Pricing the Risk of the Quality-Guarantee in a Stand Establishment Service

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A stand-establishment service concept with quality guarantee was analysed. Here, the quality of stand establishment was assessed as the density of good quality seedlings evenly distributed on the plantation three years after planting. The amount of adequate premiums for the guarantee service and the risks accumulating to the service provider were studied. Monte Carlo simulation was used as a tool for analyzing the risks accumulating to the service provider of the stand-establishment in operational environments of different sizes. The premiums calculated to cover the expected amount of claims caused by the plantations not meeting the pre-set criteria were about 4–8% in addition to the approximated costs of stand establishment. The criteria used for determining the success or failure in a stand have a marked effect on the amount of premiums with a reasonable risk of ruin.

Keywords forest regeneration, risk, quality, guarantee
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1 Introduction

In Finland, some service providers have started to be interested in selling quality-guaranteed stand-establishment services for non-industrial private forest (NIPF) landowners. In such a concept, the service provider carries out all operations needed for stand establishment and in addition, guarantees the NIPF landowner that the stand will be regenerated successfully (Partanen 2000, Harstela et al. 2001). Quality guarantee of stand establishment is not yet offered regularly, nor are there general approximations for the premiums to be collected from the customer.

If for some reason establishment of a stand fails with quality-guaranteed service, the service provider will carry out the operations needed to re-establish the stand, or provide the forest landowner with other compensation, for example, a refund. This business principle transfers the risk of unsuccessful regeneration from the forest owner to the service provider. Risks also accumulate to the service provider. Therefore, to cover his share of the risk, the service provider has to obtain a premium from the forest landowner customer. This is very close to the general policy of insurance companies (Beard et al. 1977). Principles similar to those used to determine insurance premiums can be used to evaluate the risk being transferred from forest owner to the service provider. The price of the risk transferred to the service provider depends at least on the annually regenerated forest area, the probability of unsuccessful regeneration of a stand and the severity of the damage.

Here, the criteria for the success of reforestation are based both on the minimum number of good-quality seedlings per hectare and on the proportion of area with low density of good quality-seedlings. If the criteria for an acceptable regeneration result are not met, the service provider will repair plant the stand with the needed number of seedlings or give the forest owner some other type of compensation. The word "claim" has been used in this paper to describe monetary compensation based on the repair planting costs on a failed regeneration area to be paid to the owner of a failed stand. Repair-planting cost was used as a determinant for the amount of a claim, although successful repair-planting of spruce stands may be difficult, at least if the gaps to be repaired are small (Gemmel 1988a, 1988b). In terms of value, use of the discounted loss of yield in the future might theoretically be more "correct" as the determinant of a claim; but for individual cases in very early development phases of stand development it would be extremely difficult to estimate. A claim always leads to loss in profit for the service provider. Individual claims are of different amounts, depending on the size of the unsuccessful regeneration area and the severity of damage to the seedlings in a stand. The annual amount of claims consists of all individual claims received during one year.

The most probable customers for such a service could be small NIPF landowners, who acquire their silvicultural services from an external service provider. In Finland, the stand-establishment service provider is typically a forest owners' association (FOA) or forest operation entrepreneur. The forestry departments of forest industry companies also offer silvicultural services – stand establishment including soil preparation, direct seeding or planting, etc. This study was carried out in the operational environment of an FOA, but the company form has no specific effect on applicability to the results in operational environments of other service providers.

The aim of this study was to analyse the applicability of the success guarantee principle in a stand establishment service in a typical operational environment of a Finnish FOA. The main interest was to estimate the premium for different criteria for success of stand establishment. Another aim was to estimate the risks accumulating to the service provider. The results would be useful for FOAs and other silvicultural service providers who want to broaden and diversify their services to forest landowners.

