Silva Fennica 1987, vol. 21 n:o 2: 171–202

Studies on Tanzanian forest work

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SELOSTE: TUTKIMUKSIA METSÄTYÖSTÄ TANSANIASSA

Saarilahti, M., Bakena, E., Mboya, G., Minja, T., Ngerageze, T. & Ntahompagaze, J. 1987. Studies on Tanzanian forest work. Seloste: Tutkimuksia metsätyöstä Tansaniassa. Silva Fennica 21 (2): 171–202.

Four teams of two workers were timestudied in clearcutting of a cypress plantation and three teams in sulky skidding. The heart rate was recorded every 30 s. The average heart rate in timber cutting was 117.5 ±13.4 P/min, and it was mainly dependent on worker's working capacity. Average work load index was 41 ±2 % when working at 97 % performance. The production rate was then 2.5 m^3/h (crew). In sulky skidding the heart rate was lower, 106.1 ±1.1 P/min, as well as the work load (WLI 30 ±1 %) and performance rating (87 %). The low production rate (1.1 m^3/h (crew)) over 46 m distance is mainly due to underdimensioned load size. The energy expenditure in timber cutting was 21.4 kJ/min and in sulky skidding 16.3 kJ/min. Daily energy expenditure was 15.0 MJ/d, and most of the timber cutters belonged to the class "exceptionally active".

Neljää kahden miehen työryhmää seurattiin 16 päivän ajan istutetun sypressimetsikön avohakkuussa mittaamalla työvaiheajat aikatutkimuksin ja rekisteröimällä syketaajuus 30 s välein. Keskisyketiheys oli 117,5 ±13,4 P/min ja syketaajuus riippui lähinnä työntekijän suorituskyvystä. Kuormittuneisuusindeksi oli 41 ± % kun miehet työskentelivät lähes urakkatahdilla (joutuisuus 97 %). Työryhmän tuotos oli tällöin 2,5 m^3/h. Sulky-juonnossa syketaajuus (106,1 ±1,1), kuormittuneisuusindeksi (30 ±1 %) ja joutuisuus (87 %) olivat alempia kuin hakkuussa. Myös tuotos oli alhainen, 1,1 m^3/h 46 m juontomatkalla johtuen alamittaisesta keskikuormasta. Energian kulutus oli hakkuussa 21.4 kJ/min ja juonnossa 16,3 kJ/min. Päivittäinen energian kulutus oli 15,0 MJ, ja suurin osa hakkuumiehistä kuului "poikkeuksellisen aktiiviset" luokkaan.

Keywords: time study, production rate, heart rate, work load, performance rating, manual timber cutting, sulky skidding, energy expenditure
ODC 35+305+302+(678)

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Approved on 24. 6. 1987

1. Introduction

Labour intensive working methods are of great importance in many developing countries, in Tanzania for example. The need for intensifying the research in ergonomics in tropical forestry is evident (Strehlke 1971). Therefore ergonomics has been selected as one of the preferred areas in the research activities of the Faculty of Forestry at the Sokoine University of Agriculture (SUA), in Morogoro, Tanzania.

This paper is to introduce a current research project in Forest Engineering dealing with production rate, work load and energy expenditure of the Tanzanian forest workers engaged in manual timber cutting and sulky skidding.

This article is based on Special projects of five B.Sc. (For.) students, Bakena, Mboya, Minja, Ngerageze and Ntahompagaze, who collected the field data and wrote their projects individually. Saarilahti supervised the projects, carried out computations and wrote this report, based on the primary data presented by the students. The authors are indebted to the Faculty of Forestry for financing the data collection and permitting the publication of the report. Prof. M. Kärkkäinen, Dr. R. Ole-Meiludie and Pertti Harstela have read the manuscript and proposed appreciable corrections.

2. Data collection

The data were collected in the Sokoine University of Agriculture Training Forest, Olmotonyi, near the town of Arusha, in Northern Tanzania. The Training Forest is situated 36° 15' E and 3° 50' S, at the South-Western slopes of Mount Meru, the altitude varying from 1400 m to 2000 m above sea level. The forest is a man made coniferous plantation consisting mainly of *Pinus patula* and *Cupressus lusitanica* species. Soils are fine grained volcanic ashes.

