sustainability

Review

Suitability of Fast-Growing Tree Species (*Salix* spp., *Populus* spp., *Alnus* spp.) for the Establishment of Economic Agroforestry Zones for Biomass Energy in the Baltic Sea Region

Mudrite Daugaviete *, Kristaps Makovskis, Andis Lazdins and Dagnija Lazdina

Latvian State Forest Research Institute "Silava", Riga Street 111, LV-2169 Salaspils, Latvia
* Correspondence: mudrite.daugaviete@silava.lv; Tel.: +371-29154265

Abstract: The main goal of this review was to provide an assessment of the potential of fast-growing tree species for the suitable transformation of agroforestry areas for biomass production in the Baltic Sea region. Our interest was to highlight the research on the management process of agroforestry zones by establishing short rotation plantations with the tree species *Salix* spp., *Populus* spp. and *Alnus* spp. to explore the prospects of planning these zones as biomass producers. Short rotation forestry (SRF) with trees whose rotation period is 15 to 30 years, depending on the species, is the most suitable approach for management of these agroforestry zones. Willows (*Salix* spp.) and poplars (*Populus* spp.) are suitable for short rotation coppice (SRC), as these tree species can be harvested at much shorter intervals, respectively, 1–5 and 4–10 years, facilitating their use in agricultural systems. The rotation period of *Alnus* spp. in short rotation plantations for energy wood production is generally assessed to be 15–30 years. The black alder plantations in agroforestry zones are used for sawnwood and firewood production, with a rotation period of 20–40 years. The calculated repayment period of the economic agroforestry zone is about 10–15 years, if 2021 costs and prices are used.

Keywords: economic agroforestry zone; *Salix* spp.; *Populus* spp.; *Alnus* spp.; short rotation coppice (SRC); short rotation forestry (SRF); energy wood

check for updates

Citation: Daugaviete, M.; Makovskis, K.; Lazdins, A.; Lazdina, D. Suitability of Fast-Growing Tree Species (*Salix* spp., *Populus* spp., *Alnus* spp.) for the Establishment of Economic Agroforestry Zones for Biomass Energy in the Baltic Sea Region. *Sustainability* **2022**, *14*, 16564. https://doi.org/10.3390/su142416564

Academic Editors: Idiano D'Adamo and Muhammad Ikram

Received: 3 October 2022
Accepted: 5 December 2022
Published: 10 December 2022

1. Introduction

Climate change, the increasing biomass demand for energy and the expectations to reduce greenhouse gas (GHG) emissions and provide carbon storage in soils and vegetation at the same time are projected to add further pressure on managed economic agroforestry zones [1–5]. The European Green Deal foresees that sustainability and climate neutrality in several European Union (EU) countries, including the Baltic region, will be achieved by 2050 [6]. Bioeconomy is defined as an economy that uses renewable biological resources from the land and sea for energy, food and material production. One of the main perspectives of bioeconomy is the bioresource vision [7]. Climate policies, such as the Paris Agreement, will increase the demand for biomass production to meet the bioeconomic needs, including those of energy, industry and agriculture. Substitution of non-renewable resources with biological ones and the use of biomass are part of a circular bioeconomy, which plays a key role in achieving the Sustainable Development Goals [7]. The EU aims to increase the share of renewable energy in final energy consumption to 27% by 2030 [8–10]. The EU planning documents state that the use of renewable energy sources in the energy sector must be increased to promote a reduction of fossil fuel resources [11]. Each member state has set an individual target, but the overall objective of the EU countries is to reach from 42% (Estonia) to 65% (Sweden) use of renewable energy resources in the gross final energy consumption by 2030 by increasing the use of wood for energy production [12,13]. In addition, the strategy of the Baltic Sea countries for achieving climate neutrality by 2050 sets out to promote sustainable land management and a gradual transition from fossil to renewable energy sources [14–16].

In Latvia and neighboring countries, agroforestry zones contribute significantly to biofuel production, and possess climate change mitigation and nutrient retention potential [13]. The main goal of this review was to provide an assessment of the potential of fast-growing tree species for the suitable transformation of agroforestry zones for biomass production in the Baltic Sea region. The aim was to present an overview of the research on the management process of agroforestry zones by establishing short rotation plantations with the tree species *Salix* spp., *Populus* spp. and *Alnus* spp. and to explore the prospects of planning these zones as biomass producers.

2. Scope of Short Rotation Tree Species in Agroforestry

Agroforestry is an ancient agricultural practice that is widely implemented in EU countries [17–19]. EU regulation defines the term agroforestry system as a land use system, in which trees are grown on agricultural land [16,20]. In this region, agroforestry research began in the 1980s, focusing on coastal buffer zones and other landscape features designed to reduce pollution in watercourses and to produce biomass for energy at the same time [21,22]. Over the last 30 years, in-depth studies have been conducted on the effects of agroforestry zones on nitrogen (N) [23,24], phosphorus (P) [25,26] and various other pollutants. About 30–99% of nitrate (NO_3^-) and 20–100% of phosphorus (P) from runoff and shallow groundwater are retained in coastal agroforestry zones [27]. This concerns as well the production of biomass from the agroforestry systems [1,3,5,20,28–31].

Recent studies in the EU confirm that agroforestry zones on agricultural land protect surface water quality, as well as reduce soil erosion and diffuse pollution [1,3,5,28–33]. Agroforestry zones also play a key role in nature protection and flood risk reduction, as well as in the design of climate-resilient bioenergy measures and the effects of intensive agricultural and policy pressures on the environment [32]. In EU countries economic agroforestry zones are common, but the growing demand for bioenergy and agricultural products requires the establishment of even more of them [1,3,5,28–33]. Land use is much more important in determining hydrology of the catchment area than the soil type: agroforestry protection zones have a significantly higher infiltration capacity than fields or pastures [3]. Agroforestry zones as shelter belts are also very effective in removing pesticides, preserving the biodiversity of agricultural land and have a high potential for fuel, feed or fibre production [3,34].

The EU Water Framework Directive (Directive 2000/60/EC) calls for the good ecological status of waters and the reduction of pollution by 2027 at the latest [35,36]. Along with rising energy prices, future fossil fuel shortages and climate change are also driving new measures that combine energy production with environmental protection and carbon sequestration [37,38]. One way of tackling this problem is to re-evaluate agricultural systems in the combined food and bioenergy production process [36]. Specially planned and designed agroforestry zones reduce nutrient losses and retain pesticides from agricultural land, regulate water cycles, reduce the risk of floods, increase carbon sequestration, reduce greenhouse gas emissions and secure energy production from agriculture [29].

