Wood extraction with oxen and agricultural tractors

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Wood extraction with oxen and agricultural tractors

by
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PREFACE

The FAO Forestry Department has long recognized the importance of intermediate technology as a development tool. The use of animals and agricultural tractors with forestry accessories is an example, expanding the possibilities of both. Traditional agriculture and forestry complement each other.

The use of animals or small agricultural tractors with simple accessories for logging also constitutes a means of saving imported fuel. The logger can attain good levels of production at sufficiently low cost to enable him to meet the needs of both rural and other markets.

Two methods of logging which could be good alternatives for developing countries are described in this report, based on a study made in 1983 under the André Mayer Research Fellowship Programme.

Through this programme, FAO can continue to offer useful alternatives to conventional systems and, at the same time, provide the right training for young people in developing countries.

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Assistant Director-General

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SUMMARY

This study was undertaken mainly in order to demonstrate the use of oxen to skid logs in plantation and natural forests. Skidding with an agricultural tractor was also studied so that the output and costs of both methods might be compared. Research was conducted in regions of Chile where oxen have traditionally been used in forestry operations. It was found that forest enterprises with a high degree of technical abilities were using oxen to obtain their supplies of raw materials, reaching excellent levels of production with them. Their use led to savings in fossil fuel and generated employment. The equipment needed was simple and easily available.

The conclusions drawn were that oxen could be used with positive results in both plantation forests where there is clear felling or thinning, and in natural forests where there is selective extraction, whether on level ground or on steep slopes. When the costs of oxen were compared with those of agricultural tractors, it appeared that animals were more economic.

As well as a description of the methodology employed in the study, and the results, some general information is provided on oxen in forestry work, including morphological characteristics, the commonest diseases that can be diagnosed by the ox-driver, feeding, and the equipment and techniques used.

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INTRODUCTION

In the forestry enterprises of many countries today highly mechanized systems are used to extract wood. Machines have replaced two of the traditional sources of energy - human power and animal power - and their use has meant that the simple technology and skills of the past have been lost.

Machines are expensive and energy-consuming. The price of the fuel that they require rises continually and developing countries often have to pay for it in scarce foreign currency.

Draught animals, which have been used by man since ancient times, provide a solution to the need for power and the adverse effects of the energy crisis and the cost of fossil fuel. Far from being a sign of technological backwardness, their use in forestry can signify the intelligent exploitation of a resource which not only makes a useful contribution in energy saving, but also provides employment in a developing sector of the economy.

In this study of the use of oxen for skidding in Chilean forests in 1983, comparison is made with the use of an agricultural tractor.

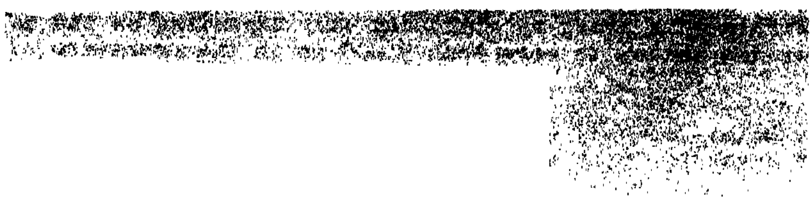
It is divided into four parts. The first outlines various general aspects of forestry in Chile, and describes the methodology used in the study and the conditions in which research was carried out. The second part deals with skidding with oxen, the animals' morphological characteristics, tractive power, feeding, hygiene and diseases; the equipment and techniques used, and lastly, the use of oxen in forests of Pinus radiata D Don (insignis pine, radiata pine) and in natural forests; with an analysis of times per work cycle, output and costs. Part 3 concerns skidding with an agricultural tractor in radiata pine forest, giving comparable analyses of times, output and costs. Conclusions and recommendations are presented in Part 4.

It is hoped that the study will prove useful in countries where possibilities of investment are low and unemployment is a socioeconomic problem. It should offer such countries some alternatives to skidding systems which are not profitable and help them to choose the best one in the light of their priorities, which are: economy, productivity, energy-saving and full employment.

The author, Edgar Otavo Rodrigues, is a forester working on the Project for Control and Review of Forest Utilization in Bajo Atrato-Uraba, under the National Institute for Renewable Natural Resources and the Environment (INDERENA) in the Republic of Colombia.

PART I

BACKGROUND



Ox-drawn cart in a sawmill (Los Sauces, Chile)

1.1 GENERAL ASPECTS OF FORESTRY IN CHILE

1.1.1 Geographical situation

The Republic of Chile is on the southwest coast of South America, between latitudes 17°30' and 90°S and longitudes 66°30' and 75°40'W. It is rugged and mountainous, with not more than 20 percent of flat land. The three characteristic morphological features are: mountain ranges of the Andes cordillera on the east, the coastal mountain range on the west, and lowlands between these two. The average width of the country is 177 km and its length from the northern limit to Cape Horn is around 4200 km.

1.1.2 General forestry-related features

The major forest area extends approximately from 33° to 34° S, as far as the island of Chiloé. Within this area, rainfall can vary depending on the topography, from less than 1 000 mm in the valley to more than 5 000 mm in the mountains of the south (Weber, 1957).

The cold Humboldt Current, running from the South Pole to the equator, influences all the major forest areas in Chile and prevents temperatures from rising.

Most of the forest plantations are in the central southern area of the country and cover approximately 877 186 ha. They are composed mainly of radiata pine, eucalyptus, tamarugo and other species (see Table 1).

Table 1

APPROXIMATE AREA OF FOREST PLANTATION

Species	Area (ha)	%
Radiata pine	786 136	89.6
Eucalyptus	40 800	4.6
Tamarugo	16 500	1.9
Oregon pine	8 900	1.0
Poplar	3 400	0.4
Algarrobo	3 150	0.4
Other species	18 300	2.1
TOTAL	877 186	100.0

Source: CONAF: INFOR (1983)

Chile's natural forest stretches from the central area (35°S) to the south over the slopes of the Andes and the coastal range, covering the central valley partially or totally. The area is estimated at 7 616 500 ha, with an approximate volume of 984 million m^3 (CONAF, 1983).

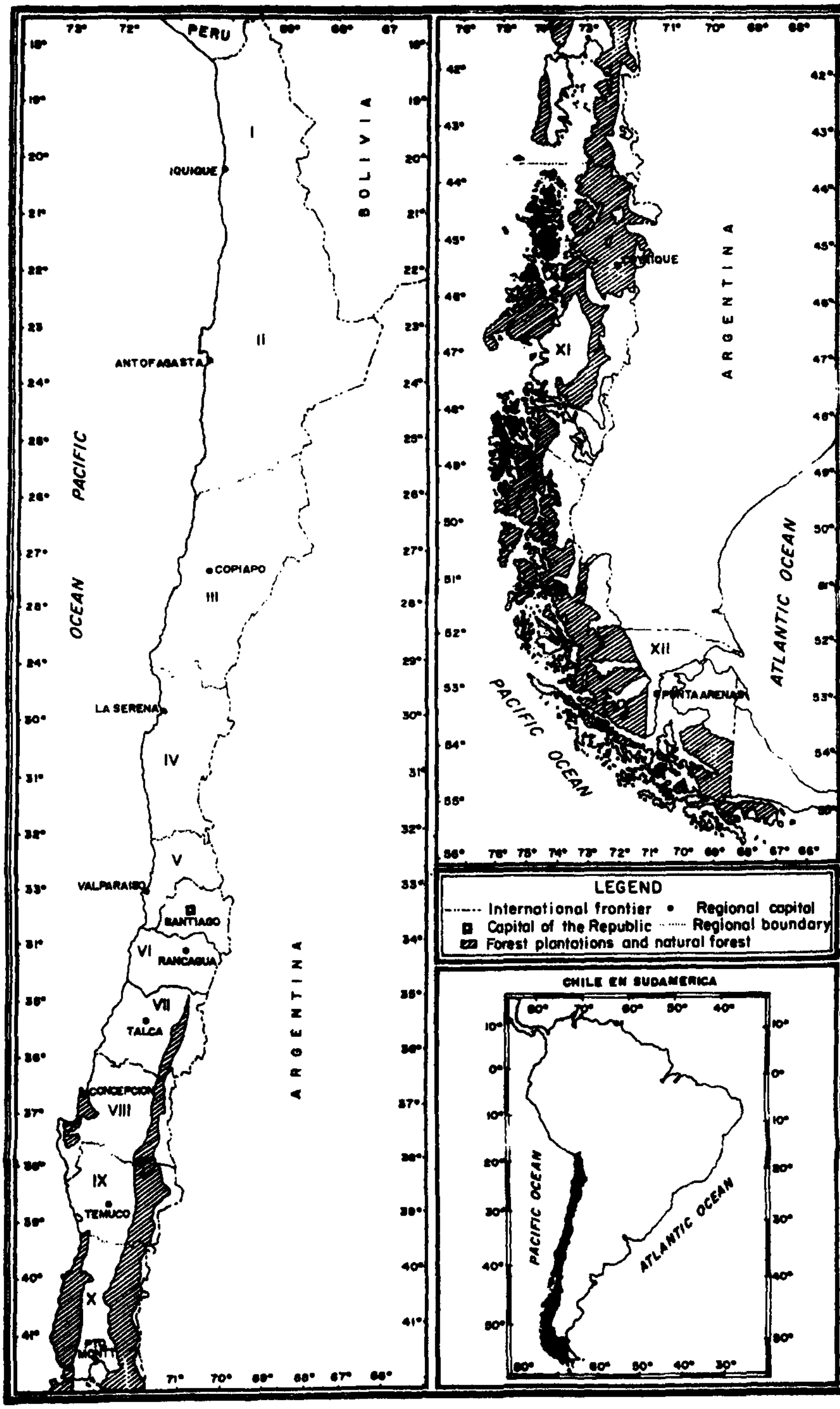


Figure 1. MAP OF THE REPUBLIC OF CHILE AND MAPS SHOWING ITS LOCATION IN SOUTH AMERICA AND ITS FORESTED AREAS

There are more than 60 tree and shrub species, mainly broad-leaved, of which some 20 are used for production of sawnwood, veneers, boards and other economically important products. The dominant species have been used by Donoso (1981) to classify 12 forest types, made up of mixed stands (see Appendix 1).

Evergreen is the most extensive and complex forest type because of its floristic variety and the economic value of some high-quality species, and because there are still relatively well conserved forest areas (Paredes, 1981).

The most marketed species are poplar, alerce, aromo, cypress, coigue, eucalyptus, laurel, lingue, luma, maño, olivillo, araucaria pine, Oregon pine, radiata pine, raulí, roble, tepa, tineo and ulmo.

The forestry sector plays a major role in the country's economy, being the second largest foreign currency earner. According to CONAF and INFOR (1983) the main export products in order of importance are: pulp (bleached, unbleached and semi-bleached); sawn wood (radiata pine and other species): logs (radiata pine and other species); newsprint; veneers and wood based panels (particle board, fibre board, plywood, block board); fine cardboard for punch cards, sulphite paper, kraft paper, cellophane paper, aluminium paper, other papers and cardboards;other minor export products (blinds and shutters, roofing shingles, radiata pine rosin, furniture, brush handles, matchwood, other processed wood products, radiata pine seeds, toys, posts and charcoal).

The species exported are, in order of importance: radiata pine, raulí, tepa, alerce,lenga, laurel, eucalyptus, radal, araucaria pine, roble, maño, Oregon pine, ulmo, aromo and tineo (CONAF and INFOR, 1983).

1.1.3 Methods and implements used

Primary logging activities are carried out mainly with chainsaws, axes and handsaws.

Practically all felling and cutting into logs in forest plantations is done with chainsaws, and debranching with axes. The work is done by teams of four to six people, one of whom operates the chainsaw while the others assist him by lopping off branches.

The tools used for these activities in natural forests are the chainsaw, the axe and, in some cases, the corvina (crosscut saw). The teams for felling and sawing logs are made up of two workers, possibly one with a chainsaw and the other with an axe, or both with hand-saw and axe.

Skidding is usually done with oxen, horses, wheeled and crawler tractors, wheeled articulated tractors, agricultural tractors with or without logging equipment, or cables. The choice of method depends on topographical conditions and how the work is organized.

Skidding distances are variable and depend on the planning of the work and on the type of forest. In plantation forests the distance for haulage with oxen is between 50 and 100 m, and with tractors between 400 and 600 m; in natural forests, the skidding distance with oxen can be as much as 1 500 m, and with wheeled or crawler tractors an average of 800 to 1 000 m.

Manual lateral loading of logs in a radiata pine forest, San Ignacio de Palomares

Long-distance transport is almost exclusively by truck or rail. Loading and unloading are manual, with hydraulic cranes and frontal loaders. Manual loading and unloading are important in handling pulpwood and sawlogs. In natural forests, muscle power is supplemented by temporary loading ramps.

1.2 METHODOLOGY USED IN THE STUDY

The methodology developed for this study was similar for skidding both by oxen and by tractors as regards calculating times, movements and output. It varied in the calculation of costs and wages; the latter have therefore been described separately.

1.2.1 Estimating times

For each work cycle, an estimate was made of the time involved in the movements in skidding operations, including normal and supplementary times.

1.2.1.1 Normal time

This is defined as the time necessary to carry out one activity in the work cycle.

1.2.1.2 Supplementary time

Also known as additional time, this is any time lost in delays or interruptions in the work. The subdivision of this time varies according to different authors; this study was based on subdivisions made by Cardiel (1974) and FAO (1970), namely: supplement for fatigue, supplement for personal needs and supplement for delays.

a) **Supplement for fatigue**

This was the rest period taken by the ox-driver or the workers in order to recover from the weariness caused by the work. It was time for relaxation, drinking water in dry weather or warming the hands when it is cold. It did not include time spent in eating.

It also included time for the oxen to rest during skidding when necessary, but did not include their midday break.

b) **Supplement for personal needs**

This was the time spent by forest workers on their physiological needs - changing clothes, among other things.

c) **Supplement for delays**

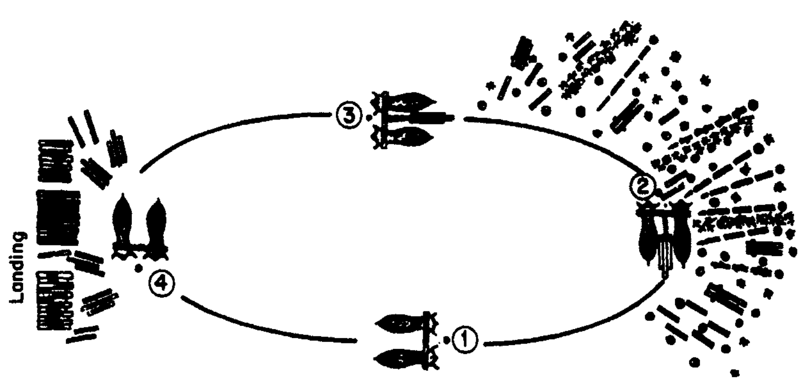
Times spent on delays may or may not be computable. The first case covered incidental delays during skidding, such as: receiving work instructions, setting up equipment on the worksite, preparing tractors or ox-teams in the skidding area, changing parts or spare parts, removing obstacles which made movement difficult over the skidding paths, picking up branches, putting in petrol, adjusting the chain or the cable if it broke, settling or restacking the load at the start of the trip, settling and rearranging the oxen's harness when it got out of place. Some drivers also allowed the oxen to pause when the animals relieved their physiological needs; this time was therefore considered computable.

Among non-computable delays may be mentioned accidental or unnecessary losses of time, including: forgetting tools, conversations between the workers, and all delays outside the normal process. These times were not computed in the study.

Computable supplementary time was totalled and distributed proportionately to each work cycle, since it was considered as an integral part of a working day and not of a specific or particular cycle.

1.2.2 **Description of movements**

The movements considered in the work cycles were: trip without load, loading, trip with load, and unloading. These phases have been mentioned by various research workers in studies of skidding time; among others, Anaya (1975), Bezada and Frisk (1980), and Córdova and Frisk (1979). Fig. 2 illustrates the stages of the cycle.



1. Trip without load
2. Loading
3. Trip with load
4. Unloading

Fig. 2. MOVEMENTS IN SKIDDING CYCLES

1.2.2.1 Trip without load

This was defined as the time spent by the tractor or the oxen when they covered, without a load, the distance from the landing to the place where the load was picked up.

1.2.2.2 Loading

This was the time recorded from the moment the team of oxen or the tractor arrived at the place where the logs were, until the moment it left. It included manoeuvering the oxen or the tractor to take up the load, arranging the logs and fastening them, but not the time spent on stacking the load, since this work was done by workers other than the driver.

1.2.2.3 Trip with load

This covered the time of transportation from the moment the tractor or team of oxen started to move with the load from the loading area until it arrived at the landing.

1.2.2.4 Unloading

This was the time from the moment the tractor or the oxen reached the landing to deliver the load until the chain or cable was fully recovered and remained on the yoke or the winch, as the case may be.

Some research workers put the above times in two groups: terminal and variable times.

Terminal times are those that tend to be constant whatever the skidding distance: they include loading and unloading.

Variable times are those that depend on the distance to be covered and the gradient of the paths. They include trips with and without load.

1.2.3 Determining times

The system used in measuring time is known as 'cycle reset' timing with return to zero, suggested by Morrow (1957) and ILO (1970). The time of each activity in the skidding cycle was read and recorded, the hands were returned to zero without stopping the clock, and recording of the time of the subsequent activity immediately started. The information was taken on successive days on a prepared form (see Appendix 2).

The size of the sample, namely, the number of cycles needed for the cases of skidding being studied, was determined statistically and the respective equations were obtained later.

1.2.3.1 Time per work cycle

This was defined as the total time spent per work cycle, including computable supplementary times. The equations were obtained by the minimum-squares method 1/ following the model $t = a + bx$, where:

t = time per work cycle, in centiminutes (dependent variable)
a,b = coefficients of the equation, terminal times
x = distance (independent variable).

1/ Work conducted in the computer centre of the Universidad Austral of Valdivia, with the collaboration of Mr. Raimundo Vega and Mr. Mario Meneses.

1.2.3.2 Time per m^3

This was the time needed to accumulate 1 m^3 of timber at the landing, and it was obtained by relating the time per work cycle to the average volume of the load.

$$T(m^3) = \frac{t}{V} = \frac{a + bx}{V}$$

$T(m^3)$ = time per m^3

t = time per work cycle, in centiminutes

V = average volume of load in m^3

x = distance.

1.2.4 Determining output

Output is expressed in cubic metres per hour (m^3/h) calculated on the basis of the relation between the average volume of load and the time per work cycle. For the purposes of calculation, the general and traditional formula used by Anaya (1975), Córdova and Frisk (1979) and other research workers was also used.

$$O = \frac{6000V}{t}$$

O = output, in m^3/h

V = average volume of load, in m^3

(6000 = centiminutes in 1 hour).

Output can also be ascertained using the following formula:

$$O = \frac{6000}{T}$$

1.2.5 Costs per unit of volume

These were calculated as the quotient between the costs per unit of time for the resources used (labour, oxen or tractor) and the production per unit of time (FAO, 1974).

The general formula used was:

$$C(m^3) = \frac{Ch}{O}$$

where: $C(m^3)$ = cost per m^3

Ch = hourly cost of the resources

O = output in m^3/h.

By introducing the output (O) formulae equations were obtained that could equally well be used to determine the costs per m^3, namely:

a) $$C(m^3) = \frac{Ch \times t}{6000\ V}$$

b) $$C(m^3) = \frac{Ch \times T}{6000}$$

The hourly cost of skidding with oxen comprised the cost per hour of the team of oxen plus the labour, in this case the hourly cost of the driver.

The variables in calculating the hourly cost of skidding with oxen and with an agricultural tractor were different; they have therefore been described separately in this study. Variables were grouped in two classes for each case — fixed costs and variable costs.

Fixed costs were those that were permanent even when there was no production, such as interest, depreciation, insurance, basic feed for the oxen, animal mortality and fixed wages.

<u>Variable costs</u> depended on the work (the operations); for example, cost of fuel, replacement of tires and special feed for the oxen.

1.2.5.1 <u>Variables applied to determine the cost of skidding with oxen</u>

This cost may be expressed as Ch = Cho + Chl

where: Ch = hourly cost of skidding

Cho = hourly cost of oxen

Chl = hourly cost of driver (labour).

a) <u>Fixed costs</u>

<u>Interest</u>

This was calculated on the basis of the capital invested in buying a team of oxen, together with the purchase value of all the accessories: collar, yoking straps, hooks, yoke and goad.

Interest is the sum paid for the use of money on loan or, in a wider sense, it is the return obtained from a productive investment of capital. For the purposes of calculation, real interest in the case of Chile was considered to be 12 percent.

$$I = \frac{1}{U}\,(Va + Vo)\,\frac{R}{100}$$

$$I = \frac{(Va + Vo)R}{100\,U}$$

where: I = cost of interest

Va = purchase value of accessories

Vo = purchase or breeding value of oxen

R = rate of interest (12 percent)

U = hours of work per annum.

<u>Depreciation</u>

Only the accessories depreciated; the oxen did not lose their value, since at the end of their working life they were sold, providing meat for human consumption.

In this study, depreciation is shown separately for metal elements (collar, chain and hooks) and less durable elements (yoke, yoking straps and goad). Their values will later be added together to give one cost.

$$Cd = \frac{Va}{NU}$$

where: Cd = cost of depreciation, per hour

N = useful life of accessories, in years

U = annual use, in hours.

<u>Feed</u>

Oxen are usually fed on silage or hay when they are used for skidding; however, the type of feed can vary, so no formula has been given for obtaining this cost.

<u>Medical and veterinary service</u>

The money invested in medical attention, medicines and vaccines was considered to be 5 percent of the purchase value of a team of oxen.

$$Cm = \frac{Vo}{U} \times 0.05$$

where: Cm = medical costs per hour

Vo = purchase or breeding value of a team of oxen

U = annual work in hours.

Cost of Mortality

This was calculated at 5 percent of the purchase price of a team of oxen, a percentage frequently used in Chile by authors such as Soto (1970). The value was obtained in the same way as the previous case.

b) Variable costs

Special feed

Additional or special feed was usually given to oxen used for skidding. Basic information and the calculation of hourly cost can be seen in Appendix 3.

Labour

This was the payment made to the driver for driving the oxen when skidding. It covered only the wages of one workman and did not include expenditure for people engaged in stacking, since this was a different job.

The wages of ox-drivers engaged in skidding in Chile are very variable. It is usual to pay by contract or by piecework, fixing a specific price which is usually quantified in two ways: i) individually, when the dimensions of the logs are on average greater than 30 cm in diameter and 2.50 m in length (sawlogs); ii) by stack metre 1/ where manual piling is quick and easy. Research carried out by the author revealed that some forest enterprises used to have their own draught animals; but because of the drivers' careless handling or their eagerness to produce, which resulted in exhaustion and weakness of the overworked oxen, the companies decided to employ contract workers with their own animals. However, some small companies were still using their own draught oxen.

Pile of pulpwood bolts arranged in stack metres (Nacimiento, Chile)

1/ 1 stack metre = the roundwood of radiata pine, usually intended for the pulp and paper industry, which when piled is 1 m high by 1 m wide and 2.44 m long.

