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Availability and Applicability of Wood and Crop Residues for the Production of Wood Composites

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Abstract: Due to high levels of volatility in both the agricultural and the forestry commodity markets, specifically, of timber and agricultural crops, it is important to identify the risks associated with the stability of supplies necessary for the production of composite materials in the Czech Republic. This study aims to accurately estimate the availability of selected raw materials that contain lignocellulose over the next 20 years. In addition, their suitability for the production of composite materials is assessed based on their physical properties. Furthermore, in the event of scarcity involving timber in the European Union, recycled wood and post-harvest residues could replace conventional raw materials in wood-based composites such as particleboards and chipboards. The viable potential of Czech forests is predicted to be between 740 and 750 million cubic meters of timber. For agricultural crops, it is estimated at 0.9 million hectares of wheat and 0.5 million hectares of canola under the current EU biofuel policy and at 0.4 million hectares if this policy is removed. According to moisture and fibre analyses carried out in our study, the most suitable candidate for wood-based composites production is soft wood.

Keywords: biomass; forest; crop residues; wood-based composites; hardwood; softwood

1. Introduction

Biomass represents an alternative energy source and also creates the possibility of reducing greenhouse gas (GHG) emissions, net carbon emissions and harmful environmental pollution caused by high fossil fuel consumption [1,2]. Biomass is among the biggest energy sources in the world and, when considering electricity production from biomass, it is the third largest renewable electricity source globally [3]. It provides approximately 14% of the world's total annual energy supply, equivalent to 1.25 billion tonnes of oil (Btoe). Coal, oil and fossil fuels are still the most prevalent fuels, but unlike biomass, they are considered an environmentally unfriendly and non-renewable energy source [4–6]. The use of biomass has increased greatly and has also been found to reduce the dependence on fossil fuels for alternative energy production [7–9]. Another aspect of biomass use is its important role in the reduction of other environmental problems [10–12].

There is a significant increase of interest in the processing of residues (especially those from agriculture and industry) into value-added products, fuels and energy, mainly using the biorefinery concept [13]. This method of processing waste products is one of the key elements of the so-called circular economy. It uses waste from agriculture and industry and transforms it into other useful products, instead of sending it to landfill or incineration. Waste biomass is mainly used in energy production as a source of hydrocarbons [14,15]. In this article, the approach to waste biomass is different and more sophisticated. The article deals with two starting materials: (i) wood, which is expected to have high price volatility and therefore should be considered by producers for alternative uses and (ii) straw, for which it is necessary to find a compromise between its use and its incorporation into the soil (burning, ploughing and similar) to maintain nutrients in the system [16–19]. It is noteworthy to mention that recycled wood and post-harvest residues could replace conventional raw materials in the forthcoming future, as there is clear evidence that in the future there will be a lack of wood materials, especially in the woodworking, energy and other sectors [20–22]. In addition, it is worth mentioning post-consumer wood waste, e.g., post-consumer wood fibreboard waste [23]. Currently, there is no commercially viable way for recycling such a waste, and therefore post-consumer fibre waste is growing rapidly [24,25]. In addition, as wood recycling is common in the majority of countries [23,26], recovered wood is being used only for relatively low-value-added products [25,27]. However, there those products have clearly a high potential from both commercial and environmental perspectives [26].

Moisture content, temperature and type of matrix are important factors that affect the quality of a prepared composition of wood fibres and post-harvest residues. In addition, the distribution of resins between the fibres and the quality of the extracted fibre affects the interfacial adhesion of a composition [28].

The origin of biomass may vary depending on its source. Two main sources of waste biomass can be identified in the Czech Republic: agriculture produces waste biomass which is, in most cases, created during the technological processing of agricultural crops [29]; forestry biomass comes primarily from unused and/or unprocessed parts of wood. In the next two sections, these two sources are described.

Wood and crop residues are readily available and can be used to valorise energy production and would otherwise lead to environmental pollution and health problems. The LCA provides praise for evaluating the ecological, social and economic sustainability of energy production from crop residues. Considering that energy can be generated from wood and agricultural residues through several methods, one has to choose the LCA test for sustainable energy production for the type and path that work best with the available raw material and the geographical conditions. The LCA approach throughout the value chain tends to the valorisation of crop residues as a policy support tool for policymakers and end users.

Forest biomass has the potential to substitute fossil fuels in the production of bioenergy and bioproducts. Many decisions have to be made when designing and planning the supply chain of forest biomass for the production of bioenergy and bioproducts. The decision-making process requires integral evaluation and consideration of a variety of sustainability factors in order to ensure real benefits to the society and the economy, in a way that is less harmful to the environment. Several studies measured and optimized the economic, social and environmental performances of forest biomass supply chains, such as that of Cambero and Sowlati [30].

