Abstract No. 118

Global diffusion of forest certification in the long run:
An agent-based modeling approach

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1. Introduction

Forest certification can be described as an eco-labeling practice that certifies sustainable forestry and assures consumers that their products are sourced from certified forests. It is a voluntary and market-based policy instrument introduced to address the challenges of sustainable forest management the world over.

Forest certification has become a reality. Almost 10% of the world's forests are certified under one of the major forest certification schemes, and 26.5% of industrial wood in the world is supplied by certified forests (UNECE/FAO, 2012, p. 108).While the target was originally tropical forests, in practice, forest certification is more common in temperate and boreal forests. A half of certified forests are located in North America, a quarter of them in EU/EFTA countries, while "only 2% of tropical forests are certified" (UNECE/FAO, 2012, p. 107; see Figure 1).

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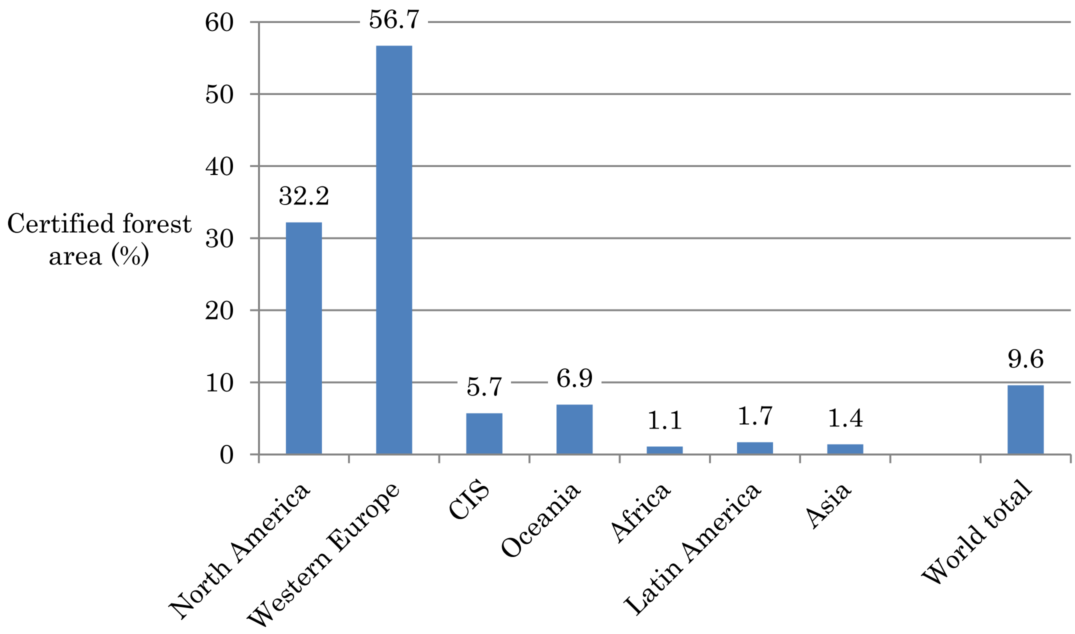

Figure 1 Regional differences in certified forests as a percentage of total forest area

Several empirical studies have been conducted on the diffusion of forest certification. Takahashi et al. (2003) examined which types of firms are more likely to seek certification. van Kooten et al. (2005) indicated that the diffusion rates of forest certification in different countries are also influenced by the socio-economic factors of those countries. However, theoretical examination of the diffusion of forest certification appears to have been undertaken only by Swallow and Sedjo (2000, 2002).

Swallow and Sedjo (2000) conducted general equilibrium analysis of forest certification, assuming mandatory forest certification, and noted possibilities that the introduction of forest certification may diminish forest ecosystem services by converting forest lands into other uses. Further, Sedjo and Swallow (2002) conducted partial equilibrium analysis and identified cases where a price premium may not arise even with the presence of green consumers who are prepared to pay such a premium.

Mason (2011) theoretically treated eco-labeling, a general category that includes forest certification, in a somewhat different way. Mason (2011) regarded eco-labeling as a policy tool that addresses information asymmetry problems between producers and consumers. Eco-labeling informs consumers whether a certain product is manufactured in an environmentally sustainable manner (this information is usually hidden from consumers). Thus, eco-labeling may solve the "lemon market" problem, which reduce social welfare due to the information asymmetry between sellers and buyers, and improve social welfare. Mason (2011) did not examine externality issues in his model and focused on producers' and consumers' surpluses arising from the market transactions of both certified and uncertified products. More important for this paper is the fact that Mason (2011) did not suppose the extension of eco-labeling to forests where wood is not harvested nor the cases in which producers exit due to eco-labeling. These phenomena are critically important in examining the consequences of forest certification.

