LONG-TERM PRODUCTION AND THE EFFECT OF TREE SIZE ON PRODUCTIVITY OF CUTTERS IN FIRST THINNINGS OF PINUS RADIATA AT TUMUT, NEW SOUTH WALES

S. N. SHAW

Forestry Commission of N.S.W., P.O. Box 103, Oberon,
New South Wales 2787, Australia

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ABSTRACT

In reviewing and updating cutter productivity figures applicable to New South Wales, a new system involving two complementary levels of study has been developed, encompassing both detailed time-study and gross data approaches.

A detailed time-study was done on a sample of 12–13 cutters with varying experience and ability, and productivity levels were related to tree size. The gross data collected showed a wide range in daily and long-term production levels. The 72 tonnes/week predicted as feasible from the detailed time study was actually achieved by only one cutter.

A gross data system could be used for monitoring productivity under a range of forest conditions, without necessarily establishing what those conditions are.

INTRODUCTION

Cutters' productivities in particular forest stands and their long-term production levels are of continual concern to the forest owner, to the utilising industry, and to the cutters themselves. Objective data are helpful, if not essential, in negotiating payment rates, comparing "cutter" and "mechanical" harvesting systems, and allocating time and costs to each product in combined sawlog and pulpwood harvesting operations.

The Forestry Commission of N.S.W. currently uses productivity data adapted from Whiteley (1973). However, discrepancies between predictions from these data and actual events necessitated a total review and updating of the information.

This paper deals with one part of the over-all project, i.e., studies in scheduled first thinnings for pulpwood in *Pinus radiata* D. Don, aged 11–15 years.

METHODS

Two complementary levels of data collection, detailed time-study and gross data, were undertaken simultaneously in three blocks of field work. Each study was of 2 weeks (10 days) duration.

According to classic work-study procedures (I.L.O. 1969) "time studies should be made, as far as possible, on a number of qualified workers". Rating of performance is also a central feature in such classic procedures.

Samset *et al.* (1969), however, set out to conduct "experimentation according to sound statistical methods without any form of subjective adjustment of the times" and dismissed performance rating as unscientific, as they reported I.U.F.R.O. had done. Harlaa (1981) also suggested performance rating in forestry is unreliable.

The New South Wales cutter workforce has had little formal job training, and it seemed appropriate to base a study on a relatively large sample of a cross-section of cutters. In fact, knowledge of the likely range and variations in productivities of cutters is perhaps just as important as knowledge of the "average".

A group of 12 cutters, comprising individuals with a broad range of cutting abilities, was selected from those working for a contractor in first thinnings in the *P. radiata* plantations at Tumut, New South Wales (using the crew from only one contractor facilitated field work supervision). Two of these 12 had only 2 months' experience as cutters, and in fact resigned shortly after the first block of field work. Additional cutters as were available at subsequent times of field work were used to replace absent cutters.

The three study areas were selected from those compartments which had been allocated to the contractor by the local Forestry Officer. Selection criteria were:

(a) Sufficient area for each cutter for approximately 2 weeks' work;

(b) Slope less than 15°;

(c) Reasonably uniform stocking and basal area.

Prior to harvesting each area was assessed according to Forestry Commission procedures, viz, systematically located 0.05-ha circular plots, one plot per 4 ha of stand to be assessed, minimum five plots, maximum 25 plots (Table 1).

TABLE 1—Summary of the three study areas

Area	Stand age (years)	M.D.H.* (m)	Before thinning		Retained		Removed		Hardwood index‡
			Stems /ha	B.A.† m^2/ha	Stems /ha	B.A. m^2/ha	Stems /ha	B.A. m^2/ha	
1	15	21.1	1238	38.3	433	17.6	805	20.7	7461
2	14	18.0	1164	34.5	356	13.2	809	21.3	3898
3	12	17.5	1145	34.4	325	12.2	820	22.2	0

* M.D.H.: mean dominant height of stand (average height of 40 tallest trees/ha)

† B.A.: basal area

‡ Hardwood Index: $[\sum_i$ (Length (dm) $\times$ mid diameter^2 (cm))$]$/ha
where i = the number of hardwood logs on each outrow within the plots.

