

# The implications of climate change for the German wood industry

A case study

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## 1 Scope and relevance

Wood has always been an important natural resource for the construction, energy and paper industry alike. However, while a growing demand for renewable resources in general can be expected due to the need for more sustainable practices in every aspect of modern societies, the global production of wood (and timber, consequently) is negatively affected by climate change and its secondary effects. Additionally, global supply chains for wood are currently affected by accumulating crises like COVID-19 and the war on Ukraine.

It is against this background that the case study at hand analyses the impacts of global climate change on the production and import/export relations of wood and wooden products in Germany. Our hypothesis is that the increasing demand for wood is coinciding with an increase of negative climatic impacts on forests which has the potential to lead to supply shortages and price hikes.

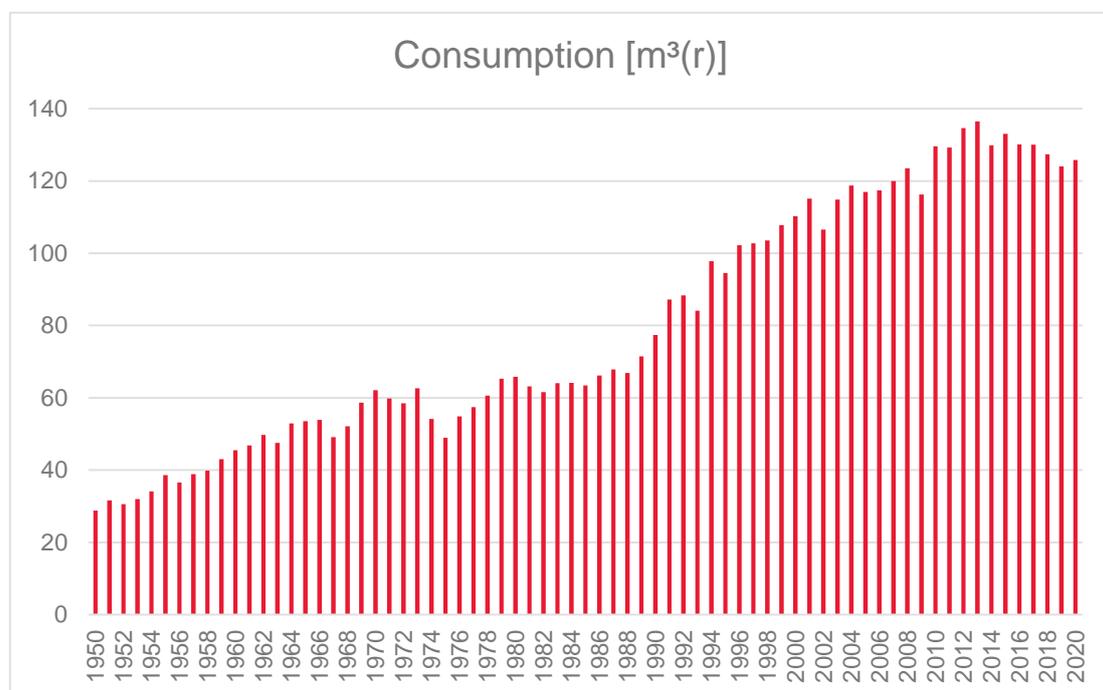
## 2 Developments in supply and demand for wood

The following sections present general developments of wood production, its different modes of consumption and trade flows in and out Germany. Subsequently, driving forces within the German market situation will be investigated before we turn to the effects of climate change on the German wood sector. In doing so, the following questions will be tackled:

- How has the consumption of wood changed over time?
- What are the current main utilizations for wood in Germany?
- What has driven changes in the consumption and use of wood in recent years?
- Where does the wood come from that is consumed in Germany? (Value/Volume?)
  - How much wood does Germany produce?
  - How much wood does Germany import?
  - How did production and imports change over time?
- What is the role of climate change in these developments presented so far?

### 2.1 Overall development of the wood sector in Germany

In Germany, the consumption of wooden forest products (including paper products) has steadily increased since the 1950s (see figure 1). While the annual consumption was at 28.83 million  $\text{m}^3$  raw wood equivalent [ $\text{m}^3(\text{r})$ ] in 1950, the demand levelled off around 60 million  $\text{m}^3(\text{r})$  until 1985. However, since that year, consumption rose to more than 100 million  $\text{m}^3(\text{r})$  in 1996 and has reached a peak of 136.51 million  $\text{m}^3(\text{r})$  in 2013 (Thünen Institut n. y.).



