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Determining Cost and Productivity of Using Animals in Forest Harvesting Operations

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Abstract: Highly mechanized systems have been used for forest harvesting in many developed countries. Logging machines have replaced the traditional sources of energy such as human power and animal power. However, they are very expensive, energy consuming, and highly correlated with the price at the fuel that is limiting factor in many developing countries[3]. In some cases where machines have very low cost efficiency and terrain conditions are not limiting, the animals can provide a solution to the need for power and make a useful contribution in energy saving. Besides, using draft animals may generate less environmental damage compared to the logging machines. In this paper, cost and productivity of using ox in skidding operations is studied due to its versatility.

Key words: Forest harvesting, animal logging, skidding with ox

INTRODUCTION

In many developing countries, animals are the main energy sources for forest harvesting operations and transportation since most logging machines have high initial purchase prices, high operating costs, and negative effect on workforce. In different regions of the world, various species of animal have been used such as oxen, donkeys, horses, elephants, lamas, yaks, and mules[3]. Among these animals, ox is commonly used in skidding operations because it is very strong and easy to drive. Besides, it provides a good yield in beef at the end of its active life, so the investment can be recovered.

There have been studies on skidding with oxen. Eisenhauer[1] studied skidding with oxen in a forest of radiata pine with the following conditions; average dbh of 32 cm, a slope of 11 percent, average skidding distance of 125 m, and log length of between 3 and 7 m. The results indicated that each m^3 of timber was produced in approximately 37 minutes and the average production for unit area was found to be 1.48 m^3/ha. In a selective thinning operation, Jelves[2] reported the average prodcution of 0.89 m^3/ha by using ox-dram cants over an average skidding distance of 25 m. Another study was conducted by Rodriguez[3] to examine the use of oxen to skid logs in plantation and natural forests. According to the results from the research, oxen could be used with positive result in plantation forest where clear cut or thinning applied, and also in natural forests where, whether on level ground or on steep slopes. In this paper, skidding with oxen will be discussed considering animal rate (hourly cost), cycle time, and productivity and cost.

MATERIALS AND METHODS

Animal Rate: Animal rate calculation is somewhat similar to the machine rate (hourly equipment cost) calculations, however, some types of cost may vary[2]. The animal rate is usually divided into three main cost components including fixed cost, operating cost, and labor cost.

Fixed Cost: Fixed cost components include the investment cost of the animal or team, double head yoke, logging chains, and any other investments with a life more than a year. The salvage cost of animal is similar to the machine rate, but in the animal case, the salvage value is often determined by its selling value for meat[4]. Since the animal yokes and miscellaneous investments usually have different life times, the fixed costs for them must be calculated separately.

Animal support costs, which include pasture rental, food supplements, medicine, veterinarian services, and any after hours care-feeding, washing or guarding, do not vary with working hours. The money investment in medical attention, medicine and vaccination can be considered to be five percent of the purchase value of a

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team of oxen[3]. Medical costs per hour can be estimated by the purchase value of a team of oxen divided by annual work in hours. Pasture area (ha/animal) can be estimated by dividing the animal consumption rate (kg/animal/month) by the forage production rate (kg/ha/month)[4]. Food supplements, medicine, vaccinations, and veterinarian schedules can be obtained from local sources.

Operating Cost: Operating cost components generally include maintenance and repair costs for yokes, chains, and miscellaneous equipment[4]. Additional or special feed given to oxen during skidding may also include operating costs.

Labor Cost: Labor cost is the cost of driver (and any other helpers) for driving the animal during the skidding operation[4]. It only includes the wage of a workman and excludes the expenses for people worked during stacking. For full year operation, it is calculated by dividing the social costs by the average number of working days or hours for the driver[4].

