Between Biodiversity Conservation and the Supply for Broadleaved Wood: A Case Study of State Forests National Forest Holding (Poland)

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Abstract: Climate change is an important issue that increasingly affects our lives. One of the proposals for mitigating climate change is fighting biodiversity loss, which can support climate mitigation and adaptation actions. In Poland, the possibility of excluding large tracts of forest areas from use is being considered. The discussed exclusion of forest land from use will affect the timber supply and market, especially for broadleaved wood. The main purpose of this analysis is to present a timber supply forecast, with a particular focus on the possibility of obtaining broadleaved hardwood timber in Poland from forests managed by State Forests National Forest Holding under three scenarios that assume different criteria for selecting forest areas for protection. The work was divided into two main phases: (1) the analysis of historical sales volume of wood products and average sale prices of hardwood during the period 2011–2020; (2) the preparation of a forecast of the potential possibility of maintaining broadleaved hardwood production in the three decades between 2020 and 2049. In the forecast, it was assumed that about 2.7 million hectares of planted and production forests are excluded from use in order to implement the provisions of the 2030 Biodiversity Strategy. In Scenario “1”, the supply of merchantable broadleaved roundwood volume will be reduced to 14%–18% that of Scenario “0”. In Scenario “II”, 55% of the “0” scenario is harvested, and in Scenario “III”, 33%–37% of the “0” scenario merchantable broadleaved roundwood is harvested. The introduction of restrictions on timber harvesting as a result of Poland’s compliance with European Union requirements in the area of environmental protection will lead to a significant reduction in the supply of timber on the market. This may lead to a further increase in timber prices and an increase in the importance of large timber buyers at the expense of local buyers. The recommendations contained in the policy objectives that the EU sets for the states should be supported by a thorough analysis when selecting areas for strict protection.

Keywords: timber production; timber market; protection; forest forecasting; broadleaved; roundwood and pulpwood assortments; wood

1. Introduction

Human activities can influence the rate and magnitude of temperature rise. Key climate threats include the risk of environmental degradation, the loss of biodiversity, and ecosystem services and benefits provided by forests. Climate change affects forest ecosystems in many ways. The exacerbation of natural disasters (fires, floods, heat, and hurricanes) associated with climate change compels us to look for ways to mitigate them. Forest ecosystems, which are simultaneously exposed to the effects of destructive elements, play...
a special role in this task. This has also been recognized by the European Union (EU), which has announced the Biodiversity Strategies [1] and is working on the European Forest Strategy [2], as well as the new European Union Strategy for Adaptation to Climate Change [3].

The above recommendations, which apply to all EU members, provide for an increase in the areas of forest excluded from use. These forests will primarily provide regulatory services by mitigating the effects of climate change and protecting biodiversity resources. The consequence could be a limited amount of available wood raw material on European markets. The new situation will be global (it will not only affect EU countries), as there are strong interconnections between EU national markets and others [4,5].

The implementation of the targets set by the EU member states to slow down climate change will also have an impact on forestry. As a result, there will be changes in forest management, which will be reflected in the amount and structure of wood offered on the timber market. The effects of the reduced timber supply will not only affect the timber industry, whose situation can be alleviated by imports, but also forest owners, who will feel the economic consequences of the restrictions on timber harvesting [6]. The extent of potential restrictions on the use of planted and productive forests will have numerous negative social and economic impacts [7], including an increase in the price of wood products and the loss of many jobs, particularly in businesses associated with wood processing in rural areas [8–12]. The deficit in wood raw materials may be further exacerbated by the commitment to increase the share of energy derived from renewable sources, including forest biomass [13].

The paradigm of multifunctional forestry (MUF) is implemented in Poland. The implementation of the precept of multifunctionality should be understood as management that ensures the sustainability of all forest functions. MUF is implemented on the basis of forest management plans. A forest management plan is a basic forest management document developed for a specific site and contains a description and assessment of the forest condition, as well as objectives, tasks, and methods of forest management. A simplified plan is developed for a forest with an area of at least 10 ha, representing a compact forest complex, and contains a brief description of the forest and the areas intended for afforestation, as well as basic forest management tasks. All forest areas managed by SF NFH have a valid FMP. As forest management on SF NFH is carried out according to the principles of sustainability, sustainable development, and nature conservation, most of the forest areas have international FSC (Forest Stewardship Council) certificates, and all of them have PEFC (Programme for the Endorsement of Forest Certification Schemes) certificates. In Poland, there is no tradition of planting forest trees. Poland has the best forecasts for the fast-growing tree species poplar (especially the variety “Hybrid 275”) and European larch (Larix decidua Mill.), but the areas of these plantations are of little importance.

In Poland, the decline in the supply of timber from broadleaved tree species, which have exceptional technical properties (often not replaceable by softwoods) that determine their use, may prove particularly acute. At the same time, the resources of timber from broadleaved tree species are smaller, and the age of technical maturity is higher than for conifers. Moreover, given the changing demand, there is no possibility of a rapid change in the structure of wood supply [14–16] since it is shaped by “no forest” factors (e.g., the trend for wood of certain species or technological changes in the wood industry), which makes the analysis of changes in the wood commodity market, changes in the technology of logging, and the situation in the market for forestry services a complex activity [17–20]. One phenomenon that mitigates the above difficulties, including the growing demand for wood, is the dynamic change in wood processing technology (industry), including the introduction of modified wood in many applications on an increasingly large scale.

