EVALUATION OF PRODUCTIVITY AND COST OF CHAIN SAW VS MANUAL TOOLS IN THE CHIR PINE FORESTS OF PAKISTAN

BY

ASIF KAMAL SIDDIQUI

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Prof. Eldon D. Olsen

To improve the present state of Forestry and the condition of forest workers is an important goal to be achieved in developing countries. With the growth of population, demand for wood products is increasing tremendously. Prices have gone up manyfold. One way to meet this demand is to increase productivity by reducing the wastage of wood and by saving time on various operations. The present tools and equipment are no longer adequate to achieve this goal so we should introduce new machines in timber harvesting. Chain saws, the first step toward mechanization, was introduced successfully, about 40 years ago in Europe and Northern America. This study indicates that chain saws can be used effectively in the hilly forests of Pakistan. Productivity is increased 92 % and 29 % compared to manual tools, based on its effective time and total time respectively. The cost of the output of one cubic meter of wood with a chain saw is decreased 35 % considering its effective time but for its total time, cost is

increased 6 % over the manual tools. This increase in cost may be reduced considerably by reducing the high delay times through better planning and crew vocational training.

APPROVED :

Eldon D. Olsen

ASSOCIATE PROFESSOR OF FOREST ENGINEERING
IN CHARGE OF MAJOR

William A. Atkinson

HEAD OF THE DEPARTMENT OF FOREST ENGINEERING

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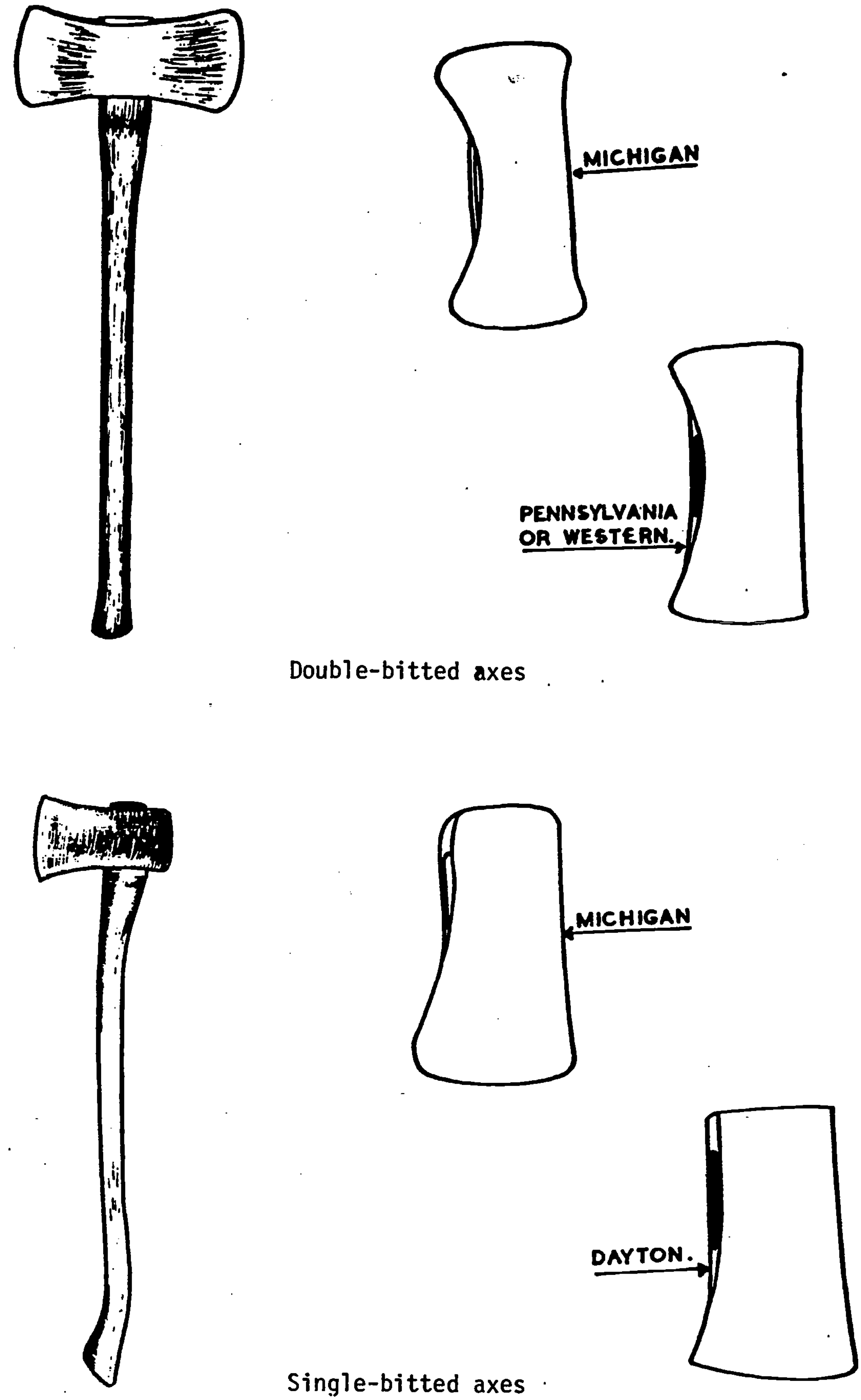
1. INTRODUCTION

Tree felling must be one of the very old activities of the human race. Perhaps it started in the prehistoric periods of civilization when man lived in caves. Man of that time must have been using some crude type of tools, made out of stone, for the felling of trees. With the passage of time and due to the developments in every field of life, the tools and equipment used in timber harvesting have changed and improved. While thinking about tree felling the very first tool which strikes a human mind is "Axe", which is still being used in the developing countries as the main tool for felling and conversion. The second useful tool is a cross-cut-saw which is also used side by side with axe. In the mid thirties, these tools were replaced by the chain saw in Europe and the United States. Now even more sophisticated machines like hydraulic shears and feller-bunchers are used for timber harvesting. But the axe is still there as a helping tool. The following is the summary of the evolution of harvesting technology in the United States. (Encyclopedia of American Forest Conservation History, 1983)

- **Before 1789** : Colonists harvested America's forests using tools and methods which they brought with them from Europe. Perhaps at the same time or a little earlier British colonists arrived in Indo-Pak Sub-continent and they must have brought with them the same type of tools. (The concept of Axe was already there which one can observe from the early history of the Potowar Plateau.)

- **1789** : First American single-bitted, heavy and balanced felling axe evolved to fell the large and heavy trees. (Fig. 1 & 2)
- **1816** : American axe was copied in England and soon it was used in most parts of the world.
- **1850 & before:** Use of double-bitted axe, on major scale in Pennsylvania, was started. (Fig. 1 & 2)
- **1863** : Thirteen different type of axes were in use and curved handle became standard.
- **1870** : Cross-cut-saw, which was used earlier only for bucking, was adopted for felling of trees; included racker teeth and use of tempered steel.
- **1880s** : The use of two-man cross-cut-saw became common on the Pacific Coast. It could save two thirds of the time of felling. (Fig. 3)
- **1890s** : Cross-cut-saws were manufactured having different number of rackers and cutters depending upon the type of wood. Saw become the main felling tool.
- **1870 -1905** : In the search of mechanical power saw, the first Ransom Steam Tree Feller appeared in 1870 and a gasoline-powered saw appeared in 1905, in Eureka, California.



Double-bitted axes

Single-bitted axes

FIG. 1. TYPE OF AXES

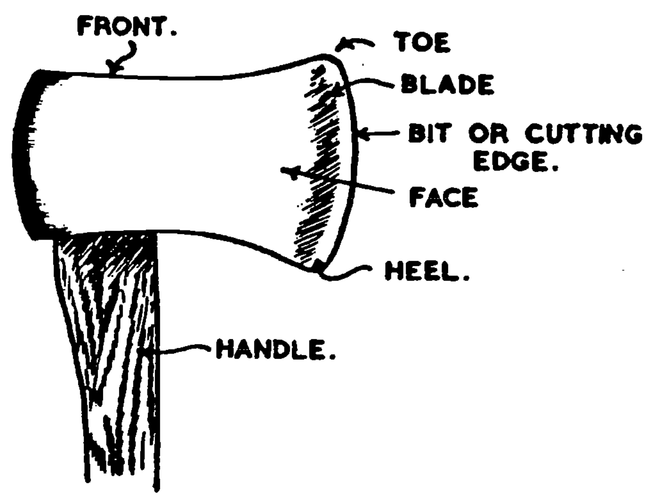
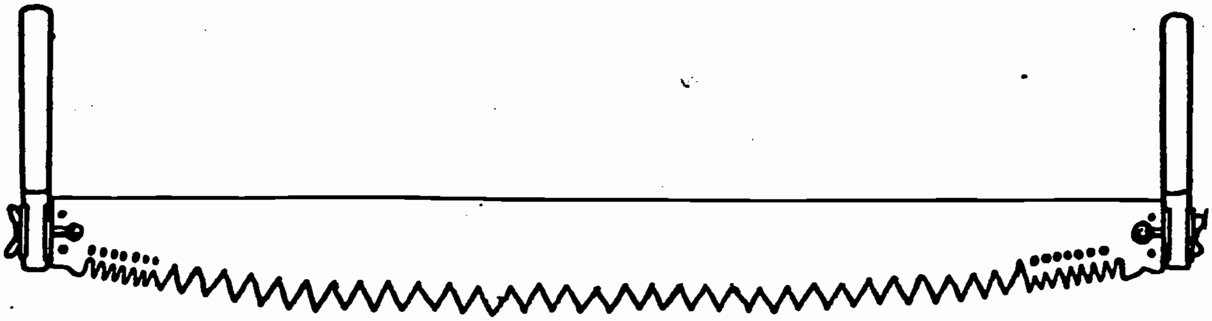


FIG. 2. Nomenclature of Axe

- 1920s	:	Bucksaw evolved which was lighter and comparatively better working tool for pulp wood only.
- 1927	:	The great break through had come. Andreas Stihl of Stuttgart, Germany built the first portable gasoline-powered chain saw.
- 1930	:	The first American gasoline-powered chain saw, on large scale was built by Eastman Gardiner Company of Laurel, Mississippi.
- 1940	:	Hydraulic shears with one blade were built.
- 1947	:	An improved chipper saw chain was produced by a former logger named Joe Cux, of Portland, Oregon.
- 1960	:	A variety of single and double-bladed hydraulic shears were in use. Which were followed by the different type of Feller-bunchers

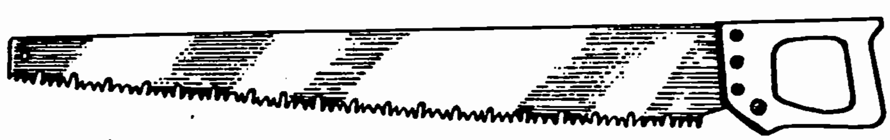
Forest work is one of the most strenuous jobs which requires strength, skill and stamina of the worker. Besides workers capabilities there are some other factors which effect the output of the workers like climate, tools, terrain and species.

In all developing countries the present state of forest work is poor. On one hand the wages of the workers are low and on the other hand they have to work with old and primitive tools without any insurance against accidents and vocational training. Consequently the result is a very low productivity, high wastage of



Two-man Peg-toothed
Cross-cut-Saw

Two-man Racker-toothed
Cross-cut-Saw



One-man Cross-cut-Saw

FIG. 3. Type of Cross-cut-Saws

valuable timber and a low socio-economic status of the forest workers. This all indicates an urgent need of research and studies for the improvement of present condition. With the introduction of improved tools and better timber harvesting methods the productivity will increase which would also effect the socio-economic condition of forest workers. The present study has been carried out in the Chir pine (Pinus roxburghii) hilly forest area of North West Frontier Province of Pakistan. This will be the first attempt of its kind to compare the productivity and cost of timber harvesting with conventional tools and chain saw in these coniferous forests.

1.1 The Country

Pakistan lies outside the main Himalayan range, in the sub-tropical area between 24° and 37° North latitude and 61° and 75° East longitude. The southern part of the country is mostly sandy while the central plains are alluvial and sub-himalayan plateau. The northern part comprises of the chain of high Himalayan mountains. The second highest peak of the world known as K-2 lies in the Karakuram range. Most of the mountain peaks are more then 7,000 meters (23,000 ft.) high. The area above 5,000 meters (16,400 ft.) remain permanently covered with snow. The tree growth occurs between the altitude of 500 to 3,300 meters (1,600 to 10,800 ft.), on the ridges and slopes. The terrain in temperate forests is mostly steep and make difficult situations for harvesting operations. On the other hand, in sub-tropical chir pine forests the terrain is comparatively less steep but occasional occurrences

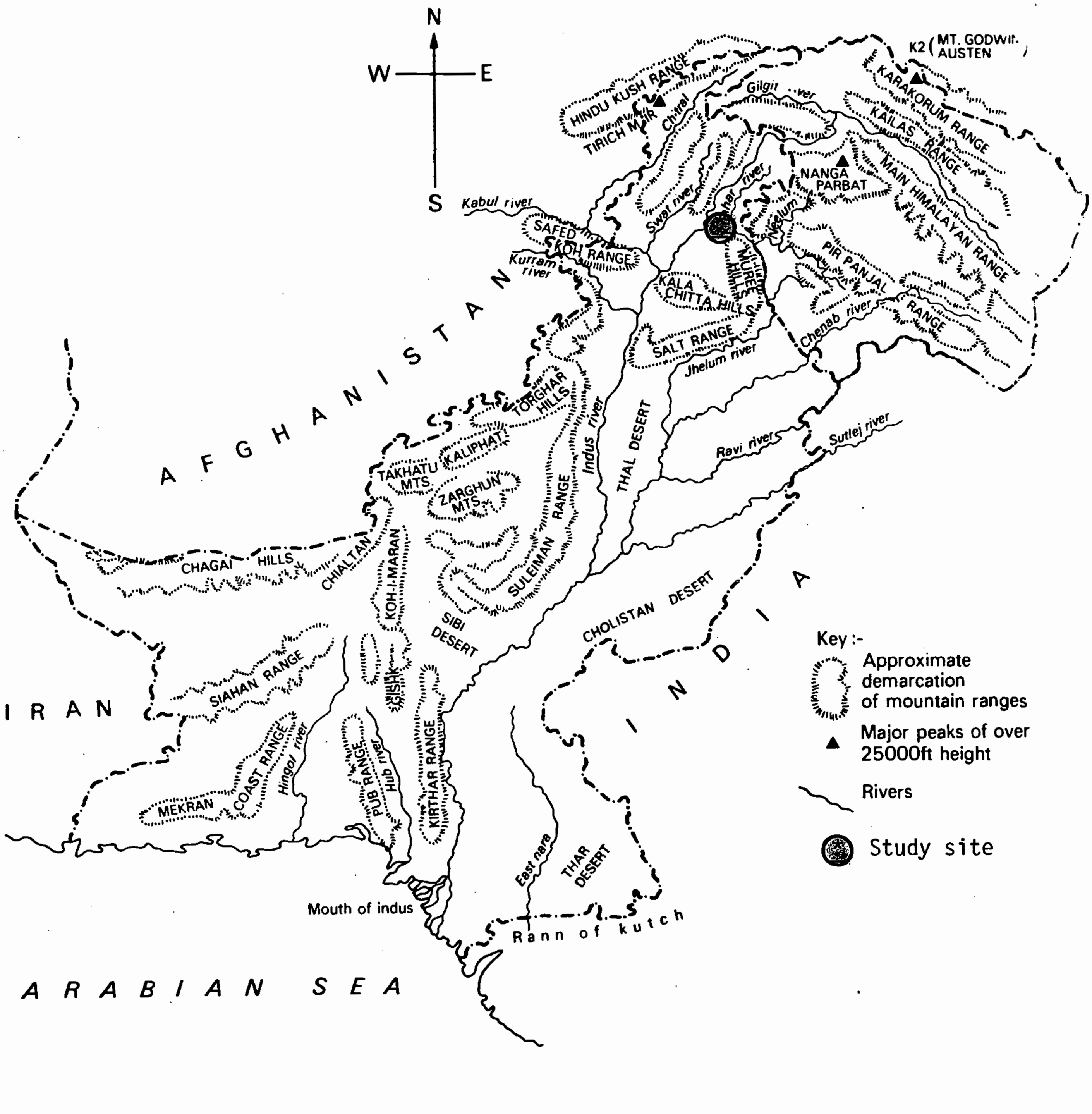


FIG. 4. Map of Pakistan showing main rivers and mountain ranges

of steep and rugged ground and abrupt falls are also common. The table below shows the general terrain classification of temperate forests of Paryai in Hazara District.

TABLE - 1

TERRAIN CLASSIFICATION OF TEMPERATE FOREST OF PARYAI

SLOPE CLASS %	AREA UNDER DIFFERENT CLASSES (ha)	%
0 - 25	9.7	1.8
26 - 40	6.5	1.2
41 - 60	3.7	0.7
61 & ABOVE	530.5	96.3

(Source : Anwar, K. 1985. cited by Siddiqui, K.M. 1987)

1.2 Climate

The variable topography of the country effects the climate considerably. Summers are hot and dry in the south but the duration of winters is short and mild. In the central part of the country, the summers are extremely hot with maximum temperature up to 50° C in the month of June, while the winters are cold and chilly. In the northern and north western part of the country summers are pleasant but the winters are very cold and freezing.

1.3 Land use

Basically Pakistan is an agricultural country with 22.9 % of its land area under agriculture. The total contribution of the Agriculture sector towards the national GNP is 22 %. Country is divided into the following six administrative zones.

TABLE - 2

ADMINISTRATIVE DIVISION OF THE COUNTRY

PROVINCE/ TERRITORY	CAPITAL OF PROVINCE/ TERRITORY	TOTAL LAND AREA (million ha)
Punjab	Lahore	20.63
N.W.F.P.	Peshawar	10.17
Sind	Karachi	14.09
Baluchistan	Quetta	34.72
Northern Areas	Under Federal Govt.	7.04
Azad Kashmir	Muzaffarabad	1.33
Total : -		87.98

(Source: Amjad, M. 1987)

1.4 Population

Pakistan is one of the most populous countries of the world. According to the population census report of 1981, the country's total population,including the state of Azad Kashmir is estimated at **86.8** million. The population density at that time was 106 persons per square kilometer. The proportion of urban and rural population is 28 and 72 % respectively. The current growth rate of population is estimated at 3 % per annum. With this growth rate the present (1990) estimated population is **110.23** million. The following table shows the distribution of population in the different provinces of Pakistan.

TABLE - 3

PROJECTED POPULATION OF PAKISTAN. 1990

PROVINCE/ TERRITORY	POPULATION 1981 (million)	PROJECTED POPULATION 1990 (millions)
Punjab	47.63	60.49
N.W.F.P.	13.26	16.84
Sind	19.03	24.17
Bluchistan	4.33	5.50
Northern Areas	0.56	0.71
Azad Kashmir	1.98	2.52
Total :-	86.79	110.23

The literacy rate in Pakistan is 26.2 percent, which is extremely low and hence one of the major cause of backwardness and slow progress. The average per capita income in Pakistan, according to 1986-87 survey, was Rs. 5,783.00 (US $ 263.00). The average number of members per household is 6.

2 FORESTS AND FORESTRY IN PAKISTAN

2.1 History

Forest & Forestry in Pakistan have a very old history. The northern forest areas of Pakistan are on the route of the invasions and migrations that took place during a period of thousands of years. The destruction of forests was due to the increasing pressure of settlers and also due to their livestock. The management of these forests, for the first time was started about 120 years ago. The main emphasis was conservation but during world war I and II, the whole system was again disturbed and destruction was quite high. In 1947, at the time of independence of Pakistan, these forests were already exploited to their maximum. The main objective of management, over the years have been exploitation of productive forests to meet the needs of the people for timber and fuel-wood and protection of watersheds for sustained supply of water. To achieve these objectives, the selection system has been practiced in the temperate forests and the shelterwood system in the sub-tropical chir pine forests with long rotation periods of more then 120 years. In the past, the forest department was only dealing with silviculture and protection and the exploitation was done by the contractors. The standing trees in the forest were sold to the contractors on unit volume basis, by the forest department and they were allowed to fell, extract and sell timber in the market. Due to the high demand of timber and shortage in supply, timber prices increased considerably and illicit felling of trees became the common practice on a large scale. Moreover those private contractors were only interested in their big profits and they never thought of improving the harvesting techniques or the development of the forest. This practice was continued up to 1973-74 and forests suffered great losses due to excessive cutting by the contractors and also by the local population living near by. This system was abolished in 1973-74 and the provincial forest department took charge; but due to the untrained staff and almost no experience of commercial exploitation and extraction the productivity was extremely poor. In 1977-78, a semi-autonomous provincial organization named as "N.W.F.P. Forest Development Corporation" was formed for the harvesting, extraction and marketing of timber from the forests of N.W.F.P. In the same way "Azad Kashmir Logging and Sawmilling Corporation" was assigned for the forest operations in the State of Azad Kashmir and the provincial forest departments of Punjab and Sind were given the responsibility to perform the timber harvesting. In sub-tropical chir pine forests, harvesting operations continued throughout the year except the two months of fire season (15th May to 15 July) and in temperate forest the work stops due to heavy snow in the months of December to March. In the irrigated plantations of Punjab and Sind harvesting operations are performed in the months of August to February and planting is done in the rest of the months of the year.

2.2 Forest Area

Pakistan is not a forest rich country. Land area under forest is only 4.74 million ha, which is 5.4 % of the total area of the country. The main reason for this meager forest area is, that 70 - 80 % land of the country is in arid or semi-arid zones where the amount of rainfall is too low to support extensive forest growth. The following table show the forest lands areas of other regional countries.

TABLE - 4

FOREST AREAS OF REGIONAL COUNTRIES

COUNTRY NAME	FOREST AREA, PERCENT OF TOTAL LAND AREA
Bangladesh	15.3 %
China	17.7 %
India	23.7 %
Malaysia	64.5 %
Sri Lanka	42.4 %

(Source: Amjad, M. 1987)

2.3 Forest Type of Pakistan

2.3.1 Coniferous Forests

The hilly forests of the country, on one hand present the greatest potential to meet the softwood timber demand and on the other hand they set a big challenge for the forest scientist and engineers for their management and harvesting. The production forests exist on the tops, ridges and the slopes of the high mountains at an elevation of 1000 to 3,300 meters (3,300 to 10,800 ft). They cover 1.959 million ha of land and account for 41.4 % of the total forest area. These forests are the main source of construction timber but their vital importance lies in their services towards conservation of soil and water resources of the country, control of floods, prevention of siltation of dams and water reservoirs and provision of recreational spots. More than 52 % of these forests are as protected forests because of their above mentioned services. The classification of coniferous forests, on the basis of climate, altitude, soil and vegetation is given in the following table.

