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Original article

Characterization of elements of the wood exploitation of *Pinus maestrensis Bisse* in "El Franco", Guisa

Caracterización de elementos del aprovechamiento maderero de *Pinus maestrensis* Bisse en "El Franco", Guisa

Caraterização de elementos do aproveitamento madeireiro de Pinus maestrensis Bisse em "El Franco", Guisa

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ABSTRACT

The study was carried out in the area of "El Franco", Guisa municipality, Granma province, Cuba. The objective of the research was to characterize elements of the operations in the forest exploitation of the species *Pinus maestrensis Bisse*. Information from the database of the forest management project of the Empresa Agroforestal Granma, a Digital Terrain Model and an Integrated Geographic Information System for Forest Management were used to calculate the density of the road network. Through field observation, the organizational collection system was classified and extraction, collection and loading activities were described. The result was that the area has a road network composed of 23,3 km of 1st, 2nd and 3rd category roads distributed in 35,7 %, 17,9 % and 46,4 % respectively with a total density of 41 m/ha^{-1} and trails that do not fully comply with the geometric characteristics established for forest roads. The logging areas have a ring pattern, with the abandonment of commercial-sized logs and the use of wood handling techniques that cause health and safety problems, showing an insufficiently planned harvesting system.

Keywords: Timber extraction; Gathering; Harvesting.

RESUMEN

El trabajo se desarrolló en la zona de "El Franco", municipio Guisa, provincia Granma, Cuba. El objetivo de la investigación consistió en caracterizar elementos de las operaciones en el aprovechamiento forestal de la especie *Pinus maestrensis* Bisse. Se utilizó información de la base de datos del proyecto de ordenación forestal de la

Empresa Agroforestal Granma, un Modelo Digital del Terreno y un Sistema de Información Geográfico Integrado de Gestión Forestal a partir del cual se calculó la densidad de la red caminera. Mediante observación de campo se clasificó el sistema organizativo de acopio y se describieron las actividades de extracción, acopio y carga. Como resultado se obtuvo que el área presenta una red vial compuesta por 23,3 km de caminos de 1ra, 2da y 3ra categoría distribuidos en un 35,7 %; 17,9 % y 46,4 % respectivamente con una densidad total de 41 m/ha^{-1} y vías de arrastre que no se ajustan en su totalidad a las características geométricas establecidas para los caminos forestales. Los acopiaderos presentan un esquema en anillos, con abandono de trozas de dimensiones comerciales y uso de técnicas de manipulación de la madera que ocasionan problemas de salud y seguridad evidenciando un sistema de aprovechamiento insuficientemente planificado.

Palabras clave: Extracción maderera; Acopio; Aprovechamiento forestal.

RESUMO

O Trabalho desenvolveu se na zona de “El Franco”, município de Guisa, província de Granma, Cuba. O objectivo da investigação foi caracterizar elementos das operações no aproveitamento florestal da espécie *Pinus maestrensis Bisse.* Empregara se informação da base de dados do projeto de gestão florestal da empresa Agroflorestal Granma, um modelo digital do Terreno e um Sistema de Informação Geográfico Integrado de Gestão Florestal através do que calculou se a densidade da rede caminheira. Mediante a observação de campo classificou se o sistema organizativo de acópio e descreveram se as atividades de extração, recolha e carregamento. Como resultado se obtive que a área presenta o esquema em anelos, a área tem uma rede rodoviária composta por 23,3 km de estradas de 1ª, 2ª e 3ª categorias distribuídas em 35,7 %, 17,9 % e 46,4 % respectivamente com uma densidade total de 41 m/ha-1 e trilhos que não obedecem plenamente às características geométricas estabelecidas para as estradas florestais. As áreas de exploração florestal têm um padrão circular, com o abandono dos toros de dimensão comercial e a utilização de técnicas de manipulação da madeira que causam problemas de saúde e segurança, apresentando um sistema de abate insuficientemente planeado.

Palavras-chave: Extração de madeira; Constituição de reservas; Exploração florestal.

