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Wood Bioenergy and Land Use

A Challenge to the Searchinger Hypothesis

Roger A. Sedjo, Brent Sohngen, and Anne Riddle

1616 P St. NW
Washington, DC 20036
202-328-5000 www.rff.org

RESOURCES FOR THE FUTURE

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Abstract

A concern of many environmentalists is that the use of biomass energy will decimate the forests. Searchinger et al. (2008, 2009) examined this issue related to corn ethanol and suggested that substituting corn ethanol for petroleum would increase carbon emissions associated with the land conversion abroad necessary to offset the decline in corn availability. Associated with these concerns is the overall issue of climate change (IPCC 2006). This issue is broader than simply corn. If agricultural croplands are drawn into the production of biofuel feedstocks, commodity prices are expected to rise, triggering land conversions overseas, releasing carbon emissions, and offsetting the carbon reductions expected from bioenergy. Using a general stylized forest sector management model, our study examines the economic potential of traditional industrial forests and supplemental dedicated fuelwood plantations to produce biomass on submarginal lands. It finds that these sources can economically produce large levels of biomass without compromising crop production, thereby mitigating the land conversion and carbon emissions effects posited by the Searchinger Hypothesis.

Key Words: biomass, forests, fuelwood, land use, land conversion, wood biomass, bioenergy, carbon emissions, feedstock, Searchinger Hypothesis, climate change

JEL Classification Numbers: Q1, Q16, Q23, Q24, Q42, Q54

Contents

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Introduction

Bioenergy is an important form of renewable energy that, together with wind and solar power, will contribute to US energy security through the first half of the 21st century and perhaps well beyond. Indeed, more than 30 states have put renewable portfolio standards (RPS) into effect that require that renewable energy, including bioenergy, be increasingly used to meet a certain percentage of electrical power generated through time, often with a target percentage by some date. For example, the EIA (2012) has projected that biomass energy consumption will double by 2025 and increase another 30 percent by 2035.

An important characteristic of bioenergy is that, along with the other major renewables, it is credited with having a small or zero carbon footprint and in some cases can sequester net carbon. Although the size of the carbon benefit will vary by bioenergy type, a direct net carbon benefit is almost always associated with the substitution of bioenergy for fossil fuels, particularly over the longer run. This is an important feature, given concerns about greenhouse gas emissions and global warming. However, issues have been raised with respect to the indirect effects of biomass energy on carbon emissions. This paper addresses some of the bioenergy issues with a focus on wood as the major feedstock for bioenergy.

Types of Bioenergy

Biological materials can be a feedstock for the production of energy through direct combustion of biomass to supplement or replace traditional fossil fuels such as coal, oil, or gas. Also, biomaterials can be used as feedstocks for the production of liquid fossil fuel substitutes, called biofuels. As a result of regulation, including both subsidies and Renewable Fuel Standards, a potentially large market exists for liquid transport biofuels, such as ethanol, as a substitute for or supplement to petroleum.

* Roger Sedjo is a senior fellow and director of the Forest Economics and Policy Program at Resources for the Future (RFF); Brent Sohngen is a professor of resource economics at Ohio State University; Anne Riddle was a research assistant at RFF at the time of this study.

One approach to using biomass is to convert biomass into synthetic gases through the combined combustion gasification (CCG) process; this in turn can produce a host of liquid fuel outputs that are substitutes for fossil fuels. However, this approach is very capital-intensive and inordinately expensive at this time. In recent years, biomaterials, particularly corn in the United States, have been the major source of feedstock for the production of ethanol and other petroleum substitutes using less capital-intensive approaches. Elsewhere, other biofuel feedstocks, such as sugar in Brazil and palm oil from Asia, are important for the production of transport fuels, including diesel fuel produced in Europe from imported palm oil. Cellulosic materials, including grasses, agricultural waste, and wood, offer potential as important biofuel feedstocks. Most of these sources have awaited technological improvements, importantly in the form of suitable and affordable enzymes needed to break down the plant cellulose. Today commercial facilities are beginning to be used, and cellulosic materials have become economically and commercially viable for liquid fuel substitutes.

Additionally, these sources, particularly wood, can be used directly as a feedstock to produce heat and electrical power though direct combustion or through cofiring in combination with fossil fuels such as coal. Wood has been an important source of energy for the wood-processing industry (e.g., pulp and lumber) for many decades. Today biomass is particularly attractive as a substitute for coal in existing coal-fired electrical facilities, as conversion of many of those facilities from coal to biomass energy sources is relatively inexpensive. Although not covered in this study, the potential also exists for the creation of renewable chemicals and bio-based products from biomass feedstocks.

Bioenergy Issues and the Searchinger Hypothesis

A number of issues have arisen associated with the development and use of bioenergy. One of these is what some have called the “food or fuel” conflict (Runge and Senauer 2007). This issue has been observed in the United States, as almost 40 percent of the total corn crop has been utilized for ethanol production. Additionally, bioenergy is typically land-intensive. A strong criticism of bioenergy has been that changes in the land use to produce bioenergy feedstocks, and thereby reduce the use of fossil fuels and their carbon emissions, may be associated with land use changes and the carbon emissions accompanying these changes. A major concern of many environmentalists is that the use of wood for energy will compromise the forests as a result of heavy wood withdrawals. Moreover, some have questioned the efficacy of using wood for bioenergy as a vehicle to reduce global warming carbon emissions.

Searchinger et al. (2008, 2009) and Fargione et al. (2008) examined the similar question of land use and related land use changes associated with corn-based ethanol. Specifically, they studied the effects of a substantial increase in corn-based ethanol on greenhouse gas emissions when taking into account emissions from potential land use changes induced by ethanol production. Their analyses focus on grain crops and biofuel production. Searchinger et al. (2008, 2009) examined a case in which US corn ethanol production was projected to increase to 15 billion gallons a year by 2015. A concern articulated is that higher domestic demand and higher prices have reduced corn exports. Their argument is that the reduction in exports in turn has created shortages abroad, thereby generating incentives to convert natural landscapes in foreign countries into corn cultivation to meet local food needs

Specifically, in order to expand foreign corn production, the researchers hypothesized that foreign countries would need to convert lands from natural vegetation to croplands. They assumed that all of these lands would be derived from tropical rainforests and other natural habitats holding a large supply of carbon. With their model, this land conversion would release significant volumes of carbon into the atmosphere. An unintended consequence of substituting corn for petroleum in the United States therefore would be an increase in carbon emissions associated with land conversion abroad (Searchinger et al. 2008, 2009; Fargione et al. 2008).