Legislation of the Baltic Sea region countries allows for the growing of woody biomass on agricultural land as short rotation plantations, as agriculture or plantation forests [38–41]. The maximum growing period for short rotation plantations as agriculture is 15 years, after which the plantations are restored or the land is used to grow other crops [39]. Natural forest grown on agricultural land can be registered as a plantation, if it does not exceed 20 years of age. The term "fast-growing tree plantations" in practice refers to both agricultural even-aged fast-growing tree species (willow, aspen hybrids, grey alder), grown as a short rotation tree plantation for 15 years, and afforested land-plantation forest with a maximum rotation period of 20 years. When trees are grown together with grasses or other crops, it is considered an agroforestry system, but depending on the number of trees planted, it could correspond to both agriculture and forest land [39].

According to the policies of the Baltic Sea region countries, including Latvian regulatory enactments for tree plantations and short rotation coppice, fast-growing tree species are recommended as biomass producers for economic agroforestry zones [39]. Short rotation coppice here refers to the cultivation of trees on agricultural land.

3. Tree, Shrub and Crop Components in Short Rotation Agroforestry

Short rotation forestry (SRF), with a combination of species and a rotation period of 15 to 30 years depending on the species used, is the most suitable method for the management of economic agroforestry zones [28,42–44]. Willows (*Salix* spp.) and poplars (*Populus* spp.) are suitable for short rotation coppice (SRC), as these tree species can be harvested at much shorter intervals of 1–5 and 4–10 years, respectively, facilitating their use in agricultural systems [41,43,44].

The harvesting interval of SRC for grey alder (*Alnus incana*) and black alder (*Alnus glutinosa* L.) is approx. 15–25 years [45–50]. Studies on alder plantations indicate that the potential for biomass production is similar to poplars (*Populus* spp.) and willows (*Salix* spp.) [43,44,51,52].

Suitable species such as *Salix* spp. and *Populus* spp. can be renewed with coppice 2–3 times until the shoots run out or yields are significantly reduced [43,53–56]. Assuming that most of the short rotation coppice (*Salix* spp. and *Populus* spp.) will be planted on fertile soils with a high nutrient potential as well as a successful species combination and growth conditions, the calculated average annual DM yield estimate per unit area is 5–8 t ha^{-1} (6–18 m^3 ha^{-1}) for SRF and up to 16 t ha^{-1} (39 m^3 ha^{-1}) for willow/poplar SRC [43].

Scientists have estimated the maximum biomass production potential for short rotation plantations and SRC tree species in European countries [3,57]. The highest yield in short-rotation plantations is expected from poplar hybrids, which produce 16 t DM ha^{-1} yr^{-1}, followed by *Salix* spp., which produces 14 t DM ha^{-1} yr^{-1}, hybrid aspen with a yield of 10.3 t DM ha^{-1} yr^{-1} and finally grey alder at 9.7 t DM ha^{-1} yr^{-1} [3,57,58]. This biomass production potential is similar to economic agroforestry zones with similar soil properties.

4. Model of Economic Agroforestry Zone vis-a-vis Shelter Belt Agroforestry

In the economic agroforestry zones, which serve as shelter belts, willows can be planted alone as a low protection zone or on a ditch ramp in the protection zones of larger trees. This allows movement around the ditch area without cutting large trees, as well as rows of larger trees on the wind side, which lifts wind flows over the tops of the trees, thereby preventing wind damages [3].

Within the scope of a study carried out in Latvia, scientists recommended the establishment of agroforestry zones as shelter belts marked on agricultural lands as 15 m wide strips along the ditch area (Figure 1).

Another study showed that, in agroforestry zones as shelter belts 15 m in width, willows could be planted in a double row along the edge of the shelter belt, grey alder seedlings in rows of 1–1.5 × 2.5 m and fast-growing breeds of *Populus* spp. and *Alnus* spp. in rows of 1 × 2.5 m [59].

The length of a rotation period is 15–20 years. The rotation period of willow plantations is 2–5 years (5–7 production cycles) to produce wood chips and 6–15 years to produce firewood [43,44,60]. Willows can be used to produce firewood, wood chips, pellets and charcoal [43,44,60]. The life cycle of *Populus* spp., including aspen hybrids, is 15–30 years, whereas in energy wood plantations the life cycle is 15 years [53–56,61–64]. The number of rotation cycles is 1–3. When the purpose of growing a hybrid aspen plantation is to produce energy wood, the first felling can be done earlier (in about 10 years) and then the plantation can be managed as a coppice [57,62–64]. The life cycle of *Alnus spp.* is 15–30 years.

During the first few years, in plantations of *Populus* spp. and *Alnus* spp. the line spacing can be used to grow other crops, including agricultural crops [65–68]. This uses the land more efficiently and gains additional profits. For example, barley, clover, oats, rye, wheat, corn, potatoes and other crops can be grown between the rows of poplars [66]. The cultivation of these crops reduces the growth of vegetation and forms green manure. The poplar crowns join later, limiting the availability of light, water and nutrients to these crops [68].