Czech forests are primarily utilized for commercial purposes. Certain forest areas are protected by the Czech law, and their economic utilisation is not the primary objective. Forests provide food, raw materials and alternative fuel. The most common product derived from forests is timber, which has a plethora of applications. Some of these applications include construction and fuel (heating and cooking) [31,32]. Wood can be used as an alternative bioenergy resource to replace fossil fuels (e.g., coal, oil and gas); however, it is important to state that the climate benefits of using wood as a fuel source are controversial (see, e.g., [33]). Forest biomass has additional environmental benefits in its ability to store carbon. Wood can also be used to produce construction materials such as particleboards [34]. It is also suitable for the replacement of primary products such as steel and concrete, which require excessive amounts of energy to be produced [35], such as particleboards-based structures. Nevertheless, forest materials are still highly underutilised, despite the social, economic and environmental benefits of using forest biomass. Forest biomass production also depends on the type of forest, the size and design of the storage facilities of the available material, regional and local logging and location practices [36]. The other possible source of waste biomass that can be used for energy production and construction material production is crop residues. A large amount of biomass waste is produced when cereals are harvested [37]. Briquetting technology is one of the uses of post-harvest material processing, which could be a suitable solution for improving material properties [38]. Straw is usually used to produce solid biofuels [39]. Post-harvest residues can also be used in industrial applications (e.g., production of construction materials such as particleboards) [40]. Similarly, they can be utilized for other uses in the construction sector (e.g., thatched roof) [41]. Finally, new opportunities for other innovative building materials have been explored and developed in recent years [42]). Due to biophysical limitations, there is a ceiling on the amount of forest biomass and harvest residues that can be reaped annually [43]. Theoretically, an optimal regulation with respect to limitations resulting from certain abiotic factors such as temperature, soil type, sunlight and rain is associated with the theoretical potential of maximum productivity.

Any lignocellulos material, whether for structural or for non-structural purposes, receives moisture from the environment in the form of water vapor [44], depending on the humidity of the material and the temperature and relative humidity of the surrounding air [44,45]. The application of higher atmospheric moisture to lignocellulose materials usually reduces their strength properties [46] and permanent thickness swelling [47]. Furthermore, their appearance is also often changed [48], and in extreme cases, the integrity of the boards can be compromised by moisture [49,50]. In the case of chipboards, the type and amount of adhesive and hydrophobic substances used, the production technology, the size and orientation of the chips, the degree of compression and the surface quality have a decisive influence on the sorption properties. The denser the surface layers, the slower the passage of moisture into the material [51]. These properties were measured using the methodological apparatus described below.

This study aimed to accurately estimate the availability of selected raw materials containing lignocellulose over the next 20 years for use as a lignocellulose input into final products such as wood chips and particleboard. In addition, the suitability for production of composite materials was assessed based on their physical properties, especially because in the event of a scarcity involving timber in the European Union, recycled wood and post-harvest residues could replace conventional raw materials in the wood-based composites sector.

2. Materials and Methods

2.1. Physical Properties

Some of the most important factors determined by the authors are fibre length, fibre width and equilibrium moisture. Analyses of these properties for wood-based material, wheat and canola were conducted. Although these are physiologically very different plants, when their tissues disintegrate into individual fibres, the fibres of these plants are very similar and have similar properties. All experiments were performed using a homogeneous batch of ground softwood residues from Norway spruce (*Picea abies*), hardwood pine (*Pinus radiata*), European beech (*Fagus sylvatica*) and Summer oak (*Quercus robur*) and post-harvest residues from wheat and rapeseed harvested in the Czech Republic.

The ground material was sieved through 100 mesh (0.150 mm was allowed to equilibrate with the room environment). With the moisture content being 7% of the total weight, the parameters of width, thickness, length, density (kg/m^3), moisture (%), bending strength (N/mm^2) and swelling were determined after 2 h (%). Wood shavings were of different size and thickness (from 0.1 to 1.0 mm) and showed different swelling. They were usable for particleboard production; however, they had to be reduced to finer particles. Sawdust that originated from round timber sawing and wood machining was also different depending on the kind of wood, method of sawing (frame saws, band saws and others), cutting speed, feed, etc. Especially, if used for surface layers of three- and more-layer particleboards, the sawdust has to be transformed by milling to a finer fraction, so that the boards will have smooth surface suitable for subsequent surface treatment (particularly, lamination and foliation) [45].

2.2. Fibre Length and Width

All biological material (wood and post-harvest residues) was cut into tangential fibres to measure the fibre length and width of axial parenchymal cells, and 100 serial cross-sections of 20 µm thickness were prepared from the extracted wooden block. Each of the 50 wood fibres was marked from the reference section toward their tips by serial cross sections, and the total fibre length and width were obtained by multiplying the cross-section thickness (20 µm) by the number of cross sections in which the concentrated lignocellulose fibres appeared (serial cross section method). The lignocellulose block remaining after the preparation of the serial section was macerated with Franklin's solution, and the lengths of 50 macerated lignocellulose fibres were measured using a projector (maceration method). The lengths of the 50 axial fibres of the parenchyma were individually measured in micrometres on a tangential section using according to [52].

