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THE PERCENTAGE UTILISATION OF FELLED MAHOGANY TREES IN THE CHIMANES FOREST, BENI, BOLIVIA+

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GULLISON, R.E., HARDNER, J.J. & SHAUER, A. 1997. The percentage utilisation of felled mahogany trees in the Chimanes Forest, Beni, Bolivia. The percentage utilisation of mahogany trees (*Swietenia macrophylla* King) felled by timber companies was measured in the Chimanes Forest, Beni, Bolivia. Timber companies only extract the main trunk. The volume of branch segments was measured in 22 mahogany crowns, for trees ranging in size from 0.68 to 1.72 m in diameter. Quantities of residual branch wood ranged from 0.85 m^3 for the smallest trees up to 16.3 m^3 for one of the largest trees. This wood formed from 9.5 - 50.8 % of the total tree volume (branch wood plus main trunk), the percentage increasing significantly with tree diameter. The median volume of individual branch segments ranged from 0.05 to 0.33 m^3, and also increased significantly with tree diameter. The average diameter of mahogany trees in the study site was 1.292 m. A tree this size yields 14.48 m^3 of wood in the main log, and has 8.44 m^3 of branch wood remaining in the crown (36.8 % of total tree volume). Exploitation of branch wood offers an important opportunity to increase the financial returns from logging without felling additional trees. The utilisation of branch wood may be a particularly appropriate activity for indigenous and community groups which could exploit this resource with small scale processing technology.

Key words: Residual - branch wood - *Swietenia macrophylla* - waste - extraction - sustainable - processing

GULLISON, R.E., HARDNER, J.J. & SHAUER, A. 1997. Peratus penggunaan pokok mahogani yang ditebang di Hutan Chimanes, Beni, Bolivia. Kajian peratus penggunaan pokok mahogani (*Swietenia macrophylla* King) yang ditebang oleh syarikat balak di Hutan Chimanes, Bani, Bolivia. Syarikat balak hanya memilih batang yang besar. Isipadu bahagian dahan 22 silara pokok mahogani yang saiz diameternya berjulat dari 0.68 hingga 1.72 m. Kuantiti sisa dahan kayu berjulat daripada 0.85 m^3 bagi pokok paling kecil sehinggalah kepada 16.3 m^3 bagi pokok yang paling besar. Kayu ini

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membentuk daripada 9.5 - 50.8% daripada jumlah isipadu pokok (dahan campur batang) di mana peratus bertambah dengan bertambahnya diameter. Isipadu median dahan secara individu berjulat dari 0.05 hingga 0.33 m^3, dan bertambah bergantung kepada diameter pokok. Diameter purata pokok mahogani di tapak kajian ialah 1.292 m. Pokok saiz ini menghasilkan 14.48 m^3 kayu bagi balak utama, dan 8.44 m^3 dahan terdapat pada silara iaitu 36.8% daripada isipadu kayu. Penggunaan dahan memberikan peluang untuk meningkatkan pulangan kewangan daripada pembalakan tanpa perlu menebang pokok lain. Penggunaan dahan mungkin merupakan aktiviti yang hanya sesuai untuk kumpulan masyarakat tertentu dan penduduk tempatan yang dapat mengeksploit sumber ini menggunakan teknologi pemprosesan secara kecil-kecilan.

Introduction

Sustainable forestry requires that timber supplies are utilised as efficiently as possible in order to maximise the financial returns from a given timber harvest (Noack 1995). Yet often considerable unnecessary wastage of wood occurs. The percentage utilisation of felled trees can be increased in a number of ways, including increasing the proportion of felled volume that is removed from the forest, and increasing the processing efficiency of the sawmill. Increasing utilisation rates is particularly important for certain highly-valued timber species such as broad-leaved mahogany (*Swietenia macrophylla* King). Mahogany has been overharvested throughout much of its range (Rodan *et al.* 1992). Increasing the utilisation of felled mahogany trees might help reduce logging pressure on remaining stands.

