AN ANALYSIS OF PRODUCTION AND COSTS OF THREE SMALL TRACTORS USED IN FUELWOOD HARVESTING IN NEW YORK STATE

by

Anthony P. Quadro

A technical report submitted in
partial fulfillment of the requirements for the
Master of Science degree
State University of New York
College of Environmental Science and Forestry

May, 1982

Approved:
School of Forestry

Approved:
Committee on Graduate Studies

Major Professor

Chairman, Examining Committee

Dean, School of Forestry

Assistant Vice President for
Academic Programs

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to the following persons: Dr. Richard V. Lea, for his enthusiasm and constant guidance; Dr. Donald E. Koten and Professor Charles N. Lee, for their constructive critcism and help in completing this report; Mr. Neil K. Huyler and the U.S. Forest Service for sponsoring this project; Mr. Jack J. Karnig, for the use of the Harvard Black Rock Forest; the Wood For Fuel Project, Inc. of New Paltz for supplying the machines; and finally to my wife Debra, for her patience and understanding during the entire study.

TABLE OF CONTENTS

Table of Contents Cont.

LIST OF TABLES

LIST OF TABLES CONT.

LIST OF FIGURES

AN ANALYSIS OF PRODUCTION AND COSTS OF THREE SMALL TRACTORS USED IN FUELWOOD HARVESTING IN NEW YORK STATE[1]

INTRODUCTION

The objectives of this report are to present an analysis of data obtained by time study methods for three small tractors, and to discuss the time study procedure used. The time study was designed to provide data by which the following items could be determined:

1. Owning and operating costs
2. Production time
3. Operating and non-operating delay time
4. Operational capabilities and limitations
5. Environmental impact

The timber resources of New York State are substantial and have increased steadily between 1950 and the last Federal estimation in 1977. The gross annual growth of all hardwood species in New York State was 2.7 million cords in 1976 (USFS, 1978).[2] Until the incorporation of firewood use estimates, the annual growth of growing stock continued to be almost twice as much as "removals" (Bertozzi, 1982). In 1980, aproximately 1.3 million hardwood cords were harvested for industrial

---

1 The study was funded by the following cooperating agencies:

The Research Foundation of the State University of New York for the College of Environmental Science and Forestry, Syracuse, N.Y., Project 210-6268A (SUNY-ESF).

USDA Forest Service, Northeastern Forest Experiment Station, Broomall, PA. Agreement 23-571 (NEFES).

Wood For Fuel Project, Inc., New Paltz, N.Y., New York State Energy Research Development Authority (NYSERDA).

2 Preliminary USFS data (1981) indicates a greater amount for growth.

use with another two and one half times as much consumed as home fuelwood (Bertozzi, 1982).[1] Taken together, the annual hardwood harvest is approximately 80 percent greater than the last available annual growth volume estimate of the hardwood growing stock. The New York State Department of Environmental Conservation predicts an increase of an additional 18 percent during the 1981-1982 wood burning season (Bertozzi, 1982).

The projected increase in fuelwood consumption and the excessive drain on the hardwood growing stock indicates the need for improved management of New York's hardwood forests. Approximately three-fourths of the states' forests are hardwood (Bertozzi, 1982). Effective management of this resource will be required to insure that the available supply of quality hardwood is not depleted. Trees which are suppressed, of poor form, diseased, dying, or defective in some other way should be utilized for firewood rather than trees which exhibit quality sawlog potential. However, difficulty arises in encouraging desirable management due to several factors involving both forest land owner attitudes and economic considerations.

Approximately 58 percent of forestland in the United States is owned by non-industrial private owners (Clawson, 1979). The greatest proportion of these owners are in the Northeastern United States, and a large proportion of their lands are unmanaged. If thinned properly,

---

1 Other estimates may be lower due to a decrease in casual burning.

these stands should be capable of increased production of quality forest products.

Unfortunately, many past attempts to stimulate the non-industrial private woodlot owner to manage his stands have failed. Recent trends in ownership patterns indicate that much of the forest acreage has been purchased by persons motivated by desire for recreational use, aesthetics and speculation purposes; they seem unwilling to sell timber (Marler and Graves, 1974). Also, many landowners have a fear that harvesting operations using large equipment may destroy the forest's usefulness for their purposes (Gabriel, 1975). A New York study has shown that it is not the removal of timber, but the manner in which it is removed that is most often criticized by suburban forest owners (Gabriel, 1975). When the timber is sold, usually in the owners' later years when the property is no longer desired purely for aesthetic reasons, the timber is often sold at the logger's discretion to reap the maximum stumpage value.

Economic reasons are also a factor in harvesting small low quality trees. Markets for this material are usually hard to find. Although a good firewood market exists in some areas, the value of fuelwood remains below that of sawlogs and other forest products while the costs of harvesting with conventional harvesting systems are rising. Certainly, the low volume producer does not have the same equipment needs as the high volume producer, and it is not feasible for most small landowners to invest in large equipment for removal of poor quality suppressed and dying trees. Future willingness to manage small woodlots may depend on methods which prove to be both economically and aesthetically pleasing. Because of landowner aesthetic and economic constraints, an alternate means of removal may be necessary. One such means would employ the use of small, lightweight, four-wheel drive tractors for skidding.

Before these machines should be suggested for use, they should be tested to determine their productivity, owning and operating costs, damage to residual trees, and limitations and capacities. While highly variable, up to 50 percent of the total cost of moving the logs from the stump to the mill can be attributed to skidding costs (Uebler, 1978). Therefore, it should be determined whether the small tractors will reduce skidding costs, or have comparable costs with less environmental impact before recommending their use to harvest fuelwood trees.

A main objective of this report is to present the productivity and costs of the three small tractors tested. However, since only a few small tractors have actually been tested, and then only in a superficial way, the description of the test method will also be a major portion of this paper. Since so many variables exist in the skidding operation, the final results of the time study are subject to a large amount of variation for different areas, operators, and operating conditions. However, if the reader understands the methods used and the reasoning behind the data collected, he can estimate the change in production and costs for his particular operation; or, he can run his own test for his machine in his particular area.

The objective of any harvesting system is to remove products, yet minimize costs and increase profit. To do this, the operator must have believable production standards. These standards should be based upon good records. These should enable the operator to determine his costs based on production, time, and cost rates for equipment and labor. The stopwatch time study is a practical method of measuring these factors for logging operations (Conway, 1976). Time and motion studies have been used for a number of years in forestry, in skidding operations. Early time studies were done on skidding with horses (Canadian Pulp and Paper, 1943), and have been used extensively since then, however, very few detailed studies have been done with smaller tractors. If small tractors are to play an important role in fuelwood harvesting, this type of study becomes essential.

SCOPE

This report shows results of a time study performed on three tractors:[1]

1. The Holder A60, of Germany
2. The Pasquali 993, of Italy
3. The Skogsmyran (Forest Ant), of Sweden

The tractors were tested on two slope classes on rugged terrain with rock outcrops and boulders throughout. The effects of variables on the operation of these machines were determined by regression equations. Owning and operating costs were then determined for each slope class. An indication of environmental impact (damage to the harvested site) was also determined along with production capabilities and limitations of each machine. All times were analyzed by operational functions within the skidding cycle, along with delay times associated with each function.

Before the presentation of the study method and data analysis, a brief review of prior studies on small tractors is appropriate.

1 Use of trade, firm, or corporation name in this report is for informational clarity of reader and does not imply endorsement by the agencies involved herein of any product or service to the exclusion of others that may be suitable.

LITERATURE REVIEW

Time study is the analysis of a given operation to determine the elements of work required to perform it, the order in which these elements occur, and the times which are required to perform them effectively (Maynard, 1956). The timing of operations is essential to all production and cost estimates; and time costs are the basis of most industrial efficiency control (Mathews, 1942).

Although several small skidder studies have been reported, methods and details of the testing have not been reported in detail. Most testing was done over very short time periods with only general recommendations and costs reported.

In 1962, the Canadian Pulp and Paper Association recognized the importance of small skidders by running a "small skidder forum" in which four small skidders were tested (Davidson, et al., 1962). These tractors were timed to develop an indication of performance, production times, and owning and operating costs. The following variables were determined as being important:

1. Average distance
2. Average load
3. Travel time per trip
4. Choking and unhooking time per trip
5. Positioning time per trip
6. Delay time per trip
7. Average time per trip

Ground and stand conditions were described, but no attempt was made to quantify the effects of independent variables such as distance, weight, or slope on times or cost. The machines in general pulled an average of 2-5 cords per man day, averaging 12-25 minutes per trip.

In 1968, the Holder A20 was tested by the Candian Pulp and Paper Association for the extraction of early thinnings (Whayman, 1968). The following recommendations were suggested for use of this small tractor:

Method of operation:

1. Trails 10 ft. in width and 145 ft. apart
2. Roads straight with no side slope
3. Herringbone felling, trees 30°-60° to trail
4. Loads winched, tops first

Ground condition:

1. Slopes not over 21 percent
2. Obstacles under 12 in. high

Allowances:

1. Personal time 22 percent
2. Other work 11 percent
3. Contingencies 4 percent

Miscellaneous:

1. Wheel chains imperative to prevent wheel spin and rut formation
2. Directional felling and proper trail layout

Conclusions:

1. "These light machines promise to make a useful contribution to productivity in early thinnings but the larger frame steering tractors are more appropriate for clear felling or late heavy thinnings."

This study was statistically a limited study which reported general recommendations for use of small tractors in early thinnings, in particular, the Holder A20.

The <u>Norther Logger</u> has editorialized several times about the need for machinery that can harvest small woodlots without badly tearing up the landscape, and at a price the operator can afford. In a 1970 interview with an owner of a 25 HP Kubota with Farmi winch (Fowler, 1970), it was found that the logger averaged 3-4 cords of wood per day and used only .5 gallons of fuel per day. Again, however, no detailed study was performed.

An article entitled "Yellow Cabs in the Woods" (Hoffman, 1981), described the use of small tractors for bunching cut trees and skidding them to the major skid trail where a larger skidder would pick up the load and skid it to the landing. Hoffman determined that production increased by 0.8 cords per hour and that cost decreased by approximately $6.00 per cord. He indicated that much time is saved by bunching small material with the light cable and chokers. The light cable is easier to drag through the woods, and winching longer distances is possible. Table one gives a breakdown of the skidding operation in percent work time and factors affecting this time. The small tractors save time in bunching by gathering logs more easily and using less fuel in doing so.

Table 1. Primary transportation (Hoffman, 1981).

Time Elements	Work Time	Factors
Trip out	15%	Distance Topography Soil Road standard Equipment choice
Bunching	58%	Trees/ac. Brush Ground conditions Distance Cable and Choker Size & No. Stem size Winch/speed
Trip in	19%	Trip out factors Load size
Landing	8%	No. of stems Size of chokers No. of products

Most of the time is attributed to the bunching function. Also, there are more variables affecting the bunching function than the other functions. Table 2 shows the increase in productivity and decrease in cost when the small tractor is used for bunching. Conventional skidder data indicates a conventional operation assuming however, that the skidder was used to bunch optimum size loads before skidding, the Skidder and Tractor data are for the operation using the tractor to bunch loads for the conventional skidder to skid to the landing.

Table 2. Thinning - JD440 cable skidder in Maine (Hoffman, 1981).

	Conventional Skidder	Skidder and Tractor
Skid distance	466'	391'
Bunch production	1.51 cds/hr	2.31 cds/hr
Skid production	4.97 cds/hr	4.97 cds/hr
Bunch cost/cord	$11.27	$4.97
Skid cost/cord	$3.42	$3.42
Total cost	$14.69	$8.39

The article states that 4 cords per day can be expected with skidding distances of 500-600 feet and 11 cords per day when bunching up to 100 feet. The conclusion was that small equipment does have a place in the woods whether bunching on a high production job or performing the whole job on a small woodlot. Small equipment, however, cannot move large loads over long distances at a satisfactory cost -- there is no substitute for conventional equipment in that application. Small equipment should be used with discretion, and with planning and forethought, many of the problems associated with removing wood in thinning operations can be reduced.

Several small tractors are currently being marketed. Of these most are foreign models from Germany, Japan, Italy and the Scandanavian countries. Although several of these machines have been on the market for some time, there is only limited data available which states valid production and cost data under different ranges of environmental conditions. A recent study done on the more modern small tractors conducted in Vermont, (Stevens and Smith, 1980), suggests production rates for three different small tractors determined from two different sites over a two week period. However, that study was intended only to demonstrate the feasibility of using small tractors to thin pole size hardwoods, and not intended as research for comparison of three machines. The three tractors: Holder A55F, Kabota B7100, and Quadractor were tested on two sites selected to offer a good representation of Vermont terrain with variable slope, rock outcroppings, poor drainage, and large scattered surface boulders. The stands cut were thinned by removing 25-30 percent of basal area. Conclusions were as follows:

1. Using a small four wheel drive tractor, it is entirely feasible to produce firewood on a silviculturally sound basis.
2. An average skidding cost of $12.93 per cord was secured in the two trails completed in the summer of 1978. The average production per hour was 0.58 cords with a tractor and operator cost of $7.50/hour.

3. Fifty cords would be the maximum annual production for this type of unit per year.[1]

4. For those individuals who want to produce firewood on a commercial basis, a larger tractor of 30-40 HP is recommended.

5. Based on experience in these trials, economical skidding distances of up to ¼ mile are feasible for 8-20 HP tractors.

6. 30-40 HP tractors should be economical up to ½ mile.

7. Only four wheel drive tractors should be used.

8. Any tractor should be equipped with some winch capability.

9. Any tractor used for logging should have a safety cage to protect the operator.

10. Wheel chains should be available and used if necessary.

Due to the large number of variables affecting harvesting operations, data which is determined in a study of this nature must be controlled and fully documented if it is to have validity in application. Otherwise, data will simply indicate recommendations. There is a need for documented studies which describe the methods, conditions, and results of a cost and productivity analysis of these small skidders. The present study serves as one such study.

---

1 In the opinion of this author, this figure is too low.

APPROACH AND GENERAL DESIGN

The Wood for Fuel Project, Inc. of New Paltz, New York, a corporation funded by NYSERDA, had as one of its objectives a need to determine the owning and operating costs of three tractors. The SUNY, College of Environmental Science and Forestry was asked to provide technical assistance in determining this objective. It was decided that a time study should be performed to obtain necessary data. The W.F.F. Project was funded for trials of the tractors but not for a detailed time study.

At nearly the same time, the U.S. Forest Service, Northeast Experiment Station solicitation for Hardwood Initiative listed "costs of owning and operating small tractors," as a possible project. As a result, a cooperative project was developed around the three agencies.

An area was needed where the study could be done under controlled conditions. Permission was granted to test on the Harvard Black Rock Forest. This area was a convenient location and provided a wide variety of conditions to test the equipment.

Equipment

Pasquali 993 - The Pasquali 993 is a 30 HP articulated, four wheel drive, diesel tractor. In the present study a Farmi single drum winch was mounted on the tractor. The Pasquali is manufactured in Italy by Pasquali, Inc. (See Figure 1).

For skidding purposes, the Pasquali is equipped with a protective roll bar, and under body protection pan. The front tires were weighted with approximately 75 pounds of calcium chloride solution. Table 1

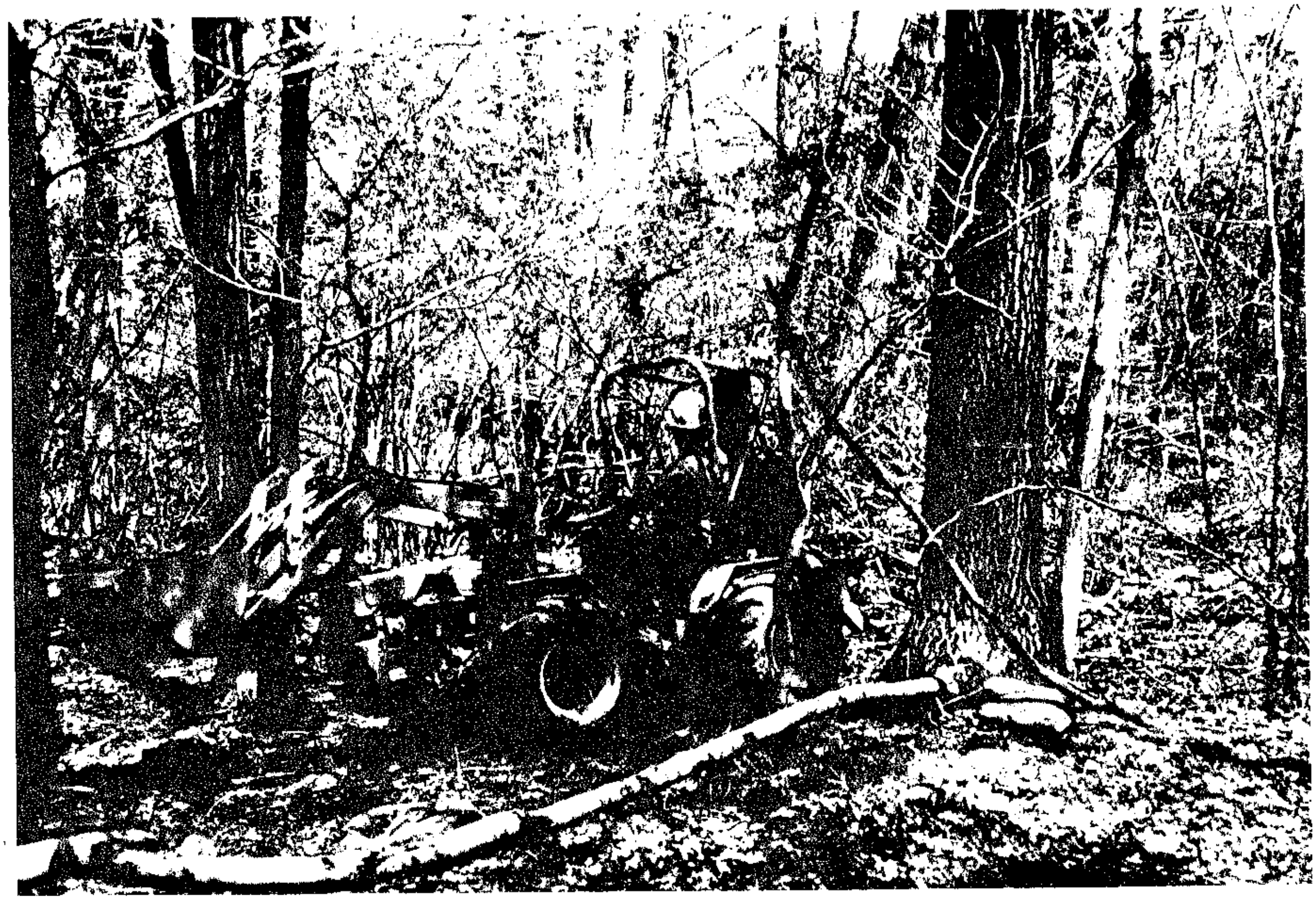


Figure 1. The Pasquali 933

and 4, Appendix A, show the tractor and winch specifications and the June 1981 list price.

The Holder A60 - The Holder A60 is a 48 HP, articulated four wheel drive diesel tractor. This tractor is equipped with a steel protective cage, a double drum winch, and rear butt plate. It is manufactured in Germany by Holder, Inc. (See Figure 2.) The winch used with this machine was the Ingland Winch 3000 "Perfect" double drum winch.

The front wheels were weighted and the front tires were filled with calcium chloride. The understory is protected by a steel pan. Tables 2 and 4, Appendix A, show the tractor and winch specifications and the June 1981 list price.

The Forest Ant - The Forest Ant (Skogsmyran) is a 12 HP, articulated, four-wheel-drive machine with a clam bunk, and a knuckleboom crane with jaw type grapple. The engine is a four stroke, air cooled, gasoline engine. The Forest Ant is manufactured in Sweden by Trelleborg, Inc. (See Figure 3.)

The Forest Ant is unique in that it is operated with a steering column from in front of the machine. Since the Forest Ant is unique, a more detailed explanation of its control is necessary.

The vehicle is steered by manipulating the steering column. When the column is moved to one side, a hydraulic valve operates a steering cylinder causing the machine to turn in the same direction. The steering column operates the following functions:

1. Forward/Stop/Reverse
2. Turn Left/Right
3. Low Speed/High Speed
4. Throttle

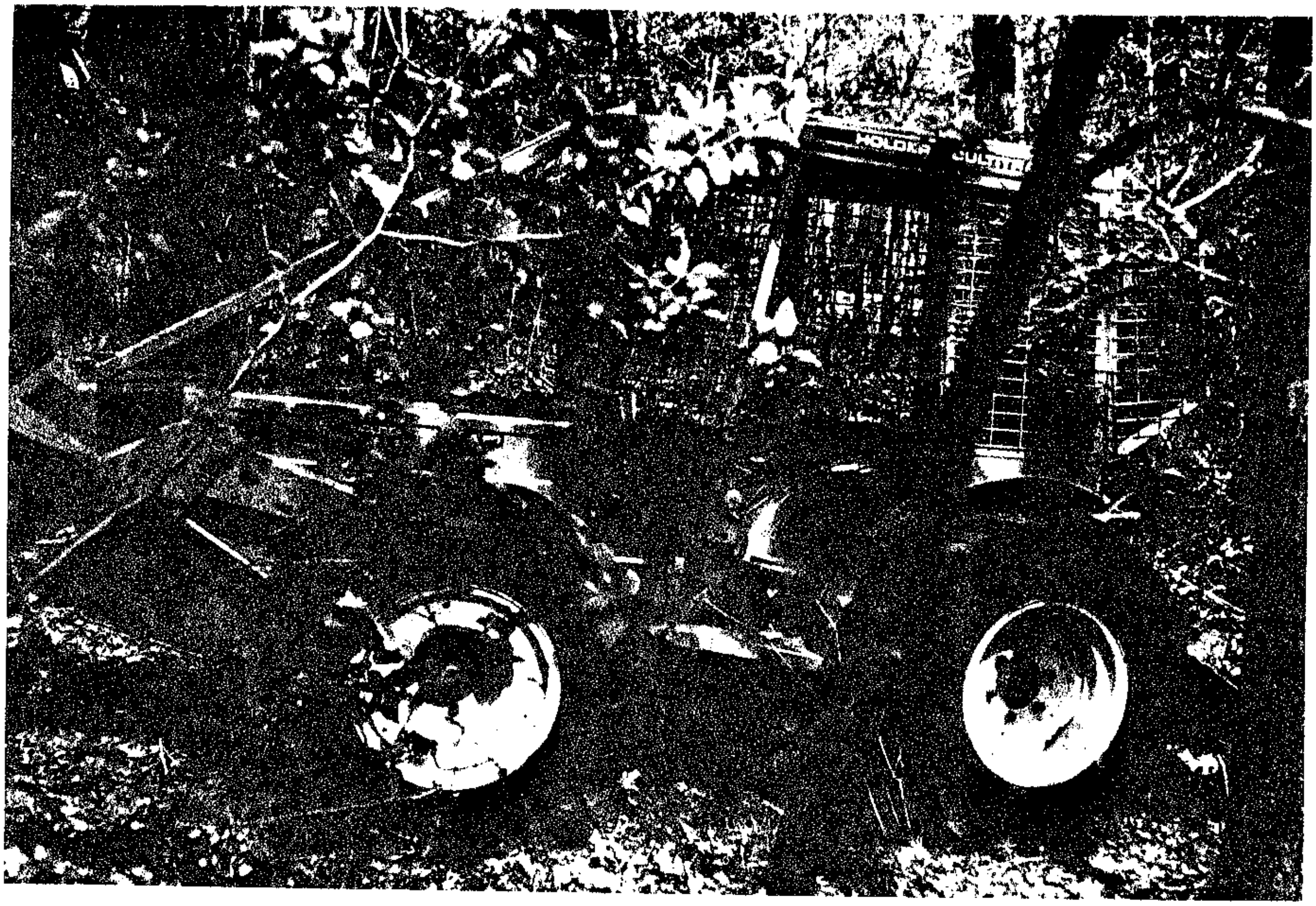


Figure 2. The Holder A60

Figure 3. The Forest Ant

The column is pulled away from the machine for forward, pushed towards the machine for reverse. Counterclockwise rotation of the steering column gives low speed, clockwise rotation gives high speed. The crane controls are located on top of the machine (see Figure 4). The first four levers from the right control:

1. Boom swing left or right
2. Inner boom
3. Outer boom
4. Grapple

A sleeve or "dead man" is located on the steering column as a protective device. If the operator stumbles and grabs the column the sleeve will simply slide and prevent the operator from being run over. Tables 3 and 4, Appendix A, show the machine and crane specifications and the June 1981 list price.