**Figure 1: Wood consumption in Germany (Thünen Institut n. y., own illustration)**

Wood is being used as a commodity for various purposes. The main uses are the production of wooden goods and the energetic use of wood and by-products of the manufacturing

industries in both the private and the commercial sector. The energetic use of wood products has experienced a steady increase since 1987 which slowed down only since 2009, mostly using sawing by-products. To date, 75 % of burned wooden products in Germany are by-products or wood waste (FNR, 2018). As for the material usage of wood products, a similar trend is detectable however disrupted by a peak (and a following drop) in 2007 (Mantau, 2012). In 2016, material and energetic use of wood were on par in terms of volume at about 63.8 million m<sup>3</sup>(r) (German Federal Ministry of Food and Agriculture 2021).

One major industry using processed woods is the building sector. Experts concluded that building construction consumed 16.3 million solid cubic meter equivalents [m<sup>3</sup>(s)] of wood products in 2012 (Weimar & Jochem, 2013). While this information cannot depict the situation in recent years, considering the share of wood constructions in buildings conveys a tendency of the development (FNR, 2019). As for residential buildings, this share has increased from 14.6 % in 2009 to 17.8 % in 2018. For non-residential buildings, the picture is not as straightforward as for residential buildings, but rather declining.

As politics and social developments have been supporting the use of wood in the building sector in recent years, assuming the continuity of this trend stands to reason. The current agenda “Charta for Wood 2.0” set out by the Federal Ministry of Agriculture and Food explicitly lists the expansion of wood use in the building sector as one of several goals regarding the sustainable consumption of wooden forest products (German Federal Ministry of Food and Agriculture 2021). Consequently, institutional barriers regarding wood constructions are will need to be abolished in addition to propagating wood use in the construction sector.

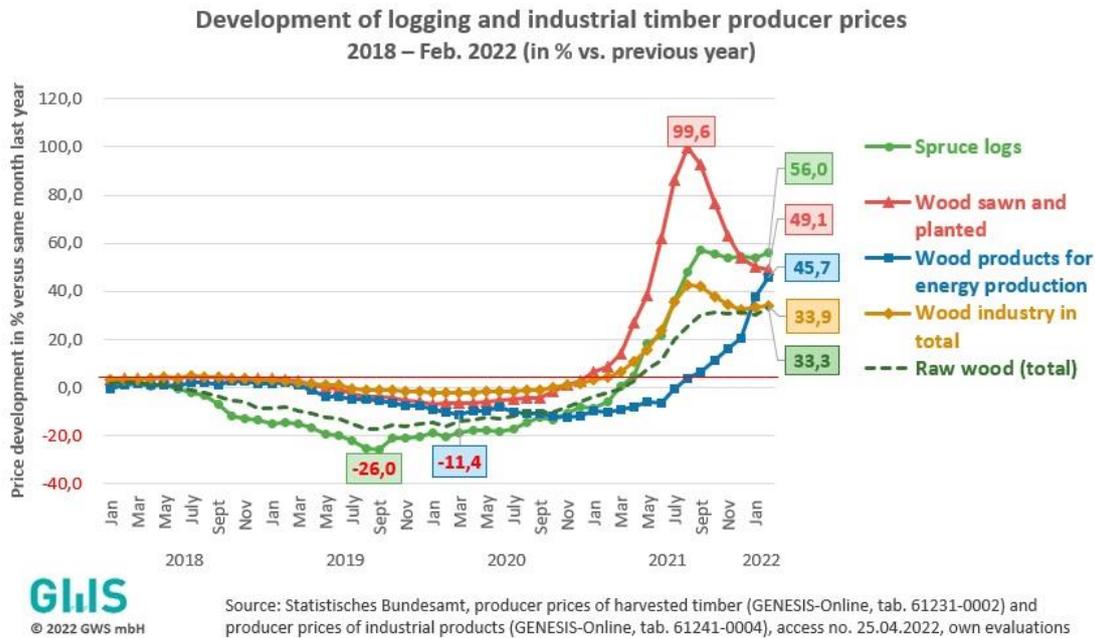
While building sector data provides specifics on wood utilization to some extent, this is not the case for other sectors with a significant wood consumption. Thus, one has to rely on economic data here to assess a trend in their wood use. However, this data does not allow for a quantification of the wood consumption due to the variation of global wood prices. As every other market, the wood market is prone to crises and shocks.

