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Tradable permits in logging operations

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ABSTRACT: The paper presents a new system of tradable permits combined with ecological bonds that is able to promote environment-friendly logging technologies, supposed to be less harmful to the forest ecosystem. All loggers deposit in advance ecological bonds on to-be-harvested volume basis and a certain number of permits to damage is freely given per each cubic meter, by the public authority. After surveying the damage caused throughout all harvested tracts, the number of permits on the volume basis is recomputed for each logger according to the magnitude and importance of damage caused. The logging company that caused smallest damage and saved most permits is allowed to sell to another competitor the number of permits which makes the difference between the two companies. The main section of the paper presents five simulations based on reliable scenarios that have been developed on some effective data referring to two types of damage produced by seven Romanian logging companies in 1999, in Suceava state county forest. Firstly, the deterministic scenario shows that environment-friendly companies become more competitive due to the new system because they have an additional income from sold permits. Conversely, companies unable to protect the environment are to pay more for being in business and thus their capacity to buy more timber is diminished. Assuming that companies able to get money due to this kind of trade are also able to improve their technology and can afford to buy more timber, it was demonstrated that the technological transfer is encouraged by the new system that might be combined with a regular compensation paid to the landowner as well. The greater the bond, the more advantageous the system for fewer and fewer companies. The lower the bond, the more companies can take advantage of the system but less money is collected from a given market.

Keywords: tradable permits; logging operations; revolving bonds

Multiple-purpose forest management is an untenable theoretical concept, but it increases the risk of failure as anyone who must selectively harvest trees has just a few logging options to contemplate, each of them being a potential threat either for the future generation of trees or for the remaining trees. When harvesting old large-crowned trees the logger has to use heavy equipment and therefore, some hydromorphic degradation of the soil is inevitable (HERBAUTS et al. 1996; LACEY, RYAN 2000). This risk is not negligible in the European boreal forest, where winters are warmer and warmer and it is almost impossible to skid all logs onto frozen soil, as a common rule of thumb recommends. The destructive effect upon physical properties of forest soils has been presented in recent literature, and it is proved that the most important damage occurs during ground-based skidding, being associated with the first trips (BALLARD 2000; GRIGAL 2000).

As the regeneration process is continuous on larger and larger areas, logging operations are performed now and then, according to prescribed managerial provisions, but more often than it is the case for an even-age stand where only a few commercial thinnings and final cutting are enough. The lower the intensity of extraction, the higher the degree of damage to the residual stand. For example in Malaysia it was found that traditional logging operations, without prior planning of felling directions, brought about 60 damaged trees per hectare while the loss can be reduced to 40 trees per hectare if the whole process is carefully designed and supervised (MARN, JONKERS 1981).

The biodiversity should not be at stake when different logging technologies are used. Comparing the effect of ground skidding and helicopter logging upon biodiversity indicators in floodplain forests, JONES et al. (2000) found no significant difference between the two logging technologies eight years after logging operations. Nevertheless, the richness in species does not necessarily mean good-quality timber at maturity age. Therefore some attempts are worth mentioning in this respect. In order to design a feasible and optimal set of economic incentives to improve the logging operation quality, BACH (1999) developed an *optimal control* model and simulated alternative outcomes. Two basic alternatives were considered: an *area-dependent subsidy* and a *volume-based subsidy*. Appraising the present value of an average concession of 10,000 ha, it was found that without any subsidy for logging operations and a higher ef-

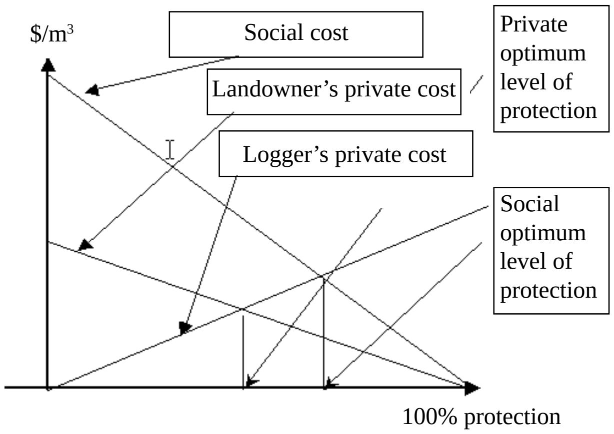

Fig. 1. Social optimum vs. Private optimum of damages

fort to protect the remaining trees the total value decreases from $ 1.51 m to $ 0.81 m. An interesting outcome is the relationship between the relative price of additional effort needed to protect residual stand and the relative price of timber. It was found that if the price of effort is set to one, prices for all four groups of the species considered should increase by 147% to persuade the concessionaires to reduce damage.

The paper is organized as follows. The second section, which is the largest one, presents a new system of tradable permits in five sub-sections focused on motives to adopt tradable permits, and the social optimum level of damage vs. the private optimum when the landowner behaves as a risk seeker. This section ends with designing the system that is further employed in a spreadsheet simulator used to demonstrate how the new system is supposed to work. The basic information gathered from real logging operations and the expected results of the new combination of economic instruments are presented in the third section. Conclusions and comments end the paper.

TRADABLE PERMITS FOR LOGGING OPERATIONS

MOTIVES TO ADOPT TRADABLE PERMITS

It has been a long time since tradable (or marketable) permits have been used to phase out different types of pollution. Their theoretical framework can be found in DALES (1968), where they are regarded as *economic instruments able to encourage the industry to minimize costs over time, promoting so-called "dynamic efficiency"*. Extensive reviews of tradable permits in a broader context of market-oriented instruments can be found in STAVINS (2000) and TIETENBERG (1999). Basically, dynamic efficiency is achieved by encouraging firms to innovate or to improve their technology in order to pay lower abatement costs (BURTRAW 2000). This assumption has been taken for granted when designing the simulator that is presented below.