TABLE - 5

CLASSIFICATION OF CONIFEROUS FORESTS ON THE BASIS OF ALTITUDE & VEGETATION

FOREST TYPE	ALTITUDE ZONE	TIMBER SPECIES
1. Sub-Tropical	1,000 - 1,800 m (3,280 - 5,900 ft.)	Pure crop of Chir pine (*Pinus roxburghii*)
2. Wet-Temperate	1,500 - 3,300 m (4,920 - 10,800 ft.)	Mixed crop of Kail (*Pinus wallichiana*)
		Deodar (*Cedrus deodara*)
		Fir (*Abies pindrow*)
		Spruce (*Picea smithiana*)
3. Dry-Temperate	1,500 - 3,300 m (4,920 - 10,800 ft.)	All Wet Temperate zone crops and Chilghoza pine (*Pinus geradiana*)
		Juniper (*Juniperus excelsa*)

The broad-leaved species of Oaks, Walnut, Horse-chestnut, Bird-cherry, Poplar and Birch are also found on shady and wet sites within the Himalayan regions.

2.3.2 Irrigated Plantations

These are man made forests having been grown after clearing the vast tropical thorn forests, in areas where canal water could be made available. These plantations mainly comprise the following tree species:

- Shisham (Delbergia sissoo)
- Mulberry (Morus alba)
- Babul (Acacia nilotica)
- Semel (Salmalia malabarica)
- Bakain (Melia azedrach)
- Eucalytus species
- Poplar hybrid species

These plantations are the main source of timber for furniture and sports goods industries of the country.

2.3.3 Riverine Forests

The riverine forests occur on strips between the banks of the Indus river and the embankments made for the protection from the floods. These forests are the main source of mining timber and fuel wood. The main species are the following:

- Babul (Acacia nilotica)
- Obhan (Populas euphratica)
- Lai (Tamarix aphylla)
- Jand (Prospopis specigera)

2.3.4 Scrub Forests

These forests are the broad-leaved, growing in the foot-hills from elevation 500 to 1500 meters. These forests provide fuel wood to the local population and grazing to the animals. Beside this these forests are serving for the conservation of wildlife and protection of watersheds. The main species are the following:

- Phullai (Acacia modesta)
- Kau (Oleo cuspidata)

2.3.5 Mangroves Forests

These forests are the coastal forests in the Indus delta on the coast of Arabian Sea. The provide fuel wood and fodder for the live stock of the area. Due to overgrazing these forest are shrinking at a fast rate.

The distribution of forests area by types, ownership status and productivity is given in Table - 6.

TABLE - 6

DISTRIBUTION OF FOREST AREA (in 1,000 ha)

FOREST TYPE	TOTAL AREA	STATE OWNED	PRIVATE	PRODUCTION FORESTS
Coniferous	1,959	1,197	762	931
Irrigated plantations	392	233	159	142
Riverine	296	296	-	246
Scrub	1,702	900	802	158
Coastal	347	345	2	-
Others	41	17	24	-
Total :	4,737	2,988	1,749	1,477
Percentage :		63.1	36.9	31.2

(Source : The State of Forestry in Pakistan)

2.4 Growing Stock

The average growing stock, considering the total forest area, is about 98 cubic meters/ha (3,461 cft./ha) which is very low as compared to other countries. Consequently the average annual growth rate is about 0.67 cubic meters/ha. (24 cft./ha.)But when only the coniferous forest are considered the average annual growth rate is about 5.5 cubic meters/ha. (194 cft./ha.) (Seltzer et. al; 1983, cited by Siddiqui K.M. 1987). Beside the poor stocking, the age classes of coniferous forests are also not proportionate. Mature and over-mature trees are predominate in all production forests areas. For instance in Hazara and Malakand circles, the distribution of species and maturity classes in productive forests is given in Table - 7.

TABLE - 7

DISTRIBUTION OF MATURITY CLASSES IN THE PRODUCTIVE FORESTS OF HAZARA AND MALAKAND

CLASSES DISTRIBUTION	NO. OF TREES (million)	VOLUME (million m^3)	% OF TOTAL VOLUME
IMMATURE TREES (up to 37.5 cm)	15.589	7.154	13
SUB-MATURE TREES (40 - 57.5 cm)	8.306	15.522	29
MATURE TREES (60 cm & above)	5.354	30.746	58

(Source : Akbar et. al; 1986, cited by Siddiqui K.M., 1987)

Because of primitive tools and methods, loggers always prefer to work with small and sub-mature trees and they try to leave large and over mature trees in the forest. The so left large mature trees make a large proportion of growing stock and also have the following disadvantages:

- Growth rate is very small
- More susceptible to diseases
- More chances of decay and wind fall
- Low watershed value and poor soil protection

2.5 Accessibility to Forests.

Forest accessibility in the country is very low. Data collected from some forest areas, at Pakistan Forest Institute, Peshawar indicate an estimated forest road density of about 2.9 m/ha. Moreover the forests are scattered and mostly they are on the top of the hills. A considerable distance has to be travelled to reach them. The existing forest road network is also of sub-standard; they are poor in design and maintenance. The main reason for this is the inadequate funds which ultimately effect the progress of intensive management of these forests.

3. AIM AND OBJECTIVES OF THE STUDY

The main aim of the study is to increase productivity by improving the existing timber harvesting system. Though the study is small and only comprises the chir pine forest area of lower Siran Division, it is hoped that the following objectives will be achieved:

1. Estimation of forest **worker productivity** in the felling and conversion in the hilly chir pine forests of Pakistan, in relation to tree size, with chain saw and manual tools.

2. Estimation of **effectiveness of chain saw** over manual tools in relation to productivity and cost per unit of wood volume.

3. To establish a **break-even condition** between tree felling and conversion methods and their costs under present conditions.

4. Identification of basic **hurdles & problems** associated with the use of chain saw with respect to local conditions.

4. REVIEW OF LITERATURE

Little attention had been given toward the improvement of harvesting methods in the past and because of that no work could be done in the field of harvesting research, especially for the evaluation of productivity and cost of existing and improved methods of timber harvesting, in Pakistan.

A study, to compare the efficiency of power chain saw and hand tools for felling and conversion in irrigated plantations (Ayaz, M., K.M. Siddiqui: 1982) was carried out and it was found that chain saw is 25 % more efficient than hand tools.

In another study of physical work load and labor productivity in timber harvesting in the hard wood plantations of Pakistan (Ayaz, M. 1983), it is found that improved tools (Bow saw) give about 17 % of total work time saving and a significant increase of 23 % in labor productivity with a saving of about 11 % in felling and conversion cost per cubic meter as compared to conventional tools (cross-cut-saw).

Felling and conversion work with cross-cut-saw and chain saw was also compared in softwood plantations of Tanzania. (Migunga, et al.: 1983). They found no significant difference in the cost curves of cross-cut-saw, one man chain saw and two-man chain saw. On the other hand the productivity of chain saw was found 80 % more than the cross-cut-saw.

Some studies of felling, debranching and cross cutting of timber has been done in South Africa. Results are reported in bulletin No.52, of Logging Reference Manual, Vol.I, (Zaremba, 1976). The study include the same species of Chir pine (Pinus roxburghii) which has been studied in Pakistan, under the present study. The results show the felling & limbing time for various DBH classes. The results of the study are discussed in section 10 of the present study.

The present study is the first one of its nature in Pakistan. The productivity and operational costs of manual tools and chain saw are compared in relation to different influencing factors. Findings of the study will serve as guide lines for the future harvesting activities and research in the hilly forests of the Country.

5. METHODS AND SYSTEM OF TIMBER HARVESTING

"Harvesting" can be defined as a link between forest resources and its users. Users can be wood industries or a direct single user. Harvesting methods (Mikko Kantola et.al 1988) may be classified under:

1. Whole-tree method (Trees with stumps)
2. Full-tree method (felled trees with branches)
3. Stem-section method (Cross-cut with branches)
4. Tree-length method (delimbed & topped stems)
5. Assortment method (shortwood, cross-cut)

In Pakistan, generally the assortment method is applied due to the steep terrain and low forest road density.

5.1 Harvesting system

A harvesting system can be defined as the combination of differently organized men, machine and equipment, with a sequence of harvesting operations. Tree felling in coniferous forests is done manually with axe and peg-toothed cross-cut-saw. A felling group of 2 or 3 workers usually use their local axes and about 1.5 m (5 ft.) long two-man cross-cut-saws. After felling, debranching is done with an axe. The "Work-munshi", one of the staff of FDC (Forest Development Corporation) measures lengths of the required sizes and then bucking is done with cross-cut-saw.

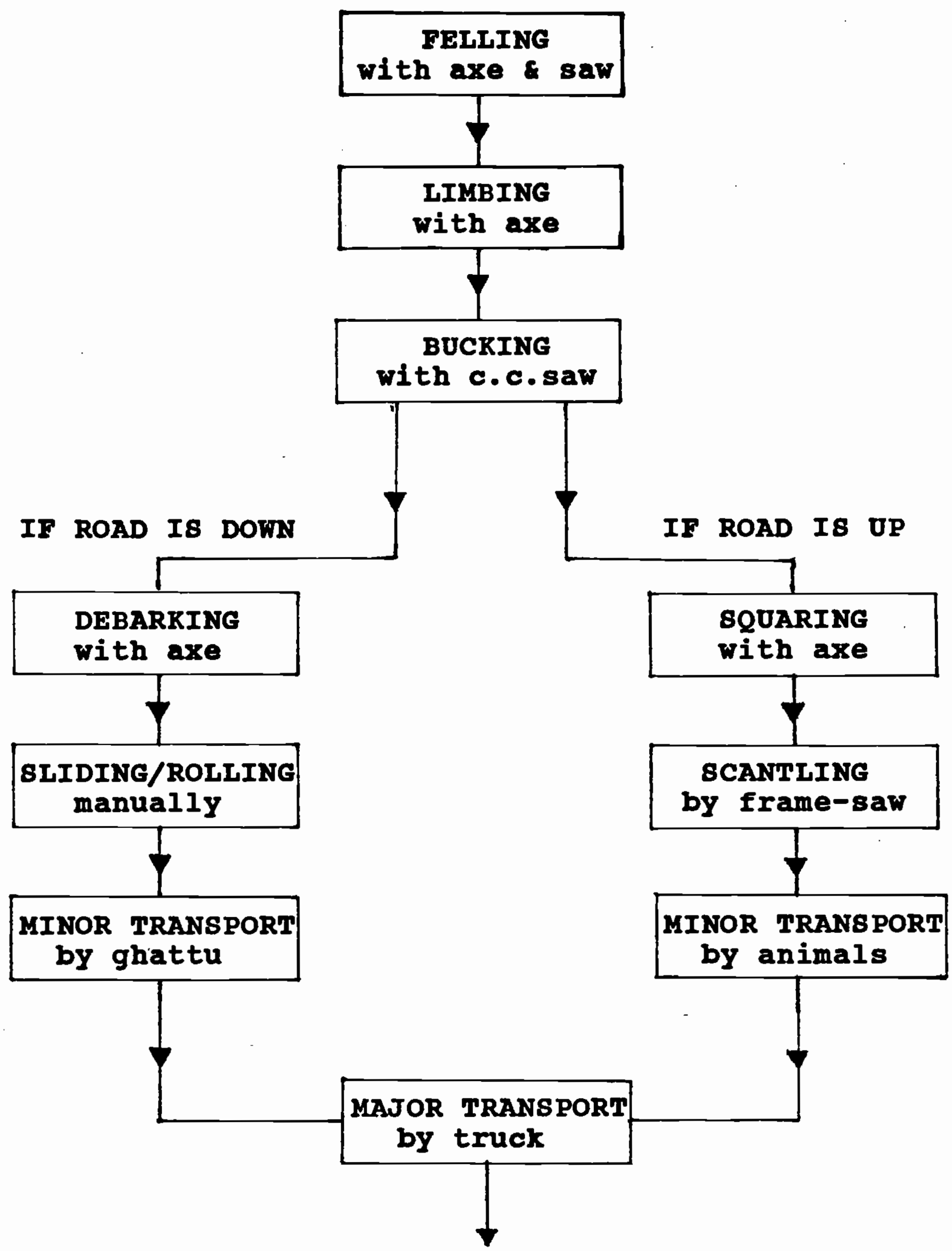
The means of primary transportation, from the felling site to transit depot, depends upon the topography, steepness of the terrain and the location of forest roads. If the forest road is down hill (below the harvest site), the method of sliding and rolling is adopted to bring logs to the road. Otherwise, logs are converted into scantlings in the forest. Usually an axe for squaring and frame-saw for the sawing are used. The scantlings are then transported to the transit depot by mules. A mule can carry two scantlings of 5.3 c.ft. (0.15 cu.m.) volume each.

Primary transportation, from the forest road to the transit depot in the forest, is done by small 4 x 4 wheeled trucks, locally called "ghattus". These are old military 4 x 4 vehicles, which have been modified by local mechanics for this purpose. A ghattu can carry about 160 c.ft. (4.5 cu.m.) of timber.

Secondary or Major transportation, from transit depot to the mill or market, is done by trucks. Loading and unloading is done manually. The following Fig. 5 shows the existing system of timber harvesting and transportation in Pakistan.

FIG. - 5

HARVESTING AND TRANSPORTATION SYSTEM



6. COST AND PRODUCTIVITY

6.1 Cost of Timber Harvesting

Cost minimization is a prime objective of the harvesting system. For a manager of the logging operation or the owner of the mill, the business of logging is undertaken to make profit. The cost of individual work element affects the final profit of the whole operation. Profit can be increased by producing more or by reducing costs. It is clear that volume of standing wood in a lot can not be increased. Moreover the job of the logger is to make sure to get all possible volume that is economically available. Hence the only choice left is to make efforts to reduce the cost. Productivity relates to time and time is always considered money. To increase profit, productivity should be increased in such a way that relative costs must not be increased.

To get optimization, cost is one of the important basic factors for the comparison of different logging systems under different conditions. Beside this, the effect of working hours, optimal replacement time of a machine, and rate of return on investment also help to compare cost of different machines and equipment; and also help to find which machine is more economical.

In logging operations, cost are mostly **direct costs** which are associated with the actual outputs. There are certain **indirect costs**, like transportation of equipment and labor to the site, rest house charges, camping facilities. These indirect costs must be included to obtain the final costs of the logging operations.

Unit cost is defined as the cost per unit volume i.e. Rupees or Dollars per cu.ft. or cu.m. Productivity is a measure of the units of wood produced in one time unit. For logging operations, unit cost is a function of productivity and the cost of a time unit. For instance, if the productivity (P) of an harvesting operation is 10 cu.m/hr. and cost per hour (H) is $ 20.00, then the unit cost (C) would be,

$$C = H/P$$

$$= \frac{20\ \$/hr}{10\ cu.m/hr} = 2.00\ \$/cu.m.$$

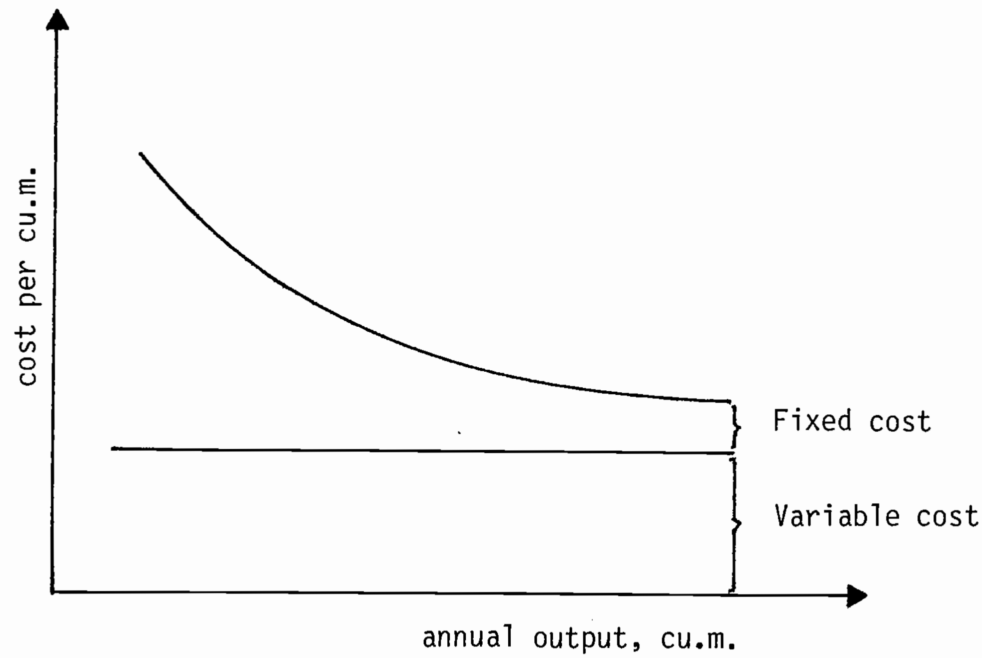
6.1.1 Classification of costs

Costs are classified into two types:

- **Variable Costs:** These costs are related to running costs and vary with production. The cost of fuel, lubricants, repair and overtime payments are all variable costs.

- **Fixed costs:** Fixed costs are constant over a defined period of time and thus independent of the level of activities. When additional units of production are produced annually, fixed cost per unit decreases. Capital investment, overhead costs, insurance and certain taxes are examples of fixed costs.

The following illustration shows the concept of fixed and variable costs and the effect of annual output on them.



6.1.2 Formulas for Total Cost and Unit Cost calculation

Logging operations usually involve both type of costs. The formulas for finding total cost and unit costs are:

Total Cost = Fixed Cost + [Variable Cost * Output]

For the unit cost, the above equation is changed by dividing both sides with the amount of output.

$$\frac{\textbf{Total cost}}{\textbf{Output}} = \frac{\textbf{Fixed cost}}{\textbf{Output}} + \frac{\textbf{variable cost * output}}{\textbf{Output}}$$

Unit cost = (Fixed cost/output) + Variable cost per unit

For the cost calculation of chain saw and manual tools, along with their operators, the "PACE" software is used (developed by Professor John Sessions, 1986).

6.1.3 Break-even Analysis

Break-even analysis is a useful technique which determines the level of output of a certain operation at which one method becomes superior to another in accomplishing some task or objective (Sessions, 1988).

To explain the idea of break-even analysis, consider the following example (Elden D. Olsen, 1989).

Problem: A timber sale appraiser is trying to decide what is the best size crew to allow for a cable thinning where the volume per acre is fairly low. He expects the logger will spend a large amount of time on road changing and wants to know if an additional 2 man prerigging crew is justified. The logging specialist has previously determined the following:

- Average setting = 8 acres
- Owning & operating cost of yarder & loader = 50 $/hr
- Avg. cycle time = 6 minutes
- Volume per turn = 400 mbf
- Effective hour = 40 minutes
- Road change time for 6 man crew = 4 hrs.
- Road change time for 8 man crew = 1 hr.
- Cost per hr. for 6 man crew = 60 $/hr.
- Cost per hr. for 8 man crew = 80 $/hr.

What is the **Break-even Volume (V)** per acre, between using the two types of crew systems ?

Solution: For the solution of this problem the fixed and variable costs for both groups are calculated.

A. 6 man-crew costs:

Volume/hr.=[.4 mbf/turn][.17 turn/min][40 min/hr.] = 2.67 mbf/hr.

Hours/setting=[8 ac/set][1 hr/2.67 mbf][V mbf/ac] = 3 V hr/setting

Hour/change = 4 hour/setting

Total cost = [{labor + machine} per hr.]*[time]

= {60 + 50} * {3 V + 4} = 440 + 330 V.......(1)

B. 8 man-crew costs

Total cost = {80 + 50} * {3 V + 1} = 130 + 390 V.......(2)

By balancing the two equations: (1 & 2)

$$440 + 330\ V = 130 + 390\ V$$

$$60\ V = 310$$

$$V = 5.17 \text{ mbf per acre.}$$

The output of the problem is illustrated in Fig. 6 which indicates the point of intersection as break-even point.

The same idea of break-even has also been used in finding the economical limbing system in the present study.

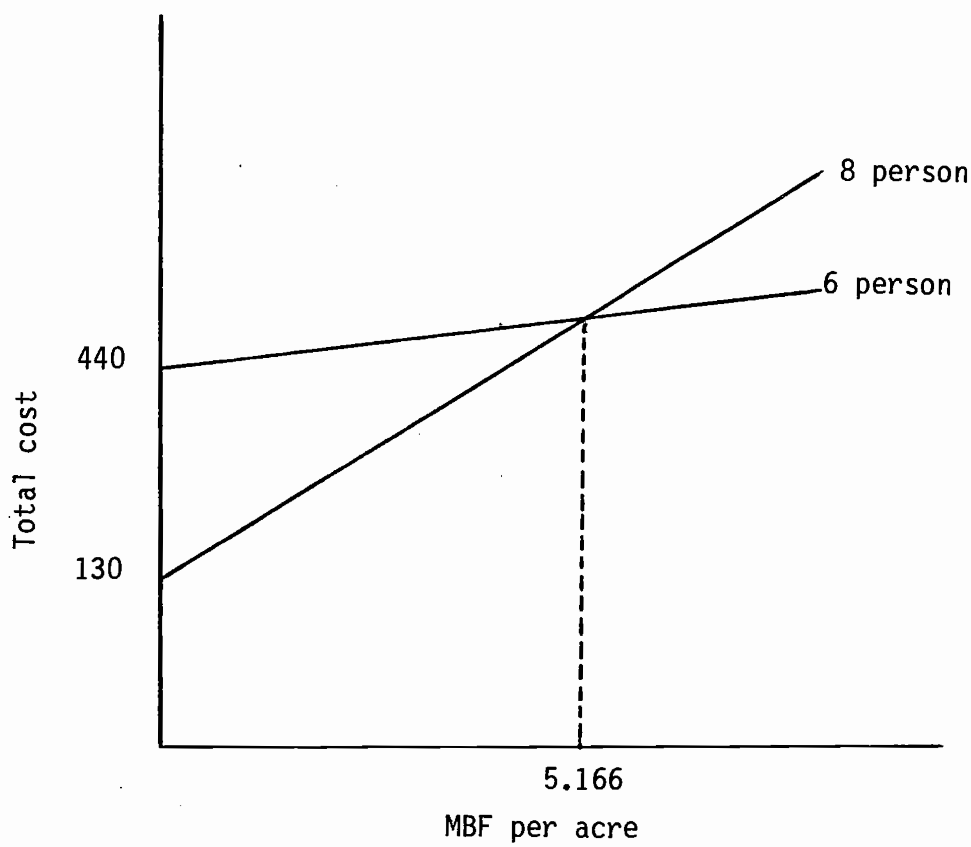


FIG: 6. Graphical solution of BREAK-EVEN problem.

