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FOREST MANAGEMENT FOR PREVENTION AND CONTROL OF THE SYREX WASP (*Sirex noctilio*) IN *Pinus taeda*

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SUMMARY

Prevention and control of *Sirex noctilio* (Hymenoptera: Siricidae) has been done by integrated management involving: monitoring for early detection by using trap trees, silvicultural practices and the use of natural enemies, such as the nematode *Deladenus siricidicola*. A commonly used method in plantations with an attack level over 50% is the immediate clear cut, the reason being that thinning, with the removal of attacked trees could leave the stand under stocked, making its conduction to advanced ages anti-economic. In this paper, the effects of different attack percentages of *S. noctilio* on *Pinus taeda* growth and production were evaluated in technical and economical terms. The data used was obtained by the simulation of growth and production of forests with ages from 12 to 16 and attack rates ranging from 0 to 70%. The study compared, for each level of attack, economic advantages of the immediate clear cut, with the extension of forest rotation age for up to 20 to 30 years. For the extension of the rotation age, the application of established integrated control was considered. The study indicated that attacked forests, maintained with age above 20 years and submitted to integrated management, tend to present higher economical advantages than the clear cut on occasion of attack, even if the attack rate is over 50%.

1. INTRODUCTION

The total reforested area in Brazil is of approximately five million hectares and, out of these, about two million are of *Pinus* spp. About 1.2 million hectares are in the Southern region and in São Paulo state, made up mainly by the species *Pinus taeda* L. and *Pinus elliottii* Engelm. The main purpose of reforestation it to supply raw material to pulp, paper, particle boards, resin processing and also wood panels industries.

Nevertheless, the existence of planted forests in a system of monoculture, and the inadequate silvicultural practices has resulted in extensive reforested areas lacking in phytosanitary conditions, making them susceptible to pest attacks. In these conditions, *Sirex noctilio* (Hymenoptera: Siricidae), which was reported for the first time in Brazil in February 1988, quickly adapted itself, reaching, in 1996, about 200 thousand hectares of Pinus spp. populations in Rio Grande do Sul, Santa Catarina and Paraná.

Because of its preference in attacking weakened trees, which normally are dominated, silvicultural control through thinning in adequate periods is the most adequate form to prevent or minimize damage caused by this pest. A strategy commonly used in plantations with attack rates over 50% is the immediate clear cut, as the use of biological control methods can not be effective in such conditions. Also, damage of *S. noctilio* causes the death of attacked trees, and drastic thinning could make the population under stocked of wood, affecting the final production.

This paper aims to study the effects of different *S. noctilio* attack rates in the growth and production of *P. taeda* and evaluate, in technical and economical terms, the recuperation of these populations, by the use of silvicultural practices and biological control.

2. LITERATURE REVIEW

2.1 Trees most susceptible to *Sirex noctilio* attack.

According to Chrystal (1928), the gender Sirex can not be considered a primary pest, because other factors should initially contribute to make the tree attractive and present adequate conditions for insect development.

Madden (1975) observed that trees initially preferred by *S. noctilio* are those that present a smaller diameter and are dominated, although the attack of dominant trees has also been reported.

Neumann et al. (1987) verified that plantations most susceptible to *S. noctilio* attack are over 12 years of age and are under stress. According to Mendes (1992), the growth curve of *P. taeda* presents highest development from the age of 12 years. Consequently, if a population is attacked during this phase, and submitted to anticipated clear cut, it will keep from producing about 60% of the expected wood and the wood obtained will have a high production cost.

As of Neumann et al. (1987), trees resistant to *S. noctilio* attack are those that have not suffered any physical damage and that have grown in adequate conditions.

2.2. Means for *Sirex noctilio* prevention and control.

According to Neumann et al. (1987), *S. noctilio* attack is a problem originated mainly by the use of inadequate silvicultural practices and recommend the following means for prevention and control:

- have thinning done in the right periods, as to reduce competition among trees and allow the removal of dominated, forked, deformed and damaged trees;
- not have thinning and pruning done in periods immediately before the emergence of adult insects;
- avoid the implantation of *Pinus* spp. populations in steep lands, which makes silvicultural management difficult to minimize lesions to trees during the silvicultural practices.

