Residues production in Pinus commercial forests for energy production

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Lages (Santa Catarina State, Brazil) has one of the most important area of forest plantations in the south of Brazil (more than 250000ha), and wood industry directly contributes with 43% of regional PIB (GDP – gross domestic production), and indirectly with 60%. So, the great number of industries and forestry activity contribute to the increase of generated residues, exceeding 200 thousand/month only in mechanical transformation industry. Frequent energy crisis and the increase on fossil fuel utilization, which intensify greenhouse effect, have promoted the foment to the use of renewable resources. This way, the study of generated residue application for energy production is strategic as in industry as in forests. For this reason, the objective in this study was to quantify any components of the trees (branch, needles and crown) in cultivation areas of Pinus, with different ages and silvicultural activities (pruning, thinning and harvesting), looking for the utilization of forestry residues for energy production. As a result of that study, it is supposed to diffuse and apply more efficient ways for using residues for energy production, improving the regional development by the pioneering in clean energy production, generator source and application target. Obtained results showed the quantity of generated residues in planted areas (3 years-old), first pruning, was 30 tonnes per ha (13 t/ha of branch and 17 t/ha of needles). In 6-years-old planted areas, second pruning, the production was 31 ton/ha (17 t/ha of branch and 14 t/ha of needles). In 10-years-old planted areas, third pruning, the production was 114 ton/ha (66 t/ha of branch and 48 t/ha of needles). In 12-years-old ones, first thinning, forest produced 45 t/ha of forestry residues (27 t/ha of branch; 8 t/ha of crown and 10 t/ha of needles). For 14-years-old ones, forest produced 64 t/ha of forestry residues (38 t/ha of branch; 7 t/ha of crown and 19 t/ha of needles). For 16 years-old areas, second thinning, was produced 41 t/ha (27 t/ha of branch; 8 t/ha of needles and 5 t/ha of crown). In harvesting (24 years-old), forest produced 95 t/ha of residues, distributed in 63 t/ha of branch, 27 t/ha of needles and 4 t/ha of crown. The next step of that project will be to determine the limits of residue quantity to be taken of the forest for energy production without jeopardizing nutrient cycling and evaluating forestry residue storage systems in the production area, in order to maximize energetic profits.

Key words: forest biomass; fuel wood; needles; branch

Introduction

In 2001 were initiated researches related to the utilization of forest residue from forestry industries in Lages/SC for energy production. The first research, which quantified and qualified residues in an area of 120 km from Lages (Brand *et al*., 2001), subsidized the implantation of an energy co-generator company based in the exclusive use of forest biomass.

Between 2003 and 2004, the implantation of that thermal and electrical energy production company promoted the valorization of the residues, having as principal result the development of a residue market, which conducted the establishment of classification, handling and material transportation units, as well the creation of new industries in the region. Environmental, economical and social problems observed in