2 Material and Methods

2.1 Quality Criteria for the Result of Stand Establishment

Four different quality criteria were used for the success or failure of a regenerated stand. The average density of good quality seedlings and the proportion of area with low density of seedlings were the basic variables of the criteria. Estimation of the proportion of the area was based on the number of sample plots with low density. The four alternative criteria for qualification of an established stand were:

1) Average density of seedlings over 1500 and less than 20% of the sample plots on the area containing 1000 seedlings or less (further expressed as 1500/1000)
2) Average density of seedlings over 1500 and less than 20% of the sample plots on the area containing 500 seedlings or less (1500/500)
3) Average density of seedlings over 1300 and less than 20% of the sample plots on the area containing 1000 seedlings or less (1300/1000)
4) Average density of seedlings over 1300 and less than 20% of the sample plots on the area containing 500 seedlings or less (1300/500)

The amount of a claim was determined by calculating the difference between the target density of 1800 seedlings per hectare, and the result from the field survey. Thus, failed parts of the regeneration area were to be repair-planted to an average density of 1800 seedlings per hectare.

Table 1. Percentage shares for failure of regeneration according to the studied criteria.

Criteria	Percentage of failure
1. 1500/1000	0.198
2. 1500/500	0.132
3. 1300/1000	0.090
4. 1300/500	0.085

2.2 Field Survey of Regeneration Areas

The Norway spruce stands studied here were planted in 1999 and surveyed in 2002. The survey method for young stands developed by Saksa et al. (2002) and Saksa (2003) was used. The data consisted of 212 regeneration areas with a total area of 363.2 ha. On every regeneration area, 15–20 circular sample plots with radius of 2.52 m^2 (area = 20 m^2) were systematically located. All established stands in the data were within the operational area of an FOA in eastern Finland. The data consisted of all Norway spruce stands established by the studied FOA in 1999.

The probability of failure for a planting area was calculated from the data set as the number of stands not meeting the set criteria divided by number of stands in the whole data set. The probabilities related to each criterion are presented in Table 1. It has to be noted that the probabilities of failure in regeneration depend on the survey method. The probability of failure in an individual stand was not dependent on the size of the regeneration area.

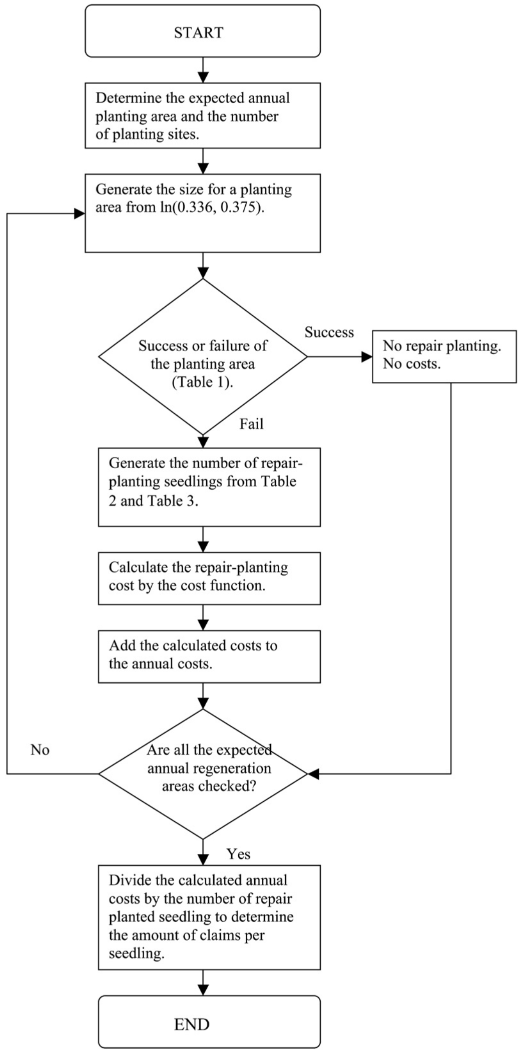

Fig. 1. The simulation model.

2.3 Simulation

Monte Carlo simulation was applied to calculate the risks for different expected total areas of regenerated stands planted by a stand-establishment service provider. A diagram of the simulation model is presented in Fig. 1. Simulation was used, instead of sampling from the original data, to imitate the risk process of obtaining the possibility to analyze larger annual areas than those in the original data set. Sampling without replacement from the original data set would have also led to biased variance of the results in large samples.

The simulations were carried out on a standard Microsoft Excel spreadsheet programme. In addition to the general features of the programme, some additional macros were needed to generate random numbers from certain density distributions. The simulation was iterated 160 times for each criterion and the expected annual area of established stands.