As multiple-use forest management is focused on timber production, which is a *private good*, and on services provided by forests (runoff and erosion control, biodiversity preservation and so forth) that are *public goods,* there are two *different* optimal levels for damage to consider: a *private optimum* and a *social optimum*.

The first attempt to propose a tradable permit system targeting the social optimum level of extraction was designed by Dr. Ian Munn (MUNN 1997). The main idea is to grant a certain amount of permits within the market, assuming that the landowners who want to harvest more than the prescribed allowable cut should purchase extra permits from the landowners intending to harvest less or nothing. On the permit supply side the price of permits increases the managerial cost and thus less stumpage is marketed at a higher price. The above-mentioned paper just broached the new subject in forest economics and no technical details about effective implementation were provided along with the theoretical background.

SOCIAL OPTIMUM VS. PRIVATE OPTIMUM LEVEL OF DAMAGE

Now let us consider the logger's private cost to prevent damage, the landowner's private cost of accepting damages[1], and the social cost of damage (Fig. 1). As the social cost refers to *public goods*, the social loss of each possible level of damage is *higher* because it is prices that are summed up for the same quantity of output, not quantities for the same price. Therefore, in spite of well-defined property rights to the land, the *optimum* level of environmental protection from the social point of view (*Sp*) is *higher* than the optimum level from a private point of view (*Po*) as it is shown in Fig. 1.

As stated above, the idea of transferable pollution rights is quite old but it has not penetrated in forest economics so far. One of the reasons of introducing tradable permits into environmental economics was the relatively low cost of transactions. STAVINS (1995) reviewed possible sources of transaction costs as follows: 1. *search of information*, 2. *bargaining and decision* and 3. *monitoring and enforcement*. The first type of costs does not represent a real problem for logging operations because any kind of damage (further referred to as externalities) can be easily found in the forest, a long time after it was incurred. The second source of expenses is the most problematic because of the nature of negative externalities. They are not homogeneous at all and the associated abatement marginal costs vary on a large scale.

According to the typology of tradable permits revised by STAVINS (1995), the type of economic instruments that are being proposed falls within *emission* permits trading, with high transaction costs incurred by *expensive monitoring.* But

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[1] A cost needs being compensated by charges and penalties.

in the case of logging operations this cost is paid anyway because it is associated with timber trade, not only with permits trade. After a logger has harvested a tract, both the logger and the forest owner survey the area in order to identify all damage the logger should be charged for.

PRIVATE OPTIMUM AND RISK BEHAVIOUR

According to Coase's rule, negative externalities can be better diminished if property rights are clearly defined and transaction costs are negligible. If a person or a community affected by a certain negative externality can bargain a compensation with the company that generates the externality, that company is interested in reducing the pollution level in order to pay less. In the case of logging process this principle holds true too, and the woodland owner is supposed to ask for an appropriate compensation for logging damages, whenever and wherever they occur during the harvesting process. In such a case, the problem is how to assess the real value of the loss. One should take into account what type of risk behaviour characterizes the landowner because the price asked for damage reflects the landowner's private disutility, which is influenced by the stumpage price. If the price is a good one, the landowner is supposed to behave like a *risk seeker* as the gain from sale is certain while the loss is uncertain and upcoming.

Consider that the total landowner's income depends upon the price of stumpage along with the compensation for logging damage. Consider the most apparent and the most likely type of damage – debarking of the remaining trees (hereinafter referred to as *residual stand).* Letting L be the present value of the loss, it holds that

$$L = V_t \cdot p_t \cdot e^{-t \cdot p} - V_{t'} \cdot p_{t'} \cdot e^{-t' \cdot p} \qquad (1)$$

the variables having the following meanings:
$V_{(t)}$ – tree volume at normal maturity age; $V_{(t')}$ – tree volume at age t' when it is harvested as salvage product; $p_{(t)}$ – expected price for average tree; t – prescribed rotation; t' – age when the tree is harvested as salvage product due to logging damage; p – discount rate.

Both the volume and the price of damaged tree are affected by *estimation errors* that cannot be avoided as long as only statistical models can be used in such a matter. The interval of confidence of the present loss is bounded by a lower value (L) and an upper value (U) as Fig. 2 shows.

Consider the disutility function as concave in the economic loss (A), i.e. the second derivative is negative. If the loss is zero, then disutility is zero, too. As it is proved by WATZOLD (2000), the uncertainty of the loss means a downward shift of the disutility function[2], from the curve A to the curve B, as the decision maker – landowner in this case – contemplates a linear combination between disutility to be compensated and the real economic loss. That means the accepted *private disutility is still zero although the future loss becomes positive*.

Further, the greater the uncertainty, the greater the accepted loss, and it is worth recalling that the volume estimation error is *larger for uneven-aged structures and little known species that are disregarded in yield tables*. Consistently with the same assumption of *risk seeking* when the price fetched by the timber is high, the accepted level of damage is higher for the *lesser-known* species, supposed to be *rare* species. Recalling the private optimum shown in Fig. 1 when timber is sold at a high price, the private optimum level is supposed to move to the left because the accepted level of damage, mentioned as a term of the harvesting contract, is higher.