Cycle Time:

Cycle Time Elements: The time elements considered in the work cycles include outhaul time, inhaul time, hook time, and unhook time. Similar phases have been mentioned in various studies. According to Rodriguez[3] there are four different cycle time elements:

1) Outhaul time: Time spent by the oxen when they covered the distance from the landing to the stump area without a load.
2) Hook time: Time spent from the moment the team and oxen arrive the stump until the moment they leave. It includes the maneuvering the oxen to take up the loads, arranging the logs and to hook them.
3) Inhaul time: Time spent from the moment the team of oxen starts to move with the log from the stump until it arrives at the landing.
4) Unhook time: Time spent from the moment oxen arrives the landing to deliver the load until the chain is recovered and remained on the yoke.

Determining the Cycle Time: Cycle time is divided into two main parts including delay time and delay-free time:

1) Delay Time: Delay time may or may not be predictable. In the first case, incidental delays during skidding include receiving work instructions, setting up equipment on the work site, preparing ox-teams in the skidding area, changing parts, removing obstacles which make movement difficult, and adjusting the chain[3]. The second case covered non-predictable delays may be accidental or unnecessary losses of time, such as forgetting tools, conversation between the workers, and all delays outside the normal process.

2) Delay-Free Cycle Time: This is the total time spent per work cycle. In order to compute cycle time, following parameters must be known: outhaul velocity, hook time, inhaul velocity, unhook time, average skidding distance, and delay time.

Table 1 shows the average values of speed and load in skidding sawlogs and pulpwood of radiata pine over different types of slope. This table is adapted from the research of skidding with oxen studied by Rodriguez[3]. In the study area, the terrain was generally very rough with slopes in some places above 30% and the soils were mostly granite rock. Approximately 20% of the extraction of raw timber was skidded by wheeled farm tractor and 80% by oxen. Some of the average tree characteristics are as follows: age of 22 years, height of 30 m, dbh of 26 cm, 380 trees/ha, and volume of 448 m^3/ha.

The dimensions of the logs transported for sawlogs were 4 m in length and 18 cm. in dbh; and for pulpwood they were 2.44 m in length and minimum 10 cm and maximum 18 or 20 cm in dbh. This study took 10 working days and the seven ox teams were studied. Each ox weighed between 500 and 700 kg.

Another area studied in the same research was about 125 m above sea level with slopes no steeper than 3 %. The predominant soils were sandy. Skidding was studied over six working days, using three ox teams. Each ox weighed 650 kg, and had a minimum of two years' experience. The specific situations studied for skidding pulpwood after thinning; the forest was 16 years old, average length of bolts transported was 7.44 m, average dbh was 10 cm, the density was 800 tree/ha, and average volume was 85 m^3/ha. The average tree characteristics for transporting sawlogs were; 19 years old forest, 1,662 trees/ha, minimum dbh of 26 cm, and minimum length of 4 m. The average speed and load during skidding of sawlogs and pulpwood with oxen on level ground with clear cuts and thinning systems listed in Table 2.

Hook times per cycle for pulpwood and sawlog were estimated as 3 minutes and 2 minutes, respectively. Unhook time, on the other hand, was less than hook time and assumed as 2 minutes for both products. The cycle time in skidding sawlogs and pulpwoods with oxen on various ground slopes and skidding distance was listed Table 3.

Table 1: Average speed and load in volume in skidding sawlogs and pulpwood with oxen over different types of slopes[3].

Log Classes	Ground Slope (%)	Average Velocity (m/min)		Volume (per cycle) m^3
		Outhaul	Inhaul	
Sawlogs	- 25.1 to - 30	30.43	29.69	0.794
Sawlogs	- 20.1 to - 25	30.05	28.91	0.679
Sawlogs	- 15 to - 20	28.87	25.39	0.718
Sawlogs	+ 10 to + 30	38.75	27.53	0.386
Pulpwood	> than - 30	28.45	24.38	0.509
Pulpwood	- 10.1 to - 20	39.44	22.3	0.509
Pulpwood	0 to - 10	43.41	25.4	0.509

Table 2: The average speed and load in volume in skidding sawlogs and pulpwood with oxen on level ground with different felling systems[3].

