New Zealand Journal of Forestry Science
a SpringerOpen Journal

PROCEEDINGS Open Access

Assessing the impact of planted forests on the global forest economy

Joseph Buongiorno*, Shushuai Zhu

From Third International Congress on Planted Forests
Bordeaux, France; Dublin, Ireland; and Porto and Estoril, Portugal. 16-21 May 2013

Abstract

Background: Planted forests are increasingly important in world forestry, natural resources conservation, and climate change policies. There is great interest in their potential for carbon sequestration and conservation of natural forests while they remain an essential source of fuelwood and industrial roundwood.

Methods: A method was developed for estimating the importance of planted forests in the global forestry sector. This was based on calculation of a global economic equilibrium with or without planted forests, using an adaptation of the Global Forest Products Model (GFPM) to simulate wood production in seven regions representing a total of 180 countries. The GFPM was then used to calculate production, consumption, trading balance, and price of forest products in 2009.

Results: The utilisation of planted forests was estimated to reduce prices of forest products by 24 - 37%, and those of manufactured products by 4 - 14%, depending on the level of processing. World production of fuelwood was 4% greater due to the utilisation of planted forests, and industrial roundwood production was 14% higher.

Conclusions: Although an increase in the level of consumption of end products was noted for all regions, production was sometimes lower if the effect of reduced prices was greater than the effect of the increase in wood supply. Nevertheless, the gain in global financial benefit to consumers far exceeded the loss of producer profits, leading to an estimated net gain of US$10,000 ha^{-1} in net present value at 2009 prices. Furthermore, planted forests reduced roundwood harvesting from natural forests by 26%, thereby contributing to ecological benefits such as carbon sequestration and biodiversity conservation.

Introduction

Planted forests, defined as "forests predominantly composed of trees established through planting and/or deliberate seeding of native or introduced species" (FAO, 2010) are becoming increasingly important in world forestry, natural resources' conservation, and climate-change policies. According to the most recent global forest resources assessment, planted forests occupy approximately 258 million ha, or 6 percent of the total world forest area (FAO, 2010). Their usefulness includes wood production and protection against erosion, avalanches, and desertification, with often a mix of purposes. The potential of planted forests for carbon sequestration and conservation of natural forests is increasingly being recognised (AFB, 2012, WWF, 2012). Furthermore, planted forests are, and will, remain an essential source of fuelwood and industrial roundwood. Recent studies suggest that they have the potential for production of up to two thirds of the global roundwood supply (Carle and Holmgren, 2008, Del Lungo et al., 2006).

The present study was concerned mainly with planted forests as sources of fuelwood and industrial roundwood. The objective was to develop and apply a method to assess quantitatively the contribution of planted forests to the world forest economy. The first part of this paper presents the theoretical framework used to describe the global competitive markets for wood and forest products and production from planted and natural forests. This is followed by the application of the Global Forest Products Model (GFPM) to forest economy data for 2009, with and

* Correspondence: jbuongio@wisc.edu
Department of Forest and Wildlife Ecology, University of Wisconsin-Madison, Russell Labs, 1630 Linden Drive, Madison, WI 53706, USA

without utilisation of planted forests. The GFPM predictions are then discussed in terms of the effect of planted forests on the world prices of specific wood products, and on the quantities consumed, produced, and traded by the main regions of the world. The impacts of planted forests on consumer and producer surplus and on harvesting from natural forests are also considered.

Materials and methods

Theory

The theoretical framework underlining the study is illustrated in Figure 1. It describes world demand, supply and trade of a single commodity (wood) produced in two regions, where Region 1 includes the parts of the world that contain planted forests while Region 2 represents the rest of the world containing no planted forests. Two scenarios were tested, one where planted forests are utilised and the other where they are not. When planted forests are utilised, the world equilibrium price is P. At that price, Region 1 (with planted forests utilised) produces the quantity S_1 and consumes the amount D_1. It exports the difference (S_1-D_1) to Region 2 (with natural- but without planted-forests), which produces the quantity S_2 and consumes the amount D_2 in such a way that D_2-S_2 = S_1-D_1. In the alternative scenario, the planted forests in Region1 are not utilised so Region 1 would produce less wood at any given price (or, equivalently it would cost more to produce a given amount). The equilibrium price would then be P' and the net exports of Region 1 would be S_1'-D_1' equal to the net imports of Region 2, D_2'-S_2'. Thus, the effect of utilising planted forests in Region 1 is equivalent to a shift of the production (supply) curve from A to B. This shift lowers the price, which increases consumption in both regions. The utilisation of planted forests in Region 1 also leads to more trade but the effect on production is variable. For example, in Figure 1: production is higher in Region 1 when planted forests are utilised but the world price is lower. Thus production is slightly lower in Region 2 when planted forests are utilised. This is because the lack of planted forests in Region 2 means the supply curve for this Region is unchanged and thus the lower price induces less production.