INTRODUCTION

In most regions of the world, forests and trees in agroforestry systems play an important role in the livelihoods of rural people by providing employment, energy, food and a wide range of ecosystem goods and services.

Activities linked to forest management, in general, produce a direct impact on the components of the environment, such as soil, water and biotic components. In order to prevent or minimize this impact, it is necessary to carry out forestry practices that lead to greater sustainability in forest management (Pimentel *et al*., 2013).

Forest managment is an essential component of achieving sustainable forest management and is one of the most controversial issues in achieving this goal. Therefore, its careful implementation is important not only to ensure the sustainability of forests but also for the continuity of forestry.

At present, Cuba's forest heritage covers 31,15 percent of the Earth's surface, showing a growth in forest cover this year compared to the 27,82 % reported in 2012, which shows sustained progress (Dirección Nacional Forestal, 2017).

However, authors such as Cándano, (2004) refer to a low efficiency of forest harvesting due mostly to the little attention given to the more expensive activities of this process: The extraction and transportation of the wood makes up about 70 % of the total costs of harvesting. Although several years have passed since this statement was made, the technological panorama of forest harvesting in the eastern region of Cuba has changed very little, and the technical equipment for carrying out this activity in some provinces has been halted in time.

In the province of Granma, the Agroforestry Enterprise of the same name, is the leading entity in the activities of forest management, it has a heritage distributed in 13 municipalities, ranging from the environments present in the valley of the Rio Cauto to those located in the Sierra Maestra, described by Notario and Rodriguez (2007) as the largest mountain range in the country.

This study was carried out with the aim of characterizing some elements in the execution of timber exploitation operations of the species *Pinus maestrensis Bisse* by the Unidad Empresarial de Base Silvícola (UEBS) Guisa developed in fragile mountain ecosystems.

MATERIALS AND METHODS

The study was conducted during February to April 2017 in the area known as "El Franco" which specifically includes stands 21 and 28 of the management area "Los Números".

Mogena *et al.,* (2007) reports that the predominant soil is lixiviated red ferrallitic and the average height above sea level ranges from 839 to 1345 m, according to data from the Meteorological Center of Granma province (2016), the average annual rainfall is 1815.75 mm.

Administratively, the management area (Figure 1) belongs to the Guisa (UEBS) Unidad Empresarial de Base Silvícola of the Granma Agroforestry Enterprise and covers an area of 83.9 km^2. The study covered an area of 5.7 km^2 (566.80 ha) which represented 6.8 % of the total area of the management area (Figueredo, 2018).

Figure. 1 - Location of the study area

Characterization of the trail network used for extraction and transport

For this activity, previous information from UEBS Guisa was used, a database from the 2008 forest management project of the Agroforestry Enterprise Granma that also integrates layers of roads, relief, rivers and a Digital Terrain Model (DTM) provided by (GEOSÍ) Cartography and Geomatic Solutions Company, GPS Garmin model, tape measure, as well as a satellite image of the year 2016 (path/row: 12/46) and the (GIS) Integrated Geographic Information System for Forest Management (SIFOMAP 4.0).

The layer of roads was used to determine the length and distribution of the first and second category roads that access the area, corroborated with the satellite image, and a representative map of the location of the roads with respect to the drainage network of the area was produced from the DTM and the use of the GIS. The tool "Drainage network" in the bar of the SIFOMAP, allows to show the different directions that can take the water currents that flow from the highest zones towards the low ones.

In the case of the third category roads (skied trails) there were different conditions to the primary and secondary roads that made it difficult to visualize and calculate their length and distribution with the GIS such as: they are not represented in the road layer, in some cases they are completely covered by the forest canopy which makes it difficult to observe them in the satellite image. In order to know their real length and distribution, coordinates were taken with the GPS every 60 m, georeferencing the measurement points and then using the GIS to represent them on a map and calculate their average distance.