The hourly cost of an ox-driver, calculated nominally on the information supplied by a Chilean forest enterprise, is shown in Appendix 3.

1.2.5.2 Variables applied to determine the cost of skidding with agricultural tractors

The methodology developed to determine costs was based mainly on the guidelines set out in research works by Anaya (1975), Overgaard (1975) and Frisk (1972) and the procedures proposed by the Caterpillar Tractor Co. (1975).

Both fixed and variable costs of an agricultural tractor of any model varied greatly. This variability depended on several factors, of which the main ones were the class of work done; local prices for tractors, petrol and lubricants; and interest rates. An exact calculation of hourly cost must therefore take into account the local experience of each region or country.

Hourly cost was determined by adding the cost per hour of the tractor to the cost of the labour of the driver and the chokerman. The general formula used was as follows:

$$Ch = Cht + Chl$$

where: Ch = total hourly cost

Cht = hourly cost of ownership and operation of tractor

Chl = hourly cost of labour.

Basic information and values of hourly cost are shown in Appendix 6.

a) Fixed costs

Interest

This is a 'loss' value and represents the income which would have accrued if the price of the tractor had been deposited in a savings bank at fixed interest. The rate used in the present study was 12 percent per annum.

$$I = \frac{1}{U}\left(\frac{Vi + Vf}{2}\right)\frac{R}{100}$$

$$I = \frac{(Vi + Vf)\ 12}{U\ (\ 2\ )100}$$

$$I = \frac{(Vi + Vf)\ 12}{U\ 200}$$

where: I = cost of interest

Vi = initial value of the tractor (including the logging winch)

Vf = resale or final value of the tractor (including the logging winch)

U = annual use of the tractor, in hours

R = rate of interest (12 percent).

Depreciation

Depreciation in forestry accounting terms is a means of recovering the original investment in a machine and accessories.

The method of depreciation suggested in this study is based exclusively on hours of use per annum.

$$Ca = \frac{Vi - (Vf + Vt)}{NU}$$

where: Ca = hourly cost of depreciation

Vi = purchase value of the tractor (including the skidding winch)

Vf = resale value of the tractor (including the winch)

Vt = replacement value of the tires

N = useful life of the tractor, in years

U = annual use of the tractor, in hours.

As may be observed from the preceding formula, tires were excluded, since they were considered as high-cost, quickly worn out articles (Caterpillar, 1975) and their replacement value was carried over from the initial price of the tractor.

Licence

This covered the expenses incurred in acquiring the licence without which the tractor could not be driven. In Chile the licence is renewed every year.

$$CL = \frac{L}{U}$$

where: CL = hourly cost of the licence

L = annual cost of the licence

U = annual use of the tractor, in hours.

b) Variable costs

Repairs

This refers to maintenance expenses, including the value of spare parts and labour but excluding the wages of the operator. Some companies or individuals kept records of these costs, which provided the best information for determining the cost per hour of repairs. Where there were no records it was usual to calculate repair costs as a percentage of the initial cost of the machine.

In the study 90 percent was used. This was the factor proposed by Caterpillar (1975) to estimate this type of cost for wheeled forest tractors working in areas where they were subject to strong impacts from stones and rocks, which were classified (by Caterpillar 1975) as Zone C. These characteristics were similar to conditions of forestry work.

$$Cr = \frac{(Vi - Vt)r}{NU} = \frac{(Vi - Vt)\,0.90}{NU}$$

where: Cr = cost of repairs per hour

Vi = purchase value of the tractor (including the skidding winch)

Vt = replacement value of the tires

N = useful life of the tractor, in years

U = annual use of the tractor, in hours

r = repairs factor = 90% = 0.90.

Tires

The cost of tires was considered separately, since it was very high. An estimate of the life of the tires was made in the light of experience.

$$Ct = \frac{Vt}{N} = \frac{Vt}{3\,000}$$

where: Ct = cost of tires per hour

Vt = replacement value of tires

N = useful life of tires, in hours.

The average life of tires was estimated at 3 000 hours (Caterpillar, 1975).

Fuel

Fuel consumption can be accurately determined at the worksite. If there is any difficulty the tractor manual may be checked.

Fuel costs varied according to the specifications of the tractor, the way the operator drove, the weight of the load, the topography and the length of time the tractor was in use, among other things. For this reason, consumption registered in the field could often be different from that shown in the manual.

In preparing the present study, fuel consumption was determined on the worksite, and the costs were calculated according to the following formula:

$Cf = Ch \times Vf$

where: Cf = cost of fuel per hour

Ch = fuel consumption per hour

Vf = value of fuel per litre.

Lubricants, filters and grease

This covers the costs of changing the oil in the engine, transmission and gear-box and other lubrication jobs.

Accessory equipment

This covers the cost of buying the steel hooks and cable needed to haul the timber.

Maintenance

This refers to the time and cost involved in the specific work of maintaining the tractor, such as checking the water in the radiator, watching the oil level, checking the brakes and fuelling the tractor. For the purposes of calculation it was estimated that the tractor driver spent 15 minutes every day on this kind of work.

Labour cost

As well as the wages paid to the tractor driver and the chokerman, these costs included bonus payments made for the volume moved.

1.3 GENERAL CONDITIONS OF THE STUDY

Information collected on draught animals involved different teams of oxen in which individual animals weighed between 500 and 700 kg. It was assumed that they all had the same capacity for work. Skidding was carried out with oxen and ox-drivers with experience and stable production levels. Observations were made in the yards of Chilean forestry enterprises.

The time study on skidding with an agricultural tractor was made in one place only, and therefore reflected only the conditions prevailing in that particular forestry enterprise.

The tractor did not have front ballast to balance the weight of the winch and the load, a condition in which power and output are not of the best. Only the cable of the winch was used in loading, without slings which shorten loading time and thus reduce costs.

Time studies of skidding with oxen and with an agricultural tractor took into account only the actual work times and computable supplementary times, disregarding time spent on other activities such as stacking and loading trucks.

PART II
SKIDDING WITH OXEN

Skidding with oxen in plantation forests (Lastarria, Chile)

2.1 DRAUGHT ANIMALS THROUGHOUT THE WORLD

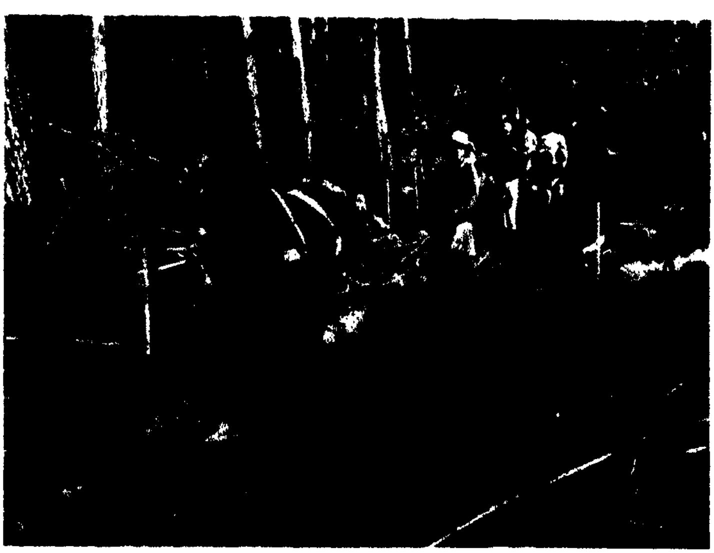
In many regions of the world animals are the principal source of energy for agricultural and forestry work and for transportation. Various species are used, the most important being bovines (cattle, buffaloes and yaks) donkeys, horses, elephants, llamas and mules. According to Ramaswamy (quoted by Starkey, 1982) there are approximately 300 million draught animals in the world, of which 225 million are bovines, used especially in developing countries.

Research by Smith (1981) and Hopfen (1970) showed the approximate geographical distribution of animals working on the land. For example, oxen as a source of energy are important in Latin America (particularly Chile, Brazil and Mexico), in Africa, especially Ethiopia and south of the Sahara, in the United Arab Republic and in southern and eastern Asia. Buffaloes are particularly popular in southeast Asia and Egypt.

Donkeys and mules are used for transportation, carrying loads and field work in South America, Egypt, the Iberian Peninsula and several countries in the Near East. Camels are used for transport in deserts and arid zones from West Africa to China. The elephant is used for work and transport in India, Sri Lanka and several countries in southeast Asia.

Horses are important draught animals in Chile, Brazil and Mexico, but in general their use is diminishing throughout the world. Llamas are used as beasts of burden in the South American Andes. The yak is used for the same purpose on the plateaux and mountain ranges in the north of Central Asia.

From the above it may be seen that there is a considerable potential in draught animals, of which very little is known compared with animals for meat or milk production. In view of their importance, Smith (1981) suggests the establishment of an international research institute to study more ways of using them.



Skidding with a horse and with oxen in a radiata pine forest
(San Ignacio de Palomares, Chile)

2.2 SKIDDING WITH DRAUGHT ANIMALS

In Chile mainly non-mechanized skidding methods are traditionally used, particularly oxen combined with some mechanised equipment. In the study only skidding with oxen was covered, with some research on the use of horses, the results of which may be found in Appendix 4.

2.2.1 Skidding with oxen

Former studies include the following:

a) Eisenhauer (1969) carried out research on skidding with oxen in a forest of radiata pine with the following characteristics: the trees were 24 years old with an average diameter at breast height (d.b.h.) of 32 cm and average height of 24 m. Density was 600 trees/ha. The logs transported were crosscut in the stand, to lengths of between 3 and 7 m.

In the above conditions, skidding on a slope of 11 percent and over a distance of 125 m, the time per m^3 was 36.86 minutes and the output was 1.48 m^3/h.

b) On the basis of information collected in natural forest by a forestry enterprise, Hernandez (1969) obtained an output of 11.37 m^3 a day skidding logs with oxen from the felling site to a feeder road, over distances of 50 to 200 m.

He also found the output was 6.55 m^3 per working day transporting logs in carts drawn by oxen from feeder roads to landings, over distances of 1 000 to 1 500 m.

c) Jelvez (1977) studied the output of oxen in a forest of radiata pine subjected to three types of thinning: selective, systematic and mixed. Skidding was done in a stand 12 years old, with 1 110 trees/ha and average diameter of 19 cm.

In the selective thinning, using ox-drawn carts over an average distance of 25 m, the time taken to transport 1 m^3 of timber was 33.79 minutes, and the output 0.89 $m3/h$. The logs were 2.44 m long.

In systematic thinning, skidding included the hauling of long logs (where the whole length or the trunk could be used) over an average distance of 37.5 m. The time per m^3 was 17.62 minutes, and the output 1.70 m^3/h.

For mixed thinning, a combination of the two systems where the average distance was still 37.50 m, the time and output were the same as in systematic thinning.

There are other studies on skidding with oxen and horses, but their results are not given here because they include stacking time, which is not taken into account in this study.

2.3 GENERAL INFORMATION ON OXEN AS DRAUGHT ANIMALS

2.3.1 Advantages and uses

Since ancient times, the ox has been used as a draught animal and although there are no precise records, it appears that cattle were used as a source of energy before they were used for milk or meat production.

The ox is versatile; it can be used in agricultural and forestry activities and as a means of transport. Oxen can be bred directly by peasants who therefore do not usually need to buy them and can also produce the feed they require. The ox is slow but steady; it is hardy, strong and easy to drive, and at the end of its active life, after having been fattened, it provides a good yield in beef, so the investment in it can be recovered.

In agriculture oxen as animal power are used mainly for ploughing and cultivating the land. As transport animals they are used mainly with carts and wagons, or for travelling on narrow paths and roads in bad condition.

Using oxen to transport forest products on rails (Forest and Timber Complex of Panguipuili, Neltume, Chile)

Using oxen for lateral loading of logs in plantation forests (Lastarria, Chile)

Oxen used to be indispensable in forest operations almost everywhere in the world (FAO, 1983); however, today they have been widely replaced by different types of machinery. For some people, oxen are a sign of technical backwardness, but it should be pointed out that many forest enterprises continue to reach good levels of production with them. Whereas the art and technique of working with them have been lost in many areas, oxen are still important in forestry activities - particularly skidding - in both plantation and natural forests.

In Chile in 1982 approximately 90 percent of sawmills (some 696),1/ three companies producing pulp and paper, and seven board factories used oxen in extracting timber, frequently combining the use of draught animals with forest tractors (CONAF, INFOR, 1983). It is estimated that there are several thousand teams of oxen used in skidding, in both plantation and natural forests. They are also to be found working in small sawmills to transport logs from the storage yard to the main saw, and on some sites, especially in natural forests, loading logs on to trucks, doing the work usually done elsewhere by mobile cranes.

2.3.2 Morphological characteristics

Oxen employed in skidding vary from one breed to another, but there are characteristics that are common to many.

Agenjo (1945) observed certain features which should still be present in skidding oxen. The main ones (see Fig. 3) are: solid head; back of the neck must be in good condition (because the yoke rests on it); horns well set in the head and firm, well-developed and fairly straight, facilitating the fixing of the straps used to settle the yoke; neck short, thick and powerful since it takes the weight of the timber; chest wide and deep; withers well defined; hindquarters muscular or with prominent bones.

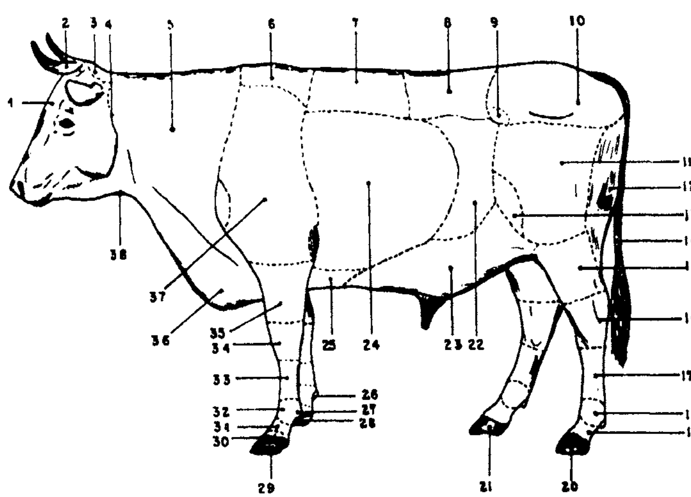


Fig. 3 PRINCIPAL MORPHOLOGICAL PARTS OF A DRAUGHT OX

1. Head 2. Horns 3. Nape of neck 4. Parotid 5. Neck 6. Withers 7. Chine 8. Loin 9. Hindquarters 10. Croup 11. Thigh 12. Rump 13. Knee 14. Tail 15. Leg 16. Hook 17. Shank 18. Fetlock 19. Pastern and coronet 20 and 21. Hooves 22. Flank 23. Stomach 24. Ribs 25. Heart 26 and 27. Fetlocks 28 and 29. Hooves 30. Coronet 31. Pastern 32. Fetlock joint 33. Shank 34. Knee 35. Upper foreleg 36. Dewlap 37. Shoulder and foreleg 38. Dewlap

1/ In 1982 there were a total of 1 498 sawmills, of which only 973 were functioning (CONAF, INFOR, 1983).

The forequarters and hindwuarters must be correctly balanced and well formed in their various parts: shoulders large and powerful; forelegs long; croup long with rectilinear rump; legs long and hook joints wide. The legs (consisting of the shanks, fetlock joints, pasterns, coronets and hooves) are very important in skidding animals; they should be short and strong, and it is also desirable that the hooves be hard and resistant.

The average weight of an ox is 600 kg.

Sizes vary with breeds and individuals. De la Maza (1969) considers average measurements to be 2.70 to 3 m in length, 1.50 to 1.80 m in height and 0.80 to 1.10 m in depth (width).

2.3.3 Castration, training and handling

In forestry work, oxen are used in pairs or teams and their success in skidding depends on taming and training and the harness used.

The calves selected should be males, because the work is hard. They should be accustomed from an early age to seeing people on the farm where they are born, and as young animals they should be in frequent contact with human beings so that they do not get frightened and are accustomed to hearing the voice of command. It is desirable to keep them in places where they have freedom to move around and exercise their muscles and joints, which help development. It is also recommended that they be separated from others of the same species.

Oxen are castrated before training. Ensminger (1970) says that castration should take place between the fourth and twelfth months, and Agenjo (1945) believes that it should be done at eight to ten months. Castration before the animal is one year old can inhibit muscular development of the fore- and hindquarters, particularly the shoulder, neck and thighs (Goe, 1983). FAO, (quoted by Goe, 1983) recommends castrating cattle when they are a year and a half to two years old. Although there are different criteria, the age of castration varies according to species, country and region.

Castration can be done at any time of the year. However, it is better to do it in periods of moderate temperature, particularly in the spring and autumn or a little before the rainy season, to reduce the possibility of infection by insect, and because excessive heat or cold produces functional disorders. The suppression of the sexual organs is intended to reduce aggressive behaviour, making the animals more docile (Navajas, 1955).

The age when training starts varies in different countries. Hopfen (1970) considers that it may be when the animals are between one and a half and two years old; FAO (1983) gives the appropriate age as after three years. A survey made by the author of this work in different forest estates in Chile found that training starts there at two and a half years and lasts for six months.

The training begins by getting the animals accustomed to a double head yoke, that is to say, being in a team, and training at this point is practically limited to toleration of the yoke. Later they draw a cart, bearing light loads that are gradually increased in order to accustom them to the necessary weights. In these two stages, when experienced oxen are available a young ox is paired with an animal already trained so that the beginner will be dominated by the strength of the adult.

In the last stage the trained ox is taken to the forest and yoked with another of the same age. The animal is considered to be completely trained when it has reached maturity (at approximately five years) and is capable of hauling full loads (FAO, 1983).

Using young oxen to draw carts in a sawmill (Los Sauces, Chile)

To handle oxen well the driver must have a good knowledge of the animals' character and a fair amount of practice. Commands are given in the local language, to avoid confusion if there is a change of ownership or district, although it is always best if one man drives the same team of oxen for several years (in practice sometimes difficult to achieve). The words of command should be short and the driver should be able to make the oxen understand when to go backward or forward and when to turn or stop. An experienced driver does not need to goad or ill-treat the oxen because the animals will obey the word of command.

An inexperienced driver sometimes keeps urging the animals on, and obtains an excellent daily output in skidding; however, in time the oxen become exhausted, output falls and the useful life of the animals is shortened.

In some places it is customary to give the ox a name, and they will obey when called by name. The animals are responsive to patting and kindly treatment; they easily become affectionate, just as they are resentful when ill-treated. The closer the link between the man and the animal, the more efficient the latter becomes.

According to FAO (1983), oxen can work up to the age of ten or 12 years, an observation that accords with the survey made by the author in Chile; and their useful life is between six and seven years.

2.3.4 Load capacity

The load capacity of oxen in skidding is in relation to the weight of the animals, the topographical conditions, the class of forest, the density of the timber and the size of the logs.

Skidding with oxen in a radiata pine forest (Nacimiento, Chile)

Maximum volumes and weights are obtained when skidding downhill. According to information gathered by the author maximum skidding loads were in natural forests, where the oxen managed to haul loads equivalent to more than twice the weight of an ox of 600 kg.

2.3.5 Pull strength, tractive effort and power

The pull strength exerted by oxen to transport logs depends on various factors, of which the principal ones are: the weight of the ox itself or of the team, weight of the load, angle of draught, distance covered, coefficient of friction between the logs and the soil, slope of the ground, method of transporting the load, climatic conditions, and intensity of the work.

The tractive effort varies between 10 and 14 percent of body weight, with speeds between 2.5 and 4.0 km/hour (Goe, 1983). The power generated by the oxen is related to the rate of work, that is to say, the faster the rate, the greater the power. For example, a team of oxen weighing approximately 1 200 kg dragging a load with a tractive effort of 120 kilopounds (kp) at a speed of 0.70 metres per second (m/s) will produce a working power which, expressed in the form of energy as suggested by Sears and Zemansky (1963), is 0.82 kilowatts per second. If this speed drops to 0.60 m/s, the power is 0.56 kW per second.

Table 2 shows some values of draught capacity (or tractive effort) and working power of oxen, which have been taken from Goe and McDowell (quoted by Goe, 1983).

Table 2

ESTIMATED DRAUGHT CAPACITY OF OXEN WITH DRAWN IMPLEMENTS AT LOW AND AVERAGE WORKING SPEEDS

Type of ox	Mature weight (kg)	Low Speed			Average speed		
		Speed (km/h)	Tractive effort (kp) 1/	Power (kW) 2/	Speed (km/h)	Tractive effort (kp) 1/	Power (kW) 2/
Light	210	2.5	30	0.25	4.0	21	0.23
Medium	450	2.5	61	0.44	4.0	45	0.50
Heavy	900	2.5	129	0.89	4.0	90	0.99

1/ 1 kilopound (kp) = 9.807 Newtons

1 Newton = $kg \times \frac{m}{s^2}$ where m = metre, s = second

1 Joule = $kg \times \frac{m}{s^2}$

1 Kilowatt/s = kw/s = 1 000 Joules

2/ Power = force x speed.

2.3.6 Feed and energy

2.3.6.1 Feeding principles

Studies on the feeding of draught animals are few and fragmentary, and therefore very little is known about nutrition and physiology, especially in developing countries (Smith, 1981).

The quantity of an ox's feed consumption is related to the animal's weight and intensity of the work. Skidding animals, because of their enormous size, have digestive organs capable of consuming and digesting large quantities of feed; however, when the work is intensive, overfeeding impedes movement and effort, prolonging rumination, with loss of work output.

Feeds and rations vary with different countries, regions, districts and customs, but in general they consist of large quantities of hay and straw, bran and plenty of water. When oxen are doing heavy work hauling logs, it is usual to feed them three times a day: in the morning, at least an hour and a half before starting work; at midday, when they are allowed to rest at the same time; and in the evening, when work is finished. When the animals are resting over the week-end, feed continues without change, but when rest periods are longer the ration may be reduced by half and they are left to graze freely.

According to Goe (1983) the feed requirements of mature working oxen are for organic maintenance and work, while immature animals have additional needs.

Active oxen need a daily ration containing 2.5 to 3.0 kg of dry matter per 100 kg of live weight of the animal (Ensminger, 1970) and could be higher for skidding oxen.

Traditionally, the basic feed of oxen has been grass, consumed directly or in the form of hay or silage; for a long time it has been the most efficient and cheapest feed. A supplement of barley or bran can also form part of the ration. Mature cattle consume 45 litres of water a day. Water is indispensable for digestion and assimilation of feed, the elimination of waste products and the regulation of body temperature. The animals should have as much water as they want.

In practice, drivers can measure the efficiency of the feed and the ration according to how they affect the animals; the loss, gain or stability in weight of the oxen is observed, since these are the visible results of the quantities given.