PROPERTY RIGHTS AND TRADABLE PERMITS

Rewording the problem of logging injuries in terms of tradable permits principle, *any logger has the right to damage*, and that one who has damaged less has the right to sell her or his "saved permits to damage" to that logger who has already damaged more, and could damage more in the future. Having rendered the problem in these terms, the public authority can assign some rights to damage per each cubic meter of timber, and these rights are further regarded as *permits*.

Consider two loggers (Fig. 3), a single type of damage – say, residual stand – each logger having a different marginal cost of preventing damage, *ceteris paribus*. The curve OA represents the first logger's marginal cost of prevention while the second logger's marginal cost is OB. Either of them has reached a private optimum level of damage, say, 70%, and 40% respectively. The area of triangle OAA' stands for the total cost defrayed by the first logger to prevent damage while the area of triangle OBB' stands for the total cost of preventive measures adopted by the second logger[3].

According to the principle of *equally distributed property rights to damage*, the second logger would have the right to damage 70%, as the first logger did, not only 40%. The second logger has the right to sell the difference of 30% of rights to damage while the first one should purchase this 'invented' commodity, *if and only if the social planner, hereinafter referred to as the principal, enforces such a market.* If the second logger had protected just 30% of residual stand, as the first one did, he or she would have paid just the area OCA', which is the difference between the area OBB' and A'CBB', which stands for the additional expenses. This outlay can be

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[2] The quoted article deals with social disutility and a social planner decision maker, supposed to be risk adverse, but the problem is the same.

[3] The two tracts are identical, so are harvested volumes. The cost of prevention measures, represented on the y-axis refers to the harvested volume. Adopting this representation is helpful for further development of the model, allowing for comparison between different loggers that have harvested different volumes.

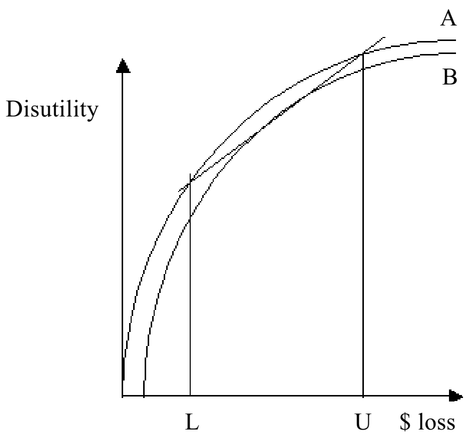

Fig. 2. The influence of uncertainty on the disutility of a risk seeker landowner

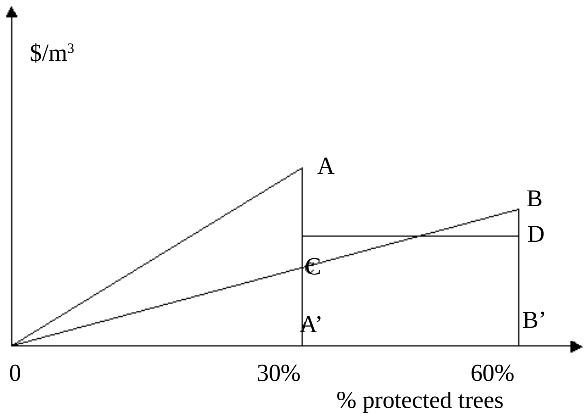

Fig. 3. Marginal costs of prevention and the fair price of permits sold out assuming that the “right to damage” (property right) is the same for the two companies

compensated if the second logger sells the rights he has to damage – that is *permits* – at the price B’D, which is based on the harvested volume. Doing so, the net cost of preventing damage defrayed by the second logger is the same as if he or she made the same bad job as the first logger, that is ensuring protection for 30% of the residual stand only. In turn, the first logger has to internalise the social cost of a worse protection, by paying the initial prevention cost (area OAA’), plus the value of permits he or she had to purchase, considering the volume-based price DB’ for each cubic meter he has already harvested.

Analytically, the fair price per cubic meter for permits to damage one percent more trees (P), sold to the worse logger, is

$$P = \frac{\int_{A'}^{B'} g(x)dx}{B'-A'} \tag{2}$$

where $g(x)$ stands for the function that relates the marginal cost of adopting protection measures by the most environment-friendly logger.

So far, nothing has been mentioned about the *transaction cost*, which is not negligible in a real world. Consider the principal’s cost of monitoring the transaction, instead of, adding up this value to the cost per permit, it is obvious that only the loser will pay the transaction cost because this transaction cost is added to the price per permit. Therefore, a higher transaction cost will encourage rather the loser to improve the quality of logging operations than the winner to maintain her or his comparative advantage over the competition.

DESIGNING THE SYSTEM

Unlike the previous approach (MUNN 1997), the system drawn in the following section is a mixture of revolving (returnable) ecological bonds[4] and tradable permits, deemed both to minimize transaction costs and to allow for a fair allocation of revenues, supposed to encourage technological progress. All bonds are gathered in a single deposit subject at commercial interest rate. The logger who will be the most competitive from the ecological point of view will get this deposit, plus an additional revenue from all the other loggers, according to the price per permit and the difference between the up-dated number of permits he has achieved and the up-dated number of permits each other logger has achieved.

The new combination of economic instruments does not substitute regular charges for damage produced to trees, soils and seedlings, supposed to be set up by the landowner, but it is deemed to reduce the negative impact of having *imperfect information* about the real cost (private and/or social) of this damage.

Although some economists are sceptical on the free distribution of permits (see STAVINS 1995), the proposed model is actually a combination of grandfathering – the number of permits per cubic meter is the same for all loggers – combined with auction, as permits are assigned to each logger along with the purchased timber and only after the auction. Who gets stumpage by auction, receives permits. More stumpage, more permits.

