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CHOOSING FORESTRY EQUIPMENT*

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INTRODUCTION

Forestry exploitation covers the felling and logging of wood directly in the forests. Exploitation of these resources must take place so as not to disturb the forest environment balance. One speaks of forest exploitation whether it be for the final felling of trees having reached their maturity, thinning cuts, or when felling for improvement of plantation standards. These operations can be carried out in forests whose function is of a protective nature or in forests which supply social services. Forest exploitation is carried out either manually or mechanically. Till the advent of mechanization, men with a great spirit of adaptability were needed, as they had to live far from home or towns for many months, and they also had to possess considerable physical strength. Today, thanks to the help of machines, the sawyer-lumberjack's job has become less tiring, and because of the high wages paid, it has come to be considered an interesting job, even by the younger generations. Access to the forest is a very important factor for rational exploitation. Logging paths and roads must be accessible to heavy trucks and be connected with the country's road network, thus enabling easy transport of timber to industry, railway stations, sea and river ports. Another point to take into consideration is the need to have specialized labour for efficient use of the machines, and this requires the creation of special schools and professional training courses.

PHASES IN FOREST EXPLOITATION

By phase, we intend a particular operation which is carried out with the same equipment. Forest exploitation is subdivided into the following phases:

Felling of trees: This phase consists in detaching the trunk from the tree stump. It is still carried out, in certain countries, by using an ax and a two-man saw. In the majority of cases, it is carried out with an engine-powered saw (see fig. 1) or with accessories equipped with hydraulic shears, or with tractor-driven disc or chain saws (see fig. 2).

Fig. 1: Felling with an engine-powered saw.

Fig. 2: Tree felled with hydraulic shears.

Limbing and cutting of tree-tops: This phase consists in limbing and cutting tree-tops from the felled trunk. It can be carried out by using an ax or engine-powered saw, in which case the latter must be less heavy and cumbersome than the saw used for felling. In certain cases, this phase also includes bucking and/or stacking of branches, depending on whether these are to serve as fuelwood or pulpwood.

Bucking: This phase consists in cross-cutting the felled trunk into several parts. The length of these parts depends on market requirements and on the timber cutting system used, as well as on transport limitations. This phase can also be carried out at road sides.

Transport: This phase is split up into three sub-phases, namely loading, the actual transport and unloading, which is the last phase of the exploitation, unless transshipment occurs at a railway station, river or sea port.

Stacking: Takes place at the road sides or at clearings, and includes possible bucking operations.

Debarking: Is carried out with manual equipment, such as hatchets, or with machines such as the one shown in fig. 3.

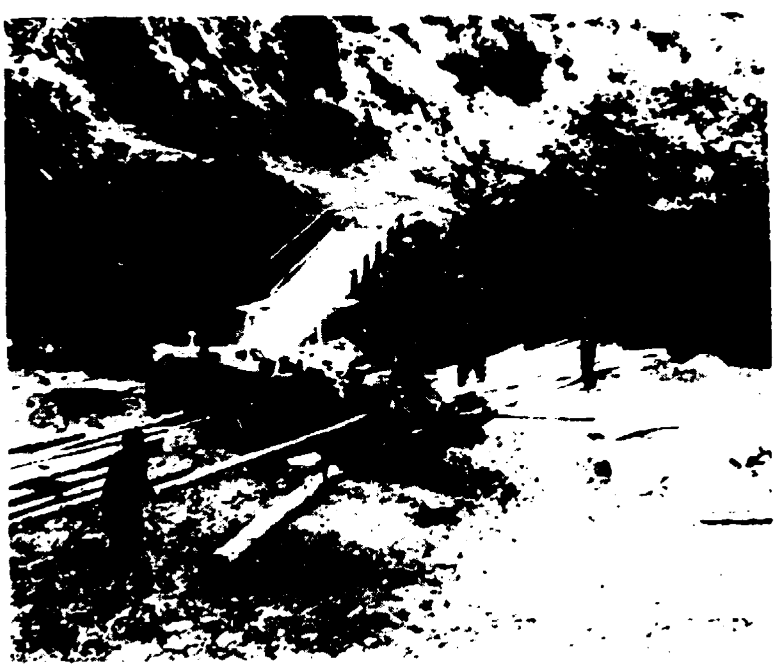

Fig. 3: Mobile ring debarker

Mechanical debarking is practically only carried out on softwood logs. Whereas the felling is al ays the first phase of exploitation, and must take place, the other phases of utilization sometimes do not all take place or else take place in a different sequence to the one listed above. Thus, in the case of small-sized trees felled during thinning cuts, and which will all be used for production of chips, the limbing and sectioning phases will be avoided, and will be replaced by the chipping process, that is to say, the reducing of the tree into chips.

