Modeling and Analysis

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Opportunities and risks for sustainable biomass export from the south-eastern United States to Europe

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Received June 28, 2017; revised September 12, 2017; accepted October 10, 2017
View online at Wiley Online Library (wileyonlinelibrary.com);
DOI: 10.1002/bbb.1845; *Biofuels, Bioprod. Bioref.* (2017)

Abstract: Import of wood pellets to the EU from the southeastern United States has increased almost ten-fold over the past seven years, driven largely by mandates under the Renewable Energy Directive. While the displacement of fossil fuels with biomass can offer significant energy diversity and climate benefits, these must be balanced against the potential detriment from unsustainable extraction of biomass resources. This study projects the scale of the sustainable biomass resource base in the US southeast through 2030 under various scenarios of industry development and domestic market dynamics. We characterise this resource base at the county level, disaggregating it by material type and spatially constraining it to ensure biodiversity conservation. Our analysis shows that there could be as much as 70 million green metric tons of sustainable export potential from the US Southeast in 2030. However, we also show the extent to which sustainable sourcing criteria applied only to EU biomass energy imports could create leakage across biomass markets, erasing gains from any sustainability mandate. This leakage risk was fairly consistent across our study scenarios and time periods, ranging from 50 to over 63 million green tons of biomass per year. Meaningful biodiversity protections can only be achieved if sustainability criteria for biomass import to the EU are combined with more comprehensive support for sustainable sourcing across biomass industries in exporting regions. © 2017 Society of Chemical Industry and John Wiley & Sons, Ltd

Keywords: bioelectricity; sustainable biomass; trade policy; renewable energy; forest residue

Introduction

Combustion of woody biomass for energy in the European Union (EU) comprises almost half of total EU renewable energy use and has grown by almost 50% since 2004, driven in large part by mandates under the Renewable Energy Directive. While significant energy diversity and climate benefits can be realized through displacing fossil energy use with biomass, without careful control of biomass sourcing, this shift also presents

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the potential for detrimental environmental outcomes. This risk is especially acute for biomass imported from outside the EU, where the establishment and enforcement of sustainable forest management practices is largely beyond the regulatory reach of EU member states.

Of the burgeoning woody biomass imports to the EU, the majority originates in the Southeastern United States, which increased its exports of biomass pellets to the EU 28 from less than one-half million metric tonnes (MMT) in 2009 to over 4.6 MMT in 2015.[1] Recognizing the opportunities and risks presented by this growing trade flow, this analysis seeks to project the amount of woody material that could be sustainably sourced from this region through 2030. This analysis is part of the larger BioTrade2020+ initiative (www.biotrade2020plus.eu), a multisectoral effort funded by the European Commission (EC), and providing evidence-based insights for the development of a sustainable European bioenergy trade strategy.

US forestry and forest product trends

Historically, the United States has been both the largest producer and the largest consumer of harvested woody biomass in the world. The US share of global wood product production peaked at 28% in 1998 and has since fallen to below 20%.[2] The amount of roundwood required for wood and pulp product demand in the USA has roughly tracked population growth,[3] and the total roundwood equivalent volume to meet US wood and paper materials demand was roughly stable through the latter half of the twentieth century.[4] US imports of sawnwood products rose in the early part of this century, as a gap began to grow between domestic production and demand. However, consumption of these products has dropped in recent years, driven primarily by a reduction in housing starts leading into and resulting from the 2008 financial crisis, as well as the shift away from print toward digital media.[4] Pulp and paper markets in the USA correlate most closely with overall trends in manufacturing; both peaked in 1998 and have dropped since.[2]

The large-scale trends in the markets for US forest products have also had an impact on the regional distribution of forestry activities. A shift from solid sawnwood toward engineered wood products has enabled an increase in the proportion of smaller-diameter trees in timber harvest. This trend, along with biodiversity conservation efforts focused especially around the Northern Spotted Owl *(Strix occidentalis caurina)* has led to a shift away from the Pacific Northwest region, which was once the center of the US forest products industry toward plantation operations in the Southeast. In the decade between 1986 and 1996, the fraction of US timber harvest in the Northwest region dropped from 26% to 15%.[5] Production attention shifted strongly to the US Southeast (US SE), and led to further investments in plantations. As a consequence, both plantation area as well as growth rates of slash pine and loblolly pine increased, bringing the US SE to produce about 60% of US annual timber harvest.[6]

The use of wood for energy in the US was 2336 PJ in 2014 or about 146 million dry metric tonnes of wood.[7] This represents 2.2% of total energy and 23% of renewable energy use. While this was a 2% increase from 2013, it is still 18% below the 1985 peak.[8] While most of the increase is coming from increasing pelletization and generation of bioelectricity, the majority of the wood use for energy is still for home heating. Approximately 2.1% of US households are heated primarily with wood, and another 7.7% use it as a supplemental heating source; most of this use is as split logs.[8]

The base case in the US Department of Energy's 2015 Annual Energy Outlook (AEO) projects a 10% increase in wood energy use by 2030 – a significant downward revision from a year earlier when the AEO projected an increase of 47% by 2030.[7] The bioelectricity industry is very reliant on policies such as technology-specific carve-outs in Renewable Portfolio Standards. As of this writing, it is unclear what implications the Trump Administration's policy changes may have on the trajectory of biomass energy in the USA.