The area experiences two rainy seasons separated by a long dry season in July–October. Generally the area has a favourable climate as far as working conditions are concerned. Mean annual rainfall is about 1000 mm and the monthly means of daily maximum temperature vary from 18.9 °C in July to 25.5 °C in February. Corresponding minima are 8.1 °C in July and 11.9 °C in April. Relative humidity ranges from 50 % in the afternoon to 80 % in the morning. The data was collected in February–March 1985. The measured temperatures inside the stand were between 16 and 18 °C when starting the daily work, and between 18 and 20 °C when finishing it. No risk of heat stress is thus evident (Axelson 1974).

Two different forest operations were studied:

- clearcutting of a mature cypress stand, and
- sulky skidding of thinnings in pine and cypress stands.

Time study, using continuous timing, was used to assess the time consumption. Heart rate was recorded using "Sport Tester", which registers the average heart rate over 5 s every 30 s, and the stored values can later be read from the memory (Saarilahti and Abeli 1985). In timber cutting the instrument was read after every tree, whereas in sulky skidding readings were taken after 0.5 – 1.0 h work. The heart rate readings were later allocated to the corresponding work elements. The production was assessed by measuring the logs: in timber cutting top and bottom diameter and length and in skidding the mid-diameter and length. The workers' maximum oxygen uptake (VO_2-max) was assessed using step test (Åstrand and Ryhming 1954) and walk test (Saarilahti 1986). The daily energy expenditure was established based on interviews concerning the daily activities of the workers, and on some time studies and heart rate registrations outside the salaried work.

The data analysis are based on stepwise regression analysis using 95 % confidence limit as an entering value. The non bias of the model was checked by plotting the residuals. A Hewlett Packard 85 microcomputer was used, and the programs were written by the author. The calculation methods are discussed more in detail when results are presented. In this study R^2 stands for (multiple) correlation coefficient squared · 100. Mean values are given either with their confidence limits at 95 % probability level or the standard deviation is given.

3. Timber cutting

31. Introduction

There are already several time studies concerning Tanzanian timber cutting. Abeli and Dykstra (1981) have studied logging in natural Miombo forests (hardwood savanna forests). Ole-Meiludie (1984) compared thinning methods both in pine and cypress stands. Migunga (1982, see also Migunga and Dykstra 1983), and Micski and Stridsberg (1981) have compared crosscut and chain saws in cutting of softwood plantations. Later some ergonomic studies have been added to time studies. Saarilahti and Abeli (1985) tested the heart rate recorder in cutting of cypress, and Saarilahti and Ole-Meiludie (1987) studied the production rate, heart rate and work load in clearcutting of pine plantation. Ergonomic aspects of Tanzanian forest work is discussed by Abeli (1979), and energy balance of Tanzanian forest workers has been studied by Abeli and Ndossi (1985).

32. Data presentation

Four teams (I–IV) of two workers (A, B) were studied, each man being followed during two days. The work consisted of clearcutting a mature (21 years old) *Cupressus lusitanica* stand. The cutting tools consisted of a Champion-toothed crosscut-saw, two axes and two wedges. Saws were generally in good condition, whereas the condition of axes was poor. There was no time lost due to delays for tool maintenance, as dull and broken saws were replaced every week and the maintenance was carried out at sawdoctor's workshop. Axe filing and minor repair was carried out by workers in their home. The workers worked under a daily task work of 9 trees/team except on Saturdays, when the task was 7 trees. The scheduled working day was 7:30–14:30 and 7:30–12.30 for weekdays and Saturdays respectively. Usually the task was finished in good time before noon. A light meal was provided at noon after which the workers left for home. The workers lived at a distance of about 4–5 km and they walked to and fro carrying their tools.

During the study, which lasted for 16 days the workers felled 125 trees and the total merchantable volume was 125.8 m^3. The workplace time was 54.04 crewhours, and the average WPT/d was 3.39 h.

Anthropometric data of the cutting crews is presented in Table 1. It is probable that the assessment of VO_2-max by step test contains some inaccuracy for 3 subjects (IIA, IVA and IVB), therefore walk test results are used for further analysis. For comparison with a previous study in Tanzania (Abeli and Ndossi 1985) and with Nordic forest workers Table 2 is presented. It can be seen that the Tanzanian workers are lighter, but their relative oxygen uptake is of the same magnitude as their Nordic workmates. However, due to the lower body weight, the working capacity is lower. The work experience was rather short due to large labour turnover. For training purposes a newcomer is usually put together with a more experienced worker. This has

Table 1. Anthropometric data of timber cutters.
Taulukko 1. Tekomiesten henkilötietoja.