Assume that for each cubic meter of wood, the principal issues n tradable permits. At the end of the year each logger will have used up some of the permits he had, according to his technology, in different ways: by destroying more or fewer new seedlings (where shelterwood systems are to be applied), debarking the remaining trees or scratching the fertile soil layer. All these negative externalities[5] are being taken into account at the end of the year and the public authority is to assess how many tradable permits are left per cubic meter harvested from each tract, as follows:

$$N_i = V_i \cdot \eta \cdot \left[1 - \left(k_1 \frac{D_i}{T_i} + k_2 \frac{S_i}{A_i} + k_3 \frac{L_i}{A_i}\right)\right]; \quad k_1 + k_2 + k_3 = 1 \tag{3}$$

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[4] Romanian National Forest Administration currently uses such ecological bonds, as each logger should deposit 5% of the tract value at the starting price.

Table 1. Values for the weights assigned to the three types of negative externalities likely to occur when an even aged stand is harvested[6]

Forest management main goal	Type of yield	Damaged trees	Damaged seedlings	Fertile soil layer destroyed
Environmental protection	secondary	0.5	0.0	0.5
	main	0.3	0.2	0.5
Timber production	secondary	0.7	0.0	0.3
	main	0.4	0.5	0.1

[6] These preliminary values are not based on relative costs of logging in different conditions and estimations of social disutility.

where variables referring to the tract i have the following meanings:

N_i – number of permits left from the tract *i*, of volume V_i,
η – initial number of permits grandfathered by the principal per each cubic meter,
T_i – total number of harvested trees,
D_i – total number of the remaining trees that were damaged during harvesting operations,
A_i – total area of the tract,
S_i – total area of natural regeneration destroyed during harvesting operations,
L_i – total area on which the fertile soil layer was removed,
$k_{1,2,3}$ – weights assigned to each type of negative externality.

The weights assigned to externalities are of crucial importance for compensating the relative advantage caused by different logging conditions. From the principal's point of view these weights should also reflect either risk aversion or risk neutrality or, on the contrary, a risk seeker behaviour (Table 1). These options depend on the type of yield, the type of damage and the main goal of forest management (timber production or environmental protection).

The level of the ecological bond plays an important role as it depends on 1. the size of the market, expressed by the transaction volume (the larger the market, the lower the bond because the winner collects bonds from a larger quantity of timber) and 2. the number of loggers operating on that market.

For each logger *j*, the number of permits per cubic meter (π_j) left for a *possible trade* is calculated as follows:

$$\pi_j = \frac{\sum_i N_{ij}}{\sum_i V_{ij}} \qquad (4)$$

where N_{ij} stands for the number of *permits saved after logging the tract i by the logger j*, and V_{ij} is the volume of that respective tract.

Having this information, the best logger can be easily designated as having the highest number of "saved" permits per cubic meter, that means the highest value for π. Every other logger comes by a number of permits equal to the product between the volumes he has already harvested and the *difference* between the highest number of tradable permits left per cubic meter (max π) and her or his own value for π. Assume that logger *X* won the competition: initially he received five permits per cubic meter and he consumed just one permit. The logger *Y* used up 1.5 permits per cubic meter, and she or he harvested a total volume of 150,000 cubic meters. *Y* should buy from *X* 150,000 cubic meters times 0.5 permits per cubic meter, which is 75,000 permits.

All other loggers should purchase from the winner the rights to harvest in the forthcoming year, and the single role of the ecological bond deposited by each logger is to ensure this trade. If at the end of the year the logger *Y* has a bond say, \$ 5,000 worth and he has to pay \$ 7,000 to be allowed to harvest next year, he will pay just the difference of \$ 2,000, otherwise he will lose the right to harvest in the forthcoming year, along with the \$ 5,000 bonds.

An interesting problem worth discussing in this context is *the relationship between the number of permits issued by the principal, his/her ability to learn from the trade and the behaviour of the companies who are trading those permits, on a small market* (ANDERSSON 1997). In our approach, although the process is completely transparent for the principal, *simulations have proved the risk of issuing an insufficient number of permits*. Therefore, it is recommended to issue more permits in the first year to be sure that only one company wins the game. The principal should also be aware that after a couple of years the number of loggers might be lower, and the risk of a "slack" market might occur again. To prevent this unwanted phenomenon, more permits are required. Sensitivity tests are presented in the last section.

The most competitive logging company may set up the price of permits sold to other companies. If the price is very high, the burden for the company could be much higher than its ecological bond and the company will fall in the red. Such a company has two options: to pay the debt or to give up harvesting ahead, losing the bonds the company has purchased. The winning company is likely to target the highest possible income by selling permits, but the principal should expect the winning company to collude with another one or, on the contrary, to squeeze

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[5] Some of them can be referred to as additional costs (damages produced to trees and seedlings), while penalties produced to the soil layer (pure negative externalities) are similar to Pigovian taxes. As long as the real private costs of damages produced to trees and seedling is uncertain, these effects will be further referred to as externalities, although an important share of these costs are frequently internalized by the logger as additional charges.

the companies placed at the second and the third places in order to get rid of them as competitors on the same market.

A key problem worth discussing in the context of tradable permits for loggers is the following: should the winner be allowed to ask any price? The answer is no because *the tradable permit system should not be used as a shield for unfair competition on the timber market.* A small logging company might purchase just a small tract by offering a huge price for timber and a low ecological bond; afterwards it may harvest the timber without being penalized and thus it might be designated as the best operator on the market. Getting this position, the company could ask such a high price of permits as one or several larger companies cannot afford to pay. So, an additional rule is necessary: *the winning company should not be allowed to ask from the next two companies prices higher than the bonds per cubic meter these companies have had*. This is one of the reasons why the *threshold bond* per cubic meter is so important and needs careful approach and successive adjustments. If it is too low, the market with tradable permits will be inefficient in the sense of promoting new technologies. If it is too high, the timber market might be distorted by an unfair competition on the other market where permits are sold.