The driving mechanism is that of the energy demand, which is added to traditional demand and generates increases in corn prices. This issue, however, is broader than simply corn. If agricultural croplands are drawn into the production of biofuel feedstocks, crop production will decline and commodity prices will rise. A rise in commodity prices can trigger the same land conversion response as with corn. Hence, the implications of the Searchinger Hypothesis would apply to agricultural commodities more generally.

The essence of the hypothesis is that a disruption of the patterns of high-valued commodities and the shifting of some of these lands to produce biomass feedstocks will drive up commodity prices, thereby inducing carbon-releasing land use changes in foreign countries.

Indeed, the hypothesis holds that cropland disruptions will persist even when biofuel production moves from grains to a cellulosic feedstock, such as switchgrass, wood biomass, and certain other plants, as these biomass “crops” could compete for prime food croplands, thereby perpetuating higher prices for traditional food crops and providing incentives for land use conversions, especially abroad. However, others believe that crop disruptions due to the substitution of biofuel crops for grains are unlikely in the absence of significant subsidies, because the financial returns to grains generally and corn in particular are so superior to biomass at any probable price relationship that it is doubtful that managers will shift high-productivity food lands into lower-valued cellulosic crops.

The Critiques

The Searchinger Hypothesis has been severely criticized by a number of analysts. One critique is by Wang and Haq (2008), the developers of the model Searchinger et al. used to estimate the foreign responses. They question the applicability of their model to the circumstances where the researchers applied it, noting that it was developed at an earlier time and for a range of use levels well below the levels for which Searchinger et al. made their estimates of land use changes. Furthermore, Wang and Haq point to the lack of empirical verification, noting that up to the time of the 2008 study, "there has been no indication that US corn ethanol production has so far caused indirect land use change in other countries" (2008, 3).

An obvious alternative to the use of cropland-disrupting grains as a feedstock is to establish cellulosic feedstocks, which can thrive on lower-quality lands and on lands marginal for most crops. Indeed, if cellulosic biofuels become a technological reality, normal market pressures would move lands in this direction. High-productivity croplands will continue to produce food, while marginal lands will be used for bioenergy. There need not be fundamental conflicts over land uses.

Some have noted that bioenergy fuels could be produced on marginal agricultural lands, croplands not in food production, or former tobacco or cotton lands. These lands could produce a grass or woody crop feedstock for bioenergy without significantly disturbing food cropland patterns, thereby avoiding the cascading effects of land conversions to create new croplands. For example, the Renewable Fuels Agency (RFA 2008) argued that "[t]here is probably sufficient land for food, feed and biofuels." That study went on to suggest, as did Sedjo (2008) separately, that "[b]iofuels production must target idle and marginal land" (RFA 2008, 9). Numerous studies have estimated a significant availability of lands marginal for agriculture but suitable for biomass production in the United States (e.g., Potter et al. 2007; Aguilar et al. 2012). The availability of such lands in accessible locations would remove pressure to substitute biomass crops on prime food lands. Indeed, Cai et al. (2011) have found the amount of lands potentially available for biomass to be very large.

Thus, the assumption of the hypothesis that large portions of US food croplands would be drawn into biomass production appears highly problematic. Rather, if the lands newly utilized for biomass production are not prime food croplands but rather submarginal agricultural lands or nonagricultural lands, then food price increases due to biomass energy would be negligible, as would land-clearing consequences both in the United States and abroad. If the biomass feedstock being established were trees or grasses, the greater production of biomass could also increase the amount of carbon sequestered in the newly established vegetation and related soils.

Moreover, recently published work suggests that increased demand for bioenergy could also increase the stock of carbon captured in forests (Daigneault et al. 2012; Sedjo and Tian 2012). The rationale of this finding is that increasing demand for wood for bioenergy will provide incentives through markets to increase the production of wood biomass. This result recognizes that demand for bioenergy affects not only the demand for biomass, but also the biomass supply through higher prices. Also, the land use changes here need not necessarily involve croplands. Finally, as discussed below, legislation has now capped the extent to which grains may be used in the United States to produce ethanol, so no new pressures from this source should occur.

Some Other Issues

The Energy Independence and Security Act of 2007 addressed the narrower corn problem of higher prices raised by Runge and Senauer (2007), and, indirectly, the implications of the higher price on land conversion raised by Searchinger et al. (2008, 2009), with a legislative cap to be placed on the amount of corn ethanol that needs to be produced in the United States to meet the mandate. It had been anticipated that ethanol production could reach 36 billion gallons by 2022, but the act has placed an annual cap of 15 billion gallons on corn ethanol production after 2015, with the difference to be made up by advanced biofuels, most of which are expected to be cellulosic plant materials, such as grasses, agricultural waste, and wood. Although the technology of producing cellulosic ethanol has been difficult, the costs have been high, and development has been slower than anticipated, these problems seem to have been largely overcome, and the appropriate technology is now being deployed into commercial production operations. However, we find that the situation involves more than simply the technical difficulties with advanced biofuels. If a statutory limit is put on the use of grains for the production of bioenergy products, as in the Energy Independence and Security Act of 2007, it is important that the other feedstocks, such as cellulosic plant materials, do not displace food crops from agricultural lands. It is commonly argued that various grasses, such as switchgrass, could be grown on agricultural lands and thus provide cellulosic biomass for biofuels. Yet this approach would still involve a reduction in the lands available for food and feed, and higher prices would promote land conversion elsewhere.