Site Location and Description

The areas selected for testing were located in the Harvard Black Rock Forest, Cornwall, New York. Appendix B, Map I, shows the forest and its topography, and the three test sites. The forest, because of its rugged terrain, provided a good test for the three machines.

Timber tracts of relatively uniform size and conditions in two slope classs (0-15% and 15-30%) were identified and inventoried. The 0-15% slope class was chosen to represent relatively flat or gentle sloping stands. The 15-30% class was chosen to represent steeper sloped areas. It was predetermined that slopes of over 30% would be too dangerous to test the machines on. The stands were mixed hardwoods, primarily oak. Table 3 shows the percent distribution by species on the sites choosen.

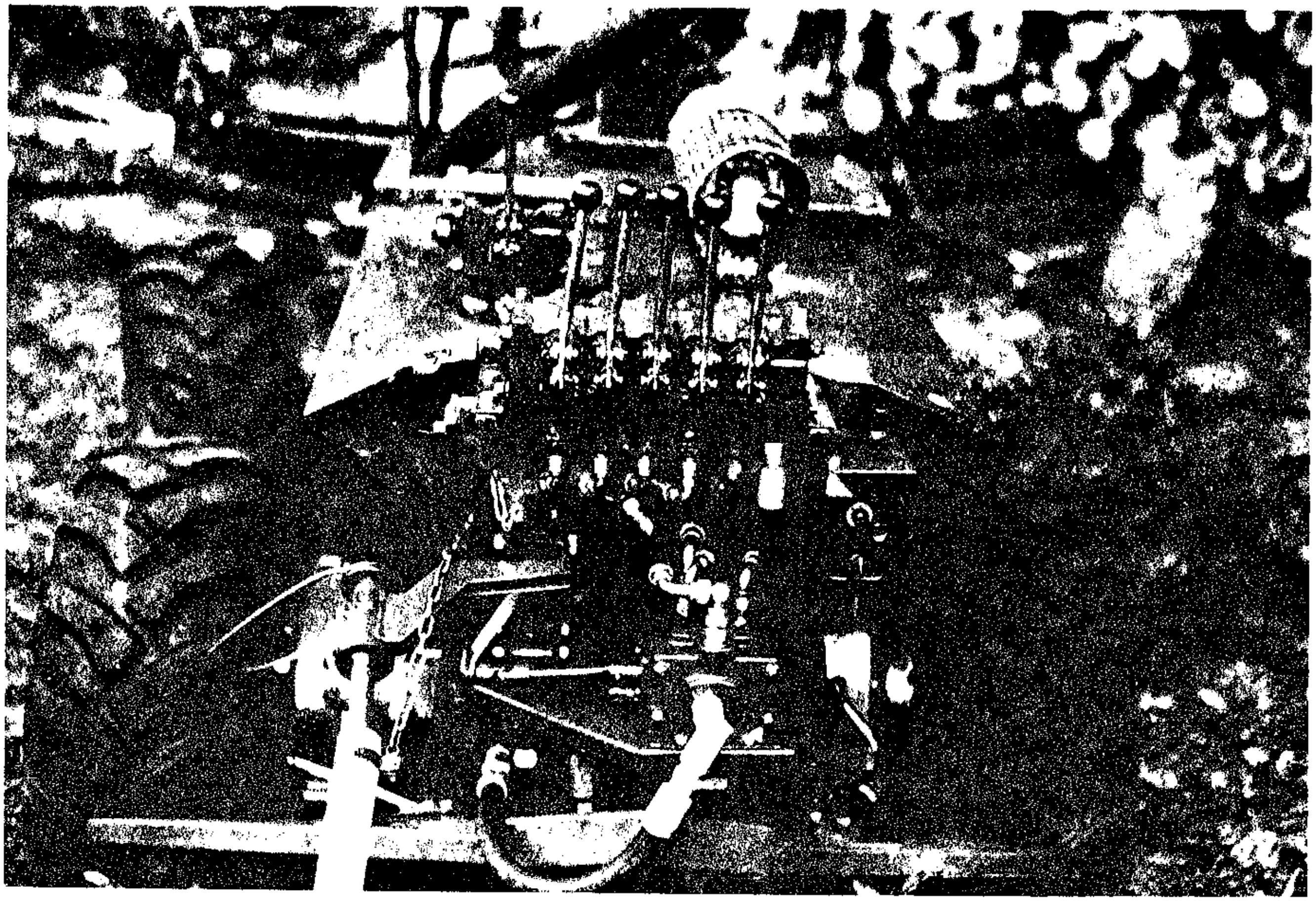


Figure 4. The Forest Ant Controls.

Table 3. Percent distribution by species at testing sites.

Species	Aleck Meadows	Continental Road	Bugs Bunny
Red Oak	36	37	57
Chestnut Oak	26	32	8
Red Maple	11	11	26
Sugar Maple	7	5	-
White Ash	4	6	-
Dogwood & Sassafras	3	-	-
Beech	3	-	-
Yellow Poplar	3	4	-
Birch-Yellow/Black	3	-	2
White Oak	2	1	5
Hickory	1	1	2
Black Gum	1	2	-
Hemlock	-	1	-

Scientific names in the same order as above: *Quercus rubra*, *Quercus prinus*, *Acer rubrum*, *Acer saccharum*, *Fraxinus americana*, *Cornus florida* and *Sassafras albidum*, *Fagus grandifolia*, *Liriodendron tulipifera*, *Betula allegheniensis* and *nigra*, *Quercus alba*, *Carya glabra*, *Nyssa sylvatica*, *Tsuga canadensis*.

The Aleck Meadows area was chosen as the 0-15% test site, and the Continental Road area was chosen as the 15-30% test site. The Bugs Bunny area which was chosen during the study, was also a 0-15% test site, however, only for the Forest Ant. The area was named "Bugs Bunny" due to its peculiar shape.

The terrain of the forest is rather severe with cliffs and steep rocky slopes throughout. The soils of the forest are formed from a glacial till which was deposited upon a granitic bedrock, and are classified as spodosols. Most of the forest surface is covered by a shallow Mor type of humus. Recent leaf litter covers the surface of the soil and is underlain by a partly decomposed semi-fibrous mat of felted hardwood debris ranging from 0.5 inches to 2.0 inches in thickness. Ninety-four percent of the forest is classified as having stony to very stony soils. The test areas have been mapped (Ross, 1958) and are classified as Rockaway very stony loam. This series is described as having friable, dark brown surface soil, with heavier brownish yellow, firm but friable, porous subsoils, and being interrupted by numberous rock outcrops. Bulk density ranges from 1.00g/cc to 1.25g/cc. Change in bulk density is used as an indication of soil compaction caused by each tractor in each skid trail. Before beginning the time study, soil samples were removed with a core sampler to determine bulk density of the undisturbed soil on the skid trails.

The areas were traversed to determine area. A pre-test inventory was performed on all tracts. The inventory indicated the following stand conditions:

Table 4. Pre-test inventory summary (per acre).

Item	Aleck Meadows	Continental Road	Bugs Bunny
Number stems	287	323	244
Basal area	116.2 ft^2 (10.79m^2)	114 ft^2 (10.59m^2)	96 ft^2 (8.91 m^2)
Cu.Ft. volume	2692 ft^3 (76.03 m^3	2416 ft^3 (68.23m^3)	1918 ft^3 (54.17m^3)
Cord Volume	33.6 cds (302 m^3)	30.2 cds (35912m^3)	24 cds (285.40m^3)
Average DBH	8.6 in (21.84 cm)	8 in (20.32 cm)	8.4 in (21.34 cm)
Area (Total)	5.3 Ac. (.150 ha)	5.7 Ac. (.1613 ha)	.95 Ac (.027 ha)

Area boundaries were determined by clinometer to keep slope classes consistent.

The Aleck Meadows area had an average slope of -7 percent. Tree form was generally good, and boles were generally straight and 2.0-2.5 logs high on dominant trees. The understory was composed of dogwood, beech, and red maple and was generally sparse. The terrain was rough with rocks and boulders throughout, and the soil was moderately well drained to somewhat poorly drained. Inventory data was obtained from 16 plots (Confidence limits ± 10.1% at the 95 percent level). The stand was a large pole stand in need of a thinning to eliminate suppressed trees, poorly formed diseased trees and overmature and suppressed trees.

The Continental Road area had an average slope of -18%, slope ranged from 15-28 percent. Tree form was good although many of the trees contained considerable butt rot. The terrain was rough and rocky; large rocks and boulders were few. The soil was moderately well drained. The understory was sparse consisting mainly of red maple and sugar maple. Inventory data was based on 10 plots (Confidence limits ± 10.1 percent at the 95 percent level). The stand was a large pole stand in need of a thinning to eliminate suppressed trees, poorly formed trees, diseased trees and overmature trees.

The Bugs Bunny area had an average slope of -6 percent; slope ranged from 0-12 percent. Tree form was good to poor with multiple stems scattered throughout. The terrain was smooth to uneven. Rocks were present, however only scattered throughout the stand. The understory was moderate consisting of red maple, red oak, chestnut oak, and black birch. Inventory data was based on 10 plots (Confidence limit ± 10.7 percent at the 95 percent level). The stand was in need of an intermediate thinning to remove clumps, trees of poor form, and diseased trees.

Test Area Setup

Following the inventory of the test stands, a harvesting plan was developed. It was decided that approximately one third of the basal area should be removed in each stand, and the stand was marked accordingly. This was primarily a low thinning, although certain larger trees were selected to create openings where needed. Test areas for each tractor in each test site were flagged at 25 ft. intervals with yellow flagging. This was mainly for the visibility of workers.[1]

The perimeter of the stand was marked at one chain intervals in red for inventory purposes. Perimeters were decided upon by: change in slope class, change in stand condition, proximity to stream or poorly drained areas, and terrain which was too rough for machine travel. Table 5 shows the pretest marked tree tally.

Table 5. Pretest marked tree tally.

Item	Pasq.	Aleck Mea. Hold.	Ant	Cont. Rd. Pasq.	Hold.	Bugs Bunny Ant
DBH Range (in)	6-16	6-17	6-17	6-16	6-16	5-9
Ht. Range (ft)	8-56	8-56	8-56	8-56	8-56	8-45
Volume (tot)(ft)	1400	1905	1028	1581	1676	546
Volume/Ac (ft^3)	778	1058	604	718	478	575
BA/Ac	35	43	26	44	48	26
Area (Ac)	1.8	1.8	1.8	1.8	1.8	1.8

1 As a side note, a heavy gypsy moth (Porthedria dispar) infestation was present in the area at the time of marking. The larva caused problems by consuming much of the plastic flagging.

Pretest marked tree tally. (Metric units).

Item	Aleck Mea. Pasq.	Aleck Mea. Hold.	Aleck Mea. Ant	Cont. Rd. Pasq.	Cont. Rd. Hold.	Bugs Bunny Ant
DBH range (cm)	15-40	15-43	15-43	15-40	15-40	12-23
Ht. range (m)	2.4-17.1	2.4-17.1	2.4-17.1	2.4-17.1	2.4-17.1	2.4-13.7
Volume (Tot) (m^3)	39.54	53.80	29.03	44.65	47.33	15.42
Volume/Ac (m^3)	21.97	29.88	17.06	20.28	13.50	16.24
BA/Ac (m^2)	3.25	3.99	2.42	4.09	4.46	2.42
Area (ha)	.05	.05	.05	.06	.10	.03

Before marking the trees, the landing and skid trails were located. The trails were flagged in blue at 50 ft. intervals from the landing to aid in determining distance traveled by the skidders. Marks were placed on the trees facing the skid trails. The fallers were directed to fall the trees in a herringbone pattern at 30-60 degree angles to the trail to facilitate bunching. Appendix B, Maps II, III, and IV, show skid road locations relative to tract boundaries and landings.

In the Aleck Meadows area, two major skid trails were marked; one, an existing grass covered trail from a previous harvest on the western boundary of the tract (trail A), and another, through the tract center (trail B). Trail A was not rocky, although an occasional rock was present at approximately 50 ft. intervals. Trail B was generally on uneven ground. Trees in the trail were cut and large rocks removed with the tractors before harvest. The trail avoided large immovable rocks. For skidding, the Pasquali and Holder used parts of trail A and B which were connected by a short trail in the tract center. The Forest Ant used only trail B. Figure 5 shows a profile of the skid trails most used by each tractor at the Aleck Meadows area.

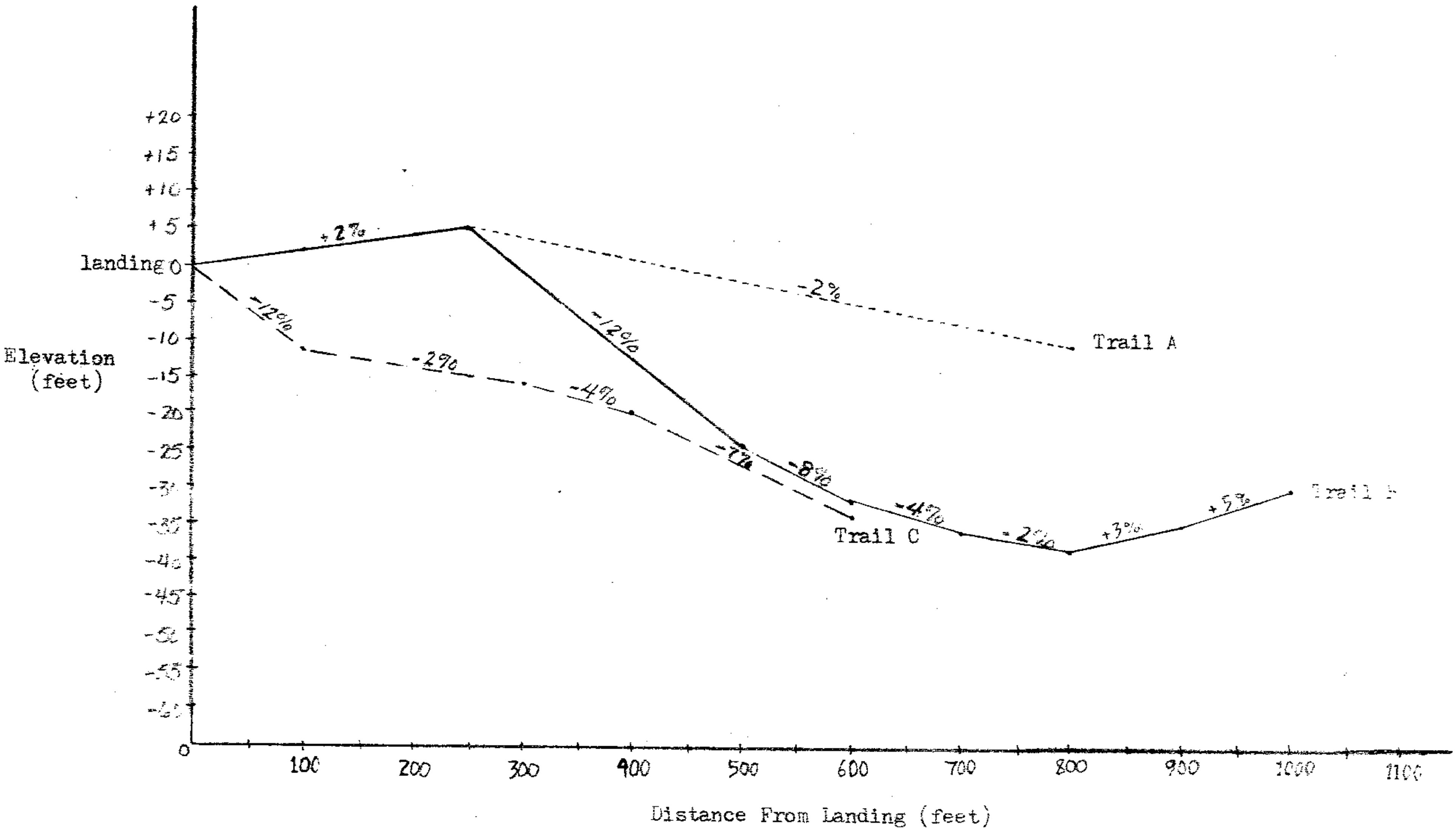


Figure 5. Aleck Meadows skid trail profiles.

An existing road was used in the Continental Road area as part of the skid trail system. The landing was located at the edge of the road above the test site. Thus, the logs had to be skidded uphill on the existing road. The existing road was grass covered, relatively smooth and had no obstacles over 6 inches. To reach this road, the logs were skidded several hundred feet in the woods. The woods trail was rocky with uneven to very uneven ground. The Pasquali utilized the first 1000 ft. of the existing road before turning into the woods; and, the Holder used the first 1400 ft. before turning into the woods. The Forest Ant was not used in this area due to reasons which will be stated later in this report. Figure 6 shows the profile of the Holder and Pasquali trails on the Continental Road area.

At the Bugs Bunny area, there was an upper trail (A) and a lower trail (b) for the Forest Ant. The ground was relatively smooth except for an occasional small rock. A profile of these roads can be seen in Figure 7.

Another site, the White Oak area, was set up to pretest each tractor. Tractor pretesting was done to determine the optimum harvesting system and procedure and to enable the driver to become more familiar with each particular machine. This area was a pole stand of mixed hardwoods, and had a slope of 0-15 percent.

Factor Definitions and Methods

The performance of any skidding device in any given situation depends on the variable time (travel time both loaded and empty), and fixed time[1] (loading and unloading logs). These were timed separately

[1] This time is fixed only in that it does not vary with distance.

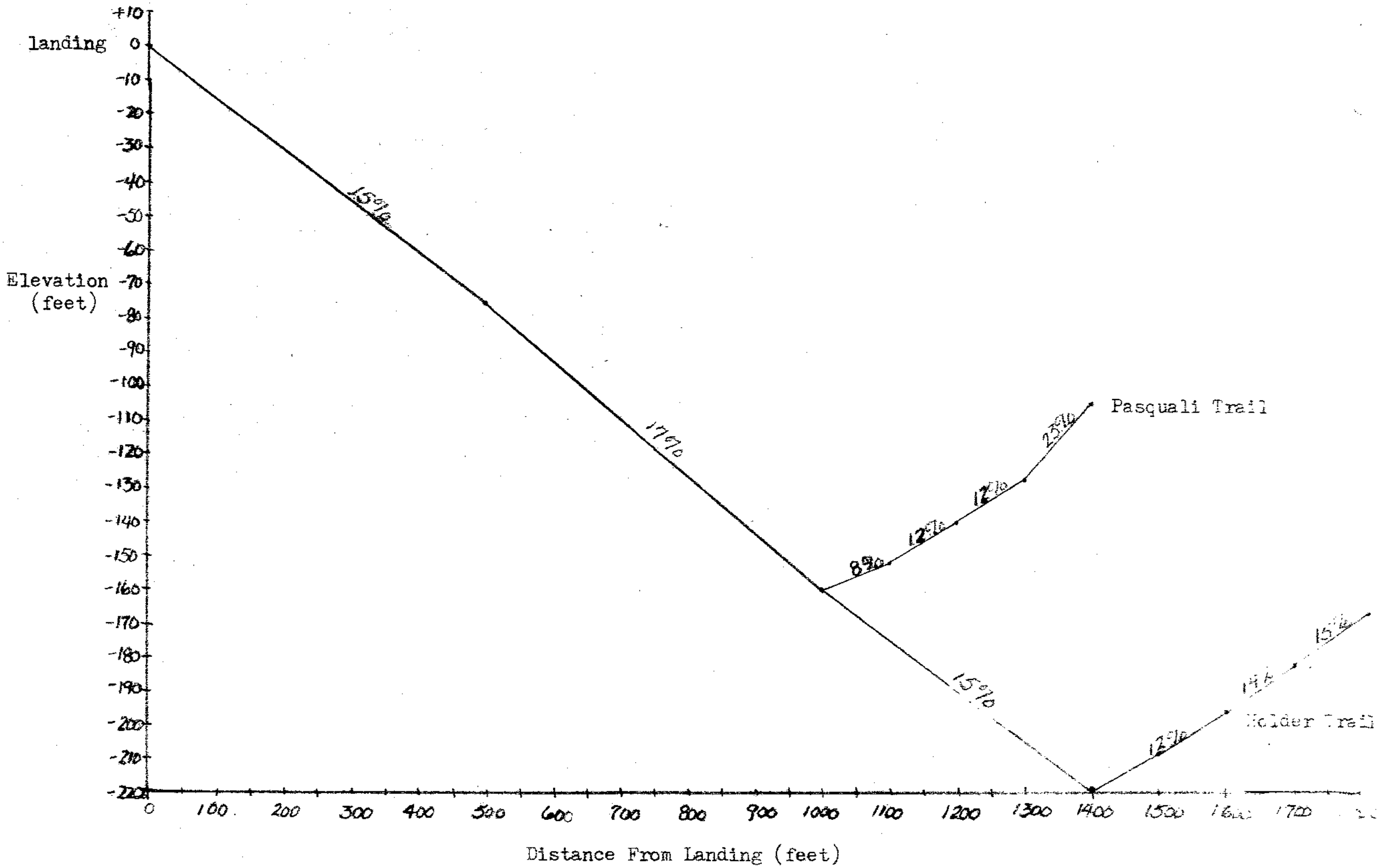


Figure 6. Continental Road skid trail profiles.

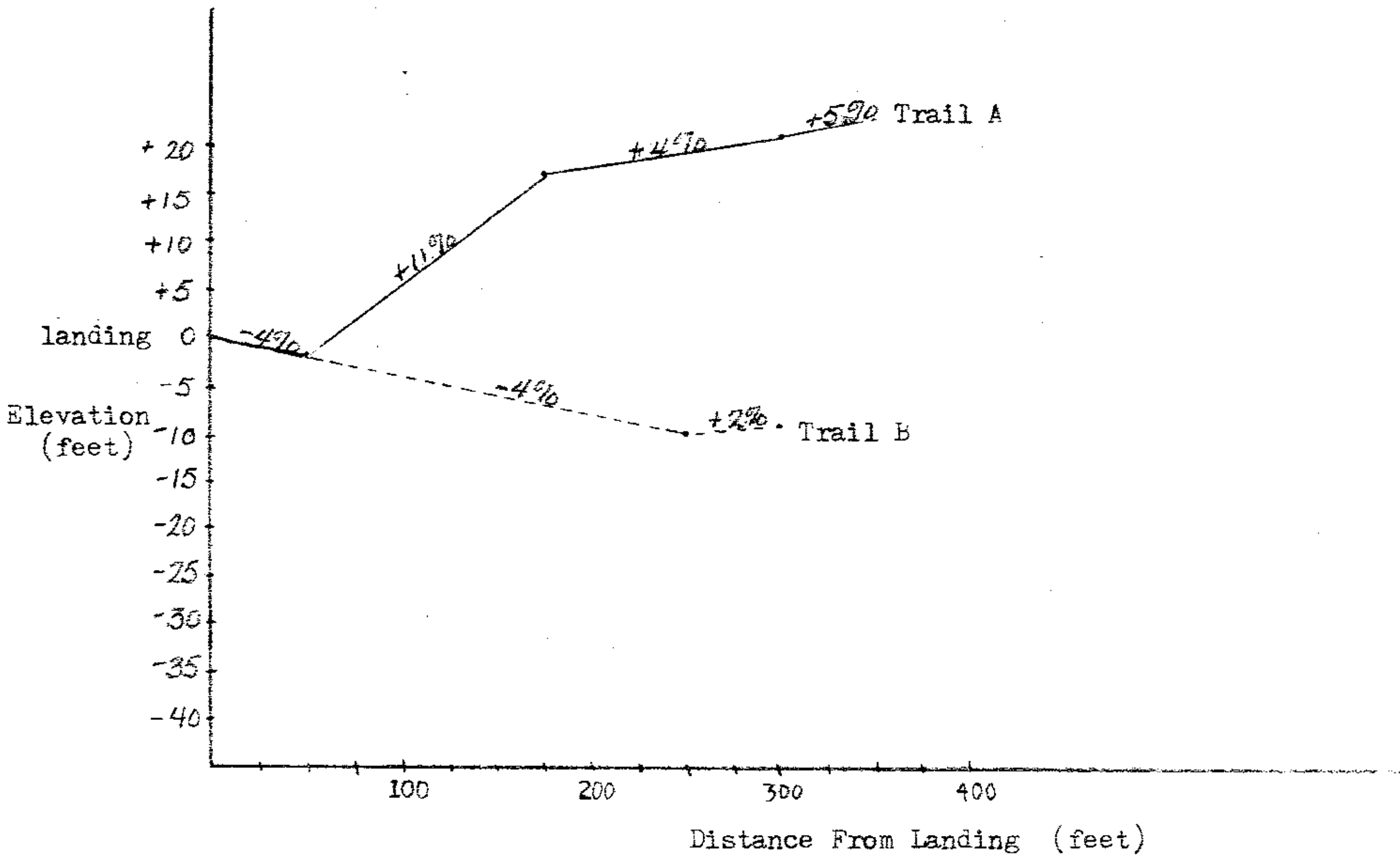


Figure 7. Bugs Bunny skid trail profiles.

as they were controlled by different factors. Under ideal conditions, fixed time plus variable time should equal total turn time. However, total turn time is usually increased by various unplanned delays. One of the purposes of a detailed time study was to determine what causes these delays, and whether they were of a recurrent nature or could be avoided (Mathews, 1942). Mathews (1942), suggests the following classification of delay:

> Fixed delay time: time lost during fixed time that cannot be attributed to mechanical failure. Controlling factors:
>
> a. Difficult ground conditions
> b. Inefficient ground crew
>
> This condition may be unavoidable when ground conditions are particularly difficult. It should be included with fixed time and reasons cited.
>
> Variable delay time: time lost when returning to or from the woods because of hangups, slipped chokers, etc. Such delays should be included with variable time in that they are normal recurrent delays on the chance.
>
> Lost time: mechanical breakdowns, waiting when it cannot be attributable to the machine, etc. These delays should not be included in fixed or variable time.