With the data obtained from the average distance of the different road categories, the density of the trail network present was calculated using the formula cited by CATIE, 2006 (Formula 1).

$$Densidad\ (m/ha) = \frac{longitud\ \ total\ \ de\ \ (m)}{superficie\ \ total\ \ (ha)} \quad \text{Fórmula (1)}$$

The percentage distribution of the roads and aspects of their geometric design were analyzed according to their category. For this, point measurements of the width and height of the cutting slope in sections of these roads were randomly made for comparison with the permissible ranges described by Notario and Rodríguez (2007).

Characterization of the extraction and collection of timber

The criteria of Cándano (1998) were used to analyse the trailing distance used, and measurements were made of the impact on the soil on the trailing tracks on plots of 500 m^2. The collection points were geo-referenced and their surfaces calculated by means of length and width measurements, taking into account their dimensions up to the point where the environment is affected by the movement of people, trucks or draught animals, as well as the average distance between one collection point and another. The organizational system of collection was classified according to the schemes described by García *et al*., (2016) where their disposition with respect to the skied trails is contemplated. From the DTM and the GIS, a map of its location with respect to the present slope in the area was elaborated, the application to which can be accessed through the button "Slope", that is in the tool bar of SIFOMAP which allows to show the variations of the slope of the land according to the ranges of selected values, a range of 10 %.

RESULTS AND DISCUSSION

General characteristics of the trail network

The main road that allows accessibility to the area of "El Franco", is part of the network of rural roads that connects the settlement Guisa and the intricate town known as "Colon" through the management area Numbers and covers 26, 8 km from the urban perimeter to the study area (Manchón, 2015).

The analysed section of this main road, extends approximately between the intersection that gives access to the town of "Chicolongo" and ends in the town of "Punta de Lanza" where it begins a secondary road that from the food store of this town extends to the community "La Escondida Abajo". In Table 1, the aspects of the trail network analysed are detailed (Table 1).

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Table 1. - Details of trail network, existing in the study area

Type	Length (km)	Width Middle of the crown (m)	% of the total number of trails	Surface (ha)	% Total Surface	Density (m/ha)
First Category	8,3	6,3	35,7	5,2	0,9	14,6
Second Category	4,2	6,0	17,9	2,5	0,4	7,4
Third Category	10,8	6,0	46,4	6,5	1,2	19,0

The total existence of roads in the area is 23,3 km for a total density of 41 m/ha^{-1}, these do not completely fit the percentage distribution ranges exposed by Notario and Rodríguez, (2007), these authors suggest a proportion of 10-25 %, 30-40 % and 40-50 % for first, second and third category roads respectively. The study showed that first category roads exceeded the maximum limit of the values with which they were compared by 10 %, while the proportion of second category roads was 12,1 % below the minimum limit.

As previously mentioned, the primary and secondary trails used for wood transport are part of the rural road network of the municipality, so the fundamental function for which they were conceived involved more a social objective than a production one in the forestry sector. The research, analyse only the section of these roads included in the study area and that their percentage distribution does not fit with those specifically established for timber exploitation is understandable.

In general, authors such as Gayoso and Alarcón, (1999) propose that the alterations caused by forest roads should not exceed 5 % of the total surface. The total area altered by this concept in the study area is 2.5 %, which is within the limits of this definition.

As can be seen in the diagrams represented in Cuban Standard 53-126, (1984), with regard to design, the width of the crown is one of the geometric characteristics of roads that, regardless of their category, determines practically the entire width of the strip where they are located, since it includes other aspects such as the size of the roadway and the paths. In relation to this parameter, the trails analysed in the second and third categories have wider widths than those established by Notario and Rodríguez (2007), since the width of the crown exceeds the range established by these authors for these categories by 1,5 m and 2 m, respectively, to the range established by these authors for these categories, they have an average width of 6 m (Figure 2) which is also over-dimensioned compared to the widths stipulated in the Norma Cubana 53-126, (1984).

Figure 2. - Measurement on a third category trail

Actually and according to Dominguez's criteria, (2003) the Norma Cubana 53-126, (1984) includes geometrical parameters that in general produce a high environmental impact and also presents diverse limitations because it does not offer any type of regulation as far as the design of the drainage works, the construction of factory works and sidings.