Areas 1 and 2 were marked for harvesting using a seventh row outrow system; Area 3 used a fifth row outrow system. Cutters felled trees on both sides of the outrow, i.e., the outrow formed the centre of each cutter's "break". Requirements were as for normal work, i.e., that the cutter should fell, delimb, crosscut, and stack every tree not paint-marked (by the Forestry Commission) for retention; log length 5 m; top end diameter (toe) 10 cm; stacks off the outrow. Each cutter used his own equipment – a power chainsaw ranging from 45 cc to 90 cc and associated tools, recoil logger's tape, tongs (scissors) or hooks. None of the cutters studied used a cant hook (logging bar) or wedges. Safety equipment ranged from vibration-dampening handles (on every saw), through chain brakes, hand mit, ear protection (muffs or plugs), eye protection, gloves, steel toe capped boots, hobnail boots, and leather apron, to a hard hat. Most cutters used just a hard hat and vibration-dampening handles.

The usual work method was to fell one tree, delimb and crosscut each log working from the tree base to top, stack all logs, and then move on to the next tree. Any hardwood on the outrow had to be crosscut to enable the forwarder to move the hardwood with its grapple and gain access down the outrow. Some cutters crosscut the hardwood before the felling operation; others crosscut it after.

DETAILED TIME STUDY

Two time-study teams were established. Each consisted of two persons, one timing and recording each element of work, and the other measuring each log of each tree.

Timing, with both analog and digital types of flyback stopwatches, was in centiminutes ($\pm$ 0.5 centiminutes). Log length (metres $\pm$ 0.05 m) was measured using a logger's recoil steel tape. Log diameter (centimetres $\pm$ 0.5 cm) was measured with callipers at the mid point and at both ends of each log. Diameter at breast height over bark (centimetres $\pm$ 0.5 cm) was also measured with callipers. All diameters were taken from a single measurement at each point.

The study monitored a cutter's work day from the time of his arrival at the study area and finished with his return to the vehicle at the end of the day. Time was divided into productive time, unavoidable delays, and avoidable delays.

A detailed list of elements and delays is given in Appendix 1. Generally, neither the times for non-productive work nor for avoidable delays were directly affected by individual tree or stand characteristics.

Factors that Affected Cutter Productivity

From the detailed time study, total productive time per tree was derived as the sum of the times for each of the elements for each tree, and this has been calculated for each cutter.

The relationship of experience and age to productivity was apparent. Cutters 19 and 20 had less than 3 months' experience and generally required more time per tree (Fig. 1) than the other cutters, who each had more than 2 years' experience. The coefficients of determination (Table 2) for the regressions for Cutters 17 and 32 are 28 and 36%, for all the other cutters the R^2 exceeds 50. Cutters 17 and 32 were aged 18 and 19 years, respectively, and the rest (except for 18-year-old No. 26) ranged from 21 to 52 years. However, all of the regressions were highly significant (Table 2).