The total impact of planted forests on the world forest economy was assessed by estimating the change in consumer and producer surplus in various regions, with and without utilisation of planted forests (Varian, 1992, pp. 222-224). Figure 2 represents the theory for a single closed economy and one product: wood. It suggests that while wood consumers always benefit from the utilisation of planted forests, this is not generally the case for wood producers.

Application of the Global Forest Products Model

The Global Forest Products Model (GFPM), described originally by Buongiorno et al. (2003) and revised by Buongiorno and Zhu (2013 a, b), was used to quantify the effects expressed in Figures 1 and 2. This model simulates demand, supply and trading of fourteen groups of commodities in 180 countries. The model computes the market equilibrium for all products in any given year and simulates the evolution of this equilibrium from one year to the next to project the future state of the sector. However, in this application only the static part of the model was used to represent the market equilibrium in 2009 with and without utilisation of planted forests. Following the method of Samuelson (1952) this equilibrium was computed by maximising the sum of the consumer and producer surplus for all products and countries:

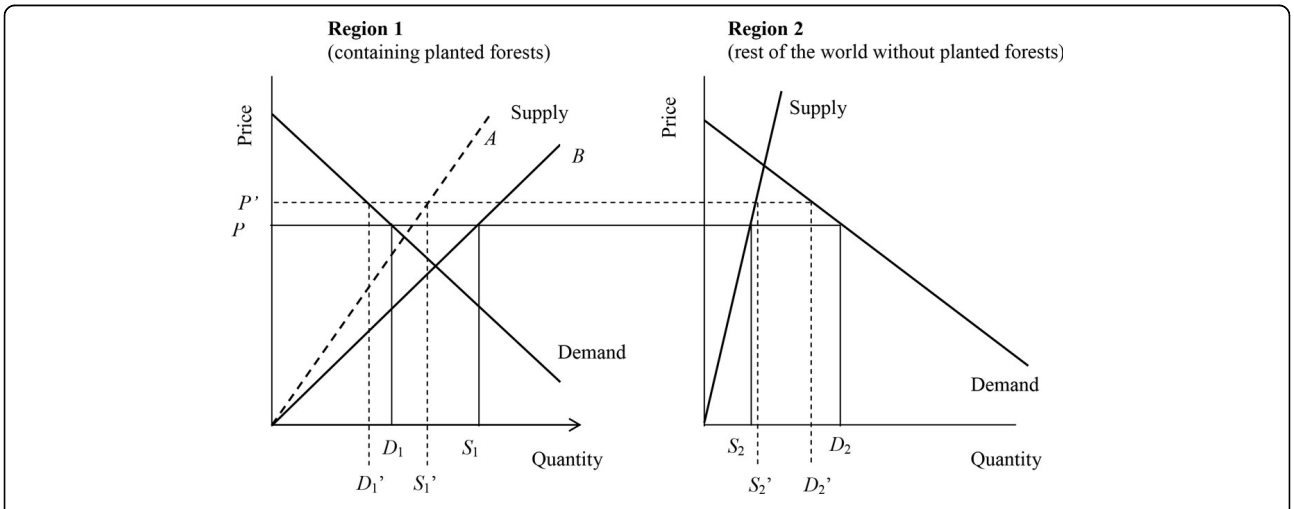

Figure 1 Effect of utilisation planted forests on world demand, supply, and trade in wood. *P* refers to price, *S* to production, *D* to consumption. *A* and *B* designate the wood supply with and without planted forests, respectively.