Specifically, for the third category roads the authors García and Vidal, (2016) establish that they should maintain values of 3,0 4,0 m wide, however, the measurements made showed a minimum value of 3,50 m and a maximum of 10,35 m which negatively influences the structure of the same bringing about an increase in unnecessary erosion within the logging areas.

Manchón, (2015) reports for this management area that, on these roads, the roadway is made of natural material with an average platform width of 5,0 meters accompanied by steep slopes ranging from 7 to 14 %. García and Vidal, (2016) suggest that this category should also be lined as this can be a constraint on the use of higher capacity trucks, for example, multi-axle trucks. Without improvement, the maximum load of the trucks, usually 3 axles, is about 15-18 tons, divided into 7-8 tons of machine and 9 tons of load, which is extremely low for this type of transport. This limitation of load to 9 tons is finally caused by the poor condition of the road network, where the lack of technical criteria in its construction prevails.

In addition, in some sections these roads have no transverse or longitudinal drainage and the platform is confined by oversized vegetation, which prevents the penetration of the sun's rays and therefore the drying of the same.

As for the layout of the main roads, regardless of whether they were built for logging, the migration from the mountains to the plains determined by living conditions has meant that trucks carrying the wood are practically the only vehicles that pass through them.

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Therefore, the disposition does not cease to be an important aspect to observe, since the surface occupied by roads brings with it levels of erosion due to the generation of sediments and the accumulation of the same in the courses of the streams, as well as an increase in the levels of fragility in the mountain ecosystems.

On the main roads, it was observed that the road that guarantees access to the area has a section built parallel to a watercourse, which is generated during the rains. This has contributed to its current state of deterioration, sometimes making it impossible to transport wood from the stockpiles to sawmill's yard. It is observed in the main roads that the area has a section constructed

The Figure 3 shows the layout of the trail network with respect to the natural drainage network generated from the digital model of the terrain. Some drainage routes are crossed by gullies and streams and are therefore prone to being affected by gullies and furrows during the rains, thus eroding the soil.

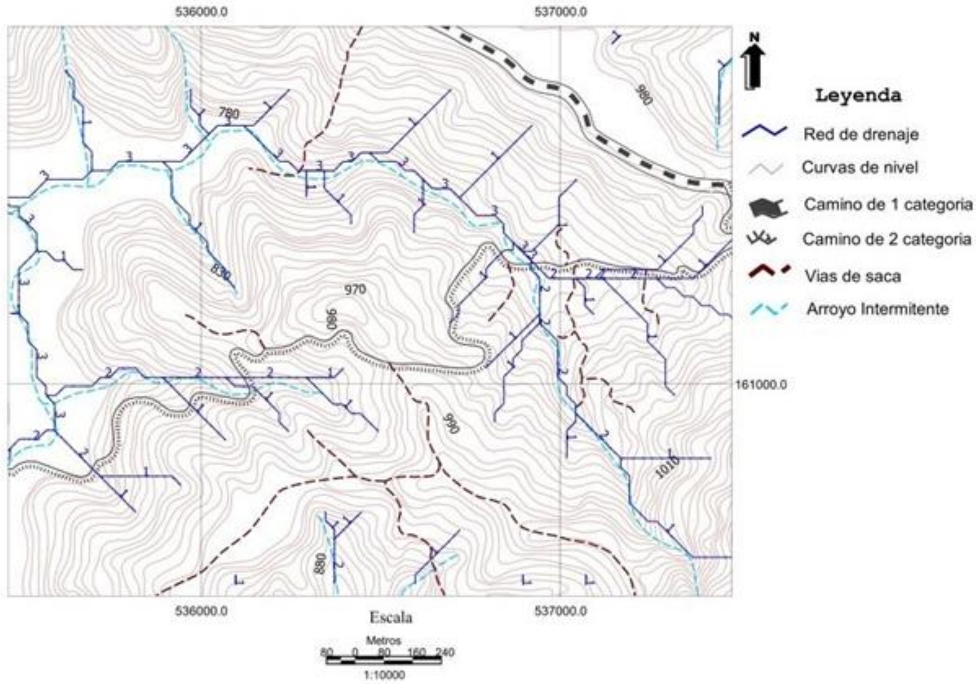

Figure 3. - Arrangement of the skied trail in relation to the drainage network

It was observed that the construction of speed bumps is practically absent in this area, despite the fact that the terrain has steep slopes, which shows little culture in the application of low-impact measures.

