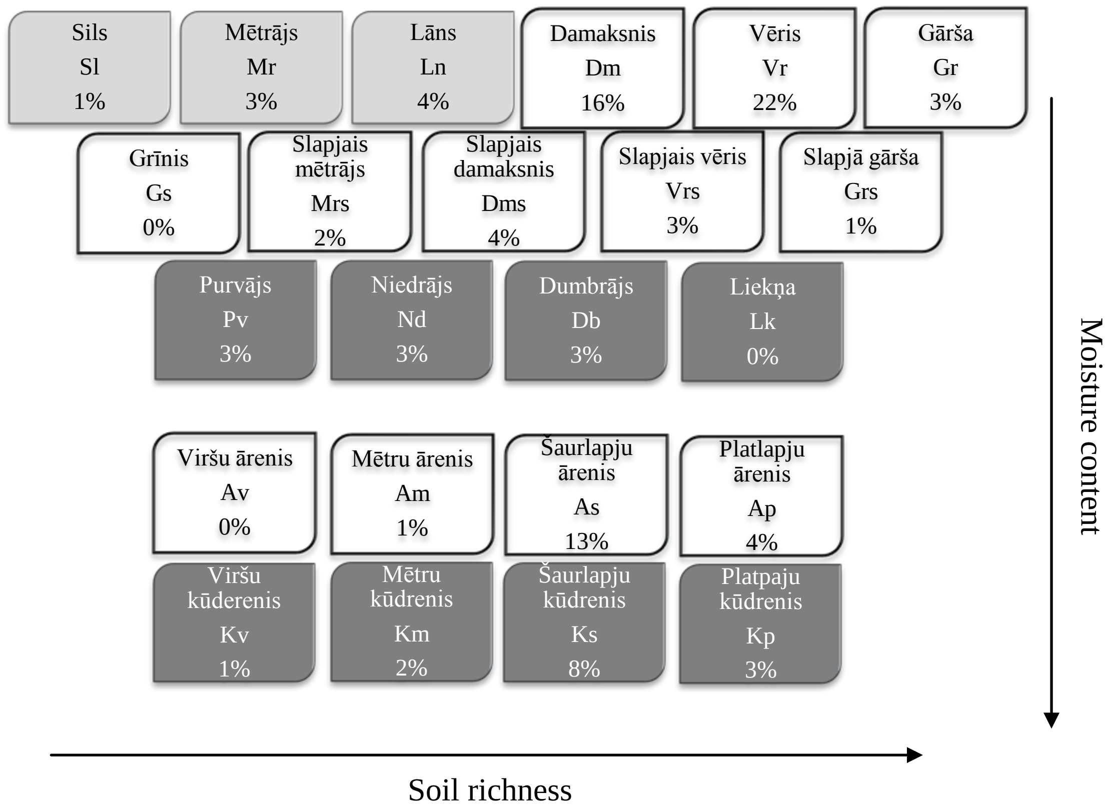

Figure 9. Forest types, abbreviation of forest type and percentage (of total area) of each type. The dark color shows the forest types, which are not suitable for extraction of logging residues. The grey color shows forest types that are not suitable for stump lifting. This rule works at the perfect weather conditions for the harvesting operation.

***Attēls* 9.** *Meža augšanas apstākļu tips, MAAT saīsinājums un katra MAAT procentuāla daļa. Tumšā krāsa norāda uz MAAT, kuri nav piemēroti mežistrādes atlieku savākšanai, un pelēkā krāsa norāda uz MAAT, kuri nav piemēroti celmu plēšanai. Šie pieņēmumi darbojas pie perfektiem laika apstākļiem mežistrādes operācijām.*

By the Latvian forest typology, there are five forest type lines. The first three are natural forest; dry, wet, and naturally wet forests on peat soils. The other two are drained; organic layer less than 20cm and more than 20cm (dark color in Figure 9). In total there are 23 forest types unevenly distributed over all five forest type lines (Figure 9).

2.3. Logging Residues

Today, logging residues are extracted from almost all forest types if the economic situation and technical possibilities allow it. Logging residues are, however, not extracted from naturally wet forest on peat soils and drained forests with organic layer more than 20 cm (Palejs, n.d.;LVMI "Silava", 2007), as the bearing capacity is low in these forest types and, therefore, residues are used for the reinforcement of strip roads.

2.4. Stump Extraction

According to data from the NFI, poor forest types, such as *Cladinoso-callunosa (Sl), Vacciniosa (Mr) and Myrtillosa (Ln),* cover 8% of the total forest area and are not economically acceptable for stump lifting.

Other excluded forest types comprise 23% of the total forest area whereas the remaining 69% is suitable for extraction of all kinds of fuel wood. Technically it is possible to extract stumps from swampy and drained forest in cold winters and dry summers. If weather conditions allow, the share of suitable forests for stump extraction may increase to 92% of the total forest area (Palejs, 2010), where poor and sandy forest stands such as Sl, Mr and Ln, are still excluded.

2.5. Assortment Structure

The average outcome of firewood from clear fellings is 10% in the private forests and 7.4% in the forests managed by the JSC Latvijas valsts meži (LVM) (Table 1). Table 1 shows the share of firewood by different tree species in the private forests. The amount of firewood assortment varies between different tree species. For pine it is only 3.7%, but for deciduous trees, except for birch, the share of firewood is up to 24.4%. Tree species like grey alder may end up as firewood for all 100% (Palejs, 2010;Lazdiņš, 2010).

Table 1. Assortment structure in the private and state forests in Latvia, year 2004 (Līpiņš et al., 2004).

Tabula 1. *Apaļo sortimentu struktūra privātajos un valsts mežos Latvijā 2004 gadā.*

Assortment	Private and other forests, (%)					State forest	
	Pine	Spruce	Birch	Other deciduous trees	Average	Average	Total amount, m^3 year 2003
For sawing, including.	74	68.6	29.9	40.8	54.5	58.1	1 952 160
Sawlogs	40.4	38.2	17	18.3	28.5	44	1 478 400
Small roundwood and packing case timber	25	29.7	10.1	18.8	22.3	14.1	473 760
I class sawlogs	8.6	0.7	2.8	3.7	3.7	-	-
Veneer logs	1	-	25.6	1.4	7.3	5.3	178 080
Poles	2	-	-	-	0.54	1	33 600
Pulpwood	**19.3**	**24.7**	**40.7**	**23.4**	**27.7**	**28.2**	**947 520**
Firewood	**3.7**	**6.7**	**3.8**	**24.4**	**10**	**7.4**	**248 640**
Total	100	100	100	100	100	100	3 360 000

2.6. Levels of biomass potential

There are two main methods of how to increase the production of forest biomass: to increase harvest intensity or to improve technologies for more efficient energy wood harvesting. In this study both methods are considered.

2.6.1. Level 1, 2 and 3:

Level 1 shows today's situation when harvest intensity is about 50% of the total annual increment in Latvia (Table 2). Harvested timber volumes are corrected according to data from SFS and represent official harvested timber volumes in 2009. From interviews with professionals from JSC LVM and LATbioNRG the share of clear fellings, which are used for extraction of logging residues today, is assumed to be 20% of all clear fellings (Keziks, 2010;Palejs, 2010). Extracted quantities from each site are supposed to be at the same level as in the Nordic countries, which is 60% (Athanassiadis et al., 2009;Lazdiņš, n.d.). This means that 40% of logging residues are left in the stand. Also, 10% of the total volume of stemwood is counted as firewood, with the exception of grey alder, where 100% is used for firewood. Because there is currently only about 50% of annual increment that is harvested and only 20% of the clear felled area is used for extraction of logging residues, no environmental and technical restrictions are applied.

Level 2 shows the actual available amount of biomass when the current harvest level is corrected in accordance with NFI data based on area and average growing stock of each dominant tree species. In this case, official data from SFS is not taken into account and harvested volumes are entirely based on data from NFI. The calculations at level 2 follow the same pattern as in level 1.

Level 3 shows the available amount of biomass if all annual increment is harvested. Calculations are done in the same way as for Level 2. Also, in this case there are no restrictions of protected areas as it is assumed that such management is not used in the long term planning.

2.6.2. Sublevels

Sublevel 1. The same pattern is used as at levels 1, 2 and 3. The extraction of stumps is introduced at 20% of all clear felled sites (60% of the stumps is extracted).

Sublevel 2. The same harvest intensity is left as in the corresponding levels at 1, 2 and 3. All clear felled sites are used for extraction of logging residues, except for sites which are on naturally wet soils and where the site index class is IV, V and Va. The restriction in this case will take away 21% of the total volume or 26% of the total area. The same principle is used for stump lifting where the only restriction is poor sandy stands. This will cause a loss in volume of 8% from the total volume of stumps and 8% from the total area. Also, the efficiency of extraction of logging residues and stumps in this case has been increasing to 80% (Athanassiadis et al., 2009) and only 20% of logging residues are left in the clear felled sites. The same rate of firewood is used as in levels 1, 2 and 3.

Sublevel 3. This is the optimal scenario if in the future the harvest intensity stays at the same level as it is in the corresponding level 1, 2 or 3. Depending on what the harvesting intensity is at the current level, calculations are done as in the sublevels 2 but with extra pulpwood added, which means an additional 28% from the volume of stem wood.

Table 2. Characteristics of different levels of biomass potential in Latvia.