Pellets markets and trade

During the past decade, pellet production has increased throughout the USA, and especially in the Southeast region. This expansion has been in large part a response to increasing EU market demand. In 2014, US wood pellet production was estimated at 6.9 million metric tonnes (MMT) – an increase of about 21% from 2013.[8] Of this material, about 4.7 MMT was exported, 98% of which was from the US South region.[9] Pellet exports from the USA to the EU have increased 8-fold since 2008,[9] though pellet production still only represents about 2% of total harvest removal in the Southeast region.[10] The USA has become the primary source of pellets to EU markets, representing more than 60% of the total wood pellet imports to the EU in 2014.

The trend towards expanding woody biomass production and export from the US SE region is expected to continue. The forward projections conducted for the US Forest Service's 2010 Resource Planning Act (RPA) Assessment.[4] anticipate that the South region will continue to be the primary timber region in the country. In all the RPA scenarios considered, the region was projected to account for over 50% of total national timber harvest, including the majority of bioenergy feedstock production.

Most woody biomass burned for electricity, and nearly all of that exported for this purpose, is in the form of biomass pellets, which are valued for their handling characteristics, storability, and energy density. Until 2010, mill residues represented the major feedstock for pellet production, but since 2011 both softwood and hardwood pulpwoods are also being used.[11,12] In 2013, about 45% of the biomass for pellets in the USA came from softwood pulpwood, about 15% from hardwood pulpwood and the remaining 40% from mill residues.[11]

The economics of wood pellet production are complex, especially where high-quality feedstocks are used. Pellet manufacturers may compete for these feedstocks with manufacturers of paper products and panel materials such as particleboard and oriented strand board.[4] While biomass pellets have, up to this point, been made almost exclusively from mill residues and pulpwood, lower quality resources such as logging residues, are expected to become important, or even dominant, if the use of wood for energy increases significantly.[4]

Methods

Our first goal was to evaluate the technical potential for biomass production in the US SE region. This production potential is then constrained to characterize the subset of this material that could be harvested sustainably and made available for export. We project 2020 and 2030 sustainable biomass export potentials for both business as usual (BAU) and High Trade (HT) cases. For the purposes of this study, the US Southeast is defined as the states of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Missouri, North Carolina, South Carolina, Tennessee, and Virginia.

Technical potential

The technical potential is defined as all of the woody biomass suitable for bioenergy that is available in the region without considering significant sustainability constraints or the feasibility of its delivery. Some very fundamental sustainability constraints are applied by not including in the technical potential any biomass derived from:

- Deforestation/land-clearing operations.
- Illegal cutting on protected lands.
- Removal of more than 67% of forestry residues.[13]

Further, we estimate potential biomass supply here, and therefore do not constrain the supply to current or projected future pelletization or supply chain capacity. Pellet mill capacity in the USA stood at 10.3 MMT/yr as of 2016.[1] Capacity development through 2030 will be driven by demand, which will in turn be driven by energy policy. Hence, this analysis seeks to project various scenarios of technically available supply without considering market capacity (i.e., pelletization and supply chain capacity). Given this, the estimates presented should be understood to set a sort of ceiling on actual pellet availability.

Historical data on forest product removals were drawn from the US Forest Service Timber Products Output (TPO) database.[14] Baseline/historic production levels were collected at a county-level resolution throughout the US SE region from the TPO database for the years 1995–2009. Nationwide data are reported less frequently through the RPA process, so these data were extracted for RPA years 1997, 2002, 2007, and 2012. These reports collate and average data collected by regional offices across the study period, so are not necessarily representative of the report year, but they do offer a good first-order approximation of different types of forestry removals across the USA.