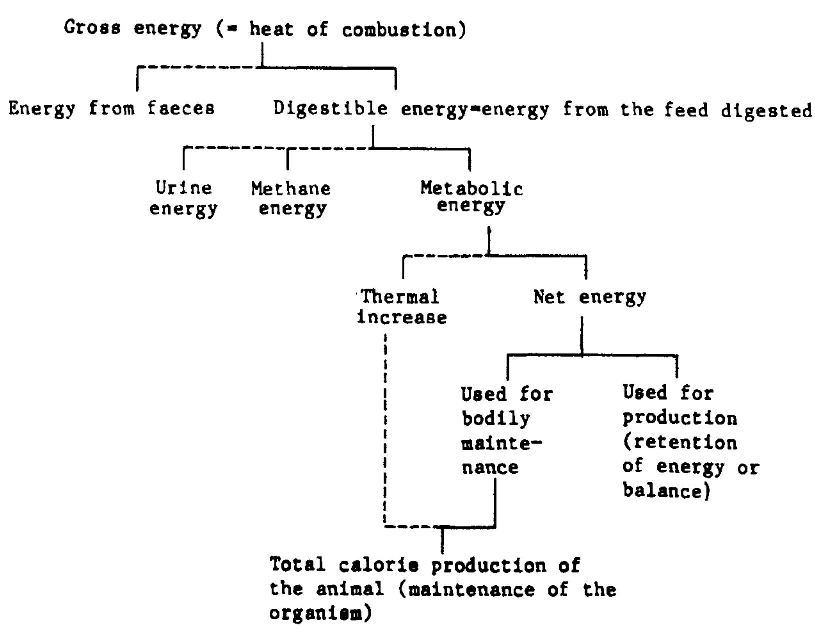
2.3.6.2 Energy requirements

Even when an ox is resting or not making any physical effort, it needs feed to replace the energy spent in its organic maintenance (for functioning of the organs, maintaining body temperature, and replacing proteins and vitamins eliminated in excretion and water eliminated in liquid and gaseous form).

After feeding, the animal loses chemical energy, which comes out of the organism in dung, urine, gases and also in the form of heat by direct radiation, conduction, convection and by evaporation through the lungs and the skin (McDonald, 1979). The remaining energy from the feed is metabolic and generates two forms of energy: thermal and net.

Thermal energy is generated by the process of digesting feed; the net energy of the feed is that which the animal uses for the maintenance of its organism, and the rest constitutes reserves to undertake physical work and for fattening. The following diagram, taken from McDonald (1979) shows the distribution of animal energy.

Gross energy (= heat of combustion)



It has been mentioned that animals, even if they are not working, need a minimum maintenance ration. If they are deprived of feed, or when the quantity received is not enough, energy for maintenance is obtained from reserves accumulated in the fat through the process known as catabolism. This leads to a loss of weight (McDonald, 1979). Working oxen need feed over and above the level of maintenance. One way of calculating the additional needs is by considering the hours of work every day, the type of work done, and the pull strength required, expressed in terms of energy.

Table 3, taken from Goe and McDowell (quoted by Goe, 1983) shows the total digestible nutrients (TDN) for oxen of different weights, working periods of 4, 6 and 8 hours a day, with efforts of 10, 12 and 14 percent compared with their body weight. On the basis of the above percentages the work was classified as light, average and heavy, respectively.

Table 3

ESTIMATED TDN NEEDS OF OXEN OF VARIOUS SIZES WORKING AT DIFFERENT RATES OF 4-, 6- and 8-HOUR PERIODS

Weight (kg)	Tractive effort (kp)	Tractive effort 1/ (%)	Speed (km/h)	Power (kW)	TDN needs 2/ (kg)		
					4 h	6 h	8 h
250	25	10	4.0	0.28	3.3	3.8	4.3
250	30	12	3.5	0.29	3.5	4.0	4.6
250	35	14	3.2	0.31	3.6	4.3	4.9
300	30	10	4.0	0.33	3.7	4.3	4.9
300	36	12	3.5	0.35	3.9	4.6	5.2
300	42	14	3.2	0.37	4.1	4.8	5.5
350	35	10	4.0	0.39	4.2	4.8	5.4
350	42	12	3.5	0.40	4.4	5.1	5.8
350	49	14	3.2	0.43	4.5	5.4	6.2
400	40	10	4.0	0.44	4.7	5.4	6.2
400	48	12	3.5	0.46	4.9	5.8	6.6
400	56	14	3.2	0.49	5.2	6.1	7.0
450	45	10	4.0	0.50	5.2	5.9	6.7
450	54	12	3.5	0.52	5.4	6.3	7.2
450	63	14	3.2	0.56	5.6	6.7	7.7
500	50	10	4.0	0.55	5.4	6.3	7.1
500	60	12	3.5	0.58	5.7	6.7	7.6
500	70	14	3.2	0.62	5.9	7.0	8.1
550	55	10	4.0	0.60	5.7	6.6	7.5
550	66	12	3.5	0.64	6.0	7.0	8.0
550	77	14	3.2	0.68	6.3	7.4	8.5
600	60	10	4.0	0.66	6.1	7.0	7.9
600	72	12	3.5	0.69	6.4	7.5	8.5
600	84	14	3.2	0.74	6.7	7.9	9.1

Source: Goe and McDowell (quoted by Goe, 1983)

1/ Percentage of body weight developed as tractive effort

2/ Includes daily needs for maintenance. TDN: digestible protein + free extract of N + digestible fibre + 2.25 (extract of digestible ether) (Morrison, 1947). 1 kg of TDN = 4.409 Mcal of digestible energy and 3.615 Mcal of metabolizable energy (ME)(Crampton and Harris, 1969).

The most common ailments of bovines are diseases of the mouth, the lungs, the stomach, the skin and the eyes, and infections of the hooves (Bock, 1977). In this study some diseases in the last three groups will be described, because these are the ones that the driver can distinguish most easily and because they are more likely to occur with oxen used in skidding. Other diseases that require immediate assistance from a veterinary surgeon are not discussed here.

2.3.7 Hygiene and diseases

The health of oxen depends largely on their environment. Hygiene is not expensive; it helps to avoid diseases, and is more useful and economic than curing them.

When there are stables or pens for skidding animals that are usually there for short periods only, they should be cleaned every day if possible. This cleaning consists of removing the dung so that oxen have a dry bed. The oxen themselves should be cleaned with a brush and water once a week, on rest days, to keep the skin healthy and free of parasites and cutaneous diseases.

Drivers should watch the animals continually to detect any sign of abnormality in their behaviour that could be the first symptom of a disease. These signs are usually connected with everyday processes, such as: physical movements, temperature, pulse, respiration, appetite, rumination, defecation, emission of urine and work output. An ox in repose respires 10 to 30 times a minute. It has from 40 to 60 pulsations a minute and a normal temperature of 38.2 to 39.5 C. With work, excitement and extremes of heat or cold, these rates rise (Wooldridge, 1962).

2.3.7.1 Skin diseases

a) Ticks

Oxen in a field or in the forest are liable to pick up ticks which stick in the animals' skin.

Ticks subtract blood, implant a toxic secretion and transmit into the blood parasites that destroy the red cells through intensive reproduction. Infestation can produce inflammations in the skin, fevers, spasmodic contractions, phenomena of paralysis, restlessness, loss of weight, damage to the skin due to bites, and loss of blood.

Drummond (1976) recommends that ticks should be controlled by applying to the host animal and to the stables acaricides based on arsenic (AS2O3) and chlorinated hydrocarbons, especially benzene hexachloride (BHC), which are economical and effective. In applying acaricides, the instructions of a veterinary surgeon should be carefully followed, since these substances can be poisonous for livestock and human beings.

b) Pediculosis

This is the result of lice in the animals, and occurs mainly in those that are badly fed and housed in unhygienic stables.

The lice suck the animals' blood two or three times a day. In piercing the skin they produce perforations and consequently pain. Large numbers of them lead to urticaria and the formation of scabs; the movement and the bites cause itching, which leads the animals to bite themselves and rub against their stalls. Lice are controlled with contact insecticides, repeating the dose every eight or ten days.

c) Ringworm

This is a disease produced by fungi (especially Trichophytun verrocosun) which are present in damp wood, fodder, mouldy straw and dung. They are very resistant in this environment but sensitive to sunlight. The fungus sticks to the base of hairs, weakening and finally loosening them, causing a smarting sensation and obliging the animals to rub themselves against anything available, thus producing round bare patches on the skin.

Ringworm is contagious and can be transmitted to humans. It can be recognized by characteristic abrasions, bare round areas covered with thick, callous flakes. This disease is treated with antimycotics such as chloromycetin, tincture of iodine, formaldehyde, creosote or salicylic acid ointments.

When, despite good feeding, isolated lesions appear year after year, the most probable reason is that the stables are infected, in which case they should be thoroughly cleaned by scrubbing with hot water and disinfectant.

d) Warts

These are caused by a virus infection and according to Book (1977) the most serious invasions are in animals with a low state of health. When warts are present all over the body the best thing is to leave the animals in peace, keeping them clean and well fed. A small wart may be removed every day with disinfected hands, applying a solution of sulphanilamide immediately afterwards.

The application of any non-irritant antiseptic is effective in controlling warts. The primitive method of tying ligatures around the base should not be used, because they may produce ulcerations, facilitating invasion by germs that can cause tetanus and other disturbances.

2.3.7.2 Hoof problems

a) Abscesses

These are infections in the lower part of the extremity produced perhaps by a nail picked up from the ground or a cut in the sole with some sharp object. They become apparent fairly quickly because the animal goes lame.

Meticulous exploration by a veterinary surgeon is needed. He makes a small cut to extract the foreign body.

b) Hoof rot

This is caused by a germ (called Fusiformis necrophorus) that can live for years in the clefts and fissures of the hooves, and reproduces when it finds the appropriate conditions, the ideal place being a lesion, cut or crack in the skin between the nails around the root of the heel. Infection is more likely when the animal repeatedly has its feet in mud, dirty water, dung or urine.

Reproduction and attack by the germs cause painful swelling followed by necrosis of the affected part, with a putrid smell. If the infection is not treated in time, secondary septic complications arise which in turn can affect a joint.

According to Book (1977), this disease may be avoided by washing the animals' feet once a week with a 3 percent copper sulphate or a 10 percent formalin solution. It is desirable for the animals to tread on a thick layer of earth or a heap of ordinary lime every day, because lime keeps the skin on top of the heel hard and dry.

c) Stones in the hooves

When the oxen have to cross gravel paths, stones can get right into the sensitive underlying tissues of the sole of the hoof, causing lameness.

If the part affected is struck with a small hammer or the handle of a spoon, the animal reacts to the pain by kicking violently. The suspect area can then be explored until the foreign body is found. Once it is taken out the cavity is filled with antibiotics, keeping the foot covered for four or five days.

2.3.7.3 Ocular disorders

a) Foreign bodies in the eye

To eliminate from the eye chips of bark, wood or twigs, take a tube of eye ointment, squeeze it a little until a small quantity appears on the nozzle, slowly approach the eye and press the ointment against the foreign body. The animal involuntarily throws its head back and the foreign body remains stuck in the ointment. Afterwards a small quantity of ointment can be inserted in the eye to avoid infection. If success is not achieved after several attempts, a veterinarian should be called.

b) Infectious keratitis (pink eye)

This takes the form of a flow of serous liquid or a closed eye. This infection can affect both eyes, and because it develops very rapidly a veterinarian should be called to treat it quickly.

It is started by a germ (called Moraxella bovis) which becomes active when there is a lesion in the surface of the eye: damage caused by foreign matter, particles of dust or irritation by flies.

2.4 SKIDDING EQUIPMENT AND HARNESS

Skidding harness for oxen should be so designed as to allow the animals to work comfortably and efficiently. Hopfen (1970) recommends several conditions to be borne in mind:

a) It must allow efficient and speedy work with the minimum of fatigue;

b) It must not be injurious to man or animal;

c) It must be of simple design and easily available materials so that it can be made locally;

d) It must be light in weight for easy transportation;

e) It should be ready for immediate use to save time.

2.4.1 Description

(Note: Only the equipment observed in use during the preparation of this study is described below.)

2.4.1.1 Double head yoke

This most ancient type of harness (Hopfen, 1970) consists of a piece of wood fixed on the head with yoking straps or belts (see Fig. 4).

The yoke should be made of light but tough wood, so that it can support weights of approximately 500 kg when the load is suspended. The length varies between 1.8 and 2.6 m and the weight 12 to 15 kg.

The under side of the yoke, which lies across the ox's neck should be arched to fit comfortably without rubbing. In Chile it is usual to include an extension at the back, called by the ox-drivers a neck flap, to spread the weight of the load and also to avoid injuries.

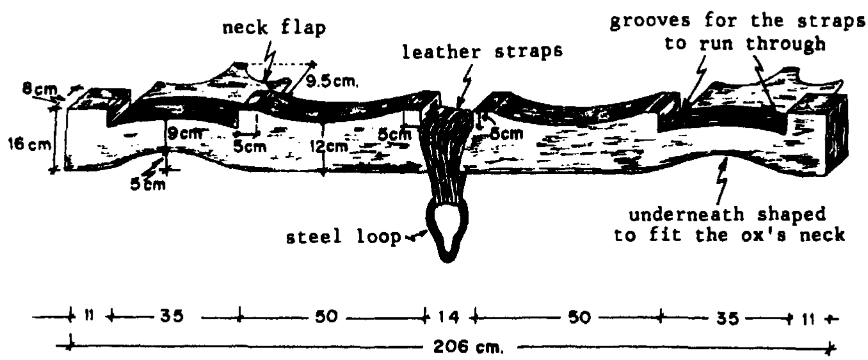
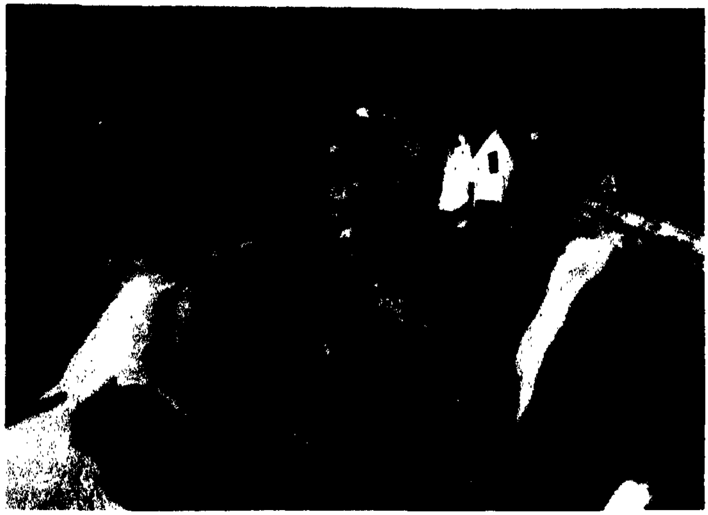


Fig. 4 Double head yoke for skidding oxen

A steel loop is fixed with leather straps in the middle of the yoke. Through this loop passes the chain that suspends or drags the load. As the loops vary in dimensions and sizes, only the most important characteristics are mentioned, namely: it is approximately 1 cm thick and pear-shaped, with a larger upper part and smaller lower part with an internal distance slightly less than the width of the link. In this way only a small turn needs to be given to the chain when loading or unloading in order to fix or release it, and the traces may be quickly and easily shortened or lengthened.



Oxen with double head yoke (CEFOR, Universidad Austral de Valdivia, Chile)

The advantages of the double head yoke over other types, listed by FAO (1983), are as follows:

a) 'Greater use is made of the animals' weight as a power source. The yoke is firmly attached to the animals' horns as against free movement on the shoulders. Pull is more even, with no loss of power in taking up the slack...

b) 'As the two oxen are firmly yoked together, they operate better as a team and coordinate their movements, together making maximum use of their combined pulling power.

c) 'When actually skidding logs the animals adapt themselves to controlling the movement of the timber by raising or lowering their heads which in turn increases or reduces the pull required to move the logs.

d) 'Oxen can be trained to pick up loads at awkward angles by facing the load, then pulling the load clear by walking backward until the load is free of obstacles ready for normal skidding in a forward direction.'

2.4.1.2 Yoking straps

These are leather straps used to tie the yoke to the ox's horns. Two are used, each about 2 m long and 1.5 - 2 cm wide.

2.4.1.3 Chains

This secures the load. It is about 5 m long and 6/16 of an inch thick. It is passed through the loop in the yoke and depending on the load to be transported has either hooks or clamps attached.

a) Chain with hooks

This is used when the chain can go under the load, usually when the logs are not very heavy or in circumstances where fastening poses no problem (see Fig. 5).

It is simple to use. The chain is passed under and around the load, and the hook fastened in.

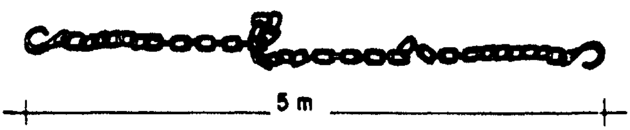


Fig. 5 Chain with hooks for skidding with oxen

b) <u>Chain with clamps</u>

The Chilean ox-drivers call these 'cats'. They are used particularly in natural forests for large-diameter heavy logs, where it is difficult to move the logs or pass the chain underneath. Two clamps on short chains linked to a ring are attached to the outside of the log without loss of time in loading and unloading (see Fig. 6).

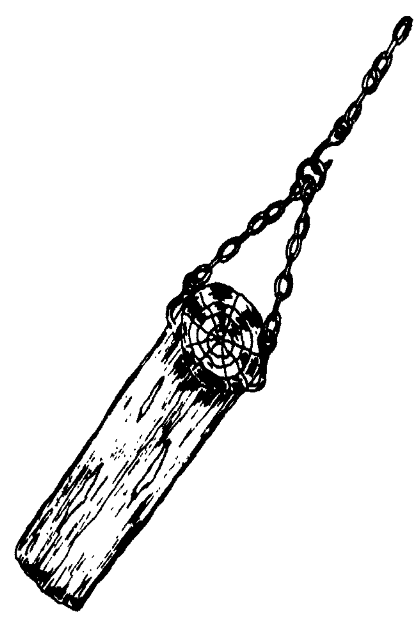


Fig. 6 Chain with clamps for transporting large-diameter logs

When the clamps are at the right angles and are well sharpened, it is not necessary to hammer them in to fasten them to the logs. It is enough to put them on by hand. When the oxen pull the load, they should remain firmly attached to the log.

In both the above cases it is usual to fasten only one end of the chain to the load, leaving the other rolled round the yoke. This saves time and increases output, since the driver needs to handle only one part of the chain.

2.4.1.4 <u>Goad</u>

A thin wooden stick about 3 m long helps the driver to guide and drive the oxen (Fig. 7). Some drivers put a prong on the end of the goad, but if the oxen are well trained and the drivers experienced, this is not necessary.

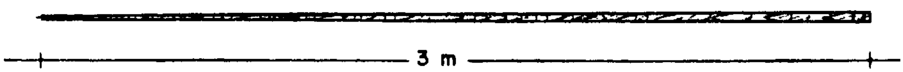


Fig. 7 Goad to guide and drive oxen

2.4.2 <u>Harnessing the oxen</u>

Harnessing the oxen is simple and is virtually limited to tying and securely adjusting the yoke to the horns and neck. However, care should be taken to avoid discomfort in the animals or the risk of accident if the yoke shifts when the load is dragged.

Team of oxen harnessed with skidding equipment (CEFOR, Universidad Austral de Valdivia, Chile)

One important point in teaming oxen for skidding is to ensure that as far as possible the two animals are well matched in height and shape. In this way their energy is put to greater use and the work is better balanced.

2.5 SKIDDING TECHNIQUE

The output and costs of skidding with oxen are favourably or adversely affected by the way in which forest utilization has been planned.

2.5.1 <u>Felling and its influence</u>

Felling in both plantations and natural forests should be planned to minimize later activities, including transport of the load by oxen.

When felling (including thinning) is selective, the trees must be made to fall in such a way that the oxen can reach the load without difficulty.

In areas of clear-felling too, planning is very important. If the trees fall in the same direction skidding is facilitated in various ways:

a) The skidding area can be divided into strips approximately 10 m wide, with one team of oxen working each strip. This avoids their crossing in front of or meeting another team on the same path. In debranching the branches can be conveniently piled at the side of the strip, and the skidding tracks remain clear.

b) The load should be picked up systematically, first the logs nearest the landing and last those farthest away. In this way as the whole area, including the paths, is gradually cleared, the movement of the oxen becomes progressively easier; they do not have to move in a zig-zag to avoid obstacles.

c) The risk of accidents is avoided.

Controlled felling and division of the area into strips
(Nacimiento, Chile)

2.5.2 Arrangement of the load

Even if felling is controlled, it is unlikely that several large and heavy logs will be lying together. These are therefore collected, using the oxen, and secured (by hand) with the chain at some 30 cm from the end of the load to prevent it from breaking loose when the oxen pull it.

Thin logs are collected by hand. A piece of wood about 15 cm across and 1.50 m long is placed on the ground, and the logs are stacked on it with a clearance of 30 cm at the ends. This facilitates fastening and subsequent transport (see photograph).

Irrespective of the type of load to be transported the following errors should be avoided: dragging a very small load; putting too many logs in one load; preparing the load in an inconvenient or awkward place (Soto, 1970).

Thin logs arranged in piles (Nacimiento, Chile)

2.5.3 Paths

Paths should be defined before felling starts, and should take the shortest route, with the minimum number of curves, to the landings. Some research recommends a maximum length of 50 m on level ground, 15 m uphill and 200 m downhill (FAO, 1983).

When the path has to be retraced several times, it is important that it should be clear of obstacles such as branches and sticks. Any stumps should be levelled, and abrupt changes from a positive to a negative slope or vice versa should be avoided.

2.6 METHODOLOGY OF STUDIES OF SKIDDING WITH OXEN

These studies on skidding with oxen were not planned in advance; information was collected on the spot during normal forest harvesting operations. So that skidding could be analysed in its traditional form no changes in the system were suggested to the ox-drivers. In the same work place the parameters described in this study were recorded using different teams of oxen, taken at random over several working days, although it was ensured that each animal weighed approximately 600 kg. This method was chosen to avoid the effect of a greater or lesser output that might be produced by one pair of animals only, due to experience, age, weight, hauling capacity or the skill of the driver.

Skidding included only minor transport; the loads were hauled over the ground with chains, with total friction between the lower surface of the load and the soil.

For each work cycle, the volume of the load was determined, the distance was measured and the gradients were ascertained in stretches of 5 m, to calculate the average slope per cycle and group them by degrees of gradient.

The times and output were recorded on the basis of the effective working hour and included only those supplementary times related to skidding as such, excluding loss of time for accidents and rest periods, e.g. for eating, during the working day.

It should be mentioned that the equations of time per cycle were obtained by using minimum squares and were the basis for the equations of time per m^3 and the output.

2.6.1 Skidding in radiata pine plantations

In radiata pine forests, depending on requirements and utilisation of the forest resource, it was usual to extract sawlogs and pulpwood. In the first case, one to four or more logs could be skidded each time. The driver collected them together, using the team of oxen, until he had obtained the desired load. In the second case, the bolts were piled up so that loads were almost uniform in volume, with 6 to 16 or more bolts per load.

Under the above conditions and on the same worksite, skidding was mixed as regards the type of logs (sawlogs or pulpwood); that is to say, they could be transported simultaneously but in different ways, it being usual to load sawlogs first and pulpwood afterwards.

In all the cases studied skidding paths had not been prepared in advance, and the information was collected in a dry period in two different areas, sloping and level.