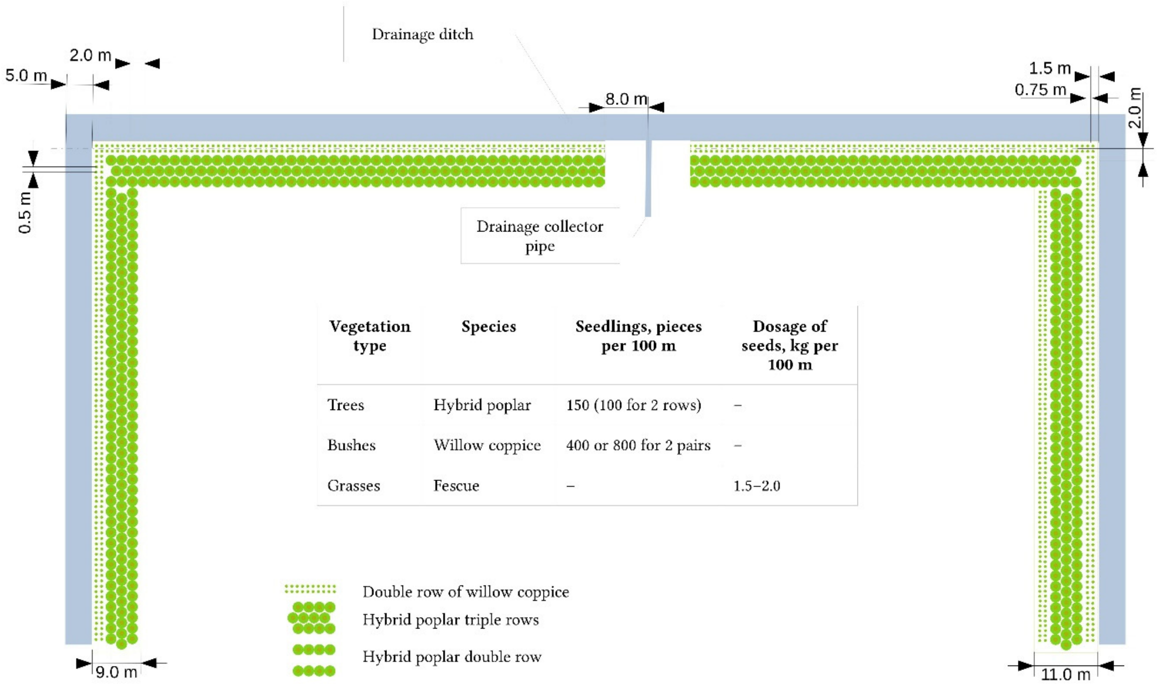

Figure 1. Principal scheme of a shelter belt.

The reason for sowing grass is to provide income in the first year after the establishment of a tree plantation. The design of a tree plantation allows the area to be used as efficiently as possible until the tree crowns close [67,69].

The biomass yields of woody plants in SRC and SRF agroforestry systems is summarized in Table 1.

Table 1. Biomass extraction potential from tree species suitable for SRF and SRC in Latvia.

Tree Species	Duration of Rotation, yr	Average Annual Growth, t DM ha^{-1}, yr^{-1}	Stock Produced	
			Per Year, m^3 ha^{-1}	Willow, Poplar: In 5 Years; Aspen Hybrids: 10–25 Years, m^3 ha^{-1}
Willow hybrids, *Salix viminalis* L. based and others	1–5	8–12	30–36; 75–90 bulk	50–60; 125–150 bulk
Aspen hybrids, *Populus tremula* L. based	10–25	23	15–20	200–400
Poplar hybrids, *Populus deltoides* L. based and other hybrids	3–5	7	5–9 9–16	20–45; 36–80
Grey alder, *Alnus incana* L.	5–15	3.4–5.5	11.8	178
Black alder, *Alnus glutinosa* L	15–20	15.5	19–26	249

Studies have shown that for the climate of the Baltic Sea region, the most suitable tree species as biomass producers are *Salix* spp., *Populus* spp. and *Alnus* spp., if they are established and managed as short-rotation plantations [20,43,44,70–73]. The average yield of willow biomass is 8 t DM ha^{-1} yr^{-1} [43]. In Sweden, the average yield is 7–20 t DM ha^{-1} [30], in Poland 7–12 t DM ha$^{-1,}$ in Germany 6–14 t DM ha^{-1} and in Latvia 8–12 t DM ha^{-1} [44].

In order to produce as much biomass as possible in a short period of time in economic agroforestry zones, it is recommended to grow poplars in short rotation (3–5 years) plantations and plantations regenerated with coppice [43,44]. The length of a rotation period is 20–30 years [30,43,44]. After 20–30 years, the plantations are replanted or the species is replaced. The recommended number of rotation periods is 3–4. At the end of rotation period, the growing stock reaches 20–45 t ha^{-1} of naturally wet wood [30,43]. The average annual increase in biomass in Europe for poplars varies from 2 to 13.5 t ha^{-1} [30,43]. The growing stock of a hybrid aspen plantation with an initial density of 1100 trees per hectare reaches 50 m^3 ha^{-1} at the age of 8 years, but, if the initial density is 2500 trees per hectare, growing stock reaches 200 m^3 ha^{-1} at the age of 10 years, 230 m^3 ha^{-1} at 15 years and −300–400 m^3 ha^{-1} at 20–25 years [64].

Research shows that in the climate zone of the Baltic Sea countries—Sweden, Estonia, Latvia, Lithuania etc.—*Alnus* spp. trees are suitable for energy wood production [3,45,49,50,58,74]. Scientists from Sweden and Finland demonstrated that grey alder plantations have the highest biomass yields at 17 t DM ha^{-1} yr^{-1} [73]. In Latvian climate conditions, the growing stock of grey alder in 5-year-old stands, depending on soil fertility and stand density, is 8–32 m^3 ha^{-1} (20–97.5 m^3 of wood chips), in 10-year-old stands it is 20–102 m^3 ha^{-1} (50–255 m^3 of wood chips) and in 15-year-old stands 34–178 m^3 ha^{-1} (85–445 m^3 of wood chips) [74–76]. Estonian scientists have found that the surface biomass produced by black alder at 21 years of age can reach 88.8 t DM ha^{-1}, giving an annual biomass production of 17.1 t DM ha^{-1} [58,73]. In Sweden, black alder is able to produce 152.3 $\pm$ 7.7 t DM ha^{-1} at the ages of 21 to 91 [45]. In Latvian climate conditions, the growing stock in black alder plantations reaches up to 249 m^3 ha^{-1} at the age of 15 years, if 2–3 root offshoots have been left near the trunk during the early tending, but at the age of maturity growing stock reaches up to 400 m^3 ha^{-1} [49,76].

In order to maximize the use of the area of an economic agroforestry zone, in many European countries herbaceous plants are grown in tree plantations. This is done for several purposes, including food and feed supply, nitrogen balance, landscape aesthetics and biodiversity, groundwater protection and on-site carbon sequestration [70,72].

Studies carried out in Latvia evaluated three different herb communities, including a community dominated by nectar plants, a community of fodder herbs and an industrial herb community. All the herb communities that were evaluated in the study are universal and can be used in different types of agricultural soils [66,68,77]. It should be noted that a grass community can only be transplanted at the same time that the economic agroforestry zone is replanted; therefore, it must be taken into account that in a few years a new community of undergrowth vegetation will replace the sown crop. The composition and productivity of the undergrowth vegetation is determined by growth conditions and the design of the economic agroforestry zone. The herb communities proposed according to an earlier study [68] are described in Table 2.