Therefore, two threshold prices are worth considering: the highest price allowed to ask for permits sold to the next two companies and the lowest price allowed to ask for permits sold to all other companies. Consequently, the highest price ($P_{\max}$) is given by relation (5), which results from equation (6) standing for the condition that the winning company may not receive from the next two companies more money than these companies have deposited in bonds.

$$P_{\max} = \frac{G}{(N_{\max} - N_3)} \tag{5}$$

The variables have the following significations: G stands for the ecological bond per cubic meter, $N_{\max}$ the number of permits saved by the winning company, N_3 the number of permits saved by the company ranked on the third position that harvested the quantity V_3. Considering the interest rate, relation (5) changes into (7)

$$P \cdot V_3 \cdot (N_{\max} - N_3) = G \cdot V_3 \tag{6}$$

$$P_{\max} = \frac{G(1+p)}{(N_{\max} - N_3)} \tag{7}$$

The lowest price is G, i.e. the ecological bond per cubic meter that is paid in advance. It means that a company unable to be ranked on the third position at least will pay for the right to harvest ahead as much as the ecological bond at least.

NUMERICAL EXEMPLIFICATION

PRIMARY DATA

In order to demonstrate the efficiency of tradable permits, two examples were developed based on real data provided by Suceava Forest County, the largest subsidiary of Romanian National Forest Administration. The input data (Table 2) show the ecological side-effects of seven logging companies that harvested in 1999. Due to the lack of data referring to damage caused to the soil layer, that kind of externality is neglected.

It was considered that all companies managed to obey the silvicultural rules and *none of them was penalized.* Having stated this assumption, it is evident that tradable permits are more advantageous because of the dynamic reduction in any kind of harvesting damage beyond any threshold that may be set up by technical standards or

Table 2. Primary data concerning yields and associated damage caused by seven logging companies

Company	FORESTFALT	EXFOR	LEX	ROMANEL	GAMAVEST	TIMBERLAND	HISUM
				Main yield			
Total harvested volume	1,734	375	2,024	5,686	959	3,596	967
Harvested trees	5,973	530	1,310	6,669	1,020	2,345	1,160
Damaged residual trees	3	1	163	21	34		
Naturally regenerated area (ha)	1	1	1	1	1	3.7	1
Naturally regenerated area where seedlings were destroyed (ha)	0	0				1.3	
				Thinnings and salvage cutting			
Harvested volume	1,806	1,302	3,506			1,986	535
Harvested trees	24,008	23,896	16,575	0	0	1,686	5,333
Damaged residual trees	28	10	0	0	0	5	3

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[7] The logger could be the buyer – when stumpage is actually sold – or could be just a contractor who is paid by the landowner for logging operations, logs being sold at the roadside afterwards.

Table 3. Relative decrease in the volume to harvest within the next year

Additional liability brought about by permits purchased at the end of the year (ROL[9]/m^3)		Relative decrease in the volume to harvest within the next year (%)
0	– 25,000	0
25,001	– 50,000	5
50,001	– 75,000	10
...	...	...
...	...	...
450,001	– 475,000	90
475,001	– 500,000	95
	More than 500,001	100

[9] Romanian currency

protocols between landowners and loggers and irrespective of the type of transaction[7].

Thereafter two scenarios have been devised: a purely deterministic one to demonstrate how tradable permits enforce competitiveness, and a stochastic one to test whether the technological diffusion might occur. The following assumptions have been adopted, some of them being considered for one scenario only.

1. Per each cubic meter of stumpage to harvest, the principal issues 500 permits[8] per year.
2. The company's competitiveness depends on its capacity to make profit. Companies are expected to respond in two ways, according to their role on the market: every additional income means more timber to purchase the next year and every additional liability means less timber available for the forthcoming year, as the willingness to pay diminishes. The company that sold permits in the previous year can afford to purchase an extra quantity available on the market because companies that purchased permits cannot afford to purchase that timber.
3. The company that has sold permits once is able to improve its harvesting technology and to decrease the degree of damage to some extent for all years ahead (for the stochastic scenario only).

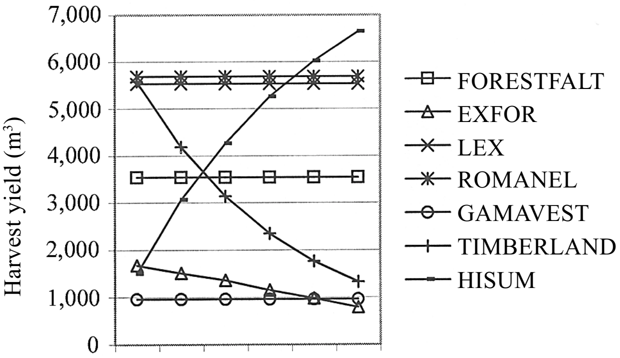

Fig. 4. Assignment scheme for 1,000 ROL/m^3 bond

4. Harvesting conditions are the same during the simulation period (for the deterministic scenario only).
5. All logging companies are reluctant to use tradable permits and they collude. Consequently, the winning company sells permits at the lowest possible prices to other companies.

The effects on the harvesting capacity brought about by additional costs of permits are summarized in Table 3.

