Store or export? An economic evaluation of financial compensation to forest sector after windstorm. The case of Hurricane Klaus.

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1. Introduction

Western European countries have been hit by several extreme windstorms during the last 15 years. In 2013 alone, four major windstorm events affected these countries, namely Christian, Cleopatra, Xaver and Dirk. Many of these extratropical windstorms had a major impact on forests and created huge windfalls. In 1999, Lothar and Martin wound their way across France, Switzerland and Germany, leaving 30 million m^3 of windfall and/or tree damages in Germany alone, amounting to a financial loss of €1.4 billion. In France, about 140 million m^3 were destroyed, resulting in a loss of €4.57 billion. Germany provided €15.3 million for windfall hauling, transportation, storage and replanting (Holecy and Hanewinkel, 2006), while the French government provided €920 million over a 10-year period in order to remove windfall timber from destroyed stands, to clear and replant stands and to create storage areas for harvested timber (CGAAER, 2010). In 2005, Denmark was hit by Hurricane Gudrun, leaving 2 million m^3 of felled forests in its wake, mostly in coniferous stands. The Danish government also provided compensation to forest owners but only for those who were covered by a minimum of a basic forest insurance policy. A public assistance of €20 million was provided, which covered about half of the estimated losses and costs (Brunette and Couture, 2008).

More recently, Hurricane Klaus hit southwestern France on 24 January 2009. Damages were concentrated in the Aquitaine region (95%) and most of the damaged trees were maritime pine [*Pinus pinaster*]: 37.1 Mm^3 over approximately 42 Mm^3 of total windfall (Bavard et al., 2013). Lecocq et al. (2009) estimated a total financial loss of €1.34-1.77 billion for maritime pine stands. In 2011, i.e., two years later, a bark beetle attack increased the total wood loss by approximately 7 Mm^3, of which 4 Mm^3 was greenwood (wood from standing trees, non-windfall) (Bavard et al., 2013). A compensation plan of €138.5M was provided by the French government in the form of subsidized rate loans (€12.5M), storage area subsidies (€25M), transport subsidies (€56M) and transshipment subsidies (€46M) (Bavard et al., 2013). This compensation plan was formulated within 6 weeks after the storm, before being approved by the European Commission on 3 June 2009. Much criticism was voiced by some stakeholders regarding the relative weight of subsidies allocated to transport and to storage (Bavard et al., 2013). In particular, some of this criticism accused the plan of being too transport-friendly and leading to subsidy leakages for the benefit of foreign processing industries.

So far, public compensation programs have been extensively studied from the perspective of their impacts on forest owner risk management decisions. Holecy and Hanewinkel (2006) advanced the idea that public compensations could have a negative impact on forest owners' insurance coverage decisions. More generally, many have argued that the expectation of liberal disaster assistance following a catastrophic event can deter homeowners from purchasing insurance (Kaplow, 1991; Harrington, 2000; Gollier, 2001; Kunreuther and Pauly, 2006; Brunette and Couture, 2008). Brunette and Couture (2008) examined the effects of public financial assistance programs on forest owners' optimal risk management decisions and showed that providing public financial assistance to non-industrial private forest owners after damage-causing events may reduce their incentive to purchase insurance or invest in protective forest management activities.

Meanwhile, the question of the impacts of these compensation programs over the whole forest sector economy has barely been addressed in the literature. In particular, the impacts on economic agents' surpluses, on trade balance deficits and on wood price dynamics are absent from the economic literature. One notable exception is Costa and Ibanez (2005) who carried out an economic analysis to assess the profitability of storage after the Lothar and Martin hurricanes in France in 1999. They estimated the impacts of storage on wood prices and its dynamics and concluded that, from an individual point of view, storage was not profitable and wood prices did not return to their pre-1999 levels. However, this study does not assess the impacts of the compensation plan on trade-offs between storage and export and on the dynamics of economic agents' surpluses. More generally, not enough studies have included meaningful economic evaluations of public policies and, to our knowledge, no study has yet to be carried out within a partial equilibrium framework.

Yet, given the amount of money invested in such plans, their policy relevance must be questioned for the entire forest sector. In particular, the impacts of the distribution of the plan among the different activities (storage, transport, transshipment) and on economic variables (wood production, consumption and prices) over the forest sector economy remain unclear since it is actually difficult to estimate what would have happened without a plan or with an alternative plan.

This paper aims at filling this gap by analyzing the impacts of the compensation plan after Hurricane Klaus within a partial equilibrium economic model framework. To do this, we modeled both the physical impact of Hurricane Klaus on French forests and the economic impacts of the compensation plan within the French Forest Sector Model (FFSM), a bio-economic partial equilibrium model of the French forest sector (Caurla et al., 2010; Caurla, 2012b). We then explored the impacts of the plan as it was negotiated compared to a scenario without a plan, and we provided insights into the relative importance of transport and storage assistance by comparing the outputs of a transport-oriented assistance scenario with those of a storage-oriented scenario and with those from the plan as it was negotiated (referred to as the "observed" plan below). Impacts on economic agents' surpluses and on wood prices are analyzed in detail.

The paper is organized as follows. Section 2 presents the FFSM bio-economic model used for the analysis and the methodology, making it possible to represent the impacts of Hurricane Klaus. Section 3 gives the simulation results relative to the impacts of the compensation plan on windfall supply and wood prices, as well as a surplus analysis. Section 4 is devoted to the conclusion.

2. *Material and methods*

2.1. The FFSM 1.0: a bio-economic model of the French forest sector

The French Forest Sector Model (Caurla et al., 2010; Caurla, 2012b) is a recursive simulation model of the French forest sector[1]. As shown in Fig.1, it consists of two interrelated modules: a forest dynamics module (FD) and an economic module (E). At each period (year), given available timber resources, timber supply functions, transformation technologies and capacities, as well as demand functions for (first-transformed) timber products, the E module computes all market equilibriums in the forest sector (Caurla, 2012a), from which it deduces the annual harvest. Harvest then enters the FD module, which computes the available timber resource at year $t + 1$. This enters the E module, and so on and so forth. The model is

[1]The detailed presentation of the model is available at http://ffsm-project.org/wiki/en/home.

implemented under the General Algebraic Modeling System (McCarl, 2013) and runs for periods of 10-20 years.[2]