Log Classes	Felling Systems	Average Velocity (m/min)		Volume (per cycle) m^3
		Outhaul	Inhaul	
Sawlogs	Clearcuts	33.95	21.92	0.417
Pulpwood	Clearcuts	40.87	30.89	0.367
Pulpwood	Thinning	46.06	32.75	0.289

Table 3. Cycle time in skidding with oxen as a function of various ground slopes and skidding distances.

Log Classes	Ground Slope (%)	Cycle Time (min)			
		Skidding Distance Classes			
		50 m	100 m	150 m	200 m
Sawlogs	- 25.1 to - 30	10.33	13.65	17.98	21.31
Sawlogs	- 20.1 to - 25	10.39	13.79	18.18	21.57
Sawlogs	- 15 to - 20	10.70	14.40	19.10	22.80
Sawlogs	+ 10 to + 30	10.11	13.21	17.32	20.43
Pulpwood	> than - 30	9.81	13.62	18.42	22.23
Pulpwood	- 10.1 to - 20	9.51	13.02	17.53	21.04
Pulpwood	0 to - 10	9.12	12.24	16.36	19.48

Table 4: Production rate and unit cost for skidding with oxen, as a function of various ground slopes and skidding distances.

Log Class	Ground Slope (%)	Load m^3/cyc	Production (m^3/hr.)				Unit Cost ($/$m^3$)			
			Skidding Distances (m)				Skidding Distances (m)			
			50	100	150	200	50	100	150	200
Sawlg	-25.1 to -30	0.794	4.61	3.49	2.65	2.24	3.75	4.95	6.52	7.72
Sawlg	-20.1 to -25	0.679	3.92	2.95	2.24	1.89	4.41	5.86	7.72	9.15
Sawlg	-15 to -20	0.718	4.03	2.99	2.26	1.89	4.29	5.78	7.65	9.15
Sawlg	+10 to +30	0.386	2.29	1.75	1.34	1.13	7.55	9.88	12.9	15.3
Pulpw.	> than -30	0.509	3.11	2.24	1.66	1.37	5.56	7.72	10.4	12.6
Pulpw.	-10.1 to -20	0.509	3.21	2.35	1.74	1.45	5.39	7.36	9.94	11.9
Pulpw.	0 to -10	0.509	3.35	2.50	1.87	1.57	5.16	6.92	9.25	11.0

The data from Table 1 and 3 can be used to compute total cycle time by using following equation:

$$CycleTime = \frac{L}{V_{out}} + \frac{L}{V_{in}} + T_{unhook} + T_{hook} + T_{delay} \quad (1)$$

where,

L = skidding distance (m)
V_{out}, V_{in} = outhaul and inhaul velocity (min/m)
T_{unhook}, T_{hook} = unhook and hook time (min)
T_{delay} = delay time (m)

Productivity and Cost:

Production Rate: In forest harvesting operations, production is generally expressed in cubic meters per hour, which is calculated based on the relationship between the average volume of load per cycle and number of cycles per hour. Number of cycles per hour is computed by dividing 60 minutes by the cycle time including delays in minutes. Then production per hour can be determined by using the equation as follows (Table 4):

$$Production = LV \times NC \quad (2)$$

where,

LV = load volume per cycle (m^3/cycle)
NC = number of cycle per hour (cycle/hr)

Unit Cost of Skidding with Ox: In order to calculate unit cost skidding with oxen per unit volume, firstly animal rate including fixed cost, operating cost, and labor cost must be known, then the unit cost can be basically estimated by dividing animal rate by the production.

The unit cost of skidding with oxen per cubic meter can be obtained by using the production and cost data as follows:

$$Unit\ Cost = C / P \quad (3)$$

where,

C = animal rate for skidding ($/hr)
P = production rate (m^3/hr)

RESULTS AND DISCUSSIONS

Based on the research data of skidding with oxen studied by[3], Table 4 shows the summary of the productivity and unit cost of skidding with oxen over different types of slopes and on level ground for clear cutting and thinning under various skidding distance categories. Figure 1 shows that cycle time of skidding on slope of + 10 % to + 20 % is less than for skidding downhill since the number of logs skidded was reduced due to the greater effort required from the oxen when skidding uphill. With a steeper downhill slope, the number of logs skidded may be dropped, thus cycle time of skidder decreases. It is also seen from this figure that the cycle time increases considerably as the skidding distance increases.