Data have been produced in a very simple manner considering the average price of stumpage and a linear relationship between the additional outlay paid to purchase permits and the willingness to pay: if the additional cost per cubic meter incurred by acquired permits equals the average price of stumpage there is no chance to buy any stumpage the subsequent year. That means a 100% relative decrease in volume if the additional cost brought about by permits equals the average price of stumpage – money goes to permits instead of stumpage. Conversely, if a company sold tradable permits, the income from this trade would increase both the affordable price for the next year and the affordable outlay for additional protective measures that can be regarded as a technological breakthrough. Say that a company gained \$ P in 1999 from marketable permits while the supply for 2000 is Q. In this case, the company could be able to pay an extra price of \$ P/2Q per each cubic meter along with an additional outlay of \$P/2Q to improve operations quality. Therefore, the stumpage that cannot be purchased by the losers goes to the winner but all of them are encouraged to damage less and less, for different reasons: to pay less in the case of losers, to gain more in the case of the winner.

RESULTS

The algorithm has been implemented in two electronic workbooks. Three different bonds have been considered (1,000 ROL/m^3, 5,000 ROL/m^3 and 10,000 ROL/m^3),

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[8] The number of permits per cubic meter and the ecological bond should be set up in such a way that only one company should win the right to sell permits. Otherwise the system is not efficient in terms of technological diffusion as more winners share the gain from selling permits.

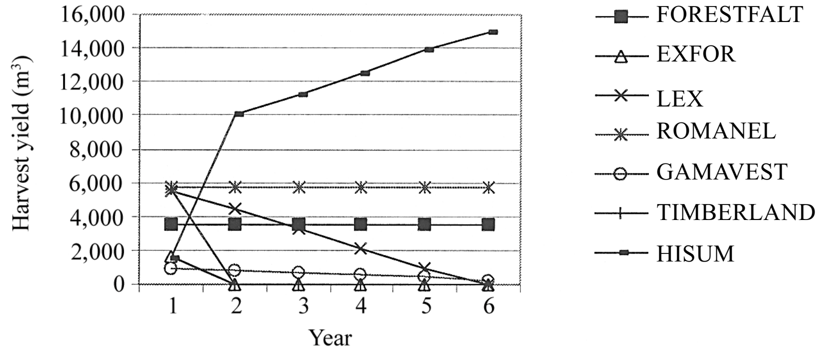

Fig. 5. Assignment scheme for 5,000 ROL/m^3 bond

a single discount rate (6%) and 500 permits per cubic meter assumed to be grandfathered by the principal each year. The main purposes of the simulation are as follows: to evaluate the effect of the ecological bond on the competitiveness of logging companies and to illustrate how the technological transfer among logging companies might occur.

The first outcome consists of three assignment schemes (Figs. 4, 5 and 6) referring to the same volume of stumpage harvested by seven companies, under three bonds and deterministic assumptions already presented.

An insignificant bond of 1,000 ROL/m^3 has a low effect on the competitiveness of companies. Fig. 4 shows that the most ecological company (HISUM) takes a little advantage of having the opportunity to sell permits. The volume assumed to be harvested by this firm ranges from about 1,500 cum in the first year to less than 7,000 cum in the sixth year of the simulation period at the expense of the worst companies, i.e. EXFOR and LEX.

Increasing the bond up to 5,000 ROL/m^3 under the same assumption of collusion between the companies the graph looks different (Fig. 5). The company that caused greatest damage and harvested the lowest volume from the very beginning (EXFOR) collapsed after the second year because of the burden of permits to buy. The second worse company, LEX, is supposed to give up harvesting in the sixth year only, and the total volume harvested by the green-hand company (HISUM) at the end of period is about ten times higher.

A bond of 10,000 ROL/m^3 seems to be most efficient in this context. As shown in Fig. 6, after the first four years of using the combination of ecological bonds and tradable permits only three companies have been left on the market. Comparing this bond with the average winning price reported in the last row of Table 3 there is no doubt that the ecological bond could not reduce very much the auctioneer's willingness to pay for wood, which is the physical commodity.

For the latter scenario, some input data have been randomly generated within specific ranges. The whole simulation is depicted in Fig. 7. The main characteristic that makes the difference from the technological point of view is how the ranges of the externalities have been randomly generated (box 2 in Fig. 7). A company that has already sold permits is able to damage less due to the better technology the company affords to employ. Such a company is hereinafter referred to as a "green logger".

The first input data refers to the harvested volume, all other data being randomly generated on this basis. The number of harvested trees is the harvested volume divided by the average tree volume. Further, all damage has been randomly generated within different ranges, depending on the type of damage and on the status of being 'green logger'. More precisely, damage has been generated as follows:

$$t = n \cdot \rho_1 \ ; \ r = s\rho_2 ,$$

where t stands for the number of damaged remaining trees, n for the number of harvested trees, r for the area of destroyed regeneration, s for the regenerated area (randomly produced, too) while ρ_1 and ρ_2, hereinafter referred to as *'technological coefficients'* have been randomly generated in different ranges, as it is shown in Table 4.