Considering the complexity of the terrain in which harvesting operations are carried out in mountainous areas, the specific distribution of the extraction routes plays a fundamental role in protecting against forest fires by acting as firebreak paths between the stands.

In general, the situation of forest roads in the area of study coincides with that proposed by Álvarez *et al.,* (2011) on the network of forest roads in the country, which states that forest roads are characterized by: little planning and investment in infrastructure; insufficient maintenance of the equipment used; very little reliability of the existing network, which does not allow access to high-capacity transport; non-

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use of improvements; minimum profile of the roads and insufficient construction of factories.

Characteristics of timber extraction

The extraction operations constitute a key link in the definition of the characteristics of the different exploitation systems used in the tropical belt, being generally the least controlled during the execution of the same.

In the study area these are carried out mainly by means of a DT 75 tractor with a 60 m cable as an attachment, using also animal traction (double-headed yoke of oxen) in the collection of the logs hired from farmers in the area.

Timber extraction always generates deterioration of the ecosystem. In the area of study, the effects caused to the soil by the dragging of the logs were manifested to a lesser degree by the use of draught animals and to a greater degree when combined with the use of tractors, since these rotated in different places, increasing the size of the affected area.

The lack of knowledge about the importance of soil conservation, the lack of training in reduced impact techniques, as well as the absence of a thorough inspection are parameters that act against the minimization of soil compaction and alteration caused by this work. Figure 4 shows how these alterations were manifested in the extraction routes, which were also influenced by the severity of the slopes.

A B C

Figure 4. - Effect of entrainment by extraction operations with DT 75

In a previous study, Figueredo, 2018, suggested that some of the activities that could be used to mitigate the effects of timber extraction on the soil might be the construction of channels across the slope of logging roads after harvesting to prevent water erosion and the use of logging remnants for placement on logging roads. In addition, trails should not be left in the direction of the slope, but should be inclined in relation to it to reduce the speed of the water, as well as to interrupt collection operations completely when the weather is exceptionally rainy.

When quantifying the effects on the soil, the results obtained show that an average of 280.3 m^2 for one hectare is affected in the evaluated sections of the trails (Figure 5).

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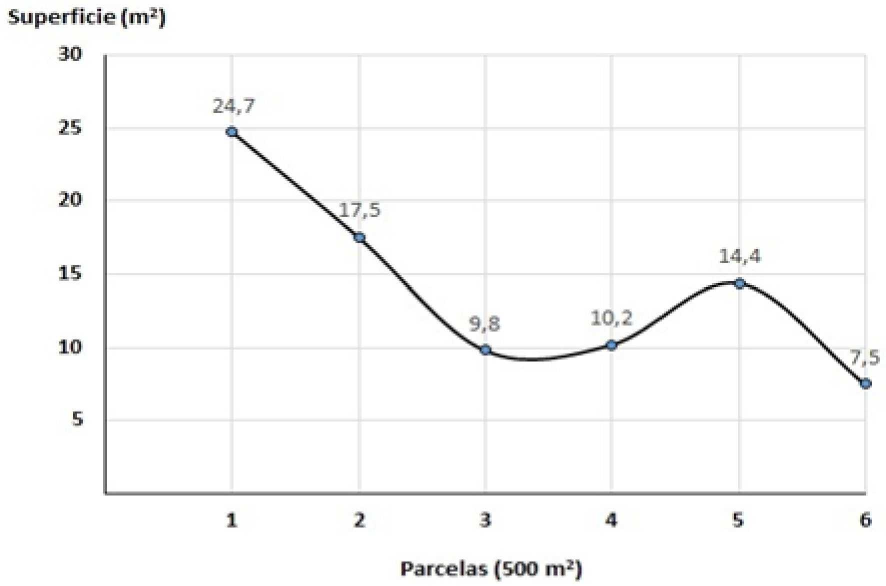

Figure 5. - Soil surface affected by wood dragging

Due to the friction between the soil and the logs, it was disturbed with a large amount of organic matter removed, coinciding with Rosabal, (2017) who, in studies of this forest ecosystem, found precisely that the alterations produced by the logs when they were moved caused the removal of organic matter and in some points layers of 5,2 cm were observed. And after the dragging, in several places, this came to be devoid of organic matter in its entirety.