In skidding sawlogs on level ground (less than 3 %) with clear-felling, cycle time was greater than those skidded downhill since on the level ground speed with load drops because of the friction, in comparison with the loaded trip downhill which has gravity assistance. The number of logs skidded downhill are greater than those skidded on level ground.

Skidding sawlogs after clear-felling, cycle time is shorter because relatively fewer pieces to be handled. In skidding pulpwood after thinning, cycle time of skidding is greater than those skidded after clear-felling since the average number of logs skidded are very high by comparing with the skidding puplwood after clear-felling.

It can be observed from Figure 2 that the production rate in skidding logs uphill decreases as the distance increases. Production rate in skidding pulpwood is greater than in skidding sawlogs, since more time is spent in loading. On the level ground, on the other hand, skidding sawlogs after clear-felling has the highest production rate due to the greater volume of load and lower number of logs transported. The unit cost in skidding with oxen over different skidding distance and slope conditions is shown in Figure 3. The figure shows that unit cost increases as the skidding distance increases. There is no significant difference in unit cost wit in the downhill slope classes for both sawlogs and pulpwood. However, skidding with ox uphill increases the unit cost up to 30%. Since the production rate of skidding pulpwood is relatively less than that of skidding sawlogs, the unit cost of skidding pulpwood becomes relatively greater than that of skidding sawlogs.