2.6.1.1 Skidding in sloping areas

The study was made in a forest enterprise 1/ where 20 percent of the extraction of raw timber was by wheeled forest tractor and 80 percent by oxen - percentages relating to roughly 6 000 and 22 000 m^3 of raw timber per month. The volume was significant, considering that these extraction systems were helping to supply a sawmill that in 1981 had a production capacity of 97 700 m^3 of sawn wood annually (equivalent to 232 000 m^3 of round timber), a pulp and paper factory with an annual capacity of 68 700 tons of newsprint (equivalent to 235 000 m^3 of round timber, and a thermal plant that was consuming 12 000 m^3 of raw timber per month; as well as selling surplus timber to other forest enterprises. The number of ox teams fluctuated between 100 and 150 a month.

The area studied was in the 'Fundo Pichun' (Pinchun estate) on the coastal range of mountains at an average height of 30 m above sea level, near the city of Nacimiento in Province of Bio-Bio. The terrain was in general very rough, with slopes in some places above 30 percent.

The soils belonged to the San Esteban series, coming from granite rocks. The first 30 cm of the profile (generally the soils to be considered in skidding) were of a sandy clay texture, prismatic structure and very plastic, adhesive and friable.

The work was being carried out without a specific management system in a forest of radiata pine with the following characteristics: age 22 years, average height 30 m; average diameter 26 cm; 380 trees/ha; basal area 46 m^3/ha; average volume 448 m^3/ha.

The dimensions of the logs transported for sawing were: length 4 m, minimum diameter 18 cm; and for pulpwood, length 2.44 m, minimum diameter 10 cm, maximum 18 or 20 cm.

The system used was clear-felling with controlled fall. The skidding area for each team of oxen was divided into strips about 10 m wide and variable in length.

This study covered 10 working days. The seven ox teams studied were on average seven years old with a minimum of one year's experience in forest work. Each ox weighed between 500 and 700 kg.

Skidding of pulpwood was on slopes from 0 to -30 percent (downhill with load). A total of 79 working cycles was distributed in the following way: 1 to -10 percent, 13 cycles: -10.1 to -20 percent, 45 cycles: on gradients of more than -30 percent, 21 working cycles.

1/ The INFORSA (Industrias Forestales S.A.) Industrial Complex

In skidding sawlogs, 112 cycles were analysed, both up and down the slope. They were distributed in the following way: a) downhill with load on gradients of -15 to -20 percent, 36 cycles; -20.1 to -25 percent, 38 cycles; -25.1 to -30 percent, 11 cycles; b) uphill with load on the gradients of +10 to +20 percent, 26 cycles.

Results, analysis and discussion

a) Speed and load

Table 4 shows the average values of speed and load in skidding in hilly areas.

Table 4

AVERAGE SPEED AND LOAD IN UNITS AND VOLUME PER DEGREE OF GRADIENT IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN

Class of logs	Degree of gradient %	Speed (cm/s)			Average load	
		Trip without load	Trip with load	Average	Units	Volume m^3
Sawlogs	- 25.1 to - 30	50.72	49.48	50.10	3.00	0.794
Sawlogs	- 20.1 to - 25	50.08	48.19	49.14	2.92	0.679
Sawlogs	- 15 to - 20	48.11	42.32	45.22	3.36	0.718
Sawlogs	+ 10 to + 20	64.58	45.88	55.23	2.00	0.386
Pulpwood	> than - 30	47.42	40.63	44.02	16.27	0.509
Pulpwood	- 10.1 to - 20	65.73	37.10	51.41	15.74	0.509
Pulpwood	0 to - 10	72.35	42.34	57.34	13.23	0.509

The average speed of the oxen when moving downhill with a load of sawlogs was 47 cm/s, and with pulpwood it was 40 cm/s. The average speed uphill without load in both cases was 56 cm/s.

From the above it may be seen that they went faster with sawlogs. This was because when transporting pulpwood the drivers had to handle the animals more carefully to avoid upsets and loss of time to restack the units.

The speed with load uphill on a slope of +10 to +20 percent was 46 cm/s, which is considered acceptable for the volume transported. The average volume was 0.39 m^3, which is low compared with the other cases studied, but it is probable that increasing the volume reduced the speed.

The average load in skidding pulpwood almost always tended to be constant although the number of units depended on the unit volume. The workers responsible for putting together and piling up the bolts were not the drivers, who generally prepared loads of 0.50 - 0.70 m^3; for this reason, an average was found for the three cases analysed.

In transporting sawlogs, the driver selected the units and approximate volume to be transported. According to how much the downward slope increased, he could increase the load, since the steeper the inclination the greater the effects of gravity and the less effort required from the oxen.

For skidding downhill, the drivers did not normally reduce the volume of the load when the gradient of the slope increased, except in very steep slopes but experience had taught them that when skidding uphill the load should be reduced considerably. In this study, the volume of load transported uphill ranged between 0.30 and 0.40 m^3.

In skidding sawlogs of radiata pine the maximum volume was 1.71 m^3 on a slope of -17.5 percent and 1.51 m^3 on an average slope of -30 percent, equivalent to 1 809 and 1 598 kg respectively 1/, hauled by a team of oxen weighing about 600 kg each. However, this does not mean that these are the maximum or optimum loads in this type of skidding.

b) Time

Tables 5 and 6 show the time equations obtained per cycle and per m^3 to skid sawlogs and pulpwood over different types of slope.

TIME EQUATIONS PER WORKING CYCLE IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN, BY DEGREES OF SLOPE

Class of logs	Degree of slope %	Equation
Sawlogs	- 25.1 to -30	t = 575.968 + 7.566 x
Sawlogs	- 20.1 to -25	t = 534.951 + 7.838 x
Sawlogs	- 15 to -20	t = 915.721 + 5.610 x
Sawlogs	+ 10 to +20	t = 53.578 +11.172 x
Pulpwood	> than -30	t = 313.322 + 7.182 x
Pulpwood	- 10.1 to -20	t = 294.099 + 6.872 x
Pulpwood	0 to -10	t = 251.335 + 6.724 x

t = Time, in centiminutes

x = Distance, in metres

Table 6

TIME EQUATIONS PER m^3 IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN, BY DEGREES OF SLOPE

Class of logs	Degree of slope %	Equation
Sawlogs	- 25.1 to - 30	T = 725.400 + 9.529 x
Sawlogs	- 20.1 to - 25	T = 787.851 + 11.543 x
Sawlogs	- 15 to - 20	T = 745.057 + 10.196 x
Sawlogs	+ 10 to + 20	T = 138.803 + 28.943 x
Pulpwood	> than - 30	T = 525.725 + 12.050 x
Pulpwood	- 10.1 to - 20	T = 493.455 + 11.530 x
Pulpwood	0 to - 10	T = 421.703 + 11.282 x

1/ 1 m^3 of green radiata pine = 1 058 kg (Railways of Chile, quoted by Pugin, 1981)

From Fig. 8 it may be seen that the time per cycle of skidding on slopes of + 10 to + 20 percent was less than for skidding downhill, which may at first sight seem strange. However, when more than one sawlog was transported over short distances, the terminal time of loading became an important factor in the total time of the cycle. In the case of a slope of + 10 to + 20 percent, the number of logs skidded was reduced because of the greater effort required from the oxen, and the terminal time to put together the two logs (the average number in the study) was less than when skidding downhill. In the latter case, the number of logs was 3.36 for - 15 to - 20 percent, 2.92 for - 20 to - 25 percent and 3.00 for - 25.1 to - 30 percent. With a steeper downhill slope, the quantity of logs that could be skidded dropped because of the risk involved, and therefore the total time of the skidding cycle dropped.

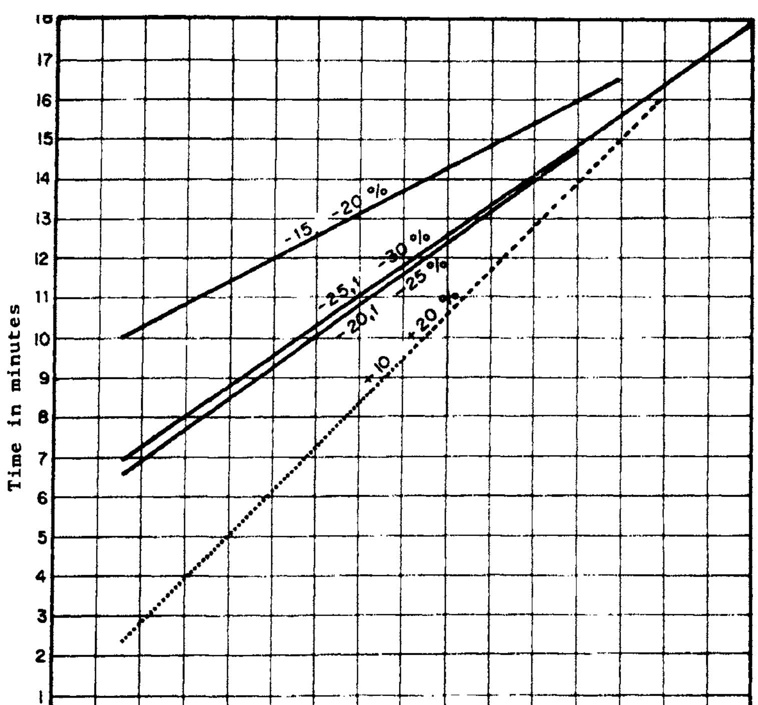


Fig. 8 TIME IN MINUTES PER WORK CYCLE TO SKID SAWLOGS WITH OXEN ON DIFFERENT DEGREES OF SLOPE

For pulpwood the situation was different. The load might consist of 6 to 16 bolts (or more) which were so closely stacked that when the chain was fastened it was as though they were only one log.

Because of this, the loading time for pulpwood varied little while that for sawlogs was more variable, depending on their number and how far apart they were.

Unloading time was much less than that for loading. It depended on the slope in the unloading area and the way the driver placed the oxen when he unfastened the load. On level ground the time tended to be less than on sloping ground. In the latter case, if the oxen remained facing at right angles to the slope, the time was greater than if they faced in the same direction. Because the load lay between the oxen, the driver was much more careful in loosening it to avoid the logs rolling and injuring the animals.

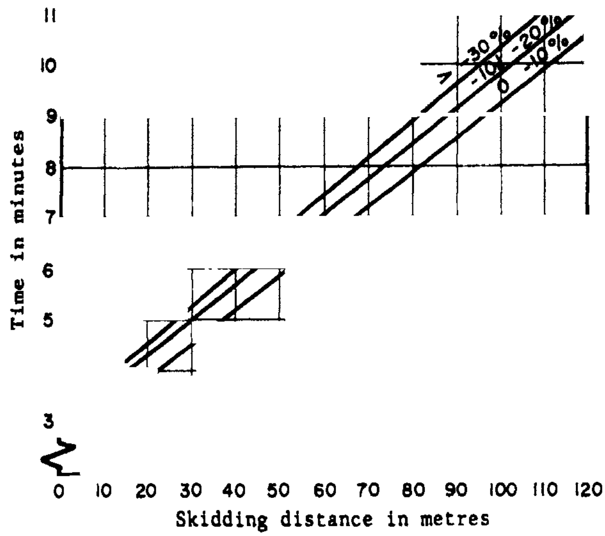
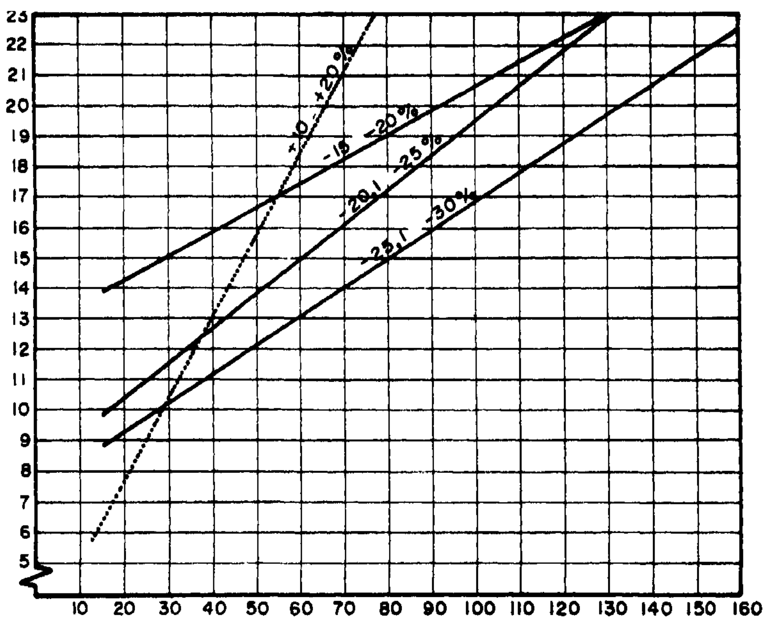


Fig. 9 TIME IN MINUTES PER WORK CYCLE TO SKID PULPWOOD WITH OXEN ON DIFFERENT DEGREES OF SLOPE

In practice the drivers usually positioned the oxen in the opposite direction to the slope so that later the stacking would be easier because helped by gravity.

Terminal times recorded for pulpwood bolts were between 2 and 2.7 minutes, of which 60 percent was for loading. For sawlogs, they fluctuated between 2.5 and 7.15 minutes, 80 percent for loading and 20 percent for unloading.

An analysis of speed, volume of load and terminal times plus the information contained in Tables 4 and 5 makes it possible to understand and analyse the times per m^3 for each of the cases studied on different levels of slope, and also the behaviour of the graph lines in Figs. 10 and 11.



Skidding distance in metres

Fig. 10 TIME IN MINUTES PER m^3 TO SKID SAWLOGS WITH OXEN ON DIFFERENT DEGREES OF SLOPE

It may be observed from Fig. 10 that the time per m^3 to skid uphill is acceptable for short distances, but as the distance increases the time also increases considerably.

Developing the time equations per work cycle and per m^3, the values of time for different distances of skidding sawlogs and pulpwood were obtained, and are shown in Tables 15 and 17 in Appendix 5.

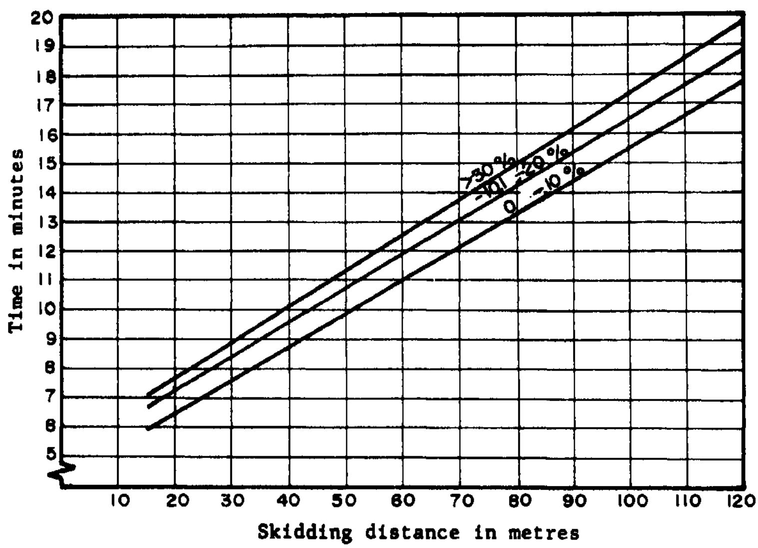


Fig. 11 TIME IN MINUTES PER m^3 TO SKID PULPWOOD WITH OXEN ON DIFFERENT DEGREES OF SLOPE

c) Output

Table 7 shows output expressed in m^3/h. Replacing this by values of distance shows the output for different degrees of slope, whose results appear in Tables 15 and 17 in Appendix 5, also shown in Figs. 12 and 13.

Table

OUTPUT EQUATIONS IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN BY DEGREES OF SLOPE

Class of logs	Range of slope %	Equation
Sawlogs	- 25.1 to - 30	$0 = \frac{4\,764}{575.968 + 7.566\,x}$
Sawlogs	- 20.1 to - 25	$0 = \frac{4\,074}{534.951 + 7.838\,x}$
Sawlogs	- 15 to - 20	$0 = \frac{4\,308}{915.721 + 5.610\,x}$
Sawlogs	+ 10 to + 20	$0 = \frac{2\,316}{53.578 + 11.172\,x}$
Pulpwood	> than - 30	$0 = \frac{3\,576}{313.331 + 7.182\,x}$
Pulpwood	- 10.1 to - 20	$0 = \frac{3\,576}{294.099 + 6.872\,x}$
Pulpwood	0 to - 10	$0 = \frac{3\,576}{251.335 + 6.724\,x}$

0 = output in m^3/h

x = distance in metres

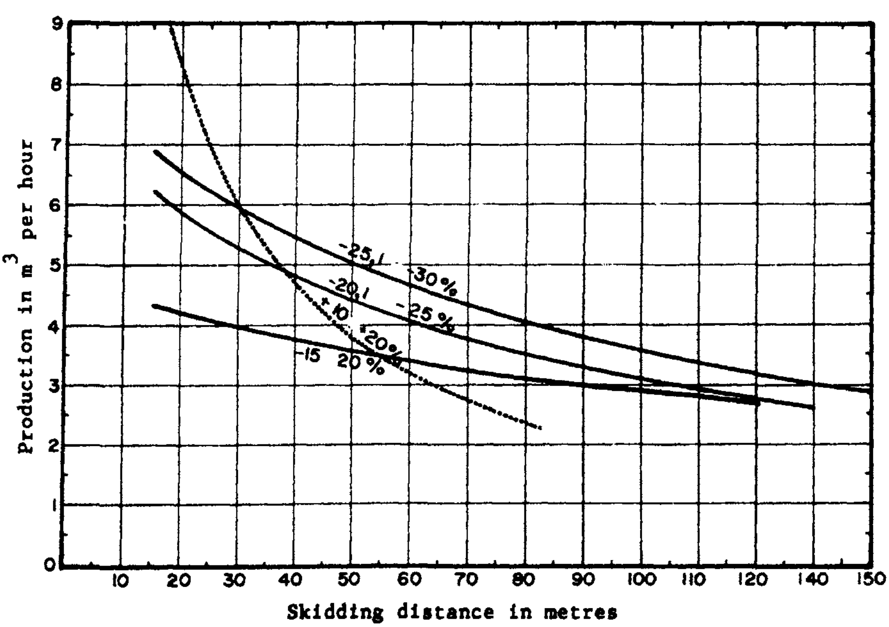


Fig. 12 OUTPUT IN m^3/h IN SKIDDING SAWLOGS WITH OXEN ON DIFFERENT DEGREES OF SLOPE

The output in skidding sawlogs uphill decreases sharply as the distance increases, the critical point being at about 55 m.

It should be pointed out that in skidding sawlogs speed of movement and volume tend to be greater than in skidding pulpwood, however, output is lower because more time is spent in loading.

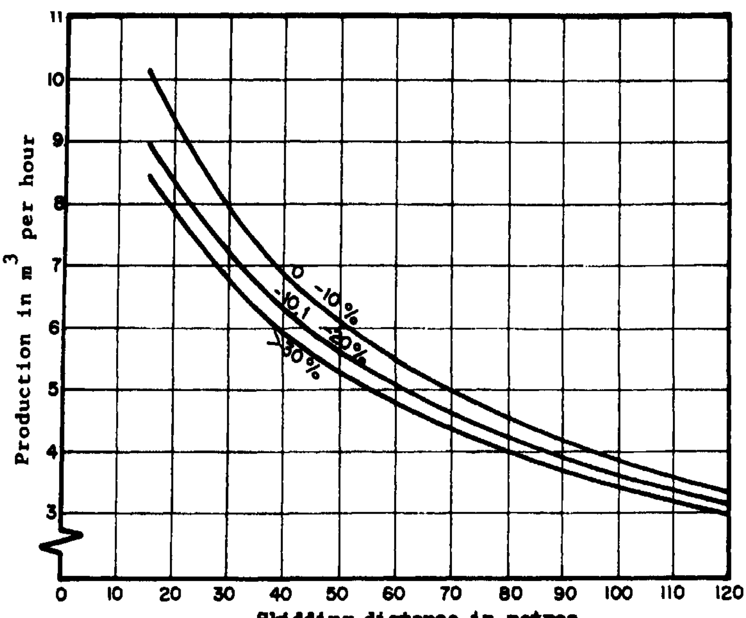


Fig. 13 OUTPUT IN M^3/h TO SKID PULPWOOD WITH OXEN ON DIFFERENT DEGREES OF SLOPE

d) <u>Costs</u>

Table 8 gives the cost equation per m^3 for skidding sawlogs and pulpwood with oxen.

Table 8

COST EQUATIONS PER m^3 IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN

Class of logs	Degree of slope %	Cost equations Ch$[1/]	US$
Sawlogs	- 25.1 to - 30	C = 9.7131 + 0.1276 x	C = 0.1120 + 0.0015 x
Sawlogs	- 20.1 to - 25	C = 10.5493 + 0.1546 x	C = 0.1217 + 0.0018 x
Sawlogs	- 15 to - 20	C = 17.0773 + 0.1046 x	C = 0.1970 + 0.0012 x
Sawlogs	+ 10 to + 20	C = 1.8586 + 0.3875 x	C = 0.0214 + 0.0045 x
Pulpwood	> than - 30	C = 7.0395 + 0.1614 x	C = 0.0812 + 0.0019 x
Pulpwood	- 10.1 to - 20	C = 6.6074 + 0.1544 x	C = 0.0762 + 0.0018 x
Pulpwood	0 to - 10	C = 5.6466 + 0.1511 x	C = 0.0651 + 0.0017 x

Cost equations as a function of distance and slope are shown in Tables 16 and 18 in Appendix 5, and in Figs 14 and 15.