Put succinctly, the issues addressed in this study finally become what feedstocks should be used, where might the requisite materials be produced efficiently, and will this production necessarily result in major crop disruptions and land use changes as hypothesized by Searchinger et al.?

Our General Approach

This paper picks up on the points of RFA (2008) and Sedjo (2008), who suggest that an approach be used where the growth of biomass for energy feedstocks would be limited to expansion of biomass production to lands of submarginal crop productivity or non-food-producing lands. Examples of these types of lands are found in marginal agricultural lands such as pastures, lands in conservation reserves, old cotton and tobacco fields, orange groves, and floodplains that experience regular flooding that severely diminishes their crop agricultural productivity. In many cases, such lands are already in grasses or low-density woodlands and could readily be modified to become higher-productivity biomass plantations without series disruptions, without involving any croplands, and without serious carbon losses.

A common finding, and the assumption used by Searchinger et al. (2009), is that forest conversion to croplands involves soil carbon losses (Cowie et al. 2006). However, numerous studies find that harvests followed by vegetative regeneration are relatively carbon neutral (Johnson 1995; Perschel et al. 2007; also see Buchholz et al. 2013 for a review of the literature on soil fluxes in forests). So if croplands are not disrupted and the amount of grain used for biofuels is capped, grain food and feed markets would not be affected by the production of bioenergy, and financial incentives for offshore land conversion and carbon releases would not occur. Our study examines the feasibility of such an approach for the United States.

Note that the important concept here is that the additional biomass to be used for bioenergy feedstocks would not disrupt the food agricultural cropping system and thus would not lead to additional natural land conversions either domestically or internationally. In essence, most of the additional biomass would be generated from lands largely out of food production currently and thereby would add to biomass stocks at a low costs in terms of reduced lands for food agriculture.

Conceptually, using the modified timber–biomass economic model, we estimate the levels of economic biomass production potentially available from these marginal lands under two bioenergy scenarios within the context of the conventional uses of the forest and croplands. Using a variant of the modified model, an additional component is the introduction of forest slash and other forest fuel materials to the biomass feedstock to estimate the effects of adding this source of biomass to the feedstock supply. The project outlined above is focused on private lands in the United States, but it could readily be adapted to examine the extent to which public lands, including Forest Service lands, might contribute to bioenergy with fuel materials drawn from forests in various forest health activities.

In summary, our analysis examines the ability of this forest–fuelwood system to meet bioenergy demand with only modest biomass price increases. If that ability is confirmed, this would indicate that major increases in bioenergy fueled by biomass need not place substantial additional demands on US agricultural lands. This would raise serious doubts about the applicability of the Searchinger Hypothesis, as this finding would imply that increased bioenergy production in the United States will have limited impact on cropland use domestically and thus land conversion abroad. Hence, biomass energy would not seriously disrupt cropping and thereby would not intensify greenhouse gas emissions and the global warming problem.

The Model

This analysis uses a variant of a well-known dynamic optimization forest management model (Daigneault et al. 2012; Sohngen et al. 1999; Sedjo and Sohngen 2013) to examine the effects of changing wood biomass demand on the existing forest and on lands in either crops or forests. The model also involves the incorporation of a forward-looking forest management projections approach, used increasingly in forestry (e.g., see Favero and Mendelsohn forthcoming; Sohngen et al. 1999; Adams et al. 1996), and maximizes the net present value of net surplus in wood biomass markets. Net surplus is defined as the area between the biomass demand curve and the land rent cost. The model, which uses a discrete time nonlinear optimization approach, is presented below. The procedure uses a general stylized forest sector model to examine the effects of an increase in the use of wood biomass energy on the amount of carbon captured in the forest over time under several hypothetical conditions.

This paper adopts and modifies the model in Daigneault et al. (2012) by adding in dedicated biofuel plantations and pulpwood harvesting. The social planner’s problem is to maximize the net present value of consumers’ plus producers’ surplus for timber harvesting as follows:

$$Max \sum_0^{\infty} \rho^t \left\{ \begin{array}{l} \int_0^{q_t^S} \left\{ D^S(q_t^S, Z_t) - f^S\left(q_t^S\right)\right\} dq_t^S + \int_0^{q_t^P} \left\{ D^P(q_t^P, Z_t) - f^P\left(q_t^P\right)\right\} dq_t^P + \\ \int_0^{q_t^B} \left\{ D^B(q_t^B, Z_t) - f^B\left(q_t^B\right)\right\} dq_t^B - C^e\left(e_t\right) - \\ \sum_i p_m^i m_t^i G_t^i - \sum_{i=b} C^B(G_t^i) - \sum_i R^i(\sum_a X_{a,t}^i) \\ \\ \end{array} \right\}. \qquad (1)$$

Table 1 describes the variables and functions in the social planner's problem. There are i total forest types in the model. Within each forest type, timber harvesting is done in age classes. The area of forests in each age class a and type i is given as $X^i_{a,t}$, and harvests are given as $H^i_{a,t}$. Timber yields are given as $V^i_a(m^i_{to})$, so that total harvest in each type is found as

$$y_t^i = \sum_a V_a^i(m_{to}^i) H_{a,t}^i. \qquad (2)$$

Total harvest for each type is then broken into the proportions used for sawtimber and pulpwood. Biomass energy can then be derived either from sawtimber harvests or pulpwood harvests. The proportion of total timber harvest used for sawtimber is φ^i, and the proportion of total timber harvest use for pulpwood is $(1 - \varphi^i)$. The proportion of sawtimber used for biomass energy is given as $\sigma^{i,S}$, and the proportion of pulpwood used for biomass energy is given as $\sigma^{i,P}$. Given these parameters, the quantities of sawtimber, pulpwood, and biomass harvested every year are as follows:

$$q_t^S = \sum_i (1 - \sigma^{i,S}) \varphi^i y_t^i$$

$$q_t^P = \sum_i \left(1 - \sigma^{i,P}\right)(1 - \varphi^i) y_t^i$$

$$q_t^B = \sum_i \left(\sigma^{i,S}\right)(\varphi^i) y_t^i + \left(\sigma^{i,B}\right)(1 - \varphi^i) y_t^i.$$

$D(\cdot)$ are downward-sloping demand functions for sawtimber (S), pulpwood (P), and biomass (B) energy in each period. These are globally aggregated demand functions that sum the harvests across different types i. Types are differentiated by growth characteristics, harvest costs, transportation costs, and other factors.