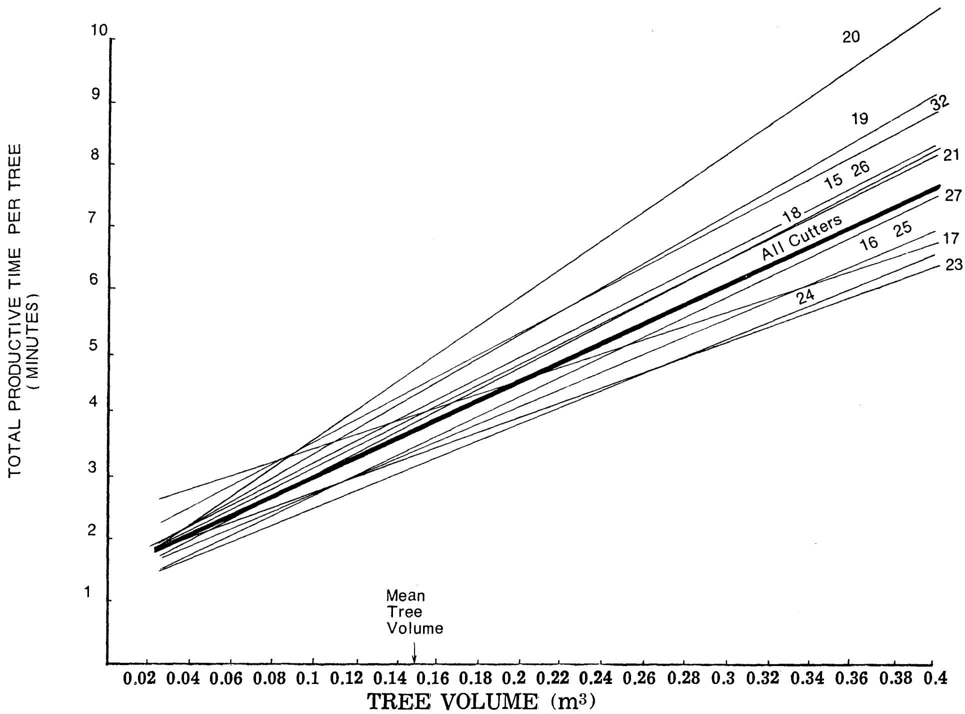

FIG. 1—Regressions of total productive time per tree against tree volume for each cutter and for all the data pooled to represent a hypothetical "average" cutter".

TABLE 2—Coefficient of determination (R^2) and number of records for each cutter's regression in Fig. 1*

Cutter No.	R^2 (%)	No. of Records
15	69	264
16	74	652
17	28	516
18	80	453
19	80	38
20	54	65
21	66	222
23	64	166
24	69	227
25	62	400
26	67	445
27	78	194
32	36	336
"Average"	56	Total 3978

* The percentage probability throughout was 0. Percentage probability is the level at which the mean square compared to the error square of the observations is significant, i.e., a probability of less than 1% means a 1% probability of that result occurring by chance.

For the mean tree volume of 0.15 m^3, "Total Productive Time" required to fell, process, and stack each tree ranged from 4.7 to 3.2 minutes (Fig. 1). The cutter who appeared to have the highest productivity, Cutter 24, had received some training in the Nordfor System and was 32% faster than the least productive cutter (20) who had only 2 months' experience.

It should be noted that speed of cutting (productivity) cannot be considered in isolation from safety procedures adopted. No attempt has been made in this study to objectively assess the level of safety which each cutter adopted. However, a subjective assessment indicated no major differences between the cutters on the level of safety in working methods.

Assuming a hypothetical cutter whose productivity equals the average of the cutters studied, the effect of varying tree size on productivity is apparent in Fig. 2.

Three 50% reductions in merchantable tree size from 0.4 m^3 require 21%, 30%, and 50% more productive time.

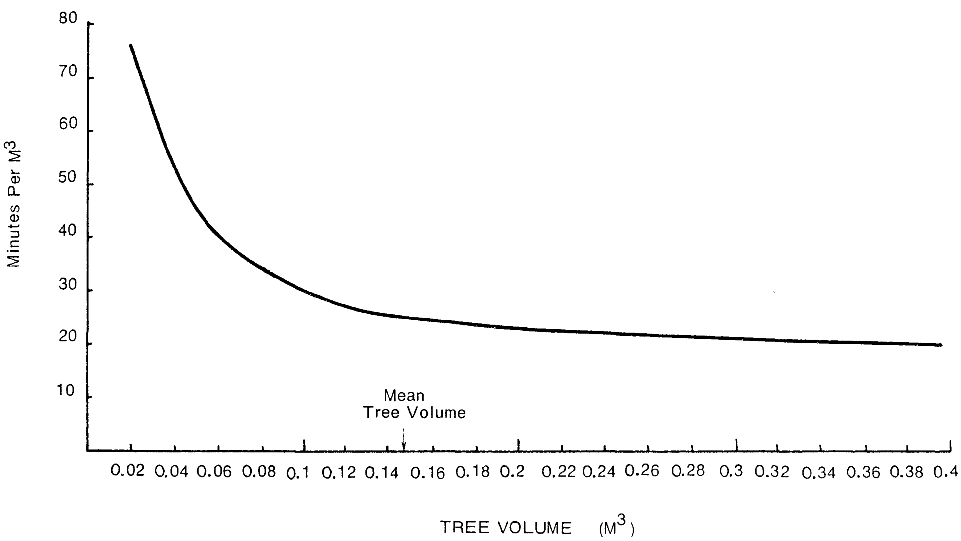

FIG. 2—Effect of tree size on productivity for the "average cutter".