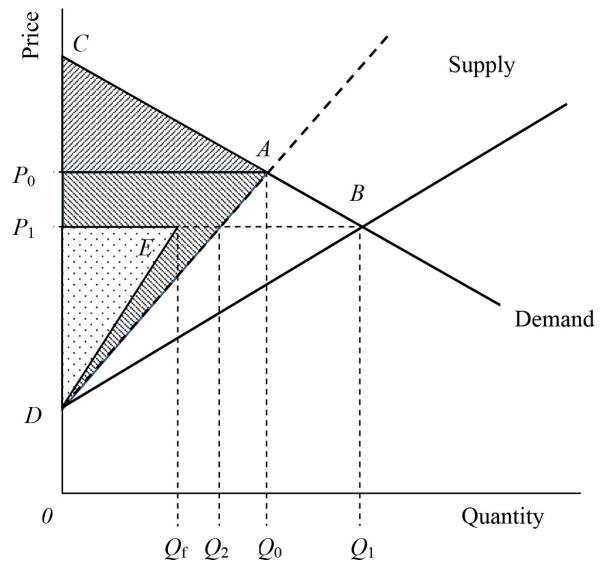

Figure 2 Consumer and producer surplus without planted forests, and with planted forests. Point *A* is the equilibrium without utilisation of planted forests, at quantity Q_0 and price P_0. Point *B* is the equilibrium with utilisation of planted forests. The area of triangle ACP_0 measures the consumers' surplus without utilisation of planted forests, the difference between the total benefits of wood consumption, measured by the area under the demand curve up to Q_0 and the expenditure on wood, $P_0 \times Q_0$. The area of the triangle DAP_0 is the profit, or producers' surplus, without utilisation of planted forests. This is equal to how much producers get for their wood, $P_0 \times Q_0$, minus the cost of production, the area under the supply curve up to Q_0. The utilisation of planted forests decreases the price of wood to P_1 and increases consumption and production to Q_1. Since the demand curve is unchanged, the price decrease and the quantity increase always increase the consumer surplus by the amount measured by the area P_1P_0AB. At price P_1, the production from planted forests is $Q_f = Q_1 - Q_2$. Thus, the producer surplus on planted forests is always positive, and equal to the area P_1ED, however the surplus of all wood producers (on planted forests or not), measured by the area P_1BD, may be higher or lower than without planted forests (area P_0AD) depending on the elasticity of supply and demand.

$$\max\left(\sum_{i,k}\int_0^{D_{ik}} P_{ik}(D_{ik})dD_{ik} - \sum_{i,k}\int_0^{D_{ik}} P_{ik}(S_{ik})dS_{ik} - \sum_{i,k}\int_0^{D_{ik}} m_{ik}(Y_{ik})dD_{ik} - \sum_{i,j,k} c_{ijk}T_{ijk}\right) \quad (1)$$

where i and j refer to countries, k to products, P is the price, D is the end-product demand, S is the raw material supply, Y is the manufactured quantity at marginal cost m, and T is the quantity transported at cost c, including tariff and taxes. The first integral measures the value of the end products to consumers, the second and third integrals the cost of production, and the last term the transport cost.

Optimisation was subject to the following demand-supply equilibrium constraint for each country and product:

$$\sum_j T_{jik} + S_{ik} + Y_{ik} = D_{ik} + \sum_n a_{ikn}Y_{in} + \sum_j T_{ijk} \qquad \forall i,k \quad (2)$$

where a_{ikn} is the input of product k per unit of product n. The left-hand side of the equation represents the sum of imports, domestic supply, and manufactured quantity of a product in a country, while the right-hand side represents the sum of domestic demand for end products, demand for input in the manufacture of other products, and exports to other countries. The primal solution of this constrained optimisation gives the quantities consumed, produced, and traded, while the dual solution gives the equilibrium price for each product and country.

The model was calibrated for the year 2009, following the procedure described by Buongiorno and Zhu (2013b). Data for production, imports, exports, and prices were obtained from the FAOSTAT database (FAO, 2012). Estimates from the USDA Forest Service Global Outlook Study (Buongiorno et al., 2012) were used to describe the elasticity of demand and supply. The GFPM provided results for 2009 that closely replicated actual observations for that year.

Shifts in wood supply due to the presence of planted forests

In the GFPM, wood supply curves that include supply from planted forests are approximated by their linear tangent at the 2009 equilibrium point:

$$P = \alpha + \beta Q \quad (3)$$

Where P is the price of wood, Q the annual production, and α and β are parameters based on the elasticity of supply and on the price and quantity observed in 2009 (Buongiorno and Zhu, 2013a). The scenario without utilisation of planted forests was represented by a shift in the supply curve to the left:

$$P = \alpha + \frac{\beta}{1 + L(f)}Q \quad (4)$$

where $L(f)$ is the proportion of wood production from planted forests.

There is little international information about the proportion of wood production that comes from planted forests. It is generally recognised that this is substantially higher than the proportion of forest area that they occupy (Sheffield 2009, AFB 2012, Carle and Holmgren 2008). In this study it was assumed that a Lorenz curve would describe the relationship between the proportion of roundwood production from planted forests in a country and the proportion of forest area occupied (see for example Gastwirth, 1972):

$$L(F) = F^{1-\frac{1}{\alpha}} \quad (5)$$

where F is the proportion of forest area occupied by planted forests, and $L(F)$ is the proportion of total roundwood production obtained from planted forests (Figure 3). Values depend on the magnitude of α. When $\alpha = 2$, the curve closely approximates observations for the Landes area of France, where planted forests occupying 6% of the national forest area produce 23% of the national removals (AFB, 2012). It also approximates the situation in the south of the United States of America, where planted forests occupying 22% of the national forest area produce 43% of the removals (Sheffield, 2009). Only results for major world regions are presented here.