In addition to substituting sawtimber and pulpwood to use as biomass, and in addition to the dedicated biofuel plantations, the model also allows residues to enter as a supply of material for biomass energy. These residues are additional materials that can be harvested from forests but currently are typically left behind because they are too costly to harvest. If biofuel demands are great enough, prices could rise and induce more harvesting of these stocks of residues. They are represented in the model as variable e_t, where residues are a function of annual harvests of timber:

$$e_t = \sum_i f(y_t^i). \tag{3}$$

The cost function for harvesting residues is strictly increasing in additional residues harvested from the landscape.

Regeneration of forests in each forest type is managed through the choice of m^i_t and the choice of hectares regenerated, G^i_t. The more management chosen at the time of replanting, t_o, the greater the yield will be when the timber is harvested. Units of management have the following effect on timber yields:

$$V_{a,t}^i\left(m_{to}^i\right) = V_a^i(1 + m_{to}^i)^{\xi}. \tag{4}$$

Timber yields at time of harvest, t, depend on management inputs at time of planting, t_0. The parameter ξ is positive and always less than 1, such that the management function will increase with increasing units of m^i_t, but at a decreasing rate. Dedicated biofuel plantations are assumed to be more costly to regenerate initially than other forests, as represented by the function $C^B(G^i)$. This is a onetime initial regeneration cost included for converting old agricultural land to short-rotation forests.

Table 1. Variables and Functions in the Forestry Problem

$D^S(\cdot)$, $D^P(\cdot)$, $D^B(\cdot)$ = global demand function for sawtimber, pulpwood, or biomass
$f^S(\cdot)$, $f^P(\cdot)$, $f^B(\cdot)$ = cost function for harvesting sawtimber, pulpwood, or biomass
q^p, q^S = quantity of sawtimber or pulpwood harvested
Z = quantity of other goods consumed
p^i = cost of a unit of management for regenerating forests
m^i = number of units purchased for regenerating forests
G^i = area of forest type i regenerated
N^i = area of dedicated biomass energy plantation regenerated
$C^B(G^i)$ = cost function for establishing dedicated biomass energy plantation
$R^i(X^i_a)$ = rental cost function for holding land in forest type i
$C^e(e_t)$ = cost function for harvesting residues from the landscape
e = quantity of residue harvested

In the baseline, equation (1) above is maximized subject to the following equations:

$$X^i_{a+1,t+1} = X^i_{a,t} - H^i_{a,t}, \tag{5}$$

$$X^i_{1,t+1} = G^i_t, \tag{6}$$

$$H^i_{a,t} \leq X^i_{a,t}, \text{ and} \tag{7}$$

$$H_{a,t}, X_{a,t}, G_t \geq 0. \tag{8}$$

In the dynamic forest management model, management activities over time respond to current and anticipated market conditions that maximize financial returns to the forest, under alternative scenarios with different rates of demand growth, elasticities of forestland supply, and growth-and-yield functions. This Methodology recognizes that demand, whether expected or actual, will influence harvest levels as well as investments in new forest production via management in the direction of increased investments in forests, such as through tree planting and silvicultural activities in this path, due to the increased demand for wood for bioenergy use and the induced increases in forest investments and management. The approach examines the intertemporal path of forest carbon stocks and changes.

Marginal Land Cost Curves

This study undertakes an analysis of marginal lands to determine the extent to which these lands could be suitable for producing cellulosic material for biomass fuel. Using data provided by the US Geological Survey (USGS) and other government entities, we have identified land that is not currently used for cropping or forest. To meet the suitability test, the land must not be in current use for crops or forest, and the productivity, precipitation, and slope must meet standards acceptable for the production of fuelwood or fuel grasses. These lands are identified by region. The regional cost curves for these lands are developed based on site productivity levels, with the highest-productivity lands being assessed as the lowest-cost producers of biomass, and each incremental decrease in productivity being associated with a higher per-unit cost of biomass. Thus, we have developed a series of biomass cost curves for each region. Note that land already in forest is also subject to productivity increases due to the price increases, which create incentives for more intensive management.

The Data

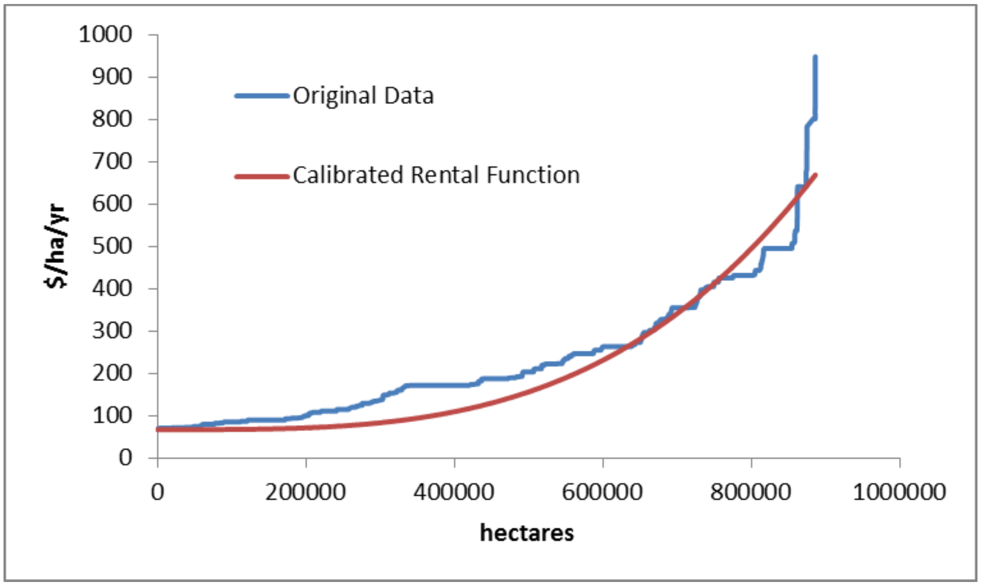
The thrust of this project is to examine the potential for biomass energy production on marginal lands in the United States. Inherently, this is a difficult research concept because “marginal lands” are defined partly by human activity and partly by their productivity capability. Individual parcels may be incapable of economically supporting some crops but capable of supporting others. It may be difficult to determine for individual parcels whether a crop is economically viable on a given parcel in a given time period; this will depend largely on crop and input prices. Landowner decisions to let land lie fallow may not be rational. In general, the literature on marginal land is conflicting or unclear because of these issues, which the data must address. We chose the Cropland Data Layer (described in the Appendix) as the data source for marginal lands because it directly measures fallow and idle parcels, reflecting landowner economic decisions rather than extrapolations based on biotic criteria. This approach purposefully confines our analysis to lands currently not in agricultural crop production.