Proportions of Productive Time, Unavoidable Delays, and Avoidable Delays

Total production is dependent on hours worked per day and the relative proportions of productive and non-productive times.

The variability of total day length and of proportions of productive work time is apparent in Fig. 3. Cutters 17 and 18 have the highest and lowest (respectively) proportions of time for avoidable delays. Cutter 24 also had 2 days with low proportions of delay times, but these days (3 and 4) were less than 4 hours total time in the forest.

Along similar lines to classic work-study procedures, predictions of production per day can be made by incorporating times for unavoidable and avoidable delays. Rather

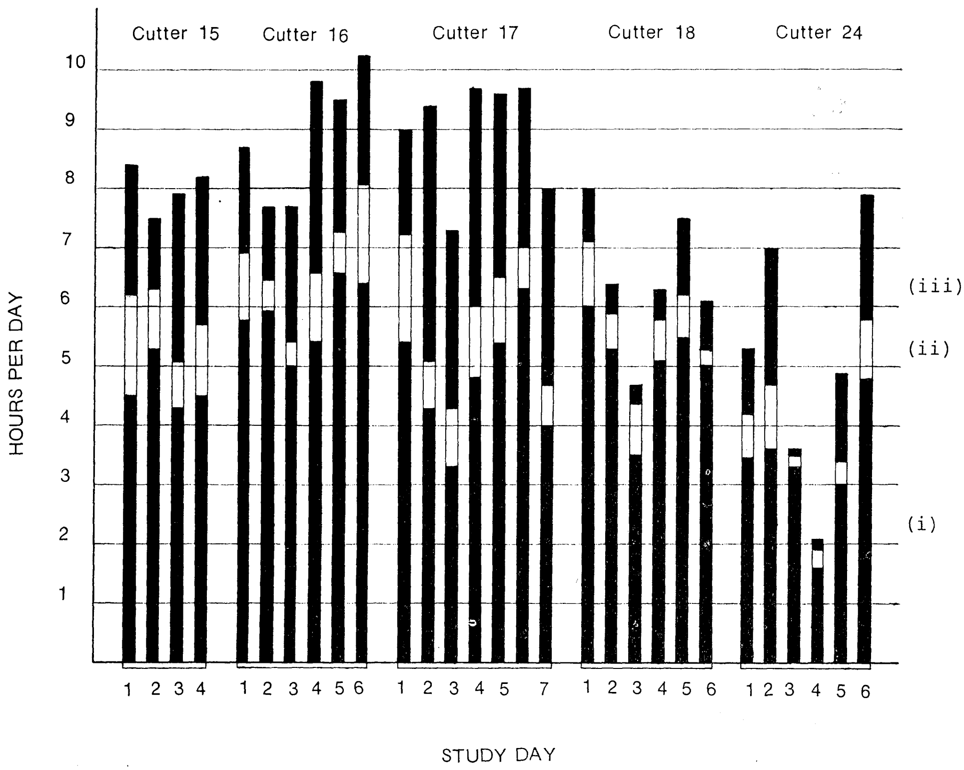

FIG. 3—Productive time, unavoidable delays, and avoidable delays per day for five cutters chosen to represent the range in the study.

than use standard figures for "rest allowances" (Wittering 1973) which might not be appropriate for New South Wales, actual times recorded have been used.

An estimate of delay time was obtained by regressing hours delay per day against total hours in the forest per day (Fig. 4).

Twenty-five minutes productive time is required per cubic metre for the average tree size (Fig. 2). In a 9-hour day (40-hour week, Timber Industry Consolidated Award 1974) an estimate of $3\frac{3}{4}$ hours of delay time can be made from Fig. 4, that is $5\frac{1}{4}$ hours productive time per day for the "average cutter"; this gives an expected productivity of 12.6 m^3/day and 63.0 m^3/week. At 0.875 m^3 solid wood/tonne (Forestry Commission of N.S.W.), that is 72.0 tonnes/week.