In 2009, planted forests occupied approximately 6% of the world forest area, 27% of the forest area in EU-27 countries, and 21% in Asia (Table 1). They were least common in South America (1% of the total area). Although Brazil had more than 5 million ha of planted forests, this represented only 1% of its total forested area. In Europe, 7% of the forest estate was planted. In Russia, more than 16 million ha of planted forests contributed only 2% of the total forest area. In North America, planted forests occupied about 5% of the forest area and they were most prevalent in the United States rather than Canada. In Africa and Oceania, 2% of the forest area was planted, mainly in South Africa, Australia, and New Zealand.

The last two columns of Table 1 show the consequences of the Lorenz curve assumption for the regional roundwood production from planted forests. Overall, 32% of world roundwood production in 2009 was derived from planted forests. In EU-27 countries, the proportion reached 52% whereas it was only 15% in South America. Worldwide roundwood production from planted forests computed from these data was estimated to be approximately 1 billion m^3. Of this, Asia contributed 459 million m^3 and Europe (including the Russian Federation) 266 million m^3.

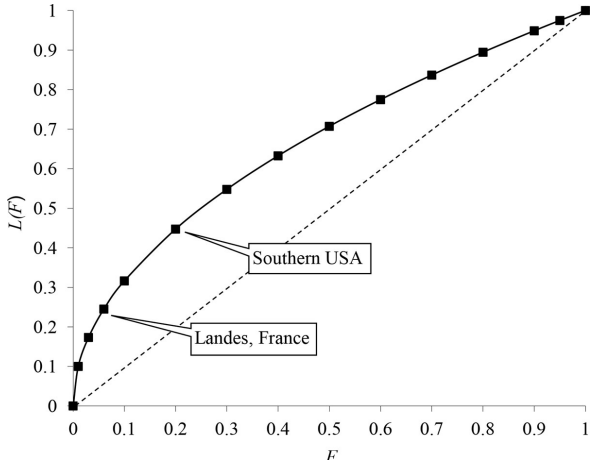

Figure 3 Assumed relationship between the proportion of planted forests in total forest area, *F*, and the proportion of industrial roundwood production from planted forests, $L(F)=F^{1-1/\alpha}$. The solid line represents the case where $\alpha = 2$. The dashed line represents the extreme case where $\alpha = 1$ and $L(F)=F$.

The GFPM was initially run for the scenario with planted forests using 2009 data. The model was then run for the scenario without planted forests using the same 2009 data after application of a shift in the roundwood supply curves to reduce roundwood production by the amount produced from planted forests. No other change was made. The difference between results with and without utilisation of planted forests gave a measure of the effect of planted forests on the global forest sector.

Results and Discussion

Effects of planted forests on forest product markets

Price

In competitive world markets, price is the most important indicator of the effect of resources and policies on demand, supply, and trade. World prices defined as the average unit value of world exports, as they were with planted forests in 2009 and as they would have been without planted forests, were calculated with the GFPM (Table 2). Depending on the product, world prices were 4 - 37% lower with planted forests. Fuelwood, industrial roundwood, and sawn wood prices showed the largest differences; printing and writing paper and paperboard the smallest. As expected, the price effect tended to decrease with the proportion of wood in the total production cost of a product.

Fuelwood production, consumption and trading

Due to the production from planted forests, estimated fuelwood consumption was higher in all regions because the price was lower. Globally, the world fuelwood consumption was 64 million m^3, i.e. 4% greater (Table 3). The largest increases were in Asia and Africa.

In contrast with the effect on fuelwood consumption, the utilisation of planted forests led to lower production of fuelwood in some regions (Table 3). This was because the difference in production was the net result of movement down the supply curve (caused by the price decrease) and the shift of the supply curve relating to production from planted forests. In some regions, notably Asia and the EU-27 countries, the positive shift of fuelwood supply due to planted forests largely compensated for the price-induced production decrease. In other regions, such as North and Central America, the negative effect of price on production was greater than the positive shift in supply from planted forests so production of fuelwood was lower. Worldwide, the utilisation of planted forests resulted in an estimated 4% increase in fuelwood production, matching the increase in global consumption.

Trade balance was altered by the utilisation of planted forests. For example, while the balance of trade for Asia

Table 1 Total and planted forest area, and corresponding estimated roundwood production in 2009.

Region	Forest area			Roundwood production		
	Total[1] (10^6 ha)	Planted forests[1] (10^6 ha)	Planted forests[1] (%)	Total[2] (10^6 m^3)	Planted forests[3] (10^6 m^3)	Planted forests[3] (%)
Africa	668	15	2	664	130	20
North/Central America	705	38	5	575	141	25
South America	868	12	1	383	59	15
Asia	591	121	21	1072	459	43
Oceania	192	4	2	66	15	23
Europe[4]	1004	69	7	634	266	42
EU-27 countries	156	43	27	410	215	52
World	4028	258	6	3394	1070	32

[1]FAO (2010) [2]FAO (2012)

[3]Authors' estimates.