Tabula 2. *Dažādu biomasas potenciāla līmeņu raksturlielumi Latvijā.*

Level	Harvest intensity, (%)	Share of clear fellings used for fuel-wood extraction, (%)	Share of extracted logging residues from a clear felling, (%)	Share of clear fellings used for stump lifting, (%)	Share of extracted stumps from a clear felling, (%)	Firewood*, (%)	Pulpwood, (%)	Forest types not used	Site index not used
1.	Present	20	60	0	0	10			
1.1.	Present	20	60	20	60	10			
1.2.	Present	74	80	92	80	10		Pv, Nd, Db, Lk and Kv, Km, Ks, Kp for logging residues / Sl, Mr, Ln for stump lifting	IV, V, Va
1.3.	Present	74	80	92	80	10	28	Pv, Nd, Db, Lk and Kv, Km, Ks, Kp for logging residues / Sl, Mr, Ln for stump lifting	IV, V, Va
2.	Present NFI	20	60	0	0	10			
2.1.	Present NFI	20	60	20	60	10			
2.2.	Present NFI	74	80	92	80	10		Pv, Nd, Db, Lk and Kv, Km, Ks, Kp for logging residues / Sl, Mr, Ln for stump lifting	IV, V, Va
2.3.	Present NFI	74	80	92	80	10	28	Pv, Nd, Db, Lk and Kv, Km, Ks, Kp for logging residues / Sl, Mr, Ln for stump lifting	IV, V, Va
3.	Increment	20	60	0	0	10			
3.1	Increment	20	60	20	60	10			
3.2.	Increment	74	80	92	80	10		Pv, Nd, Db, Lk and Kv, Km, Ks, Kp for logging residues / Sl, Mr, Ln for stump lifting	IV, V, Va
3.3	Increment	74	80	92	80	10	28	Pv, Nd, Db, Lk and Kv, Km, Ks, Kp for logging residues / Sl, Mr, Ln for stump lifting	IV, V, Va

*grey alder in 100% is assumed to be firewood

2.7. Volume Calculation

To find out what the actual potential of biomass is today, the harvest level in 2009 was calculated. The total harvested area in hectares in 2009 was used, in the calculations (Table 3). For oak and ash, the area was summed because the NFI data groups these two species together.

Table 3. Felled area by dominant tree species in Latvia, year 2009 (ha) (Valsts meža dienests, 2009b).

Tabula 3. *Latvijā izcirstā platība pēc valdošās koku sugas, 2009 gads (ha).*

Ownership	Pine	Spruce	Oak	Ash	Birch	Black Alder	Aspen	Grey alder	Total
State	21 405	10 092	46	201	11 843	612	2 547	345	47 090
Other	13 068	5 495	109	238	10 506	845	1 715	6 401	38 376
Total	34 473	15 587	155	438	22 364	1 458	4 262	6 751	85 487

In the next step, the relative numbers of clear cuts were found. To find out what is a clear cut area in relative numbers for each tree species and age class, a compiled table of State Forest Service was used showing what share of different forest management activities were carried out, divided by age classes and tree species in 2009 (Appendices 2 and 3). The total area, in ha, of clear cuts from all forest management activities for specific tree species ($Area_{CCT}$) was calculated according to:

$$Area_{CCT} = a * b \qquad \text{(ha)} \qquad [1]$$

where *a* is total felled area of each tree species from table 3 and *b* is total share of clear cuts for all age classes and specific tree species (Appendices 2 and 3).

The clear cut area, in ha, for each specific age class of each tree species ($Area_{CCA}$) was calculated according to:

$$Area_{CCA} = \frac{Area_{CCT}}{c} \qquad \text{(ha)} \qquad [2]$$

where *c* is the share of clear cuts for each specific age class within each tree species (Appendices 2 and 3).

The harvested volume, in cubic meters, at clear cuts (C_V) was obtained by multiplying the harvested area with the mean growing stock per hectare (Appendix 4) according to the equation:

$$C_V = Area_{CCA} * d \qquad (m^3) \qquad [3]$$

where *d* is the mean growing stock per hectare.

The total harvested volume is calculated by summarizing all volumes from each age class. According to statistics from SFS (State Forest Service) the total harvested volume from clear cuts is 8 937 974 m^3 in 2009 (Knēts, 2009;Valsts meža dienests, 2009b). According to [3], the harvested volume is 11.95 million solid m^3 (C_v). Because of the difference between official and obtained volumes, a correction factor of 0.748 was used for harvest volumes today. The correction factor was obtained by dividing harvested volume according SFS with the volume according calculations from the NFI. When available, the amount of biomass is calculated according the NFI where no correction factors are applied. When harvest of annual increment is calculated, a correction factor of 0.478 is used according to calculated harvested volumes in 2009. The current annual increment according to NFI is 25.28 million cubic meters (Latvijas republikas Zemkopības ministrija, 2004).

2.8. Conversion and Expansion factors

In order to obtain the quantity of biomass according to Marklund 1988 (Marklund, 1988), the following conversion and expansion factors were used for pine, spruce and broadleaves trees (Table 4). Coefficients for broadleaves trees were used for all deciduous trees species. Data in Table 4 are representative of the standing stock in Sweden's productive forests averaged for 1998 to 2002. Expansion factors were represented at the stand level and at the same shape applied for whole state level. The last update of the expansion factors was done by Petersson (2010).

Table 4. Conversion and expansion factors of different tree parts and species. 1 m^3 solid stem wood over bark corresponds to x t dry weight (Marklund, 1988;Petersson, 2010).

Tabula 4. *Dažādu koku daļu un sugu konvertācijas un ekspansijas koeficenti. 1 cieškubikmetrs stumbra koksnes ar mizu izsaka x t sausnas.*

Species	Stem and bark	Living branches and needles	Stumps	Total
Pine	0.406	0.102	0.152	0.660
Spruce	0.402	0.197	0.171	0.770
Broadleaved	0.491	0.140	0.184	0.815

As Marklund's expansion factors refer to living branches and stem wood separately, the tops of the trees are included under stem wood. To estimate the volume of the tree tops, the relative volume from the stem of the tree is calculated. According to assortment requirements at LVM, the minimal diameter of firewood assortment is six cm for pine and spruce. No minimal diameter requirements are applied to birch, aspen and black alder (Latvijas Valsts meži, 2009). For this reason the minimal diameter from each tree top is assumed to be five cm. For calculations of the tree top volume, tables for computing taper from South Sweden are used (Engren, 1949). Data about mean height and diameter in each age class from the NFI of Latvia is used. First, the relative height at 1.3 m from the total height of the tree is found by using Engren's tables (Engren, 1949). Next, the relative diameter at the height of 1.3 m from the total diameter at the stump is determined. Diameter at the stump (D_0) and relative diameter at the height where the diameter of the tree is five cm (D_5) is calculated for every tree species and every age class which has reached felling age (Appendices 5 and 6). After the relative value of the diameter at breast height is gained, it is transformed into an absolute number at stump height according to:

$$D_0 = \frac{D_{1.3}}{D_{R\,1.3}} \qquad \text{(cm)} \qquad [4]$$

where D_0 is the diameter at the stump height expressed in cm, $D_{1.3}$ is the diameter at breast height in cm and $D_{R1.3}$ is the relative diameter in %, expressing $D_{1.3}$ as a % of D_0.

The relative diameter of a tree section when the top of the tree is starting, expressed in %, (D_5) is calculated according to:

$$D_5 = \frac{5}{D_0} \qquad (\%) \qquad [5]$$

The value of D_5 is used to read the relative volume of the tree's top from the table. In all cases a form factor 0.500 is used from the book (Engren, 1949).

The volume of tree tops is excluded from the volume of the stem and bark and is instead added to volume of the branches.

2.9. Age of Final Felling

The minimum final felling age for a species is set by the Law on Forest (Anon., 2000), which means that final felling is permitted at the age of 101 for pine and larch, 81 for spruce, ash and lime tree, 71 for birch and black (common) alder, 41 for aspen, 101 for oak. For grey alder there is no age limit for final felling. Therefore in this study the minimum age is set to 21 years, which makes it reasonable for harvesting. In many cases, grey alder stands up to age of 30 years are not worth to keeping since the increment slows down and stands may start to break down if the stand density is high (Dreimanis et al., 2005). Oak and ash are represented together in the NFI, but their minimum final felling age is different. For that reason the felling age for oak and ash is in this study, considered to be 91 years (the average minimum final felling age for these tree species).

2.10. Exceptions

When the maximum levels in all scenarios are calculated, only the suitable forest types are included. In this case, forest types as *purvājs, niedrājs, dumbrājs, liekņa, viršu kūdrenis, mētru kūdrenis, šaurlapju kūdrenis* and *platlapju kūdrenis* are not used for extraction of logging residues. Also forest types sils, mētrājs and lāns are not used for stump lifting or extraction from the stand. Stands are considered poor stands if the site index is IV or higher (Appendix 1). This assumption gives a volume reduction of 20.86% for logging residues and 7.99% for extraction of stumps.

3. Results

Level 1:

With current practices, the available biomass from clear cuts is estimated to be 0.79 m odt (million oven dry tons) (Table 5). The major part of it is firewood and only 0.15 m odt comes from logging residues as branches and tops of the trees.

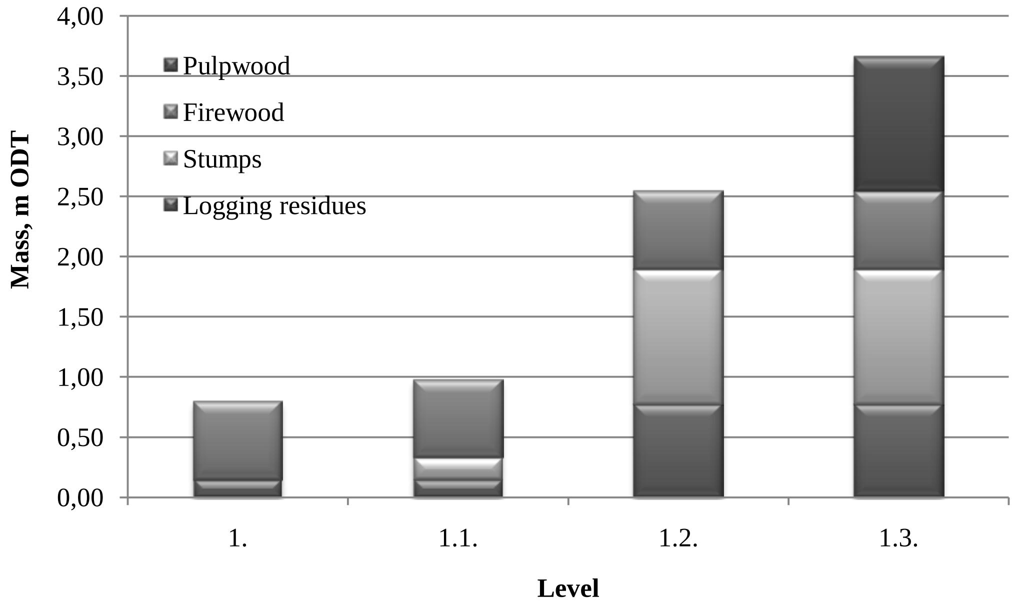

Figure 10. Available biomass at level 1 and its sublevels from logging residues, stumps, firewood and pulpwood in Latvia.