The purpose of this study is to document the percentage utilisation of felled mahogany trees by commercial logging companies in the Chimanes Forest, Bolivia. We focus on documenting the quantity of potentially exploitable branch wood that is left after removal of the main bole, and determine whether there are any relationships between tree size and utilisation efficiency that might help direct salvage activities. The paper concludes with some suggestions about how branch wood might best be exploited.

Materials and methods

Study site

This study took place in the Chimanes Forest, Bolivia, a 440 000-ha permanent timber production forest in the Bolivian lowlands. There are two main forest types in the Chimanes Forest that have significant quantities of mahogany. The first is non-flooded alluvial plains forest situated on high terraces and areas of low hills, with a standing volume of 150 - 180 m^3 ha^{-1} (all species, dbh > 40 cm) (Government of Bolivia 1993). The second forest type is temporarily flooded alluvial plains forest, situated on low terraces, which may be flooded during the rainy season, and has a standing volume of approximately 100 m^3 ha^{-1}. The fieldwork for this study was conducted in non-flooded alluvial forest. Tree species diversity varies from 66 to 92 species per hectare (Gullison *et al.* 1996). Precipitation is approximately two meters per year.

Logging operations

There are six logging companies operating in the Chimanes Forest. At the time of writing each had a concession tenure of 30 years. Harvesting is regulated through a minimum cutting diameter limit of 80 cm, and the requirement that 10 % of commercial sized trees should be left as seed trees. Mahogany has historically made up > 95 % of all harvested volume in the Chimanes Forest (Goitia 1990). Higher quality boards are sold on the international market, mainly to the United States, and lower grades are either burnt or sold domestically.

Each company owns a single sawmill, and some companies own road building and other equipment in addition (Rice & Howard 1995). Companies that do not own equipment hire small independent contractors that specialise in one or more phases of timber production. The procedure for log removal is as follows. All companies hire contractors to find and fell mahogany trees throughout the year. Trunks are skidded out by rubber-tired skidder or crawler tractor to landings during the dry season. There they are loaded onto trucks for transport to the sawmills, generally using rubber-tired, front-end loaders equipped with grapple forks. Each company owns and operates between two and four trucks for hauling logs to the mill. Hauling distances may exceed 80 km, but are more typically in the range of 20 - 30 km. Most sawmills are antiquated, and typically consist of a bandsaw headrig and one or two gang saws. Companies pay royalties on the volume of wood processed by the mill, which is back calculated from the volume of finished boards, assuming a processing efficiency of 60 %.

Residual wood measurements

The volume of branch segments was measured from mahogany crowns that remained after log extraction. The criteria for including a branch segment in our sample were the following: (i) the branch segment must be straight, (ii) the branch segment must have a length of at least one meter, and (iii) the branch segment must have a minimum diameter of 20 cm. These criteria are probably conservative, as portable sawmills can process pieces of smaller dimensions.

Twenty-two trees were systematically selected in order to represent a range of tree diameters, varying from 0.68 to 1.70 m. Note that the lower size limit of our sample is smaller than the legal cutting limit of 0.80 m. This is because illegal felling of smaller size classes is widespread in the Chimanes Forest (Gullison *et al.* 1996).

Regression analysis was used to determine how (i) the volume of extracted and residual wood, (ii) percentage utilisation, and (iii) median branch size, varied with the size of trees. In all cases, diameter of the felled tree is the independent variable in the regression analyses. It was necessary to use a logarithmic transformation on the residual and extracted wood measurements to correct for problems of heteroscedasticity (Zar 1984). Both linear and polynomial regressions were tried, and the one with the best fit is reported here.

As the 22 trees do not represent a random sample of the population of felled trees, it is not valid to use these data by themselves to calculate average percentage

utilisation of felled mahogany in the forest. However, Gullison *et al.* (1996) report that the average tree diameter in this forest type is 1.292 m. This measurement is used to calculate average per tree figures for residual volume, commercial volume, percentage utilisation, and median individual branch segment volume from the regression equations.