GROSS DATA STUDY

Gross production data were also collected for each cutter for the duration of the field work. These data included:

(a) Total production each day (assessed from a log count);

(b) Total time in the forest each day (from wrist watch times);

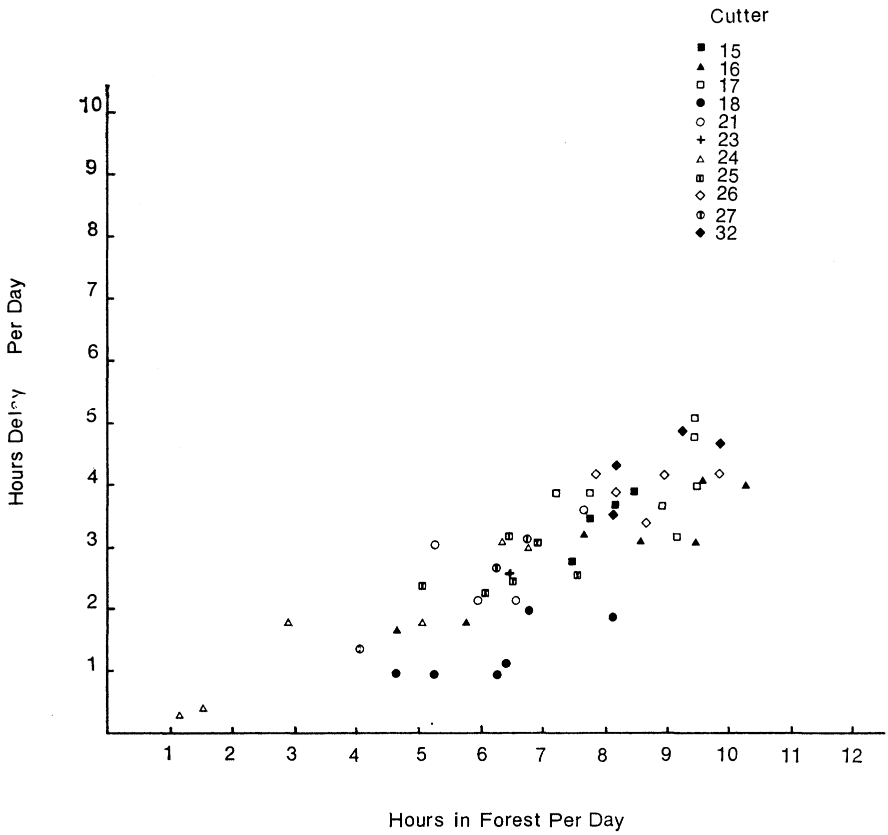

FIG. 4—Hours delay per day.

(c) An estimate of productive work time. This was obtained from electrically operated noise-activated recorders which digitally recorded all noise above 80 db (for details of these recorders *see* McCormack 1982).

Six recorders were available for use in the study, and they were worn on the cutter's belt (Fig. 5). Generally cutters did not work in adjacent bays and were therefore at least 20 m from each other, and the saw of one cutter would not be expected to activate a recorder worn by another cutter. Erroneous activity could be recorded if any other sound of 80+ db were encountered, e.g., forwarder activity at very close range or a recorder left adjacent to a radio during meal breaks, but such events were rare.

The use of the activity recorder to provide an estimate of work times assumes that for any given amount of work for any given cutter the amount of noise above 80 db will be relatively constant. A variation in the number of units of noise recorded for a given amount of production reflects some change in work conditions; a constant relationship between the number of noise units recorded and production reflects consistent work conditions.

FIG. 5—Cutter wearing activity recorder (Mk II) on belt whilst working in **P. radiata** at Tumut.

Production

Figure 6 was compiled from information collected in the detailed time study in each study area. Volume was assessed from mid-diameter and length of each log, using the Forestry Commission of N.S.W. sales log volume tables. The sum of the log volumes was regressed against the number of logs involved. Each regression is highly significant ($p < 0.1$).

Time in forest

Daily production for all cutters is shown in Fig. 7 where the volume produced each day is presented against the number of hours each cutter spent in the forest each day. Up to $10\frac{1}{4}$ hours elapsed from a cutter's arrival in the forest to his departure; a cutter produced up to 204 logs (19.1 m^3) each day.