2.3. Moisture

Accelerated exposure to moisture of the wood-based material was performed according to ASTM standards [53], but we excluded the step of vapor exposure. The fibre experiments were performed after a selected number of cycles, each consisting of vacuum, pressure, soaking and drying. All mechanical tests were performed on samples after drying and re-equilibration in a conditioning room (maintained at 21 °C and 65% RH) to standard humidity conditions (about 12% moisture content) [54,55].

Rapeseed and wheat stalks without root leaves were collected after harvesting seeds from the experimental field. The stems were air-dried and stored in a dry place. For pulping, the stems were hand-cut into pieces approximately 3–5 cm in length [56]. The moisture content was determined according to TAPPI (Technical Association of the Pulp and Paper Industry) standards (T258 om-06: Basic Density and Moisture Content of Pulpwood) after drying at 105 $\pm$ 3 °C.

This gravimetric method is amongst the most widely used and oldest methods to determine wood moisture content. It necessitates the extraction of specimen from the timber element. These are weighed before kiln-drying them at a temperature of 103 °C $\pm$ 2 K until constant mass is achieved. The moisture content u is determined from the ratio between the mass of water in the moist specimen (m u $-$ m dr) and the mass of the kiln-dried specimen (m dr). The method is standardized. The kiln-dry method delivers very exact results which are, e.g., used to calibrate measurement equipment. However, it is a destructive method, since it necessitates the extraction of specimens, and its application is rather time-consuming. The method of extraction must be chosen carefully according to the local situation. The drilling process during core extraction may lead to vapour evaporation due to temperature increase, leading to a potential corruption of subsequently determined wood moisture content. Investigations on the moisture gradient in timber elements are possible but difficult, since this necessitates the extraction and segmentation of the specimen without influencing the moisture content. Since this method is not suitable for in situ measurements, it is not applicable for monitoring concepts [57].

2.4. Time Series Analysis

The majority of analyses in the presented article address the prediction of the availability of lignocellulosic raw materials necessary for the production of composite materials. Future volumes of wood, oilseed, canola and wheat stalks are modelled using the methodology presented below.

2.5. Unit Root Test

Augmented Dickey–Fuller's Extended Test (or ADF) is a commonly used root-root test. By adapting the (autoregressive) model to AR (k), this test examines the null hypothesis (autoregressive integrated moving average) of the ARIMA process (p, I, 0) versus the stationary ARIMA alternative (p + I, 0, 0). Dickey and Fuller [58] derived the critical values from the limiting ADF test distribution when p k-l. Critical values were tabulated by Dickey and Fuller [59] for specific sample sizes. In the case of k l, the ADF test has the same limited distribution as when k = l, provided that the condition p k-I holds. Although this is an asymptotic result, the critical values compiled by Dickey and Fuller [59] in the final samples were often used for tests with arbitrary values.

2.6. Autoregressive Integrated Moving Average (ARIMA) Model

The model ARIMA (*p*, *d*, *q*) is mathematically expressed as:

$$\begin{gathered}(1-\varphi_1 B-\ldots-\varphi_p B^p)(1-\Phi_1 B^s-\ldots-\Phi_P B^{sP})(1-B)^d(1-B^s)^D Y_t = \\ (1-\theta_1 B-\ldots-\theta_q B^q)(1-\Theta_1 B^s-\ldots-\Theta_P B^{sQ})\varepsilon_t\end{gathered} \tag{1}$$

where the parameters are:

$$\varphi_1, \varphi_2, \ldots \varphi_p, \Phi_1, \Phi_2, \ldots \Phi_P,\ \theta_1, \theta_2 \ldots, \theta_q, \Theta_1, \Theta_2, \ldots, \Theta_Q, \sigma \tag{2}$$

and must be estimated (σ is the standard deviation of the errors ε_t).

The general model introduced by Box and Jenkins [60] includes autoregressive parameters as well as moving average parameters and explicitly includes differences in the formulation of the model. The three types of parameters in the model are the autoregressive parameters (*p*), the number of differencing passes (*d*) and moving average parameters (*q*).

In this paper, a Box–Jenkins approach was utilised. The model was first identified, and then the initial values for the orders of p, d, q were selected. This was done through the utilisation of ACF, PACF and the Augmented Dickey–Fuller test. Secondly, the model was estimated. The parameters were then entered into the ARIMA model. Lastly, a diagnostic review was completed to adjust the model to best fit the data. Upon completion of the above tests, by using the model parameters, a prediction could be made for the next 20 years.