We first compiled these data into seven regions in the United States: the Northeast, North-Central, Plains, South, West, Pacific Northwest, and California. We eliminated land that did not meet a productivity threshold of 10 bushels per acre per year in potential crop yield for either corn or wheat. Next, for each hectare with at least 10 bushels per acre in potential yield, we calculated potential net revenues using US Department of Agriculture (USDA) data on crop returns for each of our regions. With the remaining land, we then calibrated a land rental function for each region, assuming that the rental function has the following form:

$$R^i(\cdot) = A^i + \left(\sum_a X^i_{a,t=0} \Big/ B^i \right)^{1/0.3}.$$

Given a set of land areas and a set of land rents, we can calibrate A^i and B^i from the data. As an example, Figure 1 presents the original crop return data and our calibrated rental function for the Plains region in our model.

Figure 1. Comparison of Original Data and Calibrated Rental Function for the Plains Region



Applications of the Model

The model is first solved assuming that there is no demand for biomass energy. This constitutes the baseline case. Two scenarios are then developed that allow additional demand for biomass energy. The first scenario has a very modest demand for fuelwood, and the second scenario has a substantially higher demand for fuelwood (Table 2). The higher demand in scenario 2 is consistent with the scenario run in Daigneault et al. (2012). In both of these scenarios, biomass material can be obtained from dedicated biofuel plantations, substitution with timber stocks, and residues. Note that even the higher scenario has levels that are significantly less than the levels proposed in the Energy Independence and Security Act of 2007 and examined by Sedjo and Sohngen (2013).

Table 2. Demand for Biomass Material in Scenarios 1 and 2

	Scenario 1	Scenario 2
	million m^3 per year	
2010	1.8	40.9
2020	5.4	88.2
2030	7.5	127.8
2040	8.0	154.6
2050	8.0	167.1
2060	8.0	170.9
2070	8.0	170.9
2080	8.0	170.9
2090	8.0	170.9
2100	8.0	170.9

With higher demand for biomaterial, sawtimber and pulpwood prices rise (Figures 2a and 2b). In either case, sawtimber prices rise less than 0.6 percent in any year. In fact, in scenario 1, sawtimber production in the United States rises slightly (Figure 3a). This increase allows slightly more production of residues. Sawtimber production falls initially in scenario 2. This actually is a dynamic response to produce more timber in the long run. By withholding timber initially, forests are shifted toward longer rotation ages, and this increases longer-run timber supply. Pulpwood prices rise substantially more, around 1.5 percent compared with the baseline in scenario 1 and up to 10 percent compared with the baseline in scenario 2. Most of the substitution of material for biomass is derived from pulpwood material, given the much lower prices for pulpwood (Figure 3b).