Of the 142 daily records in Fig. 7 only 28 exceeded 9 or more hours in the forest – eight records for Cutter 17, six records for Cutters 16, 26, and 32, and one for Cutters 15 and 21.

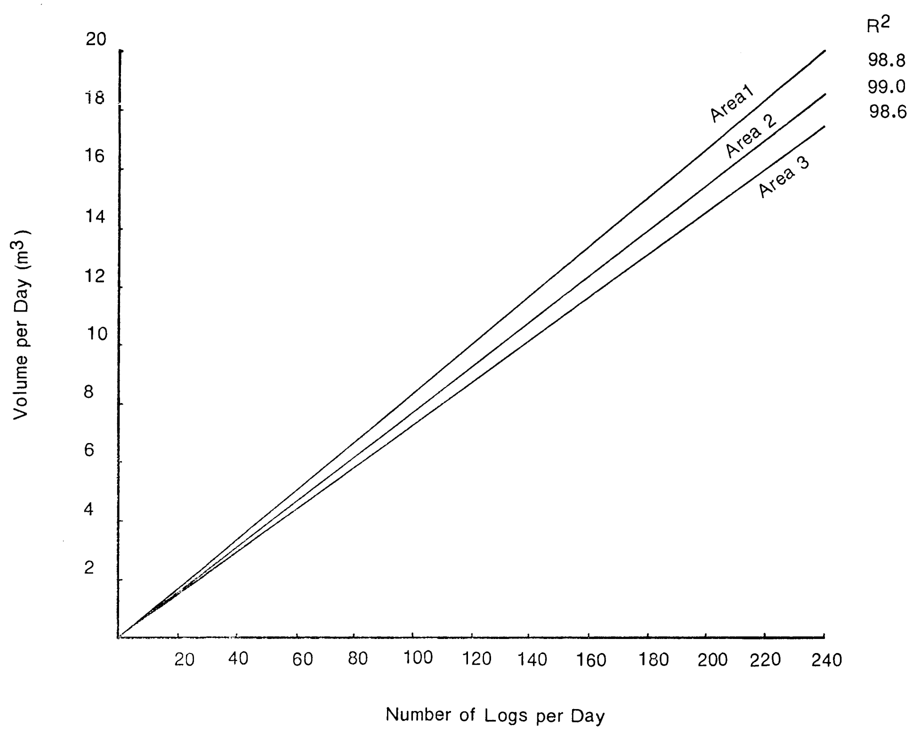

FIG. 6—Relationship between number of logs produced per day and volume for each study area.

Productive work time

Regressions of "Volume per Day against Noise Units" were derived for each cutter in each area and tested for differences. Using the 't' test at the 95% probability level only Cutter 32 showed any significant difference. The pooled information for each cutter is presented in Fig. 8; each regression is highly significant.

A Method for Monitoring Productivity

Although it has not yet been fully tested, it appears possible to use this gross data approach to monitor productivity in any area in which cutters are working.

Daily records of production and "noise units" in each area could be tested against a base-line regression such as in Fig. 8 which could be taken, for example's sake, as the productivity level in the normal or usual conditions. Statistical comparisons between the regression for the new area and the base-line regression would indicate any differences in productivity between the two areas, which in turn would indicate a change in working conditions. That is, relative productivity in various areas could be monitored without establishing what particular conditions (and interactions of those conditions) were prevailing.