Ure (1949) quoted by Sutton (1984) developed a silvicultural regime for planting *P. radiata* in New Zealand, recommending frequent low intensity thinning to maintain the strength of plants and reduce competition. These basic principles of this thinning regime formed the base of silvilcultural practices used since then in New Zealand.

For Taylor (1981), *S. noctilio* attack can be minimized if plantations are located in good quality sites with adequate management, maintaining the strength of plants, and in this manner reducing the mortality rate in initial attack phases.

Neumann et al. (1987) verified, in a 17 year old, non thinned *P. radiata* stand, that trees with a diameter under 23 cm had higher mortality rates, and those with a diameter larger than 26 cm were less attacked. Trees with diameter superior to 35 cm remained healthy and forked trees were significantly more susceptible to attack.

According to Neumann et al. (1987), trees resistant to *S. noctilio* attack are those that had not suffered any physical damage and that had grown in adequate conditions

3. METHODOLOGY

3.1 Attack percentages and characteristics of studied stands.

Attacked trees percentages were studied in the proportion of 0, 10, 20, 30, 40, 50, 60 and 70%, in two *Pinus taeda* stands, both with a site rate (given by the projection of the dominant height at 15 years of age) of 21,0 m. The first stand had 1850 trees/ha, a basal area of 52m2/ha and was 12 years old, and the second, , 1700 trees/ha, basal area of 60m2/ha and 16 years of age. Monitoring and biological control with nematode operations (in the proportion of 20% of the attacked trees in the stand) were considered.

3.2 Wood growth, production and classification data

P. taeda growth and production data, as well as wood classification for multiple uses, were obtained by simulation, using SISPINUS software Version 2.1. This software generates, from information and measurements from a young aged *P. taeda* stand, tables with growth and production prognosis, at any age and also, production prognosis tables by diameter classes, from harvested and thinned trees, for multiple industrial uses (Oliveira, 1995).

3.3 Adopted management regimes

For the first stand, the planned management regime consisted of two thinnings, being the first at 12 years (systematic thinning with the removal of one line of trees in every four, followed by the selective removal of attacked trees and of those with smaller diameters, until the 925 trees/ha proportion was reached); and the second at 16 years with selective removal of attacked trees and of trees with smaller diameters, leaving 450 trees/ha.

For the second stand a thinning was done at 16 years (systematic thinning with the removal of one line of trees in every three, followed by the selective removal of attacked trees and of those with smaller diameters, until the 900 trees/ha proportion was reached), and the second at 19 years, also with the removal of attacked trees and of those with smaller diameters, leaving 450 trees/ha.

In both cases, thinning could exceed the planned intensity by the removal of attacked trees.

The ages studied for the final harvest were from 20 to 30 years, with 2 year intervals.

It was stipulated that 2/3 of attacked trees belonged to the smaller diameter classes and the others were casually distributed among the rest of the stand. In this manner, after the application of systematic thinning of whole lines of trees, in the thinning of the remaining trees, the application of nematodes in 20% of attacked trees and the removal of the remaining trees was also considered, according to the proportion of 2/3 and 1/3.

Log dimension for different industrial uses and prices, referring to the Curitiba-PR market as of August 1996, are specified in Table 1. Production costs are presented in Table 2.

TABELA 1. DIMENSÕES DE TORAS E PREÇOS POR M^3 DE MADEIRA PARA DIFERENTES FINALIDADES INDUSTRIAIS.

Finalidade Industrial	Diâmetro Mínimo (cm)	Comprimento (m)	Preço US$/$m^3$
Laminação	25,0	2,4	24,56
Serraria	15,0	2'4	16,87
Celulose	8,0	1,2	10,64
Energia	-	-	6,00

TABELA 2. CUSTOS PARA A PRODUÇÃO DE MADEIRA DE *Pinus* spp. NA REGIÃO DE CURITIBA -PR. (AGOSTO DE 1995).

