TECHNOLOGY JOURNAL REPORT
ON SHELTERWOOD SYSTEM

A Critique on
Timber Production of *Nothofagus pumilio* Forests
by a Shelterwood System in Tierra del Fuego
(Argentina)

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2006
KATA PENGANTAR

Puji syukur penulis panjatkan kepada Tuhan Yang Maha Esa, yang telah memberikan segala rahmat dan karunia-Nya sehingga KARYA TULIS ini dapat diselesaikan. Judul yang dipilih adalah "A Critique on Timber Production of Nothofagus pumilio Forests by a Shelterwood System in Tierra del Fuego (Argentina)".


Kami menyadari bahwa karya tulis ini masih jauh dari sempurna, oleh karena itu kami mengharapkan saran dan kritik yang bersifat membangun untuk lebih menyempurnakan karya tulis ini. Akhir kata kami ucapkan semoga karya tulis ini dapat bermanfaat.

Medan, Mei 2006
Penulis
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A Critique on
Timber production of *Nothofagus pumilio* forests by a shelterwood system in Tierra del Fuego (Argentina)

By:
RAHMAWATY

**Author:** G. Martinez Pastur, J.M. Cellini, P.L. Peri, R.F. Vukasovic, M.C. Fernandez

I. Title of the Study

- As a researcher, the title provided by the authors has the element of simplicity, brevity, specificity and location and subject matter focused. The reader can easily determine what the study is all about and what it tries to investigate (Timber production and Shelterwood system) on what? *Nothofagus pumilio* forests, where? in Tierra del Fuego (Argentina) and what silvicultural system? Shelterwood system. Brief title but very informative.

- Just going through the title, one can easily understand that the concern of the research study is related to silviculture. The keywords used such as “Timber production and Shelterwood system” clearly indicate that the subject matter is in the field of silviculture.

II. Rationale, Background and Objectives of the Study

2.1. Rationale of the Study:

- The authors looked into the timber production of *Nothofagus pumilio* forests in Tierra del Fuego in Argentina using the shelterwood system.

2.2. Background of the Study:

- According the authors, the *Nothofagus pumilio* forests (commonly named `Lenga`) are the main commercial woods in South Argentina and Chile.

- The following are some background information on the species, the site attributes and the system of harvesting the people in Tierra del Fuego adopts for the Lenga species: Lenga is a medium shade intolerant species that has patchy cycles of regeneration due to the natural mortality of trees which introduces an irregular heterogeneous structure that hinders planning of forest management.

- The shelterwood system best simulates the natural dynamic by opening the canopy to allow regeneration. This practice transforms the virgin forest into a regular managed one, resulting in higher size increments, better stand health and quality of wood, in improving the harvesting index and the subsequent sawmill efficiency (Schmidt and...
Urzua, 1982).

- The shelterwood system is silviculturally appropriate to manage these woods, resulting in an abundant natural regeneration successfully installed. This is possible, because Lenga forests are mainly grow in pure stands.

- There are 220,000 ha of timberland in Tierra del Fuego (Argentina).

- Stand values of volume vary between 300 and 1300 m$^3$/ha according to site quality, stocking, growth phase and previous land management.

- There is a site quality categorization for these forests (I-V) based on the potential productivity in South Patagonia. The majority of these commercial forests belong to site quality III and show a dominant height of 20.5-24.0 m at a maturing growth phase;

- The classification of Lenga growth phases was defined by Schmidt and Urzua (1982) in optimum, maturing and senescence, according to the stand age.

- The resource supply of wood has decreased in the last years, prevailing a non desirable silvicultural system (floreo) based on the selective cut of the better timber trees.

- A non-traditional harvest system based on the whole stem extraction and the obtaining of the logs in the piling zone allows to increase the harvesting index in a significant way (Cellini et al., 1998). On the other hand, this system decreases the harvesting costs and optimizes the work of the faller, the efficiency of the skidder and diminishes the loss of logs in the forest.