Also, Cruz in 2016, refers to the fact that in 35 % of the area after the conclusion of the exploitation works the soil remained in these conditions, being at the same time these values similar to the studies of Toledo *et al.,* (2001) on logging operations in Bolivia's forests.

The loss of material, mainly in the first horizon as a consequence of the dragging collection system, is typical of animal and mechanized traction. However, considering a dragging track width of approximately 2 m, this value of 280,3 m^2 represents more than 100 m in length of these extraction tracks, a figure that is much higher than the 40-60 m\ha^{-1} established by García and Vidal (2016) for collection systems under intermediate technology.

Characteristics of stockpile and loading operations

Truck loading operations in the forest are carried out in the stockpile, where the logs are temporarily stored during the extraction process. The map represents the layout of the stockpile in the area (Figure 6).

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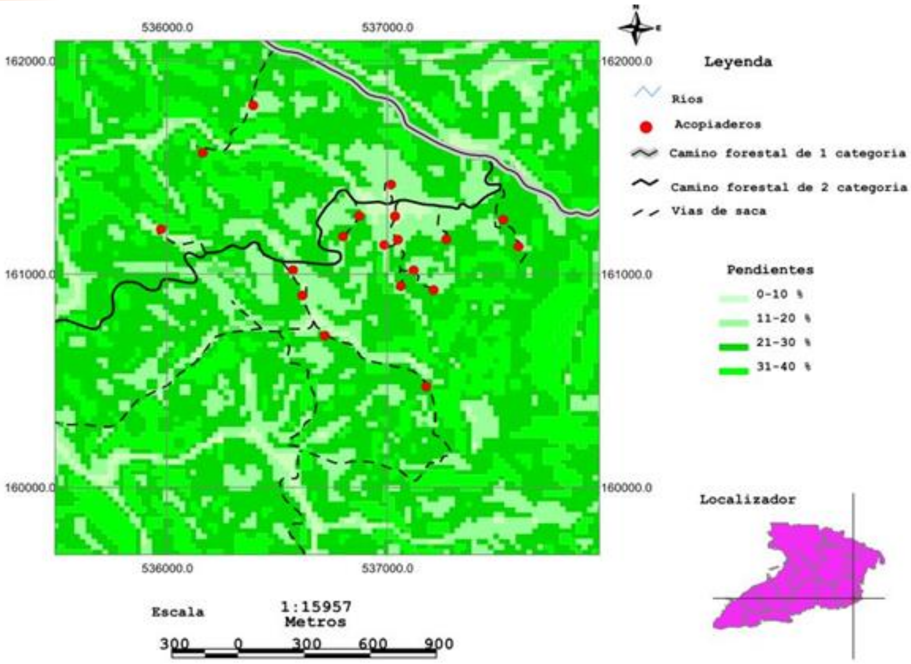

Figure 6. - Distribution of stockpiles in the area

The stockpile system used can be classified as a ring scheme (García *et al.,* 2016). In this activity, it was observed that the wood is collected at the edges of the logging roads, as the felling and extraction activity progresses, without a previous design of the location of the stockpiles. This causes a variability in its dimensions depending on the available volumes of wood. In the measurements carried out, surfaces disturbed by this concept were found in the order of 110 m^2 to 930 m^2 on an evaluated sample of 19 collection points for an average of 274.7 m^2, which is less than the range of 500 to 1000 m^2 suggested by García *et al.*, (2012b) and is conditioned by the volumes extracted, its location according to the slope corresponds to the topographical complexities of the land and most are located on slopes of less than 10 %.