A. Implantação do Povoamento	US$ 600/ha
B. Exploração	
1. Corte das árvores	US$ 0,98/m3
2. Desgalhamento	US$ 0,18/m3
3. Extração	US$ 1,00/m3
4. Traçamento	US$ 0,16/m3
5. Carregamento	US$ 0,71/m3
6. Transporte	US$ 2,30/m3
7. Descarregamento	US$ 0,67/m3
C. Administração	US$ 20/ha/ano
D. Manutenção	
1. 1° ano	US$ 150/ha
2. 4° ano	US$ 50/ha
3. 9° ano	US$ 40/ha
E. Operações de monitoramento e controle de *S. noctilio*	US$ 30/ha/5 anos

3.4 Evaluation of economic profit

For the evaluation of economic profits Planin OLIVEIRA (1997) software was used, having as its base the Annual Equivalent Value (AEV) method in which the Present Liquid Value of financial profit at a minimal appeal rate is transformed into an equivalent uniform annual series.

4. RESULTS AND DISCUSSION

Systematic thinning of whole lines with selective thinning in the remaining is constant amongst *Pinus* producers, mainly to facilitate the cutting and removal of trees. This practice was maintained in all studied simulations, nevertheless, if the producer chooses to have just selective thinning, removing attacked and inferior diameter trees, he can obtain higher wood production rates, specially in stands with attack percentages where expected thinning in not enough to remove all attacked trees.

The results obtained in the two studied stands are shown next.

4.1. 12 year-old attacked stand.

For *S. noctilio* occurrence percentages of up to 30%, systematic thinning, followed by selective thinning, was enough to remove all attacked trees at the age of 12. However, from the rate 40% onwards, the removal of all attacked trees made the remaining number of trees per hectare lower than the expected rate of 925.

Production prognosis for final harvest ages from 20 to 30 years are presented in Table 3 according to different attack rates. Economical analysis of these productions is presented in Table 4, indicating that rotation at 24 years of age presents the highest economic benefit for any rate of *S. noctilio* occurrence.

In Figure 1, profit percentages of 12 year-old attacked stands are presented related to the best profit management regime (no attack, 2 thinnings, final harvest at 24 years), in a 24 year planning horizon.

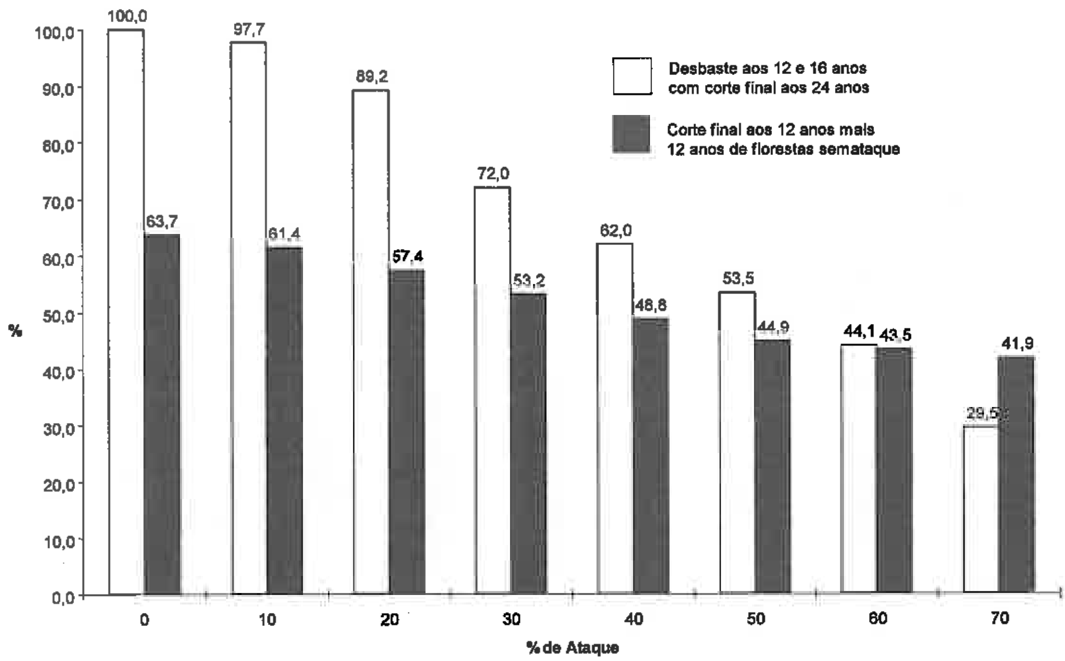

Figure 1. Profit percentages in 12 year old stands attacked by *Sirex noticilio*, in relation to the management regime of best profit (no attack, 2 thinnings, final harvest at 24 years), in a planning horizon of 24 years.