During the first outbreak of the COVID-19 pandemic, the price for lumber<sup>1</sup> fell from 460.1 USD on 17<sup>th</sup> February 2020 to 264.0 USD on 30<sup>th</sup> March 2020 on the CME Chicago stock market (Macrotrends LLC n. y.). Afterwards, the market recovered, however, reaching an all-time high in 2021 due to the rising demand for building material in the U. S. Similar developments were observed in Germany (Tandetzki & Weimar 2022). Yet, the price has started to fall again in late February, right at the time Russia invaded Ukraine, at least on the Chicago stock market. Experts are weighing up the influences of inflation, rising mortgage rates and the war against Ukraine on the price. While one might expect at a first glance that the latter would lead to a shortage in supply and thus to rising prices, experts suppose that these dynamics are outweighed at the moment by the former market developments (Zinke 2022b). The global shifts in supply chains triggered by the war will be outlined further in chapter 3.

At first, the price boom in the wood-processing industry during the pandemic in the U. S. was mirrored by the wood price developments in Germany – at least until the war against Ukraine started. As mentioned earlier, the prices decreased at the Chicago stock market after July 2021. In Germany, however, the prices for wood sawn and planted continued to increase. While there was already an increase of 99.6 % between July 2020 and July 2021 (see figure 2) this, to that date, all-time-high was even surpassed by 25.7 % in July 2022 (not shown in the figure). Generally, prices for wood in Germany continued to increase relatively on a monthly basis since the war started (German Federal Office of Statistics n. y.). Regarding wood products for energy production, these developments can be explained by energy shortage triggered by the war. But different to the American market, prices have also been

<sup>1</sup> The terms « lumber » and « timber » are used to describe wooden products in different stages of their processing cycle. However, the usage and meaning of these terms differ in various regions on the globe. Therefore, it was tried to use the basic term « wood » whenever possible in order to avoid confusion, differing terms were only used when the (English) source was explicitly mentioning another term.

rising since the timber trade embargo against Russia came into place (GWS 2022). If these developments for the German wood industry are going to continue is unclear as the construction sector as one of the main drivers for the trend in the price of wood is currently showing signs of recession (Zinke 2022a)



**Figure 2: Relative development of wood prices in Germany from 2018 to February 2022 (Source: GWS 2022 based on the German Federal Office of Statistics)**

However, not every stakeholder in the German wood industry is profiting from the rising prices. The president of the German forestry council (Deutscher Forstwirtschaftsrat) claimed that a few international investors de facto monopolized the German sawmill industry and gained huge profits through the rising demand for German processed wood. Yet, the forest owners are still paid pre-crisis rates. As a result, forest owners face low income rates despite a booming wood market and a lack of savings due to the difficult previous years shaped by extreme weather and low wood quality and prices. Therefore, some forest owners are forced to loot their (wooden) resources in order to gain some profit (Hilpmann 2021). Obviously, this is the opposite of a sustainable forest management. In 2022, the situation did not get better. Rather, German forest owners are demanding financial aid by the government in order to compensate losses. According to the German forestry council, drought and the bark beetle were responsible for losses of 12.5 billion Euro from 2019 to 2021 alone (Norddeutscher Rundfunk 2022).

Overall, it can be stated that the demand for wood in Germany is growing constantly if it is not interfered by crises of any kind influencing supply and demand (such as the global financial crisis 2007, the euro crisis 2009, the COVID-19 pandemic starting in 2020 and the war against Ukraine starting in 2022). The following subchapter is therefore going to investigate influences on the market situation in Germany.

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## 2.2 Drivers of and influences on the market situation

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In order to derive conclusions about future developments on the wood market, the following section will take drivers and influences of the market into consideration.

In this regard, two main drivers of the increase in wood consumption can be identified. On the one hand, underlying economic growth of recent years is boosting productivity and thus the consumption of wood by the various industrial sectors. On the other hand, the “rediscovery” of wood as a sustainable resource promoted its utilization.

Regarding the energetic use of wood funding programmes implemented in the early 2000s pushed this application. Besides that, seasonal fluctuations such as harsh winters expanded the private energetic consumption in 2009 and 2010. Furthermore, the increasing oil price supported this development (Mantau, 2012). The rise of oil prices, however, is nothing compared to the hike in prices for gas within weeks after the invasion of Ukraine in early 2022. In this context, the topic of energy security has resurfaced on the agenda of German politics. In this light, the association of Germany’s forest owners sees the potential for a growing share of wood pellets used for energy generation to circumvent energy scarcity (DW n. y.). Consequently, prices for firewood and wood pellets have already increased considerable. Due to the growing demand, domestic production is no longer sufficient and imports are increasing (Diaz 2022). On a European level however, the rising demand for renewable energy had positive impacts on forestry management already before the war started (Financial Times 2022).

However, there are many voices promoting to abandon this wood application in the future. This is mainly reasoned by the fact that while utilizing wood as an energy source seems sustainable at first glance, regarding the broader context bears a different picture. Not only are the gross CO<sub>2</sub> emissions from burning wood higher than those of coal or oil (Thies, 2021). Beyond that, the particulate matter set free by burning wooden resources has caused additional environmental pollution which might lead to further restrictions in the domestic use of wood as a heating source (Umweltbundesamt, 2021).