Attēls 10. Latvijā *pirmajā līmenī un tā apakšlīmeņos pieejamais biomasas apjoms no mežistrādes atliekām, celmiem, malkas un papīrmalkas.*

Level 1.1:

If stump lifting and extraction were introduced in the same clear cuts, the produced amount of biomass would rise to 0.98 m odt. This means that the introduction of stump lifting in Latvian forestry could give extra 0.18 m odt of stump biomass.

Level 1.2:

Appreciably higher volumes would be extracted if all suitable forest stands were used for production of forest biomass. Also, as scenario 1.2 shows (Table 5), an increase in extraction efficiency to 80 % would increase the available amount of logging residues and stump wood. Improvements in technologies and an increase of stands used for extraction of energy wood would give 2.54 m odt of which 1.12 m odt would be from stump extraction and 0.77 m odt from logging residues.

Level 1.3:

If the assortment of pulpwood is used for energy production, it would add an extra 1.12 m odt. If extraction technologies for energy wood from clear cuts improve from 60% to 80%, then by keeping the current harvest level, the total amount of available biomass would be 3.66 m odt.

As figure 10 shows, the available biomass from stumps is slightly higher than from logging residues and at optimal planning and with a slight improvement in technologies the availability of biomass could rise from 0.98 m odt to 2.54 m odt without including pulpwood. Improved technologies mean that more time may be spent on collection of felling residues. Also, improvements in grapples and harvester heads may increase the rate of extracted fuel–wood.

Table 5. Share, extraction intensity, and mass of stands used for biomass extraction in Latvia.

Tabula 5. *Biomasas iegūšanai izmantotās mežaudžu daļas, izstrādes intensitāte un apjomi Latvijā.*

Level	Harvest Intensity	Logging residues			Stumps			Firewood		Pulpwood		Total Mass, (m ODT)
		Share of clear fellings used, (%)	Extraction intensity, (%)	Mass, (m ODT)	Share of clear fellings used, (%)	Extraction intensity, (%)	Mass, (m ODT)	Share from total stem wood, (%)	Mass, (m ODT)	Share from total stem wood, (%)	Mass, (m ODT)	
1.	Present / 8.94 m m^3	20	60	0.15	0	0	0.00	10	0.65			0.79
1.1.	Present / 8.94 m m^3	20	60	0.15	20	60	0.18	10	0.65			0.98
1.2.	Present / 8.94 m m^3	74	80	0.77	92	80	1.12	10	0.65			2.54
1.3.	Present / 8.94 m m^3	74	80	0.77	92	80	1.12	10	0.65	28	1.12	3.66
2.	Present NFI / 11.95 m m^3	20	60	0.20	0	0	0.00	10	0.86			1.06
2.1.	Present NFI / 11.95 m m^3	20	60	0.20	20	60	0.24	10	0.86			1.30
2.2.	Present NFI / 11.95 m m^3	74	80	1.03	92	80	1.50	10	0.86			3.40
2.3.	Present NFI / 11.95 m m^3	74	80	1.03	92	80	1.50	10	0.86	28	1.49	4.89
3.	Increment / 25 m m^3	20	60	0.41	0	0	0.00	10	1.81			2.21
3.1	Increment / 25 m m^3	20	60	0.41	20	60	0.51	10	1.81			2.73
3.2.	Increment / 25 m m^3	74	80	2.15	92	80	3.14	10	1.81			7.10
3.3	Increment / 25 m m^3	74	80	2.15	92	80	3.14	10	1.81	28	3.12	10.23

Level 2:

If we assume that, suggested by the NFI data, the harvest level today is underestimated, and by keeping the same harvest intensity and increasing forest land, the timber flow from clear cuts could be 11.95 m solid m^3 over bark. Then, by utilizing the same 20% from all forest stands with 60% extracted logging residues from each, available biomass could be 1.06 m odt, from which a major part is firewood – 0.86 m odt (Figure 11).

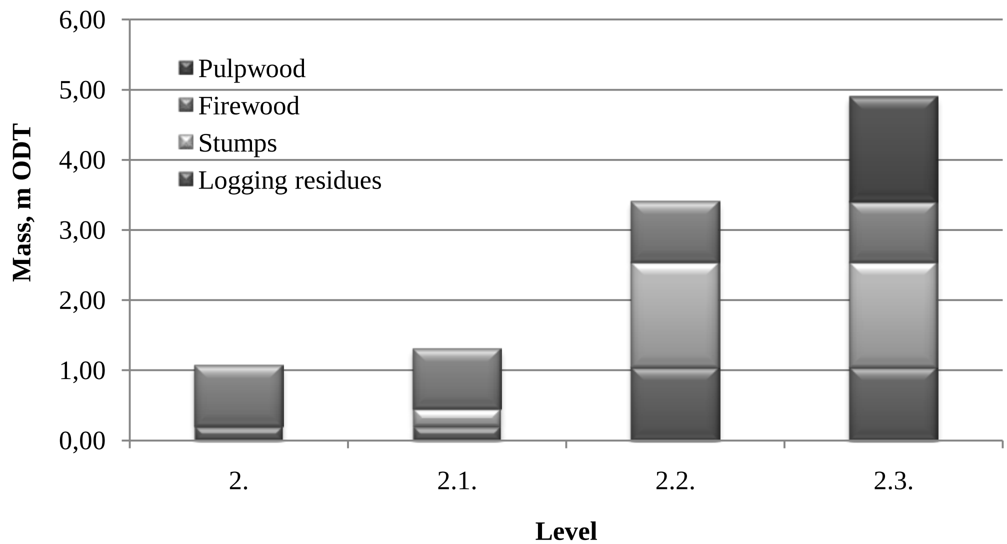

Figure 11. Available biomass at level 2 and its sublevels from logging residues, stumps, firewood and pulpwood in Latvia.

Attēls 11. Latvijā *otrajā līmenī un tā apakšlīmeņos pieejamais biomasas apjoms no mežistrādes atliekām, celmiem, malkas un papīrmalkas.*

Level 2.1:

If stump lifting is introduced in the same clear cuts where logging residues are extracted, an extra 0.24 m odt would be obtained. With such practices the total potential of biomass is 1.3 m odt.

Level 2.2:

With the optimal use of all clear cuts available for obtaining energy wood, and better handling of energy wood at the clear cuts, a total of 3.4 m odt could be obtained, 1.03 m odt would come from logging residues such as branches and tree tops, 1.5 m odt from stump lifting and a small portion is firewood, which in this case 0.86 m odt. If comparing the same situation at level 1.2, then an increase of available biomass is for 0.86 m odt annually.

Level 2.3:

If all produced pulpwood is utilized for energy purposes, the available amount can be 4.89 m odt.

Level 3:

In level 3 and its sublevels, the harvest level is assumed to be the same level as the current annual increment, which means that without changing today's order of production of energy wood, available biomass for the energy industry could reach 2.21 m odt, which is 1.42 m odt more than it is today.

Level 3.1:

If stump extraction is introduced at the same level as extraction of logging residues, then an extra 0.51 m odt could be delivered to the energy industry, which yields a total of 2.73 m odt.

Level 3.2:

In the top scenario, if all suitable clear cuts are used for production of energy wood, which includes extraction of 80% of the logging residues and stumps from 74% and 92%, respectively, of all clear cuts available, biomass could reach 7.10 m odt. In this case, 2.15 m odt is from logging residues, 3.14 m odt is from stumps and only 1.81 m odt comes from firewood.

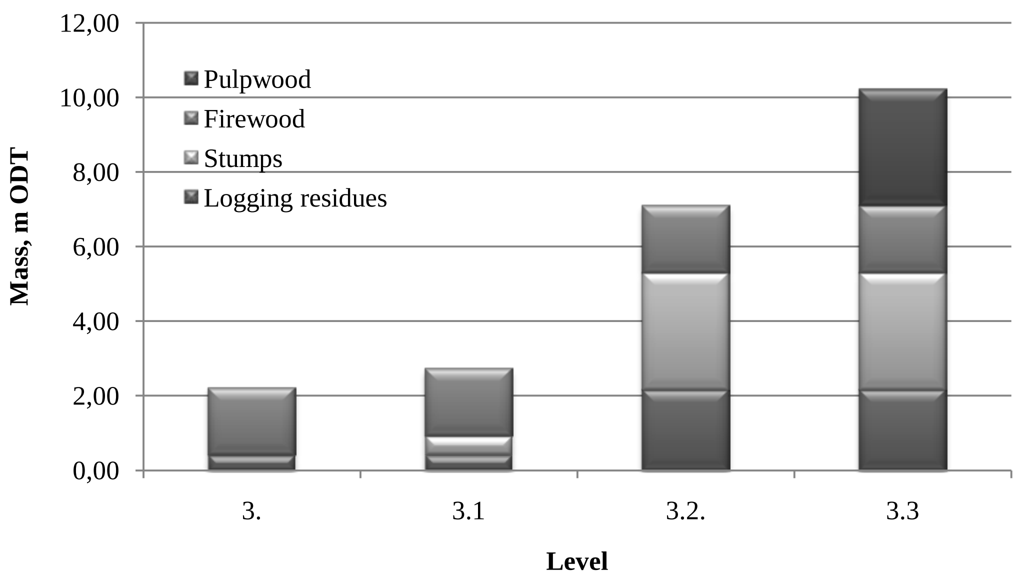

Figure 12. Available biomass at level 3 and its sublevels from logging residues, stumps, firewood and pulpwood in Latvia.