Results and discussion

Tree diameter explained much of the variation in the volume of extracted and residual wood (Figure 1). The remaining variation is likely due to the fact that height at first branching is independent of tree diameter (data not shown: $y = 15.8 - 2.04\ x$, $r^2 = 0.04$, $p = 0.40$), which introduces random variation into the relationships between residual and commercial volume with tree diameter. Quantities of residual branch wood are substantial, ranging from 0.85 m^3 to more than 16.3 m^3 per tree. In a few cases, the branch segments themselves exceeded the minimum cutting diameter limit of 80 cm.

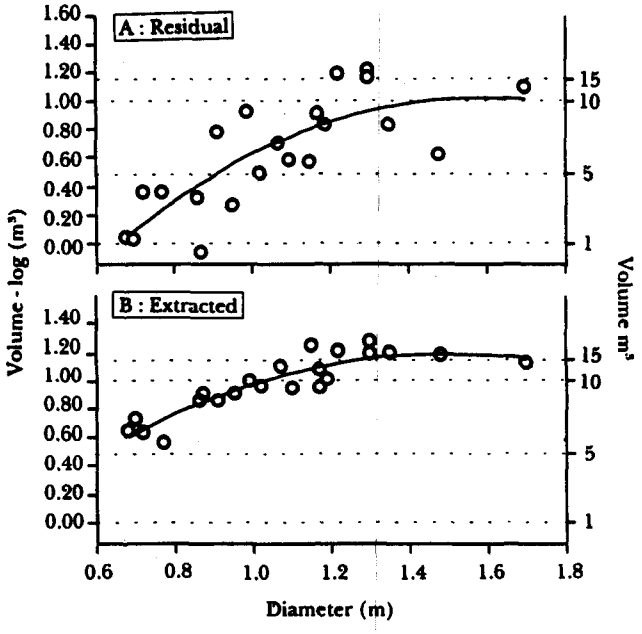

Figure 1. Residual and extracted volume (logarithmic transformation) as a function of tree diameter for 22 mahogany trees in the Chimanes Forest
A. Residual wood: $y = -1.992 + 3.82x - 1.21x^2$, $r^2 = 0.61$, $p = 0.0001$
B. Extracted wood: $y = -0.83 + 2.71x - 0.91x^2$, $r^2 = 0.84$, $p = 0.0007$

The percentage utilisation of mahogany trees ranged from 49.2 to 90.5%, and decreased significantly with increasing diameter (Figure 2). This is because as trees grow, the commercial height cannot increase, and so extracted volume only increases as a function of tree diameter. Total tree height continues to increase (Gullison *et al.* 1996), and so residual volume, which is a function of both diameter and total height, contributes more to total volume as trees get larger. The median volume of individual branch segments ranged from 0.05 to 0.33 m^3, and increased significantly with tree diameter (Figure 3).

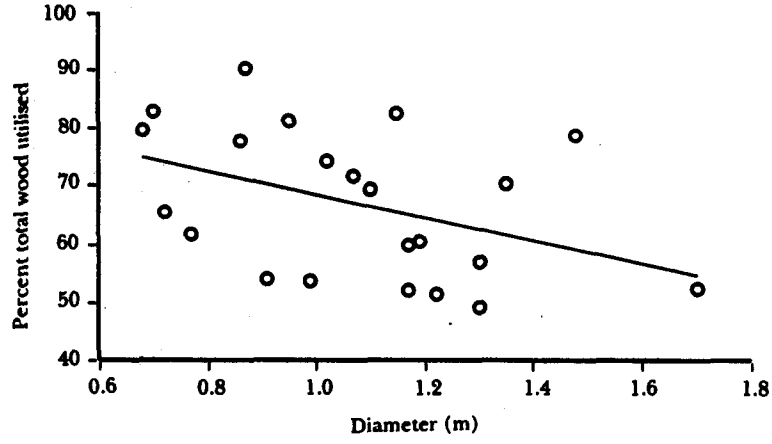

Figure 2. Percentage utilisation as a function of tree diameter for 22 mahogany trees in the Chimanes Forest ($y = 88.51 - 19.82x$, $r^2=0.17$, $p = 0.056$)