Figure 2a. Sawtimber Prices under Alternative Scenarios

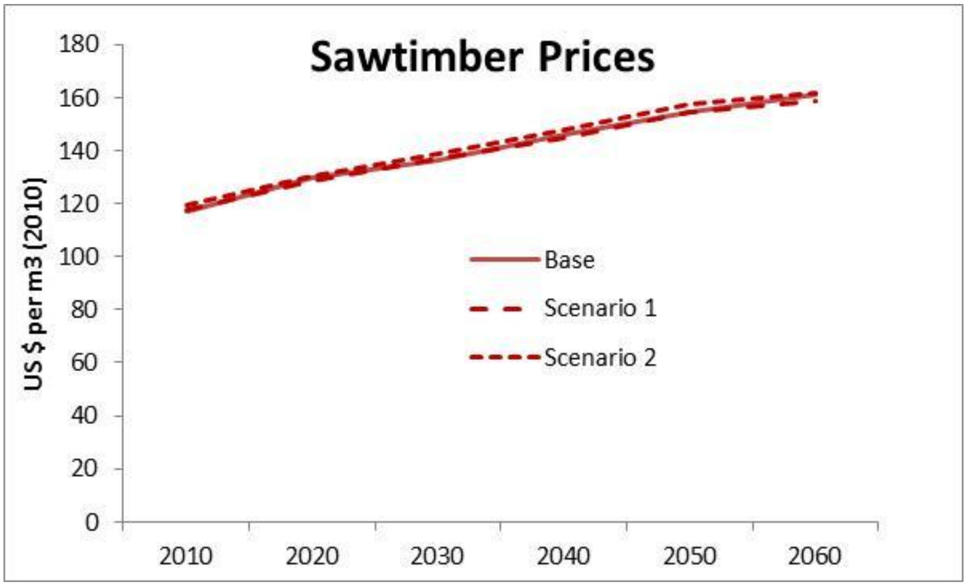


Figure 2b. Pulpwood Prices under Alternative Scenarios

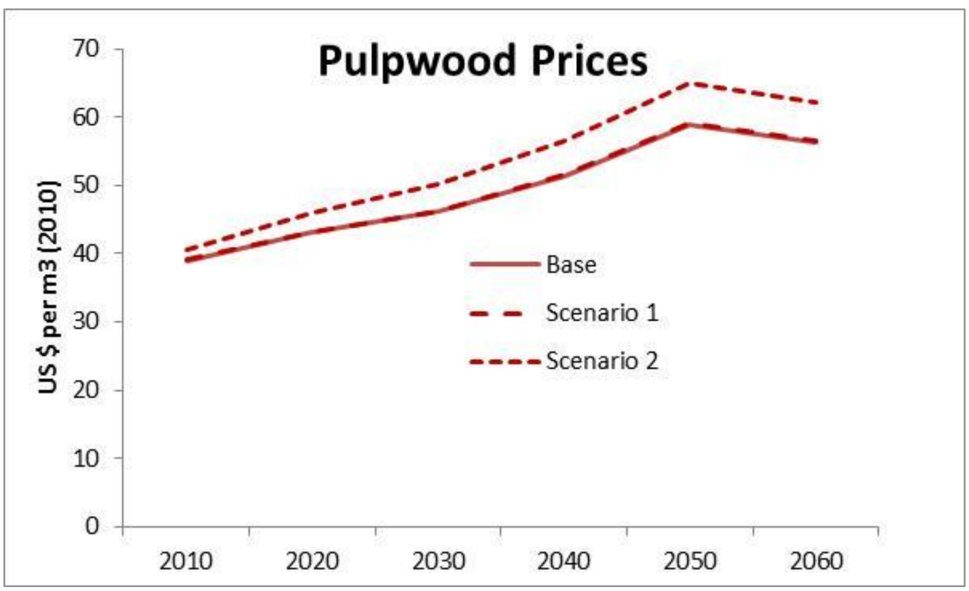


Figure 3a. US Sawtimber Production under Alternative Scenarios

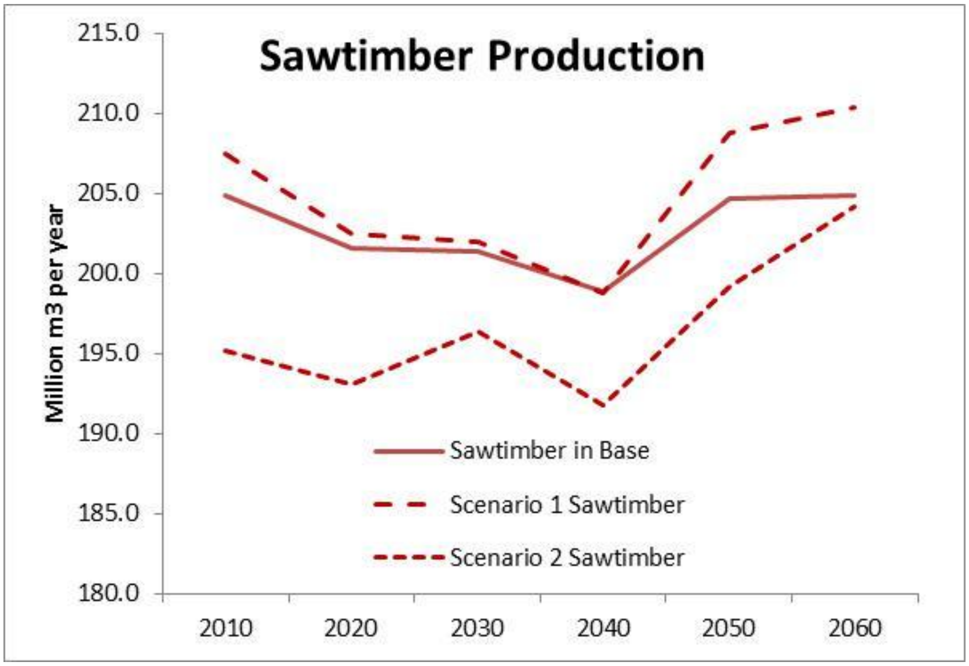
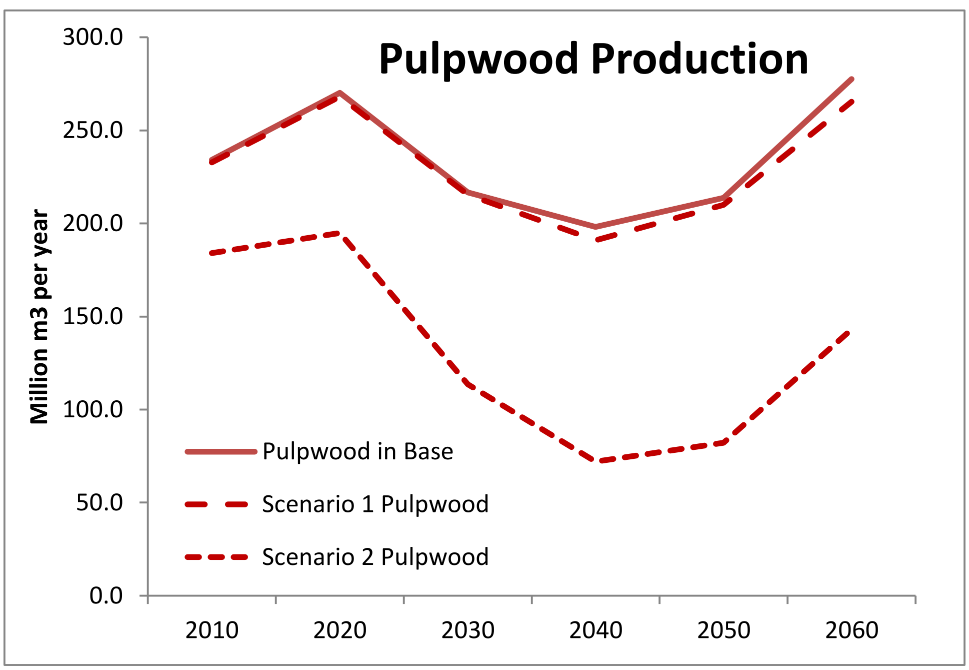


Figure 3b. US Pulpwood Production under Alternative Scenarios



In scenario 1, all three sources of potential biomass supply provide material to the market initially, with the bulk of material coming from substitution of pulpwood (Figure 4a). Some residues can be economically extracted for biofuel markets, but because they are relatively expensive to haul out of the forest, they represent a very small share of the market. Over time, residues do become relatively more important as the price of pulpwood increases. Dedicated biomass plantations become the dominant source of bioenergy supply over the long run in this scenario, although it takes a while to ramp up production of these energy plantations. The total area of biomass plantations expands from 460,000 hectares in 2020 to around 720,000 hectares in 2060 (Table 3).