Attēls 12. *Latvijā trešajā līmenī un tā apakšlīmeņos pieejamais biomasas apjoms no mežistrādes atliekām, celmiem, malkas un papīrmalkas.*

Level 3.3:

If pulpwood is added to the energy wood assortments, the total volume of biomass is 10.23 m odt. In this study 10.23 m odt is considered as the maximum available amount of biomass (Figure 12).

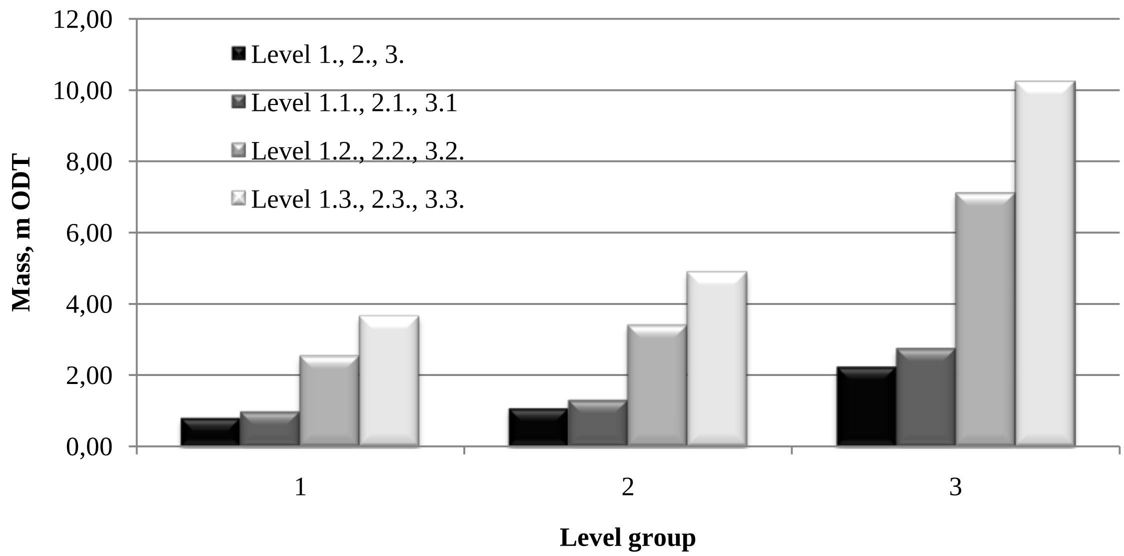

Figure 13. Available biomass at different levels in Latvia.

Attēls 13. *Latvijā pieejamais biomasas apjoms pie dažādiem līmeņiem.*

As Figure 13 shows, the fastest way to increase production of biomass is to increase harvest intensity. However, as higher is harvest intensity as more obvious is the increase of biomass gained from increased efficiency in production and collecting process. It is apparent that in the future, pulpwood may become an important product for the energy industry, as the graph at level 3 shows in Figure 13.

4. Discussion

The data provided by the NFI contained average values for each tree species and other variables used in the calculations. This made it impossible to use applied biomass functions for separate trees. Furthermore, data quality put a restriction on further calculations of biomass by regions. Other limitation from available data is that all tree species are presented as the dominant tree in the stand, which does not give information on tree species composition. Conversion and expansion factors used in the study were made for pine, spruce and birch in Sweden and were applied in the same way for calculations in Latvia by ignoring tree species composition. The conversion factor for birch was used to obtain biomass for all deciduous trees. The mixture of tree species in Latvia may be very high and some cases, the dominant tree species may build up even less than 50% from all species in the stand, but still have the highest growing stock. At large extend, reasons of so high mixture is historical development and differences in forest management itself. This also affects the assortment structure in individual stands and amount of firewood and pulpwood. Better results could be reached if the sample plot data from the NFI could be used.

To find out to what extent the logging residues are used at level 1.1, many assumptions were made based on personal communications. Even within the country, extraction of logging residues is not at the same level in all regions. As a considerable proportion of industrial biomass is exported, the extraction of logging residues is more intensive close to the harbors. The main reasons for this is a lack of technologies that use woody biomass locally, as well as higher investments in establishing a CHP or heat plants (Latvia Distric Heating Association, 2009). In addition, the calculations did not consider economical restrictions, which is a related issue to lack of local, big scale use of biomass. Small households and single farms are mostly using firewood and small forest owners are not so much interested in collecting logging residues and stump lifting as it is not their goal. This is one of the reasons why collection of logging residues is better developed close to harbors where there is market for industrial wood chips. The transport distances from the east part of the country to the harbor are much greater. Because of this, the economical aspect is not taken into account in this study.

Figure 14 shows that exported mass of biomass from Latvia during the years 2004 to 2009 was much higher than the calculated result at level 1 in this study. The main reason for this is that in the present study only direct flow of biomass from clear cuts is calculated. Losses in primary processing of roundwood are 30% to 50% (Līpiņš et al., 2004). If it assumed that 40% of losses are in primary processing of saw timber, then level 1 would give an extra 0.89 m odt of secondary biomass. Level 1.1 would then total 1.68 m odt of biomass. As shown in figure 14 the sum of all types of energy wood that was exported in 2009 reached 2.72 m raw tons. If moisture content in raw biomass is 50%, it will give 1.36 m odt of exported biomass. This shows that the results obtained in the present study could be realistic.

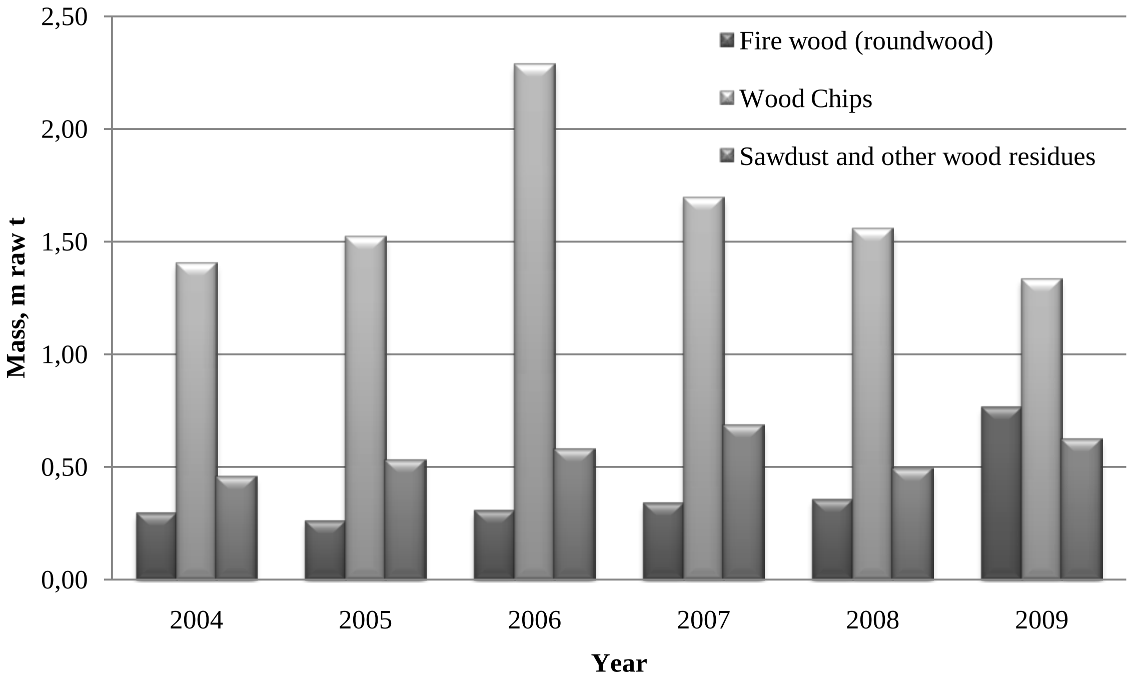

Figure 14. Export of different energy wood products from Latvia.

Attēls 14. *Dažādu enerģētiskās koksnes produktu eksports no Latvijas.*

Results given in this paper are rather close to results presented in earlier studies. Lazdiņš (2008), estimated the extracted mass of logging residues (tops, branches and low quality timber parts, which do not match up to criteria of firewood) from final fellings in the state forests to be 0.2 m odt in 2007. The estimation of available biomass at level 1, which gives an overview about production today, is 0.14 m odt, i.e. a rather close result. In this study, low quality timber is not taken into consideration. In addition only clear cuts are considered in potential calculations, which may also cause an extra error in the calculated mass of energy wood. Even if the state forest is the biggest producer of timber, private owners are also, to some extent, collecting logging residues. The problem with private forests is that there are small clear cut sizes and no cooperation between private forest owners to ensure enough big volumes in small areas. Lazdiņš (2008) estimates the total potential to be 1.4 m odt that is twice as big as the potential reported in level 1.2 of this study (0.77 m odt) where no stump biomass and firewood is extracted. An explanation for such a big difference is the same as previously mentioned, this study has some limitations and it is not considering bad quality stem wood parts. Lazdiņš also points out that the potential of stump biomass in Latvia is not apparent, but it should be at least at the same level as logging residues (Lazdiņš, 2008). Results in this study shows, that, at level 1, the potential of logging residues is 0.14 m odt, and the biomass from stumps is 0.18 m odt.