In general, the purposes of time study with which this report was concerned were: (1) to establish consistent and equitable data of performance and production, and (2) to provide a record of actual conditions associated with the data. These data were then used to predict costs and to give some indication of performance under similar conditions.

The following items were determined as necessary equipment in the present study:

1. Time study board with three stop watches.
2. Two-way radios

The time study board was especially designed for continuous time study of separate motions. Handling problems were eliminated by having one lever operate three watches. The watches were set so that while one watch timed an event, one watch was ready to time the next event, and one watch displayed the previous event's time.

The two way radios made communication easier and eliminated the need for one man to constantly follow the skidder.

Other equipment included: a pocket calculator, observation forms, measuring tape, wooden stakes and plastic flagging.

Skidding equipment operators were selected with the following qualitifications:

1. Thorough understanding of skidding operation.
2. Effective use of tools and equipment.
3. Economic use of motion.

It was necessary to break the operation down into a logical sequence of separate motions to be timed. It was arbitrarily decided that in the present study the skid cycle would be broken down into the following functions:

1. Outhaul: unloaded travel time starts at the crossing of an invisible plane between the landing and the skid trail after all logs were unhooked and the machine was in motion towards the stump site.

2. Gather: time starts when the machine comes to a stop after the outhaul in order to maneuver into a position suitable for winching logs into the machine. Time continues until logs comprising a full turn are winched in and hooked, and the machine starts in motion towards the log landing. If the

machine had to travel towards the log landing to gather logs to complete the log turn, this travel time would be considered inhaul time until the gather process for the supplementary logs starts. The tractor should proceed to the logs at the farthest point from the landing and work towards the landing while gathering.

3. Inhaul: loaded travel time begins at the time after gather when the machine starts in motion towards the landing area, and ends when the machine comes to a complete stop at the landing area.

4. Unhook: time starts when the machine comes to a complete stop at the landing area and the operator steps off of the machine to remove the chokers from the logs. Time continues until the machine passes the plane to start the outhaul, or until the operator maneuvers the machine into a position to "deck" the logs. If decking is to be done, the operator will tell the timer or radio man at the landing beforehand during the unhook.

5. Deck: time starts when the machine is in position to push logs into a pile at the landing in order to facilitate bucking or clear the landing for the next turn. This time continues until the machine passes the plane to start the outhaul.

These functions represent logical increments of the skidding operation distinguished by operating characteristics of each machine tested.

The breakdown of the skidding operating cycle was described by Flatau (1978), and its relationship to the classification system of this study is shown in Table 6.

In any skidding operation, a certain amount of time may be classified as "delay time." Delays may be attributable to the operator or the machine: they may be productive or non-productive (Conway, 1976). Productive or operational delays are those which occur due to difficult ground conditions, hang-ups, slipped chokers, inadequate ground crew, etc. These conditions may be considered unavoidable, normal recurrent delays on the logging chance and should be included in the variable and

Table 6. Breakdown of the skidding cycle.

Travel unloaded	Outhaul
Turn and maneuver	
coordinate with feller	
search for trees	
move to trees	
dismount	
pull cable to log	
set chokers	
return to skidder	
winch	
move to other trees if necessary	Gather
Travel loaded	Inhaul
Unhook	
release winch mainline and drop load	
dismount	
remove chokers	
return to skidder	
turn for return trip	Unhook
Deck if necessary	Deck

fixed time components. Non-productive delays are of two types: non-productive and idle (Conway, 1976). Waiting for logs, skid road maintenance etc., are non-productive. Idle time includes: mechanical down-time, personal time and delays caused by visitors on the job. A 1970 study (McCraw and Hallett), intensively analyzed skidding delays. Their analysis revealed that:

1. The occurrence and duration of delays is due to chance.
2. Delays are not strongly related to any of the environmental factors measured.
3. Delays were significantly different between operators, not machines.

In the present study, delays were defined as operational (productive) and non-operational (non-productive). All delays were classified as to both type and time of occurrence. The following types of delays were defined and coded:

Non-productive delay:

Scheduled

00 Maintenance: periodic scheduled maintenance on tractors as recommended by operation manuals

Non-scheduled

01 Personal: work stops due to operator's need for personal time

02 Rest: work stops due to operator fatigue

03 Machine repair time: work stops due to mechanical failure of machine

07 Non-scheduled waiting: waiting not due to operation, rain, etc.

09 Miscellaneous: look for equipment, etc. not covered by above classes.

Operational delay:

04 Dropped log: work stops to refasten log which has dropped due to improper fastening or rugged terrain

05 Hung-up tree: work stops to winch hung-up tree to a position where it can be topped, and skid to the landing

06 Swamped, stuck: work stops when the machine loses traction due to terrain, soil condition, or improper loading

08 Non-scheduled waiting: work stops due to machine related waiting, i.e., machine stalls

09 Miscellaneous: reconnaisance, skid road repair, etc. not covered by above classes

It must be remembered that delay time classification is highly variable from time study to time study. This system was selected to facilitate data collection.

Skidding productivity is dependent upon several factors, environmental and others, which have been documented by several reports (Conway, 1976; Gabriel, 1975; McCraw and Hallett, 1970; Bennett, 1962, and Mathews, 1942). Gabriel classifies these factors as controllable and uncontrollable.

Table 7. Controllable and uncontrollable skidding factors.

Controllable	Uncontrollable
1. Load size	1. Terrain
2. Skid distance	2. Topography
3. Logging method	3. Stand density
4. Crew organization	4. Tree size
5. Basis for paying men	5. Tree branching
6. Machine size	6. Cutting regulations
7. Marking system	7. Weather conditions

McCraw and Hallett (1970), state eight conditions to be measured:

1. Volume per acre
2. Windfalls
3. Brush density
4. Slope
5. Stoniness
6. Crew skill and aggressiveness
7. Skid trails
8. Wage plans

Conway (1976) also includes: soil conditions, volume/tree, and undergrowth.

All of the above variables are included in the present study. Regression analysis was performed on several of the variables affecting skidding times. Although all of the above variables can be said to affect skidding times, regression analysis was performed only on those considered to be most important and easily classified. All variables do not affect all components of the skidding cycle. For example, the outhaul time is not affected by the load size, since by definition, the outhaul is travel time unloaded. Variables were only included in the equations where applicable. The following variables were defined and coded for determination of their effect on the variability of the production times of each component of the skidding cycle:

1. Slope
   Class 1, 0-15 percent
   Class 2, 15-30 percent

2. Load size
   Weight per load measured for each turn

3. Distance
   Skid distance measured for each turn

4. Terrain
   1. Skid road with very rough terrain
   2. Skid road with rough terrain

5. Slash density
   1. 0-light slash
   2. medium-heavy slash

6. Number of logs
   Measured for each turn

All other variables were simply recorded for each tractor and area. The factors: stoniness, brushiness, weather, soil moisture, topography, and tree stand data were all described.

Forms were made up to record these variables during the test. These forms are included in Appendix C.

Data sheet I documents the general site conditions at the test sites. Personnel were listed for the system tested and general weather conditions were noted. The site was described in general terms.

Timber stand conditions were described in terms of type, basal area, cubic foot volume, and treatment. Felling was classified as directional or non-directional. Directional felling is felling whereby the feller can direct the tree to fall within a certain accepted range of angles from the skid trail.

Weather was described according to temperature, precipitation and windiness.

The soil moisture classes were defined as follows (American Pulpwood Association, 1968):

Dry: porous soils with a thin organic layer at the surface; water moves rapidly from the soil which therefore dries rapidly.

Fresh: well drained or "fresh" soil of intermediate texture with a moderately developed humus layer; water moves readily but not rapidly from the soil.

Moist: moderately (imperfectly) drained or "moist" soils with well developed organic horizons at the surface; water moves slowly from the surface.

Wet: poorly drained or "wet" soils almost continually wet in the mineral horizons; high water table present

Ground roughness was described independent of slope as an indication of obstacles such as rocks, windthrows, boulders, or holes, more than 10 inches in height or depth. Obstacle classes are defined as follows:

Very smooth ground: distance between obstacles more than 25 feet

Smooth ground: distance between obstacles 15-25 feet

Uneven ground: distance between obstacles less than 10 feet.

Very uneven ground: distance between obstacles 10-15 feet

Operator characteristics determining skill and effort:

Good:

1. Noticeably better than average
2. Good reasoning ability
3. Needs little supervision
4. Little or no lost time

Medium:

1. Works with reasonable efficiency
2. Turns out satisfactory work
3. Follows set procedure
4. Understands tools and equipment

Poor:

1. Hestitates between operations
2. Uncertain but knows what he is doing
3. Does not work systematically
4. Does not have efficiency of motion

Data sheet II is the time recording form. This form includes data from a particular day including: turn numbers, function times, delay times, weather conditions, and general comments. Stop watches were used to time the functions. Times are recorded horizontally, across the sheet to the accuracy of 1/100 minute.

Data sheet III is the log volume form. Log species, bottom diameter, top diamter, and log length are recorded in order for computer calculation of: log volume, log weight, turn volume, turn weight, average log diameter, and average log length.

Data sheet IV was used to record the solid wood content (inside bark) of the stacked bolts of wood as a check on the solid wood content of standard cords for this region.

Pre-testing

After all forms were completed and the crews selected, the tractors were transported to the Harvard Black Rock Forest for testing. Both the Pasquali and Forest Ant were transported on a standard pickup truck. The Holder had to be transported on a tilt-top trailer.

Before the actual testing started, each machine was operated for one week to determine the most efficient system of operation. Such things as: whether the machines could pull whole trees, optimum load size, optimum log length, and efficient personel use were determined. This was also a time for the operator to become familiar with each machine.

After it was determined that a machine was being used in an efficient manner, it was transported to the actual test area for time study. The skid trails were then "swamped" by removing all trees and large rocks in the trail.

Crew organization and data collection procedure

Pasquali - During pre-testing, it was determined that the desirable log length for the Pasquali was roughly 25 ft. The best system for use of this machine was:

1. One feller to fell trees, delimb, and buck to a suitable length. He also directs the skidder to possible log bunches, and helps at the log landing as time permits.

2. One skidder operator to choke, winch, skid, and unhook logs.

3. One bucker at the landing to buck the logs into 4 ft. bolts and stack for measurement.

4. Trees felled ½ day in advance.

5. Chokers attached to cable with keyhole sliders.

6. Logs attached to drawbar of Farmi winch to skid.

7. Four logs per turn.

8. Optimum skidding speed range; medium, second and third gears.

Holder - The desirable log length for this machine was found to be roughly 30-40 ft. The best sytem for this machine was:

1. One feller to fell trees, delimb and buck to a suitable length.

2. One skidder operator to choke, winch, skid and unhook logs.

3. One man to buck into 4 ft. lengths and stack at the landing (two men if available).

4. Trees felled one full day in advance.

5. Chokers attached to cable with keyhole sliders.

6. Six logs per turn.

7. Optimum skidding speed range - medium, second or third gear.

Forest Ant - The desirable log length was found to be 25-30 ft. The best system for this machine was:

1. One feller to fell trees, delimb, and buck to a suitable length. The feller helps at the landing between cutting loads. The most important job is to plan bunches of logs that can be picked up in rows. Directional felling is a must.

2. One skidder operator to pick up logs, close grapple, skid, and drop logs.

3. One man to buck at the landing and stack (optional).

4. Trees felled one-half day in advance of the operation.

5. Clam bunk should be filled enough to enable the jaws to close on the load.

6. Optimum skidding speed - high.

The operators were paid on an hourly rate of 6.75 per hour including benefits. This is a scheduled hour rate.

The timing crew consisted of two men - one, the timer, with a two way radio and clipboard, and one man stationed at the landing with a two way radio, loggers tape and folding four-foot ruler. The timer recorded all times. He recorded times in the woods directly from observation. Events occurring at the landing such as: end of inhaul, unhook, deck, beginning of outhaul, and various landing delays were transmitted via radios by the man at the landing. The landing timer measured each log of every log turn and recorded these measurements.

Times were recorded horizontally, across the sheet. When a delay occurred, the elapsed function time was recorded. The delay was then timed, coded, and recorded in the delay column. The timer then resumed timing the interrupted function. The remaining time was placed on the line directly below the time before the interruption in the same column. Subsequent times were then recorded on that lower line (see Example 1).

Example 1. Delay time recording procedure.

Turn	Outhaul	Gather	....	Delay
30	1.20		....	2.10
	1.00	12.59	....	

In the above example, a delay of 2.1 minutes occurred during the outhaul. Total outhaul time equals (not including delay) 2.2 minutes.

Skidding Procedure

At the start of every working day, five to fifteen minutes were taken to perform machine maintenance if needed, i.e., refueling, greasing, tightening of loose fittings. This was done by the operator while the other crew members performed their assorted duties. When all were ready, the operation started and timing began. Since outhaul and inhaul are travel time empty and travel time loaded, they will not be explained further, however, the gather phase differs with each machine and will be explained in detail.

Gather Time, Pasquali - At the end of the outhaul, the Pasquali maneuvered into position and lowered the Farmi winch until the feet of the frame were anchored to the ground.

The winch was operated by a control rope from a position on either side of the unit (Figure 8). The rope engages the clutch which enables the operator to select any pull from 0-5500 lbs. The clutch will slip

Figure 8. Gathering with the Farmi winch.

if the load is heavier than the selected pull to prevent damage to the cable or winch.

Trees were felled either away from or toward the tractor, to winch from either butt or top. Since winching angles should not exceed 30 degrees, the tractor was always positioned in line with the direction of pull. A snatchblock (see Figure 9) was used to minimize tractor repositioning and avoid winching sideways.

Before winching, the brakes were locked and PTO engaged. The cable was then pulled to the logs and the logs were attached. Lightweight chains (3/8"x36") were used as chokers. They were attached to the mainline with keyhole sliders to enable the operator to hookup and winch several logs at one time. When the clutch of the winch was engaged, the high pulling point helped to push the legs into the ground to anchor the unit. When the logs were near the machine, the clutch was released, the logs dropped, and they were attached to the drawbar. Logs were winched tops first when possible. The PTO was disengaged, and the three point hitch raised. The load was then skidded to the landing.

Gather Time, Holder - The gather function for the Holder was similar to that of the Pasquali. However, the setup of the Ingland-Jones winch was different from that of the Farmi (see Figure 10). After outhaul and maneuver, a butt plate was lowered hydraulically to stop logs and help anchor the machine.

After dropping the butt plate, the brake was applied and the PTO engaged. The cables were released by pushing a lever for each winch from inside of the cab. The cables were pulled out, and the logs were

Figure 9. The Snatchblock.

Figure 10. Gathering with the Ingland winch.

choked. Medium size chains were used to choke the logs (5/8"x48"). Logs were attached to each mainline with keyhole sliders. Swivel blocks were built into the winch system which enabled gathering from severe angles without re-positioning the machine, although a separate snatch-block was used for difficult winching angles and obstacles. Logs were winched to the machine by pulling back on the winch levers. The levers were then placed in the middle position to lock the load. After the logs were winched to the machine, the butt plate was raised, PTO dis-engaged, brake released, and logs skidded to the landing.

Gather, Forest Ant - Proper planning of the felling pattern was of utmost importance in the gather phase of the Forest Ant's skidding cycle. Logs had to be felled with butts towards the skid road either parallel to it or at angles less than 45 degrees in order to facilitate picking up the logs with the knuckleboom crane. Since it is very difficult to turn the Forest Ant completely around while logs are in the bunk, logs had to be felled in rows or in such a pattern to enable the Ant to proceed to the end of the row, turn, and gather the logs on its way back to the landing. Logs were lifted by manipulating the knuckle-boom crane. The pivot for the boom is on the front chassis section. Although the boom swing angle is limited to 50 degrees on each side, if the articulation joint is turned simultaneously, the crane can be turned to an effective angle of 90 degrees. The turning of the crane is controlled by means of a hydraulic cylinder.

After the operator reaches the first log to be loaded, he opens the clam grapple arms and places the log into the bunk with the crane (see Figure 11).

The clam is then closed on the log and the operator proceeds to the next log or group of logs. It is best if the logs are picked up with the butt ends toward the machine. When the logs are placed top first, they tend to slide out of the clam bunk. After the clam bunk is full, or all of the logs in the row have been gathered, the load is skidded to the landing. Whereas the logs brought in by the Pasquali and Holder are unhooked by loosening the choker chains, the Ant's load is discharged by opening the clam bunk and driving forward causing the logs to fall to the ground.

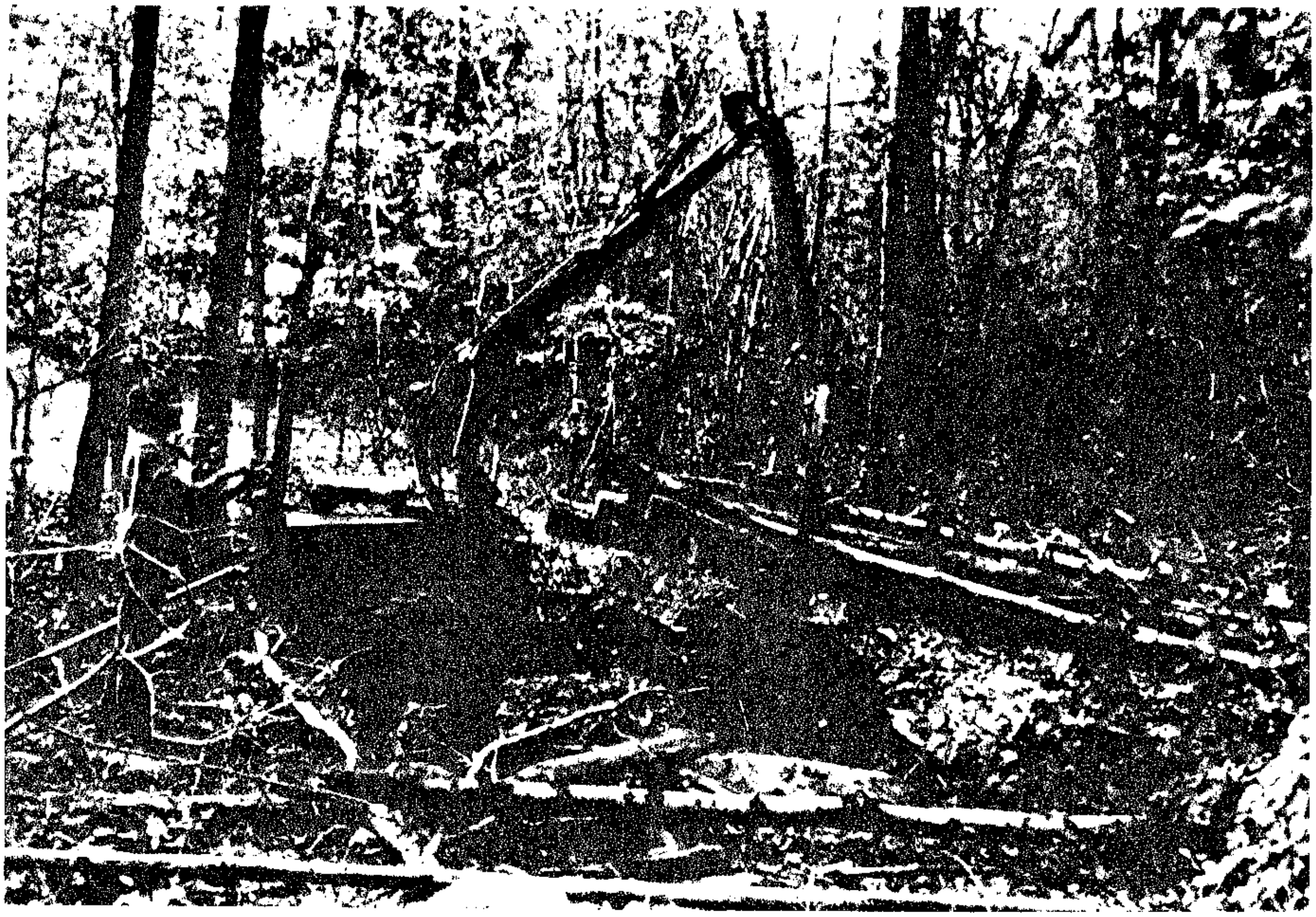


Figure 11. Manipulating the crane.

RESULTS AND ANALYSIS

Figure 12 shows the breakdown of scheduled skidding time. Each of the functions shown was timed and analyzed. Regression equations were developed for each of the main time elements (outhaul, gather, inhaul, unhook, and total turn time) against the independent variables mentioned. Total turn time (without delay) is the sum of the outhaul, gather, inhaul and unhook times. Delay time, both operational and non-operational, and deck time, were analyzed separately. Regression equations were not developed for these elements due to their inconsistent occurrence. Also, as previously mentioned, delays were due mostly to the operator, not the machine or the environment (McCraw and Hallett, 1970). Productivity data are presented by skidding function (outhaul, gather, inhaul, unhook) for each tractor. Care should be taken in comparing the productivity of the three machines due to their different structure and power ratings. The only logical basis for comparison is the cost per unit of production. Productivity is given to show the capabilities of each machine for the conditions tested. When looking at the tables, the absence of data is noticed for the Forest Ant on the steeper slopes. It was decided, after pretesting, that it was not safe or feasible to test the Forest Ant on the steeper slopes, so it was not tried.

Punched cards were used for computer analysis. SAS (Statistical Analysis System) programs were used to analyze skidding function data

Productive Time | Operating Delay Time | Non-operating delay time

- Scheduled Time
  - Outhaul Time
    - Stoppage due to work
    - Miscellaneous operating delay
  - Gather Time
    - Hang-up
    - Stuck
    - Stoppage due to work
    - Dropped log time
    - Miscellaneous operating delay
  - Inhaul Time
    - Stuck
    - Stoppage due to work
    - Dropped log time
    - Miscellaneous operating delays
  - Unhook Time
    - Stoppage due to work
    - Miscellaneous operating delay
  - Deck Time
    - Stoppage due to work
    - Miscellaneous operating delay

Non-operating delay time:

- Personnel
- Stoppage not due to work
- Misc. non-operating work delays
- Mechanical breakdown

Figure 12. Breakdown of Scheduled Skid Time

(SAS, 1979). APL was used to "preorganize" the data and to calculate all log volumes and weight.[1] The tabulated data for each machine and area is shown in Appendix D.