As can be observed, for different levels of *S. noctilio* attacks, the final harvest of the stand followed by the plantation of a new forest was only recommendable for attack rates over 60%, where the decrease of profit becomes equivalent.

4.2. 16 year-old attacked stand.

Rotation at 24 years, for any *S. noctilio* attack rate, was the most profitable amongst the 20 to 30 year rotation, as previous studies done by simulation for the prior example (attack at 12 years). Production prognosis for the stand with attack at 16 years, considering the immediate final harvest at age 24 are presented in tables 3 and 4 respectively.

The Equivalent Annual Values (EAV's) for stands with attack rates from 0 to 70%, submitted to thinning at 16 e 19 years, removal of attacked trees, treatment with nematodes and final harvest at 24 years, and with final harvest at 16 years, considering also, in this case, 8 more years of forest profit with no attacks, are presented in Table 8. Profit percentages in each situation, related to the best profit management regime (no attack, 2 thinnings, final harvest at 24 years) in a 24 year planning horizon are presented in Figure 2.

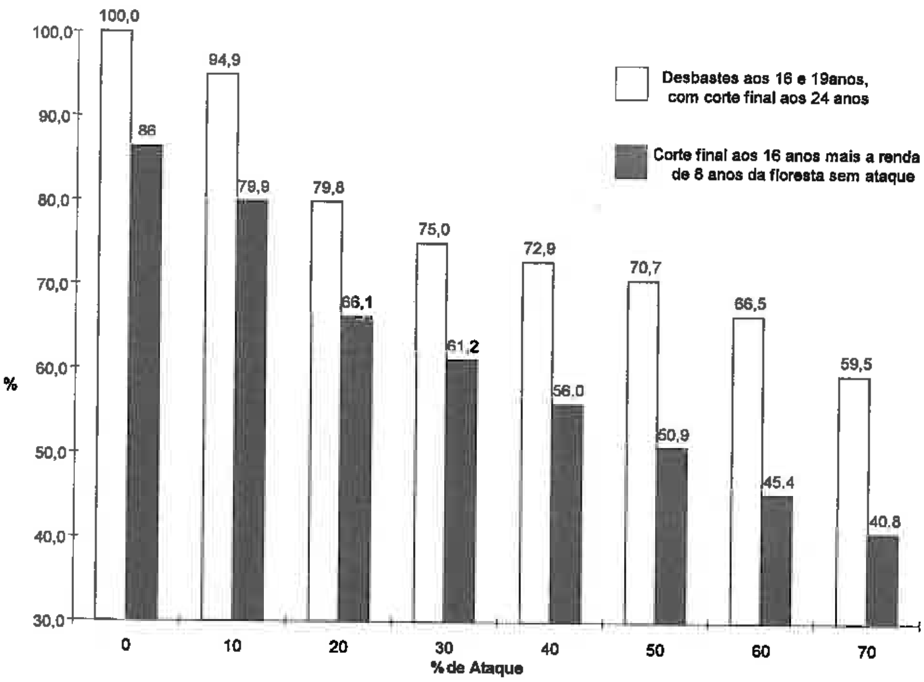

Figure 2. Profit percentage rates of 16 year old stands attacked by *Sirex noctilio*, in relation to the highest profit management regime (no attack, 2 thinnings, final harvest at 24 years), in a planning horizon of 24 years.

In terms of profit, for all attack rates, forests managed and cut at 24 years = surpass forests cut at 16 years. Taking as an example the attack rate of 50%, the immediate cut of the stand would take to losses at the order of 49,1% in economic profit, as the conduction of the stand with adequate management, would reduce this loss to 29,3%.