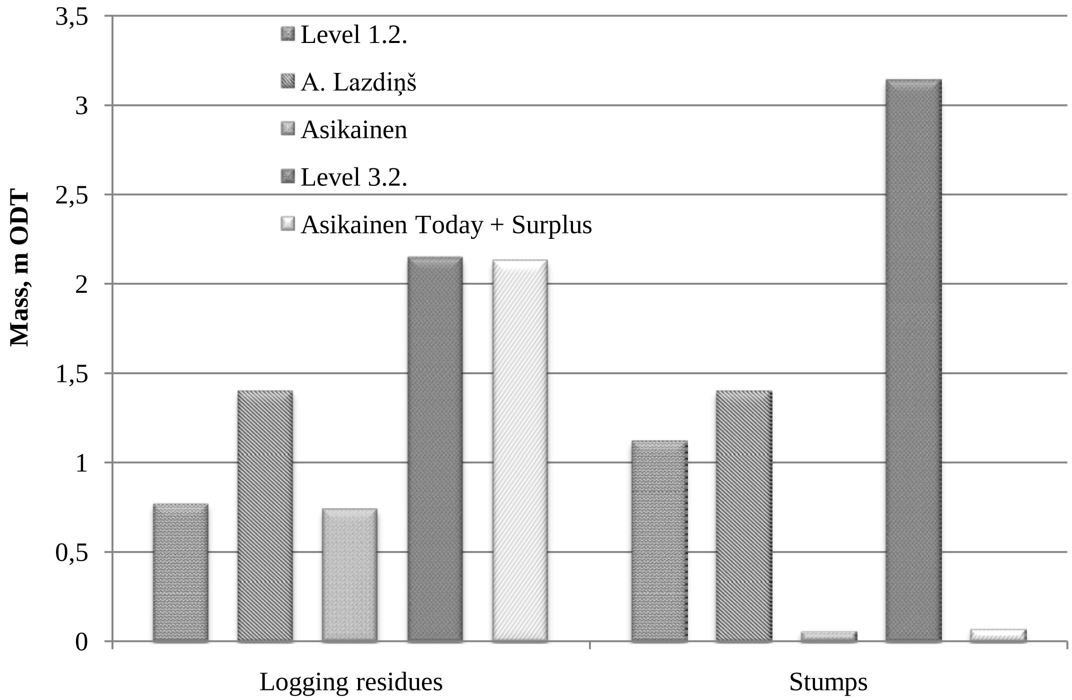

Figure 15. Comparison of biomass potential between various authors in Latvia.

Attēls 15. *Biomasas potenciāla salīdzinājums Latvijā starp dažādiem autoriem.*

Asikainen et al's evaluation of biomass potential in Latvia shows that at present there is 1.8 million m^3 of available felling residues (Asikainen et al., 2008), which corresponds to around 0.74 m odt annually (conversion coefficient 0.410). Available volumes from stumps are estimated at 0.14 m m^3, which is around 0.06 m odt (conversion coefficient 0.410) of stump biomass. Results in the present study are higher for stumps, and only slightly higher for logging residues, if optimal land use is taken into account. That means that in both cases, when comparing with Lazdiņš (2008) and Asikainen et al. (2008), the estimation of logging residues is lower. This could be due to the error introduced by treating all forest stands as monocultures stands as well as by not taking into account any bad quality timber. The surplus of annual change rate for Latvia, (annual increment which is not harvested) is estimated to be 1.39 m odt of logging residues and 0.01 m odt of stumps. In total it gives 2.13 m odt of logging residues and 0.07 m odt of stumps. Asikainen et al. (2008) have also included stem wood in the surplus results of biomass. To compare with these numbers, level 3.2 could be used, which shows biomass mass of logging residues and stumps if better methods of energy wood handling would be used, optimal land use would be considered, and the whole annual increment would be harvested. At level 3.2, biomass of logging residues (branches and tops only) is estimated at 2.15 m odt which is almost the same result as Asikainen et al. present. Stump biomass at level 3.2 is 3.14 m odt which is much higher than what Asikainen et al. estimate. The difference most probably is due to the NFI data used in this study where the updated annual increment is taken and in more detailed calculations of stump biomass, since the results are closer if comparing with papers made in Latvia. The real potential of surplus biomass by Asikainen et al. is probably even lower. Stem wood was also included.

The result of logging residues could be higher if other methodology of biomass estimations from clear fellings would be used. For example, volumes of logging residues from one hectare of clear felling or harvested merchantable timber based on practices today. This would include low quality timber which does not fit into the criteria of any other assortment. In this study, the results are more theoretical and are based on the conversion coefficients made by Marklund and Petersson (Marklund, 1988;Petersson, 2010), which do not include any deviation from practical harvest operations.

From all biomass used today in Latvia, 99% comes from forestry (Asikainen et al., 2008), but it is not the only source of biomass and therefore more work could be done to estimate future potential for other types of biomass. This study covers only biomass production in clear cuts and more work could be done to investigate other sources of woody biomass including losses in primary processing.

Cost analysis and logistics are not covered in this study but could be of high interest for future resource planning, where also GIS and Heureka software could be used.

As mentioned previously, biomass potential from logging residues could be underestimated in this study. But biomass from forestry is an important resource in Latvia, which can increase energetic independence from imported energy resources and create more workplaces in the rural regions of the country. It is one of the keys for sustainability in Latvia.

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Appendix 1. Area and growing stock divided by forest type and site index

Forest Type	Unit Type	Site Index															Total
		Ia	Ia	Ia	Ia	Ia	Ia	Ia	I	II	III	IV	V	Va	Va	Va	
Sils	Total Growing Stock								0.02%	0.07%	0.16%	0.20%	0.08%	0.01%			**0.54%**
	Area								0.04%	0.11%	0.22%	0.40%	0.15%	0.02%			**0.93%**
Mētrājs	Total Growing Stock								0.86%	1.00%	1.05%	0.20%	0.07%				**3.18%**
	Area								0.73%	0.98%	1.36%	0.19%	0.08%				**3.35%**
Lāns	Total Growing Stock							0.24%	1.78%	1.57%	0.53%	0.11%	0.03%				**4.26%**
	Area							0.15%	1.44%	1.44%	0.45%	0.05%	0.02%				**3.55%**
Damaksnis	Total Growing Stock				0.00%	0.04%	0.18%	1.87%	13.21%	3.38%	0.92%	0.16%	0.02%	0.00%			**19.78%**
	Area				0.01%	0.04%	0.11%	1.13%	11.23%	2.57%	1.00%	0.16%	0.08%	0.01%			**16.33%**
Vēris	Total Growing Stock	0.02%	0.00%	0.02%	0.05%	0.28%	1.25%	3.10%	11.86%	2.91%	0.97%	0.18%	0.01%	0.00%	0.00%		**20.67%**
	Area	0.01%	0.00%	0.01%	0.05%	0.21%	0.87%	2.33%	12.20%	3.00%	1.24%	0.40%	0.08%	0.04%	0.05%		**20.50%**
Gārša	Total Growing Stock				0.05%	0.04%	0.15%	1.12%	1.77%	0.54%	0.41%	0.01%	0.01%				**4.10%**
	Area				0.02%	0.03%	0.09%	0.30%	1.66%	0.62%	0.43%	0.04%	0.02%				**3.20%**
Grīnis	Total Growing Stock										0.00%						**0.00%**
	Area										0.01%						**0.01%**
Slapjais mētrājs	Total Growing Stock						0.00%		0.18%	0.40%	0.44%	0.23%	0.09%				**1.34%**
	Area						0.01%		0.22%	0.46%	0.56%	0.58%	0.12%				**1.95%**
Slapjais damaksnis	Total Growing Stock						0.02%	0.04%	1.37%	1.33%	0.60%	0.15%	0.04%		0.00%		**3.54%**
	Area						0.03%	0.02%	1.29%	1.11%	1.12%	0.27%	0.05%		0.01%		**3.90%**
Slapjais vēris	Total Growing Stock					0.00%	0.03%	0.15%	1.47%	0.80%	0.24%	0.11%	0.03%				**2.82%**
	Area					0.01%	0.03%	0.16%	1.35%	0.97%	0.72%	0.15%	0.04%				**3.43%**
Slapjā gārša	Total Growing Stock						0.01%	0.08%	0.27%	0.13%	0.08%	0.00%	0.00%				**0.58%**
	Area						0.01%	0.03%	0.25%	0.13%	0.11%	0.02%	0.01%				**0.56%**
Purvājs	Total Growing Stock							0.00%	0.01%	0.05%	0.17%	0.27%	0.29%	0.19%	0.07%	0.00%	**1.04%**
	Area							0.00%	0.02%	0.13%	0.30%	0.56%	0.82%	0.62%	0.30%	0.03%	**2.78%**

Appendix 1. Area and growing stock divided by forest type and site index (continued)