We only include in our analysis those classes of biomass for which bioenergy could reasonably compete economically, excluding material that is suitable for production of higher-value products, such as sawlogs (sawnwood) and veneer logs (plywood). The following classes of materials reported in the USFS TPO database were included:

- Both hardwood and softwood pulplogs.
- "Composite products," "fuelwood," and "miscellaneous"
- Logging residues at a 50% removal level for the BAU case[15] and 67% level for the HT case.[13] This category of material includes residual portions of trees cut for roundwood products, excess small pole trees, and other trees felled in the process of extracting roundwood products.
- Sawmill residues: wood and bark residues generated by mills during the processing of roundwood into primary products such as sawnwood, veneer, and wood pulp.
- "Other removals" at a 50% removal level for both cases. This category of material includes unutilized wood volume of trees cut in timber stand improvement activities (e.g. pre-commercial thinnings) or land clearings to non-forest uses. We limit our analysis to only 50% of reported/projected other removals[16] in order to exclude biomass derived through land clearing.

Spatially discrete projections of current-year and future forest product production at a county scale were derived from the Subregional Timber Supply (SRTS) Model.[17]

Table 1. Main characteristics of the RPA/SRES scenarios used in this analysis.

	RPA A1B	RPA B2
General scenario description	Globalization, economic convergence	Slow growth, localized action
Global real GDP growth (2010–2060)	High (6.2x)	Medium (3.5x)
US real GDP growth (2010–2060)	Medium (3.3x)	Low (2.2x)
Global expansion of biomass energy use	High	Medium

Source: adapted from USDA, 2012[4]

The baseline SRTS outputs were used to describe the BAU production case with high-biomass supply case derived from the joint US and global Forest Products Module (FPM) model[18] runs and scenarios developed for the 2010 USFS Resource Planning Act Assessment.[4] This USFS modelling effort projected future forest product harvest and demand under different Special Report on Emissions Scenarios (SRES) cases developed by the IPCC.[19] Parameters in the FPM relating to global and domestic population growth, GDP, global trade patterns, bioenergy use, and climate were tied to those applied in the SRES scenarios. The two primary RPA/SRES scenarios used in this analysis are the RPA A1B and RPA B2 scenarios, the key characteristics of which are described in Table 1.

Some relevant data sources, such as the FPM model outputs used for the HT scenario, are only reported at the national scale. Where this was the case, historical patterns of US-wide and US SE region share of hardwood and softwood production, as well as RPA projections of future yield, were used to determine the US SE region's 'share' of total production. Where some of the mentioned categories of biomass were not reported, the regional TPO dataset was used to impute harvest residue, mill residue, and other removals from the average historical relationship between these factors and removal rates of different classes of roundwood.

Sustainable potential

Given the specific US SE context, the concerns already raised by different stakeholders with respect to pellet production[20,21,22] and the sustainability criteria in the EU Renewable Energy Directive[23] and other EC communications, two main impact categories have been considered in detail: biodiversity and carbon balances.

With respect to carbon balances, most life cycle assessment studies show some gains from displacing EU grid electricity with bioelectricity from US pellets. Dwivedi *et al.*,[24] for example, found generation of UK bioelectricity from US pine pellets to represent a life cycle emissions reduction of between 50% and 68%. Similarly, Wang *et al.*[9] found forest biomass pellets to offer a 74% life cycle GHG emission reduction when they replace coal in UK power generation. Galik and Abt [25] also project significant net emissions benefits from displacing EU coal with pellets from the US SE region. These findings are in line with the life cycle emissions calculated in the EC's own research conducted by its Joint Research Centre.[26]

A critical consideration with most of these studies is that in their calculations of the life-cycle GHG emissions from bioenergy systems they consider combustion of biogenic fuels to be carbon neutral provided there is no loss of carbon stock in the forest. Some stakeholders have raised concerns with this approach.[26-32] However, as this is the current approach of the EC,[26] we do not consider GHG balance to be a practical constraint on biomass sourcing from the US SE for this study.

This leaves biodiversity conservation as the key constraint in determining sustainable sourcing potential for this analysis. Many forestlands of the US SE are biodiversity hotspots. The region has a relatively high rate (11%) of plant and animal species considered to be at-risk.[33] Some forest types of high conservation value on the Coastal Plain are bottomland and floodplain forests, gum-cypress, elm-ash-cottonwood, as well as some oak/hickory and oak/pine systems.