6.2 Productivity

Productivity may be defined as a relationship between input and output factors. If, for instant, Q is the output and F is the input factors of a process, then the Productivity "P" would be

$$P = Q/F \qquad \text{(Ayaz, 1986)}$$

In timber harvesting operations for the calculation of labor productivity, which is also called Technical labor Productivity, the units of output are cubic feet or meters and the duration of time used to produce that output is measured in minutes, hours, days or months depending upon the nature of the study. TLP (Technical Labor Productivity) is not always the same. It changes with the change of workers, tools, methods, crops and sites. The major factors affecting labor productivity are as under:

- Workers skill and motivation
- Physical capabilities of workers
- Timber density and type of species
- Topography and ground conditions
- Type of operations
- Quality of work required
- Climate and weather conditions
- Type of tools and equipments used

7. TIME STUDIES

Logging operations always involve considerable variations in the conditions of work, stand characteristics, terrain conditions, type of roads and many other factors which keep on changing even in the same logging operation. In addition to these external factors, there are variations in equipment and machines, methods of using equipment and also the capabilities and skill of workers. The logging analysis refers to any type of study to the estimate the effects of changes in one or the more factors on productivity and cost of logging operation, is done. (Olsen, 1989)

Logging analysis cannot be considered as a single simple formula or method for a certain situation. This is a set of tools and techniques along with professional judgment which are used in a specific situation and condition. The ultimate results or objectives of such analysis are to reduce the cost of wood or at least to stop or slow down the rising costs of timber. To achieve this goal the only possible way is to increase the yield of capital and labor with the help of the following:

- Improving the efficiency of labor.
- Development of better tools and equipment.
- Developing efficient methods of using tools and equipment.
- Better way of organizing labor.
- Providing good incentives for labor.
- Improving knowledge of reducing cost elements.
- Comparing different methods and tool/equipment for their efficiency.

- Predicting future costs.

7.1 Time Study Methods

Time-Production studies (commonly known as "time studies") may be defined as the study for the determination of the effect of varying physical factors of the work on the productivity and cost. Several type of time study methods, depending upon the nature of job, its intensity and precision, are available. Generally, time studies can be classified into three main classes:

- Method-time measurement

  Most intensive, expensive and detailed type of study usually used by the industries for highly standardized jobs with short and repetitive cycles.

- Gross-Time Studies

  These studies are collective type of studies and individual element of work is not considered, especially where only one factor is involved. These are less time and money consuming studies

- Intermediate Time Studies

  These are the moderate type of studies in between the above two. The number of work elements may vary according to the situation. Time distribution is recorded for each element of the work cycle on a time study form. (Olsen, 1989)

7.2 Multimoment Time Study Method

This method belongs to the intermediate class of time study methods and is commonly used for different forestry operations in most countries of the world. In this method, instead of time duration of a work element (activity), the frequency of its occurrence in a prefixed time interval, is recorded. (Ayaz, 1986). This method was adopted for this study for the following reasons:

- Many workers and machines can be observed at the same time, by one work study man.
- Break point between the two work elements is a source of error in other methods, but has no importance in this method.
- It is easy to learn and to work with. No long training is required for the beginners.
- Short time intervals, like 15 seconds for a full work cycle, are effective.
- A simple stop-watch or even a wrist-watch can be used effectively.

7.3 Study site

Data for this study were collected in 1985-86, from one of the on-going projects of Pakistan Forest Institute, located in Peshawar, Pakistan. This is the only research and teaching organization in the field of Forestry in Pakistan. The studies are done in sub-tropical chir pine forest of Batrasi R.F. compartment 4(i). This forest is situated near Mansehra District, in the lower Siran Forest Division. The particulars of the study site along with the harvesting crop size is given below:

Name of Forest	**:**	**Batrasi R.F., Lower Siran Division**
Compartment No	**:**	**4 (i)**
Total Area	**:**	**198 Acres or 80.13 ha.**
Altitude	**:**	**3,548 - 4,685 ft. (1,081 - 1,428 m)**
Aspect	**:**	**Eastern**
Slope	**:**	**10 - 45 % .... 80 % of area**
		45 - 75 % .... 20 % of area
Soil	**:**	**Shale & dry**
Rock available	**:**	**Granite with mica schist**
Species	**:**	**Chir pine (*Pinus roxburghii*)**
Age of crop	**:**	**small wood 60 %; medium to heavy 40 %**
DBH of crop to be cut	**:**	**Max: 35.0 in = 88.9 cm.**
		Min: 8.0 in = 20.3 cm.
		Avg: 13.7 in = 35.0 cm.
Type of cut	**:**	**Thinning**
Trees to cut	**:**	**1,672**
Standing Vol:	**:**	**50,472 cft. or 1,429.4 cubic m.**

7.4 Felling Crew

For the present study, the number of crew is kept at two, the minimum requirement for working with a cross-cut -saw. For the chain saw operation, the number of crew is also two. In most of the developed countries of Europe and in USA, the chain saw felling and conversion work is performed by one man. But in developing countries like Pakistan, where chain saw is in its introducing stage and the operators are not well experienced in the mechanism and working of chain saw, and work is in steep and comparatively difficult terrain conditions, it is considered better to have a group of two crew members. In the FAO/ILO training series 2 (1980) a team of three members has been suggested for chain saw work as operator, assistant and helper. For the present study, both chain saw operators worked in a group of two as operator and helper and they changed their position for the next tree. In this way the operator has enough time to release his tension and strain by doing some light job while the other worker is operating the chain saw. Perhaps in future the one-man chain saw operation system can be tried in Pakistan and its productivity and economics can be compared with the two-man crew.

7.4.1 Level - I, CREW

For the chain saw felling and conversion, two chain saw operators of Pakistan Forest Institute, Peshawar, who are the regular Government employees in Pay scale 5, have worked in the above forest area. They received their chain saw handling and maintenance training under the guidance of a German Instructor, at school forest of PFI and in the near by forest areas. Their particulars, age and experience is shown in the following table:

TABLE - 8

PARTICULARS OF CHAIN SAW OPERATORS

NAME OF THE OPERATOR	AGE (years)	LENGTH OF SERVICE (years)	EXPERIENCE (years)
1. Nazir Afzal	27	3	2
2. Baz Mohammad	26	2	1

They used the following equipment for the felling and conversion of tree:

- Chain saw, 056 AVEQ,.............. ONE
  with extra saw chain,
  guide bar and tool kit.(Fig. 7 a.)
- Axe, imported, weight 1.2 Kg...... ONE
- Hammer, weight 3 Kg............... ONE
- Wedges (Aluminum + Wooden)........ THREE
- Wedges, Plastic .... TWO
- Sapie (turning hook)............ ONE
- Fuel can .... ONE
- First aid kit .... ONE

Beside the above equipment they were also required to use the following protection and safety devices while working with chain saw. These protection items were provided to them as their personal kit. (Fig. 7 b.)

- Protection clothing, with safety

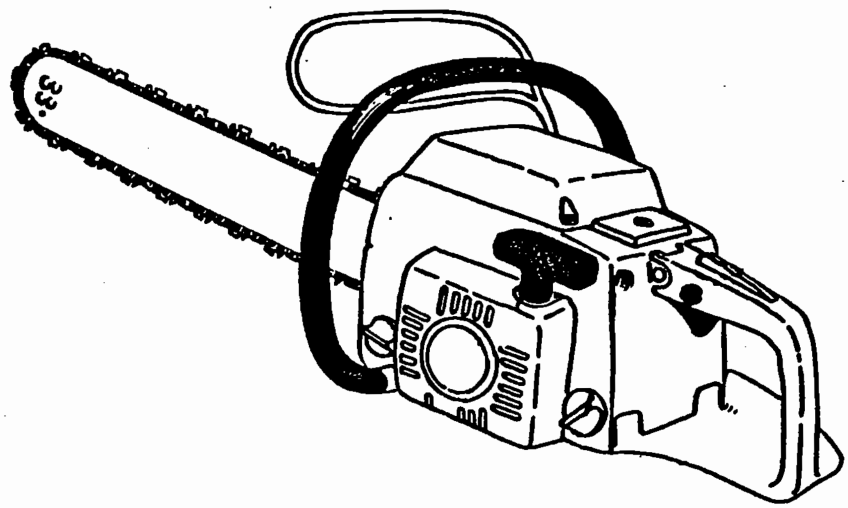


FIG. 7 a. Power Chain Saw

FIG. 7 b. Felling with Chain Saw

- Safety helmet, with ear and eye protection
- Hand Gloves
- Shoes with steel cap toe and non-slip sole

7.4.2 Level - II, CREW

For manual felling and conversion with axe and peg-toothed two-man cross-cut-saw, the local forest workers were employed on daily wage basis, because these posts are not on the regular strength of PFI. They were local villagers and were professional forest workers. They were paid a sum of Rs. 45/- per working day without any fringes benefits or allowance. Their particulars are as under:

TABLE - 9

PARTICULARS OF MANUAL TOOLS CREW

NAME OF WORKER	AGE (year)	EXPERIENCE (year)
1. Mohammad Rashid	42	20
2. Khushi Mohammad	38	15

They have used their own equipment except the triangular file which was provided to them for the sharpening of peg-toothed saw. The list of their tools is as under:

- Peg-toothed Cross-cut-saw,............. ONE
  about 5 ft. long. (Fig. 8 b)
- Axe, local made, weight 1.5 Kg........ TWO
- Wedges, steels .... THREE
- Wooden pole of about 6 ft. length..... TWO

FIG. 8.a Felling with Axe

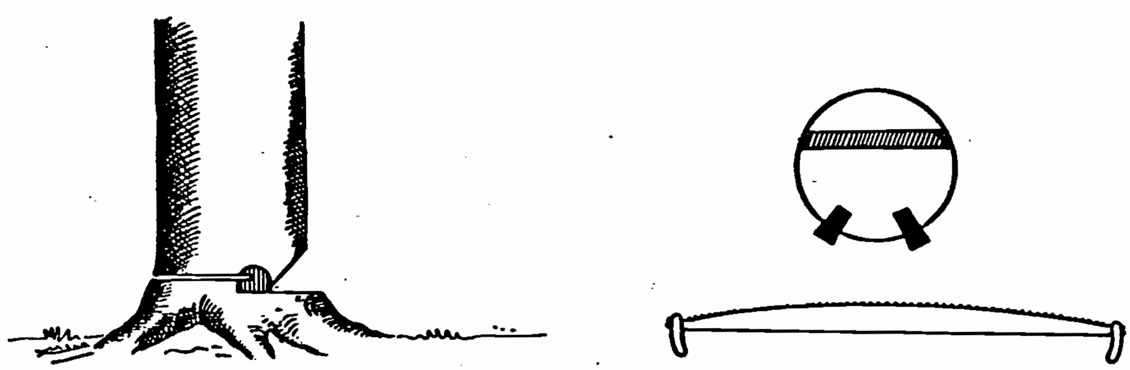


FIG. 8.b Felling with Cross-cut-Saw

used as a turning hook.

- Can with diesel, for use as .... ONE
  saw cleaner during operation.

The terrain and other local conditions were kept, as far as possible, the same for both study levels.

7.5 Recording of data

For both study levels I & II, the same multimoment method is used. The data are collected by the two Logging Assistants of the Engineering Section of Pakistan Forest Institute, who were trained in this field. For the determination of possible work elements, **Method study** is an important step before the actual time study. Two days method study was done to get a clear idea about the possible work elements in this felling operation. Number of Work elements may differ due to the crop density, terrain conditions and type of tools used. The importance of method study lies in finding better way of doing things and to get rid of unnecessary work.

A **Work Cycle** may be defined as the time period between completion of work on previous tree and the finishing of work on the present tree. Unrelated large breaks are not taken into consideration for the purpose of recording. For the present study the following work elements have been considered for both the levels:

7.5.1 Preparation

This element includes those activities which a worker performs to get prepared for the work. This includes the assembling of tools and equipment, collection of necessary information and instructions for the day's job, change of working clothes etc: In the same way it also includes the workers activities at the end of day after finishing the last tree, such as collection of tools, walk back to the store, put the equipment at proper place and change of clothes etc.

7.5.2 Walk to tree

This element starts just after the finishing the tree in hand, when worker collects his tools with the idea of moving to the next tree. The duration of the element ends after the reaching of worker to the next tree and as he gets attentive to other job after putting his tools beside the tree.

7.5.3 Clearing

The duration of this element starts when worker takes his tool or axe with the idea of cleaning around the tree and it ends when worker puts his tool back and picks another tool for the next job.

7.5.4 Felling

This element consist two parts, 1) Under cut and 2) back cut. One may consider them collectively or two separate work elements. In any case the total time of felling will be the same. This element starts when worker takes his tool with the idea of making the first cut for under cut and finishes with the fall of tree or worker starts picking his tools for the next job.

7.5.5 Hang up

This element starts when worker gets attention to it and starts preparing to release the hang up. The end point of this element ends when the tree is on the ground.

7.5.6 Limbing (debranching)

The time of this operation starts when worker takes his tool with the idea of limbing and it ends when the last branch is cut and worker puts his tool back on the ground or he gets ready for the next job.

7.5.7 Bucking (cross cutting of tree into logs)

The duration of this element starts when worker gets attentive towards the bucking of the tree and it finishes when he completes the last cut and puts his tool back on the ground or gets attentive to an other job.

7.5.8 Additional activities

Time consumed for the fixing of loose tools handles, change of saw chain or guide bar, refueling of chain saw or any other job which is not covered by any other work element.

7.5.9 Operational delay

The time of such activities like waiting of a worker for the completion of a certain job to start his job; longer duration (more than two minutes) of certain job like releasing of stuck guide bar or saw in the cut; longer duration of handle fixing; wedging; refueling; minor repair etc;

7.5.10 Personal delay

The time spent for personal jobs like drinking, smoking, chattering or short breaks for release of stress.

7.6 Data Recording Sheet

The data sheet forms, used for the time studies of both the levels are given in Appendix - IV. A time interval of 15 seconds for chain saw operation (a speedy equipment) and 30 seconds for manual tools operation are kept for the data collection. With the help of a stop-watch, the activities of each worker is noted down on the data sheet in the form of a dot after the specified observation interval, for a full work cycle. From the number of dots or point of a specific work element and the duration of time interval, the time duration of each work element or activity is calculated. One of the prerequisite for the effective use of this method is that the data collector should strictly observe the time interval and the type of activity at that specific moment should be recorded, irrespective of the fact that a short or relatively less important activity is being performed. Because this method is based on the principle of randomization and chance without any personal bias. For the calculation of time interval for each work element the sum of total dots are divided by the product of number of time intervals per minutes and the number of workers.

8. WORKING METHODS

8.1 LEVEL - I (Chain saw felling and conversion)

The sequence of work for the chain saw felling and conversion, **(Fig. 9)** is explained below:

- Felling

Felling of already marked trees is done with chain saw in following steps:

- Determination of felling direction, which may be different from the natural felling direction of the tree due to leaning, number of heavy branches, eccentric position of the crown etc;
- Clearing of working site around the tree from brush and stones. The bark at saw chain cutting site is also removed with axe in case any dirt or small stones are found there. It is essential for the care and long life of saw chain.
- Under cut, which determines the felling direction, is completed with two cuts. The first straight cut, as close to the ground as possible, up-to one third diameter depth in the stem, towards the felling direction is made and second oblique cut, at an angle of 45° - 60° is made to complete the undercut.
- Side cuts are made to the big trees (dbh > 24 inches) at the both ends of the undercut about 2 to 3 inches downward. This practice avoid the splinters and splitting

Felling

Limbing

Bucking

FIG. 9 Level - I work elements

at the time of fall.

- Back cut is made from the back side of the undercut, about 1 to 2 inches high than the straight cut of undercut, leaving the width of the holding wood about one tenth of the diameter of the tree. With the completion of back cut tree should fall if it is leaning, even slightly. Otherwise the next step is performed.

- Wedging or the use of felling lever becomes necessary if tree is uniform and standing straight. The number of wedges to be used depends upon the size of tree. These are wedged in the back cut with the help of a hammer simultaneously while chain saw is working there. This brings the tree down.

- Limbing (debranching)

The very first step, after the fall of tree, is the cleaning of the stump and the butt-end side of the stem from the splinters. The pieces of holding wood left with the log or on the stump are removed. Branches are usually removed up-to 3 - 4 inches of the top diameter of the pole. Any piece of the stem having diameter less then 8 inches is considered as pole.

- Measuring of stem for log cutting

This part of the work is the responsibility of the work Munshi of FDC, who is assigned by his organization for felling operation in the forests. He also keeps the full record of each log in his stock register. He is helped by an "Engraver" who engraves log numbers, lot number and dimension of each log on its cross section.

- **Bucking (cross cutting)**

Cross cutting of the felled trees is done on the places, already marked by the Work Munshi. Much care has to be taken while cross cutting those trees which are lying on steep slopes.

8.2 **LEVEL - II (felling & conversion with manual tools)**

The sequences of the felling and conversion operation, (Fig. 10) with manual tools i.e axe and two-man cross-cut-saw is:

- **Felling**

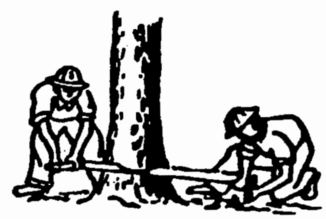
A group of two local forest workers, has done the felling and conversion of trees, with their local axes and two-man peg-toothed cross-cut-saw. They usually did less site clearing and bark removal before doing the actual felling operation. They used an axe for making an undercut towards the felling direction and a back-cut was made with cross-cut-saw. They used diesel oil, as a lubricant while working with cross-cut-saw to avoid sticking to the resin of chir pine.

- **Wedging**

In manual felling wedging was seldom done due to the fact that workers were usually felling trees in the

Felling
(under-cut)

Felling
(back-cut)



Limbing

FIG. 10. Level - II work elements

direction of their natural lean. But they had some iron wedges for this purpose. Some splitting of butt-end logs was also observed in heavy leaned trees due to slow process of cutting.

- **Limbing (debranching)**

For the debranching on the felled trees, axes were used. Usually both the workers were working simultaneously with their axes. The cross-cut-saw was also used for the debranching of some big branches.

- **Measurement of stem for bucking**

This process is explained above in the chain saw section.

- **Bucking (cross cutting)**

Cross cutting is done with peg-toothed two-man cross-cut-saw, according to the measurements of the Work Munshi of FDC. Small iron wedges were used to avoid pinching of saw in the cut during the process of bucking.

9. ANALYSIS OF DATA AND RESULTS

Different statistical parameters are used for the analysis of data for both the study levels, such as :

- Calculation of **basic statistical values** for all the variables of both the levels.
- Test of **relationship within** the independent and dependent variables of a level.

9.1 Basic Statistics of Study Variables

The recorded data is checked daily and the observed point (dots) are converted into minutes. The actual time of the cycle is also calculated from the start time of the first tree to the start time of the second tree. Both the timings are compared and if the difference is found more than 5 % the cycle is rejected and not included in the study. The following Table - 11 shows the total number of trees felled and converted for each level, their DBH with minimum, maximum and average values.

TABLE - 10

STATISTICS OF TREES FELLED AND CONVERTED

	LEVEL - I	LEVEL - II
1. NUMBER OF TREES		
1.1 Total Trees felled	148	102
2.1 Rejected, due to error in time study.	8	11
3.1 Trees considered for time study.	140	91
2. D.B.H. OF TREES.		
2.1 Minimum :	10.0 in. (25.4 cm.)	10.0 in. (25.4 cm.)
2.2 Maximum :	25.0 in. (63.5 cm.)	24.0 in. (61.0 cm.)
2.3 Average :	15.2 in. (38.61 cm.)	16.4 in. (41.6 cm.)

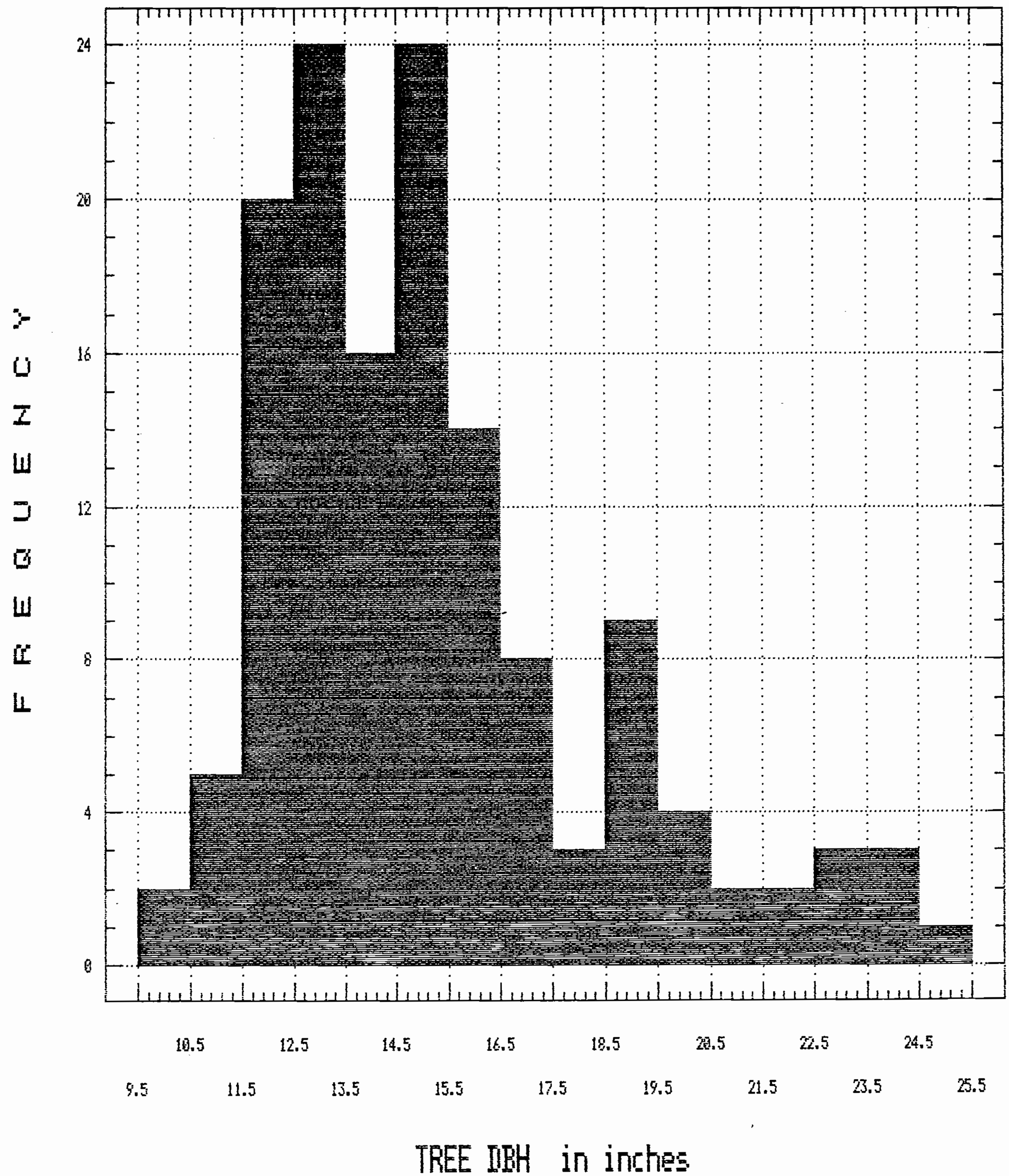
The frequency distribution of tree DBH for level-I and Level - II, are shown graphically, in the form of frequency histograms, in Fig 11 and 12 respectively. These frequency distributions indicate the different DBH classes included in the study.