Figure 4a. Sources of Biomass Supply under Scenario 1

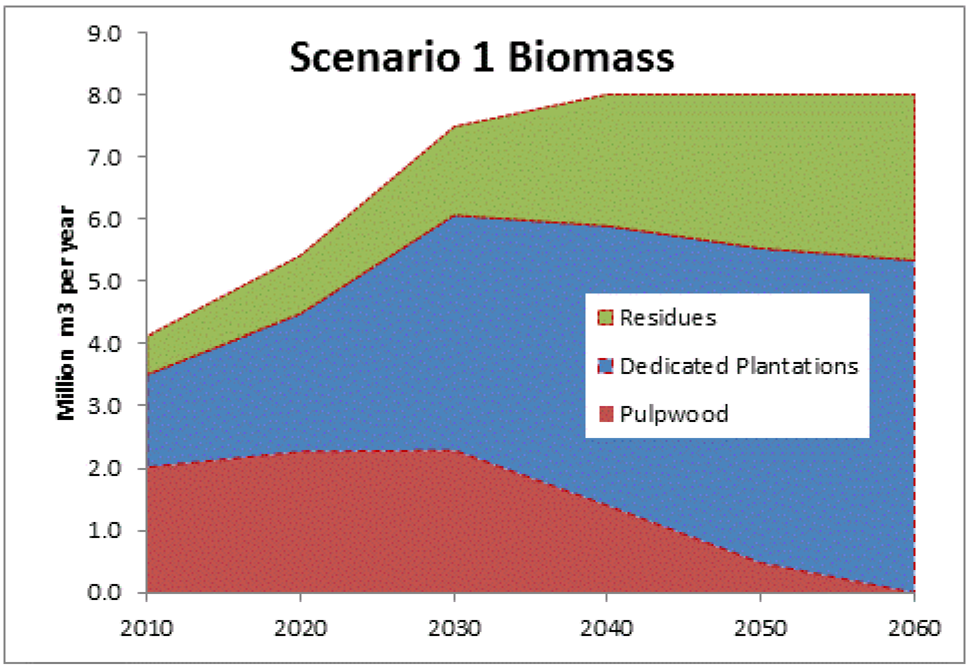
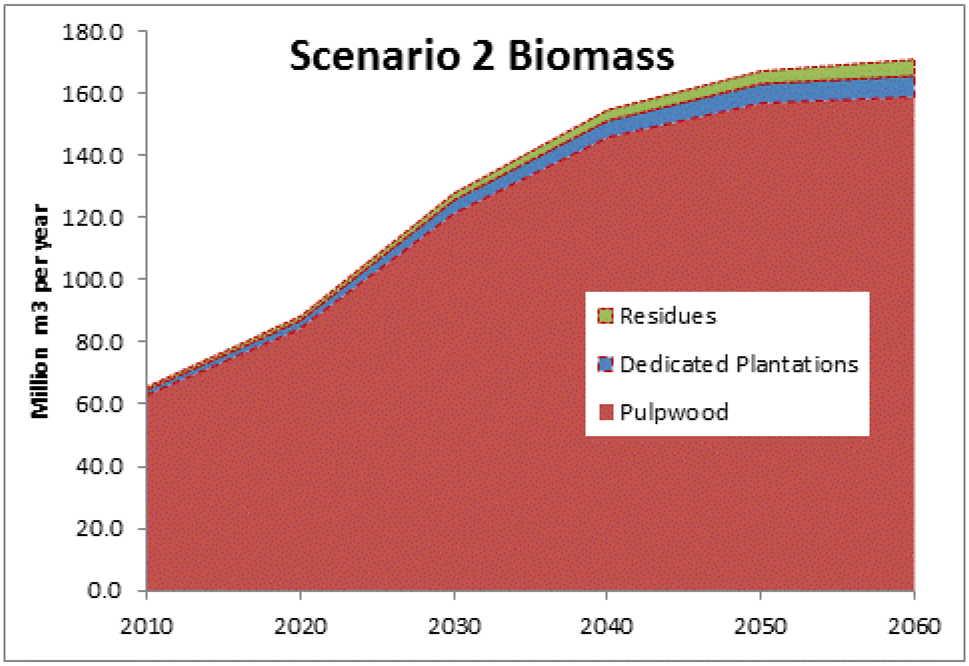


Figure 4b. Sources of Biomass Supply under Scenario 2



Under scenario 2, which substantially increases total biomass energy demand, the main source of supply becomes substitution with pulpwood material in both the near and longer terms (Figure 4b). Although the amount of residues provided does more than double in this scenario, they remain a relatively small proportion. The area of dedicated biomass plantations also increases (Tables 3 and 4), but by only about 25 percent. For this very large amount of biomass material, the main source of supply available remains the pulpwood market.

Total US supply of wood material into markets increases in both cases, although, as in the case of corn, the new energy market bids some biomaterial (wood) away from the traditional market. In scenario 1, the total increase in supply is about 5 million m^3 per year over the next 50 years. This increase is not quite enough to offset the increased demand in biomass energy, but it represents a large share. In scenario 2, the increase averages about 16 million m^3 per year over the next 50 years. This is a useful increase in supply, but it represents only about 10 percent of the total amount needed for biomass energy markets.