Productivity Analysis

The weather conditions at the time of the study were generally comfortable and did not affect production significantly.

Conditions during the study were as follows:

Precipitation	- below normal, dry
Temperature	- 75° - 95°
Wind	- slight to none
General	- most days were comfortable, soil conditions were dry, three days during the study were cancelled due to rain.

The machine operators were rated as follows:

Pasquali	- average to above average
Holder	- above average
Forest Ant	- average

Table 8 shows the averages of the data and statistics from the computer outputs. The actual output can be seen in Appendix D showing the number of turns, the mean, standard deviation, range, standard error of the mean, sum variance, and coefficient of variation. Confidence limits for the data at the $\alpha = 0.05$ level are within 10%.

The function times: outhaul (O), gather (G), inhaul (I), and unhook (U), expressed as a percentage of total time excluding delay, are shown in Table 9.

---

[1] The stacked wood cubic volume content was measured and determined to be 79 cubic feet per standard cord. The average weight per cubic foot of the mixed hardwoods was found to be 59 lbs cu.ft. This was determined from averaging all logs measured. Weights per cu.ft. from Forbes 1955. Total volume scaled 20 cords: Pile 1, 10 cords, 80 cu. ft./cord; Pile 2, 5 cords, 79 cu.ft./cord; Pile 3, 5 cords, 78 cu.ft./ cords. Weighted average, 79.25 cu.ft./cord.

Table 8. Average time and production per turn.

	PASQUALI Slope 0-15	PASQUALI Slope 15-30	HOLDER Slope 0-15	HOLDER Slope 15-30	ANT Slope 0-15
			Mins.		
Out haul	2.69	5.03	2.49	5.78	2.47
Gather	9.57	8.63	10.28	10.78	13.50
In haul	2.67	5.57	2.48	5.76	2.02
Unhook	1.71	3.31	4.11	4.55	0.96
Deck	0.16	0.15	0.32	0.20	-
Total without delay	16.80	22.69	19.68	27.07	18.95
Delays - operational	1.91	3.76	3.15	4.64	4.15
Total productive (in hours)	18.72 (0.3120)	26.46 (0.4410)	22.83 (0.3805)	31.71 (0.5285)	23.10 (0.3850)
Delays - non-productive	6.92	8.93	3.52	8.02	7.44
Total - scheduled[1] (in hours)	25.64 (.4274)	35.39 (.5898)	26.35 (.4389)	39.73 (0.6622)	30.54 (0.5093)
		MISC.			
Weight per turn - lbs.	1403	1164	2832	3091	1999
Cubic feet per turn	22.85	18.85	48.42	52.39	34.92
Cords per turn	0.29	0.24	0.61	0.65	0.44
Number of logs per turn	3.94	3.88	5.67	5.57	7.10
Number of turns	65	50	45	49	30
Average distance - feet	402	1160	627	1625	253
Total production - cords	18.8	12.0	27.4	31.8	13.2
Cords/scheduled hour	.68	.41	1.40	.98	.86

[1] Does not include travel time to and from site.

Table 9. Function time as a percent of total time without delay.

	Aleck Meadows					Continental Road				
	O	G	I	U	Σ	O	G	I	U	Σ
Pasquali	16	58	16	10	100	22	38	25	15	100
Holder	13	53	13	21	100	22	40	21	17	100
Ant	13	71	11	5	100					

Delay Analysis

As stated, delay times were analyzed separately from the main skidding functions. They were averaged to determine total average delay time, average time per function, and percent of delay time per function. Both operational and non-operational delays were analyzed. Total productive and non-productive delay times, along with each delay expressed as a percent of total delay are shown in Appendix E, Tables 1, 2, and 3.

It can be seen from these tables that in all cases, non-operational delays were greater than operational delays. Machine repair time was the greatest percentage of the non-operating delays, followed by personal and miscellaneous delays. The personal and miscellaneous delays are, in most cases, operator related delays and they could be reduced with greater operator efficiency.

Although the main skid and delay components were shown separately, operational delays should be included in the total turn time as they are normal recurrent delays on the chance (Mathews, 1942). This is the actual average production time per turn. Tables 10, 11, and 12 show the

Table 10. Average production time (including productive delay) per turn in minutes for the Pasquali.

	ALECK MEADOWS				CONTINENTAL ROAD			
	Slope 0-15% Function Time	Productive Delay Time	Total Time	Delay as a % of Function	15%-30% Function Time	Productive Delay Time	Total Time	Delay as a % of Function
Outhaul	2.69	.39	3.08	13.%	5.03	.21	5.24	4%
Gather	9.57	.69	10.26	7.%	8.63	.83	9.46	9%
Inhaul	2.67	.78	3.45	23.%	5.57	2.67	8.24	32%
Unhook	1.71	.05	1.77	3.%	3.31	.05	3.36	1%
Deck	.16	.00	.16	0.%	.15	.00	.15	00%
	16.80	1.91	18.71		22.69	3.76	26.45	

ALECK MEADOWS		CONTINENTAL ROAD	
TOTAL PRODUCTIVE (HRS)	18.71 (.3118)	TOTAL PRODUCTIVE (HRS)	26.45 (.441)
NON-PRODUCTIVE DELAY	6.92	NON-PRODUCTIVE DELAY	8.93
TOTAL SCHEDULED (HRS)	25.63 (.427)	TOTAL SCHEDULED (HRS)	35.38 (.5898)

Weighted Avg. of % Machine Utilization $\frac{18.71 + 26.45}{35.38 + 25.63}$ = 73.996% = 74%

Table 11. Average production time (including productive delay) per turn in minutes for the Holder.

	ALECK MEADOWS				CONTINENTAL ROAD			
	Slope 0-15% Function Time	Productive Delay Time	Total Time	Delay as a % of Function	15%-30% Function Time	Productive Delay Time	Total Time	Delay as a % of Function
Outhaul	2.49	.24	2.73	9%	5.78	.76	6.54	12%
Gather	10.28	1.47	11.75	13%	10.78	2.70	13.48	20%
Inhaul	2.48	.94	3.42	27%	5.76	1.11	6.87	16%
Unhook	4.11	.32	4.43	7%	4.55	0.00	4.55	0%
Deck	.32	.18	0.50	36%	.20	.07	.27	26%
	19.68	3.15	22.83		27.07	4.64	31.71	

ALECK MEADOWS		CONTINENTAL ROAD	
TOTAL PRODUCTIVE (HRS)	22.83 (.3805)	TOTAL PRODUCTIVE (HRS)	31.71 (.5285)
DELAYS (NON-PRODUCTIVE)	3.52	DELAYS (NON-PRODUCTIVE)	8.02
TOTAL SCHEDULED (HRS)	26.35 (.4389)	TOTAL SCHEDULED (HRS)	39.73 (.6622)

Weighted Avg. for Machine Ut. Rate $= \frac{31.71 + 22.83}{39.43 + 26.35} = 82.913\% = 82.9\%$

Table 12. Average production time (including productive delay) per turn in minutes.

FOREST ANT - ALECK MEADOW & BUGS BUNNY

Slope 0 - 15%

	Function Time	Productive Delay Time	Total Time	Delay as a % of Function
Outhaul	2.47	.08	2.55	3%
Gather	13.50	.90	14.40	6%
Inhaul	2.02	2.47	4.49	55%
Unhook	.96	.02	.98	2%
Deck	-	-	-	-
	18.95	3.47	22.42	

PRODUCTIVE TIME (HRS)	22.42 (.3737)
NON-PRODUCTIVE DELAY	8.12
TOTAL SCHEDULED (HRS)	30.54 (.5093)

73.4% Machine Utilization %

Table 13. Function time as a percent of total time including delay.

	Aleck Meadows						Continental Road					
	O	G	I	U	D	E	O	G	I	U	D	E
Pasquali	16	55	18	10	1	100	20	36	31	12	1	100
Holder	12	51	15	20	2	100	21	43	22	14	1	100
Ant	11	64	20	4		100						

In all cases,the inhaul percentage increased over its previous value in Table 9 and the others dropped - an indication of the greatest area of difficulty. Figure 13 shows the times graphically to show the above relationships more clearly.

Further analysis of delay time is shown in Appendix E, Tables 4, 5, 6, 7 and 8. The types of delay causing the most problems are indicated by: average operating delay time per function and per turn, operational delay as a percent of average total turn time per function, and average non-productive delay per function per turn.

In nearly all cases, getting stuck was the highest percentage delay. This is due in part to the rough terrain, but is also due to overloading, lack of tire chains, and other factors of machine, operator and environment.

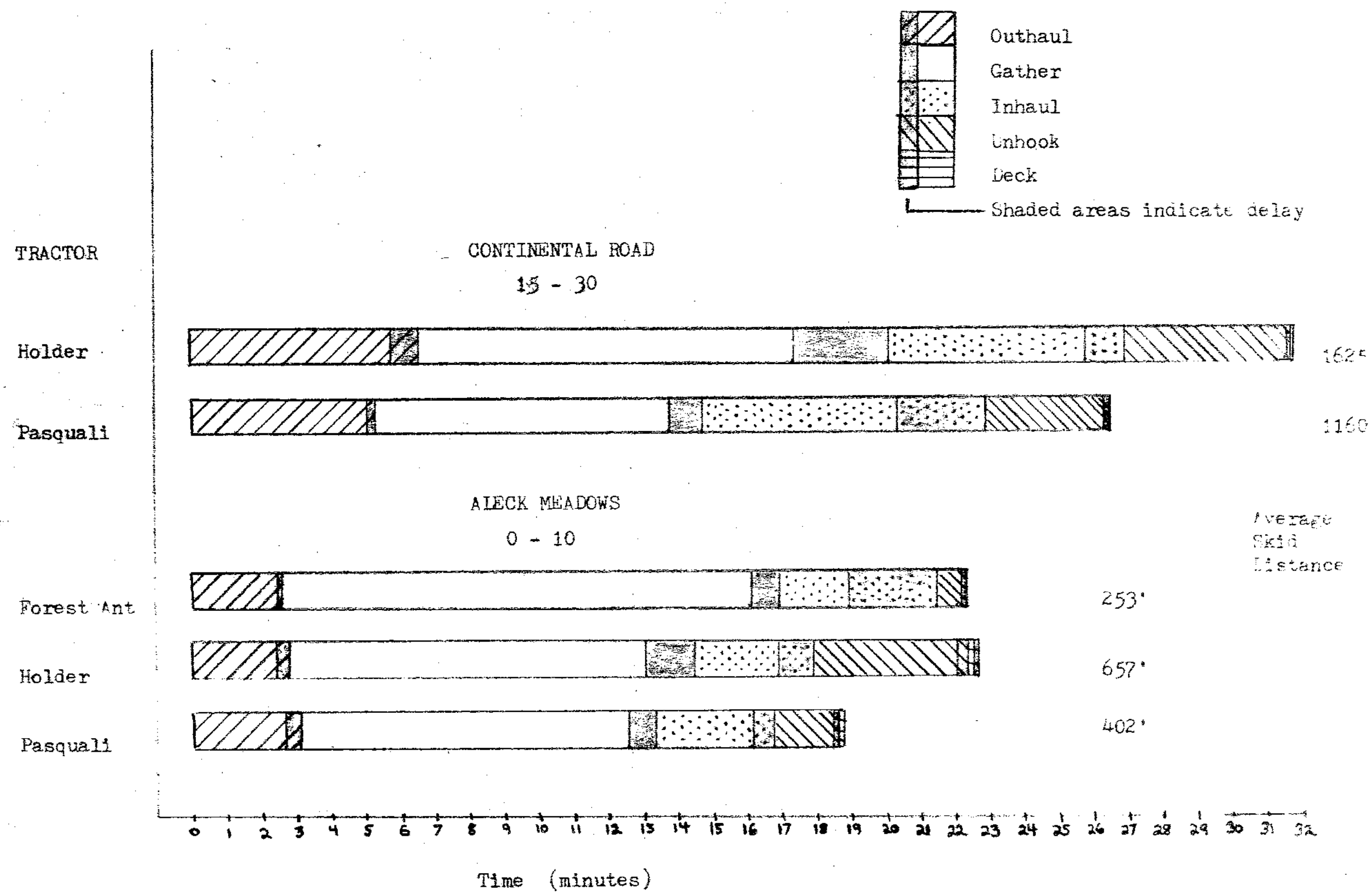


Figure 13. Bar chart of average production time.

Most delays could be reduced with experience, proper planning, knowledge of machine limitations, and knowledge of the effect of various factors on the skidding efficiency of the machine used.

Factors Affecting Skidding Production

In an effort to determine how various factors affect skidding times and consequently productivity, stepwise regressions were run on several factors. These factors were: slope, distance traveled, weight of load, terrain of skid road, slash, and number of logs. Independent variables were put into equations only where applicable. Regressions were run using the SAS "STEPWISE" procedure with the "MAXR" (maximum R^2 improvement) option. Tables 14, 15, 16, 17, and 18 show the equations developed.

Although the R^2 values indicating the percent of the variation in time explained by the independent variables are low, in comparison with other studies, (McCraw and Hallett, 1970) they are acceptable. The skidding operation contains many variables, and the ones tested account for the major variation. Other variables and interactions were regressed and did improve the R^2 values, however, they were not significant at the 95% level. Skid distance, slash, and log weight or number were significant in most equations.

Table 14. Outhaul time regression equations.

	Aleck Meadows	
Tactor	Equation	R^2
Pasquali	$Y = 0.4566 + 0.004338x_1 + 1.3794x_2$	.81
Holder	$Y = 1.0201 + 0.002345x_1$	.55
Forest Ant	$Y = 0.4470 + 0.007100x_1 + 0.5350x_2$	.48
	Continental Road	
	Equation	
Pasquali	$Y = -3.1158 + 0.006929x_1 + 1.7854x_2$	.74
Holder	$Y = -1.8064 + 0.004614x_1 + 1.4821x_2$	.53

Where:

Y = Outhaul time in minutes
X_1 = Distance in feet
X_2 = Terrain

x_2 1 if very rough
0 if rough

Table 15. Gather time regression equations.

Aleck Meadows

Tractor	Equation	R^2
Pasquali	$Y = 1.9221 + 4.5275x_1 + 0.8069_2 + 0.002397x_3$	.42
Holder	$Y = 4.4358 + 3.0382x_1 + 0.8091x_2$	.43
Forest Ant	Y = No significant equation found	

Continental Road

Tractor	Equation	R^2
Pasquali	$Y = 3.9664 + 3.7173x_1 + 0.5379x_2 + 0.00157784x_3$	.41
Holder	$Y = 6.7329 + 3.7196x_1 + 0.0009906x_3$	.39

Where:

Y = Gather time in minutes
X = Slash
0 if none to light
1 if medium to heavy
x_2 = Number of logs
x_3 = Weight in pounds

Table 16. Inhaul time regression equations.

Tractor	Aleck Meadows Equation	R^2
Pasquali	$Y = -0.0119 + 0.004267x_1 \; 0.0005160x_2 + 0.6095x_4$	.67
Holder	$Y = 1.0710 + 0.002244\,x_1$	.38
Forest Ant	$Y = 0.4541 + 0.0071x_1 + 0.0004519x_2 \; -0.1590x_3$	.65

Tractor	Continental Road Equation	R^2
Pasquali	$Y = -5.02005 + 0.0084x_1 + 0.0006181x_2$ $1.71641445x_4$	.72
Holder	$Y = -2.1086 + 0.003953x_1 + 0.0004670x_2$	.71

Where:

Y = Inhaul time in minutes
x_1 = Distance in feet
x_2 = Weight in pounds
x_3 = Number of logs
x_4 = Terrain
1 if very rough
0 if rough

Table 17. Unhook time regression equations.

Aleck Meadows

Tractor	Equation	R^2
Pasquali	$Y = 0.5907 + 0.2834x_1$	.17
Holder	$Y = 1.9657 + 0.3792x_1$	.12
Forest Ant	$Y = 0.3223 + 0.0003201x_2$	.25

Continental Road

	Equation	
Pasquali	Y = No significant equation found.	
Holder	$Y = 0.4501 + 0.7346x_1$	.30

Where:

Y = Unhook time in minutes
x_1 = Number of logs
x_2 = Log weight in pounds

Table 18. Total time regression equations.

Aleck Meadows

Tractor	Equation	R^2
Pasquali	$Y = 3.4899 + 0.0120x_1 + 4.3927x_2 + 1.1080x_3 + 0.002068x_4$	.47
Holder	$Y = 6.2172 + 0.006554x_1 + 3.6346x_2 + 1.3951 x_3$	.50
Forest Ant	$Y = 11.5138 + 0.003720x_4$	.44

Continental Road

Tractor	Equation	R^2
Pasquali	$Y = 1.1017 + 0.0159x_1 + 2.8133x_2 + 0.002025 x_4$	.64
Holder	$Y = 1.3929 + 0.009363x_1 + 4.3791x_2 + 1.0117x_3 + 0.0016x_4$	.70

Where: Y = Total time in minutes
x_1 = Distance in feet
x_2 = Slash
0 if zero to light slash
1 if medium to heavy slash
x_3 = Number of logs
x_4 = Weight in pounds

Due to the low R^2 values, the equations developed are not good predictors of skid times, although they do show how various environmental factors may affect times. The Pasquali was more sensitive to terrain conditions than the Holder or Ant on both outhaul and inhaul. The amount of slash was highly significant in the gather for the Pasquali and the Holder (large amounts of slash tangle choker chains), but not the number of logs. The Forest Ant, however, was obviously affected by the number of logs it had to lift. On the steeper slopes, both Pasquali and Holder were affected by log weight; whereas, on the flat areas, only the Pasquali was affected. It is interesting to note that in the total time equation, distance, slash, and either number of logs or weight of logs were significant for the Pasquali and Holder whereas log weight was the only significant variable in the equation for the Ant.

Owning and Operating Costs

The method used to determine the fixed operating costs was that described by Miyata (1980). To calculate these costs, the following definitions were used:

Initial Investment: the actual equipment purchase cost, less the tire cost.

Salvage Value: the amount that the equipment can be sold for at the time of its disposal. The salvage value can be considered as 20 percent of the initial investment cost.

Economic Life: the period at which the equipment can operate at an acceptable operating cost and productivity.

Scheduled Operating Time: the time during which work equipment is scheduled to do productive work.

Productive Time: that part of scheduled operating time in which the machine actually operates. Mechanical delays, personal delays weather delays, etc., are subtracted from scheduled time to to determine productive time.

Percent Machine Utilization: productive time divided by scheduled operating time, times 100.

Fixed costs: costs which do not vary with the operation. Fixed costs include: depreciation, interest, insurance, and taxes.

Operating Costs: costs which change in proportion to the operation. including: maintenance and repair, fuel, lubricants and tires.

Labor cost: the cost to keep an operator on the job, either on an hourly or per unit basis. This also includes Social Security, Federal Unemployment Insurance, State Unemployment Insurance, Worker's compensation, and other programs.

For determination of costs in the present study, most of the above information was taken directly from the time study data sheets. However, because of the relatively short time of operation, maintenance costs and tire life were determined from previously calculated information (Miyata, 1980). Interest was determined to be 18 percent, insurance 2 percent, and taxes 2 percent. Scheduled hours (SH) per year was set at 2000 hours.

SH = 8hrs/day x 250 working days/yr = 2000 hrs/yr

Total cost was determined on a scheduled hour basis, and a productive hour basis. Table 19 shows all owning and operating costs.

Table 19. Owning and operating costs.

Item	PASQUALI Aleck Meadows	PASQUALI Cont. Road	HOLDER Aleck Meadows	HOLDER Cont. Road	ANT Aleck Meadows
(P) Purchase price-machine	$11,597.90	$11,597.90	$30,438.00	$30,438.00	10,000.00
Purchase price - tires	1,000.00	1,000.00	1,896.00	1,896.00	1,000.00
(S) Salvage value (20% of P)	2,319.40	2,319.40	6,087.60	6,087.60	2,000.00
(N) Estimate life	3 yrs.	3 yrs.	3 yrs.	3 yrs.	4 yrs.
(SH) Schedule op. hrs./yr. 8 hrs. x 250 days	2,000.00	2,000.00	2,000.00	2,000.00	2,000.00
(U) Utilization percent	74 %	74%	82.9%	82.9%	73.4%
(PH) Productive time/yr.	1480	1480	1658	1658	1468
(AVI) Av. Yrly. investment	8,505.07	8,505.07	22,321.20	22,321.20	7,000.00
AVI = [(P-S) (N+1)/2N]+S					
Fixed Costs					
(D) Depreciation	3,092.83	3,092.83	8,116.80	8,116.00	2,000.00
Int., taxes, ins. AVI	--	--	--	--	--
(18-2-2) = 22%	1,871.12	1,871.12	4,910.66	4,910.66	1,540.00
Total per year	4,963.95	4,963.95	13,027.46	13,027.46	3,540.00
Total/Prod. Hr.	$ 3.35	$ 3.35	$ 7.86	$ 7.86	$ 2.41
Operating Costs					
Maintenance-% of Depr.	(67) 75%	(88) 75%	(16) 50%	(20) 50%	(20) 50%
Maintenance-per P.H.	1.57	1.57	2.45	2.45	.68
Fuel-g.p.h.@1.45/gal.	(.302 gal.)	(.364 gal.)	(.625 gal.)	(1.1 gal.)	(0.44 gal.)
Fuel-per P.H.	.44	.53	.91	1.60	.64
Oil & Lubr.	.43	.43	.63	.63	.20
(T) Tires - Life hrs.	(3000 hr.)	(3000 hr.)	(3000 hr.)	(3000 hr.)	(6000 hr.)
T x 15% repair	.38	.38	.73	.73	.19
Total/Prod. Hr.	$ 2.82	$ 2.91	$ 4.72	$ 5.41	$ 1.71
Total machine cost /prod. hr.	$ 6.17	$ 6.26	$ 12.58	$ 13.27	$ 4.12

Table 19 Cont.

Labor Costs	
Base rate - $5.00/hr.	
+ Work. Comp.	20%
Soc. Sec.	7%
Unempl. Fed.	2%
Unempl. State	3%
Disability	3%
Total	35%

Labor cost	$ 6.75	$ 6.75	$ 6.75	$ 6.75	$ 6.75
Labor/prod. hour	$ 9.12	$ 9.12	$ 8.14	$ 8.14	$ 9.20
Total cost/prod. hr.	$ 15.29	$ 15.38	$ 20.72	$ 20.41	$ 13.32

Total Cost/Scheduled hour

Fixed costs	$ 2.48	$ 2.48	$ 6.52	$ 6.52	$ 1.77
Operating costs	2.07	2.15	3.91	4.48	1.26
Labor costs	6.75	6.75	6.75	6.75	6.75
Total Cost	$ 11.31	$ 11.38	$ 17.18	$ 17.75	$ 9.78

Machine utilization was determined as a weighted average of the utilization rates from each slope class to derive one utilization rate for each tractor. Table 20 shows the machine utilization for each tractor on each area.

As stated earlier, since the machines differ so greatly in their physical makeup, the only logical way to compare them is on a cost per unit of output basis. Table 21 shows a cost comparison per productive hour for the three tractors based on an equal skid distance of 100 feet. To obtain these costs, the variable times (inhaul and outhaul) were taken out of the total turn time, prorated according to skid distance, and readded to total turn time.

Comparisons of cost per cord and cost per turn for the three tractors on each site are shown graphically on Figures 13 and 14.

Comparisons of the costs shows the Holder is the most economical machine for the conditions tested. It is interesting to note that for longer distances, the Holder is more economical on the steeper slopes. This is indicated by the crossing cost lines on Figures 14 and 15. This is probably due to the smoother skid road at the Continental Road area.