The Biodiversity Strategy assumes that at least one-third of protected areas, equivalent to 10% of the EU area, should be strictly protected. This is also in line with the proposed global target. Therefore, an additional 2.7 million hectares are earmarked for strict
protection in Poland. National parks and nature reserves are already excluded from forestry. Therefore, these areas have reduced the area estimated to be deforested. In Poland, most forests are owned by the state, whereas other areas, such as peatlands, are on private land. Therefore, the work assumes that the main challenges to achieving the goals of the strategy will be taken over by SF NFH.

The forecast was developed for three time points (decades 2021–2030, 2031–2040, and 2041–2050) in scenarios with different possibilities of practical implementation of the EU policy, whose main goal is to protect 10% of the EU land area, including strict protection of the EU primary forests and old-growth forests [21,22].

The aim of this study is to assess the possible effects of the implementation of the European Commission’s proposals for the EU biodiversity protection strategy for forests and forest management in the context of the availability of broadleaf wood on the Polish market. This objective is achieved by analysis presenting a forecast of the timber supply, with a particular focus on timber from broadleaved tree species in Poland from forests managed by SF NFH under three scenarios that assume that about 2.7 million hectares of planted and production forests are excluded from use in order to implement the provisions of the Biodiversity Strategy [1]. Therefore, the paper will indicate the scope of possible limitations in the supply of timber from broadleaved tree species.

2. Research Object

As of 31 December 2019, forests in Poland covered an area of 9.26 million ha (29.6% of the country’s territory) [23]. The largest owner of forests is the State Treasury, on whose behalf they are managed by the State Forests National Forest Holding (SF NFH), which manages 7.12 million ha, representing 78% of the forest area [23]. The State Forests National Forest Holding is a state organizational unit without legal personality and represents the state treasury within the framework of the managed property. It operates on the basis of financial independence [24]. Forest management is carried out in 430 forest districts with an average area of about 17,000 hectares. On the territory of the SF NFH, Promotional Forest Complexes (1279 thousand ha) were established. These are compact forest areas belonging to one or more forest districts where foresters promote sustainable forest management, support scientific research, and conduct forest education for society. In Poland, 68.2% of the forest area is dominated by conifers, including pine, which occupies 60.1% [23] of the area of state forests. The stands with dominant broadleaved tree species mainly comprise oak (7.9%), birch (7.1%), beech (6.1%), and alder (5.6%). The share of the area broadleaved tree species has gradually increased from 13.0% in 1945 to 22.7% in 1997 to 33.1% at present. The age structure of the forest is dominated by stands of age classes V and higher (81 years and more), III (41–60 years), and IV (61–80 years), which occupy 23.6%, 22.9%, and 20.4% of the area, respectively [23].

3. Material and Methods

The work was divided into two main areas:

- Analysis of historical sales volume of wood products and average sales prices of hardwood during the period 2011–2020;
- Preparation of a forecast of the potential possibility of maintaining timber from broadleaved tree species production in the three decades in the period 2020–2049.

In the first step, the information on the quantity of wood sold and the prices obtained from broadleaf wood was taken from the annual reports of the SF NFH on the acquisition and sale of raw wood and from the annual reports on the sale prices of individual assortments, depending on the form of sale, in the years 2011–2020.

The volume of timber sales in 2011–2020 (m³) is represented by: A—total wood volume (thin and large wood volume); B—total merchantable wood volume (large wood volume); C—merchantable broadleaved wood volume (large broadleaved wood volume); D—merchantable broadleaved roundwood volume (large broadleaved roundwood
volume); E—broadleaved pulpwood merchantable volume (large broadleaved pulpwood
volume).

The second part of the analysis used historical data to estimate the impact of achiev-
ing the EU Biodiversity Strategy target in SF NFH managed forests and thus the oppor-
tunity to harvest hardwood. Forecasting the development of forest resources consists of
processing the input data collected in the field on the state of the forest, taking into account
the effects of various phenomena on the distribution and thickness of species in age classes of
the area and into information about the nearest future.

The method for making the forecast presented below is based on the inductive ap-
proach. This type of forecasting is based on past events; the possible stages and directions
of development of the predicted phenomena are analyzed. Inductive forecasting makes it
possible to answer the question, “What will happen if certain assumptions occur?” This
type of prediction reflects conscious human activity in actively shaping the future. Such
prediction does not aim to reach the final state, as the predicted state of the forest may be
subject to further, continuous development. Forecasting activities usually refer only to a
certain period of this evolution (e.g., up to 30 years), i.e., the period during which it seems
realistic to predict the effects of the natural and economic environment on the state of the
forest. To make such forecasts (i.e., inductive forecasts), information on the condition of
the forest area covered by the forecast and knowledge of the method of converting the
events that have occurred into the expected future events (in particular, using empirical
estimates of the effects of survival and decline phenomena in the age classes) are used.