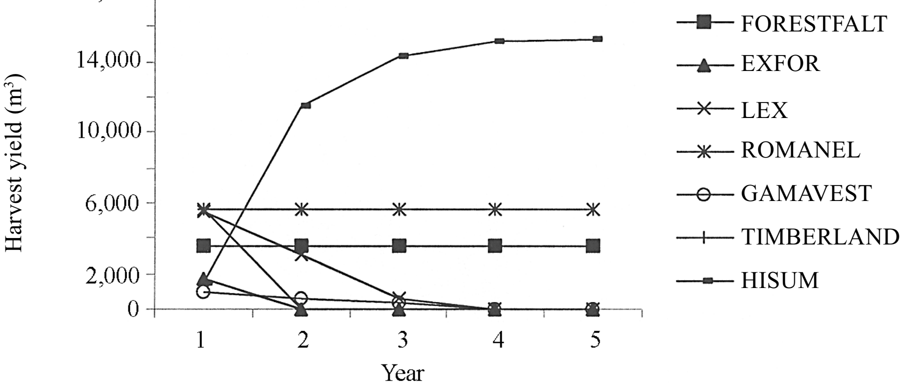

Fig. 6. Assignment scheme for 10,000 ROL/m^3 bond

Table 4. Ranges of technological coefficients have been randomly generated

Technological coefficient	Coefficient boundaries 'Green-hand loggers' min	 max	 Other loggers min	 max
ρ_1	0.0	0.40	0.1	0.50
ρ_2	0.0	0.18	0.0	0.33

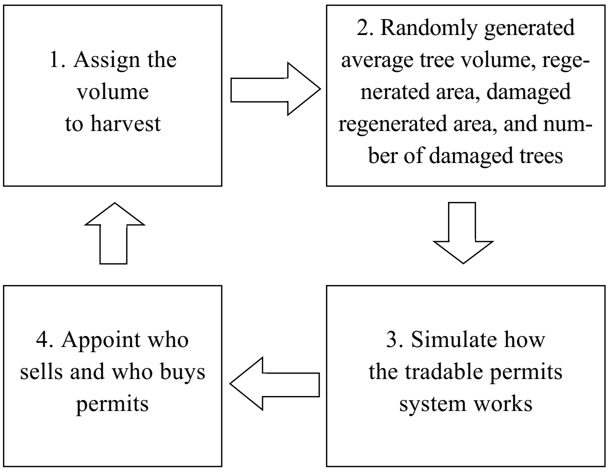

Fig. 7. Flowchart of stochastic simulation

The simulation loop described in Fig. 7 has run nine times, that means a nine-year simulation period. The same assumption of collusion between loggers has been considered and thus the principal has had to intervene on the market by means of the ecological bond only. Two levels for the ecological bond have been considered: 1,000 ROL/m^3 and 5,000 ROL/m^3.

Fig. 8 shows the result of using 1,000 ROL/m^3 ecological bonds. Because such a low bond means a sluggish competition, all the seven companies remain on the market after nine years but it is to note four of them became green-hand loggers during this period of time, presumably due to better technologies they afforded to get.

Fig. 9 shows the outcome of using a bond of 5,000 ROL/m^3. A stiffer competition is evident because only two companies (GAMAVEST and TIMBERLAND) could afford to improve logging technologies, all the other companies having harvested too small quantities of stumpage and thus having less and less chances to take advantage of sold permits.

DISCUSSIONS AND CONCLUSIONS

Nevertheless, the results provided both by deterministic and stochastic simulations are questionable since only small amounts of effective data have been processed. For instance, serious damage like removal of the fertile soil layer has been completely neglected, simply because of the lack of records.

In the real life, the outcome of the new system may be different due to new companies that enter the market. A comparative advantage once gained – low harvesting damage and the right to sell permits – might be lost in the future. However, in spite of its limitations, the model gives a clue on how the system of tradable permits can be employed to improve logging operations. It also outlines the relationship between the value of the ecological bond, the size of the market (in terms of the quantity of stumpage sold) and the competitiveness of companies, which finally depends on the value of the ecological bond.

Presumably, logging companies will collude more or less on such a market but definitely all of them will deposit the lowest acceptable bond per cubic meter. Therefore, every now and then the principal should re-consider

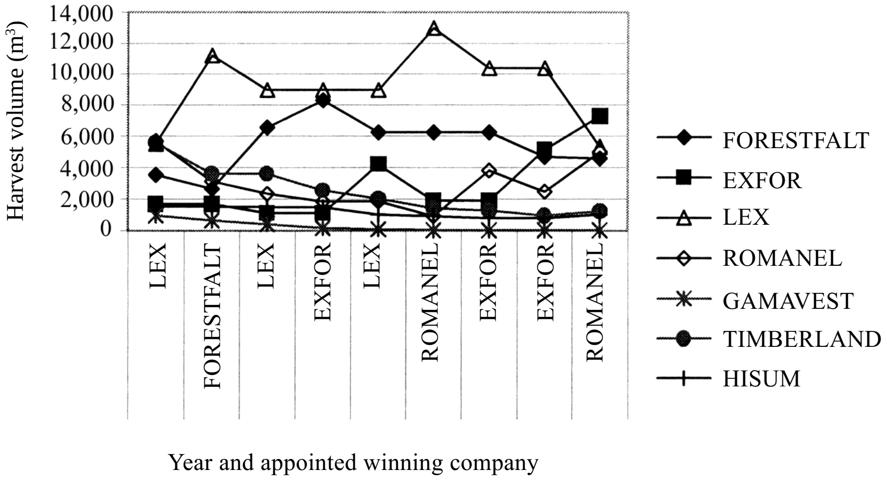

Fig. 8. Assignment scheme and winning companies for 1,000 ROL/m^3 bond – stochastic simulation