Concerning the material utilization of wood, the economic situation decisively shaped the consumption (Mantau, 2012). However, a recent push in the construction sector is based on the urge to find sustainable alternatives to currently used resources. This push climaxed in 2021 when the COVID-19 pandemic entered its second year and people were still not as keen to travel as in pre-pandemic times. Thus, a building boom emerged in Germany leading to a demand exceeding the supply by far which increased the buying prices for woodworker tremendously (Tandetzki & Weimar 2022). This and a simultaneous building boom in the U. S. led to an increase of demand for wood from Europe which led to a shortage of wood in Germany. This triggered price increase that affected German wood-processing enterprises and private building owners. However, the developments in the public sector regarding the use of wood as the main building material outlined above are likely to be aggravated by this situation as prices in public tenders are being capped and woodworking workers (Jakob 2021). How these dynamics are influencing German import/export balances will be subject to the following subchapter.

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## 2.3 Domestic growth and foreign trade rates of the German wood industries

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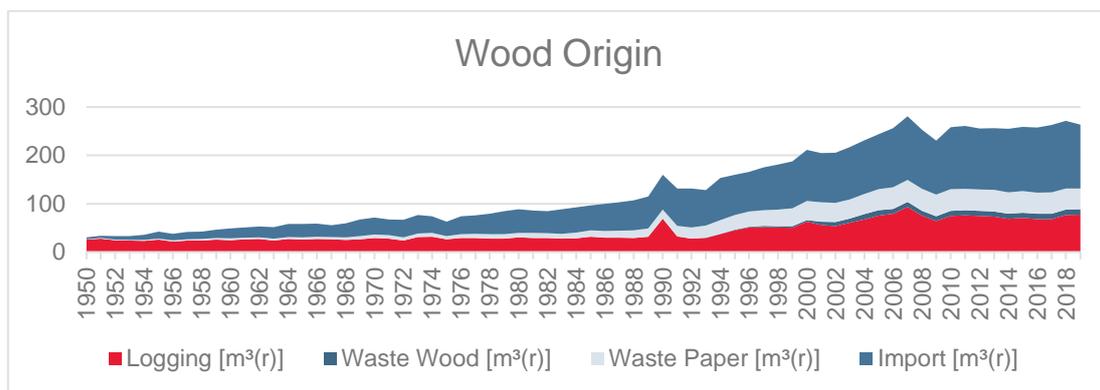
According to the “overall wood balance” published by the Thünen Institute, the origin of the wood consumed in Germany has shifted since the 1950s when the vast majority of wood consumed in Germany was logged domestically (Thünen Institut n. y.). While logging stayed at a level of around 30 million m<sup>3</sup>(r) from 1970 until 1993, imports of raw wood (as well as the

use of waste paper) increased steadily in order to allow for the growing consumption and export of wood products. Imports and domestic wood supply first came to par in 1964 at about 26 million m<sup>3</sup>(r). Imports surpassed domestic logging in 1968 and reached 73.36 million m<sup>3</sup>(r) in 1993 exceeding the internal supply by more than 40 million m<sup>3</sup>(r). It should be noted that not all of these wood resources are consumed within Germany, but large parts are exported.

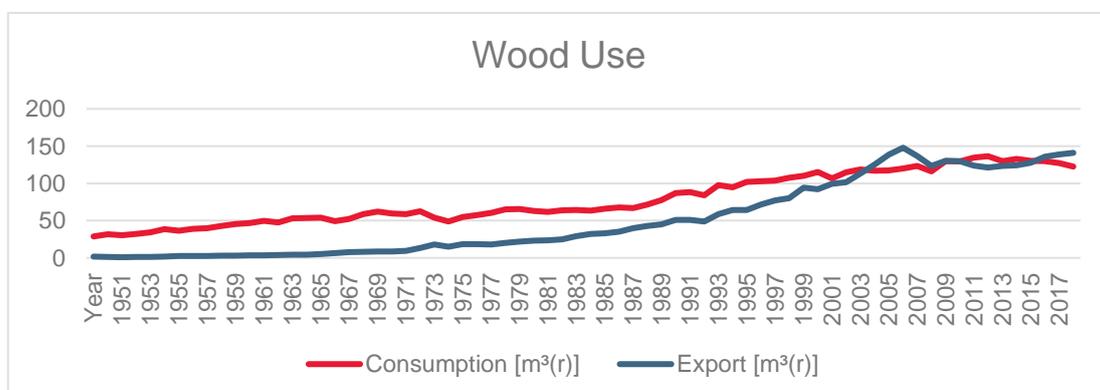
After 1993, internal wood supply strongly increased yet fluctuating with the economic developments in the early 2000s and the economic crisis after 2007. However, logging barely surpassed 75 million m<sup>3</sup>(r) since 2007 and has not yet reached the level of 2007 while imports continued to rise reaching a peak in 2018 with 140 million m<sup>3</sup>(r) wood (see figure 3). While the use of waste wood and paper have been rising moderately, the consumption and exports of wood products exceed the domestic wood supply.