1/ US$ 1 = Ch$ 86.70 (16 December 1983)

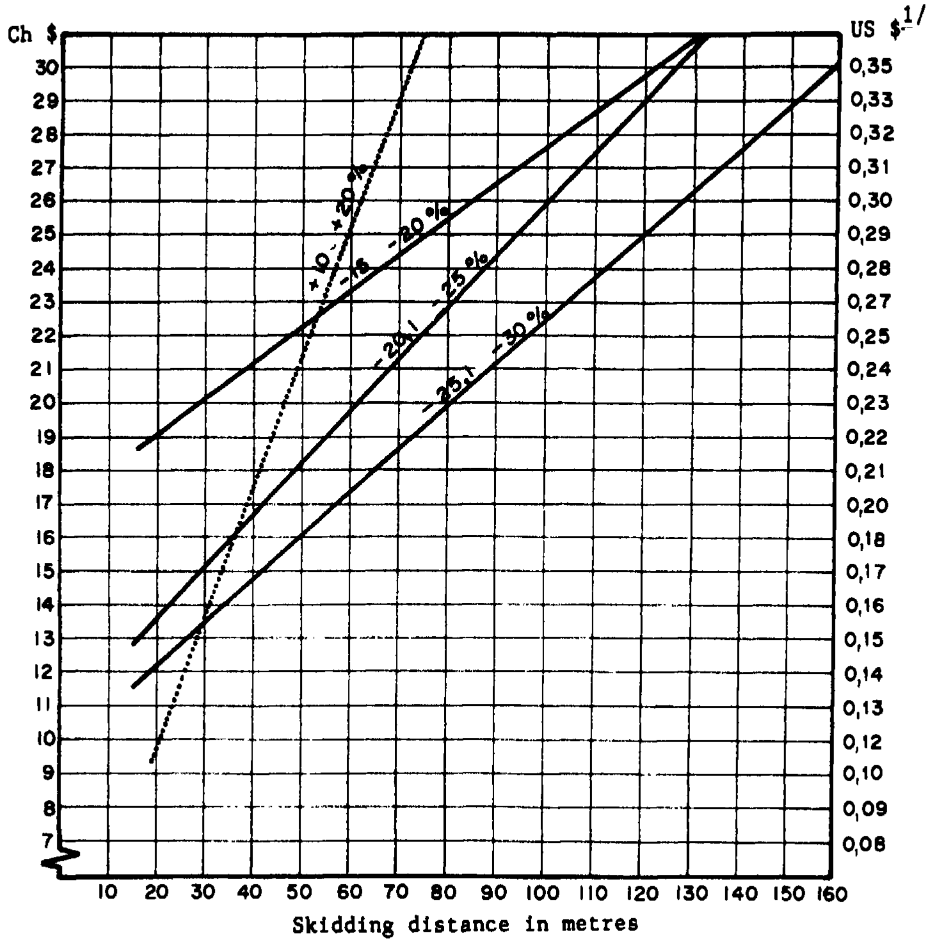


Fig. 14 **COST PER m[3] IN SKIDDING SAWLOGS WITH OXEN IN RELATION TO SLOPE AND DISTANCE**

1/ US$ 1 = Ch$ 86.70 (16 December 1983)

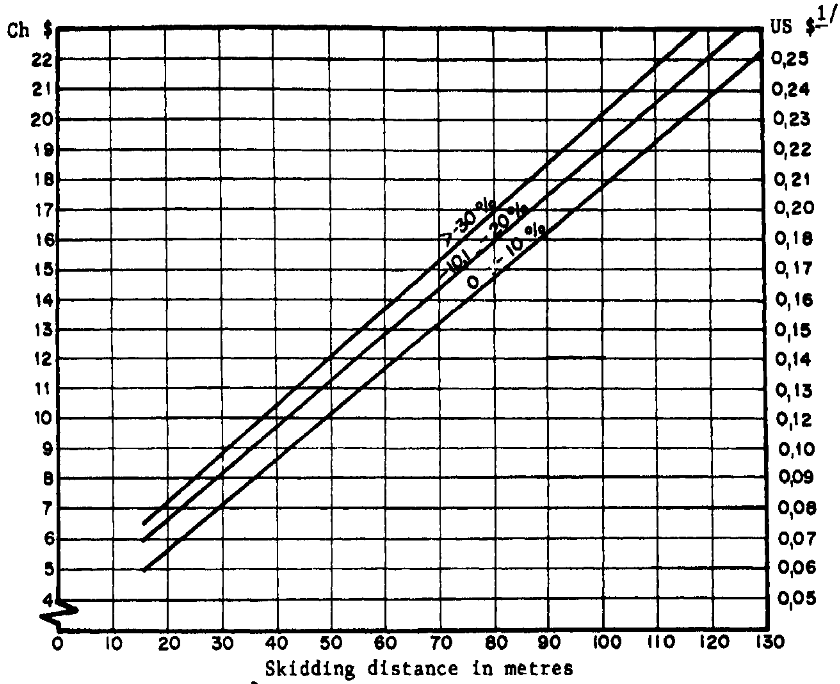


Fig. 15 COST PER m^3 TO SKID PULPWOOD WITH OXEN IN RELATION TO SLOPE AND DISTANCE

2.6.1.2 Skidding on level ground

The area studied was on the Trilahue estate in the Valle Central between the cities of Los Angeles and Cabrero, Province of Bio-Bio.

The estate was 125 m above sea level. The land was generally flat, with slopes no steeper than 3 percent. The predominant soils were sandy, belonging to the 'Coreo' series, of andesitic-basaltic origin, with fast or excessive drainage and low water retention. The profile from 0 to 23 cm had a structure of single particles, loose when dry, non-plastic and non-tacky when wet (Chile/OAS/IDB, 1964).

The Trilahue estate was an area belonging to a forest enterprise[2] which in 1982 owned directly or indirectly 140 000 ha of plantations of radiata pine. It extracted approximately 1 900 000 m^3 of timber a year, some of it exported as logs, some supplied to other enterprises producing pulp and paper, and to the domestic market for saw-wood and fuel. Where data on skidding pulpwood and sawlogs were collected, skidding was, in view of the topography (level), entirely with oxen. On other estates belonging to this enterprise, skidding was done with forest wheeled tractors, oxen and horses.

Skidding was studied over six working days, using three ox teams. On average, each ox was eight years old, weighed 650 kg, and had a minimum of two years' experience.

1/ US$ 1 = Ch$ 86.70 (16 December 1983)
2/ Forestal Mininco S.A.

The specific situations studied were: skidding pulpwood after thinning, with 66 work cycles; skidding of pulpwood after clear-felling, with 56 cycles; and skidding of sawlogs after clear-felling, with 54 work cycles.

Skidding of pulpwood after thinning was, as its name indicates, in a stand where stunted and medium-sized trees of little importance for the stability of the forest had been thinned. The forest was approximately 16 years old, with 1 800 trees/ha and 400 m^3/ha. The intensity of extraction was about 800 trees/ha and the approximate volume 85 m^3/ha. The length of bolts transported was 2.44 m with a minimum diameter of 10 cm.

Information was also collected on skidding pulpwood in a stand 19 years old, with 1 273 trees/ha and an approximate volume of 578 m^3/ha. The bolts transported had a minimum diameter of 10 cm and minimum length of 2.44 m.

Transportation of sawlogs was also studied in a forest 19 years old, with 1 662 trees/ha and an approximate volume of 578 m^3/ha. The logs transported had a minimum diameter of 26 cm and minimum length of 4 m.

Results, analysis and discussion

a) Speed and load Average speed and load are shown in Table 9.

AVERAGE SPEED AND LOAD IN UNITS AND VOLUME, IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN ON LEVEL GROUND WITH DIFFERENT FELLING SYSTEMS

Class of logs	Felling system	Speed (cm/s)			Average load	
		Trip without load	Trip with load	Average	Units	Volume (m^3)
Sawlogs	Clear-felling	56.58	36.54	46.61	1.00	0.417
Pulpwood	Clear-felling	68.11	51.48	59.79	5.18	0.367
Pulpwood	Thinning	76.76	54.58	65.67	11.72	0.289

On level ground oxen made better speed on trips without load compared with their speed on ground with a positive slope. For trips with load the speed dropped, mainly because of the effect of friction, in comparison with the loaded trip downhill.

Similarly, load volumes skidded downhill were greater than those skidded on level ground.

The average load volume of thinning was lower, because the trees thinned were of low volume compared with the average volume of trees in the stand, and the stacked and skidded loads were equal to only one tree. It would have meant a loss of time for the stacker to collect together in the same loading place thinnings equal in volume to two or more trees which, because of the felling conditions, were far apart. It would also have meant a loss of time for the driver to collect the logs of various trees to transport them in one trip over a short distance.

b) Time

The time equations per cycle and per m^3 for the three types of skidding studied are shown in Table 10. The values of their development as a function of distance are are shown in Table 19 in Appendix 5 and Figs. 16 and 17.

Table 10

TIME EQUATIONS PER WORK CYCLE AND PER m^3 IN SKIDDING SAWLOGS AND PULPWOOD ON LEVEL GROUND WITH DIFFERENT FELLING SYSTEMS

Class of logs	Felling system	Time equation per work cycle	Time equation per m^3
Sawlogs	Clear-felling	t = 108.233 + 6.824 x	T = 259.552 + 16.364 x
Pulpwood	Clear-felling	t = 223.900 + 3.948 x	T = 610.082 + 10.757 x
Pulpwood	Thinning	t = 281.569 + 3.850 x	T = 974.287 + 13.322 x

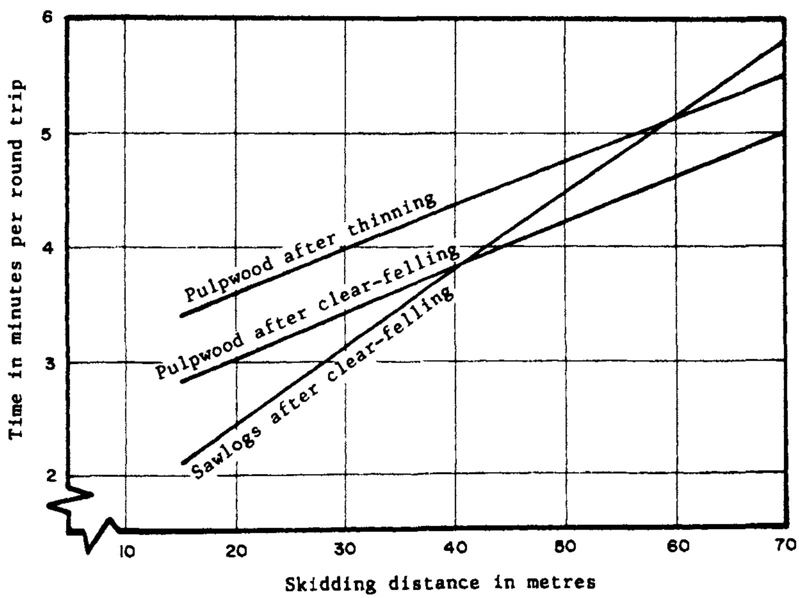
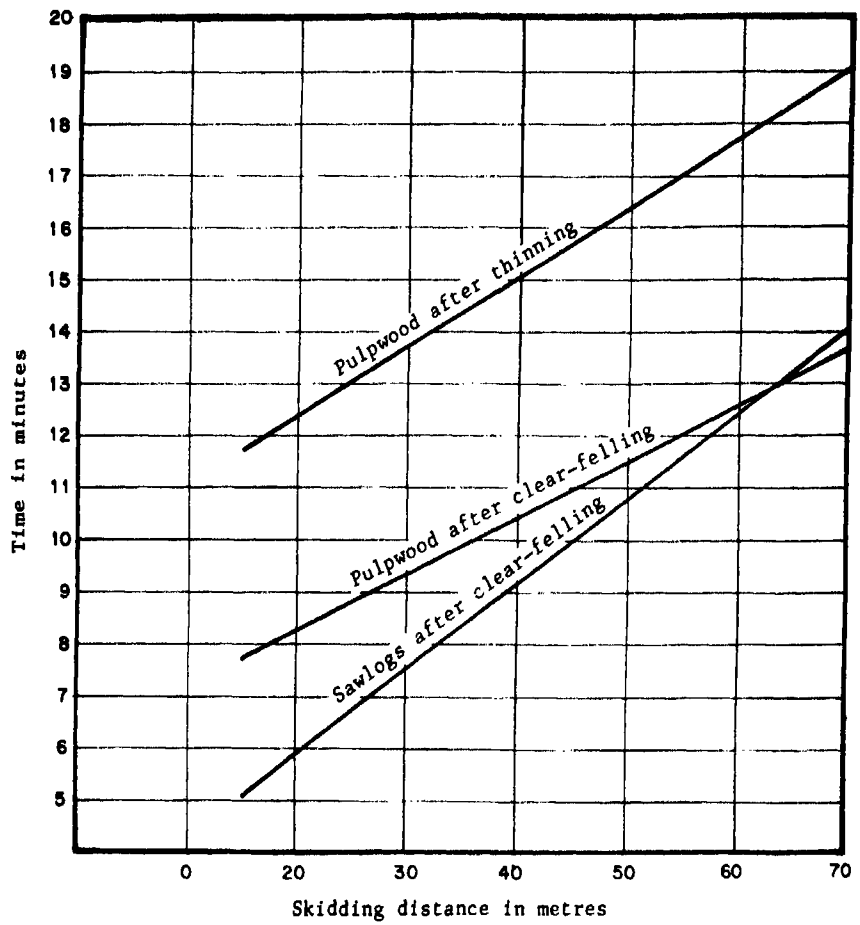


Fig. 16 TIME IN MINUTES PER WORK CYCLE TO SKID SAWLOGS AND PULPWOOD WITH OXEN ON LEVEL GROUND

The terminal times for loading and unloading in the three types of skidding were relatively short. Averages recorded were: 1.80 and 1.50 minutes for pulpwood after thinning and clear-felling respectively, and 0.80 minutes for sawlogs, or 64.37 percent, 63.35 percent and 60.50 percent, in that order.

In skidding sawlogs, terminal times were shorter because there was less handling of units, only one log being transported per trip. But in skidding pulpwood after thinning, where the average load was 11.72 units, the driver spent more time in fastening the load to prevent its working loose with movement. This led to an increase in time per work cycle and per m^3. The considerable volume of the load transported should be noted.
The difference in time per cycle for pulpwood after thinning and after clear-felling were appreciable in the total time necessary to collect 1 m^3 from different distances. Also, the speed developed by oxen in skidding pulpwood after thinning was higher. However, if volumes per load are low, the time necessary to transport 1 m^3 will be greater and output will drop.



F Fig. 17 TIME IN MINUTES PER m^3 TO SKID SAWLOGS AND PULPWOOD WITH OXEN ON LEVEL GROUND

c) Output

Output equations expressed in m^3/h are shown in Table 11; by introducing the distance, values were obtained for the three skidding systems shown in Table 19 in Appendix 5 and Fig. 18.

Table 11

OUTPUT EQUATIONS IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN ON LEVEL GROUND WITH DIFFERENT FELLING SYSTEMS

Class of logs	Felling system	Output equation
Sawlogs	Clear-felling	$O = \frac{2502}{108.233 + 6.824\,x}$
Pulpwood	Clear-felling	$O = \frac{2202}{223.900 + 3.948\,x}$
Pulpwood	Thinning	$O = \frac{1734}{281.569 + 3.85\,x}$

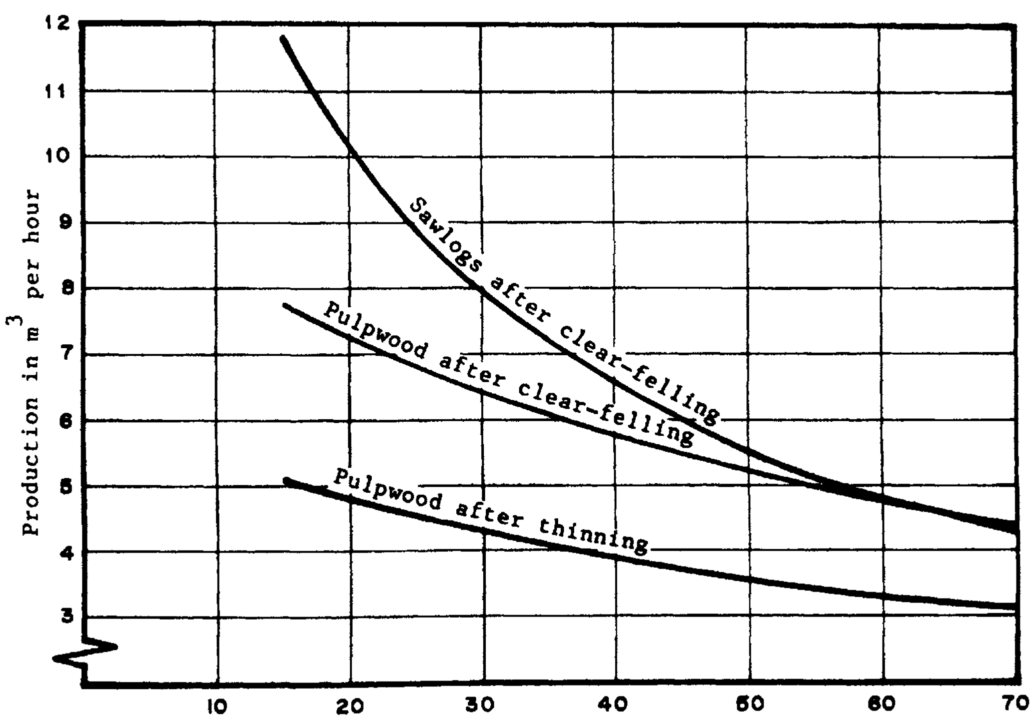


Fig. 18 OUTPUT IN m^3/h IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN ON LEVEL GROUND

The best output obtained on level ground was with sawlogs. This was due mainly to the greater volume of load and lower number of logs transported.

Output after thinning was low because of the way the forest was exploited, namely, selective felling. The small volumes of the trees affected output. It should, however, be pointed out that in this type of exploitation animals are extremely useful because they are easy to manoeuvre, even when the forest is dense.

d) Costs

The cost equations per m^3 for skidding with oxen on level ground are shown in Table 12; they were developed to provide the values for the different felling systems that appear in Table 20 in Appendix 5, on the basis of which Fig. 19 was prepared.

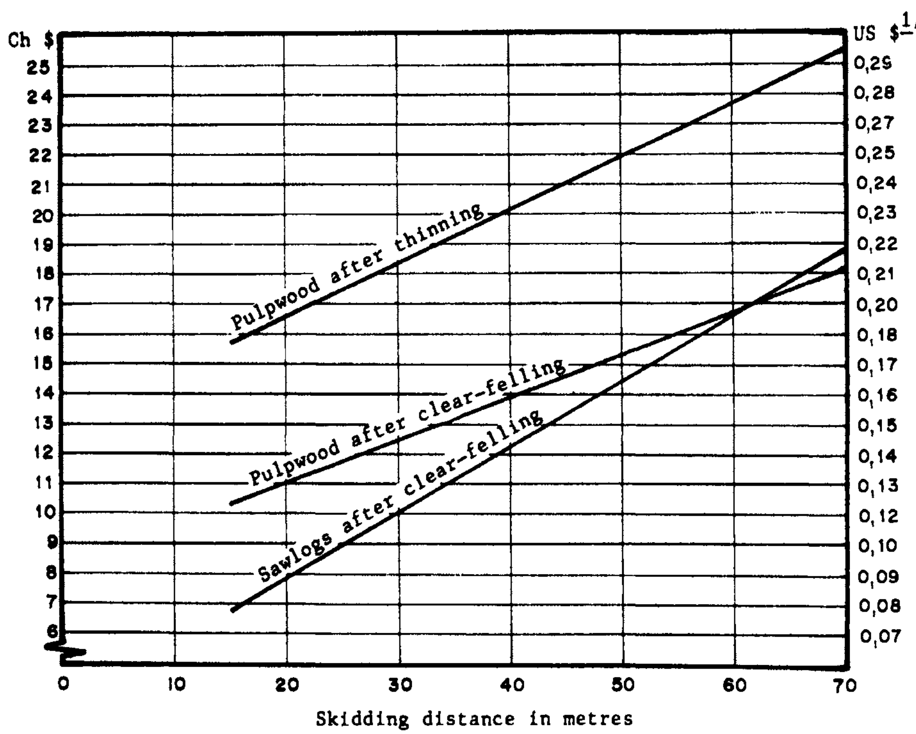


Fig. 19 COST PER m^3 IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN ON LEVEL GROUND

1/ US$ 1 = Ch$ 86.70 (16 December 1983)

Table 12

COST EQUATIONS PER m^3 IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN ON LEVEL GROUND WITH DIFFERENT FELLING SYSTEMS

Class of logs	Felling system	Cost equations	
		Ch$	US$ 1/
Sawlogs	Clear-felling	C = 3.4764 + 0.2191 x	C = 0.0401 + 0.0025 x
Pulpwood	Clear-felling	C = 8.1690 + 0.1440 x	C = 0.0942 + 0.0017 x
Pulpwood	Thinning	C = 13.0457 + 0.1784 x	C = 0.1505 + 0.0021 x

Production costs were considerably higher with thinning than with clear-felling, and were lower for skidding sawlogs.

2.6.2 Skidding in natural forests

Because of the conditions in natural forests as regards location, topography, dispersal of the species to be extracted, density of the forest, volume and weight of the logs, and because of the distances to be covered, skidding with oxen is specially suited to this type of work.

The paths used for skidding are seldom properly prepared; they are narrow, with branches, roots, stumps and other obstacles that make skidding difficult. The slopes of the paths are variable and steep, sometimes up to 60 percent.

When the slope changes, from ascending to descending (usually a very short section), or when a steep slope becomes gentler, the driver should shorted the traces (or chains) to make better use of the power produced by the oxen. In skidding downhill over very steep sections, the traces should be lengthened to prevent the logs from bumping against the hind legs of the oxen and causing them injury; in some cases, the force of gravity causes the logs to move faster than the oxen (see Fig. 20, sections aa and bb).

On the basis of a technical report presented in 1980 by the Complejo Forestal y Maderero of Pangupulli 2/ and conversations with drivers in the zone, skidding distances of up to 1 500 m and an average distance of 700 m were determined. This was largely due to selective exploitation of species which were far away from the landings and the main roads and therefore involved skidding over long distances. In 1980 the volume of timber moved in the Complex was 83 000 m^3, of which 31 000 m^3 were skidded with oxen and 52 000 m^3 with wheeled forest tractors and crawler tractors. Of this latter volume, 31 000 m^3 were moved with oxen to assist the tractors. For skidding the volume mentioned above, a total of 124 teams of oxen was used, which provided an average output per team of 3.25 m^3/day, 75.5 m^3 a month and 500 m^3 a year.

1/ US$ 1 = Ch$ 86.70 (16 December 1983)

2/ An area of natural forest in the Province of Valdivia, covering about 240 000 ha, of which about 50 percent is productive. In November 1983 there were two fixed sawmills with band saws, two portable sawmills, three fixed sawmills with circular saws, and one plywood factory, all small installations.