Operating Capabilities and Limitations

The time study indicated the operating capabilities and limitations of the machines. The Holder, being larger, was able to take more of the rugged conditions than the Pasquali and the Forest Ant. However, even the Holder had its limitations. The limitations as determined by the testing are presented as follows.

Table 20. Machine utilization.

----------------------------------Mins.----------------------------------

	PASQUALI		HOLDER		ANT
	Aleck Meadows	Cont. Road	Aleck Meadows	Cont. Road	Aleck Meadows
Out haul	174.85	251.46	112.05	283.38	74.18
Gather	622.51	431.64	462.69	528.31	404.93
In haul	173.74	278.45	111.39	282.21	60.48
Unhook	110.95	165.46	185.15	223.06	28.86
Deck	10.72	7.66	14.25	9.64	--
Operational Delays	123.98	188.09	141.98	227.33	103.95
Total productive time	1216.75	1322.76	1027.51	1553.93	672.40
Non-productive time	450.09	446.91	158.26	3393.02	243.69
(Maint., repair, personal)					
Total time	1666.84	1769.67	1185.77	1946.95	916.09
% utilization	73.0%	74.7%	86.7%	79.8%	73.4%
Weighted average	**74%**		**82.9%**		73.4%

Table 21. Cost comparison (productive hour) for the Pasquali, Holder, and Forest Ant @ 100 skid distance.

Item	Ant	Slope 0 - 15% Pasquali	Holder	Slope 15 30% Pasquali	Holder
O&O cost/p.h. O&O cost/sh	$13.32 ($ 9.77)	$15.29 $(11.31)	$20.72 ($17.17)	$15.38 ($11.38)	$21.41 (17.74)
Skid distance (ft.)	100	100	100	100	100
Cords/turn	.44	.29	.61	.24	.65
Adjusted outhaul (minutes)	1.01	.77	.44	.45	.40
Adjusted inhaul (minutes)	1.77	.86	.54	.71	.42
Total prod. time Per skid (hrs.)	18.16 (.3027)	13.82 (.2302)	17.66 (.2943)	14.13 (.2355)	19.12 (.3187)
Cost/turn @ 100'	$ 4.03	$ 3.52	$ 5.20	$ 3.62	$ 6.82
Cost/cord @ 100'	$ 9.16	$12.14	$ 8.52	$15.08	$10.49

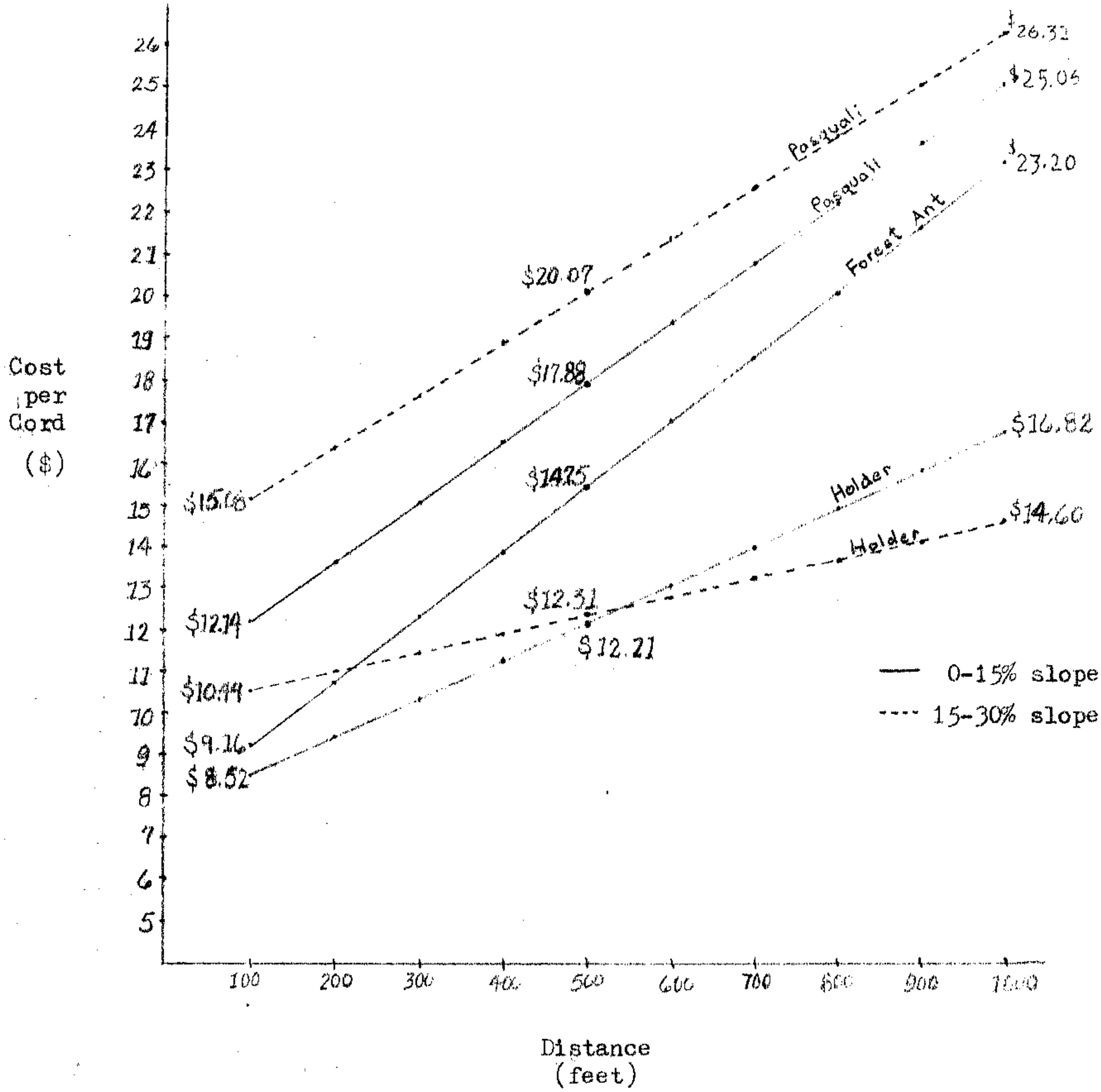


Figure 14. Cost comparison per cord at varying distance.

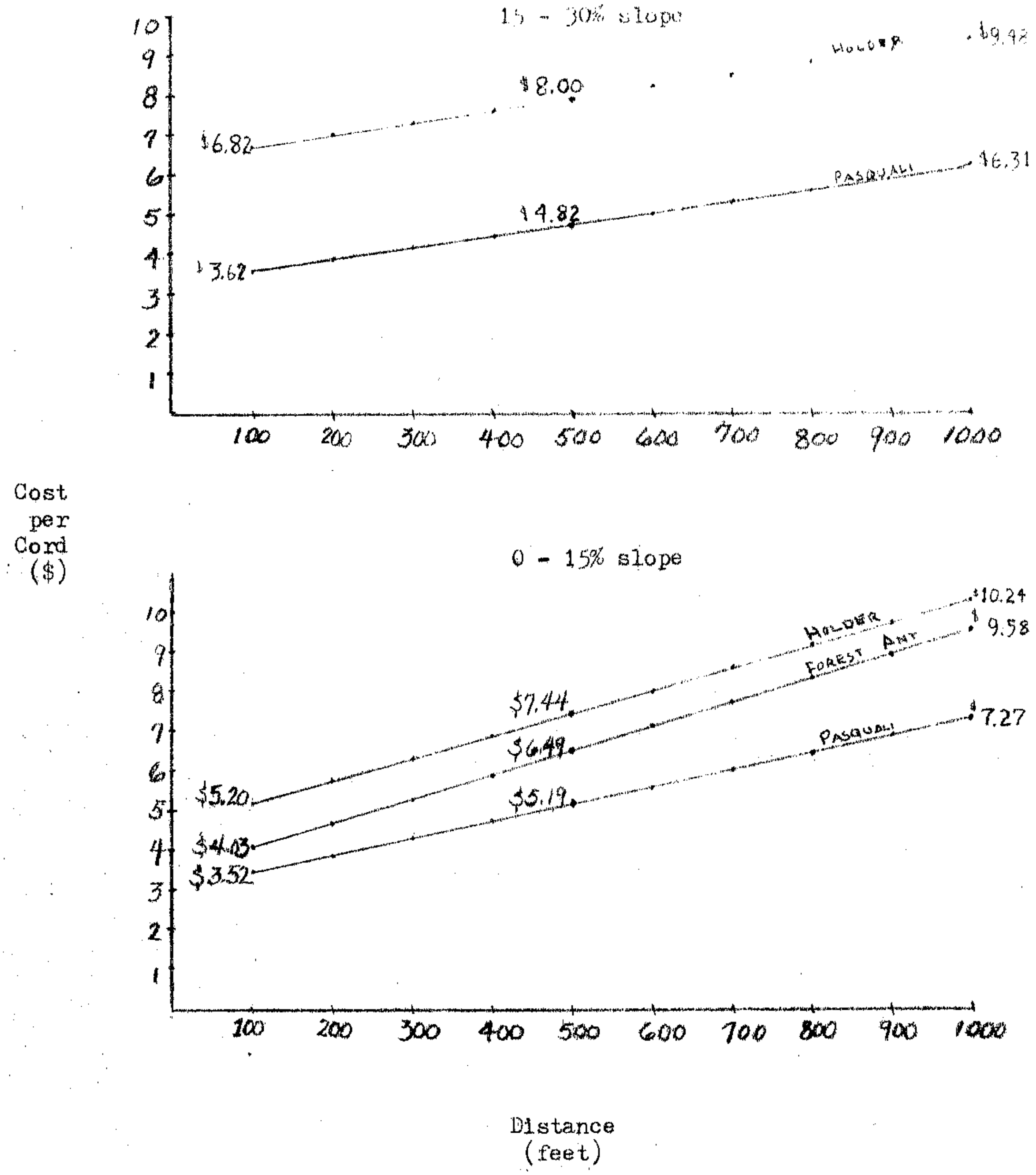


Figure 15. Cost comparison per turn at varying distance.

Pasquali - The Pasquali had excellent maneuverability. The articulated nature of the machine and the ease of steering provided a definite advantage over the conventional small farm tractor. This tractor was also easily transported, fitting on any standard pickup truck. The 30 HP diesel engine performed well and provided more than enough power to skid the logs except when a loss of traction was experienced. At times, a surplus of power was evident in the spinning of the wheels. The largest amount of delay was of this type. When more traction was needed, the four wheel drive could be locked in, but only for short straight skids since turning while locked was said to destroy the "spider gears." The large tires, 31x15.5x15, provided good floatation and weighting potential; however, tires of less width may have provided better traction by allowing the application of tire chains. Weighting of the front tires improved stability. This is a must if the machine is to be used for skidding purposes, as the bucket loader did not provide enough weight to hold the front end down while skidding.

The Farmi winch with cable and five keyhole sliders had enough power to pull almost all loads attached. However, the relatively low winching point (compared to a conventional skidder) allowed logs to get hung on stumps and rocks. It was determined that a snatchblock was essential to the operation for evading such obstacles. In most cases, the winch stabilizer anchors and brake were enough to hold the tractor in place; however, on steep slopes (over 20%) this was not the case, and the bucket had to be tipped and wedged into the ground to prevent slippage. Raising the winch after the logs were attached gave enough clearance to skid over obstacles on the skid roads. Winching the logs top first facilitated the skidding by leaving most of the log weight on the ground and lessening the tendency of the machine to raise its front end.

Due to its small size and maneuverability, the Pasquali was able to go around most obstacles in its path without damaging the trailside residuals. Beside skidding trees top first, trees should be cut into pieces 25 feet in length. Small diameter trees can be pulled full length whereas large diameter trees (14"+) should be cut shorter if possible. Tests show that the slash was an important variable causing longer skid times. Care should be taken to lop all slash to facilitate the gather time. Directional felling should be utilized wherever possible, since bunching time is greatly reduced when butts or tops are in line with the winch or at least within 45 degrees.

Due to its narrowness, the Pasquali could have been easily tipped on steep slopes if the operator was not careful. Steep slopes (over 25%) should be avoided. A moderately steep slope when combined with a slight side hill could be disastrous to the operator. In looking at the Pasquali on the 15-30 percent slopes, a very large increase in percentage time was exhibited on the inhaul. The Pasquali was being operated possibly to its limit on the steeper slopes and rough terrain of the forest. The Pasquali could clearly perform best on moderate to flat slopes with only scattered obstacles present. The test site at the Harvard Black Rock Forest, although typical for that area of New York

State, was above average in roughness. Constant use on such terrain would be detrimental to the machine.

The Pasquali's breakdowns consisted of mostly loosened fittings. On rough terrain, fittings should be checked periodically for loosening, especially those at the point of articulation. The original clutch cable had to replaced after only 5 days of operation, but after replacement with a Volkswagon brake cable, no further problems with this part occurred. Clogging of the fuel filter and fuel lines, and corrosion in the starter, caused considerable repair time. The corrosion could have been caused by moisture introduced into the machine during overseas transport.

Holder - Even though the Holder was larger than the Pasquali, it had comparable maneuverability. Steering was easy, and the turning radius was relatively short. The machine was too large to be transported on a conventional pickup, and it had to be brought to the site on a tilt top trailer. The 48 hp engine performed very well and had more than enough power in all cases; however, a loss of traction was experienced when four large oak logs were attached (approximately 17" DBH x 35 ft.). The front wheels were weighted which provided added stability.

The Ingland double drum winch proved to be very efficient; usually three logs were drawn in per cable. The rope center cables did snap on three occasions; an independent wire rope center cable may be more efficient although less flexible and more expensive. The double drum winch was more efficient than the single drum in that logs could be gathered from two directions and more logs could be skidded.

Logs being winched in were not affected as much by obstacles as the Pasquali, however, the snatchblock was used at times where large obstacles occurred. Use of the snatchblock on these occasions improved production. The backplate helped to serve as a "bumper" for incoming logs, and also as an anchor along with the brake while winching. Only rarely did the Holder need additional anchoring power. The blade on the front was very useful in moving obstacles, decking at the landing, and anchoring the machine during winching. Logs were winched both top and butt first. Since the butt plate lifted the butts off the ground, and prevented any log contact with the ground while skidding, it was better in most cases to skid logs butt first.

The excellent maneuverability of the Holder enabled it to go around most obstacles, if not directly over them. Again, with this machine, care should be taken to directionally fell trees and to lop all slash. Also, any side hill skidding should be avoided if possible. The Holder was tipped on its side during the test when the rear of the tractor was raised over a large rock on a side hill. This machine is not very wide, and on side hills may be tipped easily. Driver protection is adequate. After tipping, the cage was intact, and no injury to the driver occurred. Other than the side hill incident, the Holder performed remarkably well, and could handle any of the rough terrain conditions in this study.

The only repairs other than those attributable to the rollover, were snapped cables from winching, and a broken shift lever. The shift lever was made of cast iron and snapped during the second week of operation. A new lever was constructed from the broken lever. Rollover time was not included in the repair delay time for the Holder. Improper skid road planning was the cause of the accident, not the machine itself.

Of the three machines, the Holder was the most sturdy and trouble free. Tree length skidding could be used with the Holder, but trees larger than 14 inches DBH should be cut into shorter lengths.

Forest Ant - The Forest Ant tested in the present study was the first of its kind to enter the United States. This machine is totally different from the others tested and therefore demanded its own separate area, "Bugs Bunny." Pretesting of this machine clearly indicated that it could not readily handle the hardwoods over 9 inches in diameter. The knuckleboom loader would not lift the pieces off of the ground except in certain cases where they were very close to the machine. Even then, difficulty was experienced. Therefore, after testing in the Aleck Meadows area, the Ant was moved to the Bugs Bunny area for completion of testing. The Bugs Bunny area had similar terrain and slope conditions as the Aleck Meadows area, but more small trees were present.

In this area, the Ant proved itself highly maneuverable and efficient. Proper preplanning and skid trail layout is extremely important with the Forest Ant. If trees are not properly felled, skidding efficiency can be extremely poor. Trees should be felled in patterns as close to rows as possible. The Ant has difficulty turning once the bunk contains logs. It is not efficient for the Ant to turn to pick up more logs, even if the bunk is not loaded to capacity. Although the operator of this machine performed well, proficiency with this loader takes more time than was allotted for practice. Several weeks are needed to operate smoothly and with maximum efficiency.

The Forest Ant does have several disadvantages when working in the typical hardwood forest. Naturally occurring hardwoods generally do not grow in rows and planning removal is difficult. The machine will be useful only in removing small trees. Hung up trees cannot be safely pulled down with the grapple. Logs which are laying across each other are difficult to lift. This machine should not be used on slopes greater than 15% as it is very susceptible to tipping. In row thinnings, and thinnings of small trees, where the feller can properly align felled trees, this machine should be more economical than the conventional skidder.

The only major repair time involved was the rough running engine. It was not clear at the time of the study whether it was due to overheating or improper carburetor adjustment. At times, the constant pulling of the Ant caused a considerable heat buildup. After waiting several minutes for cooling, the machine again performed as expected.

Some advantages are that this machine caused the least damage to the residual stand with hardly any impact to the soil surface, and unhook time was very fast since no chains had to be unhooked. The slow speed of the machine enabled the operator to walk comfortably with it. However, on skids over 300 feet, turn time may increase due to operator fatigue.

Recommended Systems

Pasquali - The cost data for each of the hypothetical examples below are an average of the owning and operating costs on the two slopes per scheduled hour. Productivity is based on a 100 ft. skid as determined in Table 21 adjusted to a scheduled hour basis. The recommended system for this machine would be one man felling and helping gather, one man skidding and one man bucking at the landing and helping unhook.

Table 22 shows the cost/cord of a hypothetical operation using this machine under the conditions tested for the suggested system.

Table 22. Cost per cord for the Pasquali (100 ft. skid).

Labor Cost	
Feller	$6.75/scheduled hour
Bucker	$6.75/scheduled hour
Skidder with operator	$11.35/scheduled hour
	$24.85/scheduled hour
Production (scheduled hours)	
Time/turn	.3147 hrs
Cords/turn	.265 cds.
Cords/hour	.842 cds.
Cost/cord at 100 ft. skid	
Labor and machine	$29.51
Stumpage	$10.00
Other costs	$ 1.60
Total cost/cord	$41.11

Holder

The recommended system for this machine would be one machine operator, one feller (felling at least one day in advance), and one man bucking. With short skids (less than 750 feet), and good operating conditions, one man may be insufficient to handle the landing work load. Table 23 shows the hypothetical cost/cord for the skidding operating using this machine under the conditions tested for the suggested system.

Table 23. Cost per cord for the Holder (100 ft. skid distance).

Labor Cost	
Feller	$ 6.75/scheduled hour
Bucker	$ 6.75/scheduled hour
Skidder with operator	$17.46/scheduled hour
	$30.96/scheduled hour
Production (scheduled hours)	
Time/turn	.36 Hrs
Cords/turn	.63 cds
Cords/hour	1.7 cds
Cost/cord at 100 ft. skid	
Labor and machine	$18.21
Stumpage	$10.00
Other costs	$ 1.60
Total cost/cord	$29.81

Forest Ant - The best method for this machine would be one feller to fell and align trees, one machine operator, and one man to buck at the landing (the last man is optional). Table 24 shows a hypothetical cost per cord of the skidding operation using this machine under the conditions tested for the suggested system.

Table 24. Cost per cord for the Forest Ant (100 ft. skid distance).

Lab cost	
Feller	$6.75/scheduled hour
Bucker	$6.75/scheduled hour
Skidder with operator	$13.32/scheduled hour
	$26.82/scheduled hour
Production (scheduled hours)	
Time/turn	.4369 Hrs.
Cords/turn	.44 cds
Cords/hour	.993 cds
Cost/cord at 100 ft. skid distance	
Labor and machine	$27.01
Stumpage	$10.00
Other costs	$ 1.60
	$38.61

Residual Stand Damage

Plots for each tractor were taken after the cut to determine damage to residual trees.

On each plot a tally of the residual trees by species and diameter was made. Damage was defined as follows:

1. Bark abrasion - bark rubbed but not broken.
2. Bark skinned - rubbed off.
3. Root damage - exposed.
4. Broken off - tree destroyed.
5. Bent over - partially or entirely uprooted.
6. Felling damage.

The data taken is recorded in Table 25.

While this is a modest sample, several points appear:

1. The Pasquali tractor had less damage in general than the other two and little difference in operating on the two slopes.

2. The Forest Ant required greater maneuvering to position it close to the down trees. The felling damage resulted from the faller trying to ease the loading by seeking to fall trees for better positioning for loading.

3. The Holder damage in broken bark was probably due to the larger load per trip using the skid trails.

Soil Compaction of Skid Trails

Soil density samples of the soil in the skid trails were taken before and after logging for the three machine test areas. Bulk density measurements were attempted as a measure of compaction. The results, while, showing some compaction due to use, were so variable that no definite conclusions could be drawn. The soil mantle of the test area was very rocky and, by the end of the tests so dry that difficulty was encountered in lifting soil cores intact with testing device.

Table 25. Residual Damage Survey.

Percent of Basal Area and Number of Stems Affected

Tractor	PASQUALI				HOLDER				FOREST ANT	
Slope	0-15%		15-30%		0-15%		15-30%		0-15%	
Damage Category	BA	Stems	BA	Stems	BA	Stems	BA	Stems	BA	Stems
1. Bark rubbed	10.4	15.4	10.3	14.0	6.8	6.5	14.4	8.2	25.7	23.2
2. Bark broken	--	--	--	--	11.7	1.5	4.3	6.9	4.3	13.5
3. Root damage	--	--	--	--	2.9	1.5	--	--	--	--
4. Broken off	--	--	--	--	--	--	--	--	--	--
5. Bent over	--	--	--	--	--	--	--	--	1.4	6.5
6. Felling damage	--	--	--	--	--	--	15.2	24.4	5.7	8.4
Total Damage Noted	10.4	15.4	10.3	14.0	21.4	9.5	33.9	39.4	37.1	51.6
Total w/o #1	--	--	--	--	14.6	3.0	19.5	31.3	11.4	28.4

The indications were that compaction was, as expected, greater for the heavier machines and number of turns of use. Visual observations of the magnitude of disturbance and compaction showed that none of the machines had much effect on the soil mantle. There was evidence of a path in the skid trail and soil. It is felt that one winter's freezing and thawing will restore the soil structure to its original density and porosity.

It is questionable whether bark rub is actually damage. When the percentage of bark rub is eliminated from the total, as is shown in Table 25, the damage is decreased substantially. If felling damage is removed, damage is again substantially reduced. This indicates that very little open wound damage occurs from these small machines.

CONCLUSIONS

The test procedure used in this study provided reliable and consistent data as indicated by standard deviations and confidence limits. As long as the functions to be timed are clearly defined and broken into logical segments, the timer had no difficulty with the timing procedure, although some overall difficulties were apparent. For example, it is difficult to classify operator variability. Although the tractors were each operated by one person, day to day operator variabiity can become a problem. In this case, the timer must realize when the times are being affected by abnormal operator behavior and stop the operation. By far, the most important factor in time study is for all participants to be as consistent as possible. Pre-testing or testing the system before the time study begins is a must for consistent patterns to develop.

Again, it must be stated that the data presented pertains to the stated conditions. Regression relationships showed that environmental conditions account for only 50% of the variation in skid times. Thus different operators and other factors could significantly change the times and cost figures given. Results can be directly applied when conditions and crew organization are similar. All three of the machines are profitable to operate in these stands (the firewood was sold roadside at $50.00 per cord) and since these stands represent typical stands in the lower Catskill Region, and probably rougher than other parts of the state, the machines should be an economical alternative to conventional skidders in most areas of New York State.

Tests show that the Holder was the most versatile machine and also the least costly per cord to own and operate, followed by the Forest Ant, which was not so versatile, and the Pasquali, which was moderately versatile. Machine choice should be geared to the needs of each particular individual. The purpose of this report was to present the method of testing and result for the three machines tested. General recommendations, however, are stated as follows by machine:

Pasquali - The Pasquali was a medium cost small tractor which performed well under the conditions tested. Its best feature was its manueverabiity. The machine could also be used for mowing, shoveling or plowing, with other attachments, making it highly versatile for other uses. This machine would be an excellent choice for the farmer or small woodlot owner.