Team/Worker *Työryhmä/ Tekomies*	Age *Ikä*	Weight *Paino*	Height *Pituus*	Experience *Työkokemus*	VO2-max *Hapenottokyky*			
					Walk test *Kävely testi*	Step test *Askel testi*	Walk test *Kävely testi*	Step test *Askel testi*
	a	kg	cm	a	L/min		mL/min/kg	
I A	31	60	170	4.0	3.0	2.8	50	47
I B	34	59	175	1.2	2.3	2.3	39	39
II A	27	52	167	0.7	2.0	2.2	39	42
II B	30	53	165	5.0	2.8	4.3	52	81
III A	28	58	170	1.5	2.5	2.6	43	44
III B	32	63	169	3.5	2.7	2.7	43	45
IV A	33	55	169	4.0	2.8	5.2	51	95
IV B	31	68	180	2.0	3.3	4.7	48	69
Average *Keskim.*	31	58	171	2.7	2.7	3.3	46	57

Table 2. Working capacity of Tanzanian and Nordic forest workers.
Taulukko 2. Tansanialaisten ja pohjoismaisten metsurien vertailu.

Source *Lähde*	Weight *Paino*	VO2-max uptake *Hapenottokyky*		Country *Maa*
	kg	L/min	mL/min/kg	
This study – *Tämä tutkimus*	58	2.7	46	Tanzania
Abeli and Ndossi (1985)	59	2.5	51	Tanzania
Hansson et al. (1966)	72.5	3.5	49	Sweden
Vik (1971)	73	3.3	46	Norway
Levanto and Mälkiä (1971)	76	4.1	53	Finland
Harstela (1975)	74	3.2	44	Finland
Levanto (1976)	72	4.2	58	Finland

some impact on their workload, as seen in Section 37. There is some evidence, that the oxygen uptake increases as a function of work experience, Fig 1.

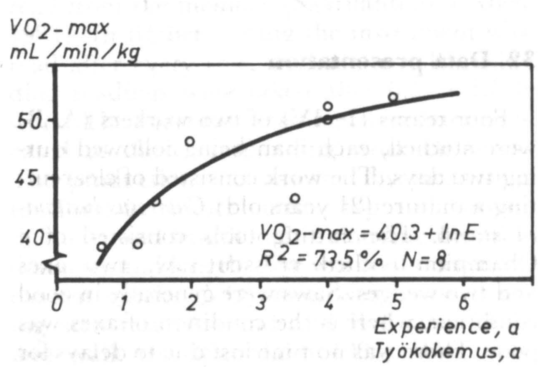

Figure 1. Oxygen uptake as a function of work experience.
Kuva 1. Hapenottokyvyn lisääntyminen työkokemuksen lisääntyessä.

33. Tree characteristics

The average tree volume was 1.0 m^3 and the corresponding average DBH 34 cm. The summary table of tree characteristics is given in Table 3. The following regression models between independent variables were developed:

$$V = 0.0632 + 0.000\,778 \cdot DBH^2 \quad R^2 = 88.3\ \% \quad (1)$$
$$h = 18.31 + 0.121 \cdot DBH \quad R^2 = 20.0\ \% \quad (2)$$
$$ACR = 0.0317 + 0.000\,236 \cdot DBH^2 \quad R^2 = 81.1\ \% \quad (3)$$
$$NLOG = 2.4 - 0.001\,17 \cdot DBH^2 + 0.004\,45 \cdot DBH \cdot h \quad R^2 = 22.7\ \% \quad (4)$$
$$LL = 5.75 + 0.000\,773 \cdot DBH^2 + 0.547 \cdot h \quad R^2 = 15.5\ \% \quad (5)$$
$$D_0 = 2.00 + 1.114 \cdot DBH \quad R^2 = 90.7\ \% \quad (6)$$

where

V is	merchantable volume, m^3
h	tree height, m
ACR	area at crosscutting points, m^2
NLOG	number of logs
LL	log length, m
D_0	stump diameter, cm
DBH	breast height diameter, cm

Crown ratio, denoted as (1 -height to the first branch / tree height), did not show any correlation with the other tree characteristics.

Volume in this study means merchantable volume, equal to the sum of individual log volumes, as well sawlogs as chiplogs.