2.3. Objectives of the Study:

- The aim of this work, as cited by the authors, was to evaluate the existence and the productive potential in quantity and quality of wood for the sawmill industry in a shelterwood seed cut of *N. pumilio* commercial forests of Tierra del Fuego (Argentina) along the range of site classes. In these, work are taken on that the maximal harvesting efficiency is achieved by the application of a complete shelterwood cut and logging through the non-traditional system described before.

III. Materials and methods

3.1. Study area

- The study area is an old-growth *N. pumilio* pure forest located in San Justo ranch – Tierra del Fuego (Fig. 1 see appendix) along the site class range defined by Martinez Pastur et al. (1997), where 'Los Castores' sawmill carries out harvesting. The regeneration method uses the shelterwood cut system (Schmidt and Urzua, 1982) according to the regulation of Tierra del Fuego forest law number 145.

- The forest land use is exclusively for timber production, without cattle grazing, but with a significant pressure of *Lama guanicoe* ('guanaco') browsing on the saplings (Skrut et al., 1997). The trial was done in 3 ha, where plots of 40 m to 50 m were installed along the even classes of site (I-V) (three plots per site class). The original structure of the
forest was characterized by the average and dominant height (100 taller trees/ha), basal area, quadratic mean diameter (QMD), number of trees/ha and total over bark volume/ha.

3.2. Marking of the leave trees, tree-falling and volume measure

This is how the authors did their set-up, as follows:
- Trees to be left of the overstory were marked, 30 m²/ha of basal area, left with a maximum distance between trees of 12 m and uniformly distributed over the unit.
- The selected trees were dominant or co-dominant, with long, full, symmetrical crowns.
- They were judged to be the better seed producers, the most wind firm (low ratio of total height over QMD) and with a minimum saw timber volume.
- The falling of the trees was carried out with qualified personnel with chainsaw. The timber stems (a cut in the base bole and another in the diameter restriction of 20 cm) were extracted with skidders to the piling zone, where the timber logs for the sawmill were obtained (3-5 m long).
- The same were classified according to quality categorization by Cordone and Bava (1997) (quality A – long logs without defects; quality B – long logs with minor defects; quality C – logs with located defects or bad form; quality D – logs with generalized defects and bad form).
- The volumes of the trees, stems and logs were measured along all the trial. The Smalian formula was utilized for the log volume estimation, while the Newton formula was used for the stems.
- Total volume of the leave trees was estimated using standard equations proposed by Peri et al. (1997).

3.3. Statistical analysis

- An analysis of variance was carried out to analyze the yield and forest structure along the site quality range, by F-test. The separation of the means was done by Tukey test. The level of significance was $P < 0.05$.

IV. Results and Discussion

4.1. Characterization of the original forest structure

The forests sampled along the site quality range possess the following characteristics:
- Structure of an old-growth irregular forest with one or two strata, without regeneration patches (Table 1).
- The average density of the stands varied between 95% and 131% for the sites I-V according to the Reineke’s index proposed by Fernandez et al. (1997).
- These values indicate that the stands are stocked or overstocked (61-82 m²/ha of basal area). Along the studied site quality range, the individual trees of the stands are
mainly in maturing growth phase (120-250 years old) (35% at 73% of the trees) and/or in senescence growth phase (ages up to 250 years) (12% at 35% of the individuals).

- An important percentage of individuals in this last growth phase (40%) were left as leave trees after the shelterwood seed cut. This type of structure is the most representative of the old-growth productive forests of Tierra del Fuego, with over mature stands, overstocked and with a high percentage of timber trees.

- Compared with the original structure of the stands between the site classes by an analysis of variance: significant differences in number of trees, QMD, average height of the stand, dominant height of the stand and total volume were detected (Table 1).

- The basal area did not present significant differences between sites, representing the maximum values for the occupation grade of the species. This was cited in other studies of N. pumilio forest structure.