9.1.1 Independent Variable

The tree DBH, the most influential variable and hence taken as the independent variable for the statistical analysis. The estimated values of height and volume of Chir pine species of the

FREQUENCY HISTOGRAM FOR DBH CLASSES FOR CHAIN SAW OPERATION

FIG. 11

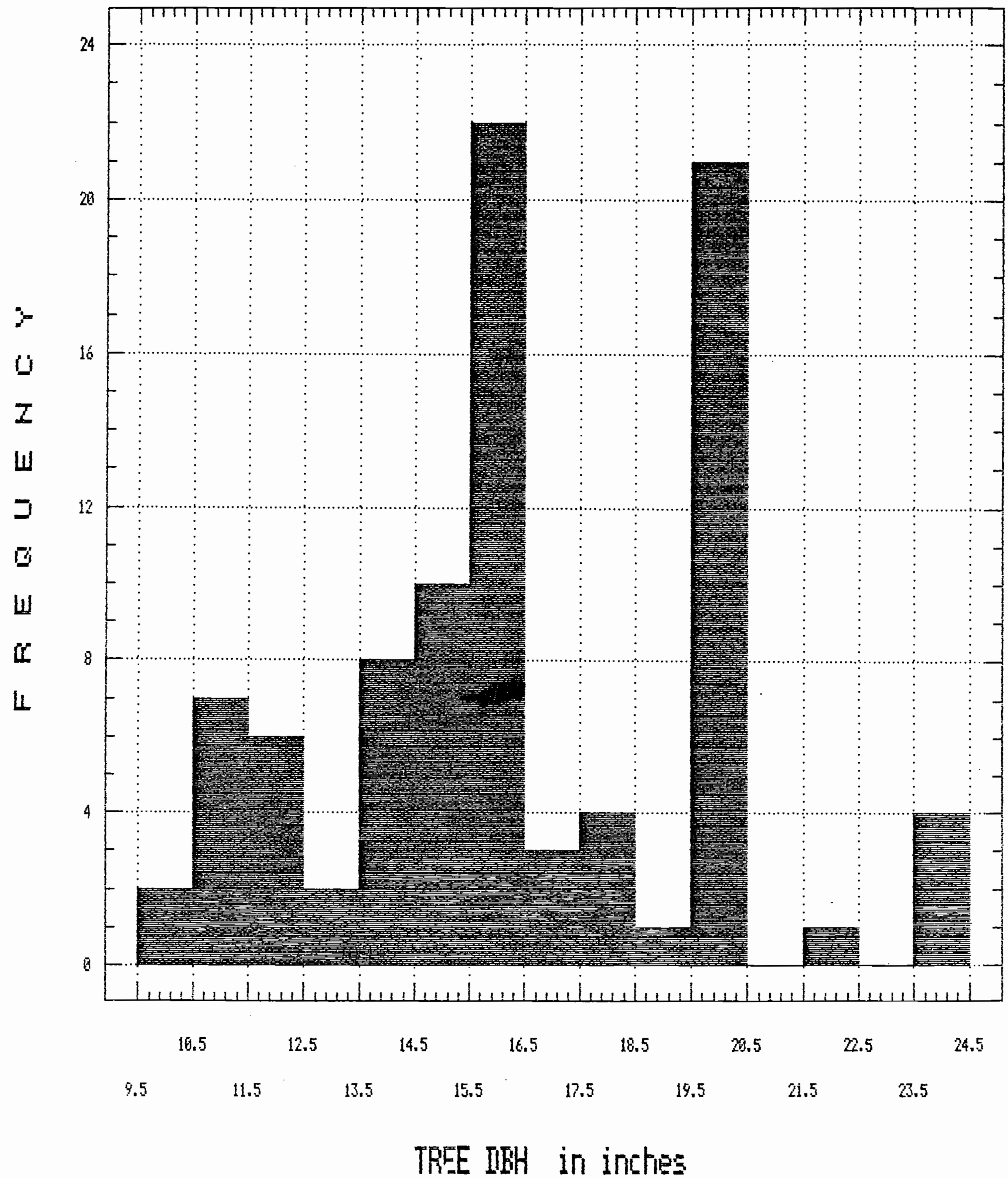


LEVEL - I

FREQUENCY HISTOGRAM FOR DBH CLASSES

FOR MANUAL TOOLS OPERATION

FIG. 12



LEVEL - II

lower Siran Forests are taken from the Volume Tables, prepared at Pakistan Forest Institute, Peshawar. (Hussain, et al; 1976) These tables are used for the estimation of productivity in this study.

9.1.2 Dependent Variables

All the rest of the work elements of a work cycle are considered as dependent variables because their work timings depend upon the DBH of the tree. For both the levels, the following work elements of a work cycle are considered as dependent variables:

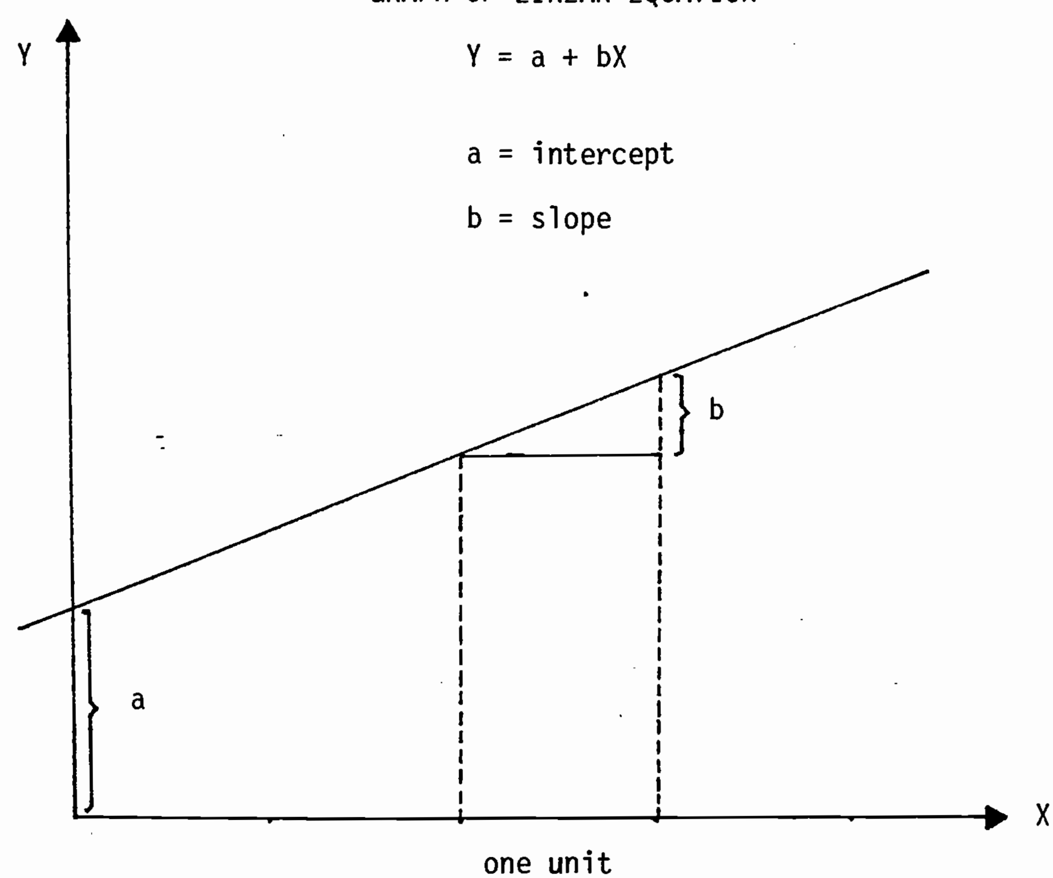
- Felling time
- Limbing time
- Bucking time
- Additional activity time
- Delays time
- Total Effective time
- Total working time

9.2 Linear Regression and Correlation

9.2.1 Regression may be defined as the use of one variable to make predictions about another. Relation between the variables could be of different type. If the higher values of a variable are associated with the higher values of the second variable, the relationship would be positive or direct. If the higher values of a variable are related to the smaller values of the other variable, the relationship would be negative or inverse. A scatter plot between two variables gives a good idea about the type of relationship. A straight line, is usually used for the linear regression and correlation analysis.

In equation Y = a + bX, the independent variable is X, dependent variable is Y and a & b are the constants. For the illustration of the various elements of straight line, a sketch is given:

GRAPH OF LINEAR EQUATION



Here "a" (some time indicated as "B_o") is called the intercept and "b" (some time indicated as "B_1") stands for the slope of the line. A method used for estimating the values of 'a' and 'b' is a model

$$Y_i = a + bX_i + e_i$$

where e_i represents the deviation of the ith point (X_i, Y_i) from the straight line $Y = a + bX$. In this method the deviation of the observed values of y from the line are minimized. It may be defined as the best estimated line as one that minimize the sum of the squares of the deviations of the observed values of y from the fitted values of y. As the values of $B_o + B_1$ are found mathematically therefore the value of SSE will be minimum. This process of minimization is called the **method of least squares,** which produce the estimates of "a" & "b".

9.2.2 coefficient of correlation

A common measure of the strength of linear association between the variables is called coefficient of correlation and is symbolized by 'r'. A general formula for the determination of "r" is:

$$r = \frac{N(\Sigma XY) - (\Sigma X)(\Sigma Y)}{[\{N(\Sigma X^2) - (\Sigma X)^2\} * \{N(\Sigma Y^2) - (\Sigma Y)^2\}]^{1/2}}$$

Where N = number of observation

Σ = Greek letter "sigma" for sum

X = Independent variable

Y = Dependent variable

This coefficient is independent of the scale of measurement of the variables and its range is $-1 < r < +1$ The square of 'r' (r^2) is called the coefficient of determination. It explains the ratio of the reduction in the sum of squares of deviations obtained by using the value of mean of Y as a predictor. The value of r^2 tells that when the best-fitting straight line is used, the variance of errors will be less than the original variance. 'r^2' lies in the interval $0 < r^2 < 1$. It gives a more meaningful interpretation of the strength of association between X and Y than 'r'.

9.3 SUMMARY STATISTICS

The data obtained from the data sheets is entered in the form of a spreadsheet using the "Symphony" software package. The following variables are considered for the statistical analysis of the data.

1. No. of trees
2. Tree DBH (Diameter at Breast Height) in inches
3. Height of tree in ft.
4. Volume of standing tree, in cft.
5. Preparation time, in minutes
6. Walk to tree time, in minutes
7. Felling time of tree, in minutes
8. limbing time, in minutes
9. Bucking time, in minutes
10. Additional Activities, in minutes
11. Delay time, in minutes
12. Effective time, in minutes
13. Total time, in minutes
14. Production per productive hour, in cft./hr.
15. Production per schedule hour, in cft./hr.

From the spreadsheet, the files were exported to another statistical software package called **Statgraphics**, for the further statistical analysis of data such as regression and correlation analysis, calculation of productivity and estimation of costs of different work elements.

TABLE - 11

LEVEL - I

SUMMARY STATISTICS FOR DIFFERENT WORK ELEMENTS TIMING

VARIABLES	DBH	VOLUME CFT	FELLING TIME	LIMBING TIME	BUCKING TIME	ADL.ACT. TIME	DELAY TIME	EFF.TM TIME	TOTAL TIME
	in inch:	(................			in minutes			....	)
SAMPLE SIZE	140	140	140	140	140	140	140	140	140
AVERAGE	15.2	35.02	3.66	3.9	2.72	1.29	16.26	11.57	27.82
VARIANCE	10.35	486.77	2.9	2.29	1.43	3.91	187.36	19.3	248.67
STANDARD DEVN.	3.22	22.06	1.7	1.51	1.19	1.98	13.69	4.39	15.77
STANDARD ERROR	0.27	1.86	0.14	0.13	0.1	0.17	1.16	0.37	1.33
MINIMUM	10	6.18	0.75	1.75	1	0	2.25	5	10.5
MAXIMUM	25	112.41	7.75	9	6	14.75	74.25	24.75	94.5
RANGE	15	106.23	7	7.25	5	14.75	72	19.75	84

TABLE - 12

LEVEL - II

SUMMARY STATISTICS FOR DIFFERENT WORK ELEMENTS TIMING

VARIABLES	DBH in inch:	VOLUME CFT	FELLING TIME	LIMBING TIME	BUCKING TIME	ADL.ACT. TIME	DELAY TIME	EFF.TM TIME	TOTAL TIME
		(.................			in minutes			..............)	
SAMPLE SIZE	91	91	91	91	91	91	91	91	91
AVERAGE	16.36	42.63	10.43	6.08	9.16	0.71	12.19	26.38	38.58
VARIANCE	11.63	534.97	5.53	7.73	7.2	0.57	20.72	47.92	91.11
STANDARD DEVN.	3.41	23.13	2.35	2.78	2.68	0.76	4.55	6.92	9.55
STANDARD ERROR	0.36	2.42	0.25	0.29	0.28	0.08	0.48	0.73	1
MINIMUM	10	6.18	6	1	5	0	4.5	12	20
MAXIMUM	24	102.46	17	13	20	4	22	48	62.5
RANGE	14	96.27	11	12	15	4	17.5	36	42.5

The summary of statistics of all the variables, of this study is given in Table - 11 and Table - 12, for Level - I and Level - II, respectively. It includes the sample size, average, variance, standard deviation, standard error, minimum value, maximum value and range of the data, for both the levels. These parameters help to check the trend of data and its dispersion.

9.4 Relation between Independent & Dependent Variables

For finding out a relationship between DBH (independent variable) and the working time of various dependent variables of **Level - I and II,** a linear regression model of the form Y = a + bX is selected on the basis of the scatter diagrams and the plotting of residuals of the dependent variables, which show no specific pattern or trend. The detail of the procedure used and its findings are mentioned below for each set of data.

9.4.1 DBH of tree & Felling time.

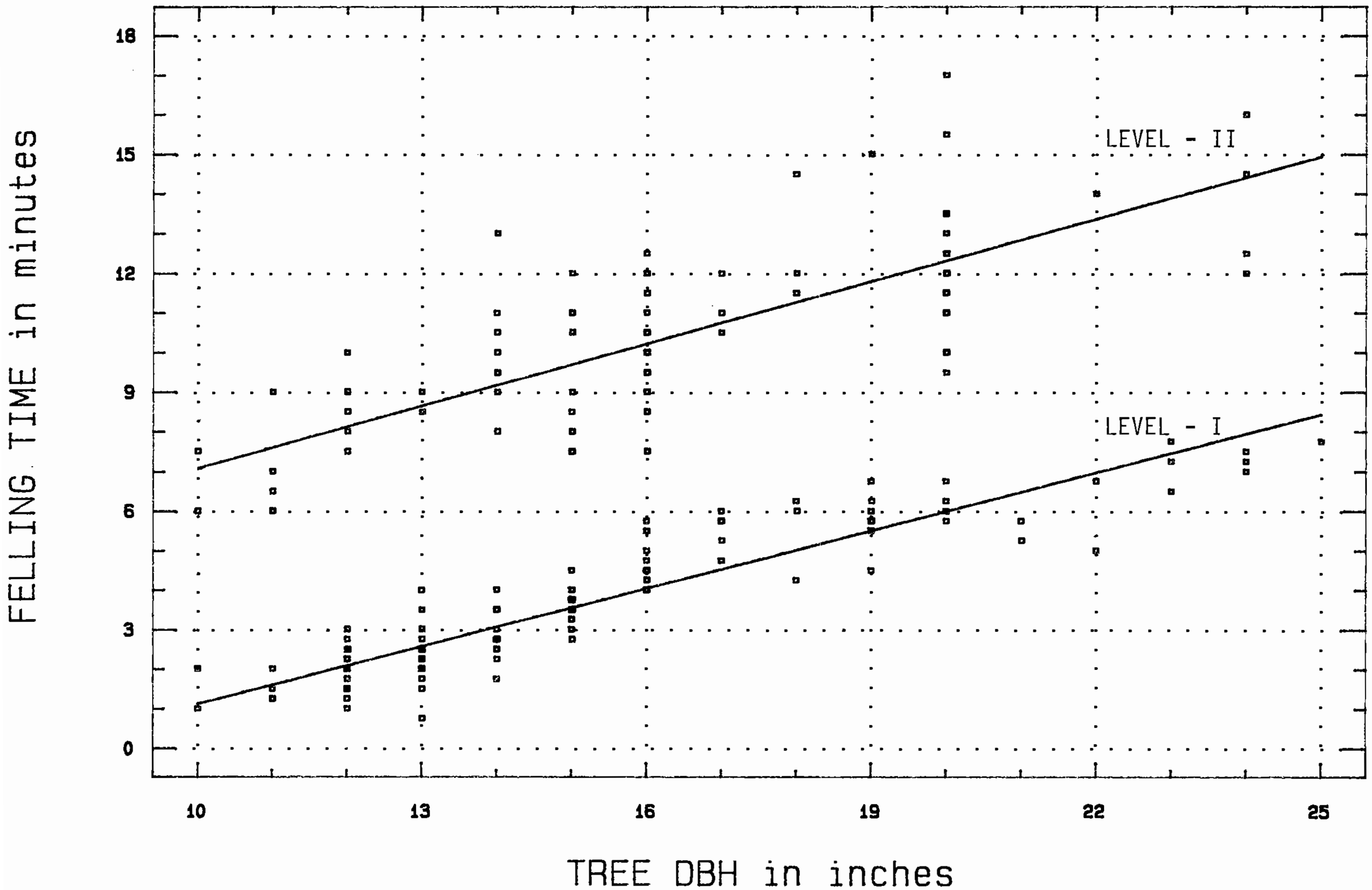
The two variables, DBH and Felling time are tested for their relationship with the method of linear regression and correlation by using the regression model Y = a + bX. The Fig. 13 shows the regression lines and Table - 20 & 21 show the regression equations along with the values of " r " (correlation coefficient), the " R^2 " (coefficient of determination) and their significance level. The regression equation, for chain saw operation is:

Y = -3.75257 + 0.487834 DBH, where Y is the estimated felling time of the tree with chain saw. While the regression equation for manual tools felling operation is:

Y = 1.85905 + 0.523725 DBH, here Y is the estimated felling time of the tree with manual tools. For both the levels this relationship is found positive and highly significant. From these regression equations the values of felling timings of trees of various DBH are estimated and are given in Table - 13.