3. Results and Discussion

According to the CZSO [61], the cultivation of crops in the Czech Republic is currently characterized by a narrow composition of field crops, where small-grained crops, such as wheat and canola, are predominant. Wheat accounts for the largest share of cereal areas.

Figure 1 shows the areas of wheat and of canola crop planted in the Czech Republic between 1940 and 2019. Concerning wheat, after the massive increase in the area planted between 1960 and 1980, a stabilization can be observed around the level of 0.8 million hectares between 1980 and 2019. This was partially due to a relative stable price in the global markets in this period (besides spikes in 2008 and 2010) and also to the relatively stable demand in the Czech Republic [62].

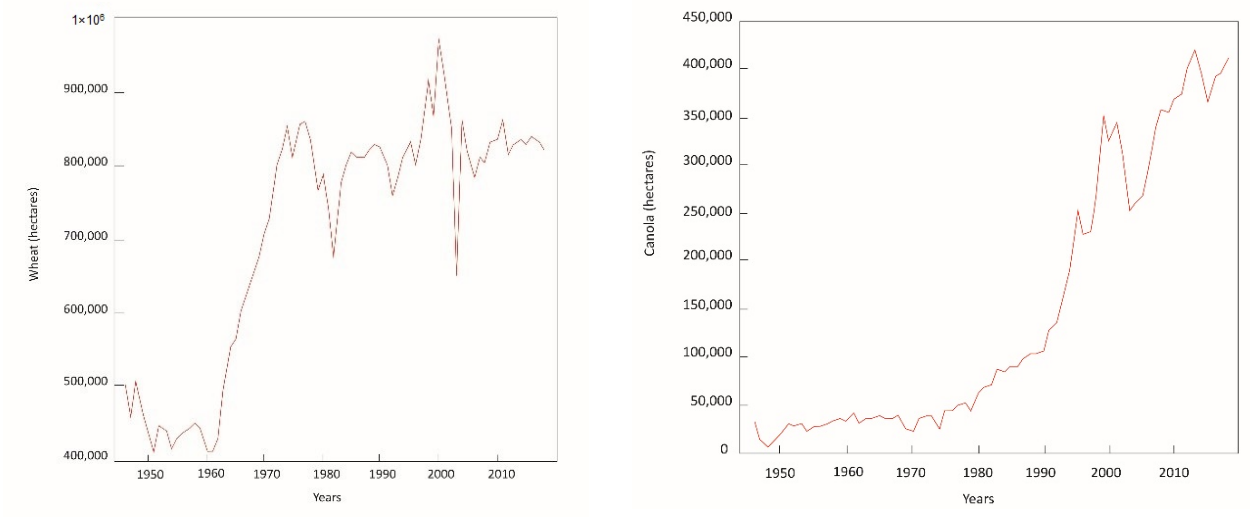

Figure 1. Development of wheat and canola sowing areas in the Czech Republic.

The variable that represents the wheat sowing area was tested for the existence of the unit root using the Augmented Dickey–Fuller test. Results of the test determined the order of differentiation for the appropriate ARIMA model. The unit root test demonstrated that we cannot reject the null hypothesis of unit root existence. Therefore, we defined the order of differencing equal to one. This means that the time series became stationary after taking the first difference. Next, ACF and PACF needed to be graphed so that proper orders for the ARIMA model could be completed. Both correlograms showed decay after the first lag, which implies that both orders were equal to one. Hence, ARIMA (1, 1, 1) was set; the estimation of future values is presented in Figure 2.