### Table 1. Analysis of variance of the structure along the site quality classes

<table>
<thead>
<tr>
<th>Site class</th>
<th>N (trees/ha)</th>
<th>QMD (cm)</th>
<th>BA (m$^2$/ha)</th>
<th>AH (m)</th>
<th>DH (m)</th>
<th>TOBV (m$^3$/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>382.5u</td>
<td>46.8c</td>
<td>76.6u</td>
<td>23.5c</td>
<td>27.5c</td>
<td>1098.7c</td>
</tr>
<tr>
<td>2</td>
<td>332.0u</td>
<td>44.9c</td>
<td>61.0u</td>
<td>22.1c</td>
<td>25.4d</td>
<td>815.0bc</td>
</tr>
<tr>
<td>3</td>
<td>246.6b</td>
<td>32.9ab</td>
<td>81.5u</td>
<td>17.1b</td>
<td>21.5c</td>
<td>897.9bc</td>
</tr>
<tr>
<td>4</td>
<td>433.3a</td>
<td>40.2bc</td>
<td>60.8u</td>
<td>14.9b</td>
<td>17.4b</td>
<td>536.4ab</td>
</tr>
<tr>
<td>5</td>
<td>1026.6c</td>
<td>25.6a</td>
<td>65.9u</td>
<td>10.4a</td>
<td>13.7a</td>
<td>397.6a</td>
</tr>
</tbody>
</table>

$N$ is the number of trees, QMD the quadratic mean diameter, BA the basal area, AH the average height of trees, DH the dominant height of trees, and TOBV the total over bark volume of trees. Values of F-test are $N(29.8)$; QMD(22.0); BA(2.5); AH(112.9); DH(376.4); TOBV(9.8). Different letters mean significant differences at $P < 0.05$.

### 4.2. Variation of the forest structure during the harvesting

The following are the result of what happened to the forest structure during harvesting:

- When the tree falling is carried out, 54-64% of the original basal area is taken out, cutting trees between 20 and 100 cm QMD, with an average range from 23 cm in a site V to 42 cm in a site I.

- On sites I-V, 256-800 trees/ha were cut, representing the removing of 78-82% of the individuals.

- In good sites (I and II) the 80% of the logged trees were in maturing growth phase, while in lower sites the percentage diminished gradually until 32%, increasing significantly the number of trees in senescence growth phase.

- The remaining canopy consisted of a cover of seed trees, uniformly distributed with 30 m$^2$/ha of basal area. In the logging of the Fuegian forests it is suggested to leave 40% of the original basal area, but this implicate a great variation in the remnant protection overstory, since it is related to the original structure.

- There are poorly-stocked forests (40 m$^2$/ha of basal area) that would remain too pen (16 m$^2$/ha) if 60% of the original basal area is cut, while the overstocked forests (90 m$^2$/ha of basal area) would remain too closed (36 m$^2$/basal area/ha). This fact took us to define an optimum basal area for the canopy protection (20-25 m$^2$ of basal area) plus 25% due to the high fallen of trees in the first posterior years to the logging of the
The remaining canopy was conformed by trees of good form, whose QMD varied gradually from 37 cm in the site V until 66 cm in the site I, being 20% of the original trees of the stand. Average inter tree distance varied between 7 and 12 m (225-70 trees/ha), for the sites V and I. The whole leave trees were in senescence or maturing growth phases, mainly of dominant class (80% of the individuals).