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the area by the lack of residue use were reduced through the consumption of the stocked residues in the patios of the industries (Brand *et al*., 2009).
In 2003, anticipating future problems on supplying, researches were initiated about stocking effect on energetic quality of the forest residues (logs, edges and veneer). Besides the increase of material quality, the project had as objective to develop a methodology of energetic analysis for the periodical evaluation of the residues that, since then, it has being used for habitual analysis of the residues. As well, this study has helped industries in order to improve handling of the stocked residues (Brand, 2007).
During the subsequent years, the implantation of a co-generator company and the increase of residue consumption by others industries have contributed for the demand and increase and prices as well. In that period, forestry industries had economical problems which promoted a decrease on production capacity, generating restrictions on the available residues content.
That panorama highlighted the need of the research actualization made in 2001 in order to verify the availability of residues for energy production. It was observed that, between 2003 and 2005, the main alteration in the area was de development of residues market, but in a disorganized way; in despite of the number of industries be the same, the production capacity increased, from 80.000 tons in 2001 to 176.000 tons/month in 2005. Although, all generated capacity was in market. Prices still had variation; from R$2,50 - R$19,38 each tons to R$15,00 – R$58,00 (Brand e Neves, 2005).
According to the methodology designed in 2001, since 2005 there was a necessity to develop researches on the use of residues generated during production operations in forests. The region has great forestry massifs, especially species of *Pinus* gener, in those great quantities of residues are generated like branches and slabs during pruning, thinning and harvesting, which, in they turn, have an important potential for energy production.
Thus, it is fundamental, for the continuity and improvement of the use of this renewable resource for clean energy production, researches which can valorize those residues, considering the limits of forestry material removing in order do not prejudice the nutrients cycle. It is important to remember that the disposal of that material in the market can contribute to improve the equilibrium between supply and demand of the residues, affecting prices positively. As well, it is needed to highlight that, when material is left on the forest, the emission of gases which promote global warming by the biodegradation process and increases the risk of fire and diseases dissemination.
Gases emission in the region will be near zero by the existence and growing of forest planting which has been verified in the last years, and the minimization of marsh gas emission by the elimination of forest residue stocks. Other important factors are social and economical impacts by the increase of employment in the assessment, treatment and transport of the material.
So, the study of that biomass application for energy generation is strategic. The objective in this research was to quantify any components of the trees (branch, needles and crown) in cultivation areas of *Pinus*, with different ages and silvicultural operations (pruning, thinning and harvesting), looking for the utilization of forest residues for energy production.

Materials and Method

The research was developed in *Pinus taeda* forests (Flobasa, Battistella Group), in Bocaina do Sul (10, 12, 14 and 24-years-old), Correia Pinto (3 and 6-years-old) and Bom Retiro (16-years-old). Five trees were brought to the ground in each forest in a parcel of 10x10 meters. From each tree was collected and weighted, separately, branches, needles and crown (part of the stem with diameter inferior to 8 centimeters, without branches or leaves).
Each tree was cubed, obtaining the total and merchantable height (minimum diameter 8 cm), and dbh.
Table 1 shows dendrometric and handling data of the evaluated forests.

Table 1 – Dendometric and handling data of the studied plantings in Santa Catarina, Brazil

Age	Planting area	Number of trees/ha	Removed trees	Silvicultural operation	Medium dbh	Total h	Medium merchantable h
3	Correia Pinto	2000	0	First pruning	10		
6	Correia Pinto	2000	0	Second pruning	16	8	
10	Bocaina do Sul	1600	0	Third pruning	20	13	9
12	Bocaina do Sul	1333	667	First thinning	22	17	11
14	Bocaina do Sul	700			21	16	11
16	Bom Retiro	800	400	Second thinning	26	21	17
24	Bocaina do Sul	550	550	Harvesting	33	27	24

Results were submitted to T test and Tukey's medium test, in order to verify the existence of variation among the analyzed ages.

Results and Discussion

Tables 2 and 3 show the results of biomass quantity generated by trees and by hectare, with different ages evaluated in this study.

Table 2 – Quantity of biomass generated by trees from different ages analyzed in forest plantings in Santa Catarina, Brazil.

Age	Weight: branches/tree (kg)	Weight: leaves/tree (kg)	Weight: crown/tree (kg)	Total/tree (kg)
3	7 c	8 de	0	15 c
6	9 c	7 ce	0	15 c
10	41 bc	30 b	0	71 bc
12	41 bc	15 cdb	12	68 bc
14	55 bc	27 db	9	91 b
16	68 bc	21 cdb	13	103 ba
24	115 a	50 a	7	173 a

Note: results following the same letter do not differ to 95% of probability by Tukey's test.

Comparatively, 10, 14, 16 and 24-years-old trees were ones that produced greater quantity of biomass per tree. Considering the pruning activity in ages 3, 6 and 10, the production of biomass during the third pruning was really significant (10 years-old). In thinning, the greater potential was in the second one. If it was considered only the removal of branches and crowns from the ground, ages 14, 16 and 24 had larger potential of biomass production.