TYPES OF EXPLOITATION

Work characteristics vary according to the type of forest exploitation and should be closely related to the type of forestry regeneration methods applied.

Selective felling implies the existance of a large concentration of wood on the area being exploited. This type of felling is characterized by the selection of a few trees, and, when these are big, one must operate in such a way as not to damage the surrounding trees, as well as the seedlings. This is not always possible, especially if the forests are serviced by few roads. In the case of thinning cuts, a small percentage of the growing stock is felled and the trees are often small in size. This creates great technical difficulties in exploitation, which are often solved to the detriment of the economic considerations of the operations.

The choice of a working system and exploitation costs are influenced by various parameters which must be kept in mind, especially by the person planning systems for moving the timber felled from the forest.

GROUND TOPOGRAPHY

The choice of logging method to be used depends, amongst other things, on the terrain's gradient or slope and its irregularities.

The terrain's gradient is a determining factor for the choice of the logging method. For terrain with a gradient of less than 20 to 25% all types of tractors hauling a load (including farm tractors) can be used, whether going uphill or downhill (see fig. 4).

Fig. 4: Two-drum winch applied onto a farm tractor.

This gradient (20 to 25 percent) is the minimum limit for working a cable-way system. Terrain with a 40% gradient can, as long as the ground is dry, be logged using four-wheel drive forest tractors (skidders), not hauling a load. Caterpillar-track tractors can be used on gradients of up to 50%, as long as they go along the lines of maximum gradient. Logging by tractors along these gradients can only take place downhill. This gradient is the minimum limit for collecting all the wood by gravity using hand-operated tools. Ground with a 40 to 60% gradient allows logging both uphill and downhill with cable-way systems (see fig. 5).

In this particular case, uphill logging is preferable, as lower lines are needed than in the case of downhill logging. Such facilities as saw horses can be lower or dispensed with as it is sufficient to lift the log heads clear of the ground. Up to these gradients it is easy to create proper

Fig. 5: Cable crane with semi-automatic carriage.

road conditions for logging and for material haulage without having to build any special supporting walls and bridges. On steeper ground with, say, a gradient of 60-80%, woods are generally of a protective nature and eventual utilization is made through cable-way systems, helicopters or balloons.

Irregularity: By this, we mean the presence of obstacles which hinder work on the ground. These obstacles can be stones, holes, rock ledges, etc. Irregular ground makes logging and road construction difficult: with the same gradient, a more expensive logging system may be required than that suitable for even ground.

Soil composition

Unlike farm soil, forest soil is very superficial and the rock stratum is covered with leaves which often hide traps for the forest operator, such as holes or cracks which are extremely dangerous for machines passing.

Clay rich soil: This type of soil has low water permeability, is very hard when dry and very slippery when wet. The high unit load for the material transportation must be exploited to the maximum when the soil is dry. With this soil it is essential to plan logging and transport during the dry season.

Damp or fresh soil: This is the type of soil one comes across most of the time. Above the mineral layer of soil, one finds a layer of leaves which encourages wheels to sink in. For this reason, it is advisable to use machines with wide caterpillar-tracks or to equip tractors with wheels, with special chains or special caterpillar-tracks, allowing a ground pressure of 100 g/cm^2.

Sandy soil: On this type of soil, machines with wide tyres and low pressure must be used. Caterpillar-tracks are very quickly worn down by the silica.

Rocky soil: This type of soil results from the heavy passage of vehicles or can be due to soil erosion. It is not advisable to use caterpillar-track tractors, in view of the low grip this type of soil offers. It would be a good thing to use low pressure tyres.

Capacity: This is the resistance limit above which soil becomes deformed when loaded with a given force. This resistance varies from a few grams to a few dozens of kg/cm^2. It can be measured with a special instrument which is inserted in the soil.

Machine rolling friction or feed resistance

Wide diameter tyres with high pressures meet with less feed resistance but also reduce soil grip.