Swallow and Sedjo's (2000, 2002) models of forest certification diffusion provide insights into several qualitative consequences that diffusion of forest certification can lead to. The authors left for empirical investigation the question of which consequences are relatively more likely to happen. However, such an investigation involves many difficulties. First, because forest products are diverse in type and quality, standardized comparison of certified and uncertified products in terms of prices and quantities is quite difficult. Second, market equilibrium may not be reached in the near future, and prices and quantities cannot probably be measured under equilibrium conditions now. I suppose modeling investigation has a role at present in clarifying the consequences of forest certification.

With such challenges in mind, this paper examines the consequences of forest certification by simulating forest managers' responses to forest certification in a simplified-world model. The novelty of this paper lies in its use of agent-based modeling (ABM), which explicitly treats heterogeneous individual agents and presents the results visually.

The outline of this manuscript is as follows. Following this introduction, the next section presents the simulation method. The third section presents the simulation results, and the fourth and last section discusses the results and concludes the paper.

2. Method

In the present study, I employ agent-based modeling (ABM) to examine the long-term effects of varying the parameters and structures of the market and its participants on the diffusion patterns of voluntary forest certification worldwide. Even though forests are diverse in their ecological characteristics as well as their locations and maturities, standard economic analyses tend to simplify such heterogeneity into a representative entity or mathematically simple approximation. ABM may be able to simulate the heterogeneity in a more realistic manner.

I assume a world consisting of 10 × 10 patches (i.e., forests), where upper patches represent lower costs of production. The owner of each patch decides whether to certify or not based on a comparison between the profits from certified and uncertified wood production. If the owner finds that certified-wood production yields a higher, positive profit than uncertified wood, he or she opts for certification. If the profit from certified wood is lower than that from uncertified wood, the owner compares the price of uncertified wood and its production cost. If the price is higher, the owner chooses to produce timber without certification. However, if the price is lower, the owner stops production. Prices and quantities are updated each time a decision is made.

The prices of certified and uncertified timber are determined by the following demand functions:

$$P_{cert} = 100 - \frac{100}{A} Q_{cert} \qquad (1)$$

$$P_{uncert} = 100 - \frac{100}{100-A} Q_{uncert} \qquad (2),$$

where P_{cert} and P_{uncert} represent the prices, and Q_{cert} and Q_{uncert}, the quantities of certified and uncertified timber, respectively. A is a green consumer index that indicates the percentage of consumers who have become green and purchase only certified timber. These demand functions indicate both green and non-green consumers are similar in the sense that both groups are proportionally and horizontally separated from the following original demand function, which is assumed to have been present before the introduction of forest certification.

$$P = 100 - 100Q \qquad (3)$$

If the price of uncertified timber is higher than that of certified timber, some of the non-green consumers are assumed to purchase certified wood, resulting in the equalization of certified and uncertified wood prices by changing the green consumer ratio index, A. The resulting prices for certified and uncertified wood can be expressed as follows:

$$P_{cert} = P_{uncert} = 100 - (Q_{cert} + Q_{uncert}) \qquad (4)$$

NetLogo4.1.3 was used to simulate this model (Wilensky, 1999). When a patch is certified, a blue flag is shown. An uncertified patch is identified by a red flag if it produces timber and by a yellow flag if it does not. Figure 2 presents a screen shot.