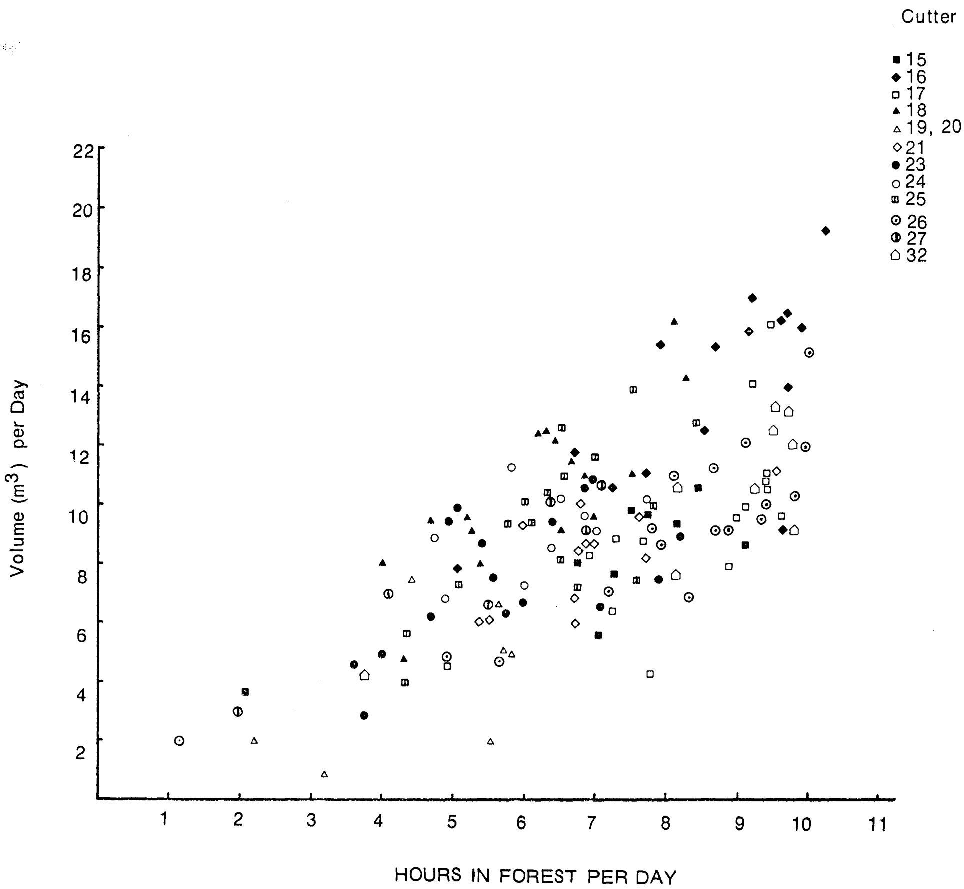

FIG. 7—Dai'y production and hours per day in the forest for each cutter.

CONCLUSIONS FOR LONG-TERM PRODUCTION LEVELS

Figures 1, 2 and 7 highlight the effect of tree size on productivity and the variations in daily production between cutters and for individual cutters.

The hypothesis developed from the detailed time-study using the hypothetical average cutter was that production would be in the vicinity of 72.0 tonnes/week but, as was seen in Fig. 7, only Cutter 16 achieved this level of production. However, the other cutters did not work the same hours per day as Cutter 16.

Two implications might be drawn from this information. Firstly, if each cutter spent 9 hours on the job each might achieve 72 tonnes/week. Alternatively, it could be that the physical workload of cutting is such that only one cutter in 12 can maintain 9 hours per day on the job and 5¼ hours productive time per day.