The preparation of a forecast for a given forest area (for 30 years) required the prepa-
ration of specific input information on the condition of the forest and the expected eco-
nomic activities carried out under certain assumptions:

- Area and volume of stands in age classes and subclasses—the current area and vol-
  ume of stands in age classes and subclasses aggregated by predominant species in
  subdivisions prepared on the basis of data from forest management plans in the for-
  est database;

- Logging intensity indices and pre-logging intensity indices by age classes and sub-
  classes quantitatively relate to the method of forest management and reflect the cur-
  rent model of forest management. These indicators (for 10 years) were determined
  based on data from forest management plans;

- The accepted possibilities of logging and preliminary logging for the next forecast
  period—from forest management plans of forest districts;

- The expected volume of current volume growth in the assumed forecast periods for
  individual forest areas was estimated using data from forest management plans re-
  viewed based on the results of the large-scale forest inventory (WISL). Estimates of
  expected current volume growth were assumed for each 10-year forecast period;

- The proportion of complex felling in logging and the average length of the renewal
  period were determined in relation to use outside the renewal classes.

The forecast was made by comparing the amount of harvest with the currently used
forest area, taking into account the age structure and the number of wood resources in
hardwood stands (the current intensity of use, hereafter referred to as forest manage-
ment) and under the conditions of implementation of the provisions of the Biodiversity Strategy,
analyzing three scenarios:

- Exclusion of the oldest age classes of stands from forest management. Under Polish
  conditions, these would be all areas of stands over 80 years old and almost half of the
  areas of stands over 70 years old (Scenario I).

- Exclusion of the most valuable natural forest complexes from forest management,
  including forests with designated Natura 2000 sites [25] and forests in Promotional
  Forest Complexes [26], a total of 171 forest districts out of 430 forest districts (Scenario
  II). The Natura 2000 network is one form of nature protection in Poland and is also
  an element of the European Ecological Network Program. Natura 2000 sites are
protected by legislation introduced by the Polish government in 2004 and operate independently of national parks, nature reserves, and other long-established forms.

- Exclusion of the most valuable natural forest complexes from forest management, including forests with designated Natura 2000 sites and stands of the oldest age classes (all stands older than 100 years and parts of stands older than 90 years, a total of 108 forest districts out of 430 forest districts) (Scenario III). The analysis considered the area of Natura-2000-protected forest areas and stands older than 100 years, as these areas are considered the most valuable.

In the “0” comparison scenario, the previous method of forest management was adopted for an area of over 7.0 million ha, with the updated table of age classes as of 1 January 2020 assumed as the baseline condition. It should be emphasized that due to the necessity of carrying out detailed analyses of individual scenarios divided into the areas where forest management is to be carried out and the areas intended for strict protection, seven data variants had to be prepared in four scenarios (“0”, “I”, “II”, “III”), including, in particular, area and volume tables of age classes, as well as intensity indices of felling (old tree stands), and pre-felling (young tree stands) for the scenarios (Table 1).

### Table 1. The area and volume of stands in age classes and subclasses according to scenarios and their variants.

<table>
<thead>
<tr>
<th>Age Classes</th>
<th>“0”</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (Millions ha)</td>
<td>Volume (Millions m³)</td>
<td>Area (Millions ha)</td>
<td>Volume (Millions m³)</td>
</tr>
<tr>
<td>Unwoodes forest land.</td>
<td>0.15</td>
<td>2.26</td>
<td>0.15</td>
<td>2.26</td>
</tr>
<tr>
<td>Holdovers</td>
<td>12.71</td>
<td>12.48</td>
<td>0.23</td>
<td>8.08</td>
</tr>
<tr>
<td>Ia (1–10 years)</td>
<td>0.33</td>
<td>0.82</td>
<td>0.33</td>
<td>0.82</td>
</tr>
<tr>
<td>Ib (11–20 years)</td>
<td>0.43</td>
<td>6.95</td>
<td>0.43</td>
<td>6.95</td>
</tr>
<tr>
<td>IIa (21–30 years)</td>
<td>0.49</td>
<td>50.28</td>
<td>0.49</td>
<td>50.28</td>
</tr>
<tr>
<td>IIb (31–40 years)</td>
<td>0.46</td>
<td>89.53</td>
<td>0.46</td>
<td>89.53</td>
</tr>
<tr>
<td>IIIa (41–50 years)</td>
<td>0.54</td>
<td>141.81</td>
<td>0.54</td>
<td>141.81</td>
</tr>
<tr>
<td>IIIb (51–60 years)</td>
<td>0.88</td>
<td>274.36</td>
<td>0.88</td>
<td>274.36</td>
</tr>
<tr>
<td>IVa (61–70 years)</td>
<td>0.80</td>
<td>262.75</td>
<td>0.80</td>
<td>262.75</td>
</tr>
<tr>
<td>IVb (71–80 years)</td>
<td>0.63</td>
<td>218.63</td>
<td>0.21</td>
<td>70.30</td>
</tr>
<tr>
<td>Va (81–90 years)</td>
<td>0.60</td>
<td>222.33</td>
<td>0.60</td>
<td>222.33</td>
</tr>
<tr>
<td>Vb (91–100 years)</td>
<td>0.46</td>
<td>177.81</td>
<td>0.46</td>
<td>177.81</td>
</tr>
<tr>
<td>VI (101–120 years)</td>
<td>0.38</td>
<td>153.10</td>
<td>0.38</td>
<td>153.10</td>
</tr>
<tr>
<td>VII (121 years) and older</td>
<td>0.19</td>
<td>77.07</td>
<td>0.19</td>
<td>77.07</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>RC</th>
<th>0.67</th>
<th>182.37</th>
<th>0.67</th>
<th>182.37</th>
<th>0.31</th>
<th>83.54</th>
<th>0.36</th>
<th>98.83</th>
<th>0.40</th>
<th>105.81</th>
<th>0.27</th>
<th>76.57</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum</td>
<td>6.86</td>
<td>1870.53</td>
<td>4.14</td>
<td>909.28</td>
<td>2.72</td>
<td>961.25</td>
<td>4.21</td>
<td>1122.76</td>
<td>2.65</td>
<td>747.76</td>
<td>4.18</td>
<td>992.79</td>
</tr>
<tr>
<td>In total</td>
<td>7.01</td>
<td>1872.79</td>
<td>4.29</td>
<td>911.54</td>
<td>2.72</td>
<td>961.25</td>
<td>4.31</td>
<td>1124.17</td>
<td>2.70</td>
<td>748.62</td>
<td>4.31</td>
<td>994.61</td>
</tr>
</tbody>
</table>