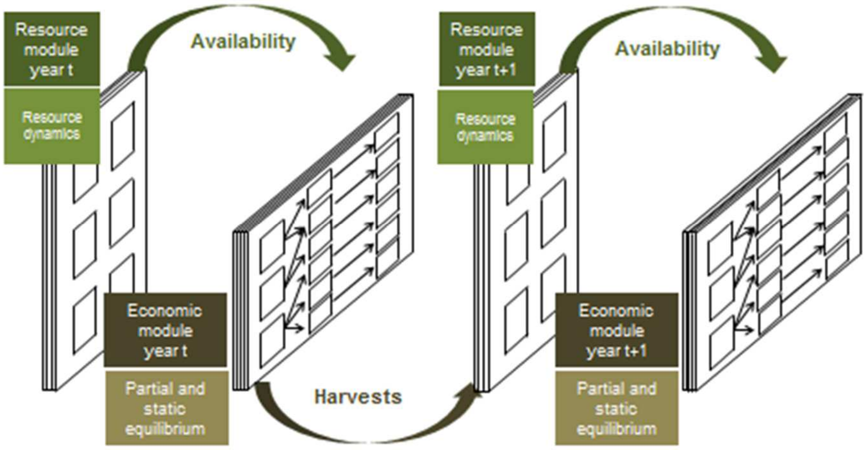

Figure 1: The FFSM is based on a recursive and modular framework.

The FD module (Caurla, 2012b, pp.129-154) simulates timber stock dynamics using a diameter-class approach. Since French forests are very diverse in terms of climate, soils, species and types of management, the FD module breaks down the timber resource into 1716 cells that differ by region (22 administrative regions), type of management (high forests,[3] coppice, mixed), species (coniferous and broadleaved) and diameter classes (a total of 13). Resource dynamics in each cell are calibrated using data from the 2005-2007 French forest inventories (Colin and Chevalier, 2009).

Between two successive years, the dynamics of wood volume for a specific cell follows the equation:

$$V_{u,t+1} = V_{u,t} \times (1 - tp_u - m_u - h_{u,t}) + V_{u-1,t} \times tp_{u-1} \times \beta_{u-1} \qquad (1)$$

[2]Since investment decisions of both wood suppliers and transformation industries are exogenous, the current version of the FFSM is ill-suited to longer-term simulations.

[3] High forests are forests that originated from seed or from planted seedlings. In contrast, coppice forests are forests where trees make new growth from the stump or roots.

where V is the volume of wood, u is the diameter class, t is the time period (year), tp_u is the time of passage for a tree in diameter class u, m_u is the rate of natural mortality in diameter class u, $h_{u,t}$ is the harvest rate (derived from the economic module of the FFSM), and β_{u-1} is a coefficient that accounts for the height growth of trees when upgrading from class u-1 to class u.

The E module (see Fig. 2) is a partial-equilibrium model of the French forest sector, from timber production to the consumption of first-transformation products. Four raw timber products are taken into account, fuelwood, pulpwood, hardwood and softwood roundwood, and six processed timber products, hardwood sawnwood, softwood sawnwood, plywood, pulp, fuelwood, and fiber and particle board. Three groups of agents are represented in the model: wood suppliers (either forest owners or forest managers on behalf of forest owners), the transformation industry and consumers (either final consumers or second-transformation industries).[4]

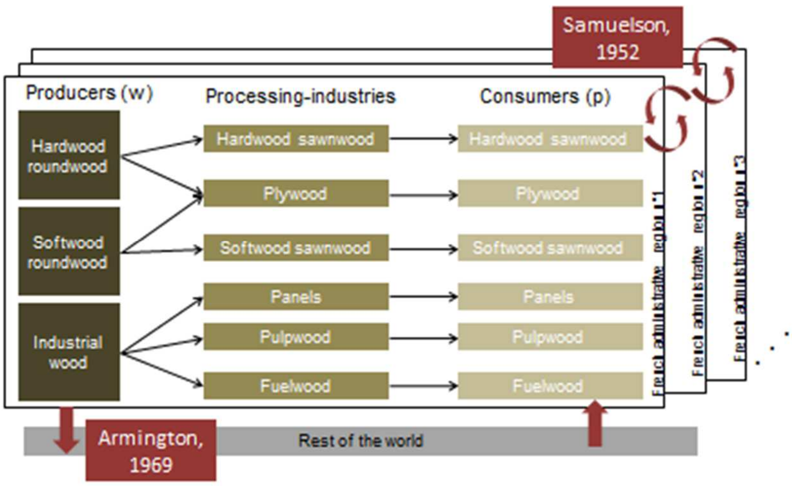

Figure 2: Description of the economic module E.

The E module distinguishes 22 administrative regions within France, and inter-regional trade is modeled assuming perfect competition and full substitutability of products across regions, according to Samuelson (1952). International trade (exports of raw products and imports of

[4]The transformation industry is modeled using Leontief production functions. Under our assumption of perfectly competitive markets, the transformation industry makes zero profit at equilibrium (Caurla, 2012a).

processed products) is modeled assuming imperfect substitutability within the Armington (1969) framework. The E module is calibrated using data from the literature and specific estimates, as presented in Caurla et al. (2010) and Sauquet et al. (2011).

The FFSM has the same partial equilibrium structure as existing global forest sector models such as the Global Forest Model (EFI-GTM) (Kallio et al., 2004), the Global Forest Products Model (GFPM) (Buongiorno et al., 2003) and the Global Trade Model (GTM) (Kallio et al., 1987; Cardellichio et al., 1989), and as national forest sector models such as the Finnish Forest Sector Model (SF-GTM) (Ronnila, 1995; Kallio, 2010) and the Norwegian Trade Models (NTM and NTM II) (Tromborg and Solberg, 1995; Bolkesjø, 2004). However, the FFSM differs from existing models on three main aspects:

- It focuses on France: 22 metropolitan French regions (corresponding to French administrative regions) and one aggregate "Rest of the World" region are represented.
- It models international trade using Armington's (1969) theory that assumes imperfect substitution between domestic and foreign products.
- Its biological module captures French forest specificities, notably the inter- and intra-regional diversity in species and silvicultural practices.

2.2. Adaptation of the model to represent the impacts of hurricanes on resources and on storage

We modified the FFSM in two ways for the study: (1) we represented the windfall wood in the FD module; and (2) we included a detailed representation of storage in the E module.

2.2.1. Modeling windfall volume in the FD module of the FFSM

Windfall volume is directly accounted for in Equation 1 (through parameter *storm* in the resulting Equation 2). We distributed the total volume of maritime pine windfall (37.1 Mm^3 in 2009) and the volume of maritime pine affected by bark beetles (4 Mm^3 in 2011) among the cells matching: (1) the region = Aquitaine; (2) the type of management = high forest; and (3) the species = coniferous. Since 98% of coniferous forests in the Aquitaine region are maritime pine, this is an accurate approximation.

$$V_{u,t+1} = V_{u,t} \times (1 - tp_u - m_u - h_{u,t}) + V_{u-1,t} \times tp_{u-1} \times \beta_{u-1} - storm_{u,t} \quad (2)$$

There is no consensus over the rate of degradation on windfall wood after a storm. In particular, there is uncertainty about the time available before logs become unsuitable due to fungal staining or decay, and infestation by insects. Focusing on *Pinus radiata*, McCarthy et al. (2010, 2012) showed that these time lapses depend on season, climate, atmospheric moisture and species. Since no scientific material is currently available for maritime pine in southwestern France, we assume a 5% degradation rate per year on windfall wood.