To evaluate the *sustainable potential* available for export, we apply three layers of spatial constraints to the technical potentials to protect areas and habitat types of high biodiversity value:

1. Protected areas, areas identified as having special conservation significance, private lands covered by conservation easements, or areas classified as wetlands or other water bodies. These sourcing restrictions were developed and presented in Galik & Abt.[25]
2. Other set-aside areas of special biodiversity concerns as per the rarity-weighted species richness index.[33,34] This index scores locations based on a combination of species richness and the rarity of the species present; we excluded any areas with a high (>1) score on this index.
3. A partial set aside based on high biodiversity conservation value forest types of the US SE. In particular, the exclusion of gum-cypress, and a 10% exclusion of oak-pine forest types.[35]

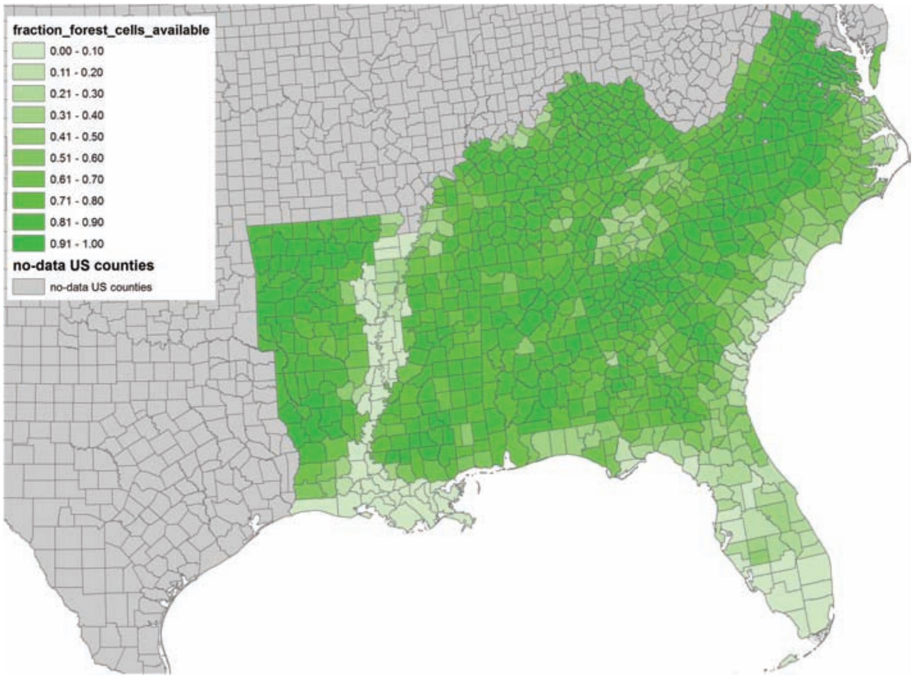

Figure 1. The sustainability constraint factor or fraction of each county's forest area that remains available for wood production after sustainability criteria is applied spatially. (Note: These results are derived from a regional-scale study, and should not be considered applicable for county-level analysis or planning, where a higher degree of local nuance is warranted.)

The three spatial constraints mentioned above overlap to a significant extent, but each also covers areas that are not otherwise excluded. By applying these three sustainability masks, we determined the fraction of each county's forested area to be excluded from production to ensure sustainability. This fraction per county was the 'sustainability constraint factor' and was multiplied by the technical potential to determine the sustainable potential per county. Figure 1 presents the spatial distribution and extent of exclusion created by these sustainability constraint factors across the US SE.

The specifics of the way these sustainability constraints might be implemented has a significant impact on the scale of the sustainable resource base. We approach this analysis considering two basic mechanisms for implementation.

1. Net technical potentials for export (after sourcing of domestic demand) are spatially constrained to avoid unsustainable impacts. This approach is referred to hereafter as the export biomass constrained (EBC) case.

$$\textit{Sustainable Export Potential} = (\textit{technical potential} - \textit{domestic demand}) * \textit{SCF}$$

2. Gross technical potentials are constrained to avoid unsustainable impacts with domestic demand then drawn from the sustainable resource base. This approach is referred to hereafter as the all biomass constrained (ABC) case.

$$\textit{Sustainable Export Potential} = (\textit{technical potential} * \textit{SCF}) - \textit{domestic demand}$$

The basic difference between these approaches is that the first (EBC) approach constrains only the biomass being counted for pellet export to those areas not creating risk of unsustainable impact. In the second (ABC) approach – the approach taken elsewhere in the BioTrade 2020+ study – sustainability criteria are applied to *all* biomass production for all applications in the region.

The first case is more realistic; while EU policymakers may well apply sustainability criteria to imported pellets, they could not extend these criteria to all biomass harvest in exporting countries. On the other hand, a regulation that only covers a small part of the market risks failing to influence overall environmental performance, creating a leakage effect, wherein sustainable biomass is sold into export markets without any actual shift in harvest practices across the landscape.

Characterizing US domestic demand

Domestic demand data were drawn from Howard.[36] These values for roundwood equivalent production of various woody biomass products were then scaled based on FPM model projections of change in domestic demand for these materials. Among panels, only composites such as particleboard and oriented strand board (OSB) were considered as competing with energy for biomass. These products have risen to about 60% of the total US panel market, and are projected to occupy 80% of the market by 2060.[37] We therefore account for 60% of structural panel demand in 2015, 65% in 2020, and 70% in 2030. The RPA scenarios used in this analysis project total future material demand nationwide. We allocate these projections to the SE region based on that region's share of total nationwide projected hardwood and softwood production.