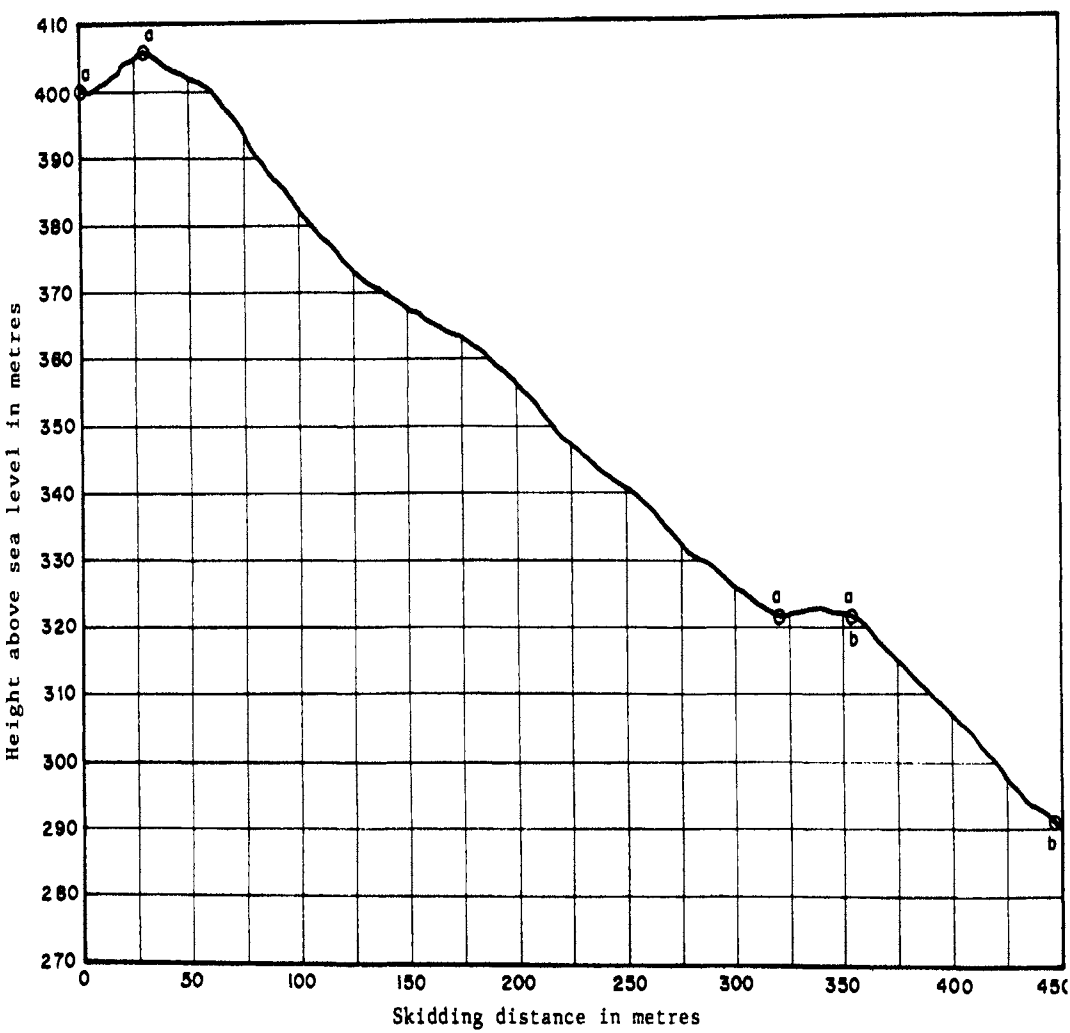


Fig. 20 PROFILE OF A PATH USED FOR OXEN SKIDDING IN NATURAL FOREST

Mention should be made of a type of skidding known as work-sharing that uses two or more ox-teams to haul a log when its weight and volume are too great (usually, above 1 300 kg) for one team to handle.

One technique in work-sharing involves placing two pairs of hooks into the front of the log with one pair on top and the other underneath. The upper pair is dragged by a team of oxen with a short trace in order to raise the log slightly. The lower pair is pulled forward with a longer trace by one or more other teams (see photographs).

Skidding with oxen in natural forest, using the work-sharing system (Neltume, Chile)

Log skidded by the work-sharing method, with chains with hooks attached to the front (Neltume, Chile)

Because of the conditions outlined earlier, skidding in natural forest must be downhill; the drivers must be experienced; and whenever possible two or more ox-teams should work on the same skidding path so that they can help each other by work-sharing when the situation so requires. Because the work is so hard, working time per day should be five to six hours, allowing the oxen a good rest period.

2.6.2.1 Conditions of the study

Skidding with oxen in natural forest was studied in a location of the Province of Valdivia, in the Andes. The altitude is approximately 400 m above sea-level and the topography very rugged. The soils in the area belong to the Malihue series; they are sandy clay, with moderately fine textures up to 65 cm, loose on the surface and slightly hard to hard in depth, friable, slightly plastic and slightly tacky (IREN-UACH, 1978).

The work studied was in a forest past maturity, owned by a forest enterprise[1/]. Extraction was selective, of species with high commercial value: coigue, (Nothofagus dombeyi), laurel (Laurelia sempervirens), lingue (Persea lingue), olivillo (Aextoxicon punctatun), tepa (Laurelia philippiana), tineo (Weinmania trichosperma) and ulmo (Eucryphia cordifolia).

Distribution per ha of trees with a d.b.h. of at least 40 cm was as follows: tepa, 6; ulmo, 2; coigue, 3; olivillo, 3; others (mañío, canelo, laurel, roble) 8-10.

The logs skidded had well defined dimensions depending on the use to be made of them. For sawing they had to be 3.60 m long with a minimum diameter of 0.30 m; for veneer production 2.80 m long with a minimum diameter of 0.48 m.

At the time information was collected for this study there were 30 ox-teams. Of these, four pairs of animals with a weight of approximately 600 kg each were studied. The drivers had more than five years' experience. Work was analysed over five days in which 23 working cycles were recorded over a maximum distance of 460 m.

Skidding with oxen in natural forest (Neltume, Chile)

1/ EMASIL, an enterprise consisting of a plywood plant with a production of 300-350 m^3/month, and a sawmill producing 670 m^3/month. (Information supplied by Germán Oettinger, forester).

The skidding paths were narrow and in most cases obstructed by roots and branches. The average slope of the paths fluctuated between -20 and -32 percent (downhill). On some short sections slopes of up to -60 percent were measured.

Results, analysis and discussion

a) Speed and load

The average speed of the oxen for the idle trip was 0.43 m/s, and for the trip with load 0.40 m/s.

The average load was 1.19 m^3, equivalent to about 1 268 kg.1/ The maximum load recorded was for a coigue (*Nothofagus dombeyi*) log, 2.64 m^3, which is equivalent to 2 905 kg or 1 453 kg for each ox. These volumes may be considered very high, but they are not altogether surprising as the steep slopes made skidding easier.

b) Time

The time equation per work cycle was found as a function of distance, and the time per m^3 as a function of distance and average volume of load.

$$t = 1\,446.138 + 5.130\,x$$

$$T = 1\,218.313 + 4.322\,x$$

where: t = time per work cycle 2/

T = time per m^3 2/

x = distance in metres.

Some time values for different skidding distances, based on development of the above equations, are shown in Table 21 in Appendix 5 and in Fig. 21.

1/ The densities used to calculate the average weight of the load were based on those suggested by Torres (1971) (in t/m^3): coigue, 1.10; laurel, 0.99; lingue, 1.09; olivillo, 1.00; tepa, 1.00; tineo, 1.10; ulmo 1.18.

2/ Time values expressed in centiminutes

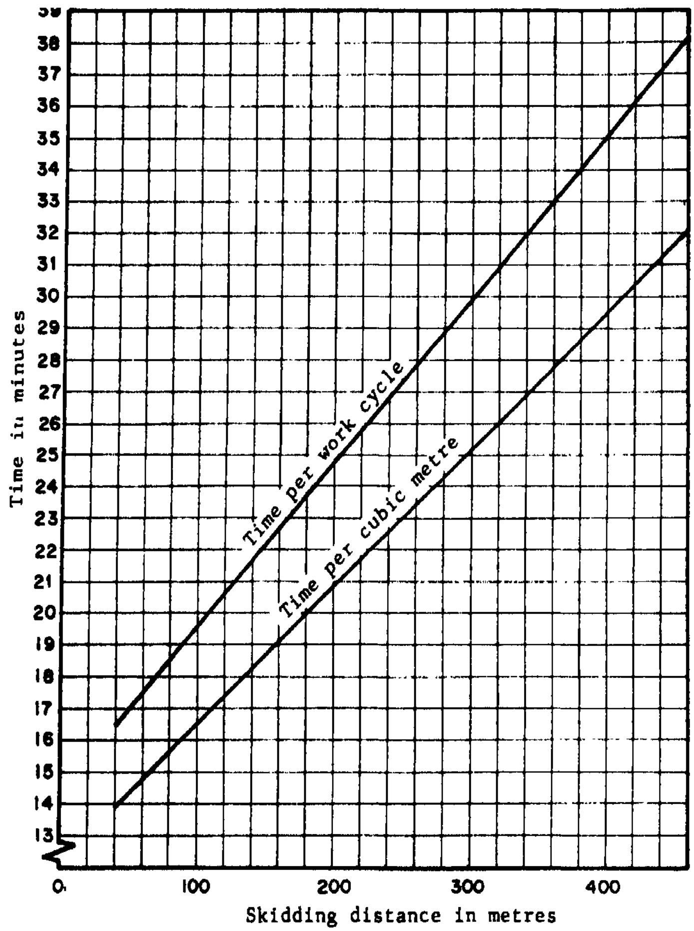


Fig. 21 TIME IN MINUTES PER WORK CYCLE AND PER m^3 FOR SKIDDING WITH OXEN IN NATURAL FOREST ON SLOPES OF -20 TO -32 PERCENT

Of the total time recorded 77.52 percent corresponds to time for the work cycle proper, apportioned as follows: trip without load, 28.72 percent; loading, 14.93; trip with load, 30.58 percent; and unloading, 3.29 percent. (The average actual time of loading was 3.39 minutes, and unloading, 0.78 minutes.) Computable supplementary time accounted for 22.48 percent which was apportioned as follows: 10.05 percent in rest for the oxen, 8.84 percent in lengthening and shortening the traces, and 3.59 percent in removing branches and other obstacles.

The time breakdown gives some idea of the hard work carried out by oxen in natural forest, where the animals have to rest repeatedly to avoid extreme fatigue.

c) <u>Output</u>

The output equation established in this study was as a function of the skidding distance and the volume of load, using an average volume of 1.187 m^3 for all work cycles. It is expressed as follows:

$$O = \frac{7\ 122}{1\ 446.138 + 5.130\ x}$$

where: O = output in m^3/h

x = skidding distance in metres.

Values of output based on the above equation are shown in Table 21 in Appendix 5, and Fig. 22 is also based on them.

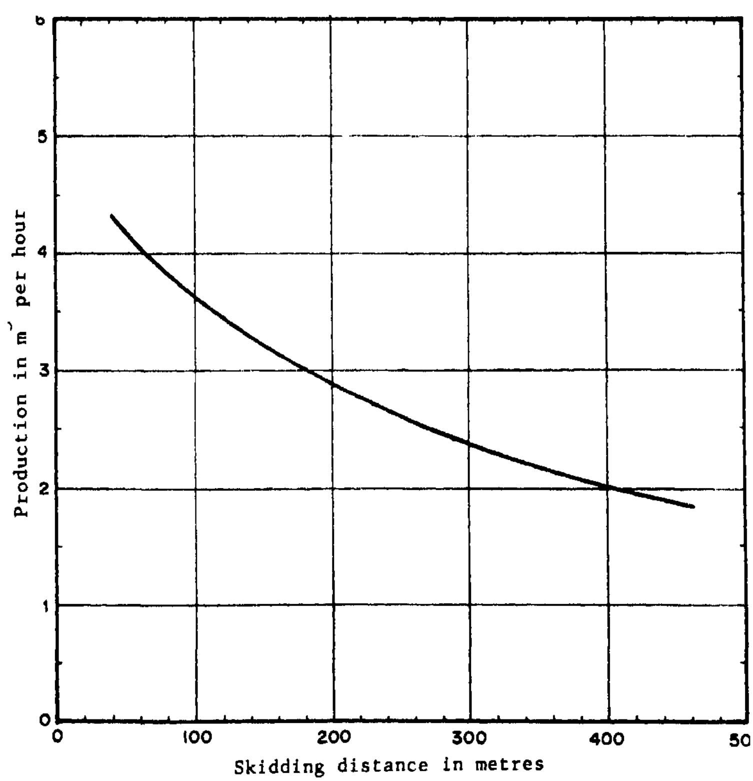


Fig.22 OUTPUT IN m^3/h FOR SKIDDING WITH OXEN IN NATURAL FOREST ON SLOPES OF -20 TO -32 PERCENT

The estimates of output over different distances refer exclusively to time taken in skidding proper and do not include time spent stacking or loading trucks, although the oxen often combine skidding with these jobs. The output per hour for a distance of 460 m was 1.87 m^3.

d) **Costs**

The cost equations obtained as a function of volume and distance were as follows:

$C\ (m^3) = 15.9112 + 0.0564\ x$ (in Ch$)

$C\ (m^3) = 0.1835 + 0.0007\ x$ (in US$)

where: $C\ (m^3)$ = cost in Ch$ or in US$

x = skidding distance in metres.

Table 21 in Appendix 5 shows the costs per m^3 in Ch$ and in US$ for different skidding distances, and Fig. 23 gives a graph of the costs.

The hourly cost of skidding with oxen in natural forests includes the cost of the hooks and chain used for log transport, but does not include the value of normal or special feed per day since oxen doing this type of work are allowed to graze freely around the forests. For this reason the hourly cost is lower than that in radiata pine forests.

It is not usual to skid over short distance in natural forests; in general, the minimum skidding distance is 200 m, giving a value of Ch$ 27.19/m^3, equivalent to US$ 0.31. The cost per m^3 of skidding for 460 m is Ch$ 41.85 or US$ 0.48. 1/

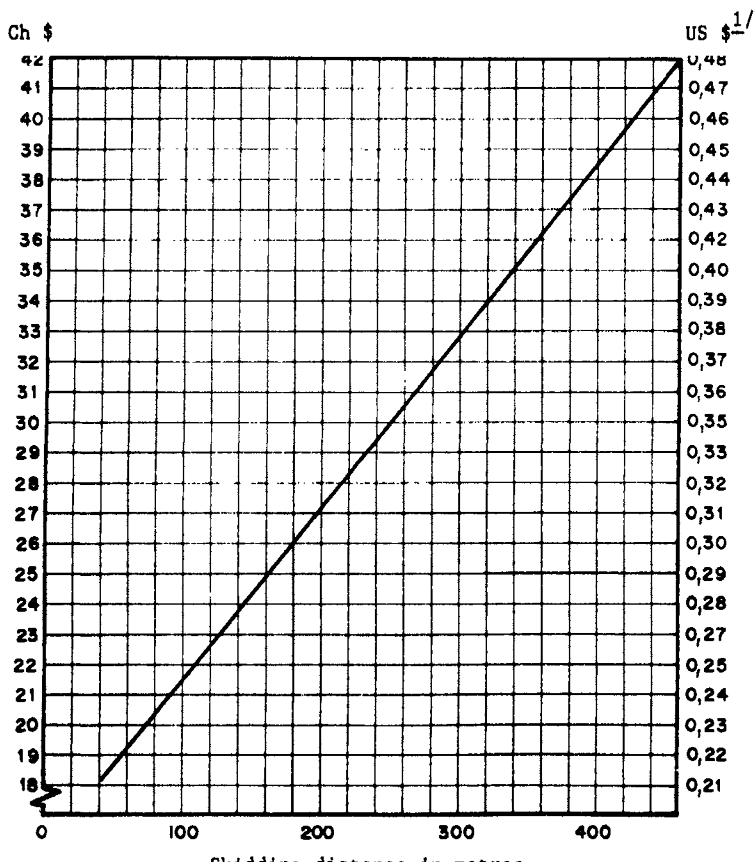
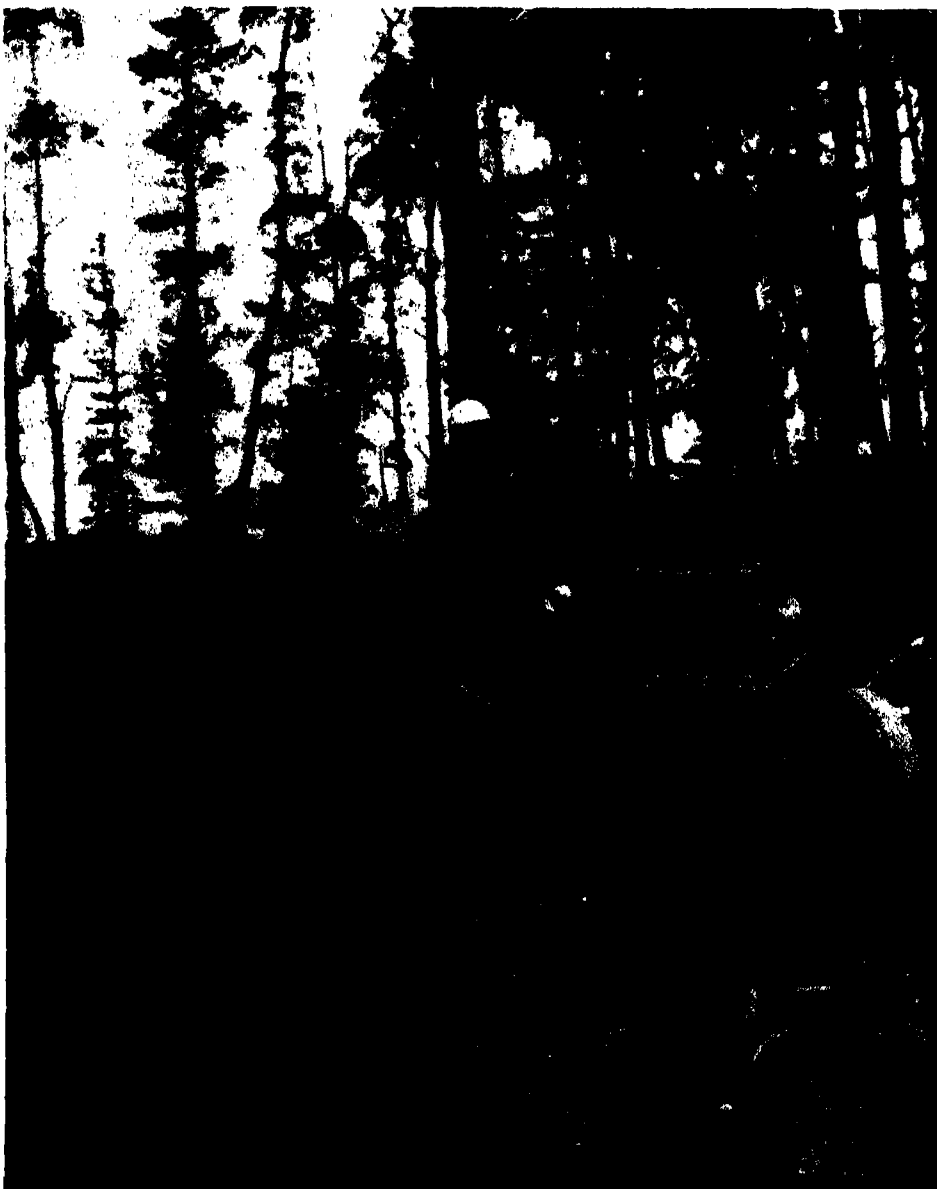


Fig. 23 COST PER m^3 TO SKID WITH OXEN IN NATURAL FOREST ON SLOPES OF -20 to -32 PERCENT

1/ US$ 1.00 = Ch$ 86.70 (16 December 1983)

PART III

SKIDDING WITH AGRICULTURAL TRACTORS



Skidding with an agricultural tractor and winch

3.1 BACKGROUND

Agricultural tractors are a multipurpose tool with many applications, particularly in soil preparation and, to a smaller extent, in sowing, working on grasslands and transporting loads with trailers.

Transporting logs with an agricultural tractor and trailer: (San Ignacio de Palomares, Chile)

In the forestry sector, agricultural tractors are used as a means of transport and for skidding in plantations. For the latter a winch is needed, driven by the tractor's power take-off. There are very few agricultural tractors with this equipment in Chile; they are used mainly by small enterprises and sawmills.

3.2 CONDITIONS OF THE STUDY

The study was made in a radiata pine forest in the neighbourhood of Lastarria, in the coastal mountain range at an altitude of 447 m above sea-level. Topography was undulating and uneven. The soils belonged to the Santa Barbara series, characterized from 0 to 25 cm by being sandy, very fine, slightly plastic and slightly tacky (Chile/OAS/IDB/1964).

The forest was an untended (not pruned and thinned) stand, 32 years old, with an average height of 35 m, average d.b.h. of 48 cm and density of 680 trees/ha. Clear-felling was practiced.

Skidding was of logs 2.80 to 3.60 m long and entire trees 22 m long with a minimum diameter of 20 cm at one end.

Skidding was downhill on an average slope of +5.85 percent and over a maximum distance of 70 m. The paths had not been laid out beforehand, nor were they given any kind of maintenance.

The tractor had no ballast (that is, a weight usually placed on the rear part, either on the chassis or on the driving wheels). For this reason, when very heavy loads, especially whole trees, were pulled, the tractor rose on its back wheels and sometimes tended to skid.

Information for the study was collected over five working days, in which a total of 83 work cycles was recorded, the sample being statistically representative. The tractor driver had seven years' experience and the chokerman three years.

3.3 TECHNICAL CHARACTERISTICS OF THE TRACTOR

(Make - Universal, model U-650 M, medium power)

3.3.1 Dimensions and capabilities

Total height - 2.42 m

Total length - 4.20 m, from the front of the front wheels to the back of the back wheels

Width - 2.05 m measured over the outside parts of the rear mudguards

Weight - 2 980 kg

Minimum turning radius - 3.4 m with a wide gauge front axis

Tractive power - 1 700 kgf, with 20 percent skidding (checked on stubble of ground)

Speeds for one turn of the axis of the crankshaft of 1 800 rpm - (1) 2.58 to 3.83 km/h; (2) 4.16 to 6.16 km/h; (3) 5.78 to 8.56 km/h; (4) 7.68 to 11.38 km/h; (5) 18.18 to 26.94 km/h

3.3.2 Engine

Model - D-110

Type - Diesel, 4-stroke, with direct injection

Nominal continuous power - 65 hp

Turn of crankshaft for nominal power - 1 800 rpm

Moment of engine for nominal turn - 25.8 mkgf

Maximum moment of engine (for 1 250 rpm) - 29.5 mkgf

Number and position of cylinders - 4 vertical cylinders in line

Diameter of the carriage - 108/130 mm

Total cylinder capacity - 4.76 litres

3.3.3 Tires

Front - 6.50 - 20

Rear - 14.0 - 38

3.3.4 Hydraulic system

Pump model - FS-PR3

Pump pressure - 100 kgf/cm2 (minimum) and 130 kgf/cm2 (maximum)

Pump flow - 40 litres/minute

3.3.5 Power take-off

536 rpm for independent take-off; 161.2 - 238.5 rpm in first gear; 260 - 385 rpm in second gear, 359 - 534 rpm in third gear.

3.3.6 Winch

This is mounted on the rear of the tractor. Mechanical operation is produced directly by the power take-off, which turns clockwise and can function independently of the transmission or synchronized with the tractor's speed of movement.

Skidding with an agricultural tractor using the upper pulley of the winch (Lastarria, Chile)

Skidding with an agricultural tractor, using the winch drum (Lastarria, Chile)

Externally, the skidding equipment consists mainly of an upper steel pulley, 8 inches in diameter, which allows short logs to be skidded without friction on the ground, i.e., suspended (see photograph); and a lower winch drum, 18 inches in diameter, driven directly by the power take-off. Used to wind in the cable, its main function is to drag the log up on to the rear of the tractor so that the trip with load can start. The winch drum is used especially in skidding logs longer than 3.60 m (see photograph).

3.4 RESULTS, ANALYSIS AND DISCUSSION

3.4.1 Speed and load

The speed recorded without load was 0.72 m/s, with load 0.68 m/s.

The average volume of skidding per work cycle was 0.69 m^3 and the maximum load was 2.18 m^3, weighing 730 and 2 306 kg respectively. 1/

3.4.2 Time

Of the total time recorded, 11.74 percent was computable supplementary time which was spent mainly in removing obstacles from the track, and making mechanical adjustments. The work cycle took 88.26 percent, apportioned as follows: trip without load, 15.39 percent; loading, 49.12 percent; trip with load, 16.20 percent; unloading, 7.55 percent.