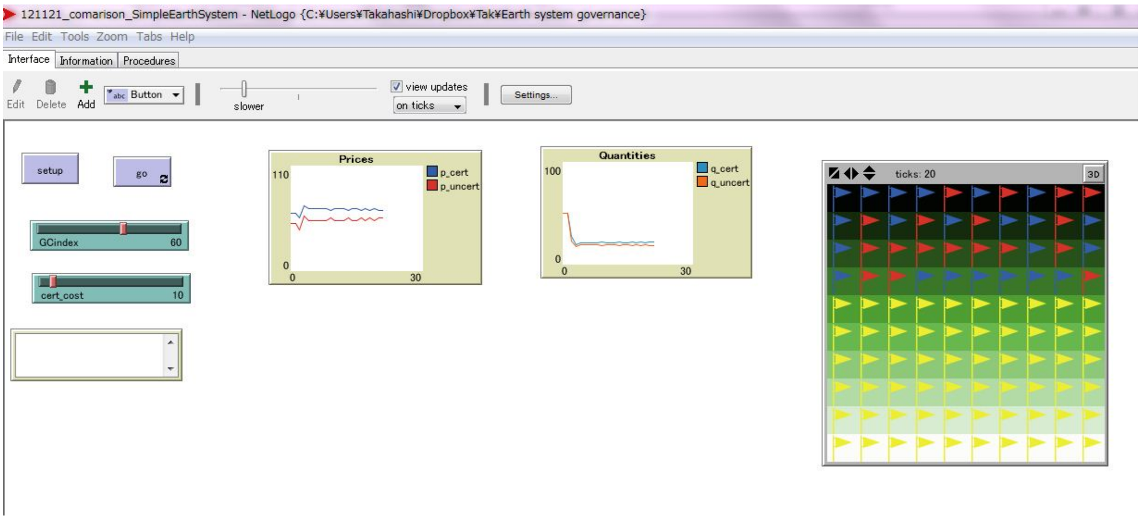

Figure 2 Screen shot of NetLogo 4.1.3

As mentioned above, a blue flag represents certified forest patch that produces timber, a red flag a non-certified forest patch that produces timber, and a yellow flag a forest that does not produce timber (and of course not certified). Patches with dark green color represent forests with lower production costs, and those with lighter color represent forests with higher production costs.

I simulated diffusion patterns by changing two parameters, the green consumer index, A, and certification costs.

3. Results

I present the results obtained by varying two parameters: the green consumer index, A, and certification costs (Table 1).

Table 1 ABM simulation results

Column 1	2	3	4	5	6	7	8	9	10
A (Green consumer index)	Certification costs	P_cert	P_uncert	Price premium	Certification cost coverage (%)	Q_cert	Q_uncert	Total	Certified-wood ratio (%)
10	10	70	58.9	11.1	111	3	37	40	8
10	20	70	58.9	11.1	56	3	37	40	8
10	30	80	57.8	22.2	74	2	38	40	5
10	40	90	56.7	33.3	83	1	39	40	3
30	10	66.7	57.1	9.5	95	10	30	40	25
30	20	73.3	54.3	19	95	8	32	40	20
30	30	83.3	50	33.3	111	5	35	40	13
30	40	86.7	48.6	38.1	95	4	36	40	10
50	10	66	54	12	120	17	23	40	43
50	20	72	48	24	120	14	26	40	35
50	30	78	50	28	93	11	25	36	31
50	40	86	48	38	95	7	26	33	21
80	10	62.5	50	12.5	125	30	10	40	75
80	20	68.8	45	23.8	119	25	11	36	69
80	30	75	50	25	83	20	10	30	67
80	40	78.8	35	43.8	109	17	13	30	57

*Column 5 = Column 3 – Column 4; Column 6 = Column 5/Column 2; Column 9 = Column 7 + Column 8; Column 10 = Column 7/Column 9

When A (green consumer index, column 1) increases, the prices of certified (column 3) and uncertified (column 4) wood generally decrease, while the price premium (column 5) increases. With an increase in A, the total production volume (column 9) appears to decrease. Even though a higher A results in a higher certified-wood ratio (i.e., diffusion rate, column 10), the diffusion rate is somewhat lower than A.

When certification costs (column 2) increase, the price of certified wood (column 3) increases and that of uncertified wood (column 4) decreases. Consequently, the price premium (column 5) increases. An increase in certification costs combined with a high green consumer index leads to a decrease in total production (e.g., A = 80, certification costs = 20, 30, 40).

4. Discussion and Conclusion

I obtained several intuitive results: a higher ratio of green consumers in the market leads to a larger price premium and a larger ratio of certified wood sold in the market; higher certification costs result in a higher price premium.

I also obtained several counter-intuitive results: an increase in A (i.e., more green consumers) leads to a depreciation of both certified and uncertified wood; certification costs are partially recovered by the price premium—i.e., 100% of the costs are not recovered. The phenomenon predicted by Swallow and Sedjo (2002), the demise of the price premium for certified wood, is not replicated in this model. Why are such counter-intuitive results obtained and why is Swallow and Sedjo's (2002) prediction not replicated? These are questions that should be investigated further.

It is too early to draw policy implications from this analysis. In a future study, the model should be examined employing, for example, different demand functional forms and other assumptions. However, the views on forest certification that I now propose are rather positive. The price premium for forest certification is persistent through different ABM runs. In addition, in the real world, the price premium for forest certification is reported to be 6.3% in Europe, 5.6% in the Republic of Korea, 5.1% in the US, and 1.5% in Canada (UNECE/FAO, 2011, p. 106). Feedback between modeling and empirical investigation will tell us what role forest certification can play in the pursuit of sustainable forest management the world over.

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