5. FINAL CONSIDERATIONS

The Sispinus and Planin software made possible the quantification of production and economic profit rates of forests with different *S. noctilio* attack rates submitted to different management regimes. Nevertheless, some aspects should be observed:

1. the system considers the geographical distribution of attacked trees in a regular manner;

2. there is the possibility of "acamamento" of remaining trees, after specially intense thinning;
3. there might be problems with roads and other difficulties for exploration and thinning;
4. some administrative strategies, linked to aspects such as commitments made to the consumer market or the supplying of raw material to adjoined factories, takes one to choose to cut stands that are not in the ideal age.

In this manner, the decision can not always be based on economical criteria. In all situations, good sense should prevail in the final decision.

An analysis of profit sensibility should be done, changing the various cost centers and prices, looking for a strategic vision that would make losses due to *S. noctilio* the lowest possible.

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TABLES

Table 3. Growth and wood production values m^3/ha of *Pinus taeda* for example # 1, without *Sirex noctilio* attacks.

AGE Years	DOMINANT HEIGHT m	N/HA	AVERAGE DIAMETER cm	AVERAGE HEIGHT m	BASAL AREA m^2	TOTAL VOLUME m^3	IMA m^3	ICA m^3
12	17,7	1850	19,0	15,2	52,4	372,0	31,0	31,0
THINNING BY THE REMOVAL OF ONE LINE IN EVERY 4, FOLLOWED BY THINNING BY THE REMOVAL OF 463 TREES								
		925	21,0	15,9	32,0	233,4	REMOVED=138,6	
14	20,0	918	22,8	17,8	37,7	313,8	32,0	38,2
16	22,1	907	24,6	19,6	43,0	395,0	33,1	40,6
THINNING BY THE REMOVAL OF 457 TREES								
		450	27,4	20,6	26,5	254,1	REMOVED=140,9	
18	23,7	449	28,9	22,4	29,4	308,0	32,6	26,9
20	25,6	447	30,7	24,1	33,2	375,7	32,8	33,8
22	27,4	444	32,4	25,6	36,5	440,4	32,7	32,1
24	29,1	441	33,8	27,2	39,5	505,1	32,7	32,3
26	30,6	436	35,1	28,6	42,1	567,7	32,6	31,3
28	32,2	431	36,2	30,0	44,4	626,9	32,4	29,6
30	33,6	425	37,3	31,3	46,4	685,5	31,2	29,3

Table 4. Wood production (m^3/ha) of *Pinus taeda* for example # 1, by industrial use classes , for *Sirex noctilio,* attack rates from 0 to 70%.

No attack	Total m^3	Veneer m^3	Sawlogs	Pulp m^3	Energy m^3
Final harvest at 12 years	372,0	12,1	210,5	125,0	24,4
1st Thinning (12 years)	138,6	3,3	64,4	57,3	13,5
2nd Thinning (16 years)	140,9	10,0	87,5	37,4	6,0
Final harvest at 20 years	375,7	202,6	136,9	30,6	5,5
Final harvest at 22 years	440,4	265,2	142,6	27,3	5,3
Final harvest at 24 years	505,1	328,4	139,3	31,8	5,6
Final harvest at 26 years	567,7	398,7	142,6	26,0	4,8
Final harvest at 28 years	626,9	453,5	135,5	28,7	4,8
Final harvest at 30 years	685,5	519,3	132,7	20,6	4,9

Attack in 10% of trees	Total m^3	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
1st Thinning (12 years)	138,6	3,3	64,4	38,7	32,1
2nd Thinning (16 years)	140,9	10,0	87,5	37,4	6,0
Final harvest at 20 years	375,7	202,6	136,9	30,6	5,5
Final harvest at 22 years	440,4	265,2	142,6	27,3	5,3
Final harvest at 24 years	505,1	328,4	139,3	31,8	5,6
Final harvest at 26 years	567,7	398,7	142,6	26,0	4,8
Final harvest at 28 years	626,9	453,5	135,5	28,7	4,8
Final harvest at 30 years	685,5	519,3	132,7	20,6	4,9

Continuation of TABLE 4.