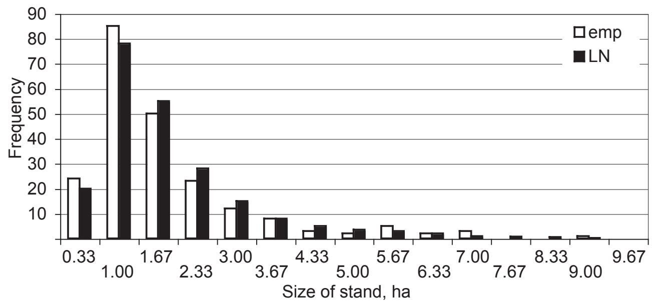

Fig. 2. Empirical (emp) and fitted (LN) size distributions of the regeneration area.

2.4 Size Distribution of Regeneration Areas

A density function of lognormal distribution was fitted to the data for sizes of the regeneration areas (Fig. 2). The parameters of the lognormal density function fitted here were μ = 0.336 and σ^2 = 0.375. Thus, the mean and the standard deviation of the fitted theoretical distribution were 1.7 ha and 1.1 ha, respectively. In the simulation process, the minimum area for a regenerated stand was limited to 0.5 hectares. Smaller areas than that were not included in the risk analysis.

2.5 Severity of Failure in Stand Establishment

The number of repair-planted seedlings on regeneration areas, based on the four different criteria, was first calculated for the original data set. The data expanded by the calculated number of seedlings needed for repair planting was then used to create prediction models for the number of repair-planting seedlings. Obviously the size of the regeneration area has a major effect on the number of repair-planting seedlings needed. The number of seedlings needed for repair planting on a failed area was calculated in two phases. Firstly, linear regression models were used to determine the expected number of seedlings for repair planting; and secondly, logarithmic regression models were used to determine the variation around the expected number of seedlings. Ordinal least squares method was used in linear regression. The variation models were fitted to the ten outermost residuals in the residual plot of the linear model. Thus, the aim of the variation models was to find roughly the upper and lower limits for the residuals. The distribution of residuals between the limits was considered to be uniform, because accurate information on the form of the distribution was hard to find in such a small data set. The use of uniform distribution for simulation in cases of unsure form of distribution has been emphasized, for example, by Parson et al. (1998). The independent variable in both models was the size of the regeneration area. Parameters of the constructed models for each criterion are shown in Tables 2 and 3. An example of the functions indicating the number of seedlings needed for repair-planting is shown in Fig. 3.

Table 2. Parameters of the linear regression models for the expected number of seedlings needed for repair-planting. The form of the model was: y = a + bx, where x is the size of the regeneration area (ha).

Parameter	Criteria			
	1 (1500/ 1000)	2 (1500/ /500)	3 (1300/ 1000)	4 (1300/ /500)
a	149.7	133.4	17.2	25.8
b	423.2	350.0	628.0	467.4

Table 3. Parameters for the variation models y = a + b ln(x), where x is the size of the regeneration area (ha).

Parameter	Criteria			
	1 (1500/ 1000)	2 (1500/ /500)	3 (1300/ 1000)	4 (1300/ /500)
a	223.0	181.2	204.7	204.7
b	176.3	174.5	250.3	238.6

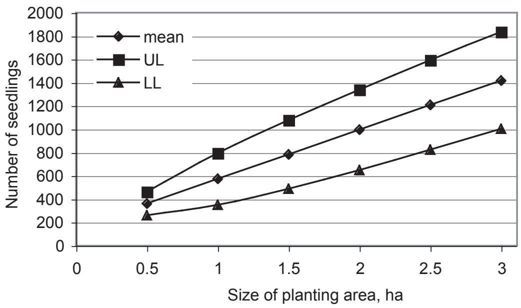

Fig. 3. Number of seedlings needed for repair-planting of stands of different sizes when criterion 1 (1500/1000) is applied. The curves indicate the mean and the upper (UL) and lower (LL) limits for the number of seedlings used in the simulations.

Table 4. Cost items of repair-planted seedlings without transportation costs (€).

Cost item	Cost per seedling
Mounding	0.12
Price of seedling	0.23
Wages of planter, social costs and instruction	0.15
Total	0.50

2.6 Cost Function for Repair-Planting

The following function was used to estimate the cost of repair-planting on every unsuccessful stand

$$C = 50 + 0.50n \text{ (€)}$$

where
C = Total cost for repair-planting of a stand
n = Number of repair-planted seedlings.