Average loading time was 2.87 minutes, which was relatively high compared with the other moments of the cycle. Loading time was reckoned from the moment when the tractor was parked to the moment when it started moving with the load, and it could not start until the log had been hauled (perhaps 20 - 30 m) and then winched into loaded position.

The time equations, including computable supplementary times, found by means of minimum squares are as follows:

$$t = 531.111 + 1.408\ x$$

$$T = 614.464 + 1.628\ x$$

where: t = time per work cycle in hundredths of a minute

T = time per m^3 in centiminutes

x = logging distance in metres.

The time equation per work cycle is a function of the distance, and that of the time per m^3 is a function of the distance and the average volume of load.

Respective times are obtained by replacing values of distance in the above equations, see Table 22 in Appendix 5 and in Fig. 24.

1/ 1 m^3 of green radiata pine weighs 1 058 kg (State Railways of Chile, quoted by Pugin)

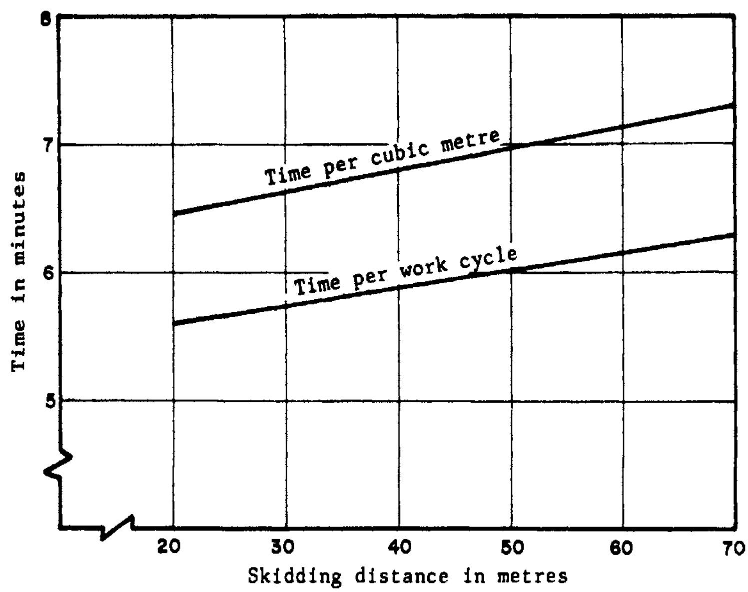


Fig. 24 TIME IN MINUTES PER WORK CYCLE AND PER m^3 TO SKID WITH AN AGRICULTURAL TRACTOR ON SLOPES OF +0.15 TO +9.38 PERCENT

The times per work cycle to skid distances of 20 and 70 m were 5.60 and 6.30 minutes respectively; and the times per m^3 were 6.47 and 7.28 minutes for the same distances.

3.4.3 Output

The output equation is as follows:

$$0 = \frac{5\ 190}{531.511 + 1.408\ x}$$

where: 0 = output in m^3/h

x = skidding distance in metres.

Output for different distances is shown in Table 22 in Appendix 5 and in Fig. 25.

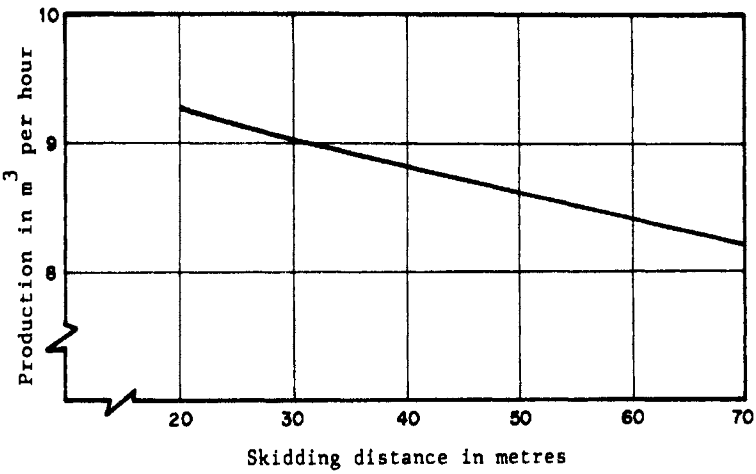


Fig. 25 OUTPUT IN m^3/h TO SKID WITH AN AGRICULTURAL TRACTOR ON SLOPES OF +0.15 TO +9.38 PERCENT

For skidding distances of 20 to 70 m, the output per hour was 9.27 to 8.23 m^3.

3.4.4 Costs

The basic information for calculating the cost of skidding, as regards both the labour force and the tractor, brought up to date to December 1983, will be found in Annex 8. The equations obtained are as follows:

$C (m^3) = 67.400 + 0.1785 x$ (in Ch$)

$C (m^3) = 0.7768 x 0.0021 x$ (in US$)

where: x = skidding distance in metres

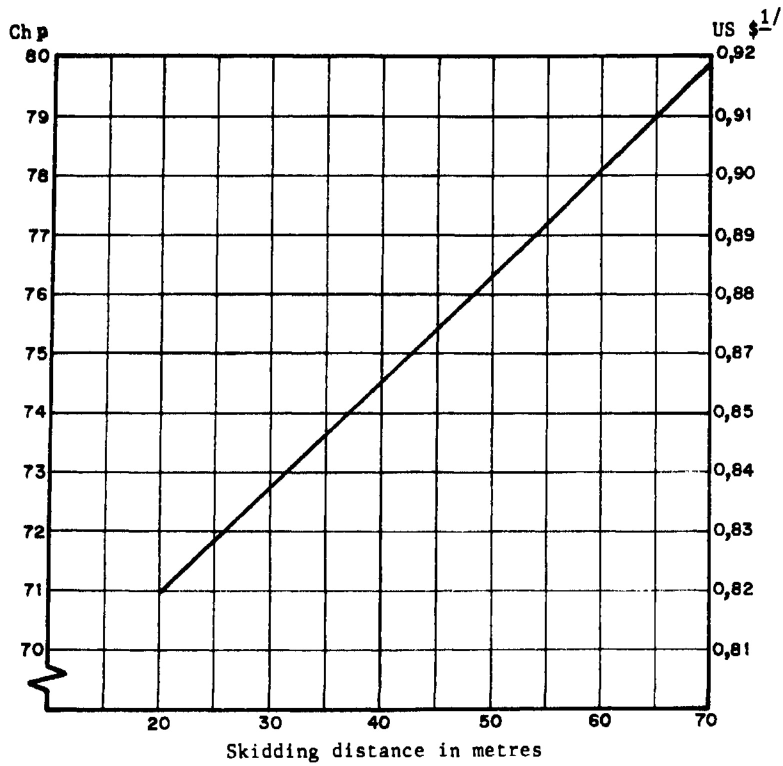


Fig. 26 COST PER m^3 TO SKID WITH AN AGRICULTURAL TRACTOR ON SLOPES OF +0.15 to +9.38 PERCENT

The costs per m^3 in Chilean pesos and US dollars for the distances recorded in the study are shown in Table 22 in Appendix 5 and in Fig. 26

The cost per m^3 to skid with an agricultural tractor for a distance of 20 to 70 m was between Chp 70.97 and Chp 79.89, equivalent to US$ 0.82 and US$ 0.92 respectively.

1/ US$ 1.00 = Ch pesos 86.70 (16 December 1983)

PART IV

CONCLUSIONS AND RECOMMENDATIONS

From both the technical and economic points of view the results from skidding with oxen have been so good that Chilean forestry enterprises with a large production capacity can meet a great part of industrial needs by using these draught animals.

The skidding equipment used with oxen is familiar to the people and within reach of those with limited means. It can be put together by the drivers, who need to purchase only the hooks and chain. Skidding chains have been used for many years with positive results. They are and will continue to be the essential element in skidding with oxen, and although chain could be replaced by cables, ropes or other accessories, it has many advantages over the others. For example, it is easy to handle, it takes up little space, it weighs and costs very little, it enables the load to be quickly fastened and unfastened, and it can be used indiscriminately for skidding sawlogs or pulpwood (for dragging one or several logs of different sizes and on different types of slope).

The use of an agricultural tractor with a winch is more expensive by comparison, because of the cost of investment, repairs, fuel and lubricants. Although output is greater the cost per m^3 is higher, as the following comparisons show.

The study showed that the cost per m^3 using the tractor over a skidding distance of 70 m and a slope of +0.15 to + 9.38 percent was Chp 79.89 (US$ 0.92), a higher amount than with oxen. In natural forest the cost per m^3 over 465 m with oxen was Chp 41.85 (US$ 0.48) for a slope of -20 to -32 percent; in plantations of radiata pine, the cost working uphill (least satisfactory way of skidding with animals) over a distance of 80 m, was Chp 32.86 (US$ 0.38). Chokermen were not used in skidding with a tractor, which can delay loading and has a marked effect on the time of the cycle primarily due to the short skidding distances studied.

The maximum skidding load with oxen was recorded in natural forest, where a team weighing approximately 600 kg each hauled downhill, on an average slope of -31 percent and over a distance of 138 m, a load of 2 905 kg, approaching two and a half times their own weight. In normal conditions in plantations of radiata pine, the weight skidded downhill by a team of oxen is 529 - 1 058 kg (0.50 - 1.00 m^3). In skidding uphill, the weight of the load is 317 - 423 kg (0.30 - 0.40 m^3). In natural forest the weight per load is almost always more than 1 000 kg.

Skidding with oxen should, as far as possible, be downhill, which means less fatigue and longer useful life of the oxen, greater output and lower costs. The principal constraint on skidding uphill is the constant fatigue of the animals and necessarily low volume of load, resulting in a lower output, which drops even further with distance. Skidding uphill should be avoided as far as possible and if it must be done, it is advisable only over short distances on maximum slopes of 20 percent. It is also recommended that oxen should not be worked on marshy ground, since the weight of the animals plus that of the load make movement difficult.

In areas where topographical conditions do not allow machines to enter to extract timber, oxen are the solution, and although the yield is not very high, for many people with limited resources their use provides a means of subsistence.

This study did not cover skidding with horses, and one should be made to bring that made by Soto in 1971 up to date. At that time attempts were being made to introduce horses into skidding and no doubt advances have been made since then. Such a study could be made in the neighbourhood of the city of Constitution, where horses are used for skidding.

The following subjects are recommended for further research on draught oxen: skidding in natural forests over distances of 1 500 m or more; the tractive force and energy produced by oxen; the feed requirements of these draught animals.

Appendix 1

A. CLASSIFICATION OF TYPES OF CHILEAN NATURAL FOREST (Donoso, 1981)

Forest types	Predominant species
Esclerófilo	Quillay, litre, maitén, espino
Palma chilena	Palma chilena, litre, peumo, quillay
Roble-hualo	Roble, hualo, peumo, lingue, olivillo, avellano
Ciprés de cordillera	Ciprés de cordillera, quillay, boldo, litre
Roble-raulí-coigue	Roble, raulí, coigue, laurel, lingue, ulmo
Lenga	Lenga, coigue, raulí, notro, radal
Araucaria	Araucaria, lenga, coigue, roble, ñirre
Coigue-raulí-tepa	Coigue, raulí, tepa, trevo, tineo, canelo
Siempreverde	Coigue, ulmo, tepa, luma, canelo
Alerce	Alerce, coigue de Chiloé, fuinque, mañío
Ciprés de las Guaitecas	Ciprés de las Guaitecas, coigue, avellano
Coigue de Magallanes	Coigue de Magallanes, canelo, maitén

B. PRINCIPAL TREE SPECIES IN AREAS STUDIED

Forest type Oak-Evergreen beech coigue

Common name	Scientific name	Family
Coigue	Nothofagus dombeyi	Fagaceae
Laurel	Laurelia sempervirens	Monimiaceae
Lingue	Persea lingue	Lauraceae
Long-leaved mañío	Podocarpus salignus	Podocarpaceae
Olivillo	Aextoxicon punctatum	Aextoxicaceae
Roble	Nothofagus obliqua	Fagaceae
Tepa	Laurelia philippiana	Monimiaceae
Ulmo	Eucryphia cordifolia	Eucryphiaceae

Forest type Coigue-Raulí-Tepa

Common name	Scientific name	Family
Canelo	Drimys winteri	Winteraceae
Coigue	Nothofagus dombeyi	Fagaceae
Short-leaved manío	Saxegothaea conspicua	Podocarpaceae
Meli	Amomyrtus meli	Myrtaceae
Olivillo	Aextoxicon punctatum	Aextoxicaceae
Raulí	Nothofagus alpina	Fagaceae
Tepa	Laurelia philippiana	Monimiaceae

Common name	Scientific name	Family
Tineo	Weinmannia trichosperma	Cunoniaceae
Trevo	Dasyphyllum diacanthoides	Compositae
Ulmo	Eucryphia cordifolia	Eucryphiaceae

Appendix 2

FORM USED FOR FIELD DATA COLLECTION IN THE TIME STUDY

Date	Page no.
Place	Finishing time
Altitude (metres above sea level	Starting time
Average slope	Total working time
Equipment used	Time-keeper

Forest species: dimensions and volumes of logs; and records of times for the operational activities per work cycle

Cycle no.							
Forest species							
	Maximum diameter						
Log	Minimum diameter						
Dimensions	Length (m)						
	Volume (m3)						
Operational activities		Times recorded					
1. Trip without load							
2. Loading							
3. Trip with load							
4. Unloading							
Sub-total							
5. Supplement for fatigue							
5.1							
5.2							
6. Personal needs							
6.1							
6.2							
7. Delays (incidentals)							
7.1							
7.2							
7.3							
Sub-total							
Total time per work cycle							

Comments

Appendix 3

DETERMINING COSTS IN SKIDDING WITH OXEN

1 HOURLY COST IN SKIDDING WITH OXEN IN RADIATA PINE PLANTATIONS

1.1 Labour costs

1.1.1 Basic information	Chp	US$ 1/
Minimum wage	217.80	2.512
Social laws (5.55%)	12.09	0.139
Legal holidays (5.28%)	11.50	0.133
Sunday (16.89%)	36.79	0.424
Rainy days (8.45%)	18.40	0.212
Transport allowance (5.76%)	12.55	0.145
Total (minimum daily):	309.13	3.565

1.1.2 Hourly cost

Hourly cost of driver's work with 7 hours' effective work per day	44.16	0.509

1.2 Hourly cost of team of oxen

1.2.1 Basic information

Purchase value of ox team	60 000	692.042
Purchase value of chain, hooks and ring	4 855	55.998
Purchase value of yoke, yoking straps and goad	1 000	11.534
Resale value of ox team	60 000	692.042
Value of normal feed (one bundle of fodder) per day	130	
Value of supplementary feed (3 kg of balanced feed) per day	44	

Useful life of oxen	: 6 years
Useful life of chain, hooks and ringe	: 5 years
Useful life of yoke, yoking straps and goad	: 1 year
Effective days of work per annum	: 200 days
Hours of annual work per team of oxen	: 1 400 hours

1.2.2 Fixed costs (hourly)

Interest on investment in oxen and accessory equipment: yoke, yoking straps, goad, chain, hooks and ring	5.64	0.065
Depreciation	1.40	0.016
Normal feed	18.57	0.214
Medicaments and veterinary services (5% of value of team of oxen)	2.14	0.025
Mortality (5% of value of team of oxen)	2.14	
Total fixed costs	29.89	0.345

1/ US$ 1 = Chp 86.70 (16 December 1983)

		Chp	US$
1.2.3	Variable costs (hourly)		
	Special feed	6.29	0.073
1.3	Total costs		
	Total hourly cost for skidding with oxen in radiata pine plantations	80.34	0.927
2.	HOURLY COST OF SKIDDING WITH OXEN IN NATURAL FORESTS		
2.1	Cost of labour		
2.1.1	Basic information		
	Monthly wages of driver	7 680	88.581
2.1.2	Hourly cost		
	Hourly cost of 124 hours of work per month (6 hours a day from Monday to Friday and 3 hours on Saturday)	61.94	0.714
2.2	Hourly cost of team of oxen		
2.2.1	Basic information		
	Purchase value of team of oxen	60 000	692.042
	Purchase value of chain, hooks, ring and crank	6.952	80.184
	Purchase value of yoke, yoking straps and goad	1 000	11.534
	Resale value of team of oxen	60 000	692.042
	Useful life of yoke, yoking straps and goad	: 1 year	
	Useful life of oxen	: 6 years	
	Useful life of chain, hooks, ring and clamp	: 5 years	
	Effective time of working per annum covering 7 months of skidding	: 868 hours	
2.2.2	Fixed costs (hourly)		
	Interest on investment in oxen and accessory equipment: yoke, yoking straps, goad, chain, hooks, ring and clamp	9.39	0.108
	Depreciation	2,75	0.032
	Medicaments and veterinary services (5% of value of team of oxen)	2.14	0.025
	Mortality (5% of value of team of oxen)	2.14	0.025
	Total fixed costs	16.42	0.190
2.2.3	Variable costs		
	These were not included in the study		
2.3	Total costs		
	Total hourly cost of skidding with oxen in natural forest. 1/	78.36	0.904

1/ Total hourly cost in natural forest does not take into account expenditure on normal feed and special feed.

Appendix 4

A. SKIDDING WITH HORSES

The existing literature on skidding with horses in Chile includes studies made by Soto (1970) 1/, on skidding sawlogs and pulpwood on various gradients, with four types of equipment. The purpose of the research was to show how horses could be used in logging radiata pine, and thus make the use of these animals more widespread. The principal constraints which became apparent were training of the animals (which varied from one to eight months) and the limited experience of the staff employed.

Draught horses have the peculiarity of working best alone, whereas oxen skid in pairs or teams. Because of this, their morphological characteristics and tractive power, which in oxen is exercised from the head and the neck and in horses from the shoulder, the harness used is different (see Fig. 27).

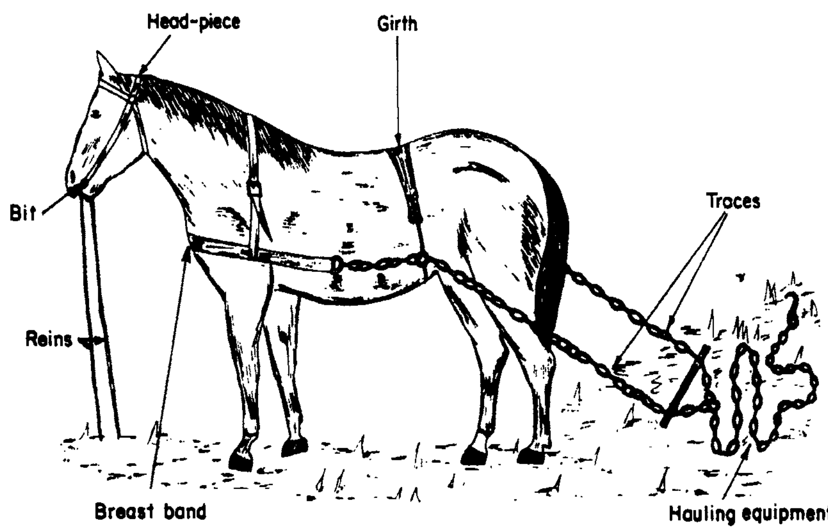


Fig. 27 DRAUGHT HORSE FOR SKIDDING, WITH HARNESS AND HAULING EQUIPMENT

The hauling equipment used in the experiments by Soto (1970) was: A Fossigen trailer (Fig. 30), VSA sledge (Fig. 31), Domänsaxen skidding tongs (Fig. 32) and skidding chains. The first three of these are of Swedish origin and, of them all, only the chain is at present used in Chile. The information on skidding with horses in this study therefore refers only to the use of chains. A description and sketches of this equipment will be found in Appendix 4B.

Data were collected on experimental skidding with horses on ground with slopes of 6-15 percent and 16-25 percent, in a 23-year old unmanaged stand of radiata pine, which had been clear-felled. The trees were on average 28 m high, with an average d.b.h. of 21 cm. Density was 1 500 trees/ha and volume 570 m^3/ha.

Sawlogs were 3.30 m long and pulpwood bolts 2.44 m long.

1/ A forestry degree thesis published by the Forestry Institute (1971)

On ground with gradients of -6 to -15 percent, the speed without load was 78 m/minute, with load 84 m/minute. The speed without load on gradients of -16 to -25 percent was 57 m/minute, with load, 55 m/minute.

Average units and volumes of load in the slope conditions mentioned above are shown in Table 13.

AVERAGE LOAD IN UNITS AND VOLUME BY DEGREES OF GRADIENT IN SKIDDING SAWLOGS AND PULPWOOD WITH HORSES

Class of logs	Degree of gradient loaded trip (%)	Average load (units)	Average load (m^3)
Sawlogs	-6 to -15	1.8	0.229
Sawlogs	-16 to -25	2.2	0.288
Pulpwood	-6 to -15	16.6	0.376
Pulpwood	-16 to -25	18.2	0.428

A graph of time and output values obtained by Soto (1970), may be seen in Figs. 28 and 29, and the equations in Table 14.

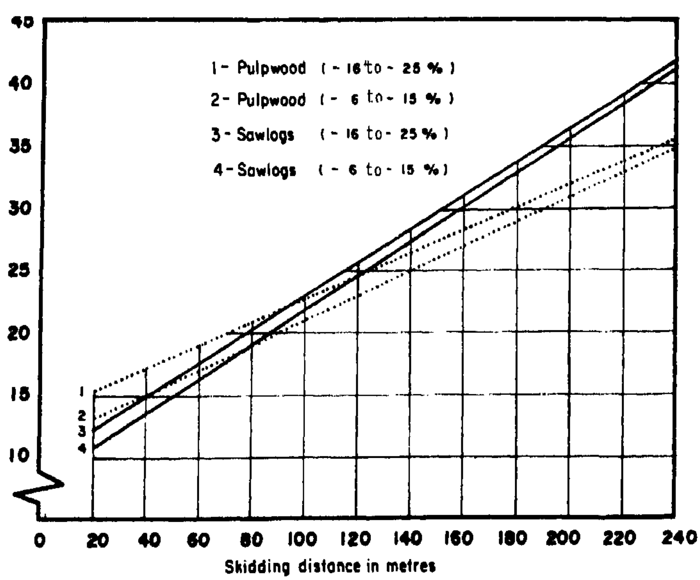


Fig. 28 TIME IN MINUTES PER m^3 IN SKIDDING SAWLOGS AND PULPWOOD WITH HORSES ON SLOPING GROUND

The time per m^3 was shorter on gentler slopes. For the first 60 m the time taken to skid sawlogs was less than for pulpwood but from this distance on it increased.