In projecting demand for conventional uses of biomass, this study uses the low-growth RPA B2 scenario for the BAU case and the more robust and renewable energy focused RPA A1B scenario for the HT case. More biomass could theoretically be available for export under a scenario of less robust global GDP growth and US biomass expansion, as these would reduce demand for biomass for conventional and energy uses. However, such a scenario cannot realistically be expected to coincide with high levels of biomass supply, so the HT case uses the higher growth scenario to project domestic demand.

This study breaks from the strict RPA/SRES scenarios in its treatment of US domestic bioenergy demand, however, because the RPA projections range widely and are driven in large part by the exogenous factor of domestic bioenergy policy. For example, the highest RPA scenario projection shows almost 2 billion short tons of biomass used for energy in the US in 2060. This would require an overhaul of US forestry and energy sectors and would clearly not leave material for export. There is no empirical basis upon which to vary the US biomass demand between BAU and HT cases. For this reason, we used the moderate domestic biomass demand growth projection from the RPA for both the BAU and HT scenarios. The demand for domestic biomass for energy presented in this scenario is roughly consistent with the projected doubling of US biomass energy production by 2030 in the 2010 Annual Energy Outlook reference case.[13]

Results

Technical and sustainable biomass potential

The base projections for this analysis are the technical potentials, or the amount of key biomass types that could technically be mobilized from the US SE region going forward. Figure 2 presents the historical data on yields of these types of biomass as well as the estimated 2015 yields and projected 2020 and 2030 yields in both BAU and HT scenarios for future technical potential. These estimates are broken down by biomass type into both hardwood and softwood pulplogs and miscellaneous removals, as well

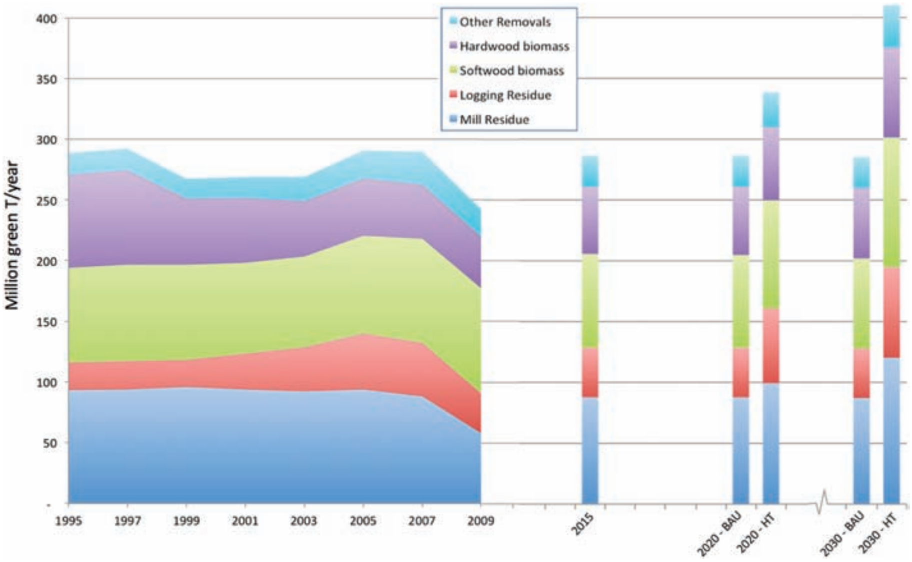

Figure 2. Historical and projected future total biomass availability. Per TPO database convention, the pulpwood, composite products, fuelwood, and miscellaneous categories are grouped together, and are here referred to simply as biomass.