GAMAVEST HISUM

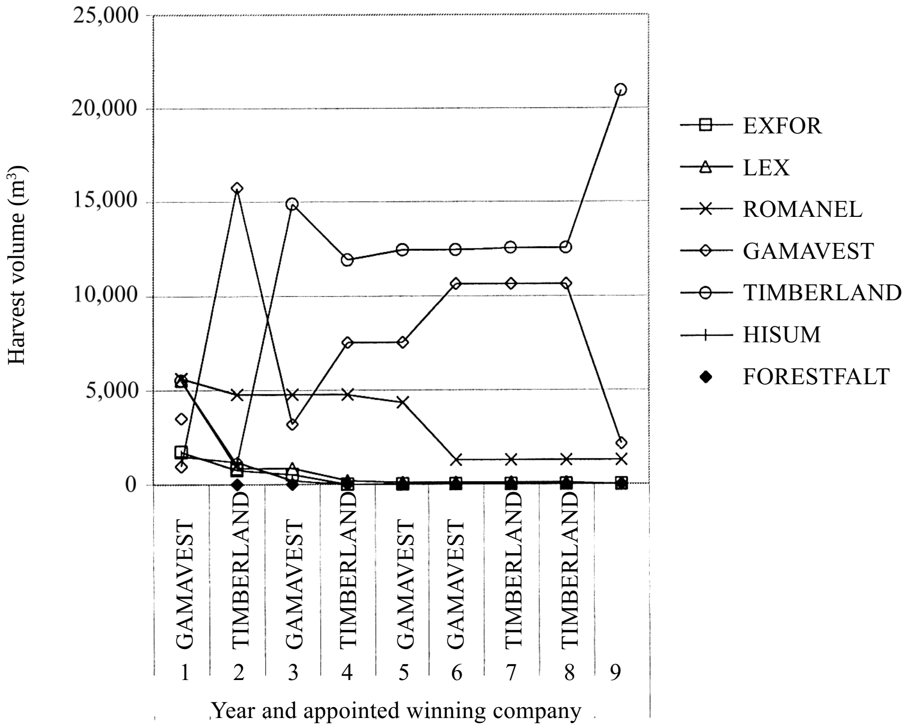

Fig. 9. Assignment scheme and winning companies for 5,000 ROL/m^3 – stochastic simulation

the three important parameters – bond value, number of permits issued per cubic meter and relative weights of damage – in order to pursue the final goal: less and less damage caused by logging operations. For instance, if the rate of specific damage goes up, the associated weight must be higher and higher. Definitely, no spectacular results will come up in the first year, but it was demonstrated that a dynamic feedback eventually occurs, and it depends on the bond value.

For the principal, an important clue on the appropriate value of the bond is the market price of more environment-friendly driving equipment, such as light tractors, skylines or horses. It is not compulsory to buy a new equipment in order to improve the quality of logging operations: money can go to skilled labour instead of sophisticated equipment. This issue could be an important matter in the context of *sustainable rural development* because there is no ecological threat in making timber harvesting a sort of ‘cottage industry’, even at the cost of lower productivity. The social responsibility of local loggers for maintaining their own environment is thus encouraged by the new system which works on the purely commercial basis and effectively rewards green-hand loggers.

It is obvious that on a small market and under a low-priced ecological bond the gain from permits is low and, most probably, less effective. The only advantage of working on a small market is a low monitoring cost. On a larger market, under a low bond, the technological progress is more likely to occur and diffuse among loggers as the simulations have demonstrated. If the principal is interested in keeping in business only a few competitive companies, then a higher bond is to be adopted, regardless of the size of the market.

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Obchodovatelná povolení k těžbě dřeva

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ABSTRAKT: Příspěvek prezentuje nový systém obchodovatelných povolení k těžbě dřeva, kombinovaný s ekologickou zárukou. Systém je schopen podporovat těžební technologie a firmy, které jsou šetrné k životnímu prostředí, tj. méně poškozují lesní ekosystémy. Všechny těžební společnosti musí před těžbou složit tzv. ekologickou záruku („bond") na základě předpokládaného objemu těžby. Tento vklad je vytvořen za účelem zajištění efektivní transakce s těžebními povoleními na konci roku. Současně pro každou jednotku (m^3) dřeva, které má být vytěženo, obdrží těžařské společnosti určité množství povolení k obchodování na konci roku, a to podle úrovně, ve které dokážou ochránit zbylý stojící porost, nárost a půdu. V dané fázi – po zjištění škody vzniklé na všech těžebních plochách – je znovu vypočítáno množství povolení pro základ objemu pro každou těžební společnost podle velikosti a závažnosti vzniklých škod. Té těžařské společnosti, která způsobila nejmenší škodu a ušetřila (tj. má navíc) nejvíce těžebních povolení, je dovoleno prodat každému dalšímu těžebnímu subjektu takové množství povolení k těžbě, které tvoří rozdíl mezi těmito dvěma společnostmi. Příslušný odpovědný orgán na tyto transakce dohlíží tak, že stanoví prahové (limitní) ceny pro těžební povolení prodané druhé a třetí společnosti, přičemž nejlepší společnost si nemůže určit více, než činí existující ekologický vklad („bond"). Hlavní část příspěvku sestává z pěti modelových simulací založených na pravděpodobných scénářích, které byly vytvořeny na základě reálných údajů o těžbách zahrnujících dva typy škod, způsobených sedmi rumunskými těžařskými společnostmi v roce 1999 v Krajských státních lesích Suceava. Za předpokladu, že nejlepší společnost zkvalitní v důsledku příjmu z prodeje povolení k těžbě své technologie, přispívá uvedený systém k vyšší konkurenční výhodě proti ostatním. V příspěvku je ukázáno, že technologické inovace jsou daným postupem podněcovány. Systém může být také kombinován s pravidelnou kompenzací, placenou majitelům půdy.

Klíčová slova: obchodovatelná povolení; těžební činnost; revolvingové vklady

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