In 2019, the most recent data provided by the overall wood balance, wood consumption amounted to 122.68 million m<sup>3</sup>(r) and exports totalled to 140.84 million m<sup>3</sup>(r). Yet, logging and waste resources added up to only 131.59 million m<sup>3</sup>(r). This, combined with the fact that export rates exceeded domestic consumption rates in recent years (see figure 4), shows that Germany is highly dependent on wood imports today (131.67 million m<sup>3</sup>(r) in 2019).

The foreign trade balance shows that Germany was a net importer of wood / wood-based products for most of the time from the post-war period onwards. This changed for the first time in 2005. However, this development was revised in the course of the financial crisis in 2011. Yet, since 2019, Germany regained its status of being a net exporter of forest products.



**Figure 3: Wood origin (Thünen Institut n.y., own illustration)**



**Figure 4: Wood use (Thünen Institut n. y., own illustration)**

The summer of 2018 harmed the German forests through heat, drought and storms. While these conditions or impacts did not reappear in equal strength in subsequent years, the bark-beetle and other varmints took advantage of the vulnerable tree populations. As a consequence, severe damages were observed in German forests leading to a record share of 74 % of damaged timber of the overall logging in 2018 to 2020. Consequently, the high domestic logging rates lead to record breaking export rates while import rates did reduce drastically leading to a positive net export balance (contrary to the positive net import balance for the previous 10 years). What is more, the situation led to a geographic shift of trade relationships of the German exporting wood sector. Since storing capacities were exhausted in neighbouring countries, which had been up that point the main trade partners of this sector, about 50 % of the wood exported from Germany in 2020 went to China (see table 1) (Spathelf et al. 2022). This shows that climatic extremes and the industry's responses can impact the trade balances and flows.

However, it has to be noted that fluctuations in third countries such as the U.S. can likewise impact the German market for forest products (Tandetzki & Weimar 2022). Accordingly, this study is going to identify these paths of impact and how they may be disturbed by climate change. In order to determine in which way climatic shifts and their echoes might affect the German market through its high dependency on wooden products, the following chapter is going to outline the projected climatic situation of Europe (Becher & Weimar 2020).

**Table 1: Change in export rates of coniferous saw wood and wood lumber from Germany from 2019 to 2020 in m<sup>3</sup> (Source: Ebner n. y. based on the German Federal Office of Statistics 2021, own illustration)**

Country destination	of	2019	2020	Change in %
USA		605,526	940,778	55.37
China		436,674	619,285	33.56
The Netherlands		543,620	541,006	-0.47
Austria		566,022	527,690	-6.77
Belgium		432,259	476,631	10.27
France		516,413	464,950	-9.97
Great Britain		333,577	296,054	-11.25
Italy		137,810	276,273	-11.86

## 2.4 The influence of climate change on Germany's wood supply chains

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Before outlining the impacts of climate change on the wood supply in the German wood market, this section will briefly touch on the projections of climatic developments for Germany and the surrounding European regions from which Germany is primarily sourcing wooden resources. In this regard, temperature, precipitation and extreme weather events such as drought periods are relevant indicators for the situation of forests and their resources in the future (Möhring et al. 2021).

Regarding the projected temperature development within Europe, the IPCC's RCP (representative concentration pathway) 4.5 scenario depicts an increase in the annual temperature of at least 1,5°C throughout Europe until the end of the 21<sup>st</sup> century in comparison to pre-industrial levels. The RCP 8.5 scenario even projects an increase in temperature of at least 3°C in most parts of Europe.

According to the RCP 8.5 scenario, annual precipitation in northern Europe is projected to increase while it is projected to decrease especially in the summer in the southern parts of Europe. These projections account for the end of the 21<sup>st</sup> century.

In particular, the interaction of temperature and precipitation, drought and soil moisture, affect the condition of forests and their resources. Events of meteorological drought are supposed to increase almost everywhere in Europe by the mid-21<sup>st</sup> century: "Future projections suggest a small drop in the magnitude of droughts in northern Europe, but substantial increases in central Europe under higher emissions scenarios, and even larger increases in southern Europe" (EEA 2021a)

Besides the climatic developments pictured above, the occurrence of further phenomena such as storms with high wind intensity, which are already leading to severe economic losses for forestry today, are projected to change (Möhring et al. 2021). According to the EEA (2021b), "the frequency and intensity of storms will increase northern and central Europe."