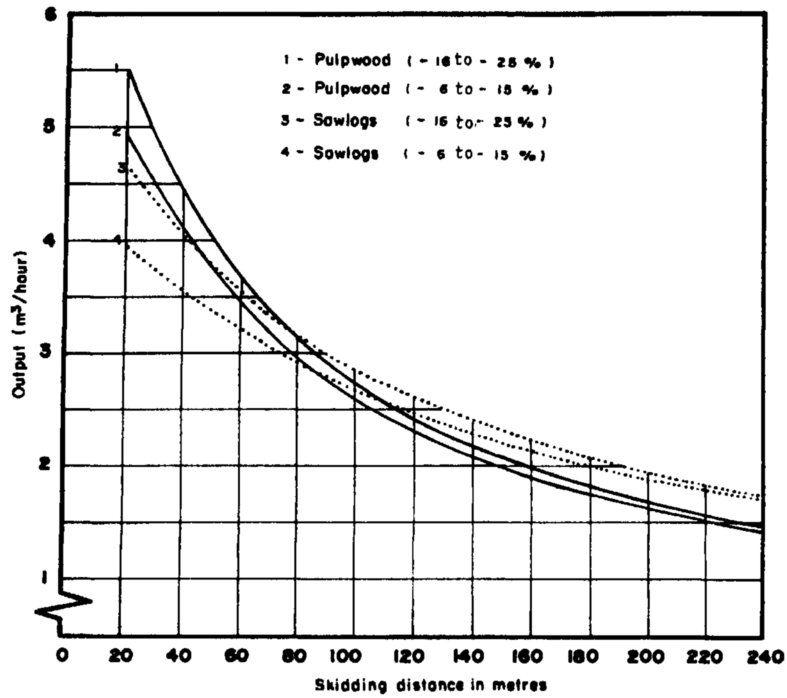


Fig. 29 OUTPUT IN m^3/h IN SKIDDING SAWLOGS AND PULPWOOD WITH HORSES ON SLOPING GROUND

Table 14

TIME EQUATIONS PER m^3 AND OUTPUT IN m^3/h IN SKIDDING SAWLOGS AND PULPWOOD WITH HORSES ON SLOPING GROUND, USING CHAINS 1/

Class of logs	Degree of slope for loaded trip (%)	Time equation	Output equation
Sawlogs	- 6 to - 15	T = 820.97 + 13.67 x	$O = \frac{6000}{820.97 + 13.67\,x}$
Sawlogs	- 16 to - 25	T = 951.39 + 13,51 x	$O = \frac{6000}{951.39 + 13.51\,x}$
Pulpwood	- 6 to - 15	T = 1109.04 + 9.97 x	$O = \frac{6000}{1109.04 + 9.97\,x}$
Pulpwood	- 16 to - 25	T = 1341.12 + 9.11 x	$O = \frac{6000}{1341.12 + 9.11\,x}$

1/ Source: Soto Sepúlveda, Dionisio

T = time per m^3 in centiminutes
O = output in m^3/h
x = distance in metres

Appendix 4

B. EQUIPMENT USED IN SKIDDING WITH HORSES

Fossingen trailer

This consists of metal thills which are joined by a swingletree to the draw bar, which controls the steering, and an arrangement of brakes for the front wheels (see Fig. 30).

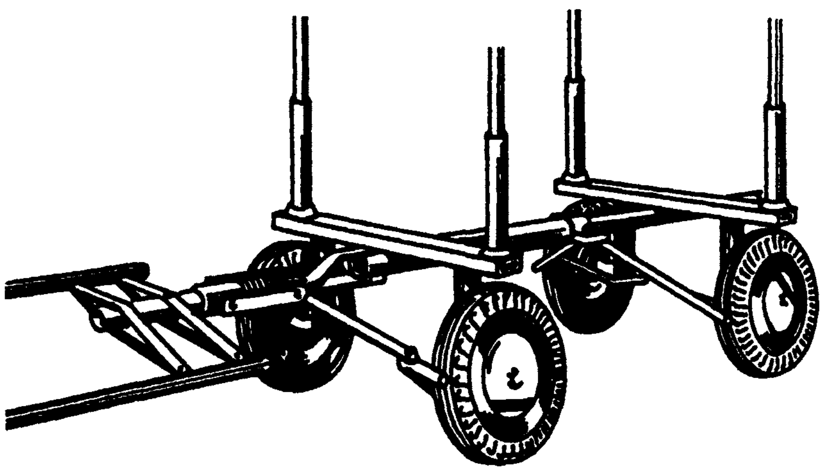


Fig. 30 Fossingen trailer (Sweden) 1/

The trailer proper consists of a front and rear assembly joined together by a tubular shaft, adjustable for different log lengths, thus allowing both assemblies to swing freely. This gives the trailer stability. There are also four metal stakes on the trailer chassis, each of which is made up of two parts so that they can be lengthened or shortened to facilitate loading from the side.

The technical specifications are: tires, 6.00 x 9: 62 cm high; 1.30 m wide, 175 kg in weight; and a capacity of 2.5 to 3 tons.

VSA sledge

This consists of a metal axle under which two runners are fixed in the form of U-shaped joists. The runners have lateral and vertical articulation (see Fig. 31).

1/ Source: Instituto Forestal de Chile

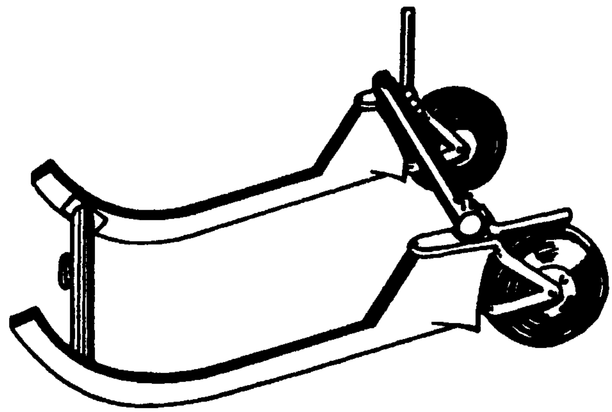


Fig. 31 VSA (Varmalands Skogsarbetsstudier) sledge (Sweden) 1/

The technical characteristics of the sledge are: 38 cm high; clearance of 30 cm above the ground; 90 cm between the runners; 78 kg total weight.

Domänsaxen skidding tongs

These consist of two mandibles, each one with a round circular steel guard 16 mm in diameter, to which the teeth are fixed.

The tongs also have a chain 5/16 of an inch thick, which passes through a tube, where the two mandibles meet, and through a ring in one of these (see Fig. 32).

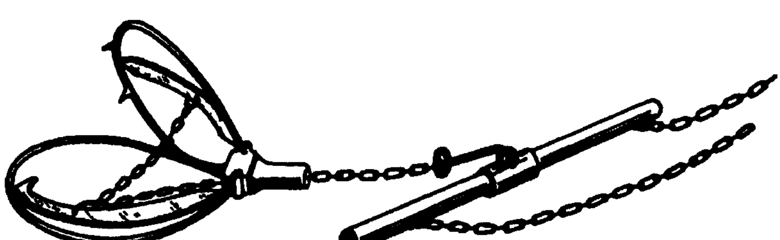


Fig. 32 Domänsaxen skidding tongs (Sweden)

The maximum opening of the tongs is 60 cm, with an approximate weight of 9.8 kg. The design is suitable for skidding large-diameter logs.

1/ Source: Instituto Forestal de Chile

Appendix 5

Table 15

TIME VALUES PER WORK CYCLE, PER m^3; AND OUTPUT ACCORDING TO DISTANCE AND SLOPE IN SKIDDING SAWLOGS WITH OXEN IN RADIATA PINE PLANTATIONS

Skidding distance (m)	Time per cycle 1/				Time per m3 1/				Output (m^3/hour)			
	Slope of the ground (%)				Slope of the ground (%)				Slope of the ground (%)			
	-25,1-30	-20,1-25	-15-20	+10+20	-25,1-30	-20,1-25	-15-20	+10+20	-25,1-30	-20,1-25	-15-20	+10+20
15	6.89	6.53	10.00	2.21	8.68	9.61	13.93	5.73	6.91	6.94	4.31	10.47
20	7.27	6.92	10.28	2.77	9,16	10.19	14.32	7.18	6.55	5.89	4.19	8.36
30	8.03	7.70	10.84	3,88	10.11	11.34	15.10	10.07	5.93	5.29	3,97	5,96
40	8.79	8.48	11.40	5.00	11.07	12.50	15.88	12.97	5,42	4.80	3.77	4,63
50	9.54	9.27	11.96	6.12	12.01	13.65	16.66	15.86	4,99	4.40	3.60	3.78
60	10.30	10.05	12.52	7.23	12.97	14.83	17,44	18.75	4,63	4.06	3.44	3,20
70	11,06	10,84	13.08	8.35	13.92	15.96	18.22	21.62	4.31	3,76	3.29	2,77
80	11,81	11.62	13,65	9.47	14.87	17.11	19.00	24.54	4.03	3,51	3.16	2,44
90	12.57	12,40	14.20		15.83	18.23	19.79		3.79	3.28	3.03	
100	13.33	13.19	14.77		16.78	19.42	20.57		3.57	3.09	2.91	
110	14.08	13.97	15.33		17.74	20.57	21.35		3.38	2.92	2.81	
120	14.84	14.75	15.89		18.69	21.73	22.13		3.21	2.76	2.71	
130	15.60	15.53	16.45		19.64	22.88	22.91		3.05	2.62	2.61	
140	16.35	16.32 2/	17.01 2/		20.59	24.04 2/	23.69 2/		2.91	2.50 2/	2.53 2/	
150	17.11	17.11 2/	17.57 2/		21.55	25.19 2/	24.47 2/		2.78	2.38 2/	2.45 2/	
160	17.87	17.89 2/	18.13 2/		22.50	26.35 2/	25.25 2/		2.67	2.27 2/	2.38 2/	

1/ Time in minutes

2/ Extrapolated values

Average skidding load: -25.1 to -30%, 0.794 m^3; -20.1 to -25%, 0.679 m^3; -15 to -20%, 0.718 m^3; +10 to +20%, 0.386 m^3.

Table 16

COST PER m^3 ACCORDING TO DISTANCE AND SLOPE IN SKIDDING SAWLOGS WITH OXEN IN RADIATA PINE PLANTATIONS

Skidding distance (m)	Cost in Chp and in US$ 1/							
	- 25.1 to -30%		-20.1 to -25%		-15 to -20%		+10 to + 20%	
	Chp	US$	Chp	US$	Chp	US$	Chp	US$
15	11.627	0.134	12.858	0.148	18.646	0.215	7.671	0.088
20	12.265	0.142	13.641	0.157	19.169	0.221	9.608	0.111
30	13.541	0.156	15.187	0.175	20.215	0.233	13.484	0.155
40	14.817	0.171	16.733	0.193	21.261	0.245	17.359	0.200
50	16.093	0.186	18.279	0.211	22.307	0.257	21.234	0.245
60	17.369	0.200	19.825	0.229	23.353	0.269	25.109	0,290
70	18.645	0.215	21.371	0.246	24.399	0.281	28.984	0.334
80	19.921	0.230	22.917	0.264	25.445	0.293	32.859	0.379
90	21.197	0.244	24.494	0.282	26.491	0.306		
100	22.473	0.259	26.009	0.300	27.537	0.318		
110	23.749	0.274	27.555	0.318	28.583	0.330		
120	25.025	0.289	29.101	0.336	29.629	0.342		
130	26.301	0.303	30.647	0.353	30.675	0.354		
140	27.577	0.318	32.193 2/	0.371 2/	31.721 2/	0.366 2/		
150	28.853	0.333	33.739 2/	0.389 2/	32.767 2/	0.378 2/		
160	30.129	0.347	35.285 2/	0.407 2/	33.813 2/	0.390 2/		

1/ US$ 1 = Chp 86.70 (16 December 1983)

2/ Extrapolated values

Average skidding load: -25.1 to -30%, 0 794 m^3; -20.1 to -25%, 0.679 m^3; -15 to -20%, 0.718 m^3; +10 to +20%, 0.386 m^3.

Table 17

TIME VALUES PER WORK CYCLE, PER m^3; AND OUTPUT ACCORDING TO DISTANCE AND SLOPE IN SKIDDING PULPWOOD WITH OXEN IN RADIATA PINE PLANTATIONS

Skidding Distance (m)	Time per cycle 1/			Time per m^3 1/			Output (m^3/h)		
	Slope of the ground (%)			Slope of the ground (%)			Slope of the ground (%)		
	> - 30	- 10.1 - 20	0 - 10	> - 30	- 10,1 - 20	0 - 10	> - 30	- 10,1 - 20	0 - 10
15	4.21	3.97	3.52	7.06	6.66	5 90	8.49	9.00	10.15
20	4.57	4.32	3.86	7 67	7.24	6 47	7.83	8.29	9.27
30	5.29	5.00	4.53	8.87	8.39	7 60	6.76	7.15	7,89
40	6.01	5.69	5.20	10 08	9.55	8 73	5.95	6.28	6.87
50	6.72	6,38	5.88	11 28	10.69	9.86	5.32	5.61	6.09
60	7.44	7.06	6.55	12 49	11.85	10 99	4.80	5.06	5.46
70	8.16	7.75	7.22 2/	13 69	13.01	12 11	4.38	4.61	4.95 2/
80	8.88	8.44	7.89 2/	14 30	14.16	13 24	4.03	4.24	4.53 2/
90	9.60	9.13	8.56 2/	16 10	15.31	14 37	3.73	3.92	4.18 2/
100	10.32 2/	9.81 2/	9.24 2/	17 30	16.46	13 24	3.47 2/	3.64 2/	3.87 2/
110	11.03 2/	10.50 2/	9.91 2/	18 51	17.62	16 63	3.24 2/	3.41 2/	3.61 2/
120	11.75 2/	11.19 2/	10.58 2/	19.72	18.77	17 76	3.04 2/	3.20 2/	3.38 2/

1/ **Time in minutes**

2/ **Extrapolated values**

Average skidding load: 0.509 m^3

Table 18

COSTS PER m^3 ACCORDING TO DISTANCE AND SLOPE IN SKIDDING PULPWOOD WITH OXEN IN RADIATA PINE PLANTATIONS

Skidding distance (m)	Costs in Chp and in US$ 1/					
	> - 30%		- 10.1 - 20%		0 - 10%	
	Chp	US$	Chp	US$	Chp	US$
15	9.460	0.109	8.923	0.103	7.913	0.091
20	10.267	0.118	9.695	0.112	8.669	0.100
30	11.881	0.137	11.239	0.130	10.180	0.117
40	13.500	0.156	12.783	0.147	11.691	0.135
50	15.109	0.174	14.327	0.165	13.202	0.152
60	16.723	0.193	15.871	0.183	14.713	0.170
70	18.337	0.211	17.415	0.201	16.224 2/	0.187 2/
80	19.951	0.230	18.959	0.219	17.735 2/	0.205 2/
90	21.565	0.249	20.503	0.236	19.247 2/	0.222 2/
100	23.179 2/	0.267 2/	22.047 2/	0.254 2/	20.756 2/	0.239 2/
110	24.793 2/	0.286 2/	23.591 2/	0.272 2/	22.268 2/	0.257 2/
120	26.407 2/	0.305 2/	25.135 2/	0.290 2/	23.779 2/	0.274 2/

1/ US$ 1 = Chp 86.70 (16 December 1983)

2/ Extrapolated values

Average skidding load: 0.509 m^3

Table 19

TIME VALUES PER WORK CYCLE, PER m^3; AND OUTPUT ACCORDING TO DISTANCE IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN ON LEVEL GROUND IN RADIATA PINE PLANTATIONS

Skidding distance (m)	Time per cycle 1/			Time per m^3 1/			Output (m^3/h)		
	Clear-felling		Thinning	Clear-felling		Thinning	Clear-felling		Thinning
	Saw-logs	Pulp-wood	Pulp-wood	Saw-logs	Pulp-wood	Pulp-wood	Saw-logs	Pulp-wood	Pulp-wood
15	2.11	2.83	3.39	5.05	7.71	11.74	11.88	7.78	5.11
20	2.45	3.03	3.59	5.87	8.25	12.41	10.22	7.27	4.83
30	3.13	3.42	3.97	7.50	9.33	13.74	7.99	6.43	4.37
40	3.81	3.82	4.36	9.14	10.40	15.07	6.56	5.77	3.98
50	4.49	4.21	4.74	10.76	11.48	16.40	5.57	5.23	3.66
60	5.18	4.61	5.12	12.41	12.55	17.74	4.83	4.78	3.38
70	5.86	5.00	5.51	14.05	13.63	19.07	4.27	4.40	3.14

1/ Time in minutes

Average skidding load: a) sawlogs after clear-felling = 0.417 m^3; b) pulpwood after clear-felling = 0.367 m^3; c) pulpwood after thinning = 0.289 m^3.

Table 20

COST PER m^3 ACCORDING TO DISTANCE IN SKIDDING SAWLOGS AND PULPWOOD WITH OXEN OVER LEVEL GROUND IN RADIATA PINE PLANTATIONS

Skidding Distance (m)	Costs in Chp and US$ 1/					
	Clear-felling				Thinning	
	Sawlogs		Pulpwood		Pulpwood	
	Chp	US$	Chp	US$	Chp	US$
15	6.762	0.078	10.329	0.119	15.722	0.181
20	7.857	0.091	11.049	0.127	16.614	0.192
30	10,048	0.116	12.489	0.144	18.398	0.212
40	12.239	0.141	13.929	0.161	20.182	0.233
50	14.430	0.166	15.369	0.177	21.966	0.253
60	16.621	0.192	16.809	0.194	23.750	0.274
70	18.812	0.217	18.249	0.210	25.534	0.294

1/ US$ 1 = Chp 86.70 (16 December 1983)

Average skidding load: a) sawlogs after clear-felling = 0.417 m^3; b) pulpwood after clear-felling = 0.367 m^3; c) pulpwood after thinning = 0.289 m^3.

Table 21

TIME VALUES PER WORK CYCLE AND PER m^3; OUTPUT; AND COST PER m^3 ACCORDING TO DISTANCE ON SLOPES OF -20 to -32 PERCENT, FOR SKIDDING WITH OXEN IN NATURAL FOREST

Skidding distance (m)	Time per cycle 1/	Time per m^3 1/	Output m^3/h	Cost per m^3	
				Chp	US$
40	16.51	13.91	4.31	18.167	0.210
60	17.53	14,77	4.06	19.295	0.222
80	18.57	15.64	3.84	20.423	0.235
100	19.59	16.51	3.64	21.551	0.249
120	20,61	17.37	3.46	21.679	0.262
140	21,64	18.23	3,29	23.807	0.275
160	22.67	19.10	3.14	24.935	0.288
180	23.70	19.96	3.01	26.063	0.301
200	24.72	20.83	2.88	27.191	0.314
220	25.75	21.69	2.77	28.319	0.327
240	26.77	22.56	2.66	29.442	0.340
260	27,80	23.42	2.56	30.572	0.353
280	28.83	24.28	2.47	31.703	0.366
300	29.85	25.15	2.39	32.831	0.387
320	30,88	26.01	2.31	33.960	0.392
340	31.90	26.88	2.23	35.087	0.405
360	32.93	27.74	2.16	36.215	0.418
380	33.96	28.61	2.10	37.343	0.431
400	34.98	29.47	2.04	38.471	0.444
420	36,01	30.34	1.98	39.599	0.457
440	37.03	31.20	1.92	40.727	0.470
460	38,06	32.06	1.87	41.855	0.483

1/ Time in minutes
Average skidding load: 1.187 m^3

2/ US$ 1 = Chp 86.70 (16 December 1983)

Table 22

TIME VALUES PER WORK CYCLE AND PER m^3; OUTPUT; AND COST PER m3 IN SKIDDING WITH AN AGRICULTURAL TRACTOR ON SLOPES OF +0.15 TO +9.38 PERCENT

Skidding distance (m)	Time per cycle 1/	Time per m^3 1/	Output m^3/h	Cost per m^3	
				Chp	US$ 2/
20	5.60	6.47	9.27	70.970	0.817
25	5.67	6.55	9.15	71.862	0.829
30	5.74	6.63	9.04	72.755	0.839
35	5.81	6.71	8.93	73.647	0.849
40	5.88	6.80	8.83	74.540	0.860
45	5.95	6.88	8.72	75.432	0.870
50	6.02	6.96	8.62	76.325	0.880
55	6.09	7.04	8.52	77.217	0.891
60	6.16	7.12	8.42	78.110	0.901
65	6.23	7.20	8.33	79.002	0.911
70	6.30	7.28	8.23	79.895	0.921

1/ Time in minutes

2/ US$ 1 = Chp 86.70 (16 December 1983)

Average skidding load: 0.865 m^3

Appendix 6

DETERMINING COSTS IN SKIDDING WITH AGRICULTURAL TRACTORS

		Chp	US$ 2/
1	LABOUR COST 1/		
1.1	Basic information		
	Monthly wages of tractor driver	14 000	161.476
	Monthly wages of chokerman	8 000	92.272
		22 000	253.748
1.2	Hourly cost		
	Hourly cost on the basis of 156 working hours per month	141.03	1.627
2	HOURLY COST OF THE TRACTOR		
2.1	Basic information		
	Purchase value of the tractor	1 577 940	18 200.000
	Final value of the tractor	134 000	1 545.559
	Purchase value of the winch	60 640	669.423
	Final value of the winch	40 000	461.361
	Replacement value of front tires	20 866	240.669
	Replacement value of back tires	84 044	969.366
	Useful life of the tractor, in years	10	
	Annual use of the tractor, in hours	1 400	
	Useful life of the tires, in hours	3 000	
	Useful life of the steel hook, in years	5	
	Useful life of the cable for the winch, in months	2	
2.2	Fixed costs, per hour		
	1) Interest	77.68	0.896
	b) Depreciation	97.12	1.120
	c) Licence	2.04	0.024
	Total fixed costs	176.84	2.040
2.3	Variable costs per hour		
	a) Repairs	98.59	1.137
	b) Tires	34.97	0.403
	c) Fuel 2.5 litres/h x Chp 35.90	89.75	1.035
	d) Lubricants, filters and grease		
	Oil for gearbox		
	$\frac{\text{6 litres x Chp 220}}{\text{1400 h}}$ =	0.94	0.011

1/ Includes social security

2/ US$ 1 = Chp 86.70 (16 December 1983)

Oil for engine case		
$\frac{17 \text{ litres x Chp } 300}{120 \text{ h}}$ =	42.50	0.490
Oil for hydraulic engine and differential		
$\frac{80 \text{ litres x Chp } 220}{1400 \text{ h}}$ =	12.57	0.145
Filters for the fuel		
$\frac{2 \text{ x Chp } 180}{3 \text{ x } 156 \text{ h}}$ =	0.77	0.009
Filters for the hydraulic engine		
$\frac{2 \text{ x Chp } 135}{3 \text{ x } 156 \text{ h}}$ =	0.58	0.007
e) Hook and cable		
1 hook to bear 2 tons of traction		
$\frac{\text{Chp } 900}{5 \text{ x } 1\,400 \text{ h}}$ =	0,13	0,001
Cable of 5/8" for the winch		
$\frac{35 \text{ m x Chp } 330}{2 \text{ x } 156 \text{ h}}$ =	37.02	0.427
f) Maintenance		
$\frac{14\,000 \text{ x } 1}{156 \text{ h x } 4}$ =	22.44	0.259
Total variable costs	340.26	3.925
3 TOTAL COSTS		
Total hourly cost	658.13	7.591

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