Holder - Although this machine costs more than the others, its operating cost was lower. This machine was maneuverable, sturdy and powerful. Although the price may be too high for a farmer or woodlot owner, for the commercial firewood producer or cooperative landowner group this machine would be an excellent choice.

Forest Ant - The Forest Ant, although not as versatile as the Pasquali, or as sturdy as the Holder, had a low investment cost and a relatively low operating cost. For stands of small diameter trees and row thinnings, this machine would be a very good choice.

LITERATURE CITED

American Pulpwood Association. 1968. Harvesting Research Project. Time Study Manual For Production Tables Study. Atlanta, Georgia.

Bennett, W.O. 1962. Forces involved in skidding full tree and tree length loads of pulpwood. Canadian Pulp and Paper Association, Montreal, Canada. Woodlands Res. Index No. 137. 19p.

Bertozzi, M. 1982. A New York State forest tax policy proposal. State of New York, Division of Equalization and Assessment. 62p.

Canadian Pulp and Paper Assn. 1943. Pulpwood Skidding with Horses. Woodlands Section Index No. 694. Canada. 137p.

Clawson, M. 1979. The economics of non-industrial private forests. Resources For the Future, Washington, D.C. Res. Pap. R-14, 410p.

Conway, S. 1976. Logging Practices, Miller Freeman Publication, Inc., New York. 416p.

Davidson, J.C., H.E. Alexander, R.D.S. Church and M.R. McKay. 1962. Small skidder forum. Pulp and Paper Magazine of Canada. 63(4) WR136-154.

Flatau, L. 1978. A suggested technique for establishing log skidder production level. Masters Thesis. State University of New York, College of Environmental Science and Forestry, Syracuse, New York. 117 p.

Forbes, R.D. 1955. Forestry Handbook. Ronald Press, New York.

Fowler, G. 1970. A method to log small woodlots. N. Logger and Timber Processor, Sept. 1979. 2p.

Gabriel, W.J. 1975. Machines and systems suitable for logging small woodlots in the Northeast. State University of New York, College of Forestry, Applied Foretry Research Institute. Syracuse, New York. Res. Rept. No. 26. 23p.

Hoffman, B. 1981. Yellow cabs in the woods. N. Logger and Timber Processor. 30(5):6-7.

Mathews, D. 1942. Cost Control in the Logging Industry. McGraw-Hill, New York. 374p.

Literature Cited Cont.

Marler, R. and P. Graves. 1974. A new management rational for small forest owners. State University of New York. College of Environmental Science and Forestry, Applied Forestry Research Institute. Res. Rept. 17.

Maynard, H.B., ed. 1963. Industrial Engineering Handbook. McGraw-Hill, New York.

McCraw, W. and R. Hallett. 1970. Studies on the productivity of skidding tractors. Can. For. Serv., Dept. of Fisheries and Forestry, Pub. No. 1281. 38p.

Miyata, Edwin S. 1980. Determining fixed and operating costs of logging equipment. USDA Forest Service Gen. Tech. Rep. NC-55. 16p.

Ross, P. 1958. Microclimatic and vegetational studies in a cold-wet deciduous forest. Black Rock Forest Paper No. 24. Harvard Black Rock Forest, Cornwall-on-the-Hudson, New York. 85p.

SAS Institute. 1979. SAS Users Guide. Cary, North Carolina. 494p.

Stevens, D.C. and N.R. Smith. 1980. Skidding firewood with small tractors. NA-GR-10. Repr. by U.S.D.A. For. Serv., N.E. area, S & P. For. Broomall, Pa. 18p.

Uebler, R.L. 1975. The effect of timber harvesting on soil physical properties for three harvesting methods in two areas of New York State. M.S. Thesis, S.U.N.Y. College of Forestry, Syracuse, N.Y. 115p.

U.S. Forest Service. 1978. Forest statistics of the U.S., 1977. U.S.D.A., Forest Service.

Whayman, H. 1968. A pygmy skidder for extracting thinnings. Pulp and Paper Magazine of Canada. 69(3/1):W-81-83.

APPENDICES

APPENDIX A

EQUIPMENT

Table 1.

pasquali

Model 993 4-Wheel Drive Diesel Tractor Specifications

ENGINE (Diesel)
Model
Ruggerini
4 stroke Diesel
Air Cooled
Brake horsepower .... 30 SAE H. P.
No. cylinders 2
Displacement .... 65.9 in^3
Bore and stroke .... 3.55 x 3.55 in.
Rated engine speed .... 3000 rpm

POWER TRAIN
TRANSMISSION
Sliding type key gear with synchronizer.
9 speeds forward
3 reverse speeds
DIFFERENTIAL
Differential on both axles.
Differential lock on front axle.
CLUTCH
8" diameter
Single dry disc clutch
PTO
Two PTO speeds
540 rpm
750 rpm
PTO can also be synchronized with all tractor speeds.

HYDRAULIC LIFT
2-point linkage and 3-point linkage.
Independent hydraulic lift system.

STEERING
Articulated in center with worm gear oil bath steering.

ELECTRICAL
Battery .... 12 volt
Starter .... 12 volt
Headlights .... 12 volt

MPH at rated engine RPM (3000)

	Range	Gear	MPH
Speeds:	Low	1st	.37
		2nd	.62
		3rd	1.43
		Reverse	.93
	Medium	1st	1.06
		2nd	1.68
		3rd	3.73
		Reverse	2.55
	High	1st	4.23
		2nd	6.84
		3rd	15.22
		Reverse	10.25

DIMENSIONS
Wheel Base .... 46½"
Maximum Height .... 42½"
Length .... 96½"
Weight .... 1786 lbs.
Tires .... 7.50 x 16
(Front & Rear)

TREAD ADJUSTMENT
(Front and Rear with 7.50 x 16 tires)
Minimum .... 33"
Medium .... 41"
Maximum .... 55"

BRAKES:
Mechanical brakes on rear axle. Hand brake also comes as standard equipment.

Winch

Farmi JL 25: Single drum, pulling capacity of 5,500 lbs., 100' cable 3/8ths inch complete with driveshaft.

List Price (June, 1981)

Model 993 Basic Tractor	$ 7,375.00
Tires & Rims 31x15.5x15 (4)	1,000.00
Fluid Fill Front Tires	80.00
Roll bar (mounted)	475.00
Under Body Protection Pan	100.00
Farmi Model JL-25 Winch	1,090.00
Skidding chains (68") (4)	110.00
Snatchblock	97.90
Total	$12,597.90

Table 2

HOLDER

Technical data

	A 55 / A60
Design	Frameless unit construction, four-wheel drive, pivotal steering
Engine	Holder 3-cylinder 4-stroke diesel engine, 2020 cc, 48 HP SAE (31 kW) at 2300 rpm Bosch injection system and regulator, direct fuel injection, almost vibration-free, excellent accelleration, ideal torque characteristic, force-feed lubrication Crankshaft on four bearings
Clutch	Single-plate dry clutch
Gearbox	8 forward gears (0.5–20 km/h–0.25–12.4 mph) and 4 reverse gears, four-wheel drive via spiral bevel gears, two differentials, individually operated diff-locks front and rear
Steering	Hydromatic steering acting on all four wheels
Brakes	Acting on all four wheels. Two independent braking systems, foot and hand brake acting on all four wheels.
Tyres	Front and rear 9.5/9–24 AS / Front and rear 10.5–20 AS
P.T.O.	Transmission P.T.O. with 540 rpm at 2100 rpm engine speed
Fuel tank	Capacity 23 litres (5 gal.), large built-in micronic fuel filter
Air filter	Large oilbath air filter and cyclone preselector upon request
Cooling	Water cooling with pump and thermostat

Driver seat	Rubber-sprung, damped, upholstered, adjustable for driver's weight	
Trailer hitch	Adjustable for height and revolving, with guard forged in one piece, for operation by the driver with one hand	
Hydraulics	Holder two-cylinder hydraulics with Bosch pump, high working pressure ensuring accurate operation of all implements. Lifting capacity 1600 kp – 3520 lbs. (16.000 N) on field bar	
Implement lift	Standard Cat. I three-point linkage	
Electrical system	12 Volt system, Bosch dynamo and starter, battery, 2 headlights, 2 front traffic indicators, 2 rear traffic and brake lights, rear reflectors, licence plate light, horn, fuse box, socket and pilot light system, combined pilot instrument including water temperature indicator and 5 control lights	
Tools	Toolbox with tools	
Tractormeter	Registering ground speed, engine and P.T.O. rpm and hours	
Permissible total weight	3000 kg (6600 lbs.)	3000 kg (6600 lbs.)
Front/rear	1500 kg/1500 kg (3300 lbs./3300 lbs.)	1500 kg/1500 kg (3300 lbs./3300 lbs.)
Empty weight without driver	1410 kg (3102 lbs.)	1600 kg (3520 lbs.)
Wheelbase	1450 mm (56 in.)	1450 mm (56 in.)
Track widths	1010/1250/1500 mm (39/48/58 in.)	1250 mm (48 in.)
Overall width	1250/1490/1740 mm (48/58/67 in.)	1520 mm (59 in.)
Overall length, incl. 3-point linkage	3120 mm (1216 in.)	3120 mm (1216 in.)
Overall height without rollover bar	–	–
Overall height including rollover bar	2000 mm (780 in.)	2080 mm (811 in.)

Winch

Igland Winch 3000 "Perfect": Double-drum, 3 metric ton per cable (6,600 lbs.) complete with driveshaft, 4 choker chains, 2x35mx10mm cables, logging plate, three-point mounted.

List Price (June, 1981)

A60 Basic Tractor with live PTO	$19,600.00
Category I Three point linkage	341.00
Tires & Rims 14.5x20 (4)	1,896.00
Wheel weights (2)	222.00
Fluid Fill - Front Tires	150.00
Forestry Cab and front roll bar	1,878.00
Under Body Protection Pans	485.00
Hydraulic Valves for Stacker	347.00
Stacker, North Am. version	2,565.00
Igland Winch 3000 "perfect"	4,850.00
Total	$32,334.00

Table 3

FOREST ANT

TECHNICAL DATA

Max width (280 - 15.5/6)	1300 mm (4' 6")
Overall length, excl. steering bar	3000 mm (10')
Crane outreach	3200 mm (10' 8")
Inside turning radius	1600 mm (5' 4")
Outside turning radius	3000 mm (10')
Ground clearance	330 mm (13")
Bunk jaws:	
Area (closed)	0.55 m^2 (5.9 sq.ft.)
Closing force	3925 Newton (400 kgf) 880 lbs.
Max load	2000 lbs.
Crane:	
Articulation angle	40^0
Slewing angle, crane	50^0
Total of above	90^0
Outreach	3200 mm (10' 8")
Slewing angle 100^0 + 2 x 40^0	180^0
(slewing angle + articulation angle)	
Lifting force:	
Max outreach	1470 Newton (Abt 150 kgf) (330 lbs.)
Min outreach	3925 Newton (Abt 400 kgf) (880 lbs.)
Grapple:	
Max area	Abt 0.12 m^2 (15 cu.")
Machine weight:	
Machine weight incl. oil and fuel	900 kg (2000 lbs)
Tractive effort:	8930 Newton (Abt 900 kgf) (2000 lbs)
Speeds:	
High speed	5.3 km/h (3.2 mph)
Low speed	3.5 km/h (2.17 mph)
Engine:	
Gas engine	8.85 kW (12 hp)
Automatic starting	
Electrical system	12 V
Fuel tank capacity	2.4 gal. U.S.
Oil capacity	1.25 l (1.20 qts.)
Fuel consumption	2-3 l/h (1.9-2.8 qts.)
Hydraulic system:	
Oil reservoir capacity	75 l (17.75 gal.)
Dual pump	
Total displacement 13/84 gal. at 3000 r/m	
Oil pressure	17.5 MPa (154 lbs/sq. inch)
Oil cleaner with suction strainer and microfilter	

Steering:
Machine follows operator automatically as he walks with steering bar which is about 2 m long (6 1/2')

Operation:
Fully hydraulic transmission.
Synchronized 4-wheel drive without differential.
Each wheel axle is driven by dual hydraulic motors via gearing.

List Price: $77,000.00

Table 4. Winch specifications.

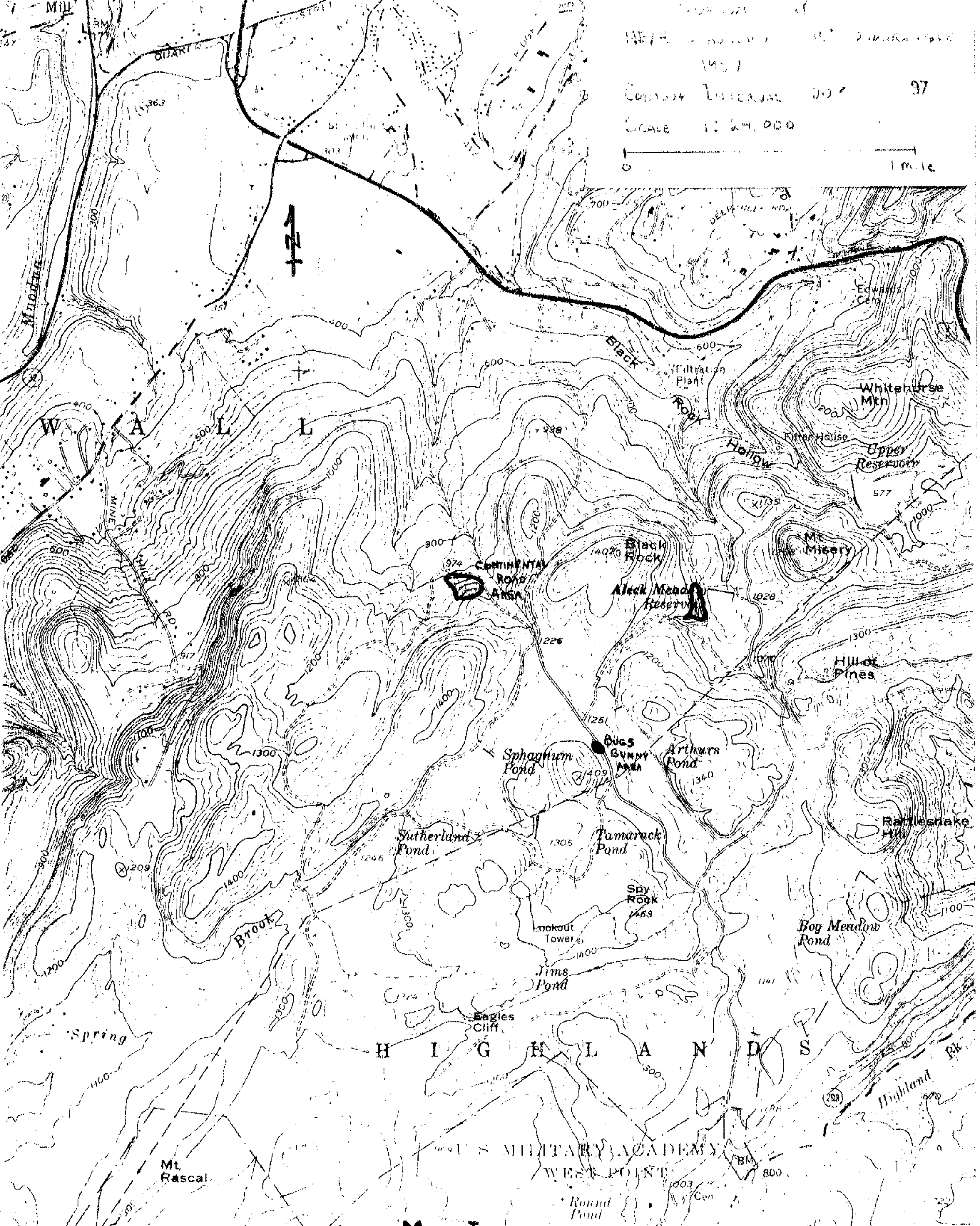
The Farmi JL25 winch, Pasquali	
Pulling capacity	5500 lbs.
Cable on drum	100 ft.
Cable size	3/8 in.
Winch speed	80-120 ft/min.
Clutch	Freidon plate
Mounting	3 point hitch
Weight	250 lbs.
HP requirement	18-30 HP

The Ingland Winch 3000 "Perfect," Holder	
Cable diameter	.39
Cable length	115 ft.
Weight of unit	335 lbs.
Winch speed	230 ft/min.
Clutch	Friction plate
Maximum pull/drum	6600 lbs.
Brake	Band brake
Controls	Manual

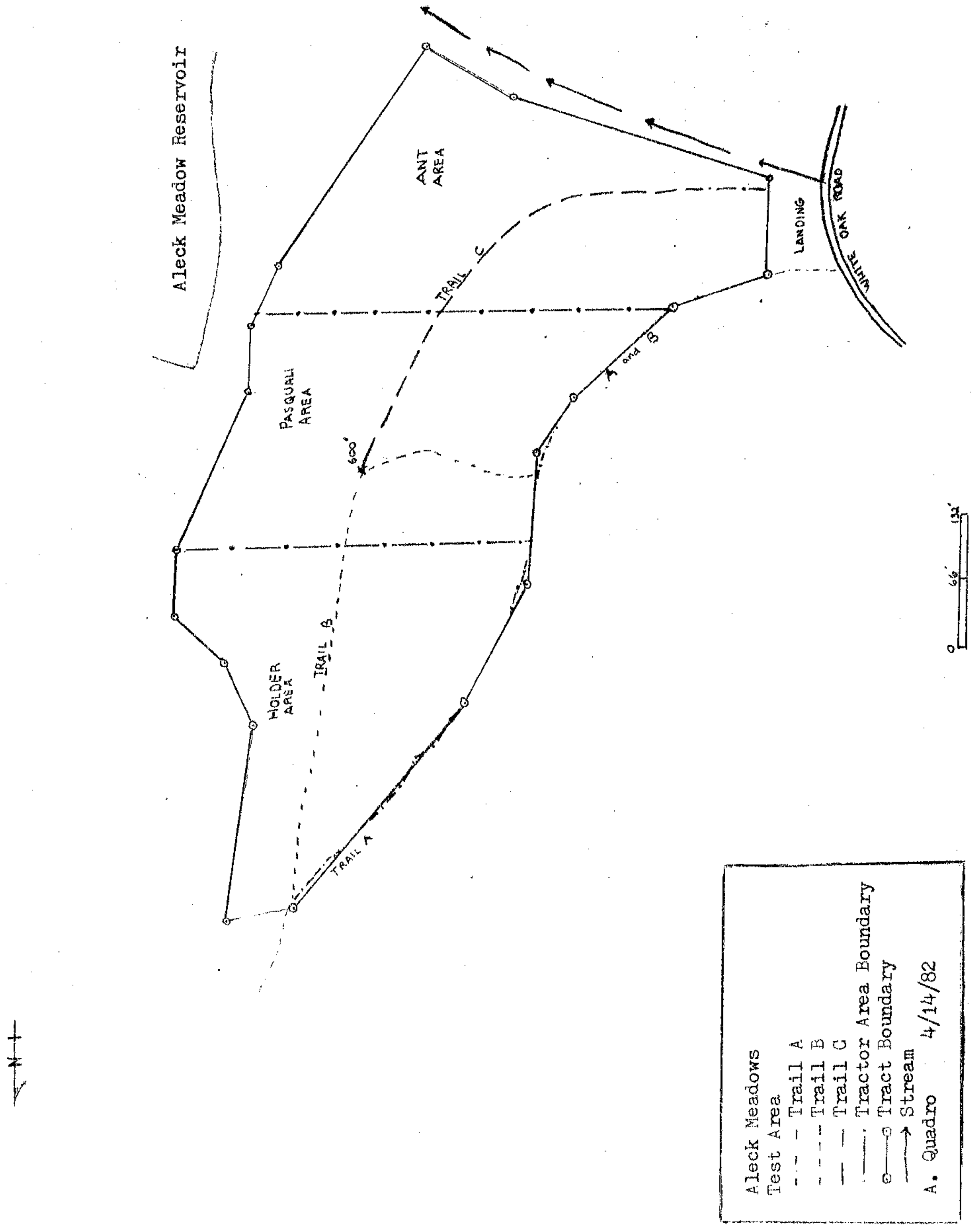
The knuckleboom loader, Forest Ant	
	@ Maximum outreach 330 lbs. @ Minimum outreach 882 lbs.
Lift	
Turning angle	50 deg.
Outreach	10.5 ft.
Grapple area	1.29 sq. ft.

APPENDIX B

MAPS

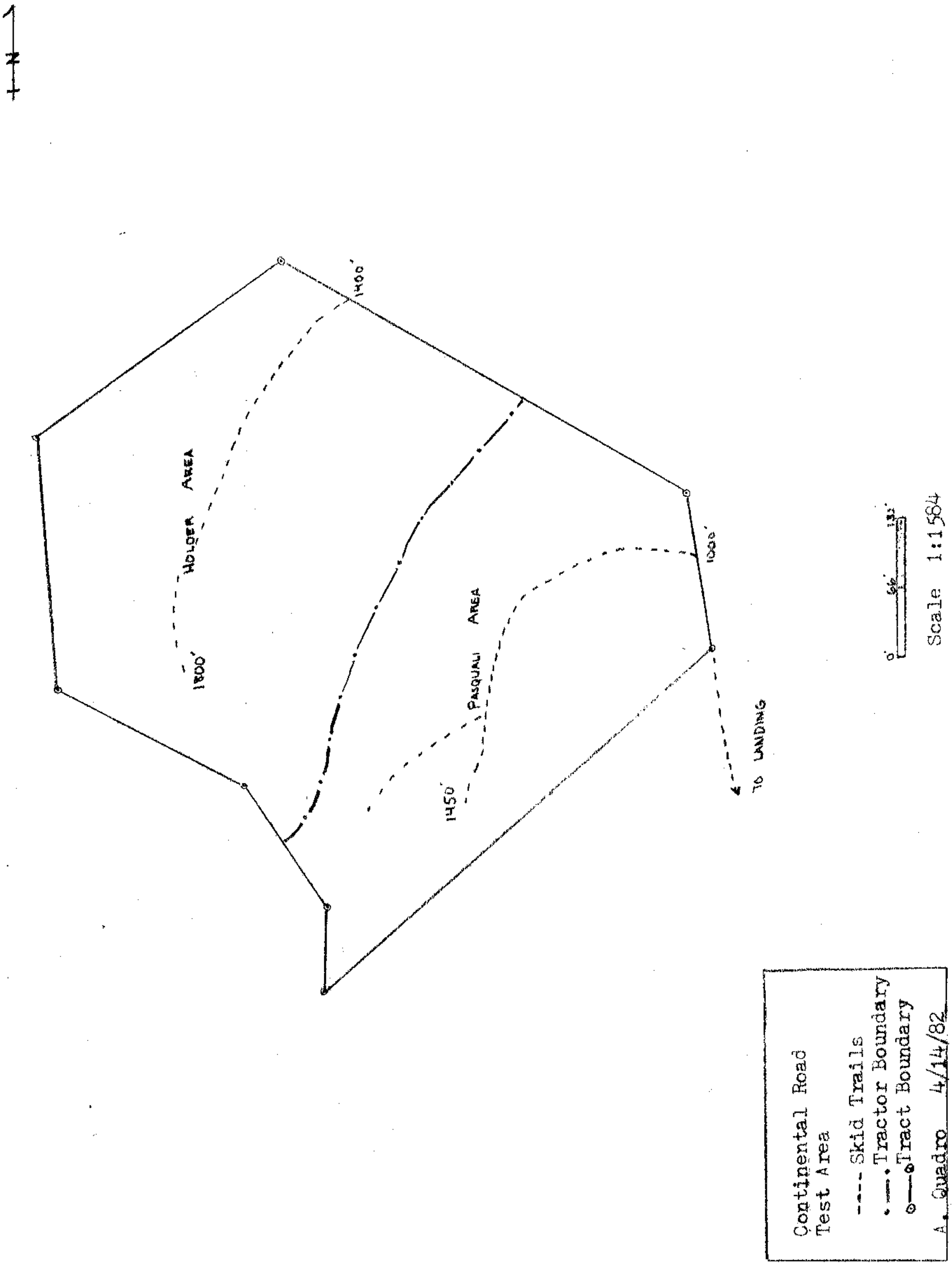

97
0
1 mile
Black Rock Hollow
Filtration Plant
Whitehorse Mtn
Filter House
Upper Reservoir
Edwards Cem
Mt. Misery
Black Rock
CONTINENTAL ROAD AREA
Aleck Meadow Reservoir
Hill of Pines
BUGS BUNNY AREA
Sphagnum Pond
Arthurs Pond
Rattlesnake Hill
Sutherland Pond
Tamarack Pond
Spy Rock
Lookout Tower
Bog Meadow Pond
Jims Pond
Eagles Cliff
Brook
Spring
W A L L
H I G H L A N D S
U S MILITARY ACADEMY
WEST POINT
Mt. Rascal
Round Pond
Highland Bk
MINE HILL RD
Moodna