Forest Type	Unit Type	Site Index															Total
		Ia	Ia	Ia	Ia	Ia	Ia	Ia	I	II	III	IV	V	Va	Va	Va	
Niedrājs	Total Growing Stock								0.13%	0.32%	0.62%	0.38%	0.21%	0.06%			**1.72%**
	Area								0.15%	0.41%	0.81%	0.84%	0.49%	0.11%			**2.82%**
Dumbrājs	Total Growing Stock						0.06%	0.06%	0.55%	0.98%	0.59%	0.21%	0.01%	0.00%			**2.46%**
	Area						0.01%	0.03%	0.54%	1.04%	1.15%	0.36%	0.03%	0.00%			**3.16%**
Liekņa	Total Growing Stock							0.01%	0.05%	0.10%	0.02%						**0.18%**
	Area							0.01%	0.07%	0.09%	0.02%						**0.18%**
Viršu ārenis	Total Growing Stock								0.01%		0.01%						**0.01%**
	Area								0.00%		0.08%						**0.08%**
Mētru ārenis	Total Growing Stock							0.02%	0.72%	0.68%	0.19%	0.04%	0.02%				**1.66%**
	Area							0.01%	0.57%	0.71%	0.17%	0.04%	0.03%				**1.53%**
Šaurlapju ārenis	Total Growing Stock				0.06%	0.15%	0.31%	1.37%	7.60%	3.21%	0.86%	0.18%	0.00%	0.00%	0.00%		**13.74%**
	Area				0.02%	0.08%	0.24%	1.00%	7.52%	2.72%	1.11%	0.22%	0.01%	0.01%	0.00%		**12.94%**
Platlapju ārenis	Total Growing Stock		0.02%	0.00%	0.02%	0.05%	0.16%	0.82%	2.54%	0.99%	0.31%	0.03%	0.01%				**4.96%**
	Area		0.01%	0.01%	0.01%	0.03%	0.10%	0.54%	2.85%	0.76%	0.31%	0.04%	0.00%				**4.67%**
Viršu kūdrenis	Total Growing Stock								0.01%	0.02%	0.03%	0.05%	0.03%	0.06%	0.00%		**0.20%**
	Area								0.02%	0.03%	0.10%	0.14%	0.09%	0.16%	0.03%		**0.57%**
Mētru kūdrenis	Total Growing Stock							0.01%	0.44%	0.75%	0.42%	0.21%	0.17%	0.02%			**2.02%**
	Area							0.02%	0.37%	0.90%	0.48%	0.26%	0.18%	0.04%			**2.26%**
Šaurlapju kūdrenis	Total Growing Stock					0.09%	0.02%	0.46%	3.85%	2.35%	1.31%	0.41%	0.05%	0.01%			**8.55%**
	Area					0.02%	0.02%	0.25%	3.80%	2.30%	1.55%	0.56%	0.08%	0.03%			**8.62%**
Platlapju kūdrenis	Total Growing Stock				0.01%		0.02%	0.19%	1.23%	0.87%	0.25%	0.05%		0.01%			**2.63%**
	Area				0.00%		0.02%	0.14%	1.21%	0.88%	0.34%	0.08%		0.02%			**2.68%**
Total Growing Stock		**0.02%**	**0.02%**	**0.02%**	**0.19%**	**0.65%**	**2.21%**	**9.53%**	**49.92%**	**22.46%**	**10.18%**	**3.18%**	**1.18%**	**0.36%**	**0.07%**	**0.00%**	**100.00%**
Area m^2		**0.01%**	**0.02%**	**0.03%**	**0.12%**	**0.41%**	**1.54%**	**6.11%**	**47.53%**	**21.35%**	**13.66%**	**5.35%**	**2.39%**	**1.05%**	**0.40%**	**0.03%**	**100.00%**

Appendix 1. Area and growing stock divided by forest type and site index (continued)

Forest Type	Unit Type	Site Index															Total
		Ia	Ia	Ia	Ia	Ia	Ia	Ia	I	II	III	IV	V	Va	Va	Va	
Total share of growing stock and area excluded from extraction of bio-fuels																	
Total Growing Stock	Logging Residues	0.00%	0.00%	0.00%	0.01%	0.09%	0.10%	0.74%	6.27%	5.44%	3.41%	3.18%	1.18%	0.36%	0.07%	0.00%	20.86%
Area		0.00%	0.00%	0.00%	0.00%	0.02%	0.04%	0.45%	6.17%	5.79%	4.77%	5.35%	2.39%	1.05%	0.40%	0.03%	26.46%
Total Growing Stock	Stump Lifting	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.24%	2.65%	2.65%	1.73%	0.52%	0.18%	0.01%	0.00%	0.00%	7.99%
Area		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.15%	2.21%	2.53%	2.03%	0.63%	0.25%	0.02%	0.00%	0.00%	7.83%

Appendix 2. Age distribution of the most common management activities according to the managed area and tree species, in %, year 2009 (Valsts Meža Dienests, 2009a)

Specie	*Management type by area*	*Age Class (years)*													*Share of total*
		0 – 10	*10 – 20*	*21 – 30*	*31 – 40*	*41 – 50*	*51 – 60*	*61 – 70*	*71 – 80*	*81 – 90*	*91 – 100*	*101 – 110*	*111 – 120*	*>120*	
Pine (Pinus sylvestris)	Pre-commercial thinning	2.34%	55.56%	24.85%	16.37%	0.00%	0.00%	0.00%	0.00%	0.88%	0.00%	0.00%	0.00%	0.00%	0.12%
	Commercial thinning	0.00%	0.07%	1.06%	4.06%	9.01%	16.14%	17.98%	20.64%	16.45%	10.23%	2.31%	0.77%	1.27%	56.77%
	Clear-cuts	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	42.50%	21.81%	35.70%	37.85%
	Selective harvesting	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	21.71%	18.64%	59.65%	5.26%
Spruce (Picea abies)	Pre-commercial thinning	3.30%	60.28%	26.53%	9.05%	0.84%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.82%
	Commercial thinning	0.01%	0.54%	11.23%	34.28%	35.65%	8.36%	5.32%	2.86%	1.03%	0.34%	0.19%	0.05%	0.14%	63.23%
	Clear-cuts	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.20%	28.95%	16.55%	7.53%	6.77%	34.77%
	Selective harvesting	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	37.85%	18.24%	20.29%	9.25%	14.35%	1.19%
Birch (Betula sp.)	Pre-commercial thinning	19.30%	80.70%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.24%
	Commercial thinning	0.04%	0.94%	4.99%	13.48%	22.98%	32.06%	21.54%	2.33%	1.04%	0.41%	0.17%	0.00%	0.00%	44.58%
	Clear-cuts	0.00%	0.00%	0.00%	0.00%	0.00%	0.43%	0.66%	52.81%	25.17%	15.03%	4.66%	0.00%	0.21%	53.22%
	Selective harvesting	0.00%	0.00%	0.00%	0.00%	0.00%	0.28%	0.62%	42.27%	25.89%	26.33%	3.52%	0.00%	0.00%	1.96%
Black alder (Alnus glutinosa)	Pre-commercial thinning	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.26%
	Commercial thinning	0.00%	0.16%	6.85%	16.17%	28.18%	23.33%	20.86%	2.49%	1.44%	0.53%	0.00%	0.00%	0.00%	44.09%
	Clear-cuts	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	60.45%	39.53%	0.00%	0.00%	0.00%	0.00%	54.17%
	Selective harvesting	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	41.15%	20.38%	38.46%	0.00%	0.00%	0.00%	1.48%

Appendix 2. Age distribution of the most common management activities according to the managed area and tree species, in %, year 2009 (Valsts Meža Dienests, 2009a) (continued)

Specie	***Management type by area***	***Age Class (years)***													***Share of total***
		0 – 10	***10 – 20***	***21 – 30***	***31 – 40***	***41 – 50***	***51 – 60***	***61 – 70***	***71 – 80***	***81 – 90***	***91 – 100***	***101 – 110***	***111 – 120***	***>120***	
Grey alder (Alnus incana)	Pre-commercial thinning	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%
	Commercial thinning	0.17%	7.56%	25.44%	28.93%	30.60%	6.93%	0.30%	0.07%	0.01%	0.00%	0.00%	0.00%	0.00%	40.91%
	Clear-cuts	0.08%	2.38%	13.98%	32.78%	38.15%	11.20%	1.44%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	56.65%
	Selective harvesting	0.00%	2.70%	8.66%	22.64%	54.41%	8.16%	3.43%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.40%
Aspen (Populus tremula)	Pre-commercial thinning	4.64%	95.36%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.75%
	Commercial thinning	0.04%	15.01%	29.10%	32.32%	10.37%	4.65%	5.64%	2.07%	0.25%	0.55%	0.00%	0.00%	0.00%	10.01%
	Clear-cuts	0.00%	0.00%	0.00%	0.00%	10.50%	25.72%	26.62%	21.19%	10.11%	4.06%	1.40%	0.41%	0.00%	87.98%
	Selective harvesting	0.00%	0.00%	0.00%	0.00%	13.26%	18.47%	30.62%	24.23%	6.06%	7.37%	0.00%	0.00%	0.00%	1.25%
Other species (oak. ash)	Pre-commercial thinning	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.70%
	Commercial thinning	0.04%	1.61%	8.32%	10.46%	20.60%	17.51%	18.41%	9.93%	4.41%	2.11%	4.35%	1.54%	0.70%	58.94%
	Clear-cuts	0.00%	0.00%	1.67%	5.42%	4.17%	0.17%	0.00%	0.00%	44.99%	16.64%	16.09%	0.00%	10.85%	37.17%
	Selective harvesting	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	3.19%

Appendix 3. Age distribution of the most common management activities according to the managed area and tree species, in ha, year 2009 (Valsts Meža Dienests, 2009a)

Specie	***Management type by area***	***Age Class (years)***													***Share of total***
		0 – 10	***10 – 20***	***21 – 30***	***31 – 40***	***41 – 50***	***51 – 60***	***61 – 70***	***71 – 80***	***81 – 90***	***91 – 100***	***101 – 110***	***111 – 120***	***>120***	
Pine (Pinus sylvestris)	Pre-commercial thinning	0.97	23.05	10.31	6.79	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	41.49
	Commercial thinning	0.85	12.75	208.30	795.04	1 763.87	3 158.29	3 518.64	4 038.84	3 219.82	2 001.90	453.03	151.10	248.21	19 570.64
	Clear-cuts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5 545.04	2 845.65	4 657.88	13 048.56
	Selective harvesting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	393.38	337.81	1 081.01	1 812.20
Spruce (Picea abies)	Pre-commercial thinning	4.20	76.70	33.76	11.51	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	127.24
	Commercial thinning	1.46	52.79	1 107.06	3 377.93	3 512.81	824.19	524.41	281.41	101.68	33.37	19.13	5.07	13.56	9 854.87
	Clear-cuts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2 178.15	1 568.57	897.02	408.07	367.02	5 418.82
	Selective harvesting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	70.26	33.86	37.66	17.17	26.64	185.59
Birch (Betula sp.)	Pre-commercial thinning	10.29	43.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.30
	Commercial thinning	3.83	93.50	497.42	1 343.63	2 291.77	3 196.77	2 147.73	232.61	103.90	40.49	16.55	0.00	0.00	9 970.73
	Clear-cuts	0.00	0.00	0.00	0.00	0.00	51.25	79.12	6 284.95	2 996.00	1 789.26	554.63	0.00	25.16	11 901.37
	Selective harvesting	0.00	0.00	0.00	0.00	0.00	1.22	2.71	185.51	113.62	115.54	15.43	0.00	0.00	438.89
Black alder (Alnus glutinosa)	Pre-commercial thinning	0.00	3.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.83
	Commercial thinning	0.00	1.00	44.00	103.91	181.09	149.91	134.02	15.98	9.24	3.41	0.00	0.00	0.00	642.57
	Clear-cuts	0.00	0.00	0.00	0.00	0.00	0.00	0.17	477.27	312.09	0.00	0.00	0.00	0.00	789.50
	Selective harvesting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.91	4.41	8.32	0.00	0.00	0.00	21.64
Grey alder (Alnus incana)	Pre-commercial thinning	1.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.92
	Commercial thinning	4.66	208.93	702.72	799.05	845.06	191.31	8.31	1.83	0.18	0.00	0.00	0.00	0.00	2 762.04
	Clear-cuts	3.01	90.96	534.66	1 253.61	1 458.86	428.32	55.07	0.00	0.00	0.00	0.00	0.00	0.00	3 824.40