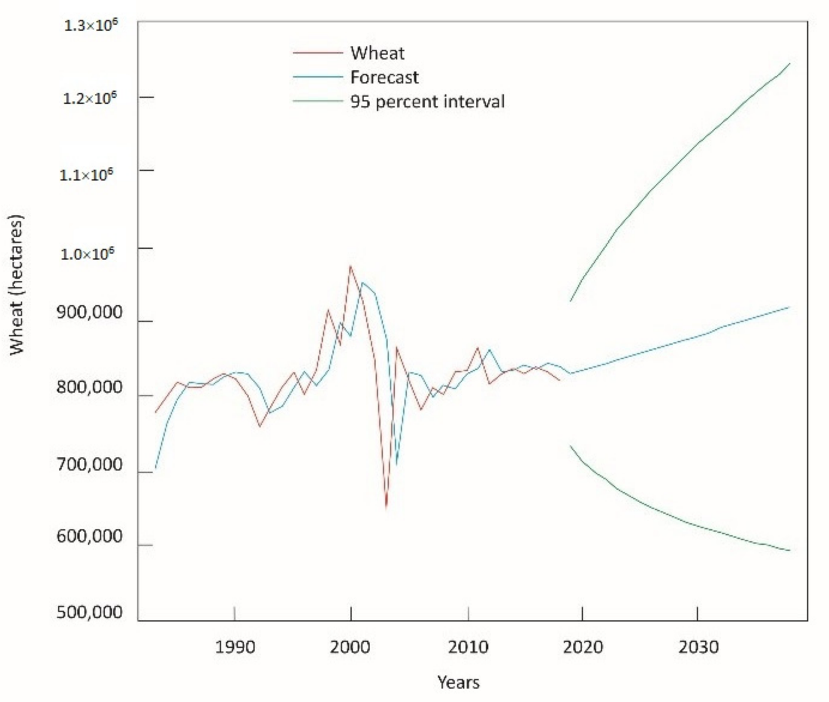

Figure 2. Prediction of the development of wheat-sowing areas in the Czech Republic.

Figure 2 demonstrates that in terms of quantity available, wheat shows a promising, albeit gradually, increasing trend to the level of approximately 900,000 hectares. No similar study has been carried out for the Czech Republic. Researchers used the ARIMA model to predict wheat area extension in Pakistan [63]. The confidence interval also showed a certain uncertainty in the prediction that goes further apart into the future. This is a common property of ARIMA models and must be taken into account when appropriate policies are introduced on the government level.

3.1. Development of Sowing Areas of Canola in the Czech Republic

According to Figure 3, canola cultivation in Czech lands was historically relatively rare (for example, it was grown on 298 ha in 1933), and canola was not used except in the production of vegetable oils. The sowing area started to increase only in the 1970s, and a boom can be observed after 1990, as shown in Figure 4 Since the regime change in the Czech Republic in 1989, canola field areas have increased by almost 400% and today encompass approximately 393,000 hectares. Canola cultivation is supported by its subsidised purchase price, which is relatively stable [64]. Since 2004, there has been a clear increase in the sowing areas of canola. The largest increase in sowing areas of maise occurred between 2000 and 2013. Since 2009, when many crops stagnated, while oilseed canola increased by 100.1%, according to the Agrarian Chamber of the Czech Republic, this increase has been primarily caused by the construction of biogas plants [64]. The sharp increase in canola after 2003 could be caused primarily by political changes related to the European shift towards renewable energy. In the last decade, Czech farmers have ranked second highest in the cultivation of canola in Europe [61]. The time series of canola was tested for the existence of the unit root. It wase concluded that the time series had a unit root of order 1. Therefore, the order for differencing could be set equal to 1. Furthermore, the AR and MA terms were determined using correlograms. Using ARIMA (1, 1, 1), the prediction of canola hectarage was determined as shown in Figure 3, where a clear forecast is presented—showing further continuous growth in the upcoming two decades.

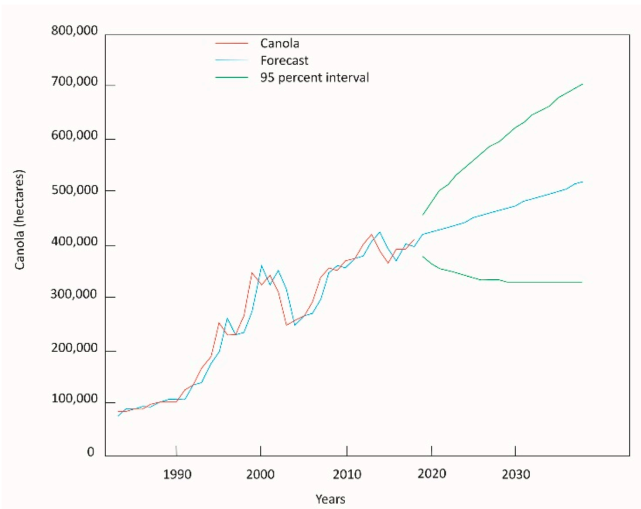

Figure 3. Prediction of canola development in Czech Republic to 2040.

As opposed to Figures 2 and 3, Figure 4 forecasts what happens if the canola subsidy programs end in 2021 and return to the 2003 levels. This was done by employing the ex-ante data and predict the trend without the introduction of the biofuel policy in the 2000s. This is a realistic scenario, as the European Commission has announced the termination of support for the promotion of the first generation of biofuels. In the Czech Republic, up to 50% of canola production is used for energy purposes, and therefore, it is likely that this scenario will materialise [61]. Both predictions were taken into account when calculating future availability.