[4] Geographical Europe defined as in FAO (2012) includes the Russian Federation. EU-27 countries are defined as in European Commission (2014).

improved because the increase in production was almost three times as great as the increase in consumption, the opposite effect was apparent in North/Central America and Europe.

Industrial roundwood production, consumption and trading

Increasing the availability of wood from planted forests decreased the price of industrial roundwood (Table 2) and this tended to increase consumption. Globally, estimated consumption of industrial roundwood was 14% higher when planted forests were utilised (Table 4), three times higher than for fuelwood. The effect in Asia was small, and in fact negative. This was because the demand for industrial roundwood is related to its use for secondary products (sawnwood, wood panels, pulp, paper and paperboard). Consumption therefore depends on the price of industrial roundwood, the price of end products, and the techniques of production. In other regions, estimates for consumption of industrial roundwood were considerably higher when planted forests were utilised, especially in Europe and South America.

The effect of planted forests on industrial roundwood production was influenced by price change and by the magnitude of the supply shift due to the utilisation of planted forests. In Asia and Europe, the supply shift was dominant and production was substantially higher in the scenario with planted forests (Table 4). In regions with few planted forests, e.g. South America, the effect of lower global prices exceeded that of the shift in supply and the

Table 2 Estimated 2009 world prices for products.

Product	Scenario with planted forests utilised	Scenario without planted forests utilised	Difference	Difference
	(US$ m^{-3})[1]	(US$ m^{-3})	(US$ m^{-3})	(%)
Fuelwood	59	93	-34	-37
Industrial roundwood	94	123	-29	-24
Sawn wood	253	309	-56	-18
Veneer & plywood	554	597	-43	-7
Particleboard	274	310	-36	-12
Fibreboard	391	423	-32	-7
	($/t)	($/t)	($/t)	(%)
Mechanical pulp	481	534	-53	-10
Chemical pulp	595	663	-68	-10
Other fibre pulp	1275	1337	-62	-5
Waste paper	149	160	-11	-7
Newsprint	628	671	-43	-6
Printing & writing paper	968	1006	-38	-4
Other paper & paperboard	919	959	-40	-4

[1]Unit value of total world exports in US$.

Table 3 Effect of the utilisation of planted forests on estimates of consumption and production of fuelwood in 2009.

Region	Consumption		Production	
	Difference (10^6 m^3)	Difference (%)	Difference (10^6 m^3)	Difference (%)
Africa	14	2	-8	0
North/Central America	6	5	-20	-13
South America	2	1	3	2
Asia	34	5	95	14
Oceania	0.3	3	-3	-21
Europe[1]	8	6	-11	-7
EU-27 countries	5	6	8	10
World	64	4	64	4

[1]Geographical Europe defined as in FAO (2012), includes the Russian Federation. EU-27 countries are defined as in European Commission (2014).

result was a lowering of production. World production was 14% higher when planted forests were utilised and this proportion matched consumption levels.

Utilisation of planted forests improved the trade balance (exports - imports = production - consumption) for industrial roundwood in Europe and Asia, but caused a decline in South America and Oceania.

Sawn wood and panels - production, consumption and trading

The world price in 2009 was 18% lower for sawn wood and 7 - 12% lower for panels when planted forests were utilised (Table 2) consequently, consumption of these commodities was higher in all regions, and 2.5% higher globally (Table 5). However, production was lower in some regions because supply was affected negatively by the price of industrial roundwood, and was dependent on technology. It was lowest in Asia, where it had a negative effect on trade balance. Wood supply from planted forests improved net trading in sawn wood and panels in North America and in Europe as a whole, but not in EU-27 countries.

Pulp and paper - production, consumption and trading

The utilisation of planted forests reduced the world wood pulp price by 10% (Table 2). This lower price tended to increase the demand for wood pulp (Table 6). However, wood pulp is an intermediate product so demand is also affected by the price of paper and paperboard and by the techniques of production. Thus, although the consumption of wood pulp was 8% higher globally due to planted forests, it was 6% lower in Asia. At the same time, because pulp supply is positively influenced by the price of pulp and negatively influenced by the price of industrial roundwood, production was higher when planted forests were utilised in areas where the effect of the pulp price was largest (South America and Europe) and lower where the price of industrial roundwood was dominant (Asia and North/Central America). The net result was that the balance of trade improved in South America and Europe, but deteriorated in North/Central America and to a lesser extent in Asia.