Table 3. Land Area for Dedicated Biofuel Crops in Scenario 1

	North-eastern	North-Central	South	Great Plains	West	Pacific North-west	California	Total
	million hectares							
2010	0	0	0	0	0	0	0	0
2020	0.1	0.1	0.06	0	0	0.2	0	0.46
2030	0.13	0.12	0.07	0	0	0.22	0	0.54
2040	0.16	0.14	0.08	0	0	0.25	0.05	0.68
2050	0.17	0.14	0.08	0	0	0.26	0.07	0.72
2060	0.17	0.14	0.08	0	0	0.26	0.07	0.72

Table 4. Land Area for Dedicated Biofuel Crops in Scenario 2

	North-eastern	North-Central	South	Great Plains	West	Pacific North-west	California	Total
	million hectares							
2010	0	0	0	0	0	0	0	0
2020	0.12	0.11	0.07	0	0	0.22	0	0.52
2030	0.15	0.13	0.08	0	0	0.24	0	0.6
2040	0.19	0.16	0.09	0	0	0.29	0.11	0.84
2050	0.21	0.17	0.09	0.02	0	0.31	0.13	0.93
2060	0.21	0.17	0.09	0.02	0	0.31	0.13	0.93

It is interesting that dedicated biomass plantations do not play a bigger role in biomass energy production in the United States. While they yield about 6.9 m^3 per hectare per year in material (or about 4.1 metric tons per hectare per year) for markets, they are also costly. We have assumed that it costs around $1,000 per hectare to establish new hectares of dedicated plantations on these marginal agricultural lands. This is a onetime cost to prepare the land for the dedicated tree fuelwood plantation. Land also is costly to rent. So, while there is clear scope to add timber plantations, the timber and pulpwood price increases we project induce the establishment of only between 500,000 and 1 million hectares of fuelwood plantations. The relatively modest increase in timber prices makes it unlikely that very large additional areas of plantations will be established, even if large areas of marginal lands are available.

Findings

The findings of the study surprised even the researchers. While it was anticipated that the newly introduced fuelwood supply sites would provide the majority of the requisite volumes of fuelwood, the actual amounts of newly developed land area projected to be going to fuelwood production were relatively modest, being between 500,000 and 1 million hectares, depending on the scenario. The vast majority of the wood moving into the bioenergy sector is drawn from the pulpwood sector, particularly in the high-demand scenario. This reflects in part the large volumes of pulpwood potentially available in US forests in the face of stagnating demand for paper and the high levels of pulpwood available as a result of the large areas of plantation established in the latter part of the 20th century.

The model suggests that the wood available for bioenergy would initially be drawn from residues and the fuelwood plantations. However, a strong and continuing demand would drive the price of fuelwood to that of pulpwood . At that point, the fuelwood and pulpwood users would compete for traditional pulpwood, with substantial volumes of pulpwood being drawn off into fuelwood. The effect of the additional demand for fuelwood from pulpwood users would be to drive up still further the fuelwood price, which was already equalize with the pulpwood price. However, even in our high fuelwood demand scenario, and contrary to some current concerns, the projections show that the pulpwood price would not increase excessively because of the large wood supply available from the pulpwood sector, some of which may be drawn from abroad. Nevertheless, the higher price would bring additional wood into the pulpwood and fuelwood markets, as well as provide incentives for additional investments in both markets.

In an earlier study by Sedjo and Sohngen (2013), an important finding was that the wood sector could provide the bioenergy necessary to meet substantial increases in bioenergy feedstock as anticipated in the EIA (2012) energy projections going into the 2020s and beyond, but only at significantly higher prices. Note that in the present study, the demand levels examined are less than those of the EIA projections into the 2020s, being roughly one-half. However, the earlier study assumes that fuelwood demand continues to rise through the latter part of the 21st century, and it provides for new wood supply sources in the form of the fuelwood plantations. An important implication with regard to the Searchinger Hypothesis is that quite high levels of future bioenergy demand could be met within the United States through a combination of new fuelwood plantations and the increased use of wood types traditionally used for pulpwood. However, there are limits to what the forest system with fuelwood plantations can economically provide. Also note that meeting bioenergy demand with wood depends on a technology being developed to make the cellulosic ethanol form of wood economically viable for biofuels.

Finally, in concept, grasses could be an alternative feedstock used for the production of cellulosic ethanol. If lands similar to those we selected for fuelwood plantations were used, the same results would probably apply for grasses, which are comparably productive. However, as with fuelwood, it is likely that pulpwood would still be needed for a major portion of biomass due to grass production and cost considerations. If pulpwood were not forthcoming, then we could expect that much larger areas of newly established grass farms on marginal lands would be required. If these grasses displaced food and feed crops, some of the problems predicted by Searchinger would presumably result. Note, however, that prime agriculture lands would be unlikely to be used for grasses, as their value for crops would continue to be much greater than their value for biomass.

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Appendix: Data Sources

Marginal lands data were extracted from the Cropland Data Layer (CDL) for 2011 (USDA NASS 2011). Produced annually by the National Agricultural Statistics Service, the CDL is a geospatial dataset of crop types for the continental United States measured to a 30-meter resolution. It is created through the use of medium-resolution satellite imagery and ground-truthed using the USDA Farm Service Agency (FSA) Common Land Unit (CLU) data and the USGS National Land Cover Database (NLCD).

Data on parcel productivity were derived from the NRCS SSURGO 2.0 soils database (NRCS Soil Survey Staff 2012), a geospatial dataset containing the results of the National Cooperative Soil Survey as collected over the course of the past century in the continental United States. SSURGO 2.0 reports soil attributes at a level most closely corresponding to soil series, or other soil components with closely aligned biotic and abiotic characteristics. The database shows crop productivity for non-irrigated soils for commodity crops, including corn, soy, and wheat, which were used as proxies for biomass productivity. Crop productivity is given in yield per acre using an appropriate unit of volume for each crop; for example, corn is reported in bushels and soy in tons.

Marginal lands parcels were geospatially overlaid with soils to extract the area and location of marginal lands with associated crop yield in corn and soy, or wheat and soy for regions where corn is not typically grown. The data were summed to report total marginal lands area per yield. Data were then compiled to the level of major forest regions in the United States: the Northeast, North-Central, Plains, South, West, Pacific Northwest, and California.