On leaves production, ages 3 and 6 had low production; 10, 12, 14 and 16 had medium production and 24 had higher production. For branches, it was verified low production in ages 3 and 6; medium in 10, 12 and 14, and higher in 16 and 24, with medium production over 60 kg/tree. For total biomass, ages 3 and 6 had low production; medium for 10, 12 and 14; and 16 and 24 high biomass production.

Thus, for individual production of the trees, considering the need of the leaves permanence on the ground, a research has to be made, the best ages were 10, 14, 16 and 24. Considering that to get economical viability for exploring residues on the field is needed a minimum production of 30 tons per hectare, in production per area unit the ages that had optimal performance were 10, 14 and 24 (third pruning and harvesting)(Table 3), considering a minimum removal, that is, just the use of branches for energy production.

Table 3 – Quantity of biomass generated by area on different ages analyzed, according to the number of trees producing biomass, in forest plantings in Santa Catarina, Brazil.

Age	Number of trees/ha producing biomass	Silvicultural operation	Weight: branches/ha (t)	Weight: leaves/ha (t)	Weight: crown/ha (t)	Total/ha (t)
3	2000	First pruning	13	17	0	30
6	2000	Second pruning	17	14	0	31
10	1600	Third pruning	66	48	0	114
12	667	First thinning	27	10	8	45
14	700		38	19	7	64
16	400	Second thinning	27	8	5	41
24	550	Harvesting	63	27	4	95

In pruning activity, the third one was that produced a more significant quantity of biomass. First and second thinning had the same potential of biomass production and harvesting produced less biomass than the third pruning, due to the reduction of leaves and branches in relation to the content of wood for industries.

Evaluating the economical impact in a quantitative way, the inclusion of the use of biomass from forests can represent 25% to 30% of the total biomass consumption of the co-generation company (30000 ton/month), which nowadays basically uses residues from industries. That matter would represent in age 10 (third pruning) the exploration of 79 hectare/month if explored all biomass potential (branches and leaves), or 136 hectare if only branches are used. For the age 14, 200 hectare for exploring branches and crowns, and 141 hectare for exploring all biomass; and in harvesting (24 years-old) would be needed 95 hectare/month with total use of biomass or 134 hectare/month if only branches and crowns are used.

That balance alteration of the raw material used would limit an alteration on the residues market, because it would decrease the pressure on the industrial residues and introduce the multiple forestry use with 20% of gain on the improvement of biomass that nowadays remains on the forests without utilization. How that category of material will permit greater control on the biomass quality before entering in the company through the establishment of the ideal sieve analysis and more homogeneous mixtures for burning and reduction of water content (previous and controlled stocking and chipping), there will be an increase on the energetic profit of biomass tons/kW of generated electrical energy conversion until 10% with relation to the real values.

Additionally, the use of forestry biomass can result in the reduction of the forestry biomass consumption from distances superior to 150 km, much more expensive (until R$ 78,00/ ton) if compared to the cost of forestry biomass production (R$ 62,00/ ton). In this sense, the reduction of acquisition cost with the energetic gains detached above can result in an internal return tax of use of those residues in 19%, comparing with the biomass from larger distances.

Conclusion

- Commercial *Pinus* forests of Lages region, in Santa Catarina, have potential of biomass for energy production.
- Biomass exploration, in an economic way, can be made in forest plantings from 10 years-old.
- Biomass production per tree was better in ages 24, 16, 14 and 10, respectively.
- Biomass production per unit of area was better in third pruning (10 years-old), harvesting (24 years-old) and second thinning (14 years-old), respectively.
- If leaves were kept on the ground, the biomass production has larger potential in ages 24 (harvesting; 10 (third pruning) and 14 (second thinning).
- In harvesting, 95 to 134 hectare/month are needed for supplying the demand of 30% of the biomass consumption for electrical energy production in Lages region.
- In third pruning, 79 to 136 hectare/month are needed to supply the demand of 30% of the biomass consumption for electrical energy production in Lages region.

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