34. Time equations

Summary statistics of the cutting time elements are given in Table 4. Debranching was the most time consuming element comprising about half (44 %) of the total time. Bucking took about one third (28 %) of the total time, and felling accounted for about one fifth (19 %). Other times, including walking, clearing and delays occupied 10 % of the total time, half of them for walking and clearing and half for unnecessary delays. Necessary delays were insignificant: as a whole the delay time was very short (5 %), showing the good organization of the work.

Elementary times were analysed using

Table 3. Tree characteristics.
Taulukko 3. Puustoa kuvaavia lukuarvoja.

Variable *Muuttuja*	Symbol *Lyhenne*	Mean value *Keskiarvo*	Min. *Min.*	Max. *Max.*
Stump diameter, *Kantoläpimitta, cm*	D_0	39	19	68
Diameter at 1.3 m, *Rinnankorkeus lpm, cm*	DBH	34	16	56
Height, *Pituus, m*	h	22.4	15.0	27.3
Crown ratio, *Latvussuhde*	CR	0.79	0.53	0.87
Log length, *Tukkiosa, m*	LL	18.94	10.2	31.9[1]
Crosscutted area, *Poikkileikattu ala, m²*	ACR	0.31	0.064	0.873
Merchantable volume, *Tukkiosan tilavuus, m³*	V	1.00	0.184	2.570
Number of logs, N *Tukkeja, kpl*	NLOG	4.4	2	8

[1] Forked – *Kaksihaarainen*

Table 4. Summary statistics of time elements, min/crew.
Taulukko 4. Keskimääräiset työvaiheajat, min/työryhmä.

Element *Työvaihe*	Symbol *Lyhenne*	Mean *Keskiarvo* min	St. Dev. *St.poikk.* min	Min. *Min.* min	Max. *Maks.* min	Proportion of total timber cutting time *Osuus kokonais-ajasta* %
Walking *Siirtyminen*	TW	0.67	0.39	0.0	1.92	3
Clearing *Raivaus*	TC	0.43	1.41	0.0	13.33	2
Felling *Kaato*	TF	4.43	2.23	1.40	11.97	19
Debranching *Karsinta*	TD	10.40	4.61	2.18	23.65	44
Bucking *Pölkytys*	TB	6.57	3.34	5.00	20.23	28
Necessary delays *Välttämättömät keskeytykset*	TN	0.05	0.22	0.0	1.55	Δ
Unecessary delays *Tarpeettomat keskeytykset*	TU	1.15	1.40	0.0	6.45	5
Total timber cutting *Kokonaistyöaika*	TTC	23.69	9.54	5.62	55.06	100
Reading time *Sykintämittausaika*	TR	2.52	1.11	0.47	5.82	–
Workplace time *Työmaa-aika*	WPT	26.21	–	–	–	–

three types of independent variables: best predictors, DBH and volume, because for the practical applications the last two independent variables are easier to use.

Walking time (TW) was independent of tree characteristics, thus being a constant:

$$TW = 0.67 \quad (7)$$

Clearing time (TC) can be considered also as a constant:

$$TC = 0.43 \quad (8)$$

Felling time was dependent on the stump crossectional area, the best models being:

$$TF = 1.07 + 0.002\,02 \cdot D_0^2 \qquad R^2 = 51.3\ \% \quad (9)$$

$$TF = 1.31 + 0.002\,57 \cdot DBH^2 \qquad R^2 = 44.2\ \% \quad (10)$$

where

TF is felling time, min
D_0 stump diametrer, cm
DBH breast height diameter, cm

Debranching time was mainly dependent on tree size. Crown ratio did not enter significantly into the model. Log length, however, seemed to improve prediction power of the model,

$$TD = -1.07 + 0.005\,42 \cdot DBH^2 + 0.259 \cdot LL \qquad R^2 = 57.5\ \% \quad (11)$$

but the following simple model is also good:

$$TD = 3.31 + 0.005\,85 \cdot DBH^2 \qquad R^2 = 53.6\ \% \quad (12)$$

where

TD is debranching time, min
DBH breast height diameter, cm
LL log length, m

The best predictor of bucking time included the number of logs together with the crossectional area at bucking points:

$$TB = -2.00 + 14.11 \cdot ACR + 0.931 \cdot NLOG \qquad R^2 = 61.7\ \% \quad (13)$$

$$TB = 1.95 + 0.003\,81 \cdot DBH^2 \qquad R^2 = 43.5\ \% \quad (14)$$

where

TB is bucking time, min
ACR crosscutted area, m^2
NLOG number of logs
DBH breast height diameter, cm