The constant in the cost function is caused by transporting the excavator and the planter. Cost per seedling (0.50 €) was estimated by calculating the cost of mounding, the price of the seedling, instruction, wages and social costs (Table 4). The sources used for cost information were cost calculation, official statistics and wage tables for forestry work (Metsäalan palkkaus 2000, Statistical yearbook… 2001).

Table 5. Average claims per originally planted seedling (€). Results from 160 annual simulations.

Expected annual planting area (ha)	Criteria 1 (1500/1000)	2 (1500/500)	3 (1300/1000)	4 (1300/500)
10.1	0.028	0.016	0.018	0.010
25.3	0.028	0.017	0.019	0.013
50.6	0.031	0.017	0.017	0.013
101.3	0.031	0.017	0.018	0.013
150.2	0.030	0.017	0.018	0.013
200.8	0.031	0.017	0.017	0.014
300.4	0.031	0.018	0.017	0.013
399.9	0.031	0.018	0.018	0.013
499.5	0.031	0.018	0.018	0.013

3 Results

3.1 Claims

The annual amount of the claims for a certain annual planting area was divided by the number of planted seedlings. The amount of claims per originally planted seedling according to each criterion and the expected annual planting area are presented in Table 5. For the lowest criterion (1300/500), the annual planting area had the strongest relative effect on the amount of claims per seedling. In this criterion the probability of failure is fairly low; therefore with small annual regeneration areas, the amount of claims per seedling remains low.

3.2 Probabilities of Ruin in Operational Environments of Different Sizes

Probabilities of ruin for different annual planting areas and premiums and criteria were calculated from the simulated results (Figs. 4–7). The curves indicate the risk that the annual amount of claims would exceed the amount of the premiums collected (Beard et al. 1977). For all criteria it became obvious that 0.01 € was too a small premium, at least for large annual planting areas. For the three lowest criteria, 4 (1300/500), 3 (1300/1000) and 2 (1500/500), as little as 0.02 euros would be enough to cover the annual risk of ruin. For the

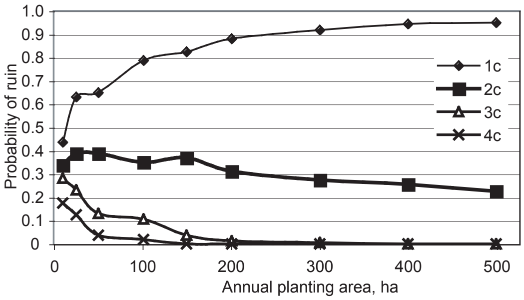

Fig. 4. Simulated risk of ruin with the success criterion 1300/1000 as a function of planted area and premiums (c = Euro cent).

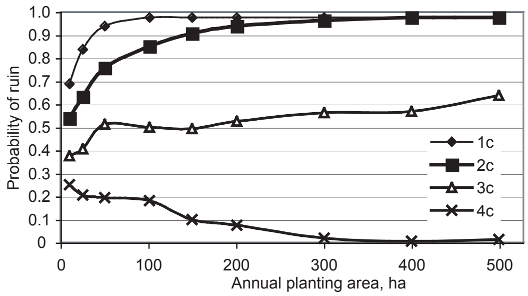

Fig. 6. Simulated risk of ruin with the success criterion 1500/1000 as a function of planted area and premiums (c = Euro cent).

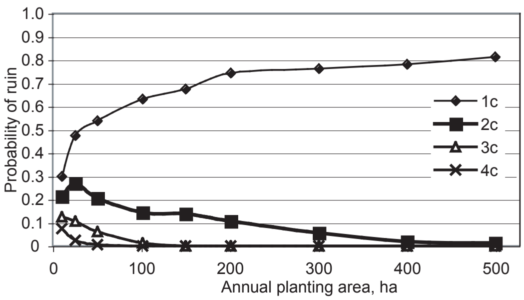

Fig. 5. Simulated risk of ruin with the success criterion 1300/500 as a function of planted area and premiums (c = Euro cent).