FIG. 13

FELLING TIME VS TREE DBH
FOR CHAIN SAW & MANUAL OPERATIONS



LEVEL - I & II

TABLE - 13

ESTIMATED FELLING TIMINGS OF TREES IN MINUTES

DBH OF TREE		FELLING TIMES in minutes	
(in)	(cm)	LEVEL - I	LEVEL - II
10	25.4	1.13	7.10
12	30.5	2.10	8.14
14	35.6	3.08	9.19
16	40.6	4.05	10.23
18	45.7	5.03	11.29
20	50.8	6.00	12.33
22	55.9	6.99	13.38
24	61.0	7.96	14.43

9.4.2 DBH and limbing time

The relationship between DBH and the limbing time for both the levels, shown in Fig. 14, is found positive and significant at 99 % level. The regression equations for the chain saw and for the manual tools operations are given below:

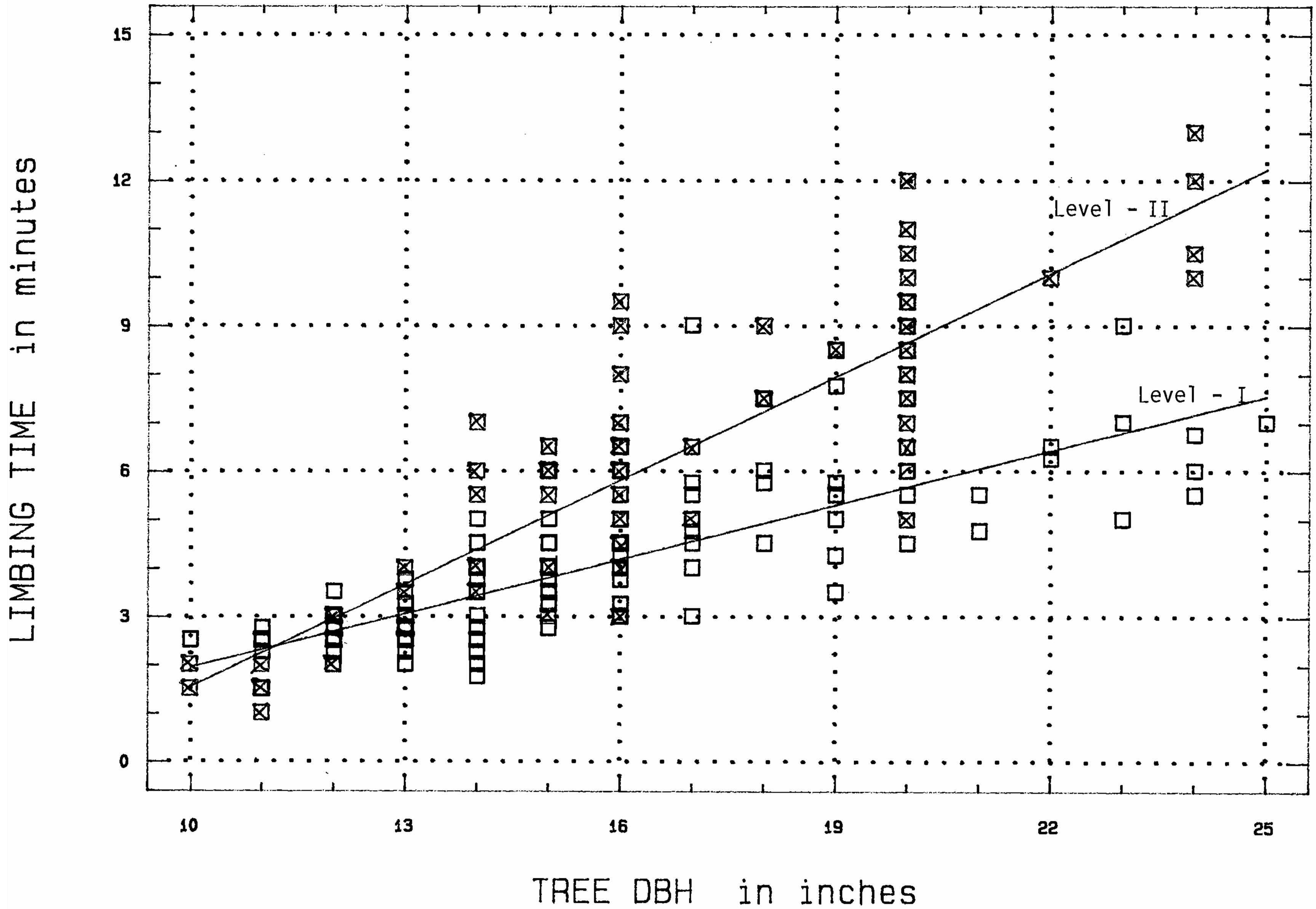
For Chain saw : $Y = -1.78508 + 0.373783\ DBH$

For Manual tools: $Y = -5.58017 + 0.712757\ DBH$

From these equations the estimated limbing time for certain DBH classes is calculated as:

FIG. 14

REGRESSION OF LIMBING TIME ON TREE DBH
FOR CHAIN SAW & MANUAL OPERATIONS



LEVEL - I & II

TABLE - 14

ESTIMATED LIMBING TIMINGS FOR VARIOUS DBH CLASSES

TREE DBH		LIMIBING TIME in minutes	
(in)	(cm)	LEVEL - I	LEVEL - II
10	25.4	1.95	1.55
11	27.9	2.32	2.26
12	30.5	2.70	2.97
14	35.6	3.45	4.40
16	40.6	4.20	5.82
18	45.7	4.94	7.25
20	50.8	5.69	8.67
22	55.9	6.44	10.10
24	61.0	7.19	11.53

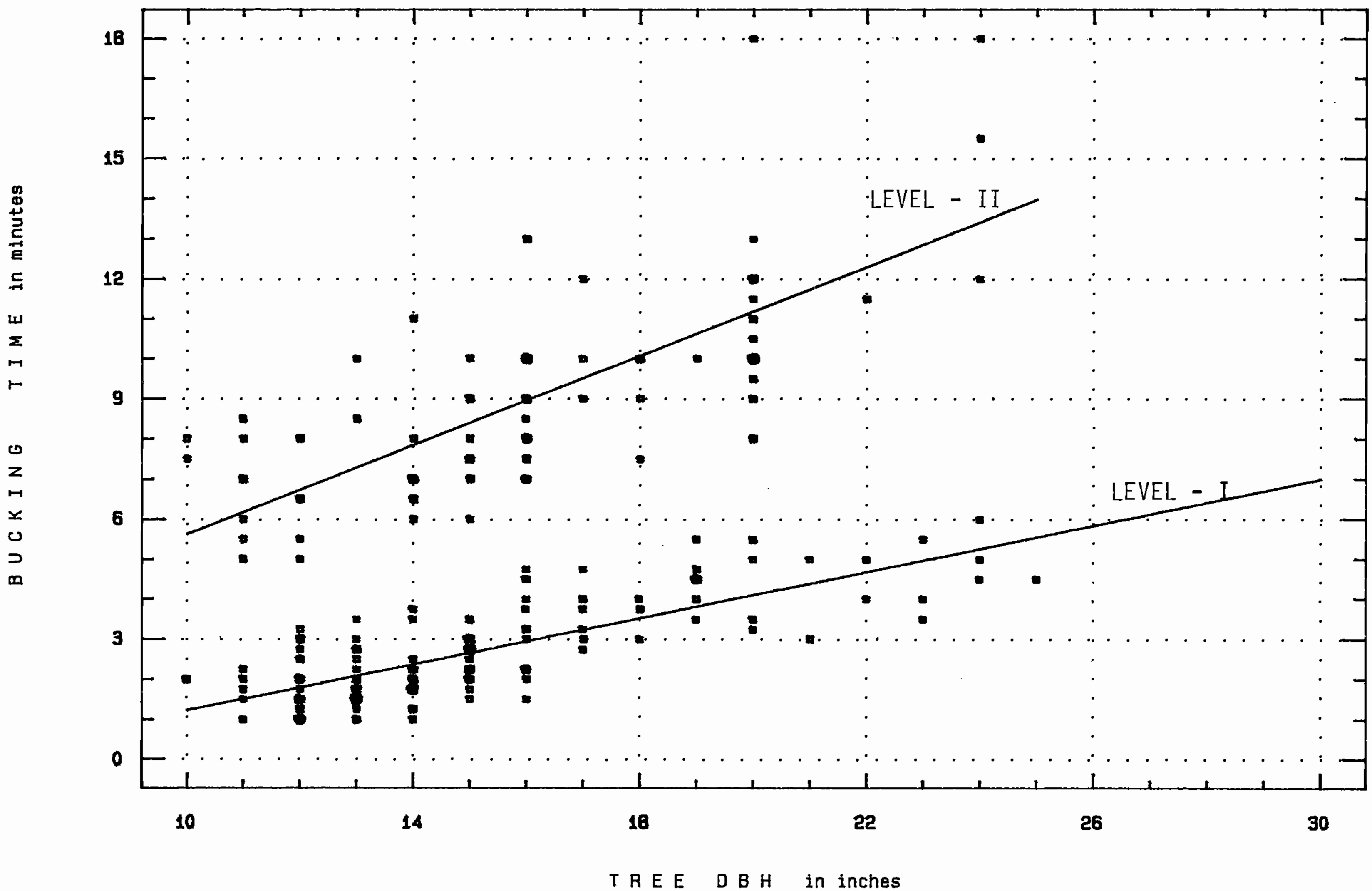
The limbing time, as indicated in the above table, for smaller trees is approximately the same but for large trees this time difference is quite high. Chain saw limbing time is about 37 % less for big trees. The regression lines are very close to each other at one end hence these are also shown separately with their 95 % confidence intervals in Appendix - VI. To check wether the two regressions are really different, a test is done as under:

Simple linear regression may differ either in their slope or in their intercepts. For the common regression test first slopes are tested and if they differ significantly, the regression are different and no further test is needed. Complete analysis table is given in Appendix - VII. The values of "F" statistic for both

FIG. 15

BUCKING TIME VS DBH

CHAIN SAW AND MANUAL TOOLS OPERATIONS



LEVEL - I & II

regression constants are found highly significant which show that both the regression lines are different.

9.4.3 DBH and Bucking time

The regression equations for the estimation of bucking time with respect to the DBH of trees, are found as under:

For Chain saw = Y = -1.66916 + 0.288619 DBH

For Manual tools = Y = 0.04466 + 0.557042 DBH

Fig. 15, shows the relative position of the regression lines derived from the above regression equations. The estimated bucking time for different DBH classes is given in Table - 15.

TABLE - 15

ESTIMATED BUCKING TIME FOR VARIOUS DBH CLASSES FOR A TWO-MAN CREW

DBH OF TREE		BUCKING TIME in minutes	
(in)	(cm)	LEVEL - I	LEVEL - II
10	25.4	1.22	5.62
12	30.5	1.79	6.73
14	35.6	2.37	7.84
16	40.6	2.95	8.96
18	45.7	3.53	10.07
20	50.8	4.10	11.19
22	55.9	4.68	12.30
24	61.0	5.26	13.41

The bucking time of the Level - I is always less than the Level - II. For small trees this decrease is about 78 % while for large trees of 24 inches DBH this decrease is about 61 %.

9.4.4 DBH of Tree and Additional activities time

Additional activities usually consist of the following: Fixing of loose handles of tools, change of saw chain or guide bar of the chain saw, refueling of chain saw, releasing of minor hang-ups or any other activity considered essential for the smooth running of operation and not covered by any other work element. The time for the additional activities in case of chain saw operation, is not related to DBH of the tree, in other words it is an independent variable. The regression analysis performed between DBH and additional activities have not shown any relationship. Hence the mean value of this work element is used in the resulting tables. On the other hand, for manual tools, DBH and additional activities are showing a positive relation as given in Table - 21. The regression equation is $Y = -0.597318 + 0.0801585$.
The mean value and estimated values of additional activities time, for Level - I and II, respectively, are shown in the following Table - 16.

TABLE - 16

ESTIMATED ADDITIONAL ACTIVITIES TIME AND THE DBH OF TREES

DBH OF TREES		LEVEL - I	LEVEL - II
(in)	(cm)	time in minutes	time in minutes
10	25.4	1.29	0.23
12	30.5	1.29	0.36
14	35.6	1.29	0.52
16	40.6	1.29	0.69
18	45.7	1.29	0.85
20	50.8	1.29	1.01
22	55.9	1.29	1.17
24	61.0	1.29	1.33

9.4.5 DBH of the Tree and Total Delay Time

Delay time, which is the sum of all non productive time, usually consists of the operational delay time, personal delay time, preparation time etc. It is an important factor which effects the efficiency, productivity and cost of a working system. Further distribution of the delay time and the effective time, for both the levels is given in the Fig. 16, which indicate the percent division of the delay time and effective time of an average work cycle.

For the estimation of the delay time for both the study levels, the following regression equations are formulated by using the linear regression model Y = a + bX

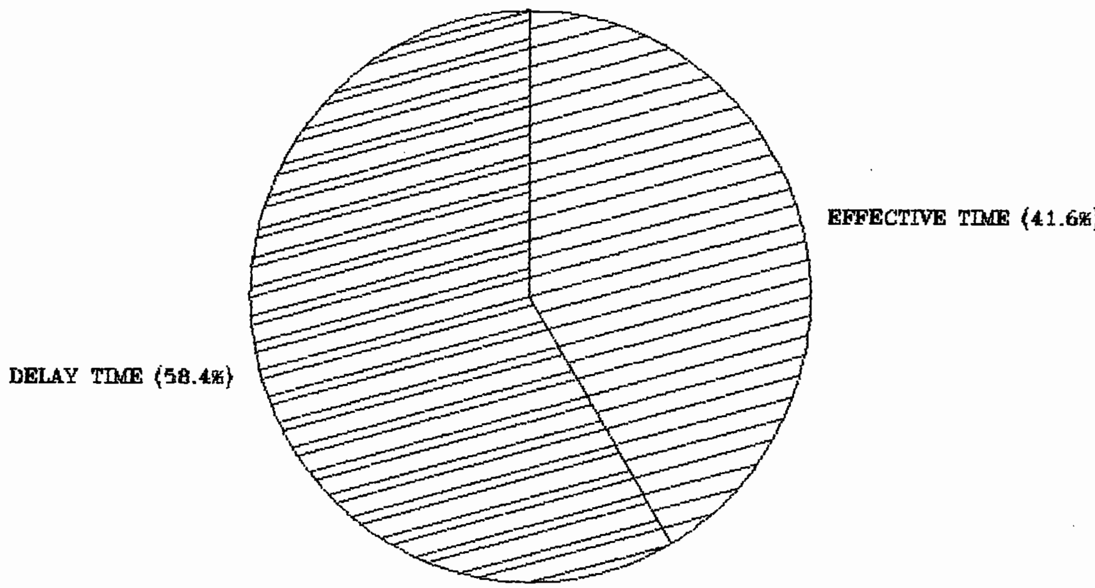
For chain saw : Y = -3.57556 + 1.304780 DBH

For manual tools : Y = 3.61034 + 0.524486 DBH

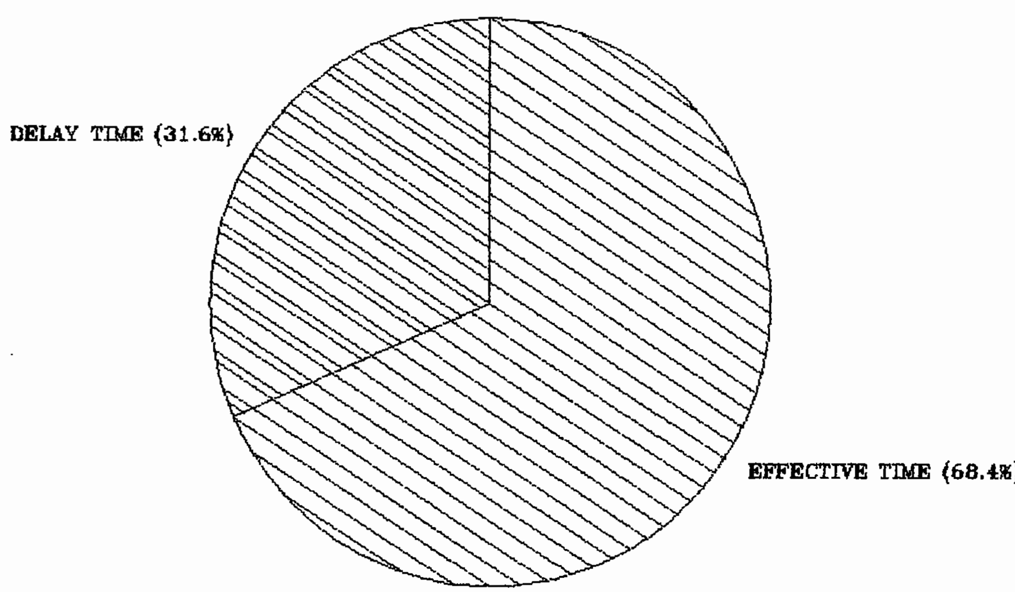
FIG. 16

BREAK-UP OF TOTAL WORK TIME

FOR AN AVERAGE WORK CYCLE



LEVEL - I



LEVEL - II

Table - 17, shows results of the above regression equations, with a high increase in delay time for the Level - I (chain saw operation) for various DBH classes. This increase at the lower DBH level is about 7 % as compared to manual tools operation and for large DBH i.e. 24 inches, this increase in delay time is about 71 % more. Which indicate the necessity of searching methods and ways to decrease this delay time up to its minimum level.

TABLE - 17

ESTIMATED DELAY TIME AND THE DBH OF TREES FOR A TWO-MAN CREW

DBH OF TREES		DELAY TIME in minutes	
(in)	(cm)	LEVEL - I	LEVEL - II
10	25.4	9.47	8.86
12	30.5	12.08	9.90
14	35.6	14.69	10.95
16	40.6	17.30	12.00
18	45.7	19.91	13.05
20	50.8	22.52	14.10
22	55.9	25.13	15.15
24	61.0	27.74	16.20

It is interesting to point out that delays are evenly distributed in each work cycle and hence are regressed rather calculating an overall average delay percentage.

9.4.6 DBH of trees and Total Effective Time

The effective or the productive time of a work cycle consists of felling time, limbing time, bucking time and the additional activities time. For both study levels, the following regression equations are formulated for the estimated effective time.

For Chain saw : $Y = -5.41716 + 1.11732\ DBH$

For manual tools: $Y = -4.27378 + 1.87368\ DBH$

Table - 18 shows the estimated effective time for different DBH classes, with a two-man crew.

TABLE - 18

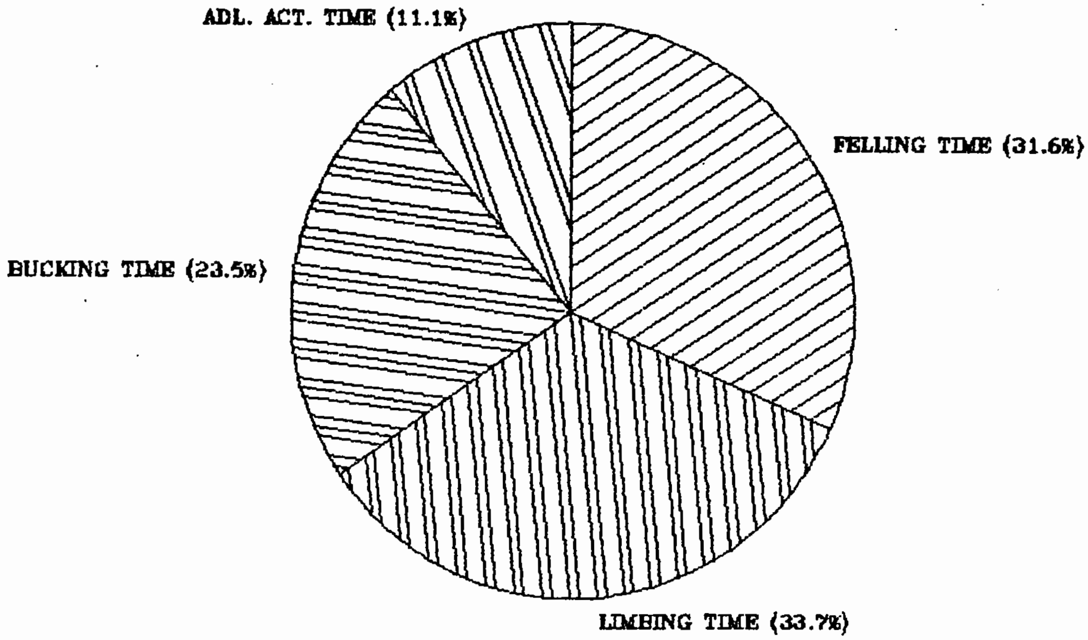
ESTIMATED TOTAL EFFECTIVE TIME FOR VARIOUS DBH CLASSES FOR A TWO-MAN CREW

DBH CLASS		EFFECTIVE TIME in minutes	
(in)	(cm)	LEVEL - I	LEVEL - II
10	25.4	5.76	14.46
12	30.5	7.99	18.21
14	35.6	10.23	21.96
16	40.6	12.46	25.71
18	45.7	14.69	29.45
20	50.8	16.93	33.20
22	55.9	19.16	36.95
24	61.0	21.40	40.95

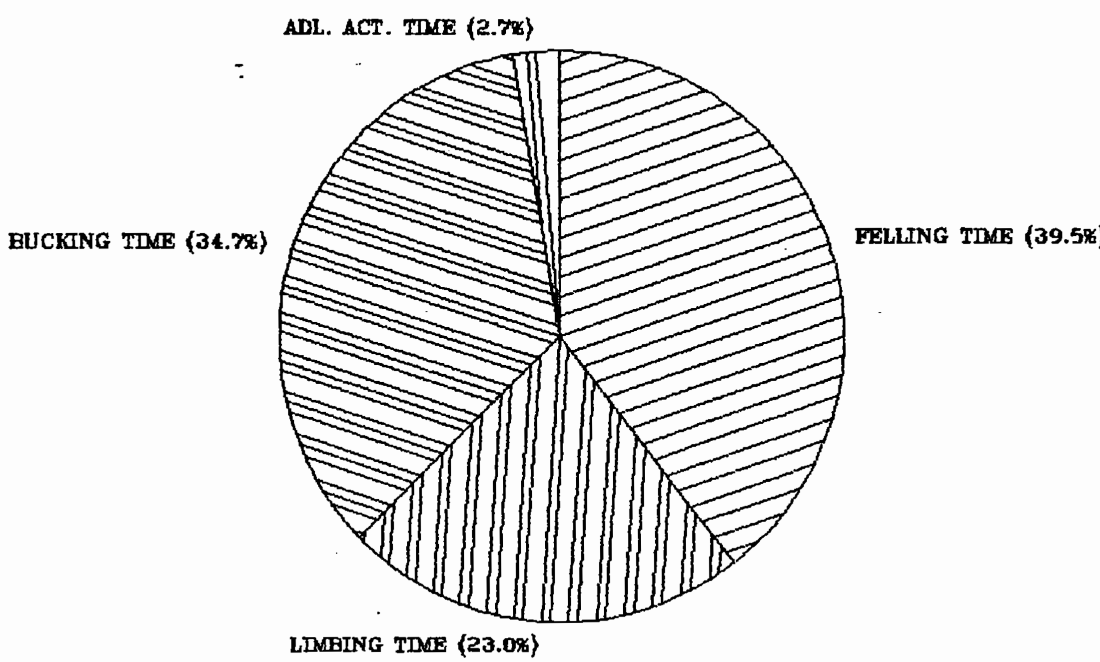
The above table indicates a decrease in the effective time for all DBH classes for Level - I from Level - II. This

FIG. 17

BREAK-UP OF EFFECTIVE TIME
FOR AN AVERAGE WORK CYCLE



LEVEL - I (Chain saw operation)



LEVEL - II (Manual Tools operation)

decrease is about 60 % for the small trees and about 47% for large trees. Fig. 17 indicates the break-up of the effective time, in percent form, for an average work cycle (DBH 16 inches) for both the levels.

9.4.7 DBH of trees and Total Work Cycle Time

Total work cycle time consists of the timings of all the work elements of the work cycle, including delay time. Its relation with the DBH of the trees is found with the help of the following two regression equations.

For Chain saw : $Y = -8.99272 + 2.42210\ DBH$

For Manual tools : $Y = -0.66344 + 2.39817\ DBH$

Table - 19, which is the result of the above regression equations, indicates the total estimated time of felling and conversion of trees for the two levels of study.

TABLE - 19

ESTIMATED TOTAL TIME FOR THE VARIOUS DBH CLASSES FOR A TWO-MAN CREW

DBH CLASS		TOTAL TIME in minutes	
(in)	(cm)	LEVEL - I	LEVEL - II
10	25.4	15.23	23.32
12	30.5	20.07	28.11
14	35.6	24.92	32.91
16	40.6	29.76	37.71
18	45.7	34.61	42.50
20	50.8	39.45	47.30
22	55.9	44.29	52.10
24	61.0	49.14	56.89

The above table indicates the decrease in the total time of felling and conversion of trees with the use of chain saw. This decrease, for small trees with DBH of 10 inches, is 35 % and for large trees with DBH of 24 inches, is 14 % less from the total time of manual tools. This decrease would be even greater if the delay time involved in the chain saw operation is reduced.