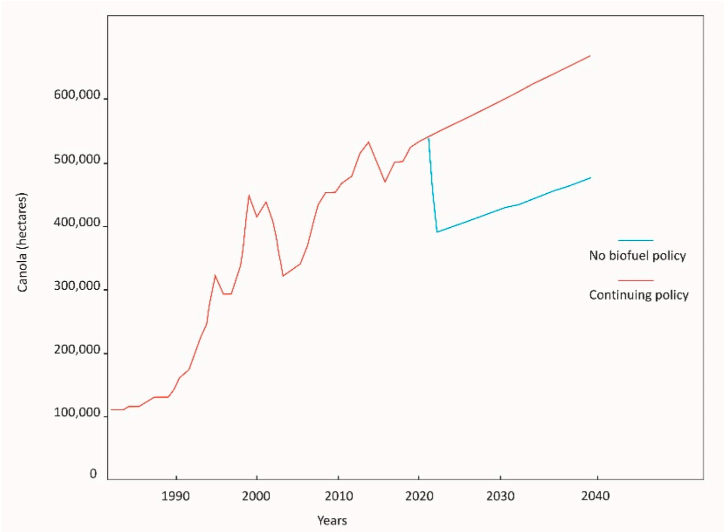

Figure 4. Prediction of canola development in the Czech Republic until 2040.

3.2. Logging Predictions in the Czech Republic

In 2017, 24,446 hectares were forested in the Czech Republic, while natural regeneration represented less than one-fifth of the forest stands. In terms of artificial regeneration, deciduous trees account for 42.3%, and conifers 57.7% of forested areas. The total average increase in 2017 reached 18.0 million cubic meters without bark. It was, therefore, lower than the total production (19.4 million m3 without bark). Czech forests have been affected by numerous natural disasters since 2000. Hurricane Kyrill struck the Czech Republic in 2006, and in the next year there was the bark beetle calamity. In 2017, wood was processed from another bark beetle calamity [61]. Therefore, the Czech Republic is currently experiencing growth in the volume of logging, which has constantly been growing in the last decades. The total volume of both deciduous and coniferous wood mass in millions of tons is presented for the years 2000 to 2019 in Figure 5.

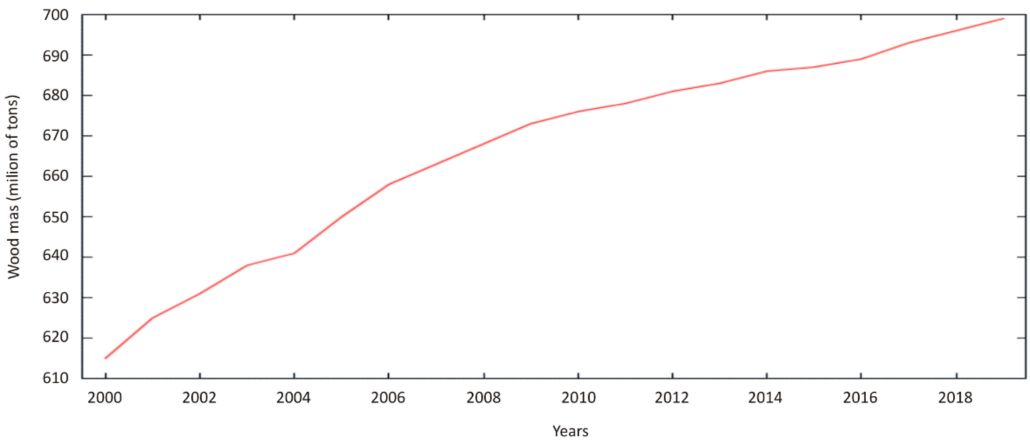

Figure 5. Total volume of both deciduous and coniferous wood mass in millions of tons for the years 2000 to 2019.

The wood mass growth prediction was completed by analysing the time series. First, the time series was examined for the existence of the unit root, and appropriate orders of the ARIMA model were set using correlograms. Consequently, the ARIMA model was set to ARIMA (1, 1, 1) as in the case of the previous crops. Using this model, a forecast of future forest logging growth was determined and is depicted in Figure 6.