4.3. Volume characterization along different site qualities

- Total volumes showed a gradient along the sites and varied between 400 and 1100 m$^3$/ha (Table 1), for the studied density levels (60-80 m$^2$/ha of basal area).
- The volume density index (VDI) (ratio of total volume over basal area) varied significantly between sites (Fig. 2A), from 6 m$^3$/m$^2$ (site V) to more than 14 m$^3$/m$^2$ (site I). These differences justify the use of this basic parameter in the biometrics characterization done in a forest inventory. This ratio gives independent of stand degree stocking information, and that is the reason why it will be the comparative parameter to use.
- The harvested volume presents significant differences between site qualities (Table 2) when the logs were obtained according to the logging system proposed by Cellini et al. (1998).
- Yield indexes (ratio of log volume over total fell volume) show a range along the sites, from 30% (site V) to 75% (site I). The stem volume density index (SVDI) (ratio of stem volume over logged basal area) varied from 2 m$^3$/m$^2$ for a site V to 11m$^3$/m$^2$ on a site I. These indexes are directly related to the efficiency in falling and kidding tasks. For each square meter of basal area that the fallers cut in a site I, they will get five times the product than in a site V. Anyway, logs will be bigger in the best sites, diminishing the costs/m$^3$ of skidding with wire ropes.
- The timber volume obtained after the conversion of stems to logs represent 55% in a site V to 76% in a site I. These volumes (log under bark volume) varied significantly between sites, from 40 to 400 m$^3$/ha (Table 2).
- The log volume density index (LVDI) (ratio of log volume over logged basal area) varied between sites (Fig. 2B), from 1 m$^3$/m$^2$ (site V) to 8 m$^3$/m$^2$ (site I).
- The number of produced logs diminishes from the better sites towards the worst (near 800 in a site I to 200 in a site V), as well as their volume average (0.5 m$^3$/log in a site I to 0.2 m$^3$/log in a site V). The proportion of small logs (less than 30 cm of diameter) are not significant in a site I (31%) but it increases upon diminishing the site quality, arriving at 79% in a site V.
- The obtaining of big logs (bigger than 40 cm of diameter) has their maximum in a site I (29%) and subsequently diminish until 5% in a site V. The whole realization of the shelterwood cut contributes an important volume of small diameter logs.
- The volume of logs discriminated by qualities is largely influenced by the site (Table 2 and Fig. 3). The percentage of A quality volume decreases from 22% in a site I to 1% in a site V. The great percentage of logs is in B and C qualities, representing the D quality volumes 5-25% of the produced logs. Traditional sawmills aim to obtain big logs.
of A or B qualities by a selective cut system (floreo) and consequently, the realization of this practice is not economically possible in forests of quality IV or V.

![Diagram A](image1)

![Diagram B](image2)

**Fig. 2.** VDI (RATIO OF TOTAL VOLUME OVER BASAL AREA) (A) and LVDI (RATIO OF LOG VOLUME OVER LOGGED BASAL AREA) (B) along the site quality range.

**Table 2.** Analysis of variance of quantity and quality of timber volume along the site quality classes

<table>
<thead>
<tr>
<th>Site class</th>
<th>SOBV (m³/ha)</th>
<th>LUBV (m³/ha)</th>
<th>LQA (m³/ha)</th>
<th>LQB (m³/ha)</th>
<th>LQC (m³/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>530.0c</td>
<td>398.8c</td>
<td>89.5b</td>
<td>154.8c</td>
<td>135.2a</td>
</tr>
<tr>
<td>2</td>
<td>338.2bc</td>
<td>263.1bc</td>
<td>50.4ab</td>
<td>121.5bc</td>
<td>76.8a</td>
</tr>
<tr>
<td>3</td>
<td>330.7abc</td>
<td>237.7abc</td>
<td>28.7a</td>
<td>77.9abc</td>
<td>89.9a</td>
</tr>
<tr>
<td>4</td>
<td>215.5ab</td>
<td>145.9ab</td>
<td>11.1a</td>
<td>27.2ab</td>
<td>79.9a</td>
</tr>
<tr>
<td>5</td>
<td>73.3a</td>
<td>42.0a</td>
<td>0.6a</td>
<td>6.0a</td>
<td>24.5a</td>
</tr>
</tbody>
</table>

*SOBV is the stem over bark volume of cut trees, LUBV the log under bark volume obtained from the stems, LQA the volume of logs of quality A, LQB the volume of logs of quality B, LQC the volume of logs of quality C, and LQD the volume of logs of quality D. Values of Ftest are SOBV(9.0); LUBV(10.1); LQA(8.8); LQB(6.3); LQC(2.8); LQD(2.1). Different letters mean significant differences at P < 0.05.