9.4.8 Efficiency Results - Test of Significance

The regression equations, obtained for the all above stated work elements are listed in Table - 20 & 21, for Level - I and II respectively. The values of coefficient of correlation "r" and the coefficient of determination "R^2" are also given along

TABLE - 20

REGRESSION ANALYSIS BETWEEN DBH AND THE TIMINGS OF DIFFERENT VARIABLES FOR THE CHAIN SAW OPERATION (LEVEL - I)

IND. VARIABLE	DEP. VARIABLES	REGRESSION EQUATION (Y = a + b X)	" r "	"R^2" %	SIGNFC. LEVEL
DBH	FELL TIME	= -3.75257 + 0.487834 DBH	+ 0.92	84.79	99 %
	LIMB TIME	= -1.78508 + 0.373783 DBH	+ 0.79	63.15	99 %
	BUCK TIME	= -1.66916 + 0.288619 DBH	+ 0.78	60.48	99 %
	* AD. ACT. TM	= Mean value : 1.29 minut	-	-	-
	EFF. TIME	= -5.41716 + 1.11732 DBH	+ 0.82	66.93	99 %
	DEL. TIME	= -3.57556 + 1.30478 DBH	+ 0.31	9.40	99 %
	TOT. TIME	= -8.99272 + 2.4221 DBH	+ 0.49	24.41	99 %

* Additional activities and Tree DBH are not correlated therefore the mean value of additional activities time is taken.

TABLE - 21

REGRESSION ANALYSIS BETWEEN DBH AND THE TIMINGS OF DIFFERENT VARIABLES FOR THE MANUAL TOOLS OPERATION (LEVEL - II)

IND. VARIABLE	DEP. VARIABLES	REGRESSION EQUATION (Y = a + b X)	" r "	"R^2" %	SIGNFC. LEVEL
DBH	FELL TIME	= 1.85905 + 0.523725 DBH	+ 0.76	57.69	99 %
	LIMB TIME	= -5.58017 + 0.712757 DBH	+ 0.87	76.41	99 %
	BUCK TIME	= 0.04466 + 0.557042 DBH	+ 0.71	50.14	99 %
	AD. ACT. TM	= -0.59732 + 0.080159 DBH	+ 0.36	13.05	95 %
	EFF. TIME	= -4.27378 + 1.87368 DBH	+ 0.92	85.23	99 %
	DEL. TIME	= 3.61034 + 0.524486 DBH	+ 0.39	15.44	99 %
	TOT. TIME	= -0.66344 + 2.398170 DBH	+ 0.86	73.44	99 %

with their level of significance. All the values of "r" are found significant at 99 % level (Significance level Table, Appendix - V) except the value of "r" for DBH and Additional Activities time for Level - I (Chain saw Operation). This association is found very weak and also negative. As stated earlier, one of the components of additional activities is the "hang-ups" of trees, which is more frequent in small size trees in a dense forest. That may be the possible cause of comparatively more additional activities time for smaller trees than the large ones, in the Level - I. This situation needs further investigation and time study.

9.5 Productivity - Calculation of

For the estimation of Total Productivity and Effective time Productivity of the two-man crew for both the levels, the fitted or estimated values of total cycle time and total effective time are taken into consideration. The volume produced in unit time, for each work cycle is calculated in the main spreadsheet of the data. The unit of volume is cubic feet and the unit of time is hour. The formulas used for the calculation of productivities are:

For Total Time Productivity of a Work Cycle

$$= \frac{\text{Total volume of the tree in cft.} * 60}{\text{Total time of Work Cycle in minutes}} = \text{cft/hr.}$$

For Effective Time Productivity of a Work Cycle

$$= \frac{\text{Total volume of the tree in cft.} * 60}{\text{Total Effective time of cycle in minutes}} = \text{cft/hr.}$$

Table - 22 shows the productivity of a two-man crew for both, within and between the study and working levels. In case of average total time productivity of two-man crew, between the two levels (chain saw operation and manual tools operation) the difference is 18.01 cft./hr. which is about 28.73 % more for the chain saw operation. While the difference of total effective time productivity between the two levels is 83.29 cft./hr. which is 91.76 % more in case of chain saw operation.

TABLE - 22

PRODUCTIVITY OF TWO-MAN CREW FOR LEVEL - I & II

TYPE OF LEVEL	TOTAL TIME PRODUCTIVITY cft./hr.	(cu.m/hr)	EFFECTIVE TIME PRODUCTIVITY cft./hr.	(cu.m/hr)	DIFFERENCE %
I	80.69	(2.28)	174.06	(4.93)	115.7
II	62.68	(1.77)	90.77	(2.57)	44.8
DIFFERENCE %	28.73		91.76		

While considering the average productivity within the two levels (productivity for total cycle time and productivity of total effective time) the difference in the two productivities, for chain saw operation is 93.37 cft./hr. which is about 115.7 % more in case of effective time productivity than the total time productivity. For Level - II, this difference is 28.09 cft./hr. which is about 44.8 % more for effective time productivity as compared to total time productivity.

9.6 COST of Work Elements

The estimation of costs of different work elements, the cost per unit time of the equipment and tools including crew, is found by using the " PACE " software, developed by Prof. John Sessions of OSU. The complete output of the computer is given as Appendix - 2 and 3. For the input of the "PACE", the following cost values, prevailing at this time, and quantities, are used:

9.6.1 Level - I, Cost Values

Machine & Equipment

- Delivered cost of Chain saw.	Rs:	13,600.00
- Salvage value	Rs:	1,000.00
- Life of machine, in years.	yr:	3
- Number of days worked/year	da:	200
- Number of hours worked/day	hr:	7
- Interest expenses	% :	10
- Repair in percent of equipment depreciation	% :	80
- Fuel consumption gallon/hr.	gl:	0.20
- Cost of fuel per gallon.	Rs:	34.00
- Lubricant,% of fuel consumption	% :	25
- Cost of lubricant per gallon	Rs:	81.00
- Cost of spare guide bar	Rs:	200.00
- Estimated life of Guide bar	hr:	300
- Cost of spare chain/Sprocket	Rs:	200
- Life of chain/Sprocket	hr:	300

Crew Cost

- Base wage of Ist Operator/hr.	Rs:	4.50
- Base wage of 2nd Operator/hr.	Rs:	4.50
- Fringe benefits, % of wage	% :	45
- Daily time of work, hr.	hr:	7
- Supervision cost, % of direct labor cost	% :	10

9.6.2 **Level - II, Cost Values**

Tools & Equipment

- Cost of Saw & Axes etc:	Rs:	500.00
- Salvage value	Rs:	0.00
- Life of tools, in years	yr:	5
- Number of days worked, days	dy:	200
- Number of hours per day worked	hr:	7
- Interest rate	% :	10
- Storage etc:	% :	2
- Repair in % of equipment depreciation	% :	20
- Diesel for cleaning saw	gl:	0.20
- Diesel cost per gallon	Rs:	30.00
- Cost of triangular file	Rs:	200.00
- Life of triangular file	hr:	50
- Cost of handles etc.	Rs:	10.00
- Life of handles	hr:	200

Crew Cost

- Base wage for Ist labor/hr.	Rs:	7.14

- Base wage for 2nd labor/hr. Rs: 7.14
- Working time per day. hr: 7
- Supervision cost (% of labor) % : 10

On the basis of above costs and quantities, the output of PACE for the two study levels is as under:

- Level - I (Chain saw operation), with two-man crew,

  Rs: 32.61 per hour OR

  Rs: 0.5433 per minute

- Level - II (Manual tools Operation), with two-man crew,

  Rs: 23.87 per hour OR

  Rs: 0.3978 per minute

For the above labor cost calculation, the hourly wages of chain saw operator, Rs. 4.15 are calculated from his monthly salary. The 45 % fringe benefits include the prevailing allowances for Government servants. He is also entitle to avail 20 days casual leave and about one month earned leave in a year. On the other hand a manual tree faller is given a sum of Rs. 50.00 per day or Rs.7.14 per hour. These per hour wages of both the workers are more or less identical if the extra benefits of the chain saw operator are included in his wages. As a sensitivity analysis, if the chain saw operator wages are also kept at Rs. 7.14, then the per hour operational cost of chain saw would be Rs. 33.96 instead of 32.61. (4 % increase) For the further cost calculation and comparison between the two study level, the method of regression analysis is used. The volume of trees in cubic feet is taken as independent variable and the cost which is calculated from the estimated time of various work elements, is taken as dependent variable. The relationship between independent and dependent variables is measured by using the Statgraphic software package for the multiplicative linear regression model of the form Y = a * X^b. The trend of the plotted points clearly reflect the curve instead of straight line and hence the multiplicative model is used for the estimations of the cost of all work elements. In this model the value of " a " is always equal to log a.

9.7 Felling cost and Volume of tree

The relationship between felling cost and the volume of trees is found by using the multiplicative form of regression equation, for both study levels. The felling cost predicting equations, derived from the output of computer, are:

For chain saw : $Y^{*} = (e)^{-1.797290} * (VOL)^{0.709009}$

For manual tools: $Y = (e)^{0.449187} * (VOL)^{0.267880}$

From the above equations, the following felling cost Table - 23 is prepared against the trees of various volumes.

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* For all estimated cost equations, Y = cost in Rupees/tree and volume is in cubic feet/tree. Conversion factor for cu.ft. to cu.m. is given in Appendix - VIII, page 131.

TABLE - 23

ESTIMATED FELLING COST AND THE TREE VOLUME

TREE VOLUME		FELLING COST in Rupees	
cft.	cu.m.	LEVEL - I	LEVEL - II
5.00	0.142	0.52	2.41
10.00	0.283	0.85	2.90
20.00	0.566	1.39	3.50
30.00	0.850	1.85	3.90
35.31	1.000	2.07	4.07
40.00	1.133	2.27	4.21
50.00	1.416	2.65	4.47
60.00	1.699	3.02	4.69
70.00	1.982	3.37	4.89
80.00	2.265	3.70	5.07
90.00	2.549	4.03	5.23
100.00	2.832	4.34	5.38
110.00	3.115	4.64	5.52
120.00	3.398	4.94	5.65

The difference in the felling costs of the two levels is quite clear. For instance the felling cost of a tree with a volume of 35.3146 cft. (1.00 c.m.) would be 49 % less in case of chain saw operation than the manual tools. The amount of this difference is greater in the smaller trees and getting lesser for the larger trees.

9.8 Limbing cost and volume of Trees

For finding out a relation between the limbing cost with the change of tree volume, for the two study level, the multiplicative regression analysis is used. The predicting equations for the estimation of limbing cost for the two levels are as under:

For chain saw : $Y = (e)^{-0.97461} * (VOL)^{0.496648}$

For manual tools: $Y = (e)^{-1.80399} * (VOL)^{0.724586}$

Table - 24, based upon the above predicting equations, shows the limbing costs for various tree volumes for the two study levels.

TABLE - 24

ESTIMATED LIMBING COST AND THE TREE VOLUMES

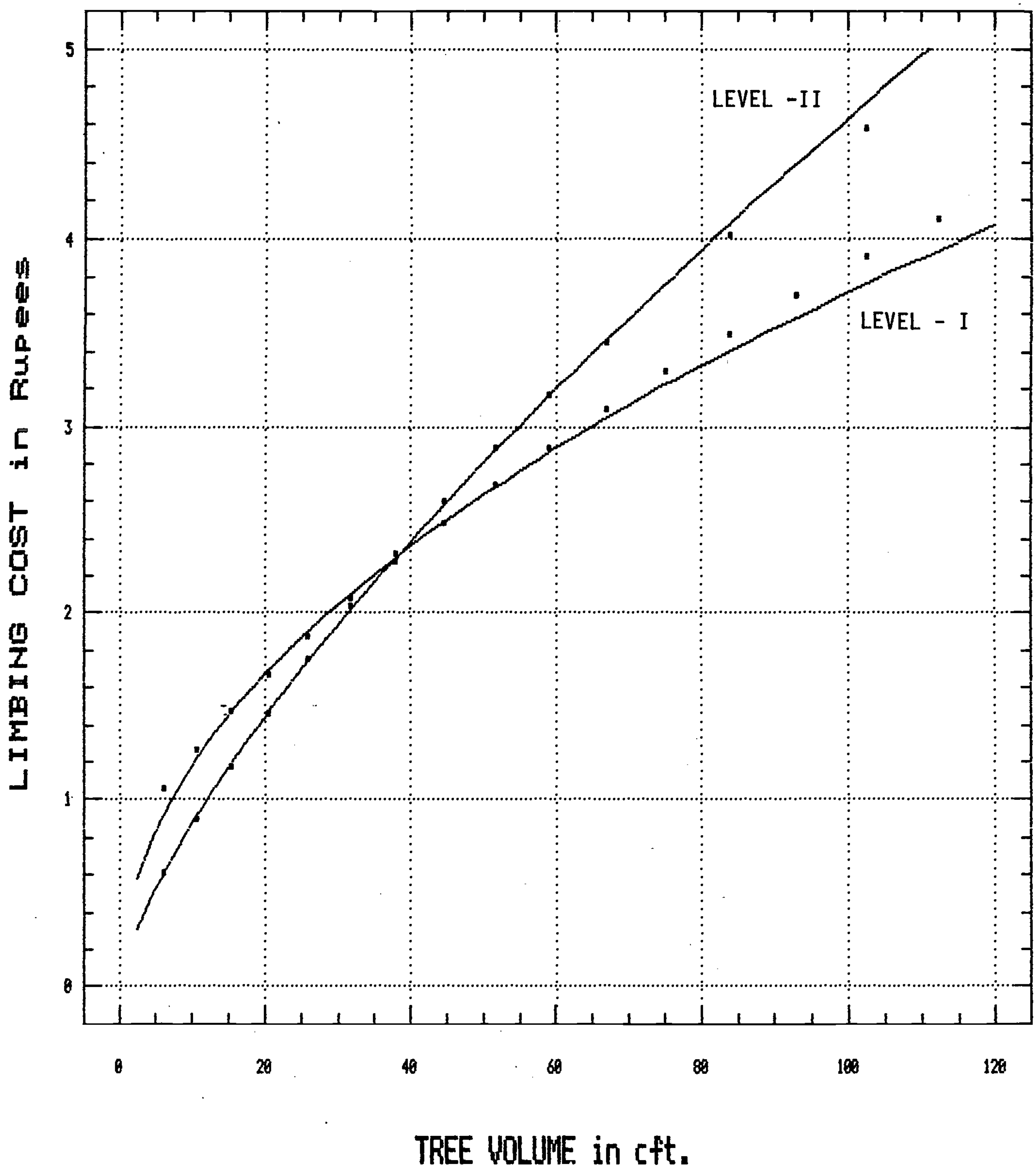
TREE VOLUME		LIMBING COSTS in Rupees	
cft.	cu.m.	LEVEL - I	LEVEL - II
5.00	0.142	0.84	0.53
10.00	0.283	1.18	0.87
20.00	0.566	1.67	1.44
30.00	0.850	2.04	1.94
35.31	1.000	2.22	2.17
40.00	1.133	2.36	2.38
50.00	1.416	2.63	2.80
60.00	1.699	2.88	3.20
70.00	1.982	3.11	3.58
80.00	2.265	3.33	3.94
90.00	2.549	3.53	4.29
100.00	2.832	3.72	4.63
110.00	3.115	3.90	4.96
120.00	3.398	4.07	5.29

9.8.1 Break-even Analysis of Limbing Costs

From the above table, it would be interesting to note that for the lower volume levels the limbing cost of level - II (manual tools) are less than the limbing costs of Level - I (chain saw). This trend goes up to the tree volume of 38 cft. (1.076 cu.m.) i.e. up to 16 inches DBH level, which indicates that the use

FIG. 18

LIMBING COST VS TREE VOLUME FOR CHAIN SAW AND MANUAL TOOLS OPERATION



LEVEL - I & II

of manual tools will be more economical for trees with 38 cft. volume or less (16 inches DBH or less). This break even point is also made clear from the cost curves of the two study levels in Fig. 18.

9.9 Bucking costs and volume of trees

For the estimation of bucking costs of the two levels of the study, the predicted bucking time is taken into account for cost calculation. The relation between tree volume and the bucking cost is found by using the multiplicative regression equations derived from the regression analysis. The equations used for the two study levels are as under:

For Chain saw : $Y = (e)^{-1.533470} * (VOL)^{0.552419}$

For Manual Tools : $Y = (e)^{0.094084} * (VOL)^{0.328840}$

Table - 25, gives the bucking costs of trees with different volumes for the two levels.

TABLE - 25

ESTIMATED BUCKING COSTS AND THE TREE VOLUMES

TREE VOLUME		BUCKING COST in Rupees	
cft.	cu.m.	LEVEL - I	LEVEL - II
5.00	0.142	0.52	1.86
10.00	0.283	0.77	2.34
20.00	0.566	1.13	2.94
30.00	0.850	1.41	3.36
35.31	1.000	1.55	3.55
40.00	1.133	1.66	3.70
50.00	1.416	1.87	3.98
60.00	1.699	2.07	4.22
70.00	1.982	2.26	4.44
80.00	2.265	2.43	4.64
90.00	2.549	2.59	4.82
100.00	2.832	2.74	5.00
110.00	3.115	2.90	5.15
120.00	3.398	3.04	5.30

Bucking costs, with chain saw, are much less than the manual tools working. At lower level i.e. for small trees with 5 cft. volume this decrease in bucking cost with chain saw is about 72 % and for large trees this decrease is about 42 %.

9.10 Additional Activities cost and Tree Volume

As stated earlier, additional activities time for chain saw operation is not related to the tree DBH or to the tree volume. Therefore its mean value is used for the cost calculation of additional activities for Level - I.

For chain saw : Y = Rs. 0.70, for all volumes.

For manual tools operation, where the two variables are having a correlation, the following cost equation is found from the regression model Y = a*X^b.

For manual tools : $Y = (e)^{-3.782190} * (VOL)^{0.681535}$

From these equations, the estimated cost of additional activities for different tree volumes are calculated and are shown in Table - 26. For Level - I the cost for additional activities is constant for all tree volumes but for Level - II it increases with the increase of volume.

TABLE - 26

ESTIMATED COST OF ADDITIONAL ACTIVITIES AND TREE VOLUME

TREE VOLUME		ADDITIONAL ACTIVITIES COST in Rupees	
cft.	cu.m.	LEVEL - I	LEVEL - II
5.00	0.142	0.70	0.07
10.00	0.283	0.70	0.11
20.00	0.566	0.70	0.18
30.00	0.850	0.70	0.23
35.31	1.000	0.70	0.26
40.00	1.133	0.70	0.28
50.00	1.416	0.70	0.33
60.00	1.699	0.70	0.37
70.00	1.982	0.70	0.41
80.00	2.265	0.70	0.45
90.00	2.549	0.70	0.49
100.00	2.832	0.70	0.53
110.00	3.115	0.70	0.56
120.00	3.398	0.70	0.59

9.11 Effective Time Costs and the tree volume

Effective time is the sum of the time of all those work elements which are related to productivity, such as felling time, limbing time, bucking time and additional activities time. The regression equations for the effective time cost and the tree volumes are:

For Chain saw : $Y = (e)^{0.100560} * (VOL)^{0.500262}$

For Manual tools : $Y = (e)^{0.924528} * (VOL)^{0.390060}$

On the basis of these equations the following Table - 27 gives the estimated effective time costs for different tree volumes.

TABLE - 27

ESTIMATED EFFECTIVE TIME COST AND THE TREE VOLUMES

TREE VOLUME		EFFECTIVE TIME COST in Rs.	
cft.	cu.m.	LEVEL - I	LEVEL - II
5.00	0.142	2.47	4.72
10.00	0.283	3.50	6.19
20.00	0.566	4.95	8.11
30.00	0.850	6.06	9.50
35.31	1.000	6.58	10.12
40.00	1.133	7.00	10.63
50.00	1.416	7.83	11.59
60.00	1.699	8.57	12.45
70.00	1.982	9.26	13.22
80.00	2.265	9.90	13.93
90.00	2.549	10.50	14.58
100.00	2.832	11.07	15.19
110.00	3.115	11.61	15.77
120.00	3.398	12.13	16.31

Above table indicate a decrease in effective time costs for all trees volumes in Level - I as compared to Level - II. At lower volume levels, say 5 cft. (0.142 cu.m.), this decrease is about 48 % than the manual tools cost. On the higher levels, i.e. 120 cft. (3.398 cu.m.) this decrease in chain saw cost is about 26 % of the manual tools cost.

9.12 Delay time Cost and the Tree Volume

Delay time of a work cycle consists of personal delay, operational delay and the time used in preparation. Delay time cost is calculated by taking the product of estimated delay time and per minute cost of the equipment/tools plus labor for the respective level. To find a relation between delay time cost and volume of tree, the linear regression analysis is performed, which has given the following multiplicative regression equations for the two study levels:

For chain saw : $Y = (e)^{0.746690} * (VOL)^{0.413958}$

For manual tools : $Y = (e)^{0.753297} * (VOL)^{0.227690}$

Table - 28, which is the result of the above equations, indicates the delay time costs for different tree volumes, in the two study levels.