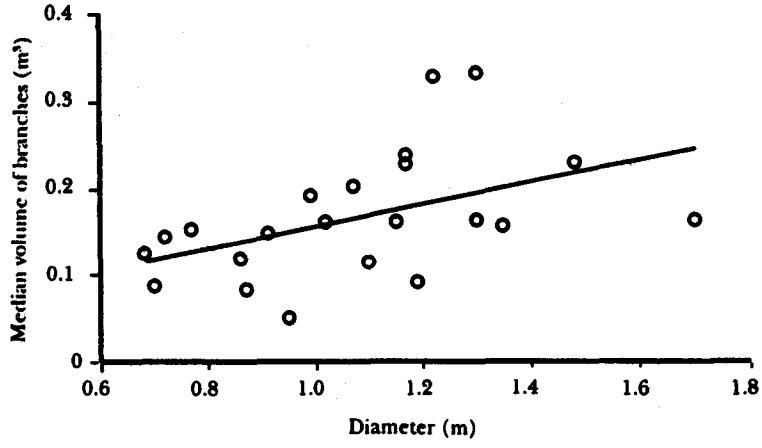

Figure 3. Median branch segment volume as a function of tree diameter for 22 mahogany trees in the Chimanes Forest ($y = 0.03 + 0.13x$, $r^2 = 0.22$, $p = 0.03$)

Gullison *et al.* (1996) report that the average diameter of mahogany in the non-flooded forest where these measurements were taken is 1.292 m. Based on the regression equations derived in this paper, the companies therefore extract on average 14.48 m^3 of wood per tree felled, leaving 8.44 m^3 of branch wood behind. The average size of individual branch segments is 0.20 m^3. Average percentage utilisation is 63.2 % of total tree volume. The latter figure is almost identical to that found by Noack (1995) in a recent survey of wood use in Africa and Southeast Asia. Excluding his measurement of stem offcuts, buttresses, and the stump (which together totalled 20.2 % of total tree volume), extracted logs on average made up 67 % of the combined log and branch volume.

The small size of the branch segments means their value will be less than that of longer sawn timber derived from the main logs. As of yet, the quality of timber produced from mahogany branch wood in Bolivian forests is unknown, but it appears to be suitable for at least the local markets. The fact that the processing of *Khaya* branch wood in Uganda was mandated in the 1960s (R. Plumptre, personal communication) also suggests that the branch wood of *Swietenia* is of sufficient quality for some markets.

Because the total volumes of branch wood and median branch segment size both increase with tree diameter, salvage operations should be directed first towards the crowns of the largest trees. The rot-resistant nature of mahogany wood means that it should be possible to retrieve branch wood from crowns that were felled some years ago. Indeed, Gullison *et al.* (1996) found that in a recent survey of 20-y-old mahogany tree-falls, many of the crowns were still intact. However, it is probably most efficient to harvest the branch wood at the same time as extracting the main log, as vehicle access will be easiest then. The possibility of combining salvage operations with replanting in the tree-fall gaps could also be considered (Gullison & Hubbell 1993).

It might be possible to encourage logging companies to extract the branches, though concessionaires have shown little interest in this activity (Gullison, personal observation). A potential means to encourage utilisation would be to tax standing volume of trees, including branch wood. The regression equations developed in this paper would easily allow the calculation of branch wood volume from a single diameter measurement of the main trunk. However, under the new forestry law in Bolivia, the current volume based tax will be replaced by an area-based tax (Anonymous 1996). It will be interesting to see whether this provides any incentive to increase percentage utilisation of felled trees.

Alternatively, it might be possible for local community or indigenous groups to exploit the branch wood. Since it can be processed with small portable sawmills such as Woodmisers, the capital requirements and technology may be more appropriate than the operation of large sawmills for these groups. Both the Chimanes Indians and the Small Business Council of San Borja have expressed a strong interest in processing residual mahogany wood in the Chimanes Forest (Gullison, personal observation). Exploitation of branches would offer a significant opportunity for local stakeholders to share the financial benefits from mahogany logging, without felling of additional trees.

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