2.2.2. Modeling windfall wood supply and storage in the E module of the FFSM

We improved the initial version of the FFSM to make it possible to deal with windfall storage. To do so, we distinguished: (1) wood stored in storage areas; (2) wood directly consumed by processing industries; and (3) wood exported. Indeed, the costs underlying these three types of trade are different, leading to different associated supply functions.

We also paid special attention to storage by distinguishing prepaid stored wood from non-prepaid stored wood since they are based on distinct economic behaviors resulting in different impacts on price dynamics. The volume of prepaid windfall wood is assumed to be fixed, whereas non-paid wood is supplied according to price dynamics following the supply function (a) presented in the next section.

The flowchart in Fig. 3 represents the additional physical flows accounted for (red/dotted lines) and their inclusion in the model.

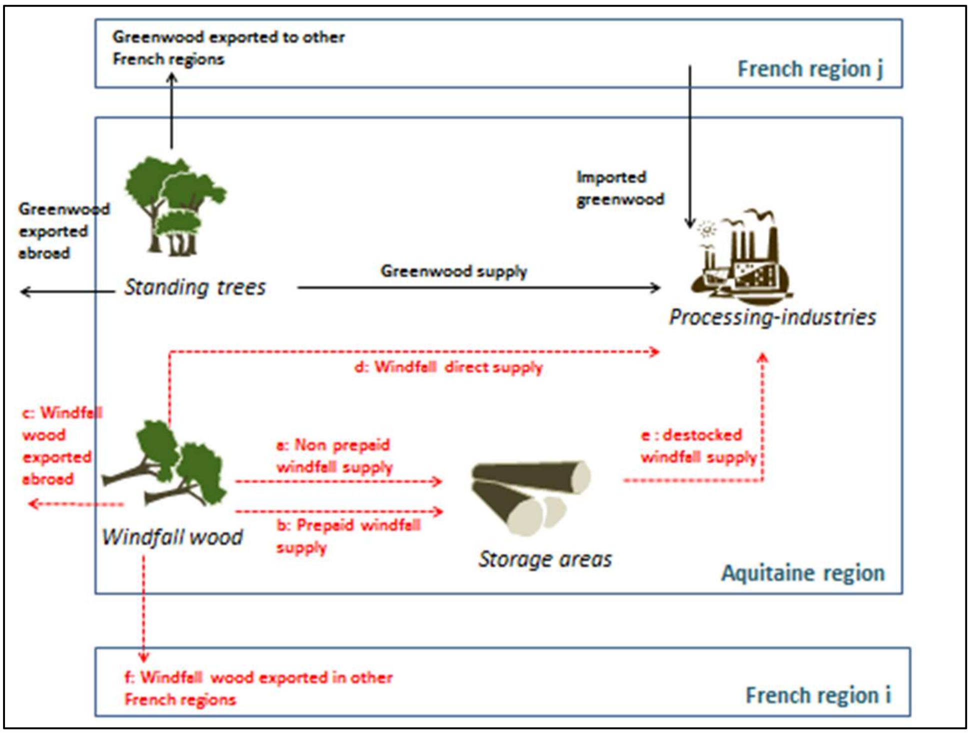

Figure 3: Red/dotted lines: additional wood flows represented in the FFSM (associated with windfall). Black/solid lines: existing flows in the FFSM (associated with greenwood).

As shown in Fig. 3 and for each year, processing industries now have to choose between greenwood, directly supplied windfall or destocked windfall from storage areas. In addition, greenwood imports from other French regions are represented through the spatial price equilibrium framework (Samuelson, 1952) of the FFSM. In the FFSM, the resulting choice implemented by processing industries among these four options is driven by both relative product prices and product availabilities. Figure 3 also shows that upstream, windfall wood suppliers have to choose between exporting their windfall abroad, exporting it to other French regions, storing it (either by pre-selling it or not) or selling it directly to processing industries. Their incentives therefore depend on: (1) wood prices; (2) subsidies allocated to storage, transport and harvests; and (3) supply elasticity values regarding wood prices.

Following this representation, we define four additional supply functions in the FFSM corresponding to the flows *a, c, d* and *e* in Fig. 3. As a prepaid windfall stock, flow *b* is fixed *ex ante* and flow *f* is accounted for in the Samuelson spatial price equilibrium framework and does not require additional supply functions.

a. <u>Non-prepaid windfall supply function:</u>

$$S_{no\_prepaid} = P(1 + sub_{storage})^{\sigma}$$

where P is the unit price of windfall wood and $sub_{storage}$ is the subsidy rate for storage. The rate of the subsidy is calibrated by trial and error so that:

$$\sum_{t=2009}^{2020} P \quad \times S_{no\_prepaid} \times sub_{storage} = Total\ observed\ amount\ of\ subsidies\ to\ storage$$

c. Windfall export abroad function:

$$X \quad = P(1 + sub_{transport})^{\sigma}$$

where P is the unit price of windfall wood and $sub_{transport}$ is the subsidy rate for transport abroad. The rate of the subsidy is calibrated so that:

$$\sum_{t} P \quad \times X \times sub_{transport} = Observed\ total\ amount\ of\ subsidies\ to\ transport\ abroad$$

d. Windfall direct supply (without storage):

$$S_{direct} = P(1 + sub_{direct})^{\sigma}$$

where P is the unit price of windfall wood and sub_{direct} is the subsidy rate for direct supply. The rate of the subsidy is calibrated so that:

$$\sum_{t} P \quad \times S_{direct} \times sub_{direct} = Observed\ total\ amount\ of\ subsidies\ to\ direct\ supply$$

e. Windfall destocking supply function

$$S_{destock} = P'^{\sigma}_{destock}$$

where $P'_{destock}$ is the price of wood destocked from storage areas.