Necessary delay (TN) time was independent of tree characteristics, hence a constant:

$$TN = 0.05 \quad (15)$$

Unnecessary delay time (TU) was randomly present, but the average time seemed to increase as a function of tree size,

$$TU = -0.52 + 0.05 \cdot DBH \qquad R^2 = 7.8\ \% \quad (16)$$

even the average time can also be used as a constant:

$$TU = 1.15 \quad (16a)$$

Effective time can, of course, be obtained by summing up elementary times. For practical applications the following direct models, however, are easier to use:

$$TEF = 0.74 + 0.012\,3 \cdot DBH^2 + 1.56 \cdot NLOG \qquad R^2 = 69.8\ \% \quad (17)$$

$$TEF = 6.70 + 0.013\,0 \cdot DBH^2 \qquad R^2 = 67.8\ \% \quad (18)$$

where

TEF is effective time, min
NLOG number of logs
DBH breast height diameter, cm

Total timber cutting time averaged 23.7 min per tree. The best model included DBH squared, crossectional area at bucking points and log length. Due to multicollinearity between tree characteristics (see eq(1)-eq(6)) the model with DBH only gives a good estimate too:

$$TTC = 1.46 + 0.007\,48 \cdot DBH^2 + 24.23 \cdot ACR + 0.286 \cdot LL \qquad R^2 = 73.1\ \% \quad (19)$$

$$TTC = 7.08 + 0.013\,7 \cdot DBH^2 \qquad R^2 = 68.4\ \% \quad (20)$$

where

TTC is total timber cutting time, min
DBH breast height diameter, cm
ACR crosscutted area at bucking points, m^2
LL log length, m

Reading time is the delay time needed to remove the recording unit from the neck of the worker, to read and record the stored heart rate readings and to tie it back. During the reading time the workers usually were standing still and it was an obligatory break for them, letting them to recover. The average reading time was 2.52 ±0.22 min. Because of the automatic running display the reading time depends on the number of stored values and it was dependent on DBH:

$$TR = -0.11 + 0.079 \cdot DBH \qquad R^2 = 32.8\ \% \quad (21)$$

where

TR is reading time, min
DBH breast height diameter, cm

Reading time represented about 10 % of the total timber cutting time, being 11 % for the smallest and 9 % for the largest trees, as an average.

Workplace time (WPT) is the sum of total timber cutting time (needed to process the timber) and reading time (needed to process the study, permitting the workers to rest). This time does not include meal time or preparation time, which often are included in workplace time (Skoglig . . . 1963).

All the volume based time equations were linear:

$$TF = 1.35 + 3.06 \cdot V \qquad R^2 = 43.0\ \% \quad (22)$$

$$TD = 3.06 + 7.29 \cdot V \qquad R^2 = 57.1\ \% \quad (23)$$

$$TB = 1.53 + 5.02 \cdot V \qquad R^2 = 51.6\ \% \quad (24)$$

$$TEF = 6.21 + 16.20 \cdot V \qquad R^2 = 71.8\ \% \quad (25)$$

$$TTC = 6.64 + 16.92 \cdot V \qquad R^2 = 71.7\ \% \quad (26)$$

where

- V is merchantable volume, m^3
- TF felling time, min
- TD debranching time, min
- TB bucking time, min
- TEF effective time, min
- TTC timber cutting time, min

35. Production rate in timber cutting

Average production rate for different time concepts is presented in Table 5. Production rate per element and worker is presented in Table 6. Production rate in felling and bucking has been calculated in square meters/hour (crew), either per stump basal area or per total crosscutted area (ACR). In debranching the production rate was calculated in m^3/h (crew), using merchantable volume (V) as a variable, because it has been found, that the production rate m^3/h was rather independent of tree size, (see eq (35)).

The average production rate in timber cutting was 2.60±0.1 m^3/h varying from 1.10 to 4.76 m^3/h. t-Test revealed that there were two different production rate levels: higher producers: teams I and IV (2.7 and 2.9 m^3/h respectively), and lower producers: teams II and III (2.4 and 2.3 m^3/h respectively). However, the variation between and within teams was small indicating that workers kept a rather constant work pace.