Table 2. Proposed grass communities in the shelter belts of hybrid aspen, poplar hybrids, grey alder and black alder.

	Nectar Plants	Fodder Grasses	Industrial Grasses
Herbaceous species	*Trifolium pratense*, *T. repens*, *T. hybridum*, *Lotus corniculatus*, *Trifolium incarnatum*, *Melilotus albus*, *M. officinalis*, *Festuca ovina*, *F. pratensis*	*Lolium multiflorum*, *L. perenne*; *Festulolium*, *Festuca pratensis*, *Phleum pratense*, *Trifolium pratense*, *T. repens*, *Medicago sativa/varia*	*Lolium multiflorum*, *Festuca arundinacea*, *F. pratensis*, *Festuca rubra; Phleum pratense*; *Alopecurus pratensis*
Rotation cycle length	5–6 years	4–5 years	5–7 years
Number of rotations recommended prior to change of species	1	1	Can be sown repeatedly
Above- and below-ground biomass	Increase of above-ground biomass, 5–6 t DM ha^{-1}; below-ground biomass about 50% of the total plant biomass	Increase in above-ground biomass, 8–10 t DM ha^{-1}; below-ground biomass about 50% of the total plant biomass	Increase in above-ground biomass, 5–12 t DM ha^{-1}, depending on growing conditions and lawn mowing regime

Perennial grasslands have a potential to produce bioenergy in temperate climate, given their growing conditions, productivity, biomass quality and productive longevity. To help to achieve these goals, a study was conducted on the growth potential of the grass *Phalaris arundinacea* L., as well as hybrid grasses (×*Festulolium*) and trees, using biogas digestate and wood ash as fertilizers [66].

5. Economic Viability of the Economic Agroforestry Zones

A number of measures affect the results of the establishment and management of an economic agroforestry zone: site evaluation (soil properties and moisture regime), overgrowth removal, soil preparation before planting, use of fertilizers, quality and delivery of planting material, planting, early tending and the management activities, biomass extraction and regeneration of the agroforestry zone.

Soil preparation costs before planting are similar for all the tree species. Data for the cost calculations are taken from the agriculture service costs database of the Latvian Rural Advisory and Training Centre and represents the situation in 2021 [78]. Soil preparation costs are the following: overgrowth removal (300 EUR ha^{-1}), herbicides (24 EUR ha^{-1}), fertilizers (173 EUR ha^{-1}), plowing (55 EUR ha^{-1}), herbicide transport (18 EUR ha^{-1}), herbicide spraying (23 EUR ha^{-1}), discing (40 EUR ha^{-1}), cultivation (33 EUR ha^{-1}), fertilizer transport (18 EUR ha^{-1}) and fertilizer spreading (19 EUR ha^{-1}), in total 701 EUR ha^{-1}.

Due to the increase in fuel prices by 26.6%, the average consumer price index increased by 8.7%, leading to an increase of the total cost [79]. Taking this into account, the total cost of soil preparation is 762 EUR ha^{-1}. It should be noted that due to continuously rising fuel prices in 2022, soil preparation costs may be significantly higher at the end of 2022 and in 2023.

The area of the economic agroforestry zone is marked according to a previously elaborated design and planted after soil preparation. Planting cost includes planting material and planting, as well as seeds and sowing. Assuming that an agroforestry zone consists of willows, on average 13,000 seedlings per hectare is the optimum number for Latvia. The total cost of establishing one hectare of a willow plantation is 1060 EUR, of which 845 EUR (75%) is the cost for planting material and 215 EUR (25%) the cost for planting. Cuttings of selected willow varieties are used as planting material, while planting is carried out using a planting machine. Prices of cuttings and planting costs are provided by harvesting every 4th to 6th year and fertilizers are used only during the establishment of the agroforestry zone.

Willow in agroforestry zones should be managed intensively by harvesting every 3rd year and fertilizers should be used after every harvest. However, this is not mandatory in agroforestry zones, which receive nutrients from surrounding cropland. The main objective of agroforestry zones is water protection by retaining nutrients and biomass production as added value. Therefore, the buffer zones should be managed extensively. In agroforestry zones surrounding agricultural lands, additional fertilization is not crucial and may even be avoided to reduce nutrient leakage to water bodies.

The mechanized harvesting method of willow SRC uses self-propelled shredders, where mowing is carried out simultaneously with chipping, while biomass is loaded into the supply tractor. The supplied biomass is stored for some time in open piles at the edge of the field to dry before further transportation. Manual harvesting can be used to produce willow cuttings or firewood from larger shoots. However, this method is very expensive considering the small dimensions of the trees. Transportation of biomass to a roadside is performed by a middle- or compact-class forest forwarder or a suitable agricultural tractor with a trailer adapted to transport long shoots. In the case of chip production, stems are comminuted with mobile chippers after a certain drying period. Biomass can be delivered to customers using tractors or chip trucks (load size up to 90 m^3 in Latvia).

The cost of mechanized willow harvesting is around 3.00 EUR bulk m^3, while manual harvesting using a chainsaw costs 43% more, 4.19 EUR bulk m^3 (Makovskis, 2021). The mechanized willow harvesting method is used in plantations with a total continuous area of at least 5 ha [44]. Therefore, in an extensively managed economic agroforestry zone, the manual harvesting method may be considered as a viable alternative to mechanized harvesting, especially because whole-stem harvesting permits drying of biomass in contrast to instant chipping with self-propelled harvesters [31]. In the extensive model, the average increment corresponds to 54 bulk m^3 ha^{-1} of wood chips [31]. Assuming that harvesting takes place once every 4 years, the total amount of wood chips per rotation corresponds to 216 bulk m^3 ha^{-1}. In the case of 6 harvests before the regeneration of an agroforestry zone, where the total output of wood chips is 1296 bulk m^3 ha^{-1}, the wood chip selling price is 9.4 EUR bulk m^3 [79]. Under such conditions, the repayment period of a shelter belt is about 10 years. However, a significant increase of forest biofuel leads to a higher economic efficiency of the agroforestry zone.