TABLE - 28

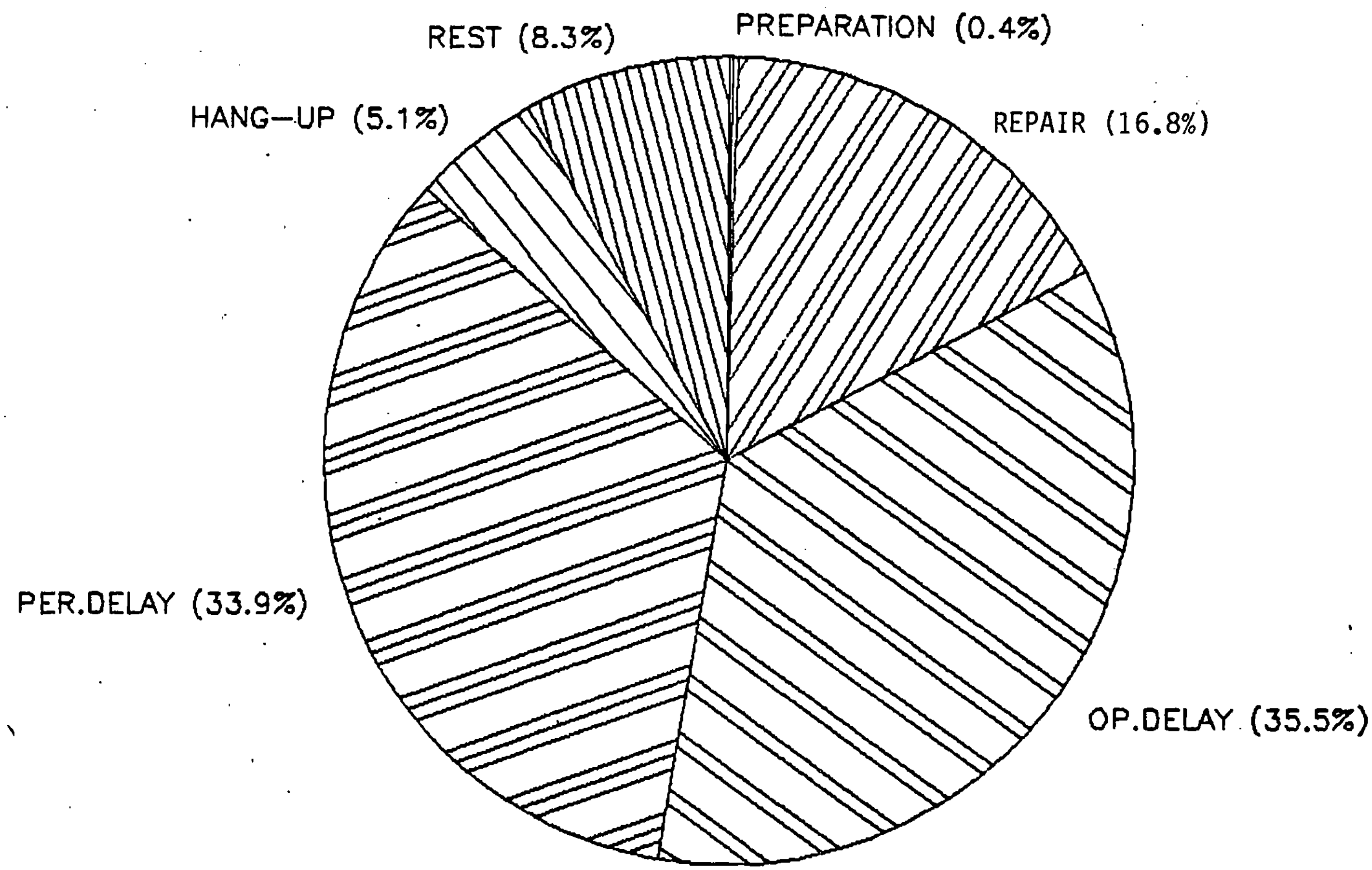
ESTIMATED DELAY TIME COSTS AND THE DIFFERENT TREE VOLUMES

TREE VOLUME		DELAY TIME COSTS in Rupees	
cft.	cu.m.	LEVEL - I	LEVEL - II
5.00	0.142	4.11	3.06
10.00	0.283	5.47	3.59
20.00	0.566	7.29	4.20
30.00	0.850	8.62	4.61
35.31	1.000	9.23	4.78
40.00	1.133	9.72	4.92
50.00	1.416	10.66	5.18
60.00	1.699	11.49	5.40
70.00	1.982	12.25	5.59
80.00	2.265	12.94	5.76
90.00	2.549	13.59	5.92
100.00	2.832	14.20	6.06
110.00	3.115	14.77	6.19
120.00	3.398	15.31	6.32

Table indicates an increase in the Level - I costs as compared to Level - II. This increase at lower volume levels is about 34 % and at higher volume levels this increase is about 142 %. It is due to the high delays involved in chain saw operations. For an average work cycle of chain saw the distribution of delay time is shown in Fig: 19.

BREAK-UP OF CHAIN SAW DELAY TIME
FOR AN AVERAGE WORK CYCLE

FIG. 19



From this Figure it can be observed that about 86 % of the delay time is associated with the operational, personal and repair delays. Operational delays are mainly waiting of a worker due to the completion of another job. The time of this delay can be reduced considerably by improving the working methods. During the waiting period the second worker can work on the next tree or instead of finishing a whole tree workers can fell two tress and then can start limbing and bucking on individual tree. In future the use of one man for the felling and conversion job will also change the present situation. For the reduction of personal delay, there are a number of factors which can effect the duration of this element.

- Chain saw is a comparatively heavy and fast operating machine and requires a good physique and health. Weak and physically small operators will soon be exhausted and this will effect their productivity and efficiency. Hence it is suggested that at the time of recruitment, well built and young people should be selected for the job of Chain saw operators.

- Fix a daily work target to be achieved by each worker and some incentive may be given for the fulfillment of that target.

- Vocational Training is a must for the chain saw operators. By this they can learn new methods and techniques for the easy and safe felling and conversion of trees which is very important from the ergonomics point of view. This will also help in reducing the personal delay.

The reduction repair and maintenance delay time is also a part of vocational training. To keep the machine in its perfect running condition is the duty of operator. The setting of proper sharpening angles of saw chain cutters will effect the quality of cut, save cutting time and will be less tiring for the operator.

9.13 Total time cost and the tree Volume

For the estimation of the total cost for the different tree volume levels, the linear regression analysis is applied and the multiplicative linear model of the from Y = a * X^b is used to find the estimated costs of the total time of the all the work elements of a work cycle. The following two equation are derived.

For chain saw : $Y = (e)^{1.158390} * (VOL)^{0.449508}$

For manual tools: $Y = (e)^{1.502510} * (VOL)^{0.336785}$

From these equations, the total time costs of various tree volumes for the two study levels are calculated and are presented in Table - 29.

TABLE - 29

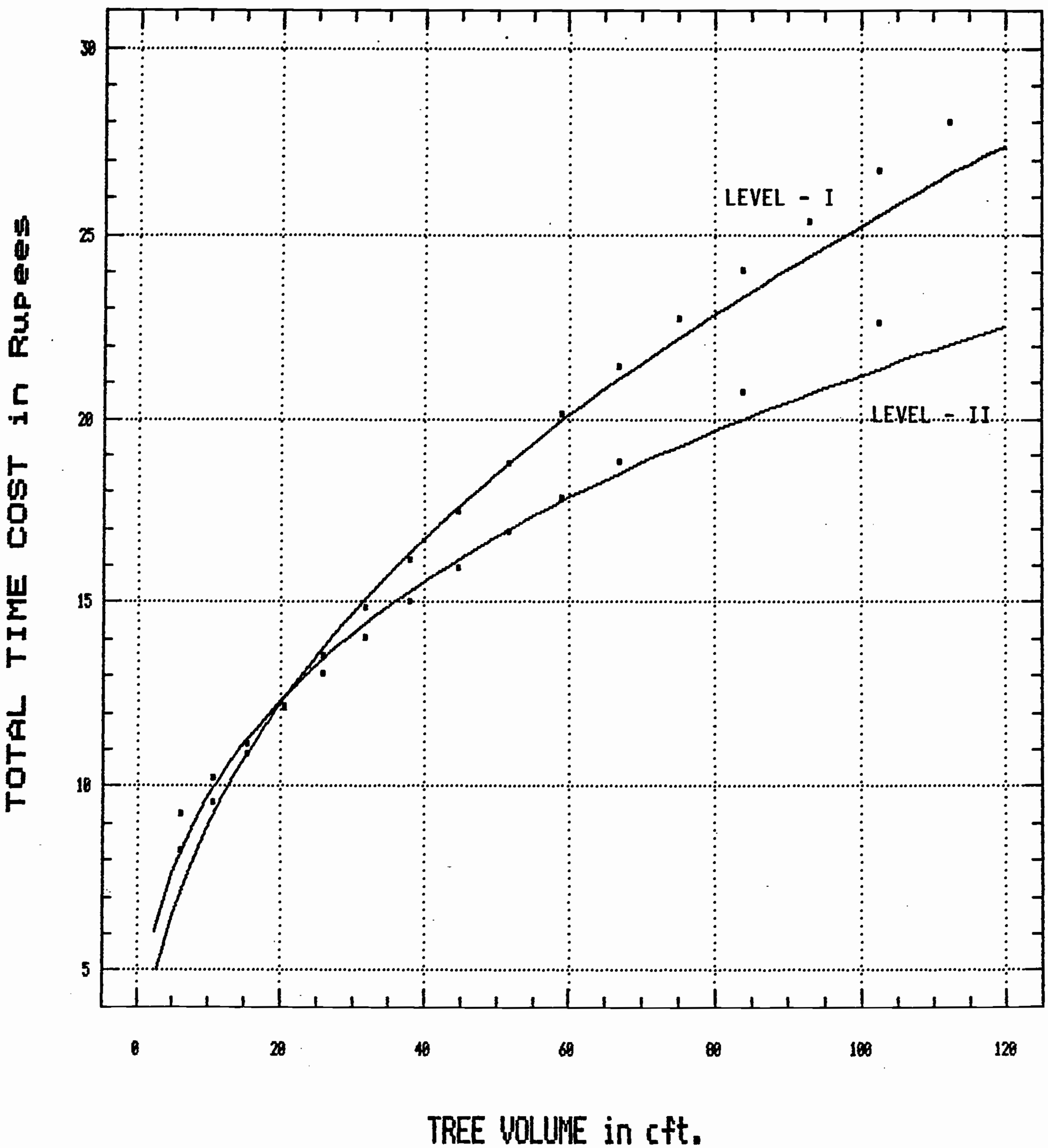
ESTIMATED TOTAL TIME COSTS AND THE TREE VOLUMES

TREE VOLUME		TOTAL TIME COSTS in Rupees	
cft.	**cu.m.**	**LEVEL - I**	**LEVEL - II**
5.00	0.142	6.57	7.73
10.00	0.283	8.99	9.76
20.00	0.566	12.24	12.32
30.00	0.850	14.69	14.13
35.31	1.000	15.81	14.92
40.00	1.133	16.72	15.56
50.00	1.416	18.48	16.78
60.00	1.699	20.06	17.84
70.00	1.982	21.50	18.79
80.00	2.265	22.83	19.65
90.00	2.549	24.07	20.45
100.00	2.832	25.24	21.19
110.00	3.115	26.35	21.88
120.00	3.398	27.40	22.53

From the above table it is evident that chain saw costs up to 20 cft. (0.566 cu.m.) volume are less than the manual tools costs and after that these costs increases with the increase of tree volume. The same results are illustrated in Fig. 20.

FIG. 20

RELATION OF TOTAL TIME COST VS VOLUME
FOR CHAIN SAW AND MANUAL TOOLS OPERATION



LEVEL - I & II

9.14 Estimated costs - A summary

The equations of the multiplicative regression models used for the estimation of the above costs, are statistically analyzed for their significance level along with the value of "r" the coefficient of correlation and "R^2" the coefficient of determination. Table - 30 and 31, consist of all these information. The values of "r" are found significant at 99 % level (Appendix V).

TABLE - 30

RESULTS OF REGRESSION ANALYSIS BETWEEN DBH AND THE COST OF DIFFERENT VARIABLES FOR THE CHAIN SAW OPERATION (LEVEL - I)

IND. VARIABLE	DEP. VARIABLES	REGRESSION EQUATION (Y = a * X^b)	" r "	"R^2" %	SIGNFC. LEVEL
VOLUME	FELL COST	=e^-1.79727 * VOL^0.709009	+ 0.99	99.97	99 %
	LIMB COST	=e^-0.97461 * VOL^0.496648	+ 0.99	99.44	99 %
	BUCK COST	=e^-1.53347 * VOL^0.552419	+ 0.99	99.69	99 %
	* AD.ACT.TM	= Rs. 0.70 for all volumes	-	-	-
	EFF. COST	=e^ 0.10056 * VOL^0.500262	+ 0.99	99.46	99 %
	DEL. COST	=e^ 0.74669 * VOL^0.413958	+ 0.99	98.94	99 %
	TOT. COST	=e^ 1.15839 * VOL^0.449508	+ 0.99	99.17	99 %

* No correlation is found between Additional Activities and Tree Volume hence the cost is calculated on the average time of the work element.

TABLE - 31

RESULTS OF REGRESSION ANALYSIS BETWEEN DBH AND THE COST OF DIFFERENT VARIABLES FOR THE MANUAL TOOLS OPERATION (LEVEL - II)

IND. VARIABLE	DEP. VARIABLES	REGRESSION EQUATION (Y = a * X^b)	" r "	"R^2" %	SIGNFC. LEVEL
VOLUME	FELL COST	=e^ 0.449187 * VOL^0.26788	+ 0.99	97.57	99 %
	LIMB COST	=e^-1.80399 * VOL^0.724586	+ 0.99	99.96	99 %
	BUCK COST	=e^ 0.094084 * VOL^0.32884	+ 0.99	98.20	99 %
	AD.ACT.C.	=e^-3.78219 * VOL^0.681535	+ 0.99	99.98	99 %
	EFF. COST	=e^ 0.924528 * VOL^0.39006	+ 0.99	98.74	99 %
	DEL. COST	=e^ 0.753297 * VOL^0.22769	+ 0.98	97.11	99 %
	TOT. COST	=e^ 1.50251 * VOL^0.336785	+ 0.99	98.28	99 %

Note: The value of intercept in equation Y = a * VOL^b is LOG a

10. DISCUSSION AND CONCLUSIONS

The present state of forest work and the workers, in developing countries like Pakistan, is poor. Very little attention has ever been given for the improvement of the harvesting operations due to the fact that all attention was paid to the management and silviculture. The forest workers are using the same century old technology for the harvesting of forests which are causing a good deal of wastage of timber and also are effecting the productivity of the forest workers. A decade ago, some developmental projects were started in the hilly forests areas of Pakistan, with the assistance of foreign agencies. Under these projects some new tools and equipment, including chain saws were introduced in the harvesting field. This study is also related to one of these developmental projects and the main objective is to compare the efficiency, productivity and cost of new tools and equipment with the conventional one.

This study, the first of its kind in Pakistan, is performed at a small scale and only in the Chir pine forest area of lower Siran Division. Hence its findings are not the final one and in a way it is the first step for further studies in other forest areas and for other species as well.

It would be interesting to compare the results of South African study (Zaremba, 1976) and the present study for the felling and limbing time with cross-cut-saw. Table 32, shows the felling and limbing time for both the studies.

TABLE - 32

FELLING & LIMBING TIME FOR CHIR PINE (Pinus roxburghii) WITH CROSS-CUT-SAW, IN PAKISTAN & SOUTH AFRICA

DIA. OF LOG (cm.)	(in.)	TWO-MAN CREW FELLING & LIMBING TIME in minutes IN PAKISTAN	IN SOUTH AFRICA
25.54	10.00	8.65	9.00
40.64	16.00	16.05	19.00
50.80	21.00	21.00	24.00
60.96	24.00	26.00	41.00

For trees of DBH up to 21 inches (51 cm.) the felling and limbing time is more or less same but for larger trees this time is 36 % less in case of present study. As stated earlier, there are many factors effecting the working time. This could be due to the difference of; terrain conditions, climate variation, type of tools and workers physique and experience.

The results of the present study, though indicating a favorable response for the chain saw use, have also indicated some major problems related to this first step towards mechanized harvesting. These problems are stated briefly and need further investigation.

10.1 High costs of new tools and equipment

Developing countries are usually not the producer or the manufacturer of these tools and equipment and hence they have to import all such material. They have to utilize their foreign exchange which is already a meager resource with developing countries. Other priorities preempt the purchase of forestry equipment using foreign exchange.

Chain saw is no longer considered a mechanized felling tool in developed countries of Europe and in North America. In these countries manual felling means felling with chain saw. But in underdeveloped or developing countries, like Pakistan this basic tools of harvesting is still out of the reach of common forest worker, due to its non-availability and also the high purchase cost compared to manual tools. This is a fact that in developed countries the 40 % of harvesting costs are related to machines and 60 % to the labors but in developing countries it is just the other way. The procurement of spare parts is another important issue. Many chain saws are lying unused due to the non-availability of spares or accessories.

10.2 Present system of Harvesting

In Pakistan harvesting of forests is still done under a contract system and contractors are unwilling to import chain saws themselves. Hence the only way to get benefitted from this important and useful equipment is through the Forest Departments and the Forest Development Corporation of NWFP. These agencies, particularly FDC, are still dealing with the foreign agencies in the country. They should start planning for the import of chain saws and spares under some easy financial terms. Also a long term agreement, most desirably with an assembling plant in Pakistan, would be the first step of transfer of technology. Instead of contractors, who took away the major part of the earnings of the forest workers, FDC should employ its own workers for harvesting of timber with chain saw. Pakistan Forest Institute, which is meant for the research and training purposes, can play an important role by providing training to the FDC workers. By this the workers productivity will increase, wastage of timber will reduce and with the passage of time the cost would also reduce. This would also have a positive effect on the wages of the forest workers.

10.3 Basic Education & Training for Chain saw

For the basic education of chain saw use, it should be included in the study and practical courses of the Provincial Forest Schools, where the foresters and forest guards are getting their education and training. A regular chain saw operators course should also be started as a long term planning for the future harvesting needs of the forests.

10.4 Instructional Manuals & Teaching Aids

In developing countries, like Pakistan the literacy rate is very low and in case of forest workers it is the least. It is therefore, essential to translate all the teaching aids material in the local languages. More emphasis should be given for the illustrative type of charts and slides shows or video films, for the better understanding of forest workers having a very nominal or no education. The instructional manuals of the equipment and machines should also be translated into local languages by the experts. It has been observed that sometime a qualified technician or foreman has problems understanding sophisticated instructional manuals in foreign languages.

10.5 Variety of Chain saws

At present there are several types of chain saws in the country which are imported by different organizations or by individuals. This includes German "Stihl", Polish, Russian, Swedish and also some American models. Most of these chain saws were without necessary kits and accessories. As a result some of them are out-of-service needing a new chain, sprocket or a carburetor kit. It is hard to arrange spares for all different type of chain saws in a developing country. It is therefore suggested that only one type of chain saw should be selected for import along with its accessories and spares. This will not only facilitate the repair and replacement but also will help the operators to get well acquainted with that type of chain saw.

10.6 Sociological effect

There is a general tendency, everywhere in the world to improve work, productivity and living conditions of forest workers by decreasing physiological work load. To get these objectives mechanization of work in logging operation is essential.

An increasing demand for wood requires a maximum utilization of wood produced by a stand. The use of chain saw will help to meet this demand by saving time and reducing wastage of timber in the forest.

Unemployment is a major problem especially in developing countries. But it is also a fact that with the increase of education level, though very small, young people have realized they could earn their living by jobs other than the back-breaking, strenuous and dangerous job of tree fallers. Situation like this was a serious problem for developed countries in 1960s. The only solution is to introduce mechanization which can reduce the intensity of hardships of work on one hand and increase productivity on the other. This will ultimately result in good salaries and better socio-economic status for workers.

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12. APPENDICES

APPENDIX - I

STEM *VOLUME (u.b.) TABLE

SPECIES : CHIR (*Pinus roxburghii*) **LOCALITY : SIRAN**

d.b.h. (cm)	Height (m)	Volume (cu.m)	
		Timber	Total
16	10.49	—	**0.170
18	12.33	—	**0.170
20	14.04	—	**0.170
22	15.62	0.021	**0.170
24	17.06	0.110	0.252
26	18.39	0.204	0.346
28	19.61	0.304	0.446
30	20.73	0.409	0.522
32	21.77	0.521	0.634
34	22.72	0.639	0.752
36	23.61	0.763	0.876
38	24.43	0.894	1.007
40	25.19	1.032	1.117
42	25.90	1.176	1.261
44	26.56	1.328	1.413
46	27.18	1.486	1.571
48	27.77	1.652	1.737
50	28.31	1.825	1.910
52	28.83	2.005	2.062
54	29.31	2.193	2.250
56	29.77	2.388	2.445
58	30.23	2.593	2.650
60	30.61	2.800	2.857
62	30.99	3.017	3.074
64	31.36	3.243	3.300
66	31.71	3.475	3.532
68	32.04	3.715	3.772
70	32.36	3.964	4.021
72	32.66	4.219	4.276
74	32.95	4.482	4.539
76	33.22	4.753	4.810
78	33.49	5.032	5.089
80	33.74	5.319	5.376
82	33.98	5.613	5.670
84	34.21	5.914	5.971
86	34.43	6.224	6.281
88	34.64	6.541	6.598

Source: Local Metric Volume Tables for Forest Tree Species in Hazara by Raja Walayat Hussain & Muhammad Afzal Cheema. PFI. 1978

APPENDIX - I (contd.)

d.b.h. (cm)	Height (m)	Volume (cu. m)	
		Timber	Total
90	34.85	6.867	6.924
92	35.05	7.200	7.257
94	35.24	7.541	7.598
96	35.42	7.890	7.947
98	35.60	8.247	8.304
100	35.77	8.612	8.669
102	35.93	8.983	9.040
104	36.09	9.364	9.392
106	36.24	9.751	9.779
108	36.39	10.147	10.175
110	36.54	10.552	10.580
112	36.67	10.962	10.990
114	36.81	11.383	11.411
116	36.94	11.810	11.838
118	37.06	12.244	12.683
120	37.19	12.689	12.717
122	37.31	13.141	13.169
124	37.42	13.589	13.626
126	37.53	14.065	14.093
128	37.64	14.540	14.568
130	37.75	15.024	15.052

Figures for height and volume were derived from metric equations :

$$V = -0.527365 + 0.018890\,H + 0.000274D^2 + 0.000016D^2\,H \quad \text{and}$$

$$\log H = 1.654990 - \frac{10.149758}{D}$$

based on British equations (3).

$$V = -18.623750 + 0.203335\,H + 0.062391\,D^2 + 0.110999\,\frac{D^2\,H}{100}$$

$$\log H = 2.170975 - \frac{3.995970}{D}$$

Total volumes obtained by addition of smallwood volume (1) in timber volume.

*To obtain overbark figures multiply values in the table by 1.35.