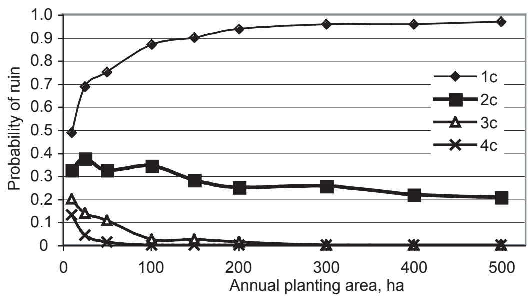

Fig. 7. Simulated risk of ruin with the success criterion 1500/500 as a function of planted area and premiums (c = Euro cent).

toughest criterion, 1 (1500/1000), not even 0.03 € was enough to decrease the annual risk of ruin as a function of planting area (Fig. 6).

3.3 Validity of the Simulation Model

The validity of the simulation model was tested by taking samples of a certain expected total area of regeneration areas and comparing the claims per seedling from these samples with figures from the simulated samples with the same expected size. Each of the samples consisted of either 6 or 30 regeneration areas. Thus the expected total area of a sample was 10.1 ha or 50.6 ha, respectively. The averages of the claims calculated from the samples are presented in Table 6.

The difference between the simulation results and the samples from the real data was tested for statistical differences.

Table 6. Sample averages of claims per seedling calculated from the data. Standard deviations are presented in parenthesis.

Expected annual planting area (ha)	Criteria 1 (1500/1000)	2 (1500/500)	3 (1300/1000)	4 (1300/500)
10.1	0.032 (0.028)	0.019 (0.022)	0.014 (0.019)	0.013 (0.020
50.6	0.033 (0.013)	0.020 (0.010)	0.019 (0.008)	0.014 (0.007)

Let
$\hat{\mu}_{sim}$ = mean taken from the simulation, and
$\hat{\mu}_{sam}$ = mean taken from the samples.

If there is no difference between these means, then

$$\hat{\mu}_{sim} - \hat{\mu}_{sam} = 0 \quad (1)$$

Table 7. Upper and lower limits of the 95% confidence interval for the difference $\hat{\mu}_{sim} - \hat{\mu}_{sam}$ with different criteria and expected sizes of the samples (ESS).

Criteria	1 (1500/ 1000)	2 (1500/ 500)	1 (1500/ 1000)	2 (1500/ 500)	3 (1300/ 1000)	4 (1300/ 500)	3 (1300/ 1000)	4 (1300/ 500)
ESS, ha	10.13	10.13	50.63	50.63	10.13	10.13	50.63	50.63
Lower limit	–0.073	–0.056	–0.036	–0.023	–0.069	–0.053	–0.028	–0.021
Upper limit	0.073	0.059	0.038	0.029	0.062	0.058	0.032	0.026

The 95% confidence interval for the difference above is simply (Schenker and Gentleman 2001)

$$\hat{\mu}_{sim} - \hat{\mu}_{sam} = \pm 1.96\sqrt{\hat{\sigma}_{sim}{}^2 + \hat{\sigma}_{sam}{}^2} \tag{2}$$

The numerical values for the upper and lower limits of the 95% confidence intervals for the difference are presented in Table 7. All the confidence limits include 0. Thus, the simulated average premiums per seedling do not differ statistically significantly from those calculated from samples drawn from the data set.

4 Discussion

For the year 2000, in the official national statistics for the region where the study area was located the total cost of soil preparation and planting was about 0.49 € per seedling (Finnish Statistical… 2001). The average cost for soil preparation was calculated by weighting the cost by the number of hectares prepared by the method used. The results of the simulations in this study show that the premiums estimated to cover the claims with a probability over 50%, i.e. 0.02–0.04 € would be about 4–8% of the planting costs, including the price of the seedling. Partanen (2000) found in his survey that the willingness to pay for a success-guaranteed forest regeneration service was about 5%. Between customer segments, however, the variation in willingness to pay was high.

It has to be noted that the probabilities of failure in regeneration results were calculated with only an inventory of one year of plantings. Different weather conditions and possibly different varieties of seedling type and quality in different years affect the result. Fungal and insect attacks may also cause variation from year to year. Another weakness in the data used here is the lack of information on the initial planting density of the stands. Despite widely used silvicultural guidelines, the initial densities surely differ from stand to stand. Low initial density in some of the stands in the data has presumably been more common than high initial density. In this case, it may have lead to slight overestimation of calculated risks.