* RC—regeneration class (forest stands that have reached their regeneration maturity and in which the renewal process has begun with complex felling).

Data were generated based on information from SF NFH forest management plans contained in the data bank of forests (BDL). The intensity indicators for logging and logging by age classes and subclasses were determined based on data from the forest management plans. They reflect the current model of forest management. A method for forecasting the development of timber resources and the volume of timber harvesting was adopted following the methods of Wysocka–Fijorek and Zajączkowski [27]. On the basis of historical data, a forecast of timber resources development and the possibility of their main exploitation was made for three 10-year periods. The procedure was as follows:

1. The sum of the products for the volume of age classes and subclasses and the index for felling and pre-felling intensity indicates the volume of felling and pre-felling in the volume dimension (in m³ of gross wood).
2. Based on the management data in the forest management plans, the share of mixed felling in the age classes in the total felling volume was determined. The addition to the unit determines the proportion of total felling.
3. To determine the volume of use, the intensity indices of logging use were multiplied by the area of each age class and subclass.
4. The volume table of age classes at the end of a given forecast period was calculated as the product of the area of each age class and age subclass at the end of the forecast period and the expected average volume.
5. The forecast for each 10-year period was prepared using the procedure outlined above.
6. Projections for timber resource development were prepared in a similar manner for all scenarios and their variants at 10-year intervals.
7. The assortment structure of harvested timber, with particular emphasis on broadleaved roundwood and pulpwood assortments, was determined based on harvest performance data for the last three years (2018–2020).

4. Results

During the period 2011–2020, state forests acquired a total of over 386 million m³ total wood volume (A), of which over 86 million m³ (22.3%) was merchantable broadleaved wood volume (C), including 22 million m³ of merchantable broadleaved roundwood volume (D) (25.6%) and 44 million m³ of merchantable broadleaved pulpwood volume (E) (51.2%).

Logging increased systematically until 2018 and amounted to over 44 million m³ due to natural disasters [28–31] (Table 2). The share of merchantable broadleaved wood volume in the total timber harvest remained 21%–24%. Merchantable broadleaved roundwood volume accounted for 5%–7%, and merchantable broadleaved pulpwood volume accounted for 11%–12% of the total harvested wood volume.

When analyzing the historical data for 2011–2020, the constant trend of an increase in the average price of timber, weighted by the amount of timber sold, is striking. The highest price increase, in 2020, was recorded for merchantable broadleaved roundwood (D) by 46% compared with 2011 prices. For merchantable broadleaved wood (C), the increase was slightly lower and amounted to over 20% in the analyzed period.

During 2018–2020, a significant price increase (with a similar supply) was observed for merchantable broadleaved roundwood. The price of merchantable broadleaved roundwood was 34% higher than the total merchantable wood price at the beginning of the period. In 2020, the average price of merchantable broadleaved roundwood was 87% higher than the overall average price of total merchantable wood. Assuming that the
proportion of broadleaved roundwood brought to market decreases, this will lead to a further increase in the price of hardwood, especially for large-sized timber. It is worth noting that the average price of merchantable broadleaved pulpwod has fluctuated in the range of 76%–81% of the average price of timber in SF NFH in subsequent years; in recent years, it has remained at the level of 79% of the average price of timber in SF NFH.

Table 2. Timber sales (thousand m³) and average prices (PLN/m³) in the period 2011–2020.