Regarding the climatic influences on the availability of forest resources, a distinction between direct impacts on environmental conditions and indirect effects can be made. The former impact refers to conditions such as droughts and storms, the latter one to infestations triggered or furthered by such conditions (Gömann, 2015).

As the introduced projections show, forests throughout Europe will have to cope with longer dry periods and decreasing overall water availability with the exception of the northernmost countries. In short term, such periods primarily affect the growth of existing forest inventory. Beyond that, longer periods resulting in droughts might lead to an undersupply with water and to a death of trees and especially seedlings. This influence on seedlings hinders the rejuvenation of forests which is fundamental for the long-term situation of forests. Furthermore, heat stress leads to an increased vulnerability of the trees. For example, the production of resin and other defensive substances by trees can be restricted (Gömann, 2015).

Beyond that, extreme weather events such as storms and heavy snow fall in winter lead to demolition of trees. While the short-term effects of such demolitions are primarily of economic nature, the long-term effects may affect wood the wood supply in future years as will be elaborated in the following paragraph. What is more, the conditions mentioned above have favoured the distribution of infestations in central European forests in recent years already. Especially the bark-beetle profits from milder temperatures and weakened forests which are unable to protect themselves under heat and drought stress (Möhring et al. 2021). Yet, not only warmer weather has increased the spread of the beetle, but also dry summers and heavy storms which have turned weakened and dead trees into incubators for beetle populations (UNECE/FAO, 2020). Beyond the bark-beetle, there are other infestations promoted by

climatic conditions and their effects. In recent years, the diploida fungus led to dehydration which partly resulted in the death of trees. Similar to the bark-beetle, this fungus seizes weakened trees and thus its spread indirectly profits from climatic developments (Bußkamp, 2018).

As future conditions are projected to develop increasingly favourable for infestations especially regarding heat and drought periods, these invasions will presumably pose a growing threat for forests. In order to contain persistent reproduction of such infestations, salvages are conducted. Consequently, extreme weather events and bark-beetle infestations have led to increased availability of wood after salvaging operations in 2018 and 2019. The harvested wood often has a lower quality but usually it is still deployable for most usages (Kirisits, 2004).

While the total amount of wood removed from forests due to bark-beetle infestations in affected European countries amounted to 9.9 million m<sup>3</sup> in 2015 it exceeded 100 million m<sup>3</sup> wood in 2019 (UNECE/FAO, 2020). Both heat stress and the vulnerability through the existing infestation lead to such explosions in damages. Here, it has to be mentioned that infestations such as bark beetles usually attack weakened trees in the first place. Yet, as soon as the population reaches a certain size, they are able to infest healthy trees as well (Biedermann, et al., 2019). This is especially the case as monocultures of certain tree species have often been populated for economic reasons (Hlásny, et al., 2019).

The increased availability of wood after salvages might have severe consequences on the otherwise relatively stable wood supply by forests. This is unless measures are being taken in terms of adapting logging activities. However, if such measures are not taken timely and to an appropriate extent, the interruption in wood supply due to irregular wood availability might be perceptible years after the salvaging operations were conducted (UNECE/FAO, 2020).

### 3 Interdependencies in the timber trade market in the context of climate change

As outlined before, international trade dynamics are affecting the German wood sector as any other sector in a globalized world. Therefore, these dynamics, although already broached earlier, will be outlined in the following investigating the following questions:

- Which countries are the main drivers of worldwide wood market?
- What has been influencing the demand of these countries in which way?
  - Macroeconomic developments
  - Wood as sustainable resource
  - Effects of climate change (e.g. beetle/drought)
  - Climate adaption/protection strategies (less logging)
- How has this changed import and export behaviour of these countries?
- How has this in turn influenced the German wood market through imports and exports?

As outlined in chapter 2.3, Germany's main source for wooden products is the European market namely its surrounding and northern European countries. However, not only the imports conducted by Germany in order to satisfy its wood demand are determining the availability of the resource. Beyond that, the export behaviour of Germany, being one of the biggest exporting countries of wooden products (Government of Canada 2018), that is driven by the worldwide demand strongly impacts the wood market situation in Germany as the situation in 2021 shows: In the first half of 2021, reports repeatedly emerged in Germany regarding a shortage of raw materials in the wood processing industry (Denkler, 2021). This shortage was majorly triggered by an increased demand for wood particularly from the U.S. due to government subsidies provided in response to the pandemic situation. These subsidies increased construction activity. Furthermore, a decline in supply from Canada – the main sourcing country of the U.S. – led the country to importing more wood from farther away. Thus, supporting funds for the U.S. industry enabled it to import vast amounts from Germany and other European countries. This in turn pressured the German market leading to the consequences outlined in chapter 2.2 (Daller, 2021).