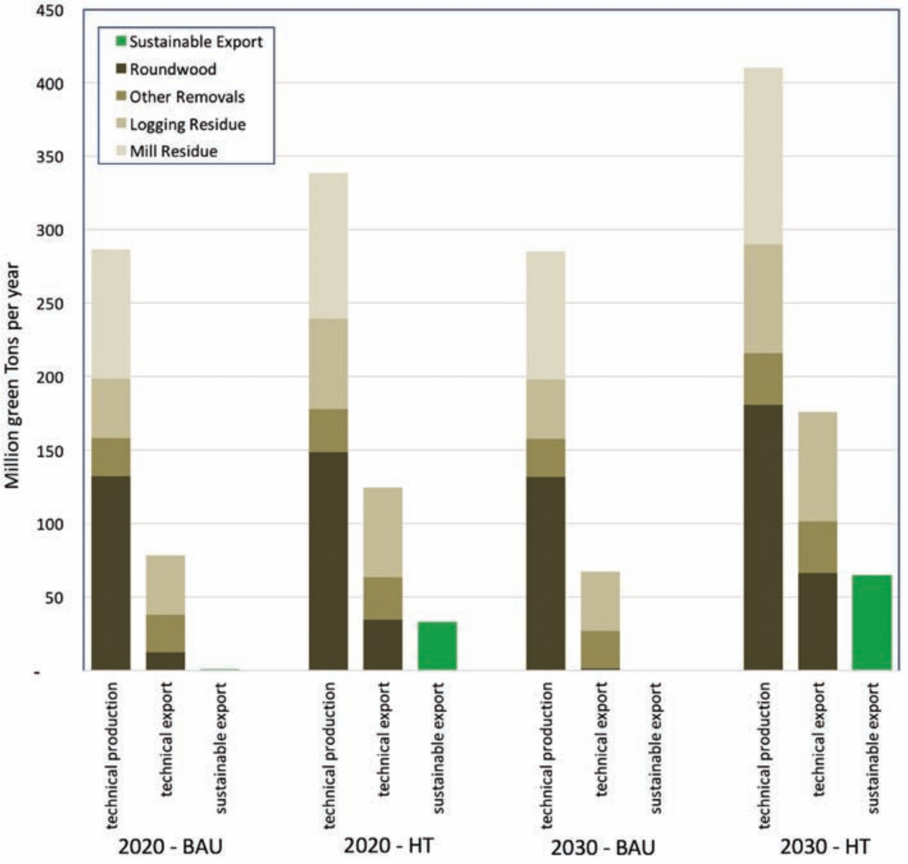

Figure 3. Projections of total technical production potential, technical export potential, and sustainable export potential if sustainability parameters were applied to all biomass harvest. Values are for green metric tonnes of wood – not pellets produced.

as the 'other removals' biomass class, logging residues, and mill residue. These technical biomass potential values exclude sawlogs and veneer logs as well as the 33–50% of harvest residue and 50% of the 'other removals' category as described in the methods section.

Combining projected production potential with projected domestic demand for the categories of biomass utilized in the pellet market, we arrive at estimates of technical export potential. Figure 3 presents the technical potential projected for the cases under investigation. Our estimates of technical potential are similar to those generated by concurrent work at the US Department of Energy.[38] Figure 3 reports these technical potentials alongside our estimate of the material potentially available for export after projected domestic demand has been met. It should be noted that these are theoretical export values, unconstrained by pelletization capacity or cost. These technical potentials are then further constrained spatially to ensure sustainable sourcing, yielding the sustainable potential projections also shown in Fig. 3. Presented here are our conservative sustainable potential values – derived for the ABC case.

The US SE is a very large geographical area, and this analysis projects material availability at a county-level spatial resolution. Figure 4 presents the projected biomass availability in the 2030 HT case at the county-level resolution.

Discussion

Technical and sustainable biomass potential

This analysis makes clear that there could be significant quantities of exportable biomass in the southeastern US if markets trend toward the HT scenario investigated here. Our BAU scenario, however, does not project significant export potentials as total feedstock production is relatively