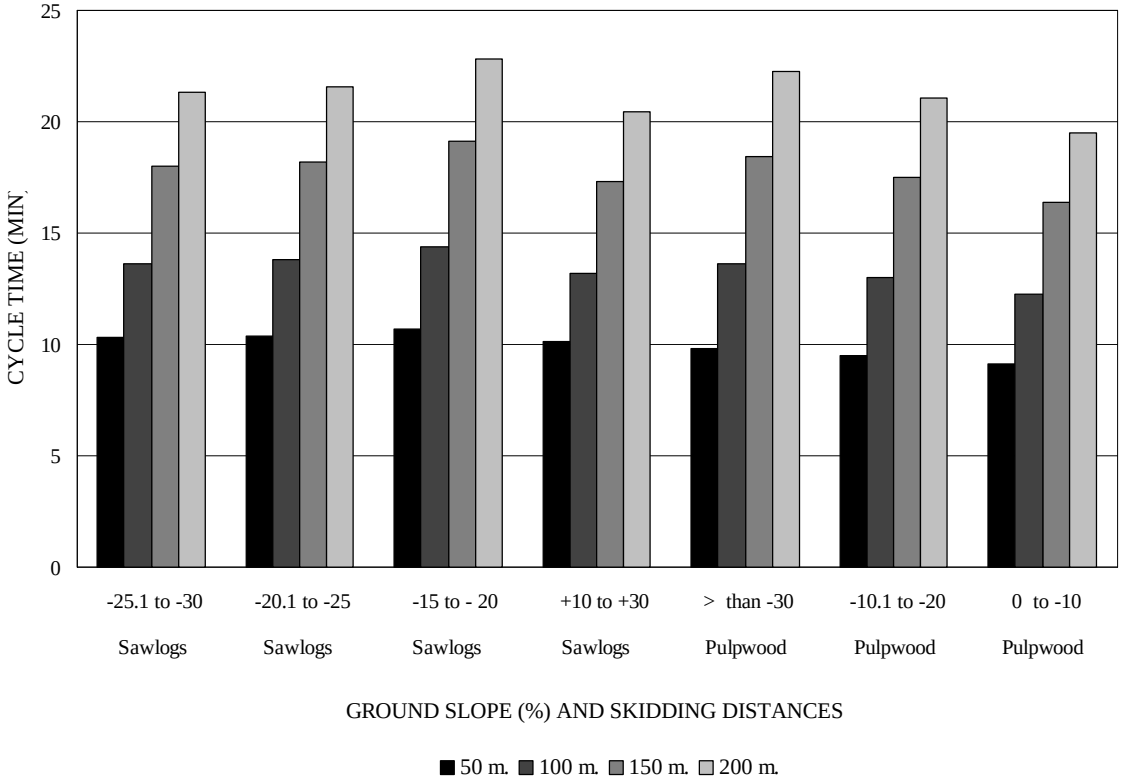

Fig. 1: Cycle time in skidding sawlogs and pulpwood with oxen over different skidding distance and slope conditions.

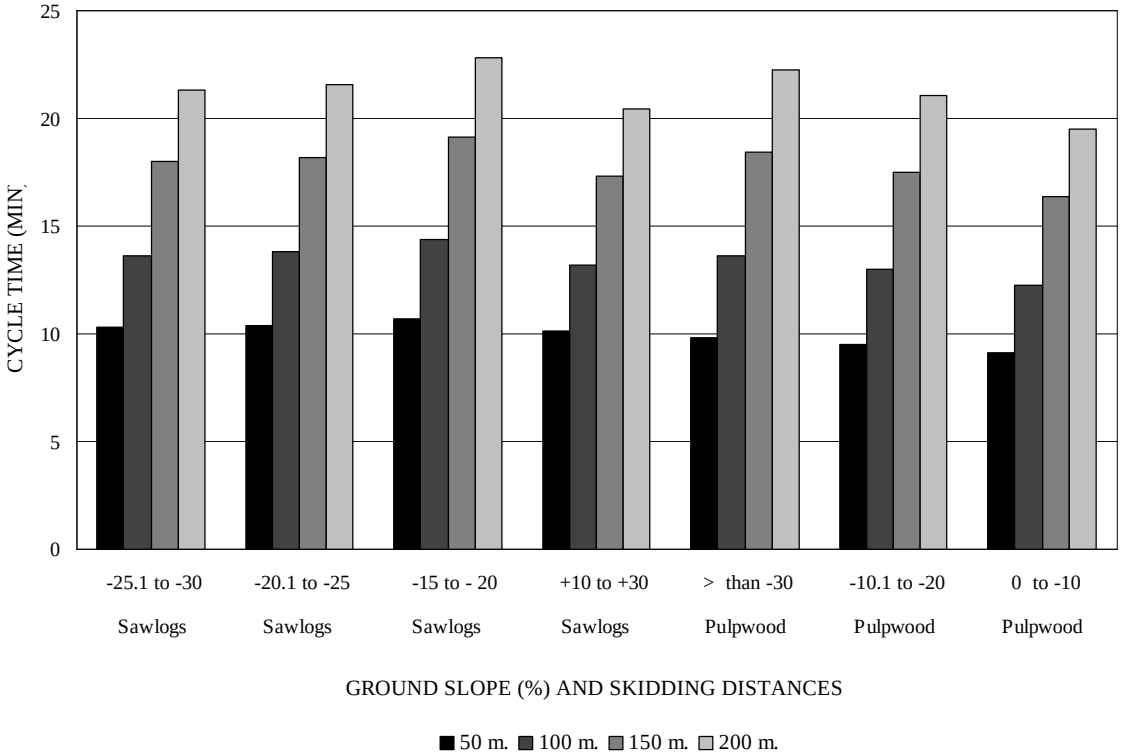

Fig. 2: Production rate in skidding sawlogs and pulpwood with oxen over various skidding distances and slope conditions.