The utilisation of planted forests had very little impact on consumption of paper and paperboard (Table 7). In accordance with the small price decrease (Table 2), world consumption was only 1% higher with planted forests than without them. However, the effects on production were variable. Asia produced 8% less paper and paperboard when planted forests were utilised because the positive effect on supply due to lower wood and pulp price was over-ridden by the lower price of output. Elsewhere the lower cost of industrial roundwood and pulp associated with the utilisation of planted forests was the dominant factor, and production of paper and paperboard was greater. The net result of differences in production and consumption was an improvement of the trade balance in North/Central America and Europe but a decline in Asia.

Table 4 Effect of the utilisation of planted forests on estimates of consumption and production of industrial roundwood in 2009.

Region	Consumption		Production	
	Difference (10^6 m^3)	Difference (%)	Difference (10^6 m^3)	Difference (%)
Africa	15	32	1	1
North/Central America	30	7	30	7
South America	59	51	-24	-11
Asia	-1	0	89	43
Oceania	4	14	-5	-8
Europe[1]	83	21	99	25
EU-27 countries	52	17	115	54
World	190	14	190	14

[1]Geographical Europe defined as in FAO (2012), includes the Russian Federation. EU-27 countries are defined as in European Commission (2014).

Table 5 Effect of the utilisation of planted forests on estimates of consumption and production of sawn wood and wood-based panels in 2009.

Region	Consumption		Production	
	Difference (10^3 m^3)	Difference (%)	Difference (10^3 m^3)	Difference (%)
Africa	425	2	2998	36
North/Central America	3748	2	20818	16
South America	1127	3	5464	12
Asia	5326	2	-23710	-10
Oceania	252	2	-2333	-15
Europe[1]	4851	3	12492	6
EU-27 countries	3921	3	-2370	-2
World	15728	2.5	15730	2.5

[1]Geographical Europe defined as in FAO (2012), includes the Russian Federation. EU-27 countries are defined as in European Commission (2014).

Table 6 Effect of the utilisation of planted forests on estimates of consumption and production of wood pulp in 2009.

Region	Consumption		Production	
	Difference (10^3 t)	Difference (%)	Difference (10^3 t)	Difference (%)
Africa	437	24	874	63
North/Central America	8370	16	-7722	-10
South America	732	10	12940	175
Asia	-2814	-6	-4667	-15
Oceania	5	0	896	46
Europe[1]	5873	13	10280	28
EU-27 countries	5196	13	10937	39
World	12603	8	12601	8

[1]Geographical Europe defined as in FAO (2012), includes the Russian Federation. EU-27 countries are defined as in European Commission (2014).

Effects of planted forests on consumer and producer surplus

The results of calculations of consumers and producers surplus, based on data obtained from the two scenarios simulated using the GFPM are in Table 8. The second column of Table 8 shows the difference in consumer benefit with and without utilisation of planted forests. For all the end products considered (fuelwood, sawnwood, panels, and paper and paperboard), the supply from planted forests was estimated to increase consumer benefits in 2009 by about $108 billion for the world, of which $43 billion in Asia, and $21 billion in Africa.

In contrast, column five of Table 8 indicates that the estimated benefit to producers globally (from both natural and planted forests) was $30 billion per year lower when planted forests were utilised than when they were not. Thus, although the benefit to producers from utilisation of planted forests (second column in Table 8) was positive in all regions, totaling US$31 billion per year, or US$119 per hectare per year, it was generally not enough to compensate for the loss of profits on natural forests. The only exception was for EU-27 countries where the utilisation of planted forests did raise the producers' benefits, though by less than US$1 billion (Table 8), due to the high proportion of planted forests in EU-27 countries (Table 1).

Table 7 Effect of the utilisation of planted forests on estimates of consumption and production of paper and paperboard in 2009.

Region	Consumption		Production	
	Difference (10^3 t)	Difference (%)	Difference (10^3 t)	Difference (%)
Africa	86	1	590	18
North/Central America	1064	1	11419	14
South America	181	1	992	7
Asia	1634	1	-13553	-8
Oceania	62	1	-13	0
Europe[1]	1093	1	4685	5
EU-27 countries	950	1	4132	5
World	4120	1	4120	1

[1]Geographical Europe defined as in FAO (2012), includes the Russian Federation. EU-27 countries are defined as in European Commission (2014).

Overall the decrease in producer benefits due to the presence of planted forests was only one third of the increase in consumer benefits. The net result was an increase in industry benefits (consumers plus producers) of approximately US$77 billion per year, which is approximately one third of the total GDP of Portugal. The largest regional impact of planted forests was observed for Asia, followed by Europe and Africa.