The average distance between stockpiles was 236 m, Cándano *et al.,* (2002) report that the best timber extraction yields for any stockpile distance are obtained using the variant where the logs are pre stockpiled with animals over short distances and then extracted to the stockpiles at the edge of the transport road; thus avoiding loss of time in moving the animals and reducing the cycle time.

Cándano *et al*., (2002) also state that the combination of animals and tractors is the most economical technology for extraction distances greater than 150 m, which are the most used to avoid costs for the construction of roads and stockpiles. At present, this statement may be contradicted by the existence of machinery with greater manoeuvrability (for example, tractor-trailers on tyres) and better technical performance that allows more efficient use of fuel, but for objective reasons and for the conditions of the area of study it continues to be an efficient and applicable variant.

In the absence of the necessary equipment in the storage areas, the truck is loaded manually using techniques such as lifting with cams or rolling when the truck is located near a slope, which makes it easier for the bolus to roll by gravity and push it to the truck bed. This loading system is quite rudimentary and is designed for

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smaller logs than those of *Pinus maestrensis* extracted from these forests, which reach up to 60 cm in diameter at the base (Figure 7 B). As an alternative, a semi-mechanized prop loading system could be used as illustrated by Garcia *et al*., (2012), which would improve performance while being ergonomically more convenient. This system requires few resources for its implementation, is appropriate for moderately heavy or light logs and allows for the use of animal traction to lift the logs, which would facilitate the work and be objectively applicable since mechanised loaders are not available.

According to Pérez, (2016) physical strain causes various types of discomfort that affect the worker's performance and in the long term produce intense ailments and diseases of the musculoskeletal system, overloading affects the whole body, but especially the spine. Lifting a 70 kg logs (approximately 2,5 m long and 0,2 m in diameter) is equivalent to a compression on the discs of the spine of 1 070 kg, so this type of manual work should definitely be eliminated.

In a study for this area of management, the same author found that 50 % of the workers who work in the warehouses suffer from diseases such as: low back pain and tendonitis, which are associated with the physical effort done.

It was also observed that it is unusual to place two shafts transversely to the direction of re-piling of the trees, which would help the movement of the trees and work in favour of this activity in the absence of front loaders.

In these stockpiles there are still problems of organization and abandonment of logs of commercial dimensions, as shown in Figure 7 A (Figure 7).

Figure 7. - (A) Disruption and abandonment of commercially sized logs in the stockpiles and (B) KRAz transport with large manually loaded logs

The loss of wood due to the abandonment of these in the storage areas evidences problems in the technological discipline, these losses also manifest themselves in the areas of felling for different concepts and with irregular behaviour, for example, when evaluating the logs or sections of logs with a minimum length of 1 meter left in the Figueredo *et al*., (2015) found that the total volume of *Pinus maestrensis* timber residues with diameter above 14 cm in six 500 m^2 plots was 3,92 m^3 , which means an unutilized volume of 13,07 m^3/ha.

Cruz *et al.,* (2016) when analyzing the losses caused by the excessive height of the stump, refer to values around 4 m^3 in seven plots of 400 m^{2}, which means an unexploited volume of 14,28 m^3/ha. However, they did not find any volume of wood due to trees abandoned on the land, although they did observe some losses due to poor cutting of the tree.

In general, the volumes of losses referred to are higher than 10,54 m^3/ha, reported by Leckoundzou *et al.,* (2004) in an evaluation of the rainforest harvesting operations of the Empresa Forestal Integral Baracoa, where among the fundamental causes of wood losses, the inappropriate cutting height is also highlighted.

The operations of extraction and collection of coniferous wood in the mountain ecosystem analysed are characterised by the fact that they form part of an insufficiently planned system of exploitation with a lack of programmed layout of forest trails and skied that do not fully comply with the geometric characteristics established for this category of forest roads.

Timber handling techniques are inadequate and cause health and safety problems, disorganization in timber stacking in stockpiles, rational exploitation and the absence of post-harvest activities indicate ignorance and lack of implementation of activities inherent in reduced impact logging.

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