As will be shown in the following, the potential influences on wood producing and processing industries under climate change may aggravate such bottlenecks triggered by relatively short-term crises. However, it will also be shown that climate change alone is likely to impact these industries and thus the global supply of wooden goods. For example, the increased demand for wood in the U.S. building sector is not least due to the required reconstructions after wildfires in California resulting from severe droughts (Denkler, 2021). This brief example points out how complex the interdependencies in the wood market are and how the German wood market is embedded in this complexity.

In order to comprehend these interdependencies, the global situation will be depicted by exemplarily outlining the situation of relevant importers and exporters in the forest product market. Moreover, it will be outlined how and to what degree these countries are already and will be influenced by climate change before the consecutive chapter is depicting the relationship between certain climatic shifts and the availability of wooden resources.

With Canada and the U. S., North America encompasses both a major exporter and a relevant importer of wooden resources. As projections depict, the North American continent will be witnessing increasing temperatures towards the end of the 21<sup>st</sup> century. According to a high emission scenario, especially the summer months are supposed to reach temperatures exceeding those of the late 20<sup>th</sup> century summer times in more than 50 % of the years (Romero-Lankao, et al., 2014). As recent years have shown, such exceptionally hot summers

lead to an increased tree mortality. Beyond that the vulnerability of trees regarding infestations increased. Relatively warm winter months facilitating high survival rates of larvae additionally promoted massive outbreaks of varmints in US and Canadian forests (Denkler, 2021). As drought severity is projected to enhance in the southwestern parts of the U.S. which will be affecting woodlands (Romero-Lankao, et al., 2014), the region with the largest share in wood supply within the U.S. will experience the largest impacts among the timberland regions (see figure 5). Such developments will not only result in heat stress and increased vulnerability regarding infestations but also in an increased tree mortality.

Beyond that, suspected warming in the western parts of North America might expose Canada's largest wood producing state, British Columbia, to heat stress and increased varmint and pathogen occurrence (Romero-Lankao, et al., 2014). Other incidents strongly impacting forests in North America are wildfires often destroying broad areas of forest lands. Projections regarding the occurrence of such fires cannot be made univocally. Yet, heat, drought and infestations are favouring the occurrence of wildfires (Mietkiewicz & Kulakowski, 2016). As mentioned above, these conditions are likely to occur more frequently suggesting that wildfire risk increases in North America (Romero-Lankao, et al., 2014).

Regarding the economic impacts of heat stress and subsequent insect infestation, it has to be noted that infested wood is in most cases still deployable as resource for most applications. As mentioned above, beetles infesting the bark of trees or fungi often lead to aesthetic changes of the wood which do not limit its further qualities (Kirisits, 2004). Yet, infestation lowers the price of wood.

At the same time, varmint outbreaks have to be counteracted which is often done by salvaging harvests. In such cases, the allowable cut of healthy trees that have not been infested and were planned to be cut is often adjusted accordingly. This on the one hand prevents an oversupply and price decline on the wood market. On the other hand, such measures have to be taken to prevent future wood shortages due to insufficient regrowth (Corbett, et al., 2016). Thus, if the wood salvaged due to infestation does not exceed the amount of forest regrowth and the salvaged wood is applicable for commercial applications, the economic consequences seem containable. Yet, similar to the situation described for Europe (see chapter 2.3 and 2.4), it is not clear what extent future outbreaks benefited by the consequences of climate change will reach.

From 2018 on, Canada's forests have been facing more frequent outbreaks of the mountain pine beetle. The pine beetle is being discussed as one factor that makes forests more vulnerable to wildfires (Perrakis et al., 2004; Harvey et al., 2013; Meigs et al., 2015), also in the case of fires in Canada that lead to a regional shortage in harvests (Meyer, 2021). Thus, the economic use of wood and the way it shapes current forests further aggravate potential threats for silviculture and the forests in general which will be amplified by climate change anyways.

While Canada and the U.S. are large contributors to the global wood market, possible influences by other contributors should be mentioned. In this regard, China as the world's largest importer of wooden products and the Russian Federation being the largest exporter to China and a large supplier to other countries should be mentioned as well.

Projected temperature increases in Asia are supposed to be particularly strong throughout Russia due to the country's northern location. Depending on the emission scenario chosen, temperature increase range between 2°C and 6°C while the average precipitation amount per year is expected to increase accordingly except for most western parts of Asia (Hijioka, et al., 2014).