This resistance value is: $R = K \times P$; where K = rolling friction coefficient; P = vehicle's weight.

K's value varies according to the type of route and to whether the machines are equipped with tyres, caterpillar-tracks or steel wheels.

Type of route	Low pressure tyres	Caterpillar-tracks	Steel wheels
Dry road	0.03-0.04	0.03-0.04	0.02
Dry, clay rich soil	0.05-0.08	0.05-0.06	0.06
Sandy, loose soil	0.08-0.15	0.06-0.10	0.09
Muddy soil	0.10-0.20	0.08-0.12	0.15

Sliding friction: This is the force needed to make an object or body slide along the soil. It depends on the type of soil and the shape of the object or body. In the case of logs, it is very important that the latter have their tops lifted clear, off the soil as this reduces the drag friction coefficient.

The friction value for trunks whose tops touch the soil and, therefore, meet with obstacles, can be higher than 1. When these tops are kept clear of the soil, the coefficient is equal to 0.2-0.3.

Maximum tractive force of a machine: Tractive force is given by: $F = K \times P$.

Adherence or grip coefficient is given by:

$$K = \frac{F}{P}$$

where F = maximum tractive force of the machine at the hook expressed in Kg, P = Total weight of the machine expressed in tons. This coefficient depends on the nature and humidity of the soil, but also on the use of either rubber-tyred or caterpillar-track machines.

Type of route	Tyres	Metallic wheels	Caterpillar tracks
Gravel, road dry or wet	0.7		1.2
Compacted dry path, clay-rich soil	0.5		0.9
Compacted wet path, compact soil	0.4		0.7
Loose, wet soil	0.2		0.5
Loose, dry soil	0.4		0.3
Frozen or snow-covered soil	0.1		0.1
Metallic wheels on sandy soil		0.4	
Metallic wheels on roads		0.5	

Climate:

Climate is a very important factor and must be taken into consideration when choosing equipment to be used and work systems to be adopted.

Thus, in northern countries, with a very long winter, it is important to plan the first phases of exploitation during summer, whereas the logging can be carried out in winter, by sliding logs along snow-covered paths (see fig. 6). In tropical countries, it is impossible to carry out this type of work during the monsoon season, therefore this phase will have to be planned for when the soil is dry.

Fig. 6: Logging on snowy paths. Logs are joined together by chains and the hooks are towed by a farm tractor.

There may be problems for the remaining trees due to wind. One must plan work with great care so as to avoid damages as far as possible.

Top layer of soil

Another point to be considered is the type of wood which has to be extracted that is to say, tree size (diameter and height). The exploitation system changes, depending on whether we are faced with:

1) a virgin forest, in which case, a rational road network must be studied;
2) a forest where exploitation has already taken place in compliance with a management plant in which case we should only fell marked trees and find excellent road conditions;

3) a forest which has been exploited without a management plan and where, generally speaking, one finds conditions which are somewhere between the above-mentioned two conditions.

ECONOMIC ASPECT

The economic aspect is extremely important for the preparation of a forestry exploitation plan. The price of standing trees will be more or less high, depending on whether the owner of the forest is an administrative body or a private person, and on economic conditions in the country. This price also depends on the ease of extraction and transport of the timber to the industry, sea ports or railway stations.

Should there be no roads in the forest, heavy capital investments will be needed for their construction, and this must be taken into account by the firm concerned.

Sometimes, this work is carried out directly by the State or other administrative bodies, as it is of interest to the whole community. To evaluate exploitation costs, the company must add all costs which it will have to sustain during the various work phases to the price of the standing trees.

Social welfare costs, costs for accident insurance, salaries, wages and possible overtime work, are also extremely important factors.

SOCIAL ASPECT

Type of labour, its qualification, and the possibility of using the same men on the job for many years, allow a higher degree of accuracy to be achieved and better machine maintenance. Unfortunately, it is not always possible to have regular labour, as for example, climate often does not permit continuous work; eg. rain in the tropics and prolonged winters in Northern countries. There are countries with high population density, where labour is cheap and even competitive with machines. In other countries, labour is badly paid and a lumberjack's job is very hard.

In this case, mechanization can contribute towards qualifying personnel, even if training courses may be necessary and even if years of experience may also be necessary to obtain good machine drivers and qualified maintenance personnel.