Appendix 3. Age distribution of the most common management activities according to the managed area and tree species, in ha, year 2009 (Valsts Meža Dienests, 2009a) (continued)

Specie	***Management type by area***	***Age Class (years)***													***Share of total***
		0 – 10	***10 – 20***	***21 – 30***	***31 – 40***	***41 – 50***	***51 – 60***	***61 – 70***	***71 – 80***	***81 – 90***	***91 – 100***	***101 – 110***	***111 – 120***	***>120***	
Grey alder (Alnus incana)	Selective harvesting	0.00	4.38	14.06	36.75	88.33	13.24	5.57	0.00	0.00	0.00	0.00	0.00	0.00	162.33
Aspen (Populus tremula)	Pre-commercial thinning	1.49	30.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.02
	Commercial thinning	0.17	64.03	124.16	137.94	44.26	19.86	24.06	8.84	1.05	2.36	0.00	0.00	0.00	426.73
	Clear-cuts	0.00	0.00	0.00	0.00	393.67	964.30	998.26	794.64	379.25	152.08	52.40	15.37	0.00	3 749.90
	Selective harvesting	0.00	0.00	0.00	0.00	7.09	9.87	16.36	12.95	3.24	3.94	0.00	0.00	0.00	53.43
Other species (oak. ash)	Pre-commercial thinning	0.00	4.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.17
	Commercial thinning	0.12	5.64	29.08	36.57	72.03	61.23	64.35	34.73	15.42	7.36	15.22	5.40	2.45	349.60
	Clear-cuts	0.00	0.00	3.68	11.94	9.20	0.37	0.00	0.00	99.17	36.69	35.47	0.00	23.93	220.44
	Selective harvesting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.90	0.00	0.00	0.00	0.00	18.90

Appendix 4. Areas of forest stands, clear cuts in hectares and harvested volumes in cubic meters, and mean growing stock on hectare in cubic meters

Dom. Species		Age Class (years)													Total
		1_10	11_20	21_30	31_40	41_50	51_60	61_70	71_80	81_90	91_100	101_110	111_120	>120	
Pine	AREA, thousand ha	36.70	35.04	27.21	39.51	64.32	101.19	131.44	117.26	108.59	80.31	60.89	41.24	70.84	
	Clear cut 2009, thousand ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.55	2.85	4.66	
	Harvested Volume, M m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.82	0.96	1.47	4.25
	Mean growing stock on ha	0.61	13.80	94.71	130.80	197.12	238.10	257.81	287.37	309.37	316.21	328.65	337.02	315.37	
Spruce	AREA, thousand ha	46.01	34.74	84.90	96.93	58.99	50.80	51.96	41.62	29.48	13.77	12.01	6.22	9.94	
	Clear cut 2009, thousand ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.18	1.57	0.90	0.41	0.37	
	Harvested Volume, M m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.48	0.26	0.12	0.11	1.64
	Mean growing stock on ha	0.39	21.88	91.13	179.43	219.15	243.09	274.22	311.53	312.00	307.88	286.35	286.72	295.45	
Birch	AREA, thousand ha	137.49	79.04	67.23	114.92	155.73	154.12	95.10	52.49	19.37	5.18	1.69	0.31	0.88	
	Clear cut 2009, thousand ha	0.00	0.00	0.00	0.00	0.00	0.05	0.08	6.28	3.00	1.79	0.55	0.00	0.03	
	Harvested Volume, M m3	0.00	0.00	0.00	0.00	0.00	0.01	0.02	1.83	0.92	0.53	0.13	0.00	0.01	3.42
	Mean growing stock on ha	3.72	39.22	110.01	166.18	219.23	256.73	270.75	291.81	306.24	296.16	234.86	167.87	255.98	
Black alder	AREA, thousand ha	15.21	10.27	24.30	26.24	30.93	28.25	17.63	5.88	2.45	0.00	0.00	0.00	0.00	
	Clear cut 2009, thousand ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.31	0.00	0.00	0.00	0.00	
	Harvested Volume, M m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.09	0.00	0.00	0.00	0.00	0.27
	Mean growing stock on ha	2.05	52.84	134.64	198.72	255.63	306.11	341.42	366.43	301.39	0.00	0.00	0.00	0.00	
Grey alder	AREA, thousand ha	53.53	59.61	83.58	70.66	33.38	8.14	1.26	0.00	0.00	0.00	0.00	0.00	0.00	
	Clear cut 2009, thousand ha	0.00	0.09	0.53	1.25	1.46	0.43	0.06	0.00	0.00	0.00	0.00	0.00	0.00	
	Harvested Volume, M m3	0.00	0.01	0.08	0.26	0.32	0.10	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.76
	Mean growing stock on ha	8.03	80.21	148.85	204.14	216.69	226.69	293.92	0.00	0.00	0.00	0.00	0.00	0.00	

Appendix 4. Areas of forest stands, clear cuts in hectares and harvested volumes in cubic meters, and mean growing stock on hectare in cubic meters (continued)

Dom. Species		Age Class													Total
		1_10	11_20	21_30	31_40	41_50	51_60	61_70	71_80	81_90	91_100	101_110	111_120	>120	
Aspen	AREA, thousand ha	69.89	16.37	17.27	25.43	38.28	39.97	24.35	7.83	3.55	0.74	0.69	0.35	0.00	
	Clear cut 2009, thousand ha	0.00	0.00	0.00	0.00	0.39	0.96	1.00	0.79	0.38	0.15	0.05	0.02	0.000	
	Harvested Volume, M m3	0.00	0.00	0.00	0.00	0.13	0.38	0.43	0.38	0.15	0.07	0.04	0.00	0.00	1.57
	Mean growing stock on ha	3.93	66.11	179.86	300.87	332.86	392.09	426.23	483.16	390.68	445.26	689.30	234.13	0.00	
Oak, Ash	AREA, thousand ha	3.50	1.81	2.21	3.38	5.55	4.71	6.83	4.08	5.80	3.13	1.38	0.00	4.77	
	Clear cut 2009, thousand ha	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.10	0.04	0.04	0.00	0.02	
	Harvested Volume, M m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.00	0.01	0.03
	Mean growing stock on ha	0.37	20.49	54.60	99.24	167.99	273.20	251.18	256.02	291.13	309.98	330.26	0.00	281.97	
All species	AREA, thousand ha	369.50	251.51	324.27	387.74	392.07	390.76	329.94	230.20	170.28	104.17	76.97	48.60	86.43	
	Clear cut 2009, thousand ha	0.00	0.09	0.54	1.27	1.86	1.44	1.13	7.56	5.96	3.55	7.08	3.27	5.07	
	Harvested Volume, M m3	0.00	0.00	0.06	0.23	0.42	0.39	0.32	2.27	1.85	1.12	2.29	1.08	1.58	11.95
	Mean growing stock on ha	3.69	45.54	117.82	182.07	228.09	266.64	281.41	300.74	310.15	315.06	323.81	329.56	310.63	

Appendix 5. Mean height (m) of I floor dominant tree species of forest stands by the main tree species and age class