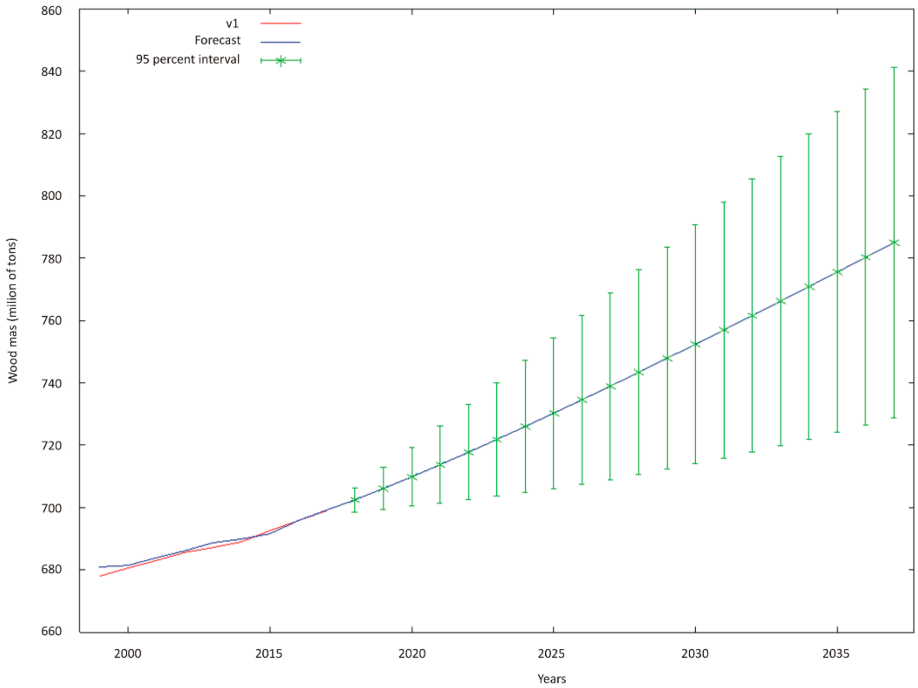

Figure 6. Prediction of total wood biomass to 2040.

The forecast of future resource availability suggests that the viable biomass potential in 2040 could be between 740 and 750 million cubic meters in the Czech Republic. This can be influenced by many factors that are not subject to modelling such as natural catastrophes (bark beetle, hurricanes, etc.).

3.3. Estimation of Residues

Currently, the estimated projections of land and biomass must be converted to residues that can be potentially used for the production of particleboards or chipboards. For wheat, canola and wood, a table was created that illustrates the average yield of post-harvest residues and wood biomass residues that can be utilised in the process of particleboard production. The prediction was calculated based on the data obtained from Table 1.

Table 1. Average yield of post-harvest residues and wood biomass residues that can be utilised in the process of particleboards and/or energy production.

Biomass	Residues Usable for Particleboard Chips and Energy Purposes Yield (t/ha)	Sources
Wheat straw	4.3	[65]
Canola straw	3.6	[66]
Wood residues	50% of 1.75% of total wood mass	[67]

In Table 1, details of the basic material characteristics of wheat straw, canola straw and deciduous and coniferous wood are presented. These characteristics are important for the properties of the resulting composite materials. The data show that in all four cases, after pulping, the obtained natural fibres are very similar, as shown in Table 2.

Table 2 shows the basic morphological characteristics of wheat straw, rapeseed straw, deciduous and coniferous wood.

As it can be seen from Table 2, the length of wheat and rapeseed fibres is similar to that of deciduous trees and, at the same time, is lower than that of conifers. The slenderness coefficient for the said raw materials is acceptable for fibre formation in the production of composite materials, but it is clear that the values for straw and deciduous trees did not reach the values of coniferous wood.

Table 2. Properties of the materials.

Lignocellulosic Raw Material	Fibre Length (mm)	Fibre Width (µm)	Slenderness Ratio	Equilibrium Moisture (%)
wheat straw	0.4−3.2	8−34	75.79	11.8
canola straw	0.7−2	9−20	54.73	12.4
softwood	2−6	20−40	134.45	10−12
hardwood	0.3−2.2	17−42	38.98	
Average *	2.1	23.75	75.99	11.73
Median *	1.575	25.25	65.26	11.8

* The average and median between the observed post-harvest residues and wood.

The combination of soft and hard wood with other plant materials (rapeseed straw, wheat straw and other residues after harvest from renewable sources) creates new functional properties of lignocellulosic composites [68]. The results obtained in the production of particleboards containing rapeseed straw showed that further research into mechanical and technological properties is needed. The same was observed for wheat straw and post-harvest residues, whose use also needs improvement for the production of lignocellulosic boards [69].

It is important to notice that the variability of properties of individual input materials that may cause problems in the production process can be, to a certain extent, mitigated by the employment of relevant technological processes.

The next table (Table 3) illustrates the possible products that can be derived from these materials and their calculated availability in the Czech Republic in 2040. In the table, predictions of available canola, wheat, and wood residues are completed by combining their estimations with their yields based on a literature review.

Table 3. Prediction of material quantities in 2040.

Lignocellulosic Source	Possible Products	Prediction of Residues (Thousands of Tons)
wheat straw	particleboards and fibreboards, insulation boards, possible board production without adhesive	3870
canola straw with no policy change	particleboards, lightweight boards, sandwich boards, construction boards, (but with a high amount of adhesive)	1800
Canola straw with policy change		1368
Softwood residues	particleboards, fibreboards, load-bearing boards, insulation boards	6738
Hardwood residues		