2.2.3. Estimation of subsidy rates in the observed scenario

The calibration of the observed scenario is based on the overall amounts of subsidies. The total observed amount of subsidies to storage equals €25M. The value of the subsidy rate $sub_{storage}$ is calibrated through a trial and error process that results in a level of subsidy of 500% (prices multiplied by 6). The total observed amount of subsidies to transport

$sub_{transport}$ equals €56M. About half of this amount was used for transport abroad. The other half was used for transport to other French regions. The value of the subsidy rate is calibrated at a 550% level, whereas transport to other French regions is also subsidized at a 550% level. The total amount of subsidized rate loans corresponds to €12.5M, which leads to, through a trial and error calibration process, a 150% subsidy sub_{direct} rate level.

2.2.4. Storage dynamics in storage areas

All windfall stored (either prepaid or non-prepaid, i.e., $S_{prepaid} + S_{no\_prepaid}$) is maintained for at least two years in storage areas before being sold. This was a required condition for the attribution of subsidies to storage (Bavard et al., 2013). We therefore imposed this constraint in the model.

After two years, windfall stored in storage areas is made available for supply $S_{destock}$. The model then computes the optimal volume of destocked windfall by taking the available stored windfall into account, as well as the level of competition with (1) greenwood and (2) directly supplied windfall (S_{direct}).

Technically, we added $S_{destock}$ to the material balance equation of the FFSM (Caurla et al., 2010; Eq. (18) p.11) in order to model the physical competition between stored windfall, non-stored windfall and greenwood. We also added a constraint that gives the quantity available for destocking. This quantity is computed as the sum of volumes that spent at least two years in storage areas:

Available quantity (t+1) = Available quantity (t) + $S_{prepaid}$ (t-1) + $S_{no\_prepaid}$ (t-1) - $S_{destock}$ (t)

2.2.5. Estimate for the price elasticity of windfall supply

For the simulation analysis, a price elasticity of windfall supply is required to calibrate the model. When estimating the timber supply equation and the price elasticity, the problem of being unable to identify what we are looking for may arise, simply because we have market data and it is difficult to separate the demand from the supply function. A way to deal with this issue is to estimate a system of simultaneous equations that depict a model of market equilibrium consisting of timber demand and supply equations. The joint determination of quantity and price makes these variables jointly dependent and thus endogenous. However, several variables can be assumed to be determined outside the model, making it possible to identify all of the parameters of interest. Estimation results show a price elasticity of supply equal to 0.92, significantly different from 0 at the 1% level. The estimation methodology and results are described in detail in Appendix A.1.

2.2.6. Presentation of the alternative scenarios

As mentioned in the introduction, our aim is to question the distribution of the plan among the different activities (storage, transport) on economic variables (wood production, consumption and prices). To do that, we tested two alternative scenarios, namely a "storage" scenario and a "transport" scenario. We assumed that in both scenarios, the total amount of money released for subsidies was equal to the amount in the "observed" scenario. In the "storage" scenario, transport subsidies are reduced by €20M. Subsidies to storage are then increased by this amount in the FFSM so that the total amount of money released remains stable compared to the "observed" scenario.[5] Similarly, in the "transport" scenario, subsidies to storage are reduced by €20M and transport subsidies are increased by this amount.[6]

By comparing "storage" and "transport" scenarios, we aimed to assess the impacts of the share of subsidies on: (1) total supplied quantities and distribution of the supplied quantities; (2) price dynamics; and (3) surplus gain dynamics.

3. Results

3.1. Impacts of the plans on windfall supply

Table 3 shows the total harvested volume over the period 2009-2020 for the four scenarios considered. We can observe that the total harvested volume is lower in the "without a plan" scenario compared to the three scenarios with plans. This is because windfall harvest is faster when a plan is implemented, therefore reducing the risk of forest degradation. Meanwhile, total harvest volumes are similar for the three alternative "with plan" scenarios, revealing that

[5] New subsidy rates are calibrated through a trial and error process: 800% for storage and 200% for transport.
[6] New subsidy rates are calibrated through a trial and error process: 200% for storage and 800% for transport.

the total volume harvested does not depend on the type of activity subsidized but, instead, on the total amount of subsidies.

Table 3: Total windfall supply for the 2009-2020 period and its distribution among storage, direct consumption and export abroad.

	Storage in storage areas Mm^3	Supply for direct consumption in processing industries Mm^3		Export abroad Mm^3	Total Mm^3
		In the Aquitaine region	In other French regions		
"Without a plan" scenario	7.14	5.19	7.47	5.2	25
"Observed" scenario	10.16	3.22	7	8.66	29.04
"Transport" scenario	6.56	3.34	6.89	12.15	28.94
"Storage" scenario	13.25	3.25	6.99	5.37	28.86

Then, as expected and as shown in Table 3, the quantity of windfall stored increases in the storage scenario and decreases in the transport scenario compared to the observed scenario. More precisely, over the entire period (2009-2020), reallocating €20M of transport subsidies to storage increases the quantity of windfall stored by 30%. On the other hand, reallocating €20M of storage subsidies to transport decreases the volume of windfall stored by approximately 48% in the transport scenario.

Conversely, the quantity of windfall exported increases in the transport scenario and decreases in the storage scenario compared to the observed scenario. More precisely, exported windfall increases by 40% in the transport scenario and decreases by 38% in the storage scenario when the two scenarios are compared to the observed scenario and for the period 2009-2020.

As a consequence, the volumes destocked from storage areas are also bigger in the storage scenario compared to the transport scenario (see Figure in Appendix A.2).

3.2. Impacts of the compensation plan on wood price

Figure 5 presents projected wood prices in the Aquitaine region for all scenarios over the 2009-2020 period.