The last two columns of Table 8 show estimates of industry benefits from utilisation of planted forest per unit of planted forests in 2009, and the present value of a constant future stream of the same amount at a real interest rate of 3 percent per year, respectively. The average global increase was US$300 per hectare per year. The present value of this constant yearly amount over an infinite horizon would be US$300/0.03 = US$10,003 per hectare, but it varied considerably by region, and approached US $29,000 per hectare in Africa.

Effects of planted forests on natural forests

Another important positive effect of planted forests implied by these results is the reduction of harvesting from natural forests. This has obvious ecological benefits, including conservation of biodiversity and carbon sequestration. Calculations from 2009 data suggest that the utilisation of planted forests reduced world harvesting from natural forests by 816 million m^3, or 26% (Table 9). Although a considerable amount, this was 6% less than the proportion of roundwood production from planted forests (Table 1). The difference was attributed to reduction in roundwood price associated with production from planted forests which increased the demand for roundwood and the amount harvested from both planted and natural forests. Asia, followed by Europe, showed the largest absolute reduction in natural forest harvesting due to global availability of wood from planted forests.

Conclusions

The theory of competitive global markets for wood and wood products suggests that the primary effect of utilising planted forests is production of more wood at any given price. Working on this assumption, application of the Global Forest Products Model to 2009 data indicated that the utilisation of planted forests reduces the world price of all wood products in rough proportion to the amount of product cost related to the wood content. As a result, world consumption (and production) of wood products is

Table 8 Effect of the utilisation of planted forests on consumer surplus and producer surplus in 2009.

Region	Difference in consumer surplus	Difference in producer surplus			Total benefit to industry		
	(10^9 US$)	Planted forests (10^9 US$)	Natural Forests (10^9 US$)	All Forests (10^9 US$)	(10^9 US $)	(US$ ha^{-1} y^{-1})	(US $ ha^{-1})[1]
Africa	21.4	3.1	-11.6	-8.5	12.9	858	28609
North/Central America	15.5	4.6	-10.6	-6.0	9.6	252	8400
South America	9.5	1.7	-7.4	-5.7	3.9	334	11130
Asia	43.1	12.1	-17.9	-5.8	37.2	307	10241
Oceania	1.1	0.5	-1.6	-1.1	0	-1	-28
Europe[2]	16.8	8.7	-11.8	-3.1	13.7	199	6639
Eu-27 countries	12.7	7.1	-6.2	0.9	13.6	319	10647
World	107.6	30.6	-60.8	-30.2	77.4	300	10003

[1]Present value of a constant future stream of the same amount at a real interest rate of 3% per year.
[2]Geographical Europe defined as in FAO (2012), includes the Russian Federation. EU-27 countries are defined as in European Commission (2014).

increased by the utilisation of planted forests. This global increase ranges between 14% for industrial roundwood and 1% for paper and paperboard. Consumption of end products (fuelwood, sawnwood, panels, paper and paperboard) was commensurately higher in all seven regions investigated. However, production of these commodities, as well as that of roundwood and pulp, could be negatively affected as it depends on the proportion of wood obtained from planted forests, the techniques involved in transforming wood into products, and the price of raw materials and end products.

Due to the lower price and higher consumption of end products, the financial benefit to consumers was found to be higher with the utilisation of planted forests than without them, in all regions examined. However, globally, the financial benefit to producers was lower because the increase in planted-forest producer benefit did not compensate fully for the decrease in natural-forest producer benefit. Planted forests therefore induced a transfer of financial benefit from natural-forest wood producers to consumers of end products and planted-forest producers. Nevertheless, the total benefit (producer + consumer benefits) increased in most regions and at global level. Estimates suggest that the average net present value of future financial benefit from planted forests throughout the world would be approximately US$10,000 hectare.

Data for 2009 indicate that world harvesting from natural forests is 816 million m^3 (26%) lower due to the utilisation of planted forests. The consequent increase in ecological benefits such as biodiversity and carbon storage must be considered and should be investigated in future work which should also include gathering better country-specific data on the extent and production of planted forests. In future benefit-cost analysis of planted forests, the distributive effects noted above should also be recognised to evaluate the full social impact of new investments.

Table 9 Effect of the utilisation of planted forests on differences in the amount of roundwood harvested from natural forests in 2009.

Region	Roundwood harvested from natural forests		Difference, 10^6 m^3 (%)	
	With planted forests utilised[1] (10^6 m^3)	Without planted forests utilised[2] (10^6 m^3)		
Africa	535	664	-130	-20
North/Central America	434	565	-131	-23
South America	324	403	-79	-20
Asia	613	888	-275	-31
Oceania	51	73	-22	-31
Europe[3]	368	546	-178	-33
EU-27 countries	195	287	-93	-32
World	2324	3139	-816	-26

[1]Estimated from Table 1.
[2]Predicted from GFPM simulations.
[3]Geographical Europe defined as in FAO (2012), includes the Russian Federation. EU-27 countries are defined as in European Commission (2014).