Early development of spruce stands can be markedly improved by appropriate soil preparation and good quality seedlings. Mounding or inverting has resulted in the best growth and survival of seedlings (Örlander 1998, Nordborg 2001). In the data used here, only 9% of the regeneration areas were mounded, while most areas were scarified either by excavator or disc-trencher. The result of stand establishment could surely be improved by using mounding as a method of soil preparation. This would lead to the smaller premiums needed to guarantee success. The business principle studied here would also give the service provider an opportunity to learn how to improve the operational method of stand establishment.

The models used to describe variation were difficult to construct because the shapes of distributions were unclear. One alternative to the uniform distribution approach used here could have been to use other theoretical density functions, such as normal distribution, and to create a regression model for the term defining the variation. The shape of the conditional distribution of the variation of the number of repair-planted seedlings on a certain annual planting area was hard to determine, and there were also some extreme observations. Distributional forms of probabilities in simulation models, however, are not as important as covariability or ranges of values (Smith and Heath 2001).

The quality of stand-establishment operations carried out by FOAs varies considerably between associations and also within an association between the FOA officials responsible for instruction on stand establishment (Saksa et al. 2002). The quality of forest regeneration carried out by the FOA analysed in this study was slightly above the average for the FOAs in the same region in 1999.

Introduction of the concept of stand-establishment service with a guarantee of success requires clear agreement on the criteria to be used to measure success and failure. In addition, the inventory method has to be clearly justified. When these technical issues are collectively agreed upon, the service principle may become an integrated part of stand-establishment service. The quality guarantee could be provided in two forms: Firstly, the guarantee can be sold to the customer as insurance, i.e. an additional part of the stand-establishment service. Another option is to integrate the quality guarantee into the stand-establishment service.

References

Beard, R.E., Pentikäinen, T. & Pesonen, E. 1977. Risk theory. The stochastic basis of insurance. Chapman and Hall, London. 2nd edition. 195 p.

Gemmel, P. 1988a. Development of beeted seedlings in three Picea abies (L.) Karst. stands. Scandinavian Journal of Forest Research 3: 175–183.

— 1988b. Beeting in Picea abies (L.) Karst. Growth and damage in a field experiment. Scandinavian Journal of Forest Research 3: 201–212.

Harstela, P, Kettunen, J., Kiljunen, N. & Meristö, T. 2001. Normitaloudesta yrittäjyyteen. Puuntuotannon tulevaisuus Suomessa. Metsäntutkimuslaitoksen tiedonantoja 819. 69 p.

Metsäalan palkkaus 2000. Koulutusaineisto. X painos. Metsäpalkkauksen kehittäminen -projektiryhmä 20.12.2000. 47 p.

Nordborg, F. 2001. Effects of site preparation on soil properties and on growth, damage and nitrogen uptake in planted seedlings. Doctoral thesis. Swedish University of Agricultural Sciences. Silvestria 195. 25 p.

Örlander, G., Hallsby, G., Gemmel, P. & Wilhelmsson, C. 1998. Inverting site preparation increases growth of Norway spruce and Lodgepole pine seedlings. Scandinavian Journal of Forest Research 13: 160–168.

Parson, S.C., Hamlett, J.M., Robillard, P.D. & Foster, M.A. 1998. Determining the decision-making risk from AGNPS simulations. Trans. of the ASAE 41(6): 1679–1688.

Partanen, J. 2000. Metsäpalveluyrittäjyyden painopistealueet. M.Sc. thesis. University of Joensuu, Faculty of Forestry. 39 p.

Saksa, T. 2003. Metsänuudistamisen seurantamenetelmä ja uudistamistuloksen mittaaminen. In: Luoranen, J. (ed.). Etelä-Suomen metsien uudistaminen. Tutkimusohjelman loppuraportti. Metsäntutkimuslaitoksen tiedonantoja – Finnish Forest Research Institute, Research Papers 888: 66–73.

— , Särkkä-Pakkala, K. & Smolander, H. 2002. Työkalu metsänuudistamisen laatutyöhön. Metsätieteen aikakauskirja 1/2002: 29–34.

Schenker, N. & Gentleman, J. 2001. On judging the significant of differences by examining the overlap between confidence intervals. The American Statistician 55(3): 182–186.

Smith, J. & Heath, L. 2001. Identifying influences on model uncertainty: An application using a forest carbon budget model. Environmental Management 27(2): 253–267.

Total of 13 references