Aspen hybrids are suitable for short-rotation biomass production because they demonstrate good growth rates during early development. It is recommended to plant aspen hybrids in economic agroforestry zones, if the simultaneous cultivation of trees and grasses during a certain period of time is envisaged. These agroforestry zones can be harvested after 15 years and replanted after 30 years [64]. For the first 5 years grasses can be mowed and seeds sold. After harvest, the main timber products are pulp wood, firewood and wood chips. The calculated agroforestry zone repayment period is about 15 years, if the costs and prices of 2021 are used.

In grey alder plantations, the duration of a rotation of the SRC for energy wood production is assumed to be 15 years and the total life span 30 years (2 rotations). Then, the plantation should be restored [31]. Such plantations are managed for the production of wood chips. Studies recommend keeping grey alder in areas where it has already grown. In such a case, it is not necessary to purchase and plant seedlings, which significantly improves the economic return of the short rotation plantation of grey alder [31].

Planting black alder (*Alnus glutinosa* L.) as a short rotation crop is recommended in economic agroforestry zones with a 30–40 year rotation period. The plantation should be managed for one rotation, after which it should be restored [31]. The obtainable products are sawlogs, firewood and wood chips.

6. Conclusions

Research has shown that in the Baltic sea region, it is possible to create economically efficient agroforestry systems for biomass production by properly setting up and managing short-rotation tree plantations. The conclusions concerning the prospects and management of short rotation coppice (SRC) and short rotation forestry (SRF) for biomass production at the level of tree species are the following:

SRC with a life cycle of 15–20 years is recommended for willow (*Salix* spp.) as a biomass crop in economic agroforestry zones. The recommended rotation period of willow SRC is 2–5 years (5–7 production cycles per life cycle) for the production of wood chips and 6–15 years for the production of firewood. Willows can also be used to produce pellets and charcoal.

In poplar plantations (SRF) as biomass producers in economic agroforestry zones the recommended rotation period is 20–30 years. The recommended number of rotation cycles is 3–4. After 60–80 years, the plantations should be replanted with the consideration of the use of other species.

The recommended rotation period for hybrid aspen in SRF is 15–30 years. For energy wood production the rotation period is much shorter, 15 years. The number of rotations per life cycle is 1–3. If the purpose of the establishment of the plantation is to produce energy wood, then the first harvest can be done earlier (in about 10 years) and then the plantation can be managed as SRC.

In the grey alder plantation, the SRC life cycle for energy wood production is assumed to be 15 years (2 rotations) and the total life span 30 years, after which the plantation should be restored. The plantations are managed to produce wood chips. However, this is not an economically viable solution.

The black alder plantation is managed for sawlog and firewood production with a life span of 20–40 years, after which it can be managed as SRC or SRF.

The production potential of the shelter belts is of particular importance due to the large area of under-utilized farmlands and necessity of implementing pollution-preventing measures in riparian areas of agricultural landscapes. The importance of the shelter belts is also increased due to challenging climate change mitigation targets in the land use sector in Europe. At the same time, the shelter belts diversify economic activity in rural areas and provide access to carbon trading markets without a reduction of producing farmlands, ensuring the implementation of the targets set in the project of the nature restoration regulation. For Latvia, in spite of the importance of all the above-mentioned benefits, the most critical is the contribution to the implementation of the climate change mitigation targets set for 2030 and beyond.

Funding: This research was funded by the post-doctoral study project "Economic and environmental assessment of biomass production in buffer zones around drainage systems and territories surrounding the protective belts of natural water streams" (No.: 1.1.1.2/VIAA/3/19/437).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data available on request made to the corresponding author Mudrīte Daugaviete.

Acknowledgments: Mudrite Daugaviete contribution was supported by European Regional Development Fund (ERDF) project "Evaluation of factors affecting greenhouse gas (GHG) emissions reduction potential in cropland and grassland with organic soils" (No. 1.1.1.1/21/A/031), Kristaps Makovskis and Dagnija Lazdina contribution is covered by the ERDF project "Evaluation of climate change mitigation potential of drainage systems in cropland and grassland" (No. 1.1.1.1/21/A/030).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Don, A.; Osborne, B.; Hastings, A.; Skiba, U.; Carter, M.S.; Drewer, J.; Flessa, H.; Freibauer, A.; Hyvönen, N.; Jones, M.B.; et al. Land-use change to bioenergy production in Europe: Implications for the greenhouse gas balance and soil carbon. *Glob. Chang. Biol. Bioenergy* **2012**, *4*, 372–391. [CrossRef]
2. Holzmueller, E.J.; Jose, S. Biomass production for biofuels using agroforestry: Potential for North Central Region of the United States. *Agrofor. Syst.* **2012**, *85*, 305–314. [CrossRef]
3. Christen, B.; Dalgaard, T. Buffers for biomass production in temperate European agriculture: A review and synthesis on function, ecosystem services and implementation. *Biomass. Bioenergy* **2013**, *55*, 53–67. [CrossRef]
4. Herder, M.; Moreno, G.; Mosquera-Losada, R.M.; Palma, J.H.N.; Sidiropoulou, A.; Freijanes, J.; Crous-Duran, J.; Paulo, J.A.; Tomé, M.; Pantera, A.; et al. Current extend and stratification of agroforestry in the European Union. *Agric. Ecosyst. Environ.* **2017**, *241*, 121–132. [CrossRef]
5. Englund, O.; Börjesson, P.; Mola-Yudego, B.; Berndes, G.; Dimitriou, I.; Cederberg, C.; Scarla, N. Strategic deployment of riparian buffers and windbreaks in Europe can co-deliver biomass and environmental benefits. *Commun. Earth Environ.* **2021**, *2*, 176. [CrossRef]
6. European Commission. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018L2001 (accessed on 31 October 2022).
7. D'Adamo, I.; Gastaldi, M.; Morone, P.; Rosa, P.; Sassanelli, C.; Settembre-Blundo, D.; Shen, Y. Bioeconomy of Sustainability: Drivers, Opportunities and Policy Implications. *Sustainability* **2022**, *14*, 200. [CrossRef]
8. A European Green Deal. Available online: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en (accessed on 31 October 2022).
9. Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Available online: https://www.ipcc.ch/sr15/ (accessed on 9 November 2022).

10. Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. Available online: https://www.ipcc.ch/srccl/ (accessed on 9 November 2022).
11. EU Biodiversity Strategy for 2030. Available online: https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en (accessed on 31 October 2022).
12. Regulation Rules on Support for Strategic Plans to be Drawn Up by Member States under the Common Agricultural Policy (CAP Strategic Plans) and Financed by the EAGF and by the EAFRD. Available online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52018PC0392 (accessed on 31 October 2022).
13. EU Strategy for the Baltic Sea Region. EUSBSR. 2009. Available online: https://www.balticsea-region-strategy.eu/policy-areas/pa-bioeconomy (accessed on 31 October 2022).
14. National Development Plan of Latvia for 2021–2027. Available online: https://pkc.gov.lv/sites/default/files/inline-files/NAP2027__ENG.pdf (accessed on 31 October 2022).
15. National Energy and Climate Plan 2021–2050. Available online: https://www.climate-laws.org/geographies/latvia/policies/latvia-s-strategy-to-achieve-climate-neutrality-by-2050 (accessed on 31 October 2022).
16. National Energy and Climate Plans. Available online: https://windeurope.org/2030plans/ (accessed on 31 October 2022).
17. Augere-Granier, M.L. Agroforestry in the European Union. European Parliament. Available online: https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/651982/EPRS_BRI(2020)651982_EN.pdf (accessed on 31 October 2022).
18. Raskin, B.; Osborn, S. *The Agroforestry Handbook*; Soil Association Limited: Bristol, UK, 2019; p. 151.
19. European Commission. *Sustainable and Optimal Use of Biomass for Energy in the EU beyond 2020*; Annexes of the Final Report; Ec Directorat General for Energy Directorat C1-Renewables and CCS Policy; European Commission: Brussels, Luxembourg, 2017; p. 404.
20. Rytter, L.; Andreassen, K.; Bergh, J.; Eko, P.-M.; Kilpelainen, A.; Lazdina, D.; Muiste, P.; Nord-Larsen, T. Land areas and biomass production for current and future use in the Nordic and Baltic countries. *Sustainable Energy Systems 2050 Research Programme from Nordic Energy Res.* **2014**, *50*, 5. Available online: https://www.nordicenergy.org/wp-content/uploads/2015/02/Land-areas-and-biomass-production-for-current-and-future-use-in-the-Nordic-and-Baltic-countries.pdf (accessed on 31 October 2022).
21. d'Arge, R.C. The energy squeeze and agricultural growth. In *Economics, Ethics, Ecology: Roots of Productive Conservation*; Jeske, W.E., Ed.; Soil Conservation Society of America: Rougemont, NC, USA, 1981; pp. 99–105.
22. Peterjohn, W.T.; Correll, D.L. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. *Ecology* **1984**, *65*, 1466–1475. [CrossRef]
23. Mayer, P.M.; Reynolds, S.K.; McCutchen, M.D.; Canfield, T.J. Meta-analysis of nitrogen removal in riparian buffers. *J. Environ. Qual.* **2007**, *36*, 1172–1180. [CrossRef]
24. Bardule, A.; Lazdins, A. Carbon and nitrogen fixation in mineral soils in grey alder (*Alnus incana* (L.) Moench) stands in forested agricultural land. *Mežzinātne* **2021**, *21*, 95–109, (In Latvian with English Abstract).
25. Dorioz, J.M.; Wang, D.; Poulenard, J.; Trevisan, D. The effect of grass buffer strips on phosphorus dynamics e a critical review and synthesis as a basis for application in agricultural landscapes in France 2006. *Agr. Ecosyst. Environ.* **2006**, *117*, 4–21. [CrossRef]
26. Hoffmann, C.C.; Kjaergaard, C.; Uusi-Kamppa, J.; Hansen, H.C.B.; Kronvang, B. Phosphorus retention in riparian buffers: Review of their efficiency. *J. Environ. Qual.* **2009**, *38*, 1942–1955. [CrossRef] [PubMed]
27. Liu, X.; Zhang, X.; Zhang, M. Major factors influencing the efficacy of vegetated buffers on sediment trapping: A review and analysis. *J. Environ. Qual.* **2009**, *37*, 1667–1674. [CrossRef]
28. Jørgensen, U.; Dalgaarda, T.; Kristensen, E.S. Biomass energy in organic farming—The potential role of short rotation coppice. *Biomass Bioenergy* **2005**, *28*, 237–248. [CrossRef]
29. Dalgaard, T.; Olesen, J.E.; Petersen, S.O.; Petersen, B.M.; Jørgensen, U.; Kristensen, T.; Hutchings, N.J.; Gyldenkaerne, S.; Hermansen, J.E. Developments in greenhouse gas emissions and net energy use in Danish agriculture—How to achieve substantial CO_2 reductions. *Environ. Pollut.* **2011**, *159*, 3193–3203. [CrossRef]
30. Rytter, L.; Ingerslev, M.; Kilpeläinen, A.; Torssonen, P.; Lazdina, D.; Löf, M.; Madsen, P.; Muiste, P.; Stener, L.-G. Increased forest biomass production in the Nordic and Baltic countries—A review on current and future opportunities. *Silva Fenn.* **2016**, *50*, 1660. Available online: https://www.nordicenergy.org/wordpress/wp-content/uploads/2015/02/Land-areas-and-biomass-production-for-current-and-future-use-in-the-Nordic-and-Baltic-countries.pdf (accessed on 31 October 2022). [CrossRef]
31. Makovskis, K. Fast-Growing Woody Crop Evaluation for Biomass Production on Unused Agricultural Lands in Latvia. Doctoral Thesis, Latvia University of Life Sciences and Technologies, Jelgava, Latvia, 2021.
32. Berndes, G. Bioenergy and water—The implications of large-scale bioenergy production for water use and supply. *Glob. Environ. Chang.* **2002**, *12*, 253–271. [CrossRef]
33. Melniks, R.; Sietina, I.; Lazdins, A. Methodology for assessment of area and properties of farmlands sutable for establishment of shelter belts. In Proceedings of the Enggineering for Rural Development, Jelgava, Latvia, 25–27 May 2022; pp. 812–817. [CrossRef]
34. Conley, D.J.; Carstensen, J.; Ærtenbjerg, G.; Christensen, P.B.; Dalsgaard, T.; Hansen , J.L.S.; Josefson, A.B. Long-term changes and impacts of hypoxia in Danish coastal waters. *Ecol. Appl.* **2007**, *17*, 165–184.
35. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy. Available online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32000L0060 (accessed on 9 November 2022).