Map I

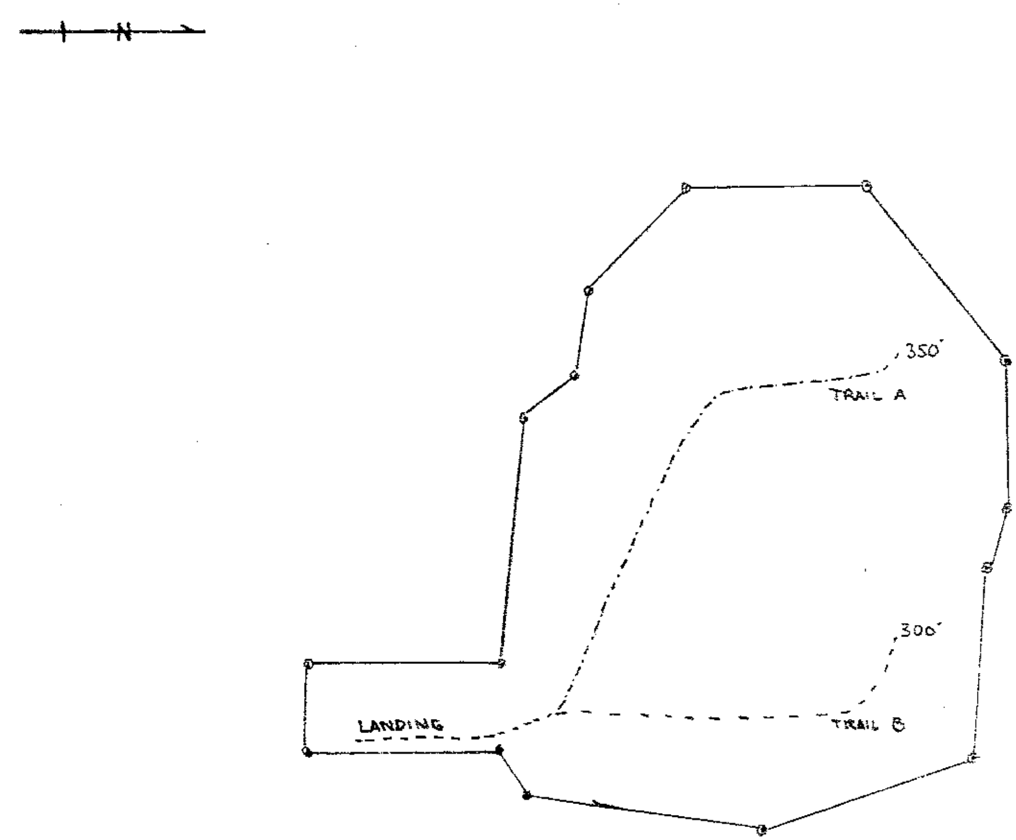


Aleck Meadow Reservoir
ANT AREA
PASQUALI AREA
HOLDER AREA
TRAIL C
TRAIL B
TRAIL A
A and B
LANDING
WHITE OAK ROAD
600'
0 66' 132'
Scale 1:1584
N
Aleck Meadows
Test Area
Trail A
Trail B
Trail C
Tractor Area Boundary
Tract Boundary
Stream
A. Quadro 4/14/82

Map II


N
1400'
HOLDER AREA
1800'
PASQUALI AREA
1450'
1000'
TO LANDING
0' 66' 132'
Scale 1:1584
Continental Road
Test Area
---- Skid Trails
.—. Tractor Boundary
o—o Tract Boundary
A. Quadro 4/14/82

Map III



Bugs Bunny
Test Area
Test Area Boundary
Trail A
Trail B

A. Quadro 4/14/82

Not To Scale

Map IV

APPENDIX C

FORMS

TRACTOR STUDY FORM #1

FS-NE-4207-63

Timers: ____________, ____________ Crew: Tractor Oper. ____________ Feller ____________

Date Started: ____________ Date Ended: ____________

Location: ____________

Weather Conditions: ____________

SYSTEM TESTED (Equipment, tools, manpower): ____________

____

Site Description: ____________

Average Slope: ____________%

Soil Moisutre: 1 2 3 4 (Circle one)

Obstacles: 1 2 3 4 5

Stand Description: ____________

Timber Type: ____________

Treatment: ____________

BA/Ac ____________ sq. ft./Ac

Residual BA/Ac ____________ sq. ft.

Cu. ft./Acre ____________ cu. ft.

Cu. ft./Acre cut ____________ cu. ft.

Directional Felling Y N (Circle one)

Operator rating (Circle one for each)

Skidder - Skill: 1 2 3 Efficiency: 1 2 3

Feller - Skill: 1 2 3 Efficiency: 1 2 3

Bucker - Skill: 1 2 3 Efficiency: 1 2 3

TRACTOR STUDY DATA SHEET II

Site Location ______________

Slope __________ %

Machine ______________

Weather ______________

Recorder ______________

Date ______________

Start Time ______________

End Time ______________

Total Time ______________

Operators-tractor ______________

Other __________ __________

" __________ __________

Turn #	Outhaul	Gather	Inhaul	Unhook	Deck	Skid Dist	DELAYS Code	DELAYS Time	COMMENTS Slope, change in condition, etc.

DELAY CODE

01 Personnel
02 Rest
03 Mechanical breakdown
04 Dropped log time
05 Hang-up
06 Swamped, stuck
07 Non-scheduled waiting note due to work (rain,
08 Non-scheduled waiting-work related (bottleneck
09 Miscellaneous

Date______________________
Site Location______________________
Weather Condition______________________
Machine______________________

Recorder______________________
Start Time______________________
End Time______________________
Total Time______________________

DATA SHEET NO. III
Volume/turn

SP.	BOT. DIB	TOP DIB	LNTH.	VOL.	SP.	BOT. DIB	TOP DIB	LNTH	VOL.	SP.	BOT DIB	TOP DIB	LNTH.	VOL.

TURN NO._____, VOL. _____ TURN NO._____, VOL._____ TURN NO._____, VOL._____

TURN NO._____, VOL. _____ TURN NO._____, VOL. _____ TURN NO._____, VOL. _____

FORM IV

Stacked Volume and Cubic Content

Pile Volume
Height ________ ft.
Width ________ ft.
Length of wood ________ ft.

Date ________
Recorder ________
Pile No. ________

Cord content ________ cds.

Per Cord
Solid Volume ________ cu. ft.

No. pcs./cd. ________

Pc. No.	i.b. Diam.¯ BA	Side 1	ΣBA	Side 2	ΣBA
2	.022				
3	.049				
4	.087				
5	.136				
6	.196				
7	.267				
8	.349				
9	.442				
10	.545				
11	.660				
12	.785				
13	.922				
14	1.069				
15	1.227				
16	1.396				
17	1.576				
18	1.767				
	Total	No.		No.	
	Sub-tot.1 & 2	No.			
				Cubic Content	
	Average			x lght=	cu.ft.

APPENDIX D

COMPUTER PRINTOUTS

DATA FO.. THE PASQUALI AT ALECK MEADOWS

OBS	TURN	OUTHAUL (min.)	GATHER (min.)	INHAUL (min.)	UNHOOK (min.)	DISTANCE (ft.)	WEIGHT (lbs)	LOGS	SLASH	TERRAIN	TOTTIME
1	1	5.00	7.10	3.53	2.21	600	898.9	5	0	1	17.84
2	2	4.80	6.30	3.27	1.40	600	1941.4	4	0	1	17.77
3	3	5.30	9.05	3.72	1.60	600	1632.2	4	0	1	19.67
4	4	3.20	7.71	3.60	2.04	625	1511.1	4	0	0	16.55
5	5	3.20	8.01	3.00	3.70	575	1288.3	4	0	0	17.91
6	6	3.16	13.08	3.00	2.20	575	939.7	4	0	0	21.44
7	7	3.04	10.10	3.13	2.17	625	2142.6	4	0	0	18.44
8	8	2.33	11.60	3.96	1.50	625	1631.6	4	0	0	19.39
9	9	3.40	12.80	2.88	1.53	625	1415.9	4	1	0	20.61
10	10	2.59	8.90	2.80	1.75	600	1913.0	4	0	0	16.04
11	11	3.00	6.15	3.85	1.65	450	913.0	4	0	1	14.65
12	12	4.66	7.01	2.88	1.01	400	1376.9	3	0	1	15.56
13	13	4.76	7.28	3.56	1.77	450	935.9	4	0	1	17.37
14	14	4.85	7.33	5.17	0.43	450	1351.0	3	0	1	17.78
15	15	4.58	3.72	3.50	1.43	475	772.2	3	0	1	13.23
16	16	4.03	8.23	4.07	1.92	475	1714.3	4	0	1	18.25
17	17	3.91	10.10	3.69	1.55	475	1059.2	4	0	1	19.25
18	18	2.38	5.48	4.29	1.35	450	1830.4	3	0	0	13.50
19	19	2.71	12.49	3.18	0.75	450	1808.8	4	0	0	19.13
20	20	2.31	8.13	2.68	1.43	450	763.5	4	0	0	14.55
21	21	2.12	8.92	4.19	1.44	450	1843.4	4	0	0	16.67
22	22	2.28	6.62	2.92	2.09	450	1804.8	4	0	0	13.91
23	23	2.27	11.25	3.85	1.47	475	1786.0	3	0	0	18.84
24	24	2.82	21.75	2.77	2.16	500	1855.1	4	1	0	29.50
25	25	2.35	10.35	3.56	1.55	550	2513.0	4	0	0	17.81
26	26	3.03	7.56	3.51	1.47	550	1787.0	4	0	0	15.57
27	27	1.88	4.26	1.70	1.10	350	1527.1	1	0	0	8.94
28	28	1.54	0.64	1.80	1.40	350	1456.3	1	0	0	5.38
29	29	1.21	11.65	1.65	1.80	350	1393.6	4	0	0	16.31
30	30	2.29	9.80	1.69	3.45	325	1473.2	4	0	0	17.23
31	31	2.86	6.84	2.19	1.31	350	892.2	4	0	0	15.20
32	32	1.96	10.04	2.73	1.46	350	1684.5	5	1	0	16.19
33	33	2.27	15.35	2.14	1.16	350	2204.5	5	0	0	20.92
34	34	2.40	11.28	1.66	1.24	325	1872.1	5	0	0	16.58
35	35	2.84	8.72	2.42	2.00	525	1306.5	5	0	0	15.98
36	36	2.00	13.63	3.36	1.98	450	1621.0	3	1	0	20.97
37	37	3.19	7.43	2.94	2.27	400	1274.8	6	0	1	15.83
38	38	3.35	9.08	3.07	2.27	400	1354.0	5	1	1	17.77
39	39	2.91	11.43	2.82	1.46	400	1530.2	4	0	1	18.62
40	40	2.58	7.62	3.25	0.86	375	1383.5	3	0	1	14.31
41	41	3.04	7.02	2.75	1.31	425	781.5	4	0	1	14.12
42	42	3.21	6.04	2.63	2.80	425	1154.3	4	0	1	14.68
43	43	4.05	8.28	3.94	2.58	525	1819.4	4	0	1	18.85
44	44	3.30	11.95	2.48	1.11	400	1436.7	3	1	1	18.84
45	45	2.66	12.09	3.40	3.19	400	2177.4	5	1	1	21.34
46	46	1.72	5.73	2.43	1.51	350	1183.8	4	0	0	11.39
47	47	1.85	10.69	1.55	1.90	300	1244.2	4	0	0	15.99
48	48	1.78	11.30	1.81	1.82	325	1381.7	4	0	0	16.71
49	49	1.53	14.96	1.57	2.24	275	1342.3	5	1	0	20.30
50	50	1.62	10.41	1.55	1.24	275	1113.6	5	1	0	14.82
51	51	1.28	10.71	1.61	0.52	225	1494.7	2	0	0	14.12
52	52	2.00	12.22	1.45	1.17	225	670.8	3	1	0	16.84
53	53	1.60	10.66	1.28	1.87	225	600.5	7	1	0	15.41
54	54	1.89	9.32	0.59	1.35	275	773.4	3	0	0	13.15
55	55	2.01	7.10	1.28	1.30	250	822.6	3	1	0	11.69
56	56	1.35	4.30	1.33	1.43	200	1635.7	4	0	0	8.41
57	57	1.10	8.82	1.97	2.16	200	1375.4	4	0	0	14.05
58	58	1.11	12.02	1.18	2.31	150	1106.4	5	1	0	16.62
59	59	0.85	6.41	0.97	1.52	150	1230.7	4	0	0	9.75
60	60	0.95	3.20	1.45	1.11	125	589.9	3	0	0	6.71
61	61	1.40	20.92	2.06	1.59	125	1386.1	4	1	0	25.97
62	62	3.32	8.21	3.08	1.98	375	1202.6	4	0	1	16.59
63	63	2.75	18.87	3.74	1.48	375	1648.9	4	1	1	26.84
64	64	3.41	12.03	1.32	0.95	350	1314.3	4	1	1	17.71
65	65	3.71	10.46	2.34	3.18	350	686.1	5	0	1	19.69

DATA FOR THE PASQUALI AT CONTINENTAL ROAD

OBS	TURN	OUTHAUL (min.)	GATHER (min)	INHAUL (min)	UNHOOK (min)	DISTANCE (Ft)	WEIGHT (lbs)	LOGS	SLASH	TERRAIN	TOTIME (min)
1	1	5.27	7.70	5.87	1.34	950	1193.4	4	0	1	20.18
2	2	6.21	7.08	4.53	3.40	1000	848.0	4	0	1	21.22
3	3	4.97	5.64	6.30	1.35	1000	826.9	4	0	1	18.26
4	4	6.84	9.28	7.45	2.68	1450	1203.8	4	0	0	26.25
5	5	7.60	9.50	8.40	2.06	1425	1117.9	5	0	0	27.56
6	6	7.02	12.25	7.19	4.20	1450	1607.1	4	0	0	30.66
7	7	3.64	7.14	5.15	1.70	1000	1310.2	4	0	0	17.63
8	8	3.57	7.37	4.34	2.00	1000	695.6	5	0	0	17.28
9	9	7.05	11.00	7.95	1.10	1400	1125.0	4	0	0	27.10
10	10	6.68	7.10	7.33	6.20	1350	1212.4	5	0	0	27.31
11	11	6.70	7.88	10.18	1.20	1400	1174.6	2	1	0	25.96
12	12	7.25	12.01	8.00	1.50	1400	1277.2	3	1	0	28.76
13	13	4.75	6.02	6.73	8.20	1200	1682.3	3	0	0	25.70
14	14	6.00	6.56	7.12	4.44	1400	763.1	3	0	0	24.14
15	15	5.58	5.93	5.10	3.85	1200	880.0	3	0	0	20.46
16	16	5.15	7.35	6.50	2.05	1200	745.9	3	0	0	21.05
17	17	4.82	5.50	5.37	3.00	1225	1077.9	3	0	0	18.69
18	18	4.65	7.11	5.71	2.50	1250	903.6	4	0	0	19.97
19	19	5.15	11.77	5.15	3.72	1250	1467.2	4	1	0	25.79
20	20	4.84	9.23	5.07	3.67	1250	1373.9	3	0	0	22.81
21	21	4.34	6.15	5.00	3.10	1175	977.1	5	0	0	18.59
22	22	5.35	6.94	6.08	4.55	1275	779.7	4	0	0	22.92
23	23	4.84	12.60	5.60	1.35	1250	1204.1	3	1	0	24.39
24	24	5.20	11.85	5.08	5.70	1225	929.7	4	1	0	27.83
25	25	5.81	7.27	7.20	2.30	1200	2217.6	2	0	0	22.58
26	26	4.23	6.45	5.97	3.34	1150	1542.5	4	0	0	21.99
27	27	5.84	15.35	4.73	4.00	1150	1129.2	3	1	0	29.92
28	28	6.10	9.75	5.70	2.35	1150	1820.0	3	1	0	23.90
29	29	3.82	12.20	4.64	4.13	1100	1506.2	4	0	0	24.79
30	30	4.45	11.00	5.31	5.21	1100	1940.2	3	1	0	25.97
31	31	4.10	10.40	4.30	2.00	1100	938.3	3	0	0	20.80
32	32	4.40	8.65	4.95	3.85	1100	951.9	4	0	0	21.85
33	33	4.75	8.95	4.85	2.47	1100	1058.2	4	1	0	21.02
34	34	4.82	11.40	4.89	3.40	1150	1639.1	4	0	0	24.51
35	35	4.43	10.05	5.76	4.37	1150	1105.7	4	0	0	24.61
36	36	4.25	6.30	4.65	4.32	1100	1131.0	4	0	0	19.52
37	37	4.85	6.80	5.80	4.10	1100	1476.9	4	0	0	21.55
38	38	4.92	6.36	3.72	4.50	1050	775.8	4	0	0	19.38
39	39	4.15	11.55	4.81	2.62	1050	1162.6	8	0	0	23.13
40	40	4.50	7.40	4.83	4.10	1050	773.0	4	0	0	20.83
41	41	4.80	6.05	4.60	1.90	1050	955.0	5	0	0	17.35
42	42	5.56	9.20	5.38	3.71	1050	1076.8	3	0	0	23.85
43	43	3.75	8.91	4.09	2.68	1050	855.0	5	0	0	19.33
44	44	4.07	9.28	4.40	3.00	1050	1043.4	4	0	0	20.75
45	45	4.02	7.25	3.98	5.08	1050	828.6	5	0	0	20.33
46	46	4.53	14.17	5.11	2.69	1100	1487.5	3	1	0	26.50
47	47	3.76	6.32	4.42	4.75	1050	559.5	4	0	0	19.25
48	48	4.30	6.05	4.04	3.79	1025	716.2	5	0	0	18.18
49	49	3.95	4.58	4.37	3.00	1025	1354.3	4	0	0	15.90
50	50	3.95	7.07	4.75	2.94	1025	1721.5	4	0	0	18.71

DATA TABLE FOR THE HOLDER AT ALECK MEADOWS

OBS	TURN	OUTHAUL (MIN)	GATHER (MIN)	INHAUL (min)	UNHOOK (min)	DISTANCE (Ft.)	WEIGHT (lbs)	LOGS	SLASH	TERRAIN	TOTTIME (min)
1	1	3.20	5.70	2.11	3.25	600	3202.4	6	0	1	14.26
2	2	2.00	6.07	2.02	4.25	600	5593.9	6	0	1	14.34
3	3	2.55	11.50	3.95	1.80	750	2994.0	3	0	1	19.80
4	4	1.40	1.80	1.30	1.30	480	1116.9	1	0	0	5.80
5	5	2.35	9.00	3.22	1.00	700	4425.8	6	0	1	15.57
6	6	2.15	9.72	2.94	3.55	650	4386.9	5	1	1	18.36
7	7	2.52	10.70	1.55	3.45	700	2572.3	4	1	1	18.22
8	8	2.75	10.60	2.82	2.12	750	3588.6	5	0	1	18.29
9	9	3.05	12.34	2.60	5.45	725	2888.2	5	1	1	23.44
10	10	1.95	11.07	2.45	4.20	800	3528.1	6	0	0	19.67
11	11	2.70	10.75	3.15	4.40	800	2331.9	6	0	0	21.00
12	12	3.25	8.22	2.90	3.90	800	2170.7	6	0	0	18.27
13	13	2.92	8.00	3.01	3.70	800	4100.9	6	0	0	17.63
14	14	3.17	6.90	3.10	3.50	850	2850.8	6	0	0	16.67
15	15	3.40	10.08	2.65	4.25	850	2775.6	6	0	0	20.38
16	16	2.91	11.04	2.65	4.01	800	3243.3	6	0	0	20.61
17	17	3.01	12.81	2.80	5.25	800	2599.2	5	1	0	23.87
18	18	3.25	12.95	2.90	6.00	800	3159.2	6	1	0	25.10
19	19	2.70	14.10	2.75	3.30	800	2870.8	5	0	1	22.85
20	20	3.13	12.67	2.50	3.00	800	2634.1	6	1	0	21.30
21	21	2.30	16.20	2.97	5.99	600	4431.3	6	1	0	27.46
22	22	3.02	10.00	2.44	5.03	650	2158.4	6	0	0	20.49
23	23	2.75	10.82	2.50	4.80	700	2873.5	6	0	0	20.87
24	24	2.90	12.27	2.53	4.57	700	3323.7	6	1	0	22.27
25	25	2.75	9.59	2.97	5.90	800	1906.5	6	0	0	21.21
26	26	2.35	9.75	2.55	4.25	700	3139.4	6	0	0	18.90
27	27	2.42	11.17	2.25	5.59	700	2033.4	7	0	0	21.43
28	28	2.07	8.85	2.25	4.00	425	1984.6	6	0	0	17.17
29	29	2.13	9.18	2.04	4.25	425	3104.5	6	0	0	17.60
30	30	2.10	12.80	2.60	3.80	450	5003.7	6	1	0	21.30
31	31	3.40	10.79	2.05	3.68	450	2458.5	6	0	0	19.92
32	32	2.10	9.15	1.58	4.98	350	2589.4	5	0	0	17.81
33	33	2.07	8.32	1.42	4.06	350	2663.8	6	0	0	15.87
34	34	1.77	8.47	2.78	4.30	350	1819.6	6	0	0	17.32
35	35	3.00	11.95	2.50	3.44	900	2355.3	7	0	1	20.99
36	36	1.90	8.90	1.52	5.40	300	4352.0	6	0	0	17.72
37	37	1.20	12.11	1.40	4.20	300	1440.7	5	1	0	18.91
38	38	1.32	14.04	1.42	6.50	300	3254.6	6	1	0	23.28
39	39	2.08	12.12	2.15	4.32	400	1596.4	7	1	0	20.67
40	40	1.92	9.73	1.71	4.45	400	2821.4	6	0	0	17.81
41	41	3.20	10.45	3.32	5.10	800	1593.3	6	0	0	22.07
42	42	2.59	8.95	2.85	4.25	700	715.4	3	1	1	18.64
43	43	1.90	10.28	2.01	4.80	550	3491.2	6	0	1	18.99
44	44	2.35	9.08	4.26	3.81	550	1510.2	7	0	1	19.50
45	45	2.10	11.70	1.95	2.00	500	1816.2	7	1	1	17.75