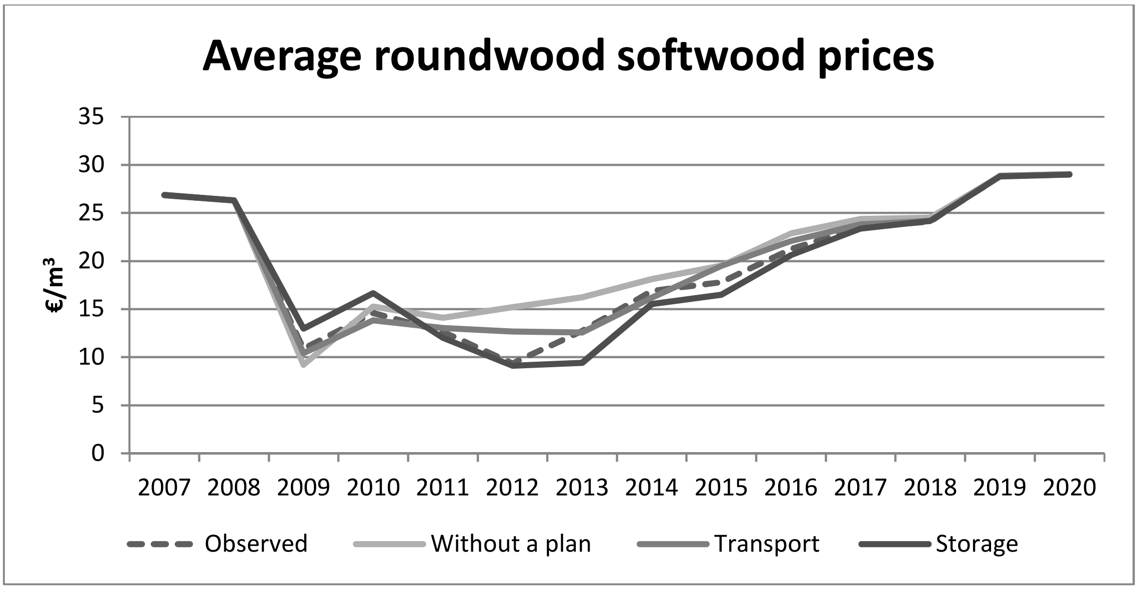

Figure 5: Wood prices computed as an index price encompassing windfall and standing tree wood prices.

Figure 5 shows that the plan reduces the price drop just after the storm compared to a scenario without a plan. This effect is even bigger in the storage scenario. This is because the additional storage makes it possible to withdraw windfall from the market, which tends to smooth the drop in price due to the massive supply of windfall after the shock. This is a policy-relevant result in a context where a major risk is the windfall wood sold off.

As of 2012, however, prices are lower in the storage scenario compared to other scenarios. This can be explained by the higher proportion of windfall wood in the overall wood mix in this scenario. In fact, more wood destocked from the storage area enters the supply mix as of 2012 (see Appendix) in the storage scenario compared to the other scenarios. Yet, since windfall wood is much cheaper than greenwood, the resulting average price remains lower in the storage scenario compared to the other scenarios. Conversely, the transport scenario leads to an earlier higher proportion of greenwood in the supplied wood overall mix. Since greenwood prices are higher than windfall prices, the overall price index in the transport scenario is higher and exceeds those of the other scenarios as of 2014.

Another policy-relevant result is therefore that increasing storage is likely to postpone the price rebound. This effect can be reduced by increasing the proportion of prepaid windfall in storage areas.

3.3. Surplus analysis

The surplus gain presented in Fig. 6 is computed as the difference between the total national economic surplus in each scenario with a plan (“observed”, “storage” or “transport”), minus the total national economic surplus in the scenario without a plan. In the FFSM, the total economic surplus is computed as the sum of the surpluses of all producers, consumers, processing industries and transport agents for all French regions.

Figure 6 shows that the gain in surplus due to a compensation plan is always positive, regardless of the proportion of storage or transport subsidies. This means that all plans projected in the model are beneficial to the forest sector. However, the discounted sum of surplus gain in 2009 for the storage scenario is much higher (about €75M with a 4% discount rate) than the discounted sum of surplus gain for the observed scenario (about €44M with a 4% discount rate) and those of the transport scenario (€28M with a 4% discount rate).
However, while the surplus gain is always higher in the storage scenario compared to other scenarios, it is higher the first two years in the transport scenario compared to the observed scenario, before going below it.
To understand these results, we propose to focus on the impacts on surplus for every group of economic agents in the FFSM. Since we cannot present the results for all agents in all regions, we focus on a representative agent for each level of the sector. We therefore successively present the surplus impacts on transformed product consumption, on greenwood supply, on destocking and on windfall supply.

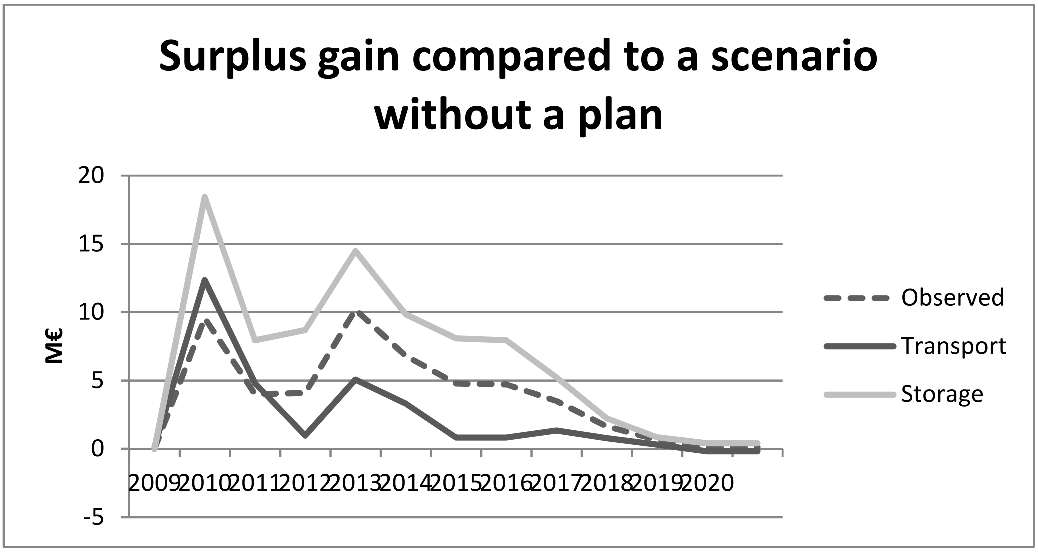

Figure 6: Total gains in surplus.

First, Fig. 7 shows two phases in the surplus gains linked to the consumption of transformed products. All plans lead to a surplus loss (negative gains) in the first two years, compared to what occurs without a plan. This is because, regardless of the level of subsidies to storage, all plans smooth price drops the first years compared to what would occur without a plan. Since the price drop is beneficial to consumers, this explains the shape of the curve. As of 2011 or 2012, however (depending on the scenario), all plans lead to positive surplus gains. These gains increase when the storage proportion increases. In fact, the price increase after 2010 is also smoothed and limited in the storage scenario because of the higher proportion of windfall wood in the overall wood mix. Consumers greatly benefit from this effect, as shown in the case of hard-sawnwood consumption in Aquitaine in Fig. 7. Because of the Samuelson price equilibrium framework, this impact is transmitted to all softwood products in all French regions.