Attack in 20% of trees	Total m³	Veneer m³	Sawlogs m³	Pulp m³	Energy m³
1st Thinning (12 years)	150,2	3,7	73,0	36,7	36,8
2nd Thinning (16 years)	131,9	8,1	76,3	42,3	5,2
Final harvest at 20 years	366,6	194,0	136,7	31,1	4,7
Final harvest at 22 years	430,4	255,2	139,9	30,6	4,8
Final harvest at 24 years	494,7	318,2	139,4	32,0	5,1
Final harvest at 26 years	556,0	386,7	136,2	28,6	4,6
Final harvest at 28 years	615,2	441,9	137,9	30,4	5,0
Final harvest at 30 years	671,6	505,5	130,6	30,6	4,9

Attack in 30% of trees	Total m³	Veneer m³	Sawlogs m³	Pulp m³	Energy m³
1st Thinning (12 years)	189,6	2,6	42,9	25,3	118,8
2nd Thinning (16 years)	95,2	3,3	48,2	37,1	6,7
Final harvest at 20 years	353,0	183,7	135,3	28,9	5,1
Final harvest at 22 years	416,1	243,5	138,5	28,6	5,6
Final harvest at 24 years	477,8	305,8	137,3	28,9	5,8
Final harvest at 26 years	538,7	372,4	132,2	28,8	5,3
Final harvest at 28 years	598,4	424,1	139,9	29,3	5,1
Final harvest at 30 years	654,5	491,8	130,6	27,0	5,2

Attack in 40% of trees	Total m³	Veneer m³	Sawlogs m³	Pulp m³	Energy m³
1st Thinning (12 years)	208,4	1,9	31,6	18,8	156,1
2nd Thinning (16 years)	73,1	2,4	34,6	30,7	5,4
Final harvest at 20 years	349,6	181,6	134,6	27,6	5,9
Final harvest at 22 years	411,4	238,7	138,6	28,7	5,5
Final harvest at 24 years	472,0	300,0	137,3	29,5	5,1
Final harvest at 26 years	532,5	357,1	140,6	29,5	5,3
Final harvest at 28 years	591,3	422,5	135,4	28,4	5,1
Final harvest at 30 years	647,8	481,8	131,4	29,2	5,3

Attack in 50% of trees	Total m³	Veneer m³	Sawlogs m³	Pulp m³	Energy
1st Thinning (12 years)	227,6	1,3	21,5	12,7	192,1
2nd Thinning (16 years)	51,4	1,5	23,2	22,7	3,9
Final harvest at 20 years	345,6	179,0	129,8	30,5	5,4
Final harvest at 22 years	406,3	235,8	136,0	28,9	5,6
Final harvest at 24 years	466,9	296,9	136,9	28,3	5,3
Final harvest at 26 years	527,3	353,9	139,8	28,3	5,4
Final harvest at 28 years	585,0	418,5	132,7	28,4	5,4
Final harvest at 30 years	641,3	477,8	130,3	27,6	5,7

Attack in 60% of trees	Total m³	Veneer m³	Sawmill m³	Cellulose m³	Energy m³
1st Thinning (12 years)	265,3	1,3	21,4	12,7	166,1
2nd Thinning (16 years)	13,7	0,2	4,1	8,0	1,4
Final harvest at 20 years	331,6	168,3	127,1	30,6	5,5
Final harvest at 22 years	391,9	223,7	131,8	30,8	5,6
Final harvest at 24 years	451,9	290,6	126,3	29,8	5,3
Final harvest at 26 years	510,2	340,2	134,1	30,5	5,4
Final harvest at 28 years	568,1	405,4	128,1	28,9	5,7
Final harvest at 30 years	623,6	457,6	132,3	28,1	5,7

Attack in 70% of trees	Total m³	Veneer m³	Sawlogs m³	Pulp m³	Energy m³
1st Thinning (12 years)	293,5	1,0	16,0	2,8	273,7
2nd Thinning (16 years)	0	0	0	0	0
Final harvest at 20 years	290,4	145,0	112,6	28,0	4,8
Final harvest at 22 years	346,1	199,5	113,5	28,1	4,9
Final harvest at 24 years	402,9	258,2	114,2	25,2	5,3
Final harvest at 26 years	457,4	314,2	110,6	27,7	4,8
Final harvest at 28 years	511,6	367,6	112,2	27,0	4,8
Final harvest at 30 years	566,6	422,2	112,2	27,0	5,1

TABLE 5. *Pinus taeda* wood production (m^3/ha) by industrial use class for example #2, with *Sirex noctilio* attack rates ranging from 0 to 70%, with final harvest at 24 years.