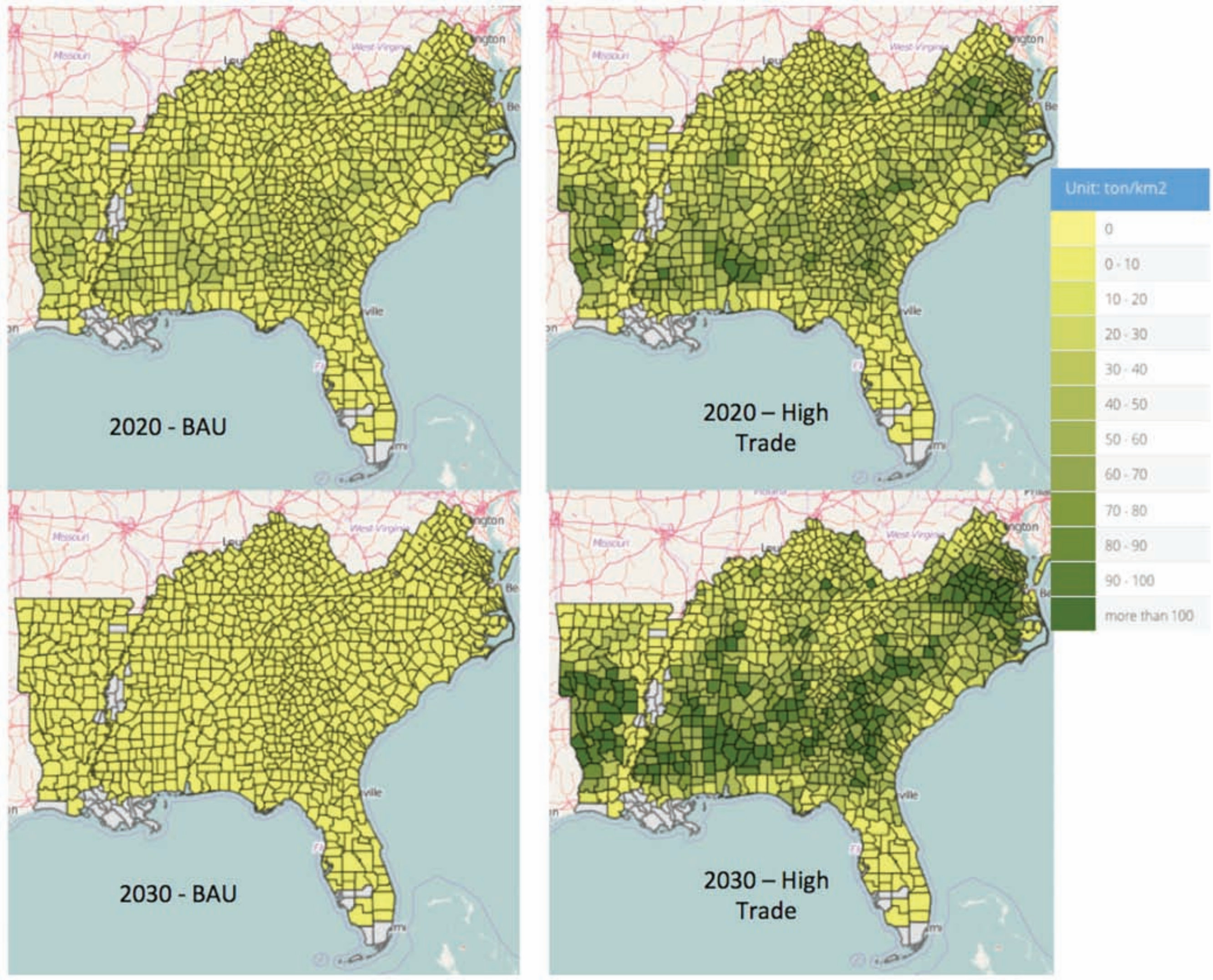

Figure 4. Spatial distribution of net sustainable potential for roundwood in the 2020 and 2030 BAU and HT cases. (Note: While these figures are presented at a county-level resolution, they result from a high-level analysis that is unable to characterize many of the smaller-scale economic, ecological, and regulatory dynamics at play in a given locality. As such, these results should not be considered applicable for county-level analysis or planning, where a higher degree of local nuance is warranted.)

flat in the 2030 timeframe, with domestic demand continuing to rise.

Notably, the exportable feedstock quantities projected for the HT scenario are significantly higher than the 6.9 million metric tonnes of pellets that are estimated to have been produced *nationwide* in 2014.[5] This is due to the fact that these are total biomass potentials, unconstrained by pelletization or supply chain capacity. It is worth noting that the pellet industry can only flourish if conventional forest industries (especially sawmilling) flourish, given the interlinkages between these industries. To a large extent, biomass energy draws on byproducts of the conventional forest products industries such as thinnings, harvest and milling residues, and similar materials. These two industries can therefore be mutually supportive.[39]

As already described, the sustainable potentials presented in Fig. 3 assume that *all biomass harvesting* in the US SE is confined to those areas deemed to meet the sustainability criteria considered here. For this reason, these are conservative estimates of availability, and in some cases the sustainable export values are very small or even negative. Negative export potential implies that domestic demand for biomass from the region is expected to be greater than total sustainable biomass availability.

It should be noted that any sustainability criteria the EC (or EU member countries) could impose on the use of biomass would only apply to the material actually used in member states. This means that while the approach presented here gives our best estimate of the amount of actually sustainable material that could be available for export from the US SE, it does not reflect the realities of the policy frameworks that might cause that material to be used. A much more likely framework would constrain sourcing in the US SE only for the bioenergy feedstock material destined for use in the EU. This approach creates the risk of leakage, wherein the products of unsustainable activities are simply shifted from the export biomass market into other sectors rather than being prevented altogether.

By comparing our estimated sustainable potential under the ABC case against the nominally sustainable potential if sourcing criteria were only applied to biomass for export, we are able to estimate the scale of the potential leakage that could be driven by such an approach. This leakage risk was fairly consistent across our study scenarios and time periods, ranging from 50 to over 63 million green tonnes of biomass per year. This risk should not be taken as an argument against applying sustainability criteria to EU pellet imports, but as indication of the limited efficacy of such a policy alone. A more comprehensive strategy, applying sustainability criteria to all imported biomass products as well as advocating for stronger protections within the United States, would go farther than a bioenergy-only policy towards meaningful biodiversity protections.