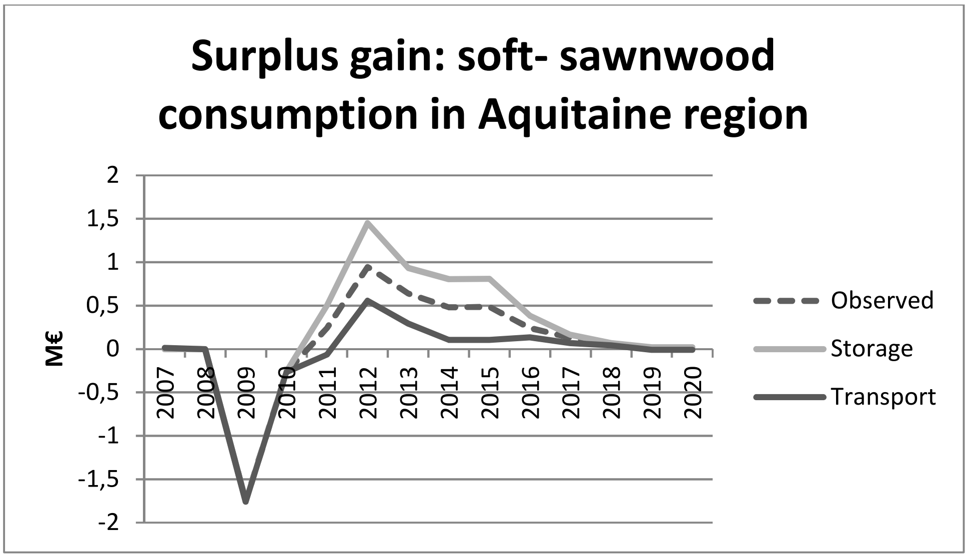

Figure 7: Gains in surplus related to hard–sawnwood in Aquitaine.

Destocking activities also benefit from reallocating transport subsidies to storage. As shown in Fig. 8, the gain in surplus is always positive and higher in the storage scenario compared to the observed scenario. This can be explained by the additional stored volume at lower storage costs. Destocking and, therefore, positive surplus gains, begin in 2011 as a result of the compulsory 2 years of storage (see Section 2.2.3).

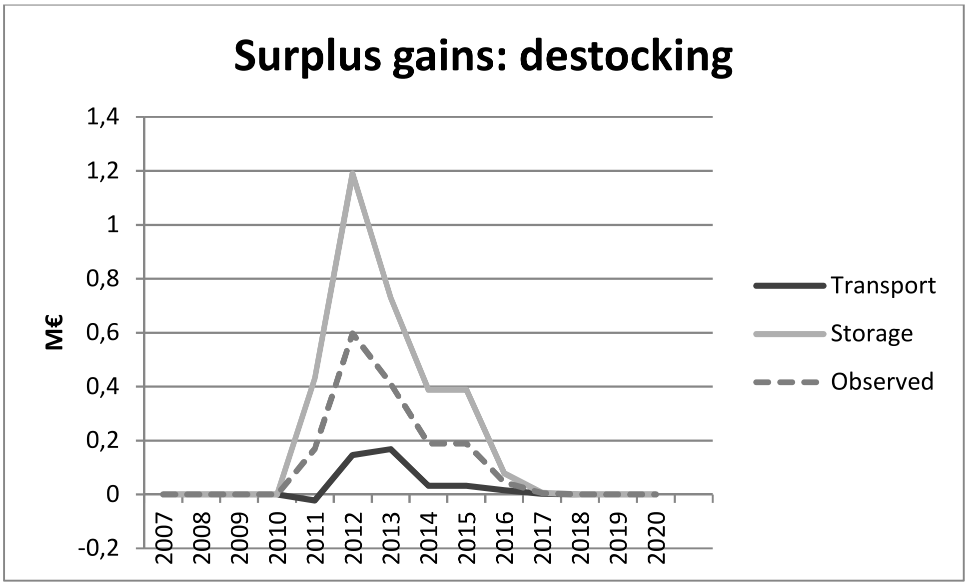

Figure 8: Gains in surplus related to destocking activities.

The surplus gains linked to windfall supply depend on the proportion of storage and transport subsidies, as shown in Figs. 9 and 10. As expected, a storage-oriented scenario is likely to increase surplus gains due to storage activity, whereas a transport-oriented one would clearly increase surplus gains due to export in an almost symmetrical way.