- The adaptation of the forest industry to the products obtained in the shelterwood cut will permit a more efficient utilization of the resource, increasing the harvesting index and diminishing the costs of logging and production. The compartmentalization expressed as total volume percentage (remnant, log and residue volumes) along the
The application of the shelterwood system implicates the use of 60% of the total volume of the old-growth forest, leaving the other 40% as the canopy of protection. The volume of residue that remains thrown in the forest or in the piling zones (mainly compound for stumps, putrid wood, branches or bark) represents between 20% and 80% of the cut volume (from sites I to V).

The volume that arrives to the sawmill represents between 34% (site I) and 11% (site V) of the total volume of the forest (or between 60% and 20% of the logged volume).

Fig. 3. Percentage of quality logs (A-D) processed in the piling zone along the site quality range.

Fig. 4. Compartmentalization expressed as total volume percentage (remnant, log and
residue volumes) along the gradient of site classes in an N. pumilio shelterwood cut system in Tierra del Fuego.

4.4. Comparison of volumetric yield between site classes

- The forests studied in the literature belong to site classes II-IV, varying the total over bark volumes between 535 and 945 m³/ha and the VDI (ratio of total volume over basal area) between 9 and 13 m³/m².

- The forest structure of these stands is comparable to those described for similar site qualities (Tables 1 and 3). The volumes obtained in the shelterwood cut system vary according to several authors, between 33 and 266 m³/ha. These differences are mainly due to the harvesting techniques that were used, as well as for the forest management objectives or the characteristics of the studied stand.

- The harvesting index (ratio of log volume over total volume) achieved along the site quality range varied in a gradient from 11% (site V) until 36% (site I), while the authors obtained values between 20% and 35%. It implicates that they have carried out a complete shelterwood cut.

- Finally, the LVDI (ratio of log volume over basal area) varies between 3 and 6 m³/m², setting within the ranges detected in our research (Fig. 2A).

Table 3. Timber volume obtained along N. pumilio forest (Chile and Argentina) in a shelterwood cutting

<table>
<thead>
<tr>
<th>Place</th>
<th>Site class</th>
<th>TOBV (m³/ha)</th>
<th>TOBV/BA (m³/m²)</th>
<th>LUBV (m³/ha)</th>
<th>LUBV/CBA (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Justo</td>
<td>3</td>
<td>850.3</td>
<td>11.6</td>
<td>235.9</td>
<td>6.0</td>
</tr>
<tr>
<td>Roca</td>
<td>2</td>
<td>945.3</td>
<td>12.5</td>
<td>250.3</td>
<td>3.8</td>
</tr>
<tr>
<td>Monte Alto</td>
<td>4</td>
<td>776.2</td>
<td>9.9</td>
<td>166.7</td>
<td>3.5</td>
</tr>
<tr>
<td>Ayacucho</td>
<td>3</td>
<td>547.6</td>
<td>11.5</td>
<td>125.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Tolhuasi</td>
<td>3</td>
<td>586.9</td>
<td>10.0</td>
<td>170.7</td>
<td>5.9</td>
</tr>
<tr>
<td>M. Crisina</td>
<td>3</td>
<td>535.1</td>
<td>10.5</td>
<td>125.2</td>
<td>4.1</td>
</tr>
<tr>
<td>P. Osvald</td>
<td>3</td>
<td>750.2</td>
<td>10.4</td>
<td>260.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Tolhuasi</td>
<td>3</td>
<td>659.0</td>
<td>10.7</td>
<td>180.0</td>
<td>-</td>
</tr>
</tbody>
</table>

a TOBV is the total over bark volume, TOBV/AB the ratio between TOBV and the basal area, LUBV the log under bark volume, and LUBV/CBA the ratio between LUBV and the cut basal area.
b Tierra del Fuego (Argentina) in Cellini et al. (1998).
c Tierra del Fuego (Chile) in Garib (1996).
d XII region (Chile) in Gonzalez (1995).
e XI region (Chile) in Ferrando (1994).
f Tierra del Fuego (Argentina) in Daffunchio and Villena (1997).
g Tierra del Fuego (Argentina) in Bava and Hlopec (1995).