While precipitation is not suspected to be the most striking issue in the upcoming decades for this region, the warming expected in Russia is projected to increase infestations and weaken forests in this regard (Hijioka, et al., 2014). Here, especially a spread of infestations due to

warmer climate is expected in regions former considered too cold for certain species (Baranchikov, Akulov, & Astapenko, 2011).

However, Russia and China are of special interest for this consideration due to the actions the countries have taken regarding climate change and adaptation. As China is increasingly restricting its own forests from being harvested in order to protect its own nature, it becomes more dependent on imports from abroad (Forest Trends & Chinese Academy of Forestry, 2019). This is primarily concerning imports from countries such as Russia which is already a large supplier of Chinese imports of forest products. However, Germany also has been impacted by such shifts (see chapter 2.4) (UNECE/FAO, 2020).

However, global trade relations changed dramatically once Russia invaded Ukraine in early 2022. One of the consequences for Russia was an import ban for wood from Western countries. As one way to try to circumvent the economic effects of this ban for Russia, Putin might move away from his initial plan to curtail wood exports. Thus, it is likely that China will profit from the situation since it has not yet proclaimed any trade bans against Russia. However, the situation does not only affect China, most likely the whole world will be affected. Germany and other European countries exporting wood may face an even bigger demand for FSC certified wood since all wood originating from Russia, Belarus and Ukraine is now being labelled as conflicted and therefore cannot be certified. Missing import opportunities for European countries for wood from Russia and Ukraine (due to missing capacities) therefore might foster domestic uses which again would impact the import situation of the U. S. which, in turn, will face limited resources for importing wooden goods from Europe which will affect prices again (O'Kelly Acumen n. y.).

While the causes of these developments are of foremost political and economic nature, their implications for the wood market beyond possible threats for forest stocks through climatic shifts are apparent. Yet, as climate change proceeds, its impacts on forests might further press countries into aggravating policies either increasing wood import demand or decreasing export volumes resulting in tightened competition for resources. As mentioned above, such influences have been observed regarding the U.S. demand for wood and are likely to re-appear as climatic projections depict. Thus, it is not unlikely that similar processes might be triggered in other countries. Since Russia will most likely be exposed to severe climatic changes and their effects on forests, similar occurrences cannot be ruled out.

## 4 Conclusion

This case study investigated the preconditions of the German wood industry with a special emphasis on the impacts of climate change today and in the future. Furthermore, other recent crises and resulting developments affecting not only the domestic wood industry but also the industries import and export behaviour were investigated. Consequently, this case study covered not only developments in Germany and Europe but also on other continents with important trade relations for the Germany wood industry.

It was shown during this case study that the melange of actors and trade relations is very complex. Moreover, the whole industry both on the supply and the demand side is very vulnerable to external shocks. While this might not be surprising at a first glance, it could be further shown that the continuously ongoing shocks triggered for wood production by climate change are likely to overlap with other shocks that influence global trade patterns (e.g. through lockdowns, trade bans or inflation). As both the German wood producing and processing industry are highly intertwined with international actors, those overlaps are likely to affect the sector in various ways.

In the course climate change, it is especially to be expected that production and logging bottlenecks may occur on different places on the globe simultaneously since the likelihood for extreme weather events like droughts and storms increases. Thus, price shocks are to be expected, especially for a slowly renewable resource like wood. Thus, the German wood industry should enhance efforts in being able to respond flexible to both bottlenecks and overproduction in the course of pest infestation.

In other words, it should improve its resilience. Obviously, the conversion of forests to strengthen them towards future climate conditions and extreme weather events is mandatory in order to prevent more severe and/or more frequent wood supply shortages. Also, the national and global efforts towards the mitigation of climate change are key in every industry sector including the wood producing and processing industry. What is more, the interconnectedness of this aim with the renewable resource wood may not be forgotten. For a sustainable transformation of the construction sector for instance, it is mandatory that there is enough wood available. Thus, strategies to enhance the flexibility under the changing conditions mentioned above of the wood sector need to be developed. These strategies should include an enhanced cooperation with neighbouring countries and other EU member states regarding the monitoring and care of the resource itself (including transnational forests), the demand, infrastructures (like storing facilities for wood and their expansion).

Bearing in mind the necessity to rebuild the German forests to strengthen their resilience under future climate, the equal distribution of profits should be observed. Since forest owners are the ones expediting the rebuilding of forests, they need to gain sufficient financial resources and incentives to be able to do so. This will ensure sustainable forestry practices in the future. Hence, the risk for market structures to change in a way that forest owners cannot gain these resources should be monitored carefully.

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