Dom. Species		Age Class (years)													Total
		1_10	**11_20**	**21_30**	**31_40**	**41_50**	**51_60**	**61_70**	**71_80**	**81_90**	**91_100**	**101_110**	**111_120**	**>120**	
Pine	AREA, thousand ha	36.70	35.04	27.21	39.51	64.32	101.19	131.44	117.26	108.59	80.31	60.89	41.24	70.84	914.54
	Mean height, m	1.18	4.31	9.86	12.93	16.68	19.84	20.84	22.18	22.89	22.75	23.35	24.08	23.34	19.44
	Mean value error, %	8.59	3.35	4.18	2.81	2.03	1.36	1.24	1.26	1.37	1.52	1.82	1.82	1.69	0.73
	Mean value error, m	0.10	0.14	0.41	0.36	0.34	0.27	0.26	0.28	0.31	0.35	0.42	0.44	0.39	0.14
Spruce	AREA, thousand ha	46.01	34.74	84.90	96.93	58.99	50.80	51.96	41.62	29.48	13.77	12.01	6.22	9.94	537.38
	Mean height, m	0.82	5.45	10.62	15.07	18.24	20.45	22.81	23.78	25.28	24.49	25.05	25.96	25.70	16.15
	Mean value error, %	6.50	3.88	1.73	1.24	1.40	1.49	1.11	1.27	1.65	3.13	3.36	4.42	2.40	1.14
	Mean value error, m	0.05	0.21	0.18	0.19	0.26	0.30	0.25	0.30	0.42	0.77	0.84	1.15	0.62	0.18
Birch	AREA, thousand ha	137.49	79.04	67.23	114.92	155.73	154.12	95.10	52.49	19.37	5.18	1.69	0.31	0.88	883.56
	Mean height, m	2.78	8.41	14.09	17.74	20.60	23.18	23.98	25.31	26.59	27.51	24.00	20.58	24.04	17.14
	Mean value error, %	3.15	2.03	1.73	1.20	0.96	0.78	0.89	1.24	1.69	5.46	10.07	0.00	7.49	0.90
	Mean value error, m	0.09	0.17	0.24	0.21	0.20	0.18	0.21	0.31	0.45	1.50	2.42	0.00	1.80	0.15
Black alder	AREA, thousand ha	15.21	10.27	24.30	26.24	30.93	28.25	17.63	5.88	2.45	0.00	0.00	0.00	0.00	161.16
	Mean height, m	2.71	8.61	13.88	17.36	19.25	21.72	23.40	24.37	25.31	0.00	0.00	0.00	0.00	17.06
	Mean value error, %	8.55	6.43	2.29	1.90	1.70	1.57	1.64	2.39	4.28	0.00	0.00	0.00	0.00	1.65
	Mean value error, m	0.23	0.55	0.32	0.33	0.33	0.34	0.38	0.58	1.08	0.00	0.00	0.00	0.00	0.28
Grey alder	AREA, thousand ha	53.53	59.61	83.58	70.66	33.38	8.14	1.26	0.00	0.00	0.00	0.00	0.00	0.00	310.16
	Mean height, m	3.28	9.66	13.73	16.92	18.58	19.52	22.59	0.00	0.00	0.00	0.00	0.00	0.00	12.58
	Mean value error, %	4.15	2.00	1.21	1.08	1.48	2.56	3.23	0.00	0.00	0.00	0.00	0.00	0.00	1.34
	Mean value error, m	0.14	0.19	0.17	0.18	0.28	0.50	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.17
Aspen	AREA, thousand ha	69.89	16.37	17.27	25.43	38.28	39.97	24.35	7.83	3.55	0.74	0.69	0.35	0.00	244.71
	Mean height, m	2.86	10.01	17.78	23.95	26.20	28.40	29.74	31.19	30.96	26.74	31.66	30.00	0.00	18.59
	Mean value error, %	4.37	4.91	3.39	1.92	1.28	1.17	0.96	1.90	2.95	11.97	0.63	0.00	0.00	2.09
	Mean value error, m	0.13	0.49	0.60	0.46	0.34	0.33	0.29	0.59	0.91	3.20	0.20	0.00	0.00	0.39
Oak, Ash	AREA, thousand ha	3.50	1.81	2.21	3.38	5.55	4.71	6.83	4.08	5.80	3.13	1.38	0.00	4.77	47.14
	Mean height, m	1.63	5.78	12.83	14.45	18.91	23.17	22.08	24.25	25.90	26.97	24.87	0.00	27.52	20.31
	Mean value error, %	21.33	13.67	11.84	4.34	2.90	3.15	3.76	4.05	2.85	5.77	8.67	0.00	2.24	3.04
	Mean value error, m	0.35	0.79	1.52	0.63	0.55	0.73	0.83	0.98	0.74	1.56	2.16	0.00	0.62	0.62

Appendix 5. Mean height (m) of I floor dominant tree species of forest stands by the main tree species and age class (continued)

Dom. Species		Age Class (years)													Total
		1_10	**11_20**	**21_30**	**31_40**	**41_50**	**51_60**	**61_70**	**71_80**	**81-90**	**91_100**	**101_110**	**111_120**	**>120**	
All species	AREA, thousand ha	369.50	251.51	324.27	387.74	392.07	390.76	329.94	230.20	170.28	104.17	76.97	48.60	86.43	3162.43
	Mean height, m	2.48	7.88	12.84	16.69	19.81	22.29	22.90	23.58	24.03	23.39	23.74	24.34	23.85	17.26
	Mean value error, %	2.14	1.40	0.88	0.72	0.67	0.61	0.65	0.78	0.96	1.32	1.57	1.66	1.42	0.46
	Mean value error, m	0.05	0.11	0.11	0.12	0.13	0.14	0.15	0.18	0.23	0.31	0.37	0.41	0.34	0.08

Appendix 6. Mean diameter (cm) of I floor dominant tree species of forest stands by the main tree species and age class

Dom. Species		Age Class (years)													Total
		1_10	**11_20**	**21_30**	**31_40**	**41_50**	**51_60**	**61_70**	**71_80**	**81_90**	**91_100**	**101_110**	**111_120**	**>120**	
Pine	AREA, thousand ha	36.70	35.04	27.21	39.51	64.32	101.19	131.44	117.26	108.59	80.31	60.89	41.24	70.84	914.54
	Mean diameter, cm	1.34	5.75	12.93	16.01	19.95	23.38	25.13	26.83	28.23	28.84	31.14	32.69	33.20	24.40
	Mean value error, %	5.69	4.66	4.38	3.35	2.32	1.56	1.33	1.34	1.38	1.67	2.00	2.02	1.80	0.78
	Mean value error, cm	0.08	0.27	0.57	0.54	0.46	0.37	0.33	0.36	0.39	0.48	0.62	0.66	0.60	0.19
Spruce	AREA, thousand ha	46.01	34.74	84.90	96.93	58.99	50.80	51.96	41.62	29.48	13.77	12.01	6.22	9.94	537.38
	Mean diameter, cm	1.08	6.18	12.22	16.53	20.48	24.14	27.10	28.89	30.63	31.49	32.95	35.55	32.41	19.03
	Mean value error, %	5.28	4.51	2.00	1.57	1.73	1.94	1.60	1.78	2.21	3.51	3.94	7.74	4.49	1.27
	Mean value error, cm	0.06	0.28	0.24	0.26	0.35	0.47	0.43	0.51	0.68	1.10	1.30	2.75	1.46	0.24
Birch	AREA, thousand ha	137.49	79.04	67.23	114.92	155.73	154.12	95.10	52.49	19.37	5.18	1.69	0.31	0.88	883.56
	Mean diameter, cm	1.93	6.68	12.47	16.60	19.98	23.30	25.42	29.05	32.44	37.30	38.69	28.55	32.53	17.10
	Mean value error, %	3.27	2.69	2.39	1.59	1.16	1.06	1.19	1.90	2.62	8.20	20.27	0.00	5.10	1.07
	Mean value error, cm	0.06	0.18	0.30	0.26	0.23	0.25	0.30	0.55	0.85	3.06	7.84	0.00	1.66	0.18
Black alder	AREA, thousand ha	15.21	10.27	24.30	26.24	30.93	28.25	17.63	5.88	2.45	0.00	0.00	0.00	0.00	161.16
	Mean diameter, cm	2.44	8.09	14.39	18.28	20.76	24.32	25.83	31.17	33.94	0.00	0.00	0.00	0.00	18.62
	Mean value error, %	21.27	7.60	2.86	2.48	2.02	1.73	2.37	2.46	3.19	0.00	0.00	0.00	0.00	1.89
	Mean value error, cm	0.52	0.61	0.41	0.45	0.42	0.42	0.61	0.77	1.08	0.00	0.00	0.00	0.00	0.35
Grey alder	AREA, thousand ha	53.53	59.61	83.58	70.66	33.38	8.14	1.26	0.00	0.00	0.00	0.00	0.00	0.00	310.16
	Mean diameter, cm	2.34	7.97	12.91	16.03	18.53	21.03	23.61	0.00	0.00	0.00	0.00	0.00	0.00	11.71
	Mean value error, %	4.97	2.45	1.49	1.17	1.50	2.87	5.39	0.00	0.00	0.00	0.00	0.00	0.00	1.53
	Mean value error, cm	0.12	0.20	0.19	0.19	0.28	0.60	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Aspen	AREA, thousand ha	69.89	16.37	17.27	25.43	38.28	39.97	24.35	7.83	3.55	0.74	0.69	0.35	0.00	244.71
	Mean diameter, cm	1.92	8.25	18.25	26.00	30.16	33.82	38.65	42.71	49.56	46.39	50.66	46.08	0.00	21.61
	Mean value error, %	4.56	7.07	5.52	2.91	2.31	2.15	2.61	3.12	5.17	19.78	3.31	0.00	0.00	2.52
	Mean value error, cm	0.09	0.58	1.01	0.76	0.70	0.73	1.01	1.33	2.56	9.17	1.68	0.00	0.00	0.54

Appendix 6. Mean diameter (cm) of I floor dominant tree species of forest stands by the main tree species and age class (continued)

Dom. Species		**Age Class (years)**													**Total**
		1_10	**11_20**	**21_30**	**31_40**	**41_50**	**51_60**	**61_70**	**71_80**	**81_90**	**91_100**	**101_110**	**111_120**	**>120**	
Oak, Ash	AREA, thousand ha	3.50	1.81	2.21	3.38	5.55	4.71	6.83	4.08	5.80	3.13	1.38	0.00	4.77	47.14
	Mean diameter, cm	1.52	6.61	19.30	19.89	22.81	28.19	30.80	31.57	43.82	47.67	47.55	0.00	65.30	31.95
	Mean value error, %	20.90	15.91	20.37	9.15	6.46	5.38	5.09	6.85	6.13	11.02	11.36	0.00	4.76	4.56
	Mean value error, cm	0.32	1.05	3.93	1.82	1.47	1.52	1.57	2.16	2.69	5.26	5.40	0.00	3.11	1.46
All species	AREA, thousand ha	369.50	251.51	324.27	387.74	392.07	390.76	329.94	230.20	170.28	104.17	76.97	48.60	86.43	3162.43
	Mean diameter, cm	1.87	7.15	13.43	17.31	21.18	24.73	26.71	28.49	30.33	30.54	32.14	33.37	34.87	19.72
	Mean value error, %	2.33	1.58	1.12	0.89	0.85	0.80	0.83	0.95	1.21	1.72	1.87	2.11	1.98	0.55
	Mean value error, cm	0.04	0.11	0.15	0.15	0.18	0.20	0.22	0.27	0.37	0.53	0.60	0.70	0.69	0.11