36. Development of a Model for Calculating the Reference Level of Carbon Dioxide (CO2) Sequestration and Greenhouse gas (GHG) Emissions Caused by Latvian Forest Management. Available online: https://www.lvm.lv/images/lvm/Petijumi_un_publikacijas/Petijumi/atsk_SEGreference_2012.pdf (accessed on 9 November 2022).
37. Liepins, J. Latvijas Kokaudžu Biomasas un Oglekļa Uzkrājuma Novērtēšanas Metodes [Forest Stand Biomass and Carbon Stock Estimates in Latvia]. *Latv. Veg.* **2020**, *30*, 1–114. (In Latvian with English Summary)
38. Latvia's Sustainable Development Strategy until 2030. 2010. Available online: https://pkc.gov.lv/sites/default/files/inline-files/LIAS_2030_en_0.pdf (accessed on 31 October 2022).
39. Law on Agriculture and Rural Development. 2004. Available online: https://likumi.lv/ta/id/87480-lauksaimniecibas-un-lauku-attistibas-likums (accessed on 31 October 2022).
40. Klavs, G. Use of Renewable Energy Resources in Regions of Latvia and Assesment of Environmental Economic and Social Benefits at the National and Regional Level (Atjaunojami enerģijas resursu izmantošana Latvijas reģionos un vides ekonomisko un sociālo ieguvumu novērtējums nacionālajā un reģionālajā līmenī). Final Review. Project No. 1-08/64/2006, Contract No. 89. Institute of Physical Energy. Available online: https://lvafa.vraa.gov.lv/faili/materiali/petijumi/2006/1_08_64_FEI_lvaf_2006.pdf (accessed on 31 October 2022).
41. Mola-Yudego, B. Regional potential yields of short rotation willow plantations on agricultural land in Northern Europe. *Silva Fenn.* **2010**, *44*, 63–76. [CrossRef]
42. Ferm, A. Birch production and utilization for energy. *Biomass Bioenergy* **1993**, *4*, 391–404. [CrossRef]
43. Dimitriou, I.; Rutz, D. *Sustainable Short Rotation Coppice Plantations. Reference Guidebook*; Lazdina, D., Ed.; WIP Renewable Energies: Munich, Germany, 2015; 108p.
44. Lazdina, D.; Lazdins, A. *Short-Rotation Willow Plantations and Their Use Opportunities*; LSFRI "Silava": Salaspils, Latvia, 2011; 36p.
45. Johansson, T. Stem volume equations and basic density for grey alder and common alder in Sweden. *Forestry* **2005**, *78*, 249–262. [CrossRef]
46. Daugavietis, M.; Daugaviete, M.; Bisenieks, J. The management of Grey alder (*Alnus incana* Moench.) stands in Latvia. In Proceedings of the 8th International Scientific Conference "Engineering for Rural Development", Jelgava, Latvia, 28–29 May 2009; pp. 229–234.
47. Bardulis, A.; Daugaviete, M.; Bardule, A.; Lazdins, A. The biomass production in above and under-ground grey alder (*Alnus incana* (L.) Moench) young stands. In Proceedings of the Solutions on Harmonising Sustainability and Nature Protection with Socio-Economic Stability, 3rd International Scientific Conference of the Vidzeme University of Applied Science and Nature Conservation Agency, North Vidzeme Biosphere Reserve, Valmiera, Latvia, 19–20 August 2010; pp. 17–18.
48. Bisenieks, J.; Daugavietis, M.; Daugaviete, M. Productivity models of grey alder stands. *Mežzinātne* **2010**, *21*, 31–44. (In Latvian with English Abstract)
49. Daugaviete, M. Above-ground biomass in young Grey alder (*Alnus incana* (L.) Moench.) stands. *Bal. For.* **2011**, *17*, 76–82.
50. Daugaviete, M.; Bambe, B.; Lazdins, A.; Lazdina, D. *Plantāciju Mežu Augšanas Gaita, Produktivitāte un Ietekme Uz Vidi [Plantation Forest Growth, Productivity and Environmental Impact]*; LSFRI "Silava": Salaspils, Latvia, 2017; 470p. (In Latvian with English summary)
51. Telenius, B.F. Stand growth of deciduous pioneer tree species on fertile agricultural land in southern Sweden. *Biomass Bioenergy* **1999**, *16*, 13–23. [CrossRef]
52. Proe, M.F.; Griffiths, J.H.; Craig, J. Effects of spacing, species and coppicing on leaf area, light interception and photosynthesis in short rotation forestry. *Biomass Bioenergy* **2002**, *23*, 315–326. [CrossRef]
53. Senhofa, S.; Zeps, M.; Matisons, R.; Smilga, J.; Lazdina, D.; Jansons, A. Effect of climatic factors on tree ring width of *Populus* hybrids in Latvia. *Silva Fenn.* **2016**, *50*, 1442. [CrossRef]
54. Senhofa, S.; Neimane, U.; Grava, A.; Sisenis, L.; Lazdina, D.; Jansons, A. Juvenile growth and frost damages of poplar clone OP42 in Latvia. *Agron. Res.* **2017**, *15*, 2113–2125.
55. Senhofa, S.; Zeps, M.; Ķēniņa, L.; Neimane, U.; Kāpostiņš, R.; Kārkliņa, A.; Jansons, A. Intra-annual height growth of hybrid poplars in Latvia: Results from the year of establishment. *Agron. Res.* **2018**, *16*, 254–262.
56. Senhofa, S.; Lazdina, D.; Jansons, A. *Papeļu (Populus spp.) Stādījumu Ierīkošana un Apsaimniekošana [Establishment and Management of Poplar (Populus spp.) Plantations]*; LSFRI "Silava": Salaspils, Latvia, 2019; 82p. (In Latvian with English summary)
57. Tullus, A.; Rytter, L.; Weih, M.; Tullus, H. Short-rotation forestry with hybrid aspen (Populus tremula L. × *P. tremuloides* Michx.) in Northern Europe. *Scand. J. For. Res.* **2012**, *27*, 10–29. [CrossRef]
58. Uri, V.; Vares, A. The above-ground biomass and production of alders (*Alnus incana* (L.) Moench., *Anus glutinosa* (L.) Gaertn., *Alnus hybrida* A.Br.) on abandoned agricultural lands in Estonia. In Proceedings of the Workshop "Management and Utilization of Broadleaved Tree species in Nordic and Baltic countries—Birch, Aspen And Alder", Vantaa, Finland, 16–18 May 2005.
59. EURDF Project No. 1.1.1.2/VIAA/3/19/437. Economic and Environmental Assessment of Biomass Production in Buffer Zones Around Drainage Systems and Territories Surrounding the Protective Belts of Natural Water Streams. Available online: http://www.silava.lv/23/section.aspx/View/261 (accessed on 31 October 2022).
60. Lazdins, A.; Kaposts, V.; Karins, Z.; Lazdina, D.; Strazdins, U.; Larsson, S. *Willow Plantation Installation and Management Guide*; LSFRI "Silava": Salaspils, Latvia, 2005; 74p.
61. Lazdina, D.; Senhofa, S.; Zeps, M.; Makovskis, K.; Bebre, I.; Jansons, A. The early growth and fall frost damage of poplar clones in Latvia. *Agron. Res.* **2016**, *14*, 109–122.