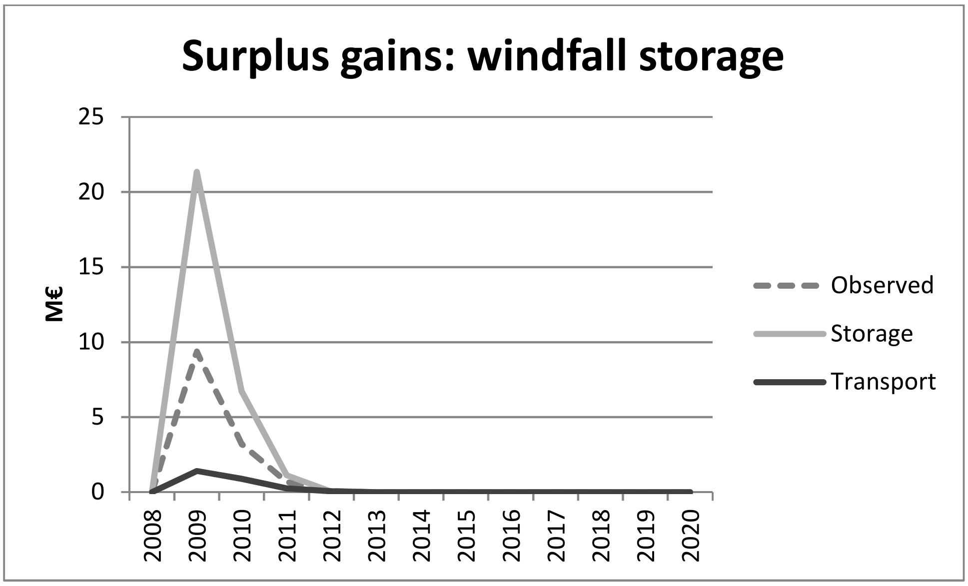

Figure 9: Gains in surplus related to windfall storage

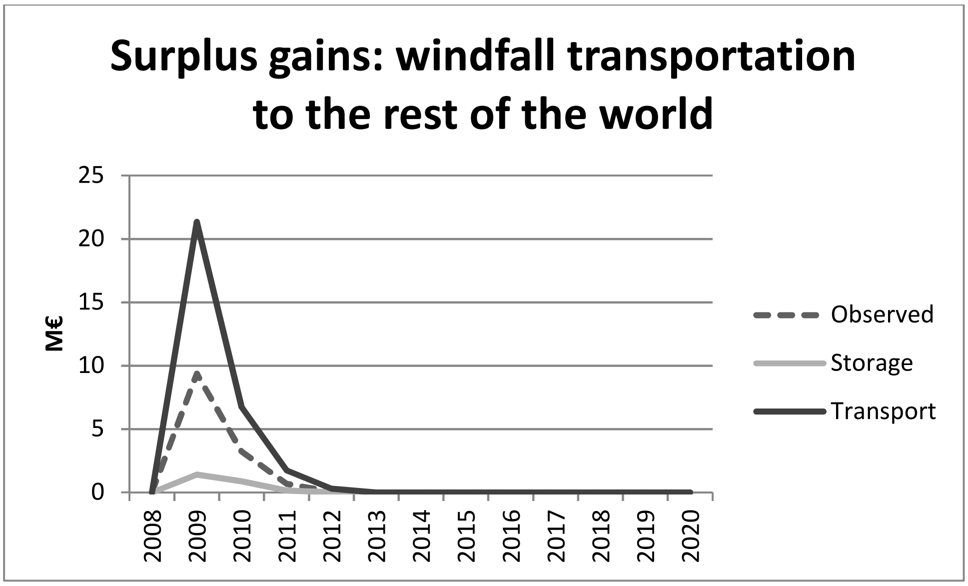

Figure 10: Gains in surplus related to export abroad

Windfall wood is competing with greenwood here, which translates into a surplus loss for greenwood supply activities. This impact is greater when the storage proportion is higher, as shown in Fig. 11. This impact is observed for all regions throughout the French territory. In the Aquitaine region, however, we must put this impact into perspective: most greenwood suppliers are also windfall suppliers; therefore, it is very likely that the overall surplus gains over the whole period are positive for wood suppliers with the implementation of a plan, regardless of the proportion of storage and transport subsidies. However, due to the negative impact of storage on greenwood supply surplus gains, it is also very likely that Aquitaine wood suppliers would prefer a transport-oriented scenario.

In other French regions, windfall surplus gains do not compensate for the surplus loss regarding greenwood supply. Increasing storage therefore leads to increased surplus loss for greenwood supply in other regions.

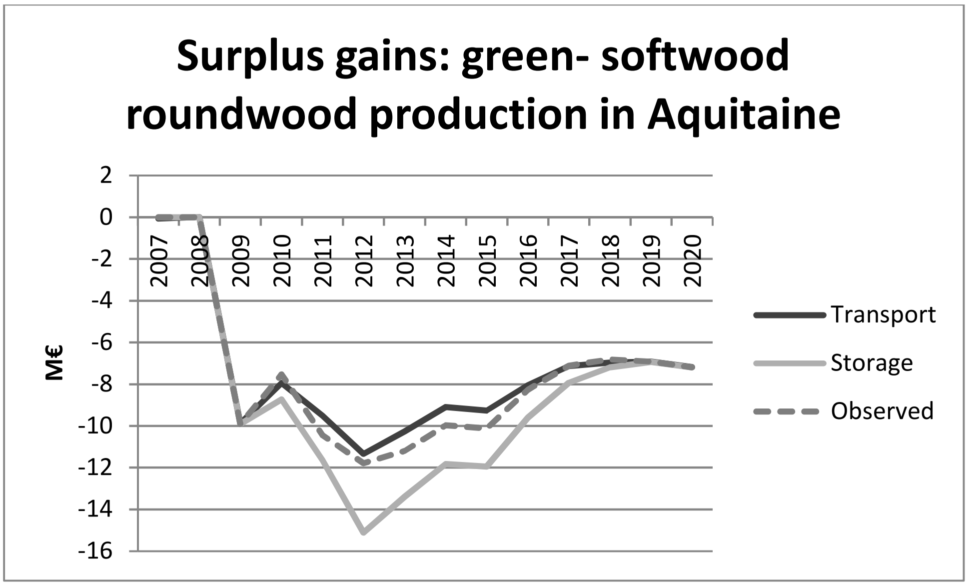

Figure 11: Gains in surplus related to greenwood supply

4. Conclusion

Our aim in this paper was to carry out an economic evaluation of a public policy implemented by the French government after Hurricane Klaus in 2009, by exploring the economic impacts of the compensation plan for the forest sector. To do so, we projected the compensation plan within the bio-economic partial equilibrium FFSM in order to analyze and compare the outputs to alternative compensation plans. Four key results arise from our analysis.

First, the compensation plan, as it was negotiated, appears to have accelerated windfall supply. Assuming a 5%/year degradation rate, the plan increased the total volume of supplied windfall by 14% compared to a scenario "without a plan". In addition, our results show that the "observed" plan favored in-site storage and export abroad compared to a scenario "without a plan", which clearly favored direct consumption.

Second, the price drop after the hurricane is reduced when the storage proportion increases. However, the price rebound is also postponed in the "storage" scenario compared to the "transport" scenario. The social acceptability of plans highly depends on the trade-off between these two impacts, making these two results policy-relevant.

Third, the gain in total surplus projected by the FFSM clearly shows that the “observed” plan was beneficial to the forest sector. With a 5%/year degradation rate in forests, the discounted sum of gains in surplus over the period 2009-2020 corresponds to €44M. We then show that reallocating part of the transport subsidies to storage would increase the total discounted gain in surplus (+70% for a reallocation of €20M of transport subsidies to storage), whereas reallocating €20M of storage subsidies to transport decreases total discounted gains by 57%. This overall impact clearly shows that increasing storage also increases total surplus for the entire French forest sector.

However, and this is the fourth main result, our simulations raise questions about the political economics of increasing storage. Indeed, the storage-oriented policy is likely to be detrimental to wood producers' surplus, especially in other French regions outside Aquitaine. On the other hand, increasing storage is clearly beneficial to consumers and storage agents. The socially acceptable proportion of storage must therefore be computed according to these two effects through a negotiation process.

In conclusion, we think our results can contribute some rationality to future negotiations for potential upcoming disasters in the forest sector in France but also in other countries subject to hurricanes. However, it is important to place them in the very specific context of the maritime pine forest in southwestern France. Indeed, in this region, the existing forest industry is strong and organized enough to articulate the upstream and the downstream of the forest sector when a natural disaster occurs. In addition, the use of existing storage areas (created after Hurricanes Lothar and Martin in 1999) significantly reduced the costs of creating new storage areas. Conversely, in other regions without forest product processing industries or storage areas, export may be a better solution. Partial equilibrium models such as the FFSM appear then to be the ideal tool to explore this possibility.

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Appendix

A.1. Estimation of timber demand and supply in the Aquitaine region

We simultaneously estimated the timber demand and supply equations from data in the Aquitaine region. We used data collected from the main operators in Aquitaine: the French National Forestry Service (ONF),[7] and from the processing industries, *Smurfit-Kappa* and *Gascogne.* ONF harvests on different forest properties that may be owned by the government, local communities or even private entities. We were able to observe nine different properties for the years 2009 and 2010. We also collected data for Smurfit and Gascogne on two properties each. The former concerned the years 2009 to 2012, and the latter are only available for the years 2009 and 2010. Altogether, we had 30 observations.