<table>
<thead>
<tr>
<th>Year</th>
<th>Wood Sale (Thousand m³)</th>
<th>Average Price (PLN/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>2011</td>
<td>35,099</td>
<td>32,805</td>
</tr>
<tr>
<td>2012</td>
<td>34,815</td>
<td>32,762</td>
</tr>
<tr>
<td>2013</td>
<td>37,082</td>
<td>34,936</td>
</tr>
<tr>
<td>2014</td>
<td>37,652</td>
<td>35,578</td>
</tr>
<tr>
<td>2015</td>
<td>37,971</td>
<td>36,046</td>
</tr>
<tr>
<td>2016</td>
<td>39,457</td>
<td>37,669</td>
</tr>
<tr>
<td>2017</td>
<td>40,421</td>
<td>38,839</td>
</tr>
<tr>
<td>2018</td>
<td>44,695</td>
<td>43,045</td>
</tr>
<tr>
<td>2019</td>
<td>41,075</td>
<td>39,336</td>
</tr>
<tr>
<td>2020</td>
<td>38,015</td>
<td>36,391</td>
</tr>
</tbody>
</table>

A—total wood volume; B—total merchantable wood volume; C—merchantable broadleaved wood volume; D—merchantable broadleaved roundwood volume; E—merchantable broadleaved pulpwod volume.

During 2011–2020, the volume of total wood sold to industrial facilities (A) increased from 82.5% to 89.1%, including merchantable broadleaved wood (C), an increase from 68.9% to 74.4% (Table 3). Almost all of the volume of merchantable broadleaved roundwood (D) went to industrial facilities, an increase from 97.4% to 99.4%. Over the 2011–2020 period, sales of wood to small (local) buyers declined significantly. Large-sized hardwood was virtually unavailable to small buyers. In addition, other buyers have limited access to merchantable broadleaved roundwood timber and little access to merchantable broadleaved pulpwod volume. The percentage of merchantable broadleaved pulpwod volume (E) sold to small buyers decreased from 29.8% to 24.0%. Merchantable broadleaved roundwood was sold to small buyers to a lesser extent, from 2.6% to less than 0.5% of merchantable broadleaved roundwood. An even greater decline in the proportion of timber sold to small buyers applies to merchantable broadleaved pulpwod timber, where the proportion of merchantable broadleaved pulpwod timber fell from 22.4% to less than 11.0% (11.4%).
Table 3. Direction of timber sales by buyer group 2011–2020.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sales to Industrial Facilities (%)</th>
<th>Sales to Small Buyers (%)</th>
<th>Sales to Other Buyers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A B C D E</td>
<td>A B C D E</td>
<td>A B C D E</td>
</tr>
<tr>
<td>2011</td>
<td>82.5 86.7 68.9 97.4 75.4 16.3 12.6 29.8 2.6 22.4 1.2 0.7 1.4 0.0 2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>83.1 86.9 69.8 98.2 78.9 15.8 12.3 28.8 1.8 18.8 1.1 0.8 1.4 0.0 2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>82.6 86.3 68.1 97.9 75.9 16.3 12.9 30.5 2.1 21.9 1.0 0.8 1.3 0.0 2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>83.9 87.5 71.2 98.2 82.1 15.0 11.7 27.4 1.7 15.6 1.1 0.7 1.4 0.0 2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>84.9 88.2 72.0 98.5 84.4 13.9 11.1 26.5 1.5 13.1 1.2 0.8 1.5 0.0 2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>85.8 88.8 72.3 98.5 85.2 12.9 10.5 26.2 1.5 12.2 1.3 0.7 1.6 0.0 2.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>86.8 89.4 72.0 99.5 85.6 12.0 10.0 26.5 0.4 11.8 1.1 0.6 1.5 0.0 2.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>87.9 90.2 73.3 99.6 86.6 10.7 9.0 25.1 0.4 10.9 1.4 0.8 1.6 0.0 2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>88.5 90.1 73.3 99.4 85.7 10.8 9.3 25.2 0.5 11.7 0.6 0.6 1.6 0.0 2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>89.1 90.4 74.4 99.5 86.3 10.3 9.0 24.0 0.5 11.0 0.6 0.7 1.6 0.0 2.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Denotes as in Table 2.

The prediction of timber harvest for the next 30 years in the “0” scenario indicates a constant increase in the amount of timber harvested, including broadleaved wood (Table 4). The projections in the assumed scenarios indicate a significant decrease in the amount of wood that can be harvested, including broadleaved wood. In Scenario “I”, the total wood volume will be 38%–44% of that projected in Scenario “0”, whereas broadleaved wood will account for about 32%–37% of the harvested volume in Scenario “0”. The projected merchantable broadleaved wood harvest in the “II” scenario is about 58%–62% of the harvest in the “0” scenario. The projected felling of merchantable broadleaved roundwood volume is about 55% of Scenario “0” and about 5% of merchantable broadleaved pulpwood volume Scenario “0”. The “III” scenario limits the merchantable broadleaved wood volume harvest to about 60%–63% of the hardwood harvest of the “0” scenario, with merchantable broadleaved roundwood volume accounting for about 33%–37% and merchantable broadleaved pulpwood volume 53%–55% of the merchantable broadleaved wood volume harvest of the baseline scenario.