Sources of uncertainty and areas for further research

A great deal of uncertainty surrounding these estimates remains, as evidenced by the range of projections for US biomass pellet export potential across recent analyses. Figure 5 presents our estimates alongside several other recent projections of future pellet production and export potentials and the recent trend in pellet production in the region.

One key reason for this broad range of estimates, and a primary source of uncertainty surrounding such projections is the fact that relatively small differences in assumptions can lead to large differences in results. An investigation of the sensitivities in this work shows that choice of RPA scenario, residue removal level, ABC vs EBC policy framework, and mixed oak woodland utilization rate for sustainability masking are the four largest variables in driving our results.

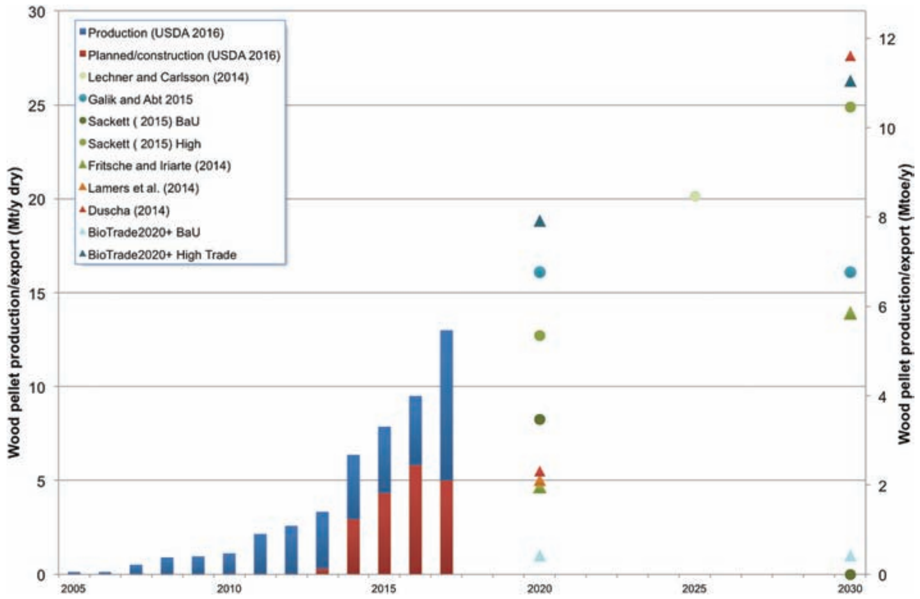

Figure 5. Review of projections for pellet production (•) and export (▲) potential in the US SE region (adapted from Hoefnagels *et al*. [40] drawing on estimates from Galik and Abt,[25] Lechner and Carlsson,[41] Sackett,[42] Fritsche and Iriarte,[43] Lamers *et al*.,[44] and Duscha *et al*. [45]). The BioTrade 2020+ HT export potential estimates are higher even than most projections of total production because we estimate the total biomass potential unconstrained by projections of pellet production capacity.

Furthermore, many of the drivers of this model are themselves sensitive to both domestic and global policy and economic circumstances, which are prone to unanticipated changes. Factors such as the composition of housing stock into the coming decades, the forward trends in pulp and paper use, and the hard-to-predict effect of insect infestations can have a large impact on the availability of biomass for pelletization and export.[46,47]

The results of our study raise new and important questions that will require further research. This analysis evaluates the amount of biomass material *available* under several scenarios but does not consider the supply chain dynamics that could constrain its being brought to market. Combining these estimates with supply chain capacity projections would enable more complete techno-economic projections of pellet availability. Further, one of the key unknowns in the ongoing development of this resource is the degree to which forestry residues will be able to be utilised for energy despite their ash composition and the engineering challenges they create for both pelletization and combustion. Further research is needed to develop and deploy harvest and post-harvest treatment practices to enable their utilization. Finally, if sustainability criteria were to be applied to EU imports of biomass pellets, this would be unlikely to significantly impact activities on the ground in the US Southeast region unless these criteria were applied across the whole of the US forest industry (an outcome that the EC could not control). A better understanding of the dynamics of this leakage in the forest industry could help the EC to determine the best framework for ensuring the sustainability of its imports.

Acknowledgements

This paper was written within the framework of the Intelligent Energy – Europe (IEE), project Supporting a Sustainable European Bioenergy Trade Strategy, IEE/13/577/SI2. 675534.

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