Table 5. Production rate of a crew in timber cutting.
Taulukko 5. Työryhmän tuotos puutavaran teossa.

Time *Aika*		Production rate *Tuotos*
Effective time, *Tehoaika*	m^3/h	2.68
Total time, *Kokonaisaika*	m^3/h	2.55
Workplace time, *Työmaa-aika*	m^3/h	2.31
Scheduled time, *Työvuoro*	m^3/h	1.16
Workday, *Työpäivä*	m^3/d	7.86

When analysing the factors affecting the production rate the following model was assumed:

PR= f(tree size, form factor, working capacity, experience, relative heart rate, tree in day).

Table 6. Production rate in felling (m^2/h), debranching (m^3/h), bucking (m^2/h) and in total timber cutting (m^3/h). Hour stands for crew hour.
Taulukko 6. Tuntituotos kaadossa (m^2/h), karsinnassa (m^3/h) ja pölkytyksessä (m^2/h) sekä puutavaran teossa (m^3/h). Tuotos laskettu työryhmän tuntia kohti (= 2 miestyötuntia).

Worker *Tekomies*	Felling *Kaato* m^2/h	Debranching *Karsinta* m^3/h	Bucking *Pölkytys* m^2/h	Total timber cutting *Puutavaran teko* m^3/h
IA	2.3±0.3	6.6±0.8	3.2±0.5	2.8±0.3
IB	2.2±0.4	6.0±1.0	3.0±1.4	2.7±0.4
IIA	1.5±0.2	6.3±1.1	2.7±1.2	2.5±0.3
IIB	1.8±0.4	5.2±1.0	3.3±0.6	2.3±0.3
IIIA	1.8±0.4	5.6±1.7	3.1±0.6	2.3±0.4
IIIB	1.9±0.6	5.9±1.0	2.6±0.7	2.3±0.3
IVA	2.0±0.4	6.9±1.0	4.4±0.7	3.0±0.5
IVB	2.1±0.2	6.3±0.8	3.4±0.7	2.8±0.8
Average *Keskim.*	1.9±0.1	6.1±0.4	3.2±0.2	2.6±0.1

Because of large variations in absolute heart rate levels between workers (see Section 361) relative heart rate was used. Relative heart rate is the worker's working heart rate divided by his average heart rate. It was found that only tree size was strongly correlated with production rate (r= 0.483***). There was some evidence that relative heart rate (r= 0.218*) and tree in day (r= 0.219*, neg) were correlated with production rate too. Production rate increased degressively as a function of tree size. It also increased if the relative heart rate increased, but decreased towards the end of the day. Because of multicollinearity (larger trees cut in the morning and decreasing heart rate towards the end of the day) only tree size entered into the model. The form factor (h/DBH) improved the models slightly:

$$PTTC = 0.070\,2 \cdot DBH^{1.09} \cdot (\frac{h}{DBH})^{0.699} \quad R^2 = 25.9\ \% \quad (27)$$
$$PTTC = 0.347 \cdot DBH^{0.561} \quad R^2 = 21.8\ \% \quad (28)$$
$$PTTC = 2.56 \cdot V^{0.317} \quad R^2 = 29.8\ \% \quad (29)$$

where

- PTTC is production rate in total timber cutting, m^3/h
- DBH breast height diameter, cm
- h tree height, m
- V volume, m^3

The production rate per effective hour was, of course, somewhat higher than for total timber cutting time, varying from 1.19 to 5.10 m^3/h:

$$PTEF = 0.083 \cdot DBH^{1.05} \cdot (\frac{h}{DBH})^{0.60} \quad R^2 = 25.6\ \% \quad (30)$$
$$PTEF = 0.363 \cdot DBH^{0.565} \quad R^2 = 22.1\ \% \quad (31)$$
$$PTEF = 2.69 \cdot V^{0.316} \quad R^2 = 30.0\ \% \quad (32)$$

where

- PTEF is production rate per effective time, m^3/h
- DBH breast height diameter, cm
- h tree height, m
- V volume, m^3

It can be seen that about 1/4 – 1/3 of the variation in production rate can be explained by the tree size, and the form factor is the only variable which adds the explanation. Production rates were higher for larger trees, and somewhat higher for taller trees (of the same diameter). Workers' characteristics do not correlate with the production rate, but it seems to increase as the worker's heart rate increases.