Table 4. Change in logging volume in the scenarios over the three ten-year periods relative to logging volume in the baseline scenario in each of the forecast periods.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Assortments</th>
<th>Forecast Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2021–2030</td>
</tr>
<tr>
<td></td>
<td>Millions m³/10 year</td>
<td>%</td>
</tr>
<tr>
<td>“0”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>382.40</td>
<td>100.0</td>
</tr>
<tr>
<td>B</td>
<td>371.16</td>
<td>100.0</td>
</tr>
<tr>
<td>C</td>
<td>81.95</td>
<td>100.0</td>
</tr>
<tr>
<td>D</td>
<td>33.20</td>
<td>100.0</td>
</tr>
<tr>
<td>E</td>
<td>40.23</td>
<td>100.0</td>
</tr>
<tr>
<td>“I”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>145.52</td>
<td>38.1</td>
</tr>
<tr>
<td>B</td>
<td>142.56</td>
<td>38.4</td>
</tr>
<tr>
<td>C</td>
<td>26.43</td>
<td>32.2</td>
</tr>
<tr>
<td>D</td>
<td>4.50</td>
<td>13.6</td>
</tr>
<tr>
<td>E</td>
<td>19.65</td>
<td>48.8</td>
</tr>
<tr>
<td>“II”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>238.44</td>
<td>62.4</td>
</tr>
<tr>
<td>B</td>
<td>230.11</td>
<td>62.0</td>
</tr>
<tr>
<td>C</td>
<td>45.88</td>
<td>56.0</td>
</tr>
<tr>
<td>D</td>
<td>18.31</td>
<td>55.2</td>
</tr>
</tbody>
</table>
In the following periods of the forecast, planned timber harvest will increase if current forest management practices are maintained (Figure 1). The introduction of the protection regime will have a significant impact on limiting timber harvest, especially in Scenario “I”. The situation is similar for merchantable wood harvesting (Figure 2). In all scenarios, one can observe the projected increase in the amount of harvested timber in the following periods of the forecast. In Scenario “II”, the predicted increase in the amount of timber to be harvested is minimal in the subsequent periods, both for the harvest of all timber and for the harvest of merchantable wood timber. The introduction of biodiversity conservation scenarios will lead to a reduction in logging in the first period to about 40% of the previous harvest in Scenario “I” and to about 60% in Scenarios “II” and “III”. In the following periods, logging will be about 45% of the “O” scenario in the “I” scenario, almost 60% in the “II” scenario, and more than 60% in the “III” scenario. The values will be very similar for total logging and merchantable wood (Figures 1 and 2).

Figure 1. Change in total logging in the scenarios compared with the historical total logging volume.
The projected harvest of merchantable broadleaved wood will increase overall in all scenarios and forecast periods (Figure 3). The introduction of individual scenario changes in the organization of forest management will significantly limit broadleaved wood harvesting. The introduction of changes in the method of forest management in Scenario “I” will lead to the adoption of 32%–37% of Scenario “0”. Scenario “II” would lead to the extraction of 56% of the hardwood, and in Scenario “III” to 43%–47% of the Scenario “0” of the merchantable broadleaved wood volume.

The projected harvest of merchantable broadleaved roundwood in the scenario that assumes forest management under current rules is larger than the current one and will increase in the subsequent periods of the forecast (Figure 4). In the “II” scenario, the projected harvest of merchantable broadleaved roundwood volume will be slightly lower than the current harvest. The projected consequence of implementing Scenarios “I” and “III” will be a significant decrease in the harvest of merchantable broadleaved roundwood. The implementation of the alternative scenarios in the harvest of merchantable
broadleaved roundwood will significantly reduce the harvest of timber. In Scenario “I”, the supply of merchantable broadleaved roundwood volume will be reduced to 14%–18% of Scenario “0”. In the “II” scenario, 55% of the “0” scenario is harvested, and in the “III” scenario, 33%–37% of the “0” scenario merchantable broadleaved roundwood is harvested.

Figure 4. Change in the amount of broadleaved roundwood merchantable volume harvested in scenarios in light of historical levels of broadleaved roundwood merchantable volume harvesting.

The harvest of merchantable broadleaved pulpwood in the scenarios with forest management constraints is similar in all scenarios (Figure 5). There are no major differences between the alternative scenarios. In the following periods, the predicted yield will increase slightly. In all alternative scenarios, the harvest of merchantable broadleaved pulpwood volume will be about 49%–57% of the projected harvest in Scenario “0”.

Figure 5. Change in the amount of harvested merchantable broadleaved pulpwood volume in the scenarios against the background of the historical harvesting size of merchantable broadleaved pulpwood volume.
5. Discussion

The amplification of the greenhouse effect can be limited by an effective and harmonized global action. Many negative consequences could be mitigated or avoided by establishing effective measures to prevent climate change. The European Union has taken such measures by setting targets under the Biodiversity Strategies [1], the European Forest Strategy [2], and the new European Union Strategy for Adaptation to Climate Change [3], among others. These policies place the European Union in a position of leadership in global climate policy when it comes to reducing emissions of harmful gases. This results in proposed changes to the existing principles of forest management.