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
Joseph Buongiorno conceived the study, did the calculations and wrote the paper. Shushai Zhu assisted in the preparation of the data and the development of the GFPM model.

Acknowledgements
This study was supported in part by a joint venture agreement with the USDA Forest Service Forest Research Station in cooperation with project leader Jeff Prestemon. We thank attendees of the 3rd International Congress on Planted Forests held 15-18 May 2013 at the Universidade Catolica Portugesa, Porto, Portugal, for comments and suggestions on our presentation, although any remaining error or interpretation remain our own.

Declaration
Publication of this supplement was funded by the New Zealand Forest Research Institute Limited (trading as Scion).
This article has been published as part of *JOURNAL* Volume 44 Supplement 1, 2014: Proceedings of the Third International Congress on Planted Forests. The full contents of the supplement are available online at http://www.nzjforestryscience.com/supplements/44/S1.

Published: 26 November 2014

References
AFB: **Manifeste en faveur des forêts de plantation en France. Alliance Forêts Bois, Pierroton.** 2012, Retrieved 1 April 2012 from: http://www.cofogar.com/fr/actualites/actualites-moment/?page = 2.
Buongiorno J, Zhu S, Raunikar R, Prestemon J: **Outlook to 2060 for world forests and forest industries. A technical document supporting the Forest Service 2010 RPA Assessment.** Asheville, NC, USA: U.S. Department of Agriculture Forest Service, Southern Research Station; 2012, [General Technical Report SRS-151].
Buongiorno J, Zhu S, Zhang D, Turner J, Tomberlin D: **The Global Forest Products Model, Structure, Estimation, and Applications.** San Diego, CA, USA: Elsevier/Academic Press; 2003.
Buongiorno J, Zhu S: **Using the Global Forest Products Model (GFPM version 2013 with BPMPD).** [Staff paper series, No. 78]. Madison, WI, USA: Department of Forest and Wildlife Ecology, University of Wisconsin-Madison.; 2013a, Retrieved 13 May 2013 from: http://labs.russell.wisc.edu/buongiorno/welcome/gfpm/.
Buongiorno J, Zhu S: **Calibrating and Updating the Global Forest Products Model (GFPM version 2013 with BPMPD).** [Staff paper series No. 79]. Madison, WI, USA: Department of Forest and Wildlife Ecology, University of Wisconsin-Madison.; 2013b, Retrieved 13 May 2013 from: http://labs.russell.wisc.edu/buongiorno/welcome/gfpm/.
Carle J, Holmgren P: **Wood from planted forests, a global outlook 2005-2030.** *Forest Products Journal* 2008, **58(12)**:6-18.
Del Lungo A, Ball J, Carle J: **Global forests thematic study, results and analysis.** [Working Paper FP/38]. Rome: Forestry Department, Food and Agriculture Organization of the United Nations; 2006.
European Commission: **Eurostat glossary: Euro enlargements.** 2014, Available at: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:EU-27.
FAO: **Global forest resources assessment.** 2010, [FAO Forestry Paper 163]. Rome: Food and Agriculture Organization of the United Nations.
FAO: **FAOSTAT Forestry data base.** Rome: Food and Agriculture Organization of the United Nations; 2012, Retrieved 13 May 2013 from: http://faostat.fao.org/site/626/default.aspx#ancor.
Gastwirth JL: **The estimation of the Lorenz curve and Gini index.** *The Review of Economics and Statistics* 1972, **54(3)**:306-316.
Samuelson PA: **Spatial price equilibrium and linear programming.** *American Economic Review* 1952, **42(3)**:283-303.
Sheffield R: **Planted forests and plantations. In WB Smith (tech. coord), PD Miles (data coord.), CH Perry (map coord.), & SA Pugh (data CD coord.).** *Forest resources of the United States, 2007* 2009, [General Technical Report WO-78] (pp. 67-69). Washington, DC: USA: Department of Agriculture, Forest Service.
Varian A: **Microeconomic analysis.** New York: Norton & Co;, 3 1992.
WWF: **Forests and wood products.** *World Wildlife Fund living forests report* 2012, (Chapter 4). Retrieved 22 May 2013 from: http://wwf.panda.org/what_we_do/how_we_work/conservation/forests/publications/living_forests_report/.

doi:10.1186/1179-5395-44-S1-S2
Cite this article as: Buongiorno and Zhu: **Assessing the impact of planted forests on the global forest economy.** *New Zealand Journal of Forestry Science* 2014 **44**(Suppl 1):S2.