In many cases, it is more expedient to pay people according to the production they supply. When a team is well organized and highly professional, one has less than four minutes down-time per hour. This figures goes up to ten minutes with badly organized teams.

Insofar as work management is concerned, three to seven minutes per hour of work must be calculated for industrialized countries, and six to fourteen minutes for developing countries. Generally speaking, when a yard's efficiency is over 0.85, it can be considered excellent; it is acceptable, if between 0.85 and 0.60, and should efficiency be below these values, the yard has an inadequate organization.

It is important to bear in mind each country's usages and customs. How for example people are used to working in a particular country, as the introduction of a new system does not always give the anticipated results.

EQUIPMENT AND MACHINES USED IN FORESTS

Manual equipment

Axe: It is, without doubt, the most ancient cutting tool. It is used for limbing, debarking and wood cleaving.

Reaping-hook, sickly or bill-hook: This tool has different shapes, depending on the country or region where it is used. Among the best, (because of its beak) is the one made in Italy. Besides cutting, it can also be used for limbing, and for pruning standing trees.

Wedge and sledge hammer: The wedge is very useful, as it facilitates felling of trees during the cutting phase, and is also very useful for cleaving wood. The wedge is hit by the sledge hammer.

Of late, iron or wood wedges have been substituted by a pad which inflates by means of the exhaust gas from the engine-powered saw.

Debarkers: The debarker can be knife-shaped, with two handles on the sides, used by pulling, or shovel-shaped, used by pushing.

Small saws: These are mounted on an aluminium handle and allow the cutting of branches 4 to 6 meters from the soil.

Engine powered saws: Wood cutting takes place by means of a chain with sharp teeth. The chain, activated by a pinion, runs along the fissure of the guide bar. Engine power varies from 2 to over 5 kW, and the length of the guide bar can vary from 32 to 92 cm. These parameters vary according to the type of wood to be cut, to its diameter, and to whether felling and limbing operations have to be carried out.

To safeguard the health of the person operating the engine-powered saw it is advisable that engine-powered saws be equipped with vibration damping systems, a chain brake, a security accelerator, and, for better comfort, especially for those people working in northern countries, with heated handles.

Cutting and rigging machines: These are machines which can be used for softwood trees located on soil with a gradient not exceeding 20 to 25 percent. The cutting tool is made with hydraulic shears or with a sharp-toothed chain. They are equipped with a special part that directs the tree's fall. There are machines which also load trees, once felled, directly onto their rear train for logging (see fig. 7).

Fig. 7: Felling with hydraulic shears and loading of the tree, complete with foliage.

Other machines, besides felling, carry out limbing and bucking of the logs into pieces of the desired lengths. Finally, in Scandinavian countries and the United States of America, where mechanization is very advanced and planning rational, machines which carry out sorting besides limbing can be used. This sorting is for quality, diameter and length, and is carried out by means of electronic instruments.

Debarking machines: Debarking can be carried out in the forest or in the mill, depending on the type of machinery selected and the types of assortment obtained. Debarking in forests is carried out with mobile debarkers whose power is obtained from tractors, whereas in the mills, these debarkers work with electrical motors.

Ring debarkers are most commonly used, with knives fitted onto the rotor. The log is fed axially through the ring and the knives remove the bark by working spiral-wise.

These knives can reach a debarking speed of 40 meters per minute and strip bark off logs of up to 80 cm in diameter.

A second type of debarking machine is the cutter debarker. The log moves forward and rotates, so that the cutter can remove the bark. These machines sometimes also remove part of the wood. Debarking speed with these machines can reach 6 meters per minute; the diameter of the logs can be over 100 cm. Lately, the cutter head has been substituted with a multi-knived head, these knives being of a small size. These latter have the advantage of giving a cylindrical shape to the log, but they also partly remove the last growth rings (see fig. 8 below).

A last type of debarking machine is one with knives assembled radially on a disc. This is used for white debarking, as it is called, because it removes part of the wood. This type of machine is used for billets for paper mills and also, because of its limited size, for operating along forest roads.