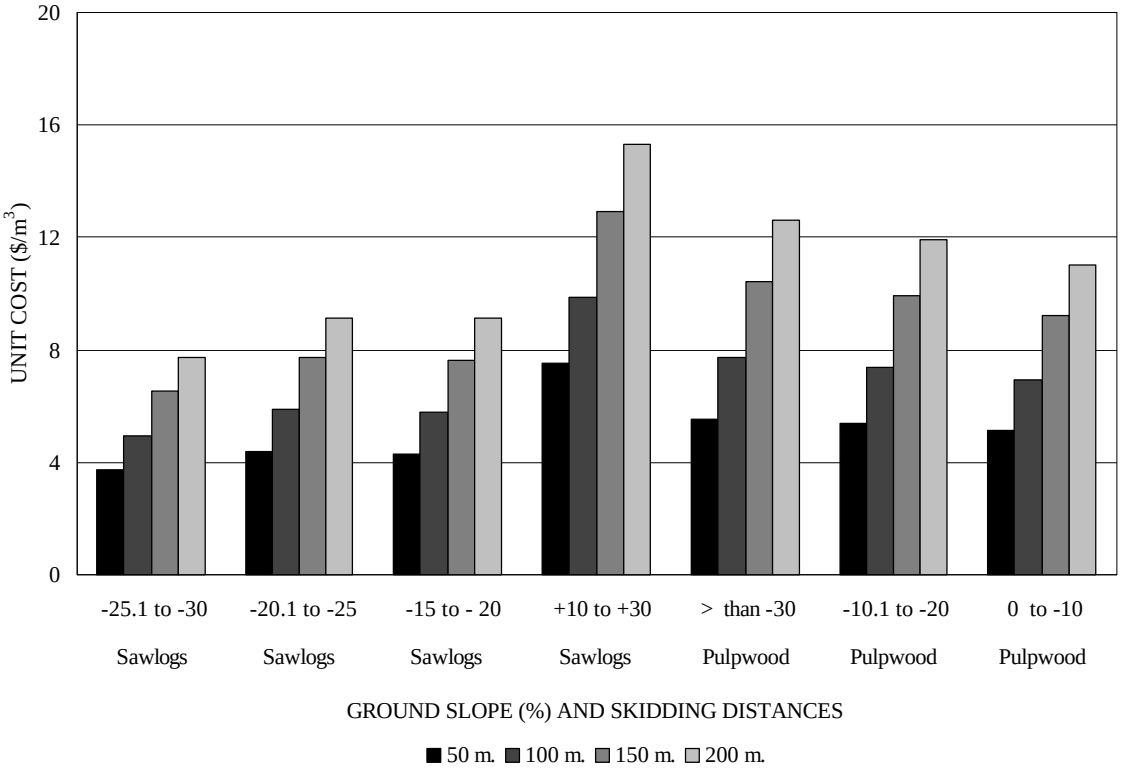

Fig. 3: Unit cost in skidding sawlogs and pulpwood with oxen over different skidding distances and slope conditions.

Concluions: In many developing countries, transporting timber from woods to the landings have been mostly done by draft animals because mechanized harvesting machines can be very expensive to purchase and maintain and hourly machine costs are highly reflected by fuel cost. Animal logging has been also used in developed countries during forest harvesting where soil compaction is the main concern, reduced stand damage is required, number of trees to be harvested is very low, and harvesting unit is not accessible by a road. In order to retain the advantages of animal logging, logging manager should carefully determine the factors effecting the cost and productivity of animal logging. Based on the previously conducted studies, this study presented the main factors affecting productivity and unit cost of skidding with ox under various operation conditions. It is expected that the logging manager can conduct economic and feasible animal logging operations by evaluating the alternatives logging plans based on these main factors.

REFERENCES

1. Eisenhauer, G., 1969. Estudio de racionalizacion de las faenas de volteo y saca en una plantacion de pino insigne. Publicacion Cientifica No. 14. Universidad Austral de Chile. Valvia. 37p.
2. Jelves, C.M., 1977. Rendimientos y costos para diferentes metodos de raleos de pino insigne, Pinus radiata D. Don. Degree thesis. Universidad de Chile. Valdivia. 59p.
3. Rodriguez, E.O., 1986. Wood Extraction with Oxen and Agricultural Tractors. Food and Agriculture Organization of the United Nations. 92p.
4. Sessions, J., 1992. Cost Control in Logging and Road Construction. Food and Agriculture Organization of the United Nations, Forest Papers 99.