4.5. Final considerations

- When a shelterwood cut is carried out, a high stand volumetric yield was obtained and the virgin forest is transformed in a regular system with all the advantages that implicates it (Schmidt and Urzua, 1982). However, it is necessary to conduct additional research in the level of canopy protection to leave (as a fixed density
level and not as a percentage of the original basal area) according to the site quality and stand conditions (wind exposition, soil humidity, slope, etc.), that could influence the post-harvesting dynamics.

- To achieve the aims of the theoretical model of a shelterwood system, it is necessary to take into account:
  - the integral harvesting of the forest products,
  - the adaptation of the sawmill industry to the wood resource,
  - the sawn products diversification and
  - the increasing of the commercial products added value.

- However, when a complete shelterwood cut is done, a high percentage of small diameter logs are produced and it is necessary to find a market for this product. In Tierra del Fuego (Argentina) the great scale chip generation is not possible, because the exportation of this product is forbidden and there is no local chip consumer industry.

- The practicability of this process (without chips production) that maximize the harvesting volumes in all the site quality range is demonstrated through the activities that 'Los Castores' sawmill is carrying out.

- This company processes 20,000-25,000 m$^3$/year (100-160 ha/year), producing 4 million board feet/year (9000-10,000 m$^3$ of saw timber/year) (40% in planks, boards and struts for the local market; 60% for the production of strips and strip-boards for the exportation market). In the sawmill, the 1997-1998 yield was 41% (ratio of sawn wood over log volume).

- The stand classification according to their site quality during the forest inventory is very important for the correct planning of the forest harvesting (Mac Lean, 1980). The site index is highly correlated in quantity and quality with the stand volumes (total and timber yielding). Site class and the stand stocking will define the levels of extraction and will determine the harvesting economical limits for a certain industry (according to the size and quality of logs that should process). Considering new alternatives in the Lenga timber management allow to get higher harvesting indexes, increasing the benefits for the forest company and diminishing the annual wood areas necessary to supply the requirements of the sawmills in Tierra del Fuego.

V. Conclusion

Based on the study, the authors concluded as follows:

- Total stand volumes varied from 400 to 1100 m$^3$/ha
- Volume density index (ratio of total volume over basal area) varied from 6 to 14 m$^3$/m$^2$.
- The volume yield present differ significantly among site qualities with log volumes between 40 and 400 m$^3$/ha.
- The number of timber logs decreases from the better sites towards the worst (800-200 logs/ha), as well as their volume average (0.5-0.2 m$^3$/log).
• Considering new alternatives in the *N. pumilio* timber management allow managers to obtain higher harvesting indexes, increasing the benefits for the forest company and diminishing the annual wood areas necessary to supply the requirements of the sawmills in Tierra del Fuego.

VI. General Comments on the Paper

• Generally, this paper is quite interesting as it presented the direct link between the silvicultural system (especially about shelterwood system, using the uniform shelterwood system and the seed cutting).

• Using the shelterwood system in this paper was very appropriate, because it was silviculturally appropriate to manage these woods, resulting in an abundant natural regeneration successfully installed. It is possible, because Lenga forests are mainly grow in pure stands.

• The reader can easy to understand about the harvesting and the kind of wood that was produced out of the system adopted (shelterwood) over a range of site qualities, but in the method, the author not mention when the research was begin and finish (how long), it would be better if the author mention it to give information to the reader.

• This paper explain that site quality has a direct relationship when it comes to wood quality. This has been long theorized by silviculturists that the silviculture has a lot to do with wood quality, but the author not mention about influent thinning and space of the trees, whereas maybe also relationship to improve the quality of wood. I think there is still a need further research to explain how is the relationship between thinning and space to improve the quality of wood.

REFERENCES


Rahmawaty : A Critique on Timber Production of Nothofagus pumilio Forest by a Shelterwood…,2006

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