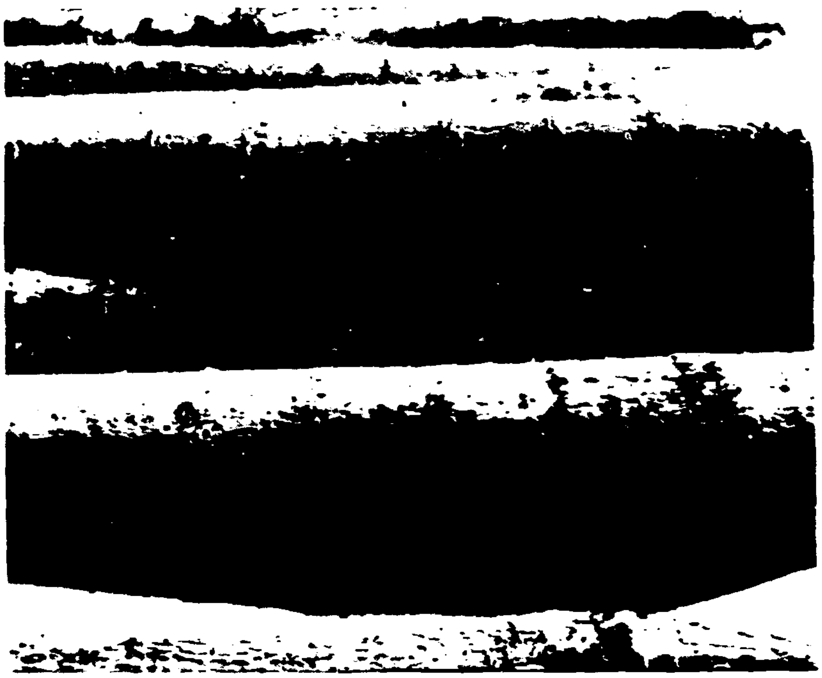

Fig. 8: Logs debarked with ring debarker: observe the removal of part of the last growth rings.

Chipping machines: These machines (see fig. 9 below) are either mobile or fixed, with either a disc or drum which chips the material introduced through a feed hatch.

The cutting plane is slanted with respect to the axis of the material introduced. By passing through a bottleneck, these chips are then blown into the trailer-truck tanks or into containers on the soil. With the chipping process, 20 to 25 percent of the crown's bio-mass is recuperated. These chips can be used in the production of particle boards.

Fig. 9: Chipping machine with direct loading of chips into the truck's tanks.

Combined machines: These are machines of considerable size, which carry out many exploitation phases.

The most important research efforts in the conception of the these machines have been towards limbing, which represents up to 30 percent of cutting and rigging work. An operation which also weighs heavily is debarking, it represents 50 to 70 percent of the total time; whereas felling only represents 5 to 10 percent.

From the above mentioned values, one can realize how much limbing a combined machine must take care of, as debarking is generally carried out in the mill.

Over the last few years cutting machines are seen more and more in Scandinavian and American forests; these also load the tree with all its branches onto their rear trains, and take these to log yards (see fig. 7 above). At this point, a limbing bucking machines completes the log preparation (see fig. 10). During this operation the trees are lifted by their stem by a hydraulic crane.

Fig. 10: Limbing and bucking machine

This stem is squeezed between two rollers which, by their rotating motion, allow the stem to slide along.

Four to six bow-shaped knives press the stem, and cut the branches they come across. A disc saw or a chain motor saw lowers itself at the operator's command, and completes bucking. If necessary, it also carries out sorting into various assortments. A very sophisticated type of combined machine, which should only be used on soil with a slope no higher than 20 to 25 percent, carries out all phases, from felling to limbing and sorting directly in the forest (see fig. 11).

Fig. 11: Sophisticated type of combined machine.

All these machines are operated by one single person and have given excellent results in coniferous forests.

Forest tractors

Tractors with self-steering wheels: These are machines which have all wheels with the same diameter and all are power-driven. Their turning circle is smaller than that of farm tractors.

Articulated tractors: The front and rear trains are held together by a hinged pivot. This allows these machines to have a very small turning circle, and, therefore, they prove to be very manageable in forests. They have four wheel drive, the wheels are of equal diameter, which allows a considerable stability and permits their use on slopes with a 30 to 35 percent gradient. These characteristics have contributed to the widespread use of this type of tractors.

Usually, these machines have a winch with one or two drums, or hydraulic grabs assembled on their rear train (see fig. 12 below).

Fig. 12: Articulated wheeled tractor with winch.

At the front, they are equipped with a bulldozer blade, which is also used to move stones, to level logging paths and is used for the preliminary stacking of logs.