DATA FOR THE HOLDER AT CONTINENTAL ROAD

OBS	TURN	OUTHAUL (min)	GATHER (min)	INHAUL (min)	UNHOOK (min)	DISTANCE (Ft)	WEIGHT (lbs)	LOGS	SLASH	TERRAIN	TOTTIME (min)
1	1	4.30	9.10	4.25	4.30	1300	2228.2	5	0	1	21.95
2	2	6.14	2.47	3.54	3.00	1000	1571.5	5	0	1	15.15
3	3	5.20	7.87	3.57	3.50	1300	2962.0	4	0	1	20.14
4	4	5.80	5.75	5.75	3.29	1650	2568.9	4	0	0	20.59
5	5	6.45	8.00	5.67	3.14	1700	1865.1	5	0	0	23.26
6	6	6.75	10.00	6.48	3.82	1750	2430.4	6	0	0	27.05
7	7	6.55	10.85	5.45	4.57	1800	1598.7	6	1	0	27.42
8	8	6.68	6.30	6.88	3.04	1800	2670.9	5	0	0	22.90
9	9	6.65	9.00	5.10	6.25	1775	2108.4	7	0	0	27.00
10	10	7.30	10.10	6.57	4.35	1850	2695.6	6	0	0	28.32
11	11	6.10	8.00	5.85	3.65	1750	2008.2	5	0	0	23.60
12	12	6.24	10.76	5.52	6.57	1800	3592.2	6	1	0	29.39
13	13	6.30	10.85	7.40	3.50	1825	3064.0	5	1	0	28.05
14	14	6.35	10.10	6.02	3.60	1800	3030.5	5	0	0	26.07
15	15	6.35	10.25	6.92	6.12	1800	4066.1	6	0	0	29.64
16	16	6.70	11.88	7.53	5.85	1800	4050.8	6	1	0	31.96
17	17	7.55	15.50	7.48	6.67	1900	3016.7	5	1	0	37.20
18	18	7.10	14.45	5.98	6.25	1850	3408.2	6	1	0	33.78
19	19	5.83	11.70	5.10	4.25	1600	3441.2	5	0	0	26.88
20	20	5.75	12.62	6.30	5.72	1700	3490.7	6	1	0	30.39
21	21	6.15	11.17	5.85	4.60	1600	4222.2	6	0	0	27.77
22	22	5.90	8.05	5.85	4.45	1550	3650.7	6	0	0	24.25
23	23	5.17	15.40	6.20	7.00	1600	4298.0	6	0	0	33.77
24	24	6.20	8.46	6.00	6.20	1600	3540.5	6	0	0	26.66
25	25	5.72	11.65	6.20	3.20	1675	3201.7	6	0	0	26.77
26	26	5.95	6.49	6.35	4.48	1700	3434.5	6	0	0	23.27
27	27	6.90	13.00	7.12	6.38	1700	3822.1	6	0	0	33.40
28	28	5.70	7.15	6.35	3.50	1600	3934.3	6	0	0	22.70
29	29	4.50	11.00	4.65	3.20	900	4523.7	5	0	0	23.35
30	30	4.92	9.50	5.20	4.35	1600	3182.9	6	0	0	23.97
31	31	3.60	13.20	5.75	3.00	1400	3951.8	6	0	0	25.55
32	32	4.15	13.40	4.48	4.53	1400	4131.9	6	0	0	26.56
33	33	5.05	9.32	5.30	5.50	1450	2996.8	6	0	0	25.17
34	34	4.30	11.40	5.20	5.20	1450	2014.6	6	1	0	26.10
35	35	4.45	17.35	4.20	5.30	1450	1835.2	5	1	0	31.30
36	36	4.20	9.90	3.55	4.60	1450	2014.7	5	0	0	22.25
37	37	3.60	10.60	3.95	2.60	1450	1535.0	3	0	0	20.75
38	38	3.50	12.31	3.35	4.20	1450	2007.0	6	0	0	23.36
39	39	4.45	14.13	5.87	5.00	1650	4711.0	6	1	0	29.45
40	40	4.65	9.90	4.87	5.05	1600	2263.4	6	0	0	24.47
41	41	4.90	11.40	5.65	5.00	1600	4886.7	6	0	0	26.95
42	42	5.35	8.10	5.44	4.65	1650	2859.7	5	0	0	23.54
43	43	7.50	17.10	7.75	5.75	1750	5016.3	6	1	0	38.10
44	44	8.01	9.75	7.21	3.50	1800	2768.6	5	0	0	28.47
45	45	7.00	10.45	6.95	5.25	1750	4600.7	6	0	0	29.65
46	46	6.41	13.48	6.27	2.70	1700	2785.0	4	0	0	28.86
47	47	6.66	10.75	6.48	3.94	1800	1920.8	5	1	0	27.83
48	49	7.40	18.35	7.47	5.42	1900	2768.0	9	1	0	38.64
49	48	5.00	10.00	5.34	3.07	1650	2715.8	5	0	0	23.41

DATA TABLE FOR THE FOREST ANT AT ALECK MEADOWS AND BUGS BUNNY

OBS	TURN	OUTHAUL (min)	GATHER (min)	INHAUL (min)	UNHOOK (min)	DISTANCE (Ft)	WEIGHT (lbs)	LOGS	AREA	TOTTIME
1	1	2.00	20.25	1.10	1.47	125	3459.5	8	1	24.62
2	2	5.05	17.50	4.00	1.40	300	3853.1	7	1	27.95
3	3	2.00	17.79	1.50	0.40	200	2105.2	6	1	21.59
4	4	3.50	16.25	5.25	0.80	450	3699.5	10	1	25.55
5	5	2.70	18.90	3.70	0.50	350	1191.3	2	1	25.80
6	6	1.90	15.80	2.30	0.70	325	1569.5	5	1	20.70
7	7	4.20	11.05	3.30	0.95	375	2199.7	5	1	19.50
8	8	3.90	16.40	2.77	1.10	400	3035.4	10	1	24.17
9	9	4.30	18.27	1.70	3.00	350	3848.8	10	1	27.27
10	10	1.55	10.90	1.75	1.00	150	761.5	4	1	15.20
11	11	2.50	15.55	2.00	2.30	200	1987.1	4	1	22.35
12	12	2.43	5.10	2.00	0.85	200	1168.3	5	1	10.38
13	13	1.95	5.60	1.70	0.20	150	552.1	4	1	9.45
14	14	1.75	12.85	1.62	0.45	200	1411.5	8	0	16.67
15	15	2.05	7.20	2.65	1.10	250	2457.0	7	0	13.00
16	16	2.00	15.45	2.07	1.20	250	2375.4	9	0	20.72
17	17	1.60	17.60	1.90	0.80	200	2535.7	10	0	21.90
18	18	2.10	9.05	1.50	0.61	200	1904.9	9	0	13.26
19	19	1.83	14.88	1.10	1.10	200	1264.2	7	0	18.91
20	20	1.80	15.62	1.70	0.92	250	3170.5	10	0	20.04
21	21	1.75	12.65	1.10	0.70	250	1038.0	8	0	16.20
22	22	4.90	14.20	2.08	0.65	300	1776.0	7	0	21.83
23	23	1.40	9.00	1.50	0.93	300	1332.5	7	0	12.83
24	24	2.55	11.30	2.30	0.45	300	1395.1	8	0	16.70
25	25	2.80	8.54	1.91	0.91	350	1694.6	5	0	14.16
26	26	2.27	12.35	1.25	0.80	300	1114.5	6	0	16.67
27	27	2.30	6.50	2.25	0.57	225	1956.8	6	0	11.62
28	28	1.65	13.60	0.70	0.55	100	1871.9	6	0	16.50
29	29	1.40	16.90	1.03	1.80	150	1616.6	7	0	21.13
30	30	1.85	17.93	0.75	0.65	200	1504.2	13	0	21.18

DATA FOR THE PASQUALI AT CONTINENTAL ROAD

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V.
OUTHAUL	50	5.02920000	1.04082942	3.37000000	7.6000000	0.14719551	251.460000	1.08333	20.696
GATHER	50	8.63280000	2.48284485	4.58000000	15.3500000	0.35112729	431.640000	6.16452	28.761
INHAUL	50	5.56900000	1.32180497	3.72000000	10.1800000	0.18693145	278.450000	1.74717	23.735
UNHOOK	50	3.30920000	1.41716959	1.10000000	8.2000000	0.20041810	165.460000	2.00837	42.825
DISTANCE	50	1160.00000000	135.90212565	950.00000000	1450.0000000	19.21946292	58000.000000	18469.38776	11.716
WEIGHT	50	1163.65200000	356.46941892	559.50000000	2217.6000000	50.41238868	58182.600000	127070.44663	30.634
LOGS	50	3.88000000	0.96129165	2.00000000	8.0000000	0.13594717	194.000000	0.92408	24.776
TOTTIME	50	22.54020000	3.60455126	15.90000000	30.6600000	0.50976053	1127.010000	12.99279	15.992

DATA TABLE FOR THE FOREST ANT AT ALECK MEADOWS AND BUGS BUNNY

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V.
OUTHAUL	30	2.47266667	1.03235230	1.40000000	5.0500000	0.18848085	74.180000	1.06575	41.751
GATHER	30	13.49766667	4.24325890	5.10000000	20.2500000	0.77470954	404.930000	18.00525	31.437
INHAUL	30	2.01600000	0.99714973	0.70000000	5.2500000	0.18205380	60.480000	0.99431	49.462
UNHOOK	30	0.96200000	0.57898484	0.20000000	3.0000000	0.10570769	28.860000	0.33522	60.186
DISTANCE	30	253.33333333	86.03661343	100.00000000	450.0000000	15.70806465	7600.000000	7402.29885	33.962
WEIGHT	30	1998.68666667	906.44755511	662.10000000	3853.1000000	165.49392438	59960.600000	821647.17016	45.352
LOGS	30	7.10000000	2.38313037	2.00000000	13.0000000	0.43509809	213.000000	5.67931	33.565
TOTTIME	30	18.94833333	5.08081319	9.45000000	27.9500000	0.92762533	568.450000	25.81466	26.814

DATA TABLE FOR THE HOLDER AT ALECK MEADOWS

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V.
OUTHAUL	45	2.49000000	0.56940958	1.20000000	3.4000000	0.08488257	112.05000	0.3242	22.868
GATHER	45	10.28200000	2.45433068	1.80000000	16.2000000	0.36587002	462.69000	6.0237	23.870
INHAUL	45	2.47533333	0.65356922	1.30000000	4.2600000	0.09742835	111.39000	0.4272	26.403
UNHOOK	45	4.11444444	1.19881676	1.00000000	6.5000000	0.17870905	185.15000	1.4372	29.137
DISTANCE	45	626.77777778	180.37258017	300.00000000	900.0000000	26.88835670	28205.00000	32534.2677	28.778
WEIGHT	45	2832.68000000	1028.03274789	715.40000000	5593.9000000	153.25007382	127470.60000	1056851.3307	36.292
LOGS	45	5.66666667	1.10782342	1.00000000	7.0000000	0.16514456	255.00000	1.2273	19.550
TOTTIME	45	19.36177778	3.39574553	5.80000000	27.4600000	0.50620786	871.28000	11.5311	17.538

DATA FOR THE PASQUALI AT ALECK MEADOWS

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V.
OUTHAUL	65	2.69000000	1.07991319	0.85000000	5.3000000	0.13394675	174.850000	1.16621	40.145
GATHER	65	9.57707692	3.71490273	0.64000000	21.7500000	0.46077697	622.510000	13.80050	38.790
INHAUL	65	2.67292308	0.98361216	0.59000000	5.1700000	0.12200207	173.740000	0.96749	36.799
UNHOOK	65	1.70692308	0.63665857	0.43000000	3.7000000	0.07896778	110.950000	0.40533	37.299
DISTANCE	65	402.30769231	132.56212259	125.00000000	675.0000000	16.44230769	26150.000000	17572.71635	32.950
WEIGHT	65	1402.70307692	432.83184775	589.90000000	2513.0000000	53.68618336	91175.700000	187343.40843	30.857
LOGS	65	3.93846154	0.94994939	1.00000000	7.0000000	0.11782672	256.000000	0.90240	24.120
TOTTIME	65	16.64692308	4.11368141	5.38000000	29.5000000	0.51023938	1082.050000	16.92237	24.711

DATA FOR THE HOLDER AT CONTINENTAL ROAD

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V.
OUTHAUL	49	5.78326531	1.13673763	3.5000000	8.0100000	0.16239109	283.38000	1.29217	19.656
GATHER	49	10.78183673	3.05529232	2.4700000	18.3500000	0.43647033	528.31000	9.33481	28.337
INHAUL	49	5.75938776	1.13103273	3.3500000	7.7500000	0.16157610	282.21000	1.27924	19.638
UNHOOK	49	4.55224490	1.19300088	2.6000000	7.0000000	0.17042870	223.06000	1.42325	26.207
DISTANCE	49	1625.00000000	208.10404049	900.0000000	1900.0000000	29.72914864	79625.00000	43307.29167	12.806
WEIGHT	49	3091.05918367	945.31095654	1535.0000000	5016.3000000	135.04442236	151461.90000	893612.80455	30.582
LOGS	49	5.57142857	0.88975652	3.0000000	9.0000000	0.12710807	273.00000	0.79167	15.970
TOTTIME	49	26.87673469	4.69057672	15.1500000	38.6400000	0.67008239	1316.96000	22.00151	17.452

APPENDIX E

DELAY ANALYSIS

Table 1. Productive and non-productive delay times for the Pasquali.

	Aleck Meadows	
Operational Delay	Total Time (Mins.)	Percent of Total Delay
Dropped log	13.64	2.3
Hung-up tree	21.23	3.7
Swamped - stuck	32.56	5.6
Non-scheduled waiting (work-rel.)	13.57	2.3
Miscellaneous	42.98	7.4
	123.98	21.60%
Non-Productive Delay		
Scheduled maintenance	30.00	5.2
Rest	10.72	1.8
Personal	59.83	10.4
Machine Repair Time	263.47	45.9
Miscellaneous	86.07	14.9
	450.09	78.4%
Total Delay	574.07	100.0%

Table 1. Cont.

	Continental Road	
Operational Delay	Total Time (Mins.)	Percent of Total Delay
Dropped log	54.88	8.6
Hung-up tree	20.82	3.2
Swamped - stuck	82.07	12.9
Non-scheduled waiting (work-rel.)	1.62	.2
Miscellaneous	28.70	4.5
	188.09	29.6%
Non-Productive Delay		
Scheduled maintenance	15.00	2.3
Rest	19.30	3.3
Personal	21.64	3.4
Machine Repair Time	342.92	54.0
Miscellaneous	48.05	7.5
	446.91	70.4
Total Delay	635.00	100.0

Table 2. Productive and non-productive delay times for the Holder.

	Aleck Meadows	
Operational Delay	Total Time (Mins.)	Percent of Total Delay
Dropped log	2.74	.9
Hung-up tree	37.62	12.5
Swamped - stuck	34.60	11.5
Non-scheduled waiting (work-rel.)	.25	.8
Miscellaneous	66.77	22.2
	141.98	47.2%
Non-productive Delay		
Scheduled maintenance	60.00	19.9
Rest	3.22	1.0
Personal	26.09	8.6
Machine Repair Time	64.00	21.3
Miscellaneous	4.95	1.6
	158.26	52.7%
Total Delay	300.24	100.0%

Table 2 Cont.

	Continental Road	
Operational Delay	Total Time (Mins.)	Percent of Total Delay
Dropped log	28.30	4.5
Hung-up tree	83.19	13.4
Swamped - stuck	22.72	3.6
Non-scheduled waiting (work-rel.)	.67	.1
Miscellaneous	92.45	14.9
	227.33	36.6%
Non-productive Delay		
Scheduled maintenance	10.00	1.6
Rest	2.05	.3
Personal	54.97	9.6
Machine Repair Time	321.00	51.7
Miscellaneous	--	--
	393.02	63.3%
Total Delay	620.35	100.0%

Table 3. Productive vs. non-productive delay times for the Forest Ant.

	Aleck Meadows/Bugs Bunny	
	Total Time (Mins.)	Percent of Total Delay
Operational Delay		
Dropped log	13.62	3.9
Hung-up tree	.50	.1
Swamped - stuck	26.28	7.5
Non-scheduled waiting (work-rel.)	43.03	12.3
Miscellaneous	20.52	11.7
	103.95	35.7
Non-productive delay		
Scheduled maintenance	30.00	8.6
Rest	13.00	3.7
Personal	33.94	9.7
Machine Repair Time	113.83	32.7
Miscellaneous	52.92	9.3
	243.69	64.2%
Total Delay	347.64	100.0%

Table 4. Analysis of delay time in minutes for the Pasquali at Aleck Meadows.

Machine: Pasquali

Area: Aleck Meadows

Average Operation Delay Per Function

Delay Type	Function: Outhaul	Gather	Inhaul	Unhook	Deck	Total Avg. Delay Time Per Turn = 1.90 mins.
Dropped log	--	--	.2098	--	--	
Hung-up tree	--	.2302	.0686	.0278	--	
Stuck	.0032	.0309	.4594	--	--	
Work Rel. Wait	.0903	.0878	.0100	--	--	
Miscellaneous	.2965	.3411	.0346	.0126	--	
Totals	.3900	.6900	.7824	.0404	--	

Operational Delay As a % of Average total Turn Time Per Function

Delay Type	Function: Outhaul	Gather	Inhaul	Unhook	Deck	Operational Delay = 10% Total Turn Time
Dropped log	--	--	6.08	--	--	
Hung-up tree	--	2.24	1.99	1.57	--	
Stuck	.10	.30	13.31	--	--	
Work Rel. Work	2.93	.86	.29	--	--	
Miscellaneous	9.63	3.32	1.00	.71	--	
Total Percent	12.65%	6.72%	22.68%	2.28%	0%	

Non-Productive Delay Time As Average Time Per Function

Delay Type	Function: Outhaul	Gather	Inhaul	Unhook	Deck	Non-Op. Delay = 6.44 mins/ turn
Non-work rel. wait	--	--	--	--	--	
Rest	--	--	--	--	.1649	
Personal	.0234	.0280	.1048	--	.7643	
Machine Repair Time	--	--	--	--	4.0534	
Miscellaneous	.0183	.2472	--	--	1.0351	
Total	.0417	.2752	.1048	0	6.0177	

Scheduled Delay Time

Delay Type	
Maintenance of Machine	30 mins. time

Table 5. Analysis of The Delay time in minutes for the Pasquali at Continental Road.

Average Operating Delay Time Per Function

Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck	
	Function					
Dropped log		.2980	.7996			Total Avg. Delay/Turn = 3.756 mins.
Hung-up tree	--	.4164	--	--	--	
Stuck	--	.0040	1.6314	.0060	--	
Work Rel. Wait	.0164	--	--	.0160	--	
Miscellaneous	.1936	.1116	.239	.0240		
Totals	.2100	.8300	2.670	.0460	0	

Operational Delay As A % of Average Total Turn Time Per Function

Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck	
	Function					
Dropped log	--	3.15	9.70	--	--	14.2% of Total Turn Time 26.45 is Op. Delay
Hung-up tree	--	4.40	--	--	--	
Stuck	--	.04	19.80	.18	--	
Work Rel. Work	.31	--	--	.48	--	
Miscellaneous	3.69	1.18	2.90	.71	--	
Total Percent	4.00%	8.77%	32.4%	1.36%	0	

Non-productive Delay As An Average Time Per Function

Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck	
	Function					
Non-work rel. wait	--	--	--	--	--	Total Non-Op. delay/turn = 8.644 mins/turn
Rest	--	--	--	--	.3860	
Personal	.0140	--	.1966	--	.2222	
Machine Repair Time	.0124	.2240	--	--	6.6220	
Miscellaneous	.0258	.6286	.0428	--	.2696	
Total	.0522	.8526	.2394	--	7.4998	

Scheduled Delay Time

Delay Type	Total Time
Machine maintenance	15 mins.

Table 6. Analysis of delay time in Minutes for the Holder at Aleck Meadows.

Average Operating Delay Time Per Functon

Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck	
	Function					
Dropped log	--	.0222	.0387	--	--	Total Ave.
Hung-up tree	--	.8360	--	--	--	Delay Time/
Stuck	--	--	.7689	--	--	Turn =
Work Rel. Wait	--	--	--	.0056	--	3.15
Miscellaneous	.2442	.6111	.1349	.3089	.18	
Totals	.2442	1.4693	.9424	.3145	.18	

Operational Delay As A % of Average Total Turn Time Per Function

Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck	
	Function					
Dropped log	--	.19	1.13	--	--	16% of Total Turn
Hung-up tree		7.11	--	--	--	Time is
Stuck	--	22.48	--	--	--	Operational
Work Rel. Work	--	--	--	.13	--	Delay
Miscellaneous	8.95	5.20	3.94	6.97	.18	
Total Percent	8.95%	12.5%	27.56%	7.09%	36%	

Non-productive Delay As An Average Time Per Function

Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck	
	Function					
Non-work rel. wait	--	--	--	--	--	Total Avg.
Rest	--	--	--	--	.0716	Non-Op. Delay Turn
Personal	.1033	.2216	--	--	.2549	= 2.19 min.
Machine Repair Time	--	--	--	--	1.4200	
Miscellaneous	--	--	--	--	.1147	
Total	.1033	.2216	0	0	1.8612	

Scheduled Delay Time

Delay Type	Total Time
Machine maintenance	60.00 mins.

Table 7. Analysis of delay time in minutes for the Holder at Continental Road.

Average Operating Delay Time Per Functon

Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck	
			Function			
Dropped log	--	--	.5776	--	--	4.64 mins.
Hung-up tree	--	1.6631	.0347	--	--	op. delay/
Stuck	.0214	--	.4422	--	--	turn.
Work Rel. Wait		--	.0137			
Miscellaneous	.7412	1.0373	.0378	--	.0704	
Totals	.7626	2.7004	1.1060	0	.0704	

Operational Delay As A % of Average Total Turn Time Per Function

Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck	
			Function			
Dropped log	--	--	8.41	--	--	15% of
Hung-up tree	--	12.34	.51	--	--	total turn
Stuck	.33	--	6.44	--	--	time is
Work Rel. Work	--	--	.20	--	--	op. delay.
Miscellaneous	11.33	7.70	.55	--	25.92	
Total Percent	11.66%	20.03%	16.10%	0	25.92%	

Non-productive Delay As An Average Time Per Function

Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck	
			Function			
Non-work rel. wait	--	--	--	--	--	Total avg.
Rest	.0041	.0378	--	--	--	non-op.
Personal	.5594	.2973	.0255	--	.3416	delay/turn
Machine Repair Time	.8082	.0102	.1531	--	5.5790	= 7.82
Miscellaneous	--	--	--	--	--	
Total	1.3717	.3453	.1786	0	5.9206	

Scheduled Delay Time

Delay Type	Total Time
Machine maintenance	10.00 mins.

Table 8. Analysis of delay time in minutes for the Forest Ant at Aleck Meadows and Bugs Bunny.

Average Operating Delay Time Per Functon

	Function				
Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck
Dropped log	--	0.0317	.4233	--	--
Hung-up tree	--	0.0167	--	--	--
Stuck	0.0117	0.0256	.6083	--	--
Work Rel. Wait	--	--	1.1100	--	--
Miscellaneous	0.0693	0.5983	--	0.0175	--
Totals	0.0810	0.9027	2.0416	0.0173	0.000

Total Delay/Turn = 3.4669 mins.

Operational Delay As A % of Average Total Turn Time Per Function

	Function				
Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck
Dropped log	--	.22	9.43	--	--
Hung-up tree	--	.12	--	--	--
Stuck	.46	1.78	13.55	--	--
Work Rel. Work	--	--	24.72	--	--
Miscellaneous	2.72	4.15	7.72	1.76	--
Total Percent	3.18%	6.27%	54.92%	1.76%	0.000

Total delay is 15.5% of 22.42 mins.

Non-productive Delay As An Average Time Per Function

	Function				
Delay Type	Outhaul	Gather	Inhaul	Unhook	Deck
Non-work rel. wait	--	--	.3243	--	--
Rest	--	.0067	--	--	.4267
Personal	.5400	.2380	--	--	.3533
Machine Repair Time	--	.6050	.7433	--	2.4500
Miscellaneous	--	--	--	--	1.7640
Total	.5400	.8497	.7433	.0000	4.9940

Sum total = 7.13 min/ turn

Scheduled Delay Time

Delay Type	Total Time
Machine maintenance	30 mins.

VITA

Name: Anthony P. Quadro

Date and Place of birth: November 28, 1956
Wilkes-Barre, Pennsylvania

Education:

Name and Location	Dates	Degree
Wyoming Area High School West Pittston, PA	1970-1974	
The Pennsylvania State University	1974-1978	B.S. Forest Science
State University of New York College of Environmental Science and Forestry Syracuse, NY	1980-1982	M.S. Silviculture and Forest Influences

Employment:

Employer	Dates	Position
Research Foundation State University of New York College of Environmental Science and Forestry	1981 - present	Graduate Research Assistant
State University of New York College of Environmental Science and Forestry	1980 - 1981	Teaching Assistant
Pennsylvania Gas and Water Co. Wilkes-Barre, PA	1978 - 1980	Forester