Table 3 demonstrates the slight dominance of wood residues in the Czech Republic. Combined residues from both crops can substitute roughly 85% of wood biomass (logging growth). It is important to notice that, while the quantity available is relatively similar, the economic variables may play an important role. When discussing wood biomass and wood residues, it is also worth mentioning their potential usage for the production of biochar [70], as economically feasible and profitable utilisation of woody residues from the excelsior industry is an on-going challenge. Practical problems are also associated with the possible use of wood biomass or straw. An inherent property of biomass is its low material density. The ratio between bulk density and particle density for different types of straw is between 17 and 18% [14]. By densifying the material, it is, therefore, possible to achieve substantial volume reductions and space-saving during logistics operations and, possibly, purification. Through these processes, we can obtain a material with properties that far exceed those of the starting cellulosic material [14,71]. The resulting product can thus be a nanofibre. Pressure processing has been shown to be an effective method for removing most non-cellulosic materials, producing a treated fibre composed predominantly of cellulose and residual lignin [13,72–78]. Another promising method of processing lignocellulosic material are chemical or biological methods [79–83]. Composite materials made from nanofibres or with an admixture of lignocellulosic biomass can be used in a wide range of applications. Ref. [84] analysed the use of lignocellulose from a cotton straw as an additive to asphalt used for pavement production. The resulting product met the standards for road asphalt. Hýsek et al. [85] analysed the effect of different types of surface treatment of winter wheat husk on the properties of the composite material, as well as on composite materials made from these pre-treated raw materials. In their study [85], they also found that chemical, hydrothermal and plasma pre-treatment erodes the waxy surface of wheat husks, which in turn leads to better adhesion between the husk and the adhesive.

It was further mentioned in the article that the adhesive used has a great influence on the final product. Ang et al. [86] investigated the use of a lignin-based copolymer for composite wood panels. In their analysis, the same result was found, i.e., that the adhesive has a significant effect on the resulting quality, and it is a significant challenge to obtain a natural and economically acceptable product. At the same time, it turns out that adhesives can be problematic in recycling due to their composition, which is not the case with natural materials. The mechanical strength of particleboards depends on the interactions between the surface of the particles and the used binders. Vapor-extractable compounds produced by lignin and hemicellulose degradation with steam are responsible for the self-adhesion capacity of agro-resources during thermocompression of the binderless particleboards. By using a biobased adhesive, the mechanical resistance is improved and allows adapting the formulation to the required behaviours of the final material, such as improvement of the water and fire resistance, while keeping good thermal properties. Bio-based adhesives provide a sustainable solution to improve indoor air quality and to formaldehyde concerns [87]. However, bio-based adhesives suffer from several different issues that hinder their usage industrially, such as availability for tannins, lack of adhesion for starches, poor water resistance for hydroxyl group-enriched materials or viscosity for long-molecule chain polymers. Eco-friendly HDF panels with acceptable physical-mechanical properties and close-to-zero formaldehyde emissions, fulfilling the European standards, can be produced from hardwood fibres bonded with a very low conventional UF resin (3%) and a novel ammonium lignosulfonate at a content of 6% to 10%, depending on the dry fibres [21]. No particleboards could be produced using the ALS without crosslinker, highlighting the need for a crosslinker if the lignosulfonate is used without modification. More work in finding suitable crosslinkers for bio-based materials is needed, but until then, pMDI is a promising crosslinker that works for most bio-based adhesives. This study demonstrated the potential to combine ALS and pMDI in particleboard manufacturing; however, the chemical interaction between the polymers needs to be further elucidated for their optimum usage. Thus, further work in lowering the pMDI amount, optimizing pressing parameters and modifying the lignosulfonate formula should be done as the next step to confirm that the ALS is truly contributing to the final adhesion strength. Another path was taken by Jiang et al. [88], who converted corn straw into dust particles, replacing synthetic polyols in polyurethane foam production to obtain a composite material with better physical properties such as strength and density. On the contrary, the flexural strength decreased. No effect on thermal properties was found.

4. Conclusions

In this paper, a prediction of supply stability of lignocellulosic biomass from agricultural post-harvest residues and wood was made for the Czech Republic, showing, especially, that the cultivation of crops is characterized by a rather narrow composition of field crops, where small-grained crops (as wheat and canola) predominate. This is the first study from this geographical area that provides predictions in a complex way—considering both quantity and quality (from a physical point of view) of the assessed materials. Furthermore, this study also took into account the future removal of the EU biofuel policy (subsidies). Based on our predictions, their dominance will also remain in the upcoming decades. Particularly, we estimated 0.9 million hectares of wheat and 0.5 million hectares of canola under the current EU biofuel policy and 0.4 million hectares without it. These areas were converted into actual amount of material available. Furthermore, based on our predictions, further growth in logging volume can be expected, caused, especially, by the bark beetle, with forecasted total wood biomass availability being around 6800 thousands of tons in 2040, which means that in terms of actual material available, wood biomass is predicted to be more readily available. Finally, according to moisture and fibre properties, the most suitable candidate for wood-based composites production was identified as soft wood. However, it is appropriate to consider further materials to substitute wood, also considering the full social (environmental) costs and benefits.

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