Carrier tractors with semi-trailers: The rear train is formed by a platform provided with a crane with hydraulic grabs for loading and unloading logs (see fig. 13 below). These machines are very easy to handle and this is why they are widely used throughout the world for the transport of both logs and by-products to be used for energy purposes.

Fig. 13: Carrier tractor with semi-trailer

Crawler tractors: These are rigid machines which were, and still are, used for opening roads in virgin forests. They can also be used for logging. In this case, they are provided with a winch.

Crawler tractors with oscillating wheels: Unlike the previous tractors, the oscillating wheels allow these machines to overcome obstacles more gently. These machines can be found especially in the Soviet Union and in Canada.

Crawler tractors with semi-trailers: They couple the advantage of having a trailer with that offered by the crawler track. They are very useful machines on marshy or snow-covered land.

Accessories to apply on forest tractors

Winches: These are usually placed on the rear trailer and can be with one or two drums. With winches of this type, the tractor can be used as an engine power-station for a small cable aerial. It is useful to assemble a small winch onto the front part of the tractor, to help the machines get out of marshy land.

Inlet hatch for logging: This is formed by four rollers placed on the sides of a rectangle. The winch rope passes through the hatch. The hatch allows tops of trunks to be kept clear of the soil with the advantage of not spoiling the wood or damaging the roads. Less friction allows machine operation with less powerful engines and, therefore, saving on energy consumption. This logging hatch reduces engine effort by 25 to 40 percent.

Semi-trailers: These are constituted by a two-wheel axle. Trunk tops, as well as tops of whole trees, are placed along the axle-bar.

Trailers: These are used for loading logs. They can be with a single or double axle.

It is very important that an axle-bar be power-driven as, besides making it easier to overcome strong gradients uphill, this makes going downhill safer as the trailer, within certain limits, holds back the tractor.

Forest trailers are provided with a crane with hydraulic grabs for loading and unloading materials. When they are equipped with a double axle, on a pivot pin system, they allow the load to overcome obstacles gently.

Angle dozers: These blades are applied onto the front of tractors and are used to level soil which is to be re-forested or to open roads in virgin forests.

Harrow ploughs: These tools are used to till the soil for reforestation. They can be attached to farm tractors.

Stumpers: These are accessories shaped like shears, for cutting, with two over-riders to enable uprooting of the tree stump. They are applied onto big tractors and excavators.

This system is very widespread in Scandinavian countries. It allows increasing yield of the wood mass by 15 to 20 percent. This wood, after having been washed, is then chipped and mixed in a ratio of 10 to 15 percent with other wood material. It is used by the paper industry.

TIMBER LOADING AND MEANS OF TRANSPORTATION

Timber loading: Loading wood manually is disappearing in favour of loading with hydraulic cranes. We have already mentioned this earlier, when speaking of articulated carriers and forest trailers. Filling containers, directly in the forest, with chips and small logs for the paper-mills, has proved to be the best solution. The loading of these small logs can be carried out with conveyor belts which can also be used to feed chipping machines. Trailer tractors provided with big hydraulic grabs have proven very useful for the loading and unloading of trailer-trucks.

Land transport: For timber transportation, trucks with or without trailers, tractor semi-trailers, and trucks with semi-trailers are used (see fig. 14 below). When transport takes place on sandy roads, it is advisable that the vehicles have more than one rear axle, so that weight is more evenly distributed on the soil.

Fig. 14: Trucks and trailers used for transport

These vehicles must be equipped with low gears and extra brakes, should they have to go down steep gradients with a full load. Besides hydraulic cranes, they can be equipped with special devices, known as the multilift system, for loading containers (see fig. 15 hereunder).