We collected information on marketed timber quantities, expressed in stacks, as well as the unit prices per stack. We also knew which type of wood was marketed (i.e., roundwood vs. industrial wood). Quantities and prices were transformed into logs so that the coefficients could be directly interpreted as price elasticities. Moreover, in order to identify a potential difference in the elasticity of the two types of wood products, we crossed the price and the variable indicating the type of wood. In addition, the joint determination of quantity and price made these variables jointly dependent and, therefore, endogenous. However, several variables are only explanatory in the demand equation, such as operator's identity and forest ownership, and thus make it possible to identify all of the parameters of interest. Descriptive statistics of variables used in the estimated model are presented in Table 1.

Table 1. Descriptive statistics of variables used in the estimated model

Variable	Description	Mean	Std. dev.	Min	Max
QUANTITY	Marketed timber quantity, in stacks	289434	486269	266	2009038
PRICE	Unit price, in €/stack	8.56	9.64	0.55	38.18
IW	Type of wood product Dummy = 1 for industrial wood	0.40	0.50	0	1

[7] The French National Forestry Office (ONF) is a public institution whose main objective is to manage national forests and other public forests according to the Forest Regime, as well as to carry out tasks of general interest entrusted to it by the French government.

ONF	Dummy = 1 for ONF	0.60	0.50	0	1
SMURFIT	Dummy = 1 for SMURFIT	0.27	0.45	0	1
Gascogne	Dummy = 1 for Gascogne	0.13	0.35	0	1
Private	Dummy = 1 for private ownership	0.60	0.50	0	1
Government	Dummy = 1 for state ownership	0.20	0.41	0	1
Communal	Dummy = 1 for communal ownership	0.20	0.41	0	1

Notes: Number of observations N=30 (=13 properties and T= 2 to 4).

We initially used a procedure adapted to panel data, i.e., accounting for the observations of individuals over several time periods. However, the null hypothesis of joint non-significance of fixed individual effects for each equation cannot be rejected at the 5% level. Consequently, we estimated our model assuming that all observations were independently distributed with the Seemingly Unrelated Regression (SUR) estimation method.

Results showed a price elasticity of supply that was significantly different from 0 (with a value of 0.92) at the 1% level, and the difference in the elasticities of the two types of wood was not significant. That means that the price elasticity does not depend on the type of wood product. An additional Wald test allowed us to definitively conclude that there was no difference in price elasticity regarding the type of wood product.

Estimation results are presented in Table 2. First of all, these results show quite a good model adjustment with $R^2 = 0.32$ for the supply equation and $R^2 = 0.71$ for the demand equation. All coefficients are significantly different from 0, at least at the 5% level. The estimated price elasticity of supply is 0.9162. This means that a 1% increase in the timber price results in a rise of 0.92% in the quantity supplied. The coefficient associated with the dummy IW is significantly positive, indicating a greater quantity of industrial wood sold compared to roundwood. The positive sign of the dummy for the year 2009 shows a positive impact of Hurricane Klaus on the quantity of timber supplied as a result of the new supply of windfall.

On the demand side, we found a demand price elasticity of approximately -0.42, revealing a demand from operators that is weakly elastic. We also found a significant impact of operator identity on the demand and a significant difference with respect to forest ownership. Finally, the negative coefficient of the 2010 dummy variable indicates that the timber demand is significantly lower in 2010, the year after the hurricane.

Table 2. Estimation results of the supply function (N=30)

Variable	Estimation	Standard error	t-Value	Pr > |t|
Supply equation **(R^2=0.32)**				
Constant	8.2884	0.8022	10.33	<0.0001
Log(Price)	0.9162	0.2945	3.11	0.0045
IW	2.2813	0.6873	3.32	0.0027
Y2009	1.3012	0.6296	2.07	0.0488
Demand equation **(R^2=0.71)**				
Constant	14.0659	0.8376	16.79	<0.0001
Log(Price)	-0.4194	0.1908	-2.20	0.0383
ONF	-3.7639	0.6426	-5.86	<0.0001
SMURFIT	-1.5542	0.5339	-2.91	0.0079
Private forest	1.0968	0.4877	2.25	0.0344
Communal forest	1.4344	0.4877	2.94	0.0073
Y2010	-1.2953	0.3738	-3.46	0.0021

A.2. Dynamics of destocked wood

Figure 4 shows the dynamics of destocked wood from storage areas. Destocking activity starts in 2011 as a result of the mandatory period of two years. The last volumes of destocked woods are released in 2019 for all scenarios.

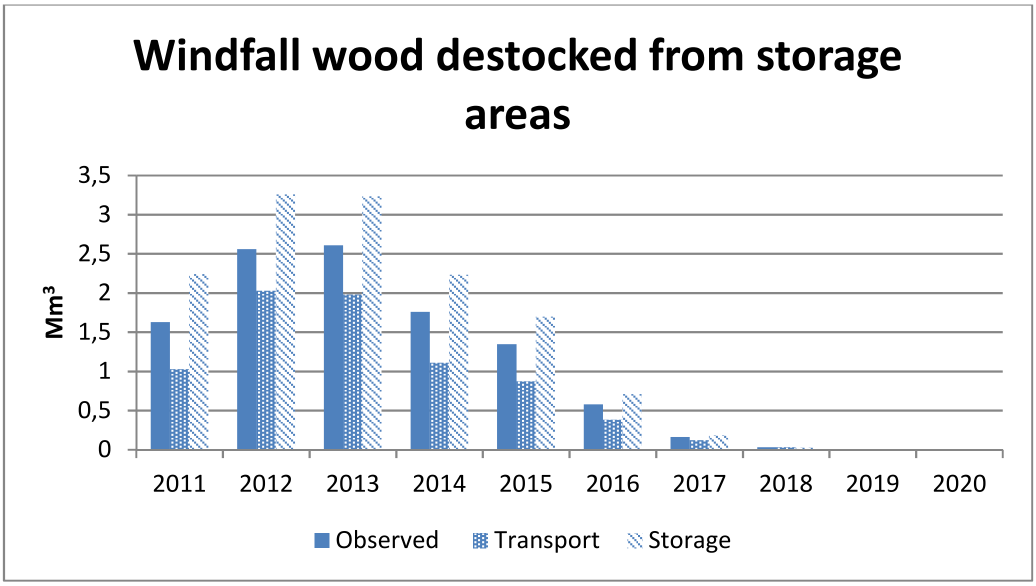

Figure 4: Windfall destocking dynamics.

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