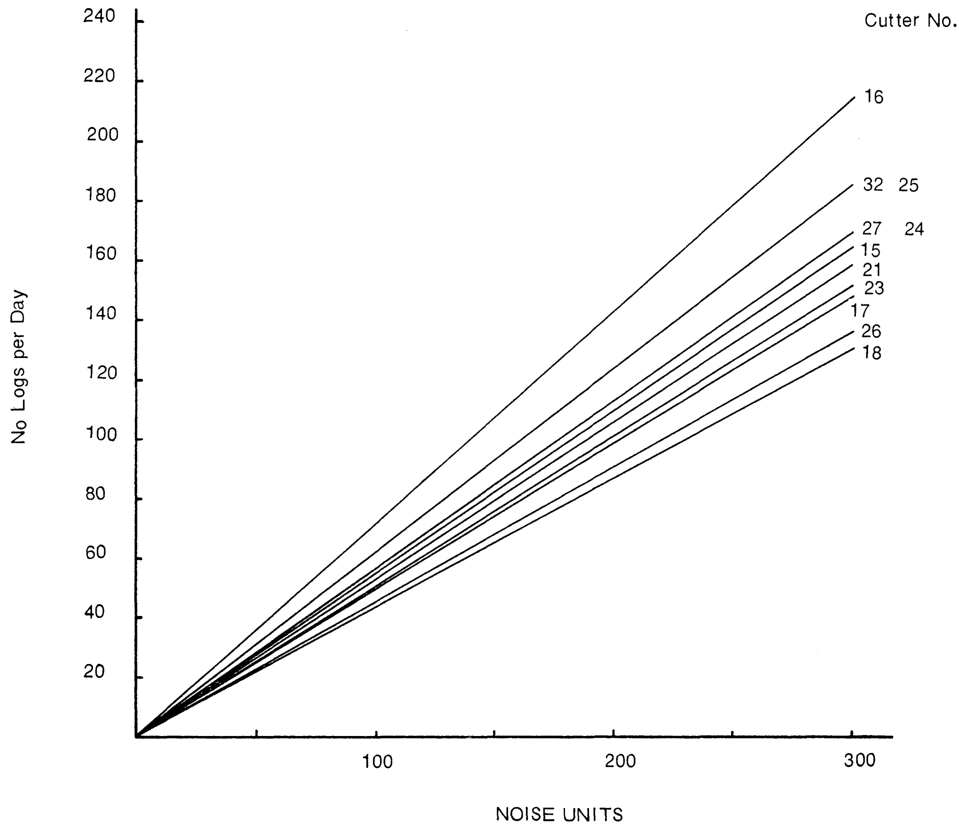

FIG. 8—Regressions for each cutter based on gross data - noise units per day and volume per day.

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APPENDIX 1

ELEMENTS USED IN THE DETAILED TIME STUDY

Total time in the forest can be divided into three main sections:

(a) Productive Time: time spent actually working and producing.

(b) Unavoidable Delays (synonymous with non-productive worktime): time spent undertaking necessary operations to enable productive work to proceed; generally beyond the control of the cutter.

(c) Avoidable Delays: time spent on delay elements within direct control of cutters, and largely dependent on characteristics of each cutter.

PRODUCTIVE TIME

(a) Walk, inspect, and prepare: time taken to select and walk to the next tree and to prepare around the base of the tree to gain necessary work room.

(b) Fell: time for scarfing cuts and backcuts to be made and till the tree is on ground.

(c) Walk and delimb: time to delimb each tree from tree base to tree top, including walking to the next branch whorl.

(d) Walk and measure: time required to hook tape into log, inspect tape for length, and any time spent waiting for tape to recoil.

(e) Clear slash: time required for cutter to move branches, already delimbed from the current or previous trees, away from the work area so that other elements may proceed. (Does not include slash on log stacks).

(f) Stack: time required to place logs into stacks.

(g) Clear slash from stacks: time required to move delimbed branches and/or tree heads from an area which is about to have logs stacked on it, or from logs already in stacks.

(h) Return delimb: time spent delimbing any branches missed in the original delimbing elements usually from top to base of tree.

UNAVOIDABLE DELAYS (NON-PRODUCTIVE WORK)

(a) Sharpen chain.

(b) Saw maintenance.

(c) Refuel: includes time to check fuel levels.

(d) Move hardwood: time to move hardwood which is hindering any other element.

(e) Cutting hardwood: time to cut hardwood which might be hindering any other element, or which is in the outrow and must be cut to allow a forwarder access down that outrow.

(f) Talk to supervisor.

(g) Wind hazard: time spent necessarily waiting for dangerous high wind speeds to ease.

(h) Rain, hail, snow: time spent in shelter when rain, hail, or snow have interrupted work.

AVOIDABLE DELAYS

(a) Saw jam - felling: time spent removing saw from jam.

(b) Saw jam - crosscutting: time spent removing saw from jam.

(c) Hang-up: time spent trying to dislodge any particular tree which has been "hung-up" (usually in adjacent trees). It does not include time where a cutter after one "hang-up" moves to another tree which is then directionally felled across the first in an attempt to dislodge it, nor does it include any of the increased delimbing time which might result with the intermingling of branches from two or more trees felled together.

(d) Walk to and from the vehicle.

(e) Drink.

(f) Meal: time from start of meal to preparation for return to work; it may include "rest".

(g) Injury: includes time to remove sawdust from eye, first aid to cuts and splinters.

(h) Smoke: may include "rest".

(i) Personal.

(j) Talk to studyman: may also include "rest".

(k) Talk to workmates: may also include "rest" and time spent helping workmates with hang-up, saw maintenance, etc.