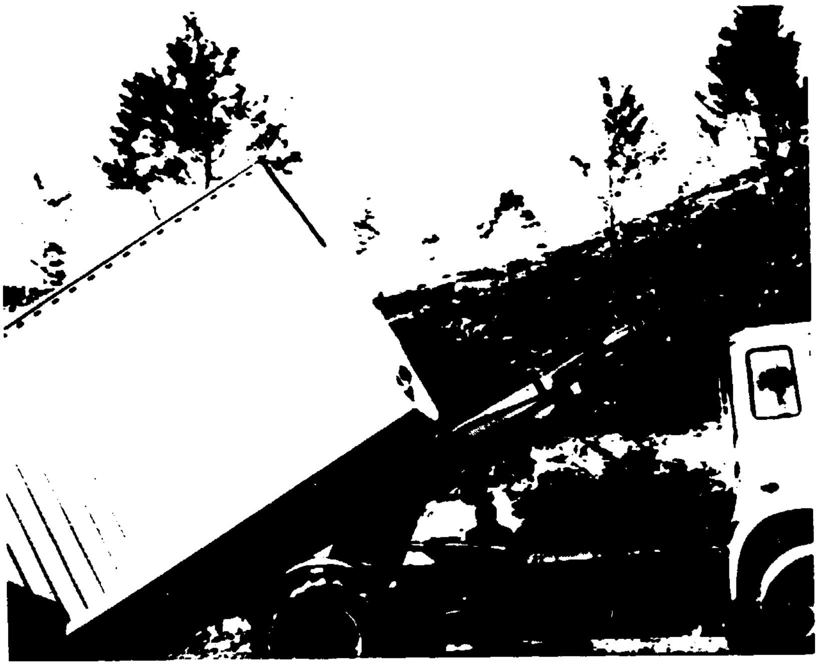

Fig. 15: Multilift system

Aerial transport: This transportation method can be carried out as follows:

- with a cable crane and/or cable-cars.

These can be:

- with one single mobile cable, a "lasso" or fixed cable, or cable with overhanging wire;
- with two cables, one carrying and one towing;
- with three cables, two carrying and one towing, forming a closed ring.

These cables, when three, can have one carrying, one towing and a recall cable, allowing the platform to also work horizontally (see fig. 16 below).

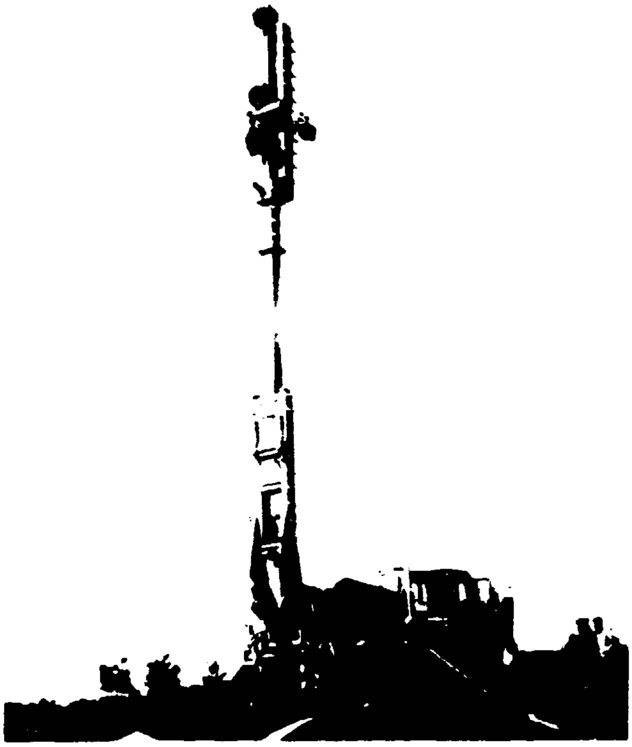

Fig. 16: Mobile extendable mast with three cables.

Helicopters: These are very useful when there are no access routes into the forest. Their carrying capacity varies according to altitude, on whether the material is seasoned or not, and on whether transportation is to be carried out going up or downhill, besides obviously depending on engine power.

Balloons and airships: The use of these means of timber transportation is currently at the experimental phase. They are particularly used in the United States.

Water transport: Floating of timber. This is the most ancient form of transportation in countries abounding in rivers or lakes (see fig. 17).

Fig. 17: Sorting of rafts.

Owners of the material (composed of single logs or logs bound together to form huge rafts, are singled out by means of a small plate, affixed to these single logs. When they reach the mill downstream, one can single them out, either manually or electronically, and also single out timber characteristics. Often, this material is stored on frozen lake surfaces and it is only when thawing sets in that the logs will start their journey. It is normal that a certain number of logs do not arrive at their destination, because they remain entangled or trapped along the way and cannot always be recovered.

Boat transport: Wood material, logs or chips, is transported by boats with larger or smaller capacities. These boats, usually made of steel, are equipped with all accessories for the loading and unloading of the material.