**Figures adopted.

APPENDIX - II

Chain Saw cost Calculation

Summary

*** CHAIN SAW "STIHL - 056 AVEQ" WITH TWO CREW MEMBERS ***

Ownership		
Depreciable value:	Rs	12,600.00
Equipment depreciation:	Rs	4,200.00 / Year
Interest expense:	Rs	940.00 / Year
Taxes, license, insurance and storage:	Rs	0.00 / Year
Annual ownership cost:	Rs	5,140.00 / Year
Ownership cost (Subtotal):	Rs	3.67 / Hour
Machine operating		
Repairs and maintenance:	Rs	2.40 / Hour
Fuel and oil:	Rs	10.85 / Hour
saw chain	Rs	0.67 / Hour
G. Bar & Sprocket	Rs	0.67 / Hour
Equipment operating cost (Subtotal):	Rs	14.58 / Hour
Labor		
Direct labor cost:	Rs	13.05 / Hour
Supervision and overhead:	Rs	1.31 / Hour
Labor cost (Subtotal):	Rs	14.36 / Hour
OWNERSHIP COST	Rs	3.67 / Hour
OPERATING COST	Rs	14.58 / Hour
LABOR COST	Rs	14.36 / Hour
Machine rate (Ownership + Operating + Labor)	Rs	32.61 / Hour

Equipment Ownership Costs

Delivered equipment cost	Rs	13,600.00
Minus line and rigging cost	Rs	0.00
Minus tire or track replacement cost	Rs	0.00
Minus residual (salvage) value	Rs	1,000.00
Life of equipment (Years)	#	3.00
Number of days worked per year	#	200.00
Number of hours worked per day	#	7.00
Interest Expense	%	10.00
Percent of average annual investment for: Taxes, License, Insurance, and Storage	%	0.00
Depreciable value:	Rs	12,600.00
Equipment depreciation:	Rs	4,200.00
Average annual investment:	Rs	9,400.00
Interest expense:	Rs	940.00
Taxes, license, insurance and storage:	Rs	0.00
Annual ownership cost:	Rs	5,140.00
Annual utilization (Hours per year):	#	1,400.00
Ownership cost (Dollars per hour):	Rs	3.67

APPENDIX - II (contd.)

Equipment Operating Costs

Percent of equipment depreciation for repairs	%	80.00
Fuel amount (Gallons per hour)	#	0.20
Fuel cost (Per gallon)	Rs	34.00
Percent of fuel consumption for lubricants	%	25.00
Cost of oil and lubricants (Per gallon)	Rs	81.00
Cost of Saw Chain	Rs	200.00
Estimated life of Chain (Hours)	#	300.00
Cost of	Rs	0.00
Estimated life of (Hours)	#	0.00
Cost of Guide bar & Sprocket	Rs	200.00
Estimated life of G. Bar & Sprocket (Hours)	#	300.00
Repairs and maintenance:	Rs	2.40
Fuel:	Rs	6.80
Oil and lubricants:	Rs	4.05
saw chain	Rs	0.67
	Rs	0.00
G.Bar & Sprocket	Rs	0.67
Equipment operating cost (Subtotal):	Rs	14.58

Labor Costs

Base wage for 1st crew position (Per hour)	Rs	4.50
Base wage for 2nd crew position (Per hour)	Rs	4.50
Base wage for 3rd crew position (Per hour)	Rs	0.00
Base wage for 4th crew position (Per hour)	Rs	0.00
Base wage for 5th crew position (Per hour)	Rs	0.00
Base wage for 6th crew position (Per hour)	Rs	0.00
Fringe benefits	%	45.00
Travel time per day (Hours)	#	0.00
Operating time per day (Hours)	#	7.00
Percent of direct labor cost for supervision	%	10.00
Total number of workers:	#	2.00
Total crew wage (Per hour):	Rs	9.00
Direct labor cost:	Rs	13.05
Supervision and overhead:	Rs	1.31
Labor cost (Subtotal):	Rs	14.36
Total operating cost (Operating+Labor):	Rs	28.94

APPENDIX - III

Manual Tools cost calculation

------------------------------------ Summary ------------------------------------

*** TWO-MAN CROSS CUT SAW (PEG-TOOTHED) AND AXE (LOCAL) WITH 2 WORKERS ***

Ownership		
Depreciable value:	Rs	500.00
Equipment depreciation:	Rs	100.00 / Year
Interest expense:	Rs	30.00 / Year
Taxes, license, insurance and storage:	Rs	6.00 / Year
Annual ownership cost:	Rs	136.00 / Year
Ownership cost (Subtotal):	Rs	0.10 / Hour
Machine operating		
Repairs and maintenance:	Rs	0.01 / Hour
Fuel and oil:	Rs	6.00 / Hour
triangular files	Rs	2.00 / Hour
handles	Rs	0.05 / Hour
Equipment operating cost (Subtotal):	Rs	8.06 / Hour
Labor		
Direct labor cost:	Rs	14.28 / Hour
Supervision and overhead:	Rs	1.43 / Hour
Labor cost (Subtotal):	Rs	15.71 / Hour
OWNERSHIP COST	Rs	0.10 / Hour
OPERATING COST	Rs	8.06 / Hour
LABOR COST	Rs	15.71 / Hour
Machine rate (Ownership + Operating + Labor)	Rs	23.87 / Hour

Equipment Ownership Costs

->Delivered equipment cost	Rs	500.00
Minus line and rigging cost	Rs	0.00
Minus tire or track replacement cost	Rs	0.00
Minus residual (salvage) value	Rs	0.00
Life of equipment (Years)	#	5.00
Number of days worked per year	#	200.00
Number of hours worked per day	#	7.00
Interest Expense	%	10.00
Percent of average annual investment for:		
Taxes, License, Insurance, and Storage	%	2.00
Depreciable value:	Rs	500.00
Equipment depreciation:	Rs	100.00
Average annual investment:	Rs	300.00
Interest expense:	Rs	30.00
Taxes, license, insurance and storage:	Rs	6.00
Annual ownership cost:	Rs	136.00
Annual utilization (Hours per year):	#	1,400.00
Ownership cost (Dollars per hour):	Rs	0.10

APPENDIX - III (contd.)

Equipment Operating Costs

->Percent of equipment depreciation for repairs	%	20.00
Fuel amount (Gallons per hour)	#	0.20
Fuel cost (Per gallon)	Rs	30.00
Percent of fuel consumption for lubricants	%	0.00
Cost of oil and lubricants (Per gallon)	Rs	0.00
Cost of tr angular Files	Rs	100.00
Estimated life of Files (Hours)	#	50.00
Cost of	Rs	0.00
Estimated life of (Hours)	#	0.00
Cost of handles	Rs	10.00
Estimated life of handles (Hours)	#	200.00
Repairs and maintenance:	Rs	0.01
Fuel:	Rs	6.00
Oil and lubricants:	Rs	0.00
triangular Files	Rs	2.00
	Rs	0.00
handles	Rs	0.05
Equipment operating cost (Subtotal):	Rs	8.06

Labor Costs

Base wage for 1st crew position (Per hour)	Rs	7.14
Base wage for 2nd crew position (Per hour)	Rs	7.14
Base wage for 3rd crew position (Per hour)	Rs	0.00
Base wage for 4th crew position (Per hour)	Rs	0.00
Base wage for 5th crew position (Per hour)	Rs	0.00
Base wage for 6th crew position (Per hour)	Rs	0.00
Fringe benefits	%	0.00
Travel time per day (Hours)	#	0.00
Operating time per day (Hours)	#	7.00
->Percent of direct labor cost for supervision	%	10.00
Total number of workers:	#	2.00
Total crew wage (Per hour):	Rs	14.28
Direct labor cost:	Rs	14.28
Supervision and overhead:	Rs	1.43
Labor cost (Subtotal):	Rs	15.71
Total operating cost (Operating+Labor):	Rs	23.77

SHEET NO: 12

APPENDIX - IV

TIME STUDY DATA SHEET

MANUAL TOOLS OPERATION

FOREST DIVISION: Lower Siran RANGE: Batrasi COMPTT. NO: 4(i)

STUDY LEVEL: II CREW SIZE: 2 DATE: Aug. 18, 1987

TIME INTERVAL: 0.5 mint: WEATHER: clear RECORDED BY: Ajmal

1 SL NO	2 TREE NO	3 TREE FEATURE	4 WORK CYCLE START	5 PREP TIME	6 OPR. DELAY	7 PERS. DELAY	8 WALK TO TREE	9 CLR. TIME	10 UNDER CUT TIME	11 BACK CUT TIME	12 LIMBING TIME AXE	13 LIMBING TIME SAW	14 BUCK TIME	15 ADL. ACTIVITY	17 TOTAL TIME
		DBH 16" HT: 83.41 VOL: 38.01	2.10 T: 32.0 %E = 1.59												
		POINT		-	20	16	2	-	8	32	12	-	34	2	126
		MINT:		-	5	4	.5	-	2	8	3	-	8.5	.5	31.5
		DBH 20 HT: 93.58 VOL: 66.91	2.42												
		POINT		-	16	8	4	4	16	24	8	32	48	8	118
		MINT		-	4	2	1	1	4	6	2	8	12	2	42

APPENDIX - IV (contd.)

SHEET NO: ________

TIME STUDY DATA SHEET
FOR CHAIN SAW OPERATION

FOREST DIVISION: ________ RANGE: ________ COMPTT. NO: ________

STUDY LEVEL: ________ CREW SIZE: ________ DATE: ________

TIME INTERVAL: ________ WEATHER: ________ RECORDED BY: ________

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17
SL NO	TREE NO	TREE FEA-TURE	WORK CYCLE START	PREP TIME	OPR. DELAY	PERS. DELAY	WALK TO TREE	CLR. TIME	UNDER CUT TIME	BACK CUT TIME	LIMBING TIME	BUCK TIME	ADL. ACTIVITY	TOTAL TIME	CH: SAW RUNNING TIME
		DBH													
		HT:													
		VOL:													
		POINT													
		MINT:													
		DBH													
		HT:													
		VOL:													
		POINT													
		MINT													

APPENDIX - V

TABLE Correlation coefficients at the 5% and 1% levels of significance

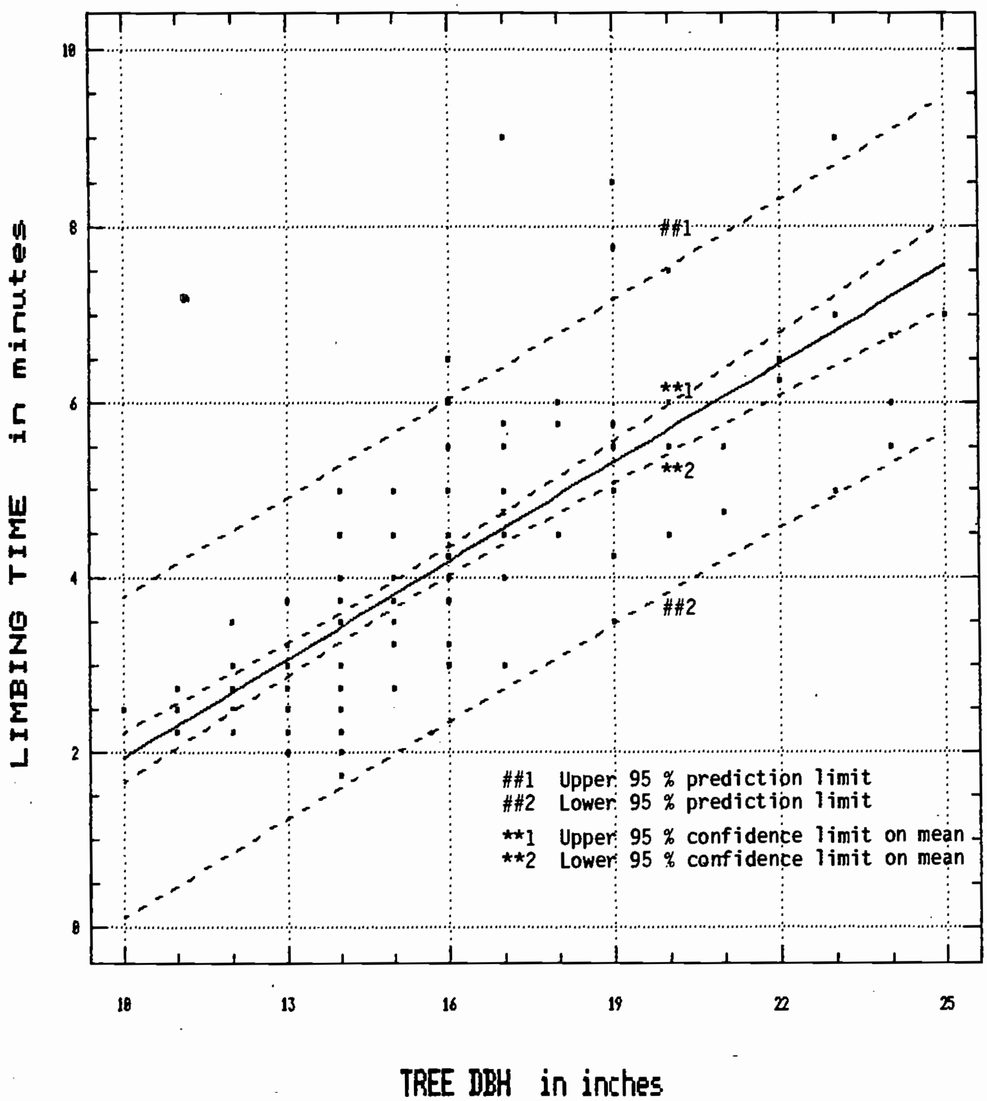
Example: **When *N* is 52 and *df* is 50, an *r* must be .273 to be significant at .05 level, and .354 to be significant at .01 level.**

Degrees of freedom $(N-2)$	.05	.01	Degrees of freedom $(N-2)$	.05	.01
1	.997	1.000	24	.388	.496
2	.950	.990	25	.381	.487
3	.878	.959	26	.374	.478
4	.811	.917	27	.367	.470
5	.754	.874	28	.361	.463
6	.707	.834	29	.355	.456
7	.666	.798	30	.349	.449
8	.632	.765	35	.325	.418
9	.602	.735	40	.304	.393
10	.576	.708	45	.288	.372
11	.553	.684	50	.273	.354
12	.532	.661	60	.250	.325
13	.514	.641	70	.232	.302
14	.497	.623	80	.217	.283
15	.482	.606	90	.205	.267
16	.468	.590	100	.195	.254
17	.456	.575	125	.174	.228
18	.444	.561	150	.159	.208
19	.433	.549	200	.138	.181
20	.423	.537	300	.113	.148
21	.413	.526	400	.098	.128
22	.404	.515	500	.088	.115
23	.396	.505	1000	.062	.081

Source: Garrett, Henry E. 1962. Statistics, in Psychology and Education.

APPENDIX - VI

REGRESSION OF LIMBING TIME ON TREE DBH FOR CHAIN SAW OPERATION

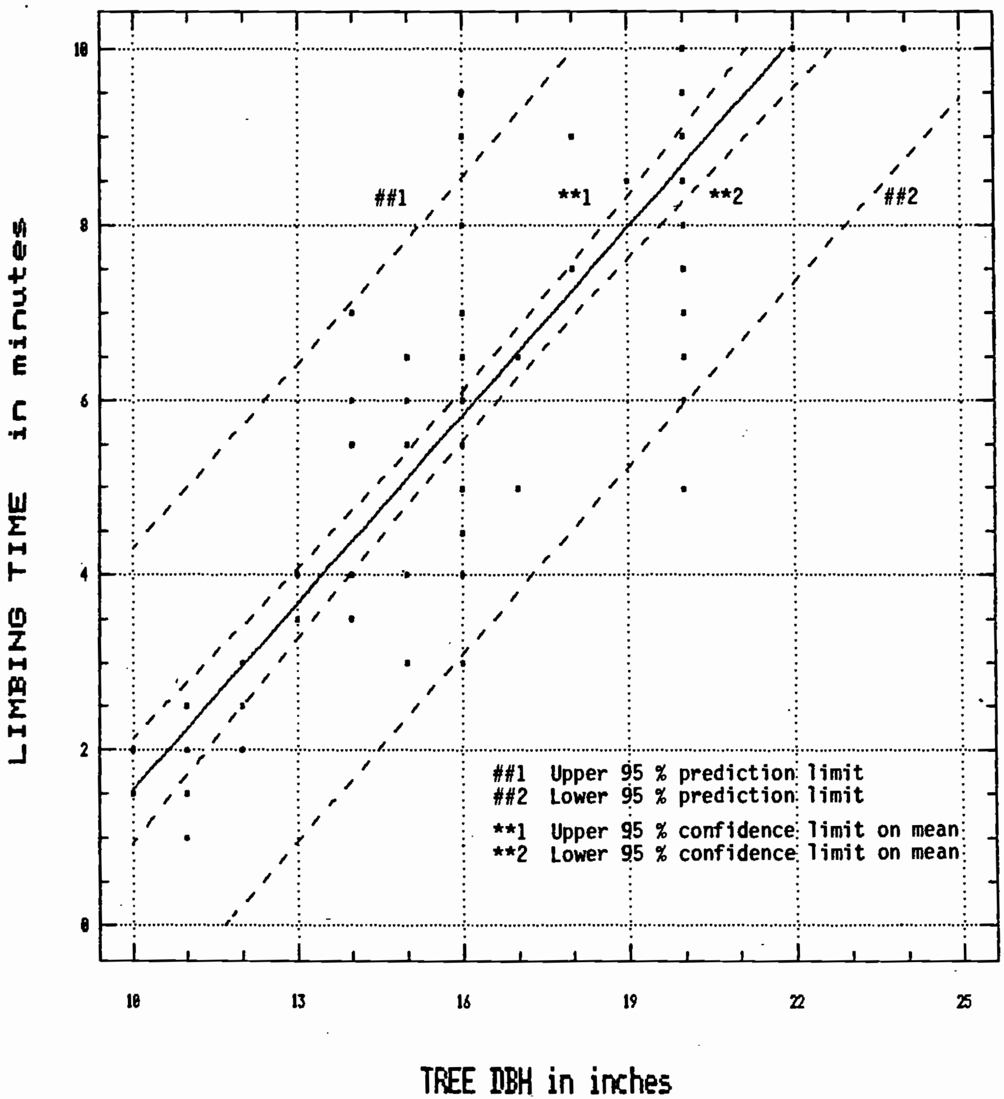


LEVEL - I

APPENDIX - VI (contd.)

REGRESSION OF LIMBING TIME ON TREE DBH

FOR MANUAL TOOLS OPERATION



LEVEL - II

APPENDIX - VII

TESTING FOR THE COMMON REGRESSION, FOR DBH OF
TREES VS LIMBING TIME, FOR CHAIN SAW AND MANUAL TOOLS

LINE #	LEVEL	d.f.	Σy^2	Σxy	Σx^2	residules d.f.	residules SS	residules MS	residules "F"
1.	I	139	318.25	537.65	1,438.40	138	117.29	-	-
2.	II	90	696.13	746.28	1,047.03	89	164.21	-	-
3.	POOLED RESIDULES					227	281.50	1.24	-
4.	DIFFERENCE FOR TESTING COMMON SLOPE					1	69.62	69.62	56.15 *
5.	COMMON	229	4,014.38	1,283.93	2,485.43	228	351.12	1.54	-
6.	DIFFERENCE FOR TESTING INTERCEPT					1	134.58	134.58	87.39 *
7.	AS SINGLE REGRESSION	230	1,277.92	1,424.10	2,559.98	229	485.70	-	-

*Significant at 1 % level.

APPENDIX - VII

(Continued)

DATA AND
FORMULAS USED IN CALCULATION:

	1. For Level - I (Chain saw operation)	2. For Level - II (Manual tools)
N =	140	91
ΣX = DBH of tree	= 2128	1489
ΣY = Limbing time	= 545.5	553.5
ΣXY =	8829.25	9803.00
ΣX^2 =	33784.00	25411.00
ΣY^2 =	2443.75	4062.75

$\Sigma x^2 = \Sigma X^2 - (\Sigma X)^2 / N$ $\Sigma y^2 = \Sigma Y^2 - (\Sigma Y)^2 / N$

$\Sigma xy = \Sigma xy - ((\Sigma X)(\Sigma Y)) / N$

$b = \Sigma xy / \Sigma x^2$

$a = \overline{Y} - b.\overline{X}$

$SS = (\Sigma xy)^2 / \Sigma x^2$

For combined data for a single linear regression:

$N = (140 + 91) = 231$ d.f. $= 230$

$\Sigma Y = (545.5 + 553.5) = 1099$, $\Sigma Y^2 = 6{,}506.50$, $\Sigma X = 3{,}617$,

$\Sigma y^2 = 6{,}506.5 - (1099)^2 / 231 = 1{,}277.92$, $\Sigma x^2 = 2559.98$

$\Sigma XY = (9803 + 8829.25) = 18{,}632.25$

$\Sigma xy = 18632.25 - (1099) * (3617) / 231 = 1424.10$

APPENDIX - VIII

CONVERSION TABLE

1. CURRENCY

1.1	Pakistani currency unit..................Rupee					
1.2	1 Rupee	=	0.0465 US $			
1.3	1 US $	=	21.50 Pak. Rupees			

2. UNITS OF LENGTH

2.1	1 in.	=	2.54 cm.	=	0.0254 meters	
2.2	1 ft.	=	30.48 cm.	=	0.3048 meters	
2.3	1 cm.	=	0.3937 in.	=	0.0328 ft.	
2.4	1 meter	=	39.37 in.	=	3.281 ft.	
2.5	1 mile	=	1608.64 meter	=	1.61 km.	
2.6	1 km.	=	1093.00 yards	=	0.62 mile	

3. UNITS OF AREAS

3.1	1 sq. in.	=	6.452	sq.cm.		
3.2	1 sq. ft.	=	929.0	sq.cm.	=	0.0929 sq.m.
3.3	1 sq. cm.	=	0.155	sq.in.		
3.4	1 sq. m.	=	1550.0	sq.in.	=	10.765 sq.ft.
3.5	1 acre	=	0.4047	hectare		
3.6	1 hectare	=	2.47	acres		
3.7	1 sq. mile	=	2.59	sq.km.		
3.8	1 sq.km.	=	0.386	sq.mile		

4. UNITS OF VOLUME

4.1	1 cu.in.	=	16.39	cu.cm.
4.2	1 cu.cm.	=	0.061	cu.in.
4.3	1 cu.ft.	=	0.0283	cu.m.
4.4	1 cu.m.	=	35.314	cu.ft.

5. UNITS OF TEMPARATURE

5.1 0° C = 32° F

5.2 100° C = 212° F

5.3 To convert Fahrenheit into Celsius: subtract 32, multiply by 5 and devide by 9

5.4 To convert Celsius into Fahrenheit: mutiply by 9, devide by 5 and add 32.