62. Zeps, M.; Auzenbaha, D.; Gailis, A.; Treimanis, A.; Grinfelds, U. Evaluation and selection of hybrid aspen (*Populus tremuloides* × *Populus tremula*) clones. *Mežzinātne* **2008**, *18*, 19–34.
63. Zeps, M.; Jansons, A.; Smilga, J.; Purina, L. Growth intensity and height increment in a young hybrid aspen stand in Latvia. In *Proceedings of the 8th WSEAS International Conference "Recent Researches in Environment, Energy Systems and Sustainability", Faro, Portugal, 2–4 May 2012*; Ramos, R.A.R., Straupe, I., Panagopoulos, T., Eds.; WSEAS Press: Attica, Greece, 2012; pp. 120–124.
64. Zeps, M. Potential of hybrid aspen (*Populus tremuloides* Michx. × *Populus tremula* L.) production in Latvia. Doctoral Thesis, Latvia University of Life Sciences and Technologies, Jelgava, Latvia, 2017.
65. Terauds, V. *Meadows and Pastures, (Pļavas un ganības)*; Zvaigzne: Riga, Latvia, 1972; pp. 57–64.
66. Lazdina, D.; Rancane, S.; Makovskis, K.; Sarkanabols, T.; Dumins, K. Hybrid aspen and perennial grass agroforestry system interactions. In Proceedings of the 4th European Agroforestry Conference "Agroforestry as Sustainable Land Use", Nijmegen, The Netherlands, 28–30 May 2018; Nijmegen, Agroforestry Federation and University of Santiago de Compostela: Lugo, Spain, 2018; pp. 523–527.
67. Jansone, B.; Rancane, S.; Dzenis, V.; Jansons, A. Guide to Perennial Grass Seed Production. *Skriveri* **2008**, *265*, 70.
68. Rancane, S.; Makovskis, K.; Lazdina, D.; Daugaviete, M.; Gutmane, I.; Berzins, P. Analysis of economical, social and environmental aspects of agroforestry systems of trees and perennial herbaceous plants. *Agron. Res.* **2014**, *12*, 589–602.
69. Karklins, A.; Lipenite, I.; Daugaviete, M. Carbon stock and forest productivity planted on agricultural land. In Proceedings of the Abstracts of International Conference "Humus forms and biologically active compounds as indicators of pedodiversity", Tartu, Estonia, 27–28 August 2012; p. 15.
70. Callessen, I.; Grohneheit, P.E.; Ostergard, H. Optimization of bioenergy yield from cultivated land in Denmark. *Biomass Bioenergy* **2010**, *34*, 1348–1362. [CrossRef]
71. Sollen-Norrlin, M.; Ghaey, B.B.; Riontoul, N.L.J. Agroforestry Benefits and Challenges for Adoption in Europe and Beyond. *Sustainability* **2020**, *12*, 7001. [CrossRef]
72. Zhang, X.; Liu, X.; Zhang, M.; Dahlgren, R.A.; Eitzel, M. A review of vegetated buffers and a meta-analysis of their mitigation efficacy in reducing nonpoint source pollution. *J. Environ. Qual.* **2010**, *39*, 76–84. [CrossRef]
73. Aosaar, J.; Varik, M.; Uri, V. Biomass production potential of grey alder (*Alnus incana* (L.) Moench.) in Scandinavia and Eastern Europe: A review. *Biomass Bioenergy* **2012**, *45*, 1–26. [CrossRef]
74. Miezite, O. The Productivity and Structure of Grey Alder. Doctoral Thesis, Latvia University of Life Sciences and Technologies, Jelgava, Latvia, 2008.
75. Bardulis, A.; Daugaviete, M.; Lazdins, A.; Bardule, A.; Liepa, I. Biomass structure and carbon accumulation in surface and root biomass in young alder *Alnus incana* (L.) Moench stands in agricultural land. *Mežzinātne* **2011**, *23*, 71–88.
76. Daugaviete, M.; Bardulis, A.; Lazdina, D.; Daugavietis, U.; Bardule, A. Potential of producing wood biomass in short rotation Grey alder (*Alnus incana* (L.) Moench.) plantations on agricultural lands. In Proceedings of the 25th NJF Congress, Riga, Latvia, 16–18 June 2015; pp. 394–399.
77. Lazdiņa, D.; Daugaviete, M.; Rancāne, S.; Daugavietis, U.; Bārdulis, A. *Alnus incana* L. growth rates—In a perennial tree plantation—In a short-rotation coppice shrub. In Proceedings of the Scientific-Practical Conference "Balanced Agriculture", Jelgava, Latvia, 21 February 2019; pp. 143–147.
78. Comparison of Average Prices of Technical Services in Latvia in 2021 and 2020. Available online: http://new.llkc.lv/sites/default/files/baskik_p/pielikumi/1.tabula_6pdf (accessed on 31 October 2022).
79. Ministry of Finances: The rise in consumer prices continues to be driven by external factors (FM: Patēriņa cenu pieaugumu turpina ietekmēt ārējie faktori). Available online: https://www.fm.gov.lv/lv/jaunums/fm-paterina-cenu-pieaugumu-turpina-ietekmet-arejie-faktori (accessed on 31 October 2022).