Originally, the paradigm of sustainable forest management was focused on ensuring a continuous supply of timber. Over time, it has been extended to include a wide range of forest ecosystem services [32]. Despite the change in scope mentioned above, the economic basis of forest management is still wood as a raw material, even from the perspective of society. Therefore, information on the status and structure of wood resources and forecasting their long-term changes is essential for effective forest management. The decision-making process in management planning is constantly adapted to the changing needs related to forest management [33,34]. One of the most important decisions foresters make to ensure the sustainability and proper development of the forest is to correctly determine the level of logging use [35], not only in forest management plans prepared for a 10-year period, but also in forecasts of resource development over longer periods.

This paper presents the predicted results of timber resources development in three consecutive decades. The methods used made it possible to estimate the condition of the forest and the possibility of harvesting timber in the area over a 30-year period. Assuming that the intensity of logging and pre-logging indicators will change by age classes and subclasses, which roughly means that forest management in terms of intensity of use throughout the forecast period according to the assumptions made. Of great practical importance is the presentation of the projected changes in forest condition and the possibility of harvesting timber in felling and pre-felling, as well as the changing area and stand structure in a given forest area during the forecast period. The presentation of the planned harvesting volume and assortment structure of the timber against the background of changes in the structure of the area and stand and, among other things, the intensity of use allows taking a long-term view of the planned tasks. The use of forecasts in planning the consequences of planned changes in forest management can contribute to a more comprehensive analysis of the desired direction of forest stand development.

The timber availability projections presented are flawed by a lack of knowledge of the consequences of such exclusions (large areas of planted forests) on forest health. The lack of practical experience of forest condition trends in the case of such exclusions meant that the final outcome of the analysis had to disregard the effects of natural tree mortality and the possibility of potential phenomena of large-scale weakening or decay of forests. This fact is also important in the context of the ability of forests, particularly primary forests and old-growth forests, to absorb and store significant carbon resources. The exclusion of forests from use also affects the provision of ecosystem services by them, which should be maintained and strengthened [36], especially as the research evidence is inconclusive regarding the extent of synergistic and competitive relationships between forest use (timber harvesting) and the extent of ecosystem services [37].

The Biodiversity Strategy does not prescribe specific definitions and solutions. Therefore, the analysis considers three alternative approaches and relates its results to the current state. The differences in the results in the scenarios and in the subsequent forecast periods result from the nature of the assumed constraints. Implementation of the scenario that excluded the oldest stands from use (Scenario “I”) resulted in a significant reduction in the availability of large-sized timber from broadleaved tree species. The exclusion of naturally valuable stands (Scenario “II”) resulted in a smaller reduction in the amount of timber harvested than the exclusion of the oldest stands. A reduction in the supply of large and medium-sized timber from broadleaved tree species will be of a similar magnitude.
The middle scenario, which excluded the oldest and inherently valuable stands (“III”), reduced timber harvesting significantly, especially for large but also for medium-sized timber. In the short term (which in the context of forest management is about 30 years), excluding large wood will increase resource size, average age, and average abundance. In the long term, the condition and structure of forests will change due to the likely loss of stand stability, abiotic and biotic threats, and management and economic impacts that may cause SF NFH to lose the ability to self-finance.

The recommendations contained in the EU strategy as an element of the European Green Deal requires circular forest management, taking into account, among other things, the need to supply society with wood and to meet the needs of the economy while enabling both the production of wood and the protection of biodiversity. The growing demand for wood products is increasing anthropogenic pressure on forest biodiversity [38]. The alternative scenarios adopted in the study are based on the assumption that about 2.7 million ha of forest are excluded from use. For each scenario, indicators were used that were calculated on the basis of current forest management practices and adapted to the selected forest areas.

Forest ecosystems have long-term development cycles. In managed stands, there are stages of development that result from the way the forest is managed. In areas where forestry has not been practiced for a long time, all natural stages of stand development occur [38]. It can be assumed that the implementation of the scenarios will lead to a significant change in forest structure, which will differ greatly from both the model of managed forests and the structure of near-natural forests.

It seems that Scenario “I” in particular is an approach that is difficult to implement in practice. In the “II” and “III” scenarios, the exclusion of certain areas seems more feasible but has unacceptable economic and social consequences.

Recently, significant changes in the timber market have been observed, not only in Poland [14,15,39–41] but also in other countries [22,42–44]. Climate change is becoming more severe. On the one hand, they lead to large amounts of wood entering the market, e.g., as a result of pest gradation, windthrow, and drought [39,45–47]. On the other hand, the introduction of an increasing number of deciduous species is beginning to be considered an antidote to climate change [48,49]. The problem is that fluctuations in the supply of timber to the market occur here and now, and changes in the supply of hardwoods as a result of actions taken today will occur in the future. Reductions in timber supply can have far-reaching consequences that are particularly severe for local communities [50]. Simultaneous conservation across Europe increases log costs for the Western European forest industry but does not prevent the leakage of roundwood harvests to Russia [6].