Railway transport: This form of transporation was particularly used till the middle of this century. In certain countries it is still the most commonly used form of transportation. With the construction of roads, open to heavy traffic, railway lines have been greatly reduced.

COST OF THE MACHINES

To calculate the cost of machines, one must take fixed an variable costs into account.

Fixed costs: These are costs which exist whether the machine is operating or not.

(a) Depreciation

It is very important to define depreciation costs, thereby allowing an owner to find the necessary capital for replacing the machine when it becomes unserviceable. The calculation is made by dividing the cost of the machine by the presumed number of working hours. This applies if one has not foreseen any proceeds from the sale of the second-hand machine. Otherwise these must be subtracted from the original cost of the machine. In practice, it is advisable to follow the first procedure. The number of hours varies according to the type of the machine and the work required from it. If the number of hours is limited, one may find that after a few years - even if the machine is still in working order - new, more efficient, and higher yield machines are available. In this situation, the machine therefore depreciates, and one has the phenomenon of obsolescence.

The depreciation period foreseen for the aforesaid situation, practically never corresponds to the technical endurance of the machine, which is always longer, as the machine can be profitably used for secondary types of work. For example, a forest tractor can be used to operate a debarking or chipping machine or can be used for shifting timber in logyards. Technical endurance is worked out by the number of hours a machine can work before wear and tear results in repair costs becoming very high. That is to say, that particular number of hours which allows reducing he amount between fixed costs per hour and repair costs per hours, to a minimum.

It can be more profitable to calculate depreciation costs separately, with regard to parts of the machine, as, for example, in the case of crawler-tracks, as they wear out rapidly.

(b) Interest on capital

This rate varies greatly according to whether the capital was supplied by banks or by local development boards.

(c) Insurance, remittances, etc.

Generally speaking, these rates have an incidence ranging from 0.5 to 1 percent on the machine's price.

Variable costs: These vary according to the number of the machine's working hours:

(a) Repairs

To make this calculation, the accessories the machine is equipped with must also be taken into account such as the winches, logging arches, blades, etc.

Repair costs:

Machine cost:
Technical endurance period (hours between repairs) x real daily working hours x K.

K = repair coefficient. This becomes higher with a machine that breaks down and has a high repair cost. This coefficient usually varies from 0.4 to 1.2.

Actual working hours — Machines are never under constant working pressure all day long. Tractors, for example, in the case of logging actually work 5-6 hours out of every 8; cable cars 4-5, and motor saws, 5-6.

It is obvious that, in the beginning of the technical endurance period, repair costs will be limited and that at the end of this period these repair costs will be equivalent to double the calculated value. This must be kept in mind when depreciation hours provided for do not correspond with those relative to technical endurance, but are lower, because of obsolescence.

(b) Fuel, lubricating oils, electricity

The calculation for fuel consumption is made on the basis of consumption diagrams supplied by the engine builders. Data obtained must be correct in relation to actual working hours. Precise consumption is in the region of 200 to 240 g/HPh (petrol), for gas engines; 160 to 210 g/HPh (fuel oil), for Diesel engines. One must also consider lubricating oils and other lubricants necessary for good machine operation. The costs can be evaluated at 10 to 20 percent of fuel cost.

(c) Parts subject to rapid wear

These include cables for winches; tyres; limbing; debarking and chipping knives, etc. These costs are calculated by dividing purchase cost by hours of use.

By adding fixed costs to variable costs, one obtains the hourly cost of the machine.

EXPLOITATION COSTS

From machine costs, as seen above, one can proceed to cost per cubic meter of material used. Various costs can be represented graphically thus permitting an evaluation of which system is more suitable theoretically; the construction of roads, or logging by helicopter; bucking the tree in the forest itself, or in log yards. All the various data can be inserted into a computer which will rapidly give the desired answers. Nevertheless, one must always consider the labour force which will be using the machine (availability, qualifications, cost, etc.).

CONCLUSIONS

The choice and purchase of a machine can be accomplished in a few days, whereas years of training are needed to obtain a good tractor or cable-car driver.

Evaluation errors are often at the basis of an exploitation project's failure. Men are not machines and traditions cannot be wiped out by turning a key. In spite of this, mechanization along with adequate training can solve many social and economic problems in developing countries.