S. noctilio attack rate %	Age (years)	total m^3	veneer m^3	Sawmill m^3	cellulose m^3	energy m^3
0	16	203	25,4	102,2	64,4	11
	19	129,4	7,5	75,6	40,8	5,5
	24	426,7	237,7	156,2	27,4	5,4
10	16	203	22,8	93,7	49,8	36,7
	19	129,4	7,5	75,6	40,8	5,5
	24	426,7	237,7	156,2	27,4	5,4
20	16	203	20,3	47,4	35,2	100,1
	19	129,4	7,5	75,6	40,8	5,5
	24	426,7	237,7	156,2	27,4	5,4
30	16	204,4	17,7	39,4	21,5	125,8
	19	129,4	7,5	75,6	40,8	5,5
	24	426,7	237,7	156,2	27,4	5,4
40	16	228,3	15,6	39,4	20,3	153
	19	102,3	7,9	60,7	30	3,7
	24	437,4	249,7	155	27,3	5,4
50	16	293	25,2	71,1	16,9	179,8
	19	53,5	2,5	29,6	18,8	2,6
	24	422,4	238,1	145,4	33,1	5,8
60	16	321	23,3	74,9	15,6	207,2
	19	16,8	0,5	10,1	5,6	0,6
	24	429,3	245,1	146,4	32,2	5,6

TABLE 6. *Pinus taeda* wood production values (m^3/ha) by industrial usage class, for example #2, considering final harvest at 16 years.

S. noctilio attack rate (%)	Total	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
0	537,8	77,1	292,1	145,8	22,8
10	537,8	74,5	283,6	131,2	48,4
20	537,8	72,0	237,3	116,6	111,9
30	537,8	69,4	228,9	102,1	137,5
40	537,8	66,8	220,4	87,5	163,1
50	537,8	64,3	211,9	72,9	188,7
60	537,8	61,7	203,4	58,3	214,4
70	537,8	59,1	195,0	43,7	240,0

TABLE 7. Equivalent annual values for example #1, considering final harvest from 20 to 30 years.

S. noctilio Attack (%)	Final harvest age							Final harvest-12 years plus replanting*
	12	20	22	24	26	28	30	
0	68,2	144,9	149,5	149,5	149,5	141,9	136,6	95,2
10	63,1	141,1	146,0	146,0	146,0	138,7	133,5	91,8
20	54,2	127,0	132,0	133,0	132,8	127,7	122,4	85,8
30	44,8	98,5	105,0	106,7	107,6	103,8	100,2	79,6
40	35,0	83,2	89,9	92,7	92,3	90,8	86,5	73,0
50	26,1	68,3	75,9	80,0	80,0	78,5	75,0	67,1
60	23,0	51,8	60,0	66,0	65,7	65,4	61,8	65,0
70	19,5	27,7	37,5	44,1	46,2	45,9	44,3	62,7

* After the stand cutting, made at age 12, replanting took place, in which there will be no *S. noctilio* attack, being cut at age 24, allowing best economic profit.

TABLE 8. Equivalent annual values for example #2, considering final harvest at ages 16 and 24.

S. noctilio Attack (%)	Final harvest age		Final harvest-16 years Plus replanting*
	16	30	
0	106,5	128,2	110,7
10	98,4	121,7	102,4
20	74,3	103,3	84,8
30	66,3	96,1	78,4
40	58,2	93,4	71,8
50	50,1	90,6	65,3
60	42,0	85,2	58,8
70	33,9	76,3	52,3

* After the stand cutting, made at age 16, replanting took place, in which there will be no *S. noctilio* attack, being cut at age 24, allowing best economic profit.