The problem of the impact of implemented activities on timber supply was noted in the development of the Forestry Strategy [2]. It was also pointed out that restrictions on timber harvesting in one region of the world or in Europe should not lead to excessive exploitation of forests in another part of the world. Such a situation necessitates the development of scenarios for action. Such scenarios have been developed for Sweden, among others [51], indicating the locations of the trade-off. Limiting timber harvesting may lead to the liquidation of some, especially small, timber processing sites. It may also lead to a lengthening of the transport route of raw wood and an increase in the cost of transporting wood. In Poland, the availability of good quality timber from broadleaved tree species for small buyers is already difficult, as demand is greater than supply.

In implementing the tasks of EU forest policy, consideration should be given to the impact of the policy on long-term changes in general economic conditions, the (often poorly considered) social and ethical dimensions of these issues, and the ability of stakeholders at different levels to understand and share its objectives. Over the last decade, timber supply has increased, whereas the average price of timber has increased. This proves that the demand for wood is not being met by the supply. Planned measures at the EU level, such as the Biodiversity Strategy and the Forestry Strategy, will bring potential changes in forest management. Regardless of restrictions on forest management or
reductions in the volume of timber harvested, most of the restrictions will apply to hardwood stands as these have the greatest biodiversity. This will exacerbate the problem of timber from broadleaved tree species availability. Such a situation will lead to a further increase in prices for large and medium-sized hardwoods. The proportion of timber sales to industrial operations will increase, and the availability of timber to small, often local, customers will decrease. A reduction in the supply of timber from broadleaved tree species combined with a reduction in the amount of wood available to small customers will lead to changes in the local wood processing market [52].

The supply of timber depends primarily on the area of managed forests, their production capacity, and age structure [46]. Due to the nature and long-term cycle of forest production, it is not possible to increase or decrease the volume of wood (unlike other products) in any way. In the course of forest resources management, the volume and assortment structure on the primary timber market should be optimized, in line with changing economic conditions [39,45] and also to the need to protect and maintain the sustainability of forest resources. Our findings are also relevant for forest management and conservation practice, as they show that environmentally sound management over long periods of time is essential for sustainability. Our study and the studies of other authors illustrate that it is possible to create empirical models that predict harvest with high discriminating power at the national or regional level based on forest attributes [53–57]. Our results highlight the need to protect remaining old-growth forests, which are diminishing, and the need to balance conservation and management objectives in the future to ensure sustainable forests in Eastern Europe [58]. According to [59], based on a study conducted in Norway, a balance can be found between industry/economy and regional political interests.

6. Conclusions

Action to mitigate climate change is essential. Excluding large areas of forest from use can have significant economic and social impacts. Over the past decade, the amount of timber harvested, including hardwood, has increased, and the price of that timber, especially large-sized timber from broadleaved tree species, has increased. The increase in the average price of timber from broadleaved tree species has been greater than that for the other timber groups. The price increase for large-sized hardwood was particularly noticeable. The structure of the main purchasers of broadleaved timber has also changed, especially for those of large-sized hardwood. Customers with large production capacities and less adaptability to changing market conditions are becoming increasingly important. Access to high-quality timber from broadleaved tree species for small customers is limited.

The recommendations contained in the policy objectives that the EU sets for its states should be supported by a thorough analysis when selecting areas for strict protection, defining terms such as strict protection and old-growth forest, and deciding on the methods used to finance the economic consequences of forest protection. The voice of the local community should be taken into account when deciding on the exclusion of individual areas from use. If the recommendations contained in EU strategies and policies aim to reduce logging, consideration should be given to where the EU will source the missing timber, whether it is possible to introduce financial instruments to stabilize timber prices or what impact changes in the supply of local timber will have on the timber industry, and what measures should be taken to prevent the destruction of forests in other parts of the world.

This paper presents the results of methods used for forecasting changes in the supply of timber from broadleaved tree species based on the model used in Poland to forecast the development of forest resources. The timber resource development model is an inductive model, which limits the possibilities of its validation. When developing forecasts of timber supply development, taking into account the adoption of various criteria for the strict protection of forests, we did not consider climate change. In further research, we should pay
attention to an additional problem that we are increasingly facing not only in Poland, namely multifactorial forest dieback. Due to the lack of precise definitions of strict protection, the 2030 Biodiversity Strategy assumes that the definition is consistent with the Polish approach, i.e., a complete ban on forest management. Therefore, this paper presents the possible extent of restriction of hardwood availability on the Polish market. Depending on the assumed definition of strict protection and the definition of the rules for the expansion of the stands to strict protection, the restrictions on the procurement of hardwood will be in the range of 0 to 60%.

Author Contributions: E.W.-F.: Conceptualization, Methodology, Investigation, Software, Formal analysis, Data curation, Writing—review and editing; P.G.: Investigation, Writing—original draft, K.J.: Writing—original draft, Writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors report no declaration of interest.

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