Felling production rate is expressed in m^2/h (stump basal area per crewhour). It varied between 0.82 and 5.0 m^2/h, the average being 1.92 m^2/h. The production rate can be considered rather constant, independent on tree characteristics, because of low correlation coefficient (PF/DBH, r = 0.289**), and low explanation power of the model:

$$PF = -1.509 + 0.98 \cdot \ln DBH \quad R^2 = 9.5\ \% \quad (33)$$

where

- PF is felling production rate, m^2/h
- DBH diameter at breast height, cm

Debranching production rate can be expressed either by using the pole length (log length) or the debranched log volume (merchantable volume) as a unit. The production rate in metres of log length (PDm) varied from 52 to 405 m/h the average being 130 m/h. It was strongly dependent on the tree diameter as shown by the following model:

$$PDm = \frac{6438}{DBH^{1.14}} \quad R^2 = 41.0\ \% \quad (34)$$

where

- PDm is production rate in debranching, m/h
- DBH breast height diameter, cm

The production rate expressed in merchantable volume (PDv) varied from 2.3 to 16.6 m^3/ha. It can be considered as constant, due to very low changes as a function of tree diameter and very low explanation power:

$$PDv = 3.30 + 0.082 \cdot DBH \quad R^2 = 9.7\ \% \quad (35)$$

where

- PDv is production rate in debranching, m^3/h
- DBH breast height diameter, cm

The production rate in bucking is expressed in total crosscutted log end area (ACR) m^2/h. The production rate varied from 1.2 to 9.6 m^2/h the average being 3.21 m^2/h. It was independent of tree characteristics.

36. Heart rate in timber cutting

361. Average heart rate

The average heart rate in total timber cutting was 117.5 ± 2.4 P/min, see Table 7. When analyzing the factors affecting the heart rate, the following model was assumed:

HR= f(working capacity, experience, production rate, tree size, tree in day, difficulty).

Variable "Difficulty" was a subjective, 3 or 4 class variable describing the saw pinching or work pace in active elements:

Felling: 0 = no saw pinching . . . 3 = frequent pinching
Debranching: 0 = normal work pace . . . 3 = distinguishly low pace
Bucking: 0 = no saw pinching . . . 4 = saw pinching in every log.

Maximum oxygen uptake (working capacity) alone explained nearly the half of the variation in heart rate during timber cutting, and the simple model eq(36) was accurate enough for describing heart rate/working capacity interaction, see also Fig. 2:

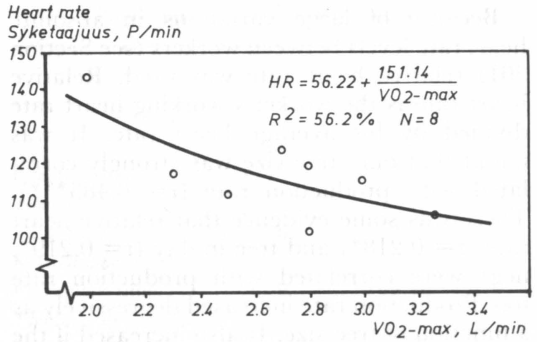

Figure 2. Heart rate as a function of working capacity.
Kuva 2. Syketaajuuden riippuvuus työntekijän hapenottokyvystä.

$$HRTTC = 58.25 + \frac{153.75}{VO_2\text{-max}} \qquad R^2 = 43.7\ \% \quad (36)$$

where

HRTTC is heart rate in timber cutting, P/min
VO_2-max maximum oxygen uptake, L/min

The best model explained less than 2/3 of the total variation:

$$HRTTC = -521.34 + 244.65 \cdot VO_2\text{-max} + \frac{643.60}{VO_2\text{-max}} - 0.813 \cdot TID - 5.63 \cdot DIFdeb \qquad R^2 = 57.2\ \% \quad (37)$$

Table 7. Heart rate in timber cutting by elements.
Taulukko 7. Syketaajuus puutavaran teossa.

Worker *Tekomies*	Felling *Kaato*		Debranching *Karsinta*		Bucking *Katkonta*		Clearing *Raivaus*	Walking *Siirtyminen*	Timber cutting *Puutavaran teko*		N
	Heart rate, *Syketaajuus, P/min*										
	M	STD	M	STD	M	STD	M	M	M	STD	
IA	114.9	12.3	115.6	7.8	114.6	12.4	105	100	115.0	9.4	14
IB	115.4	8.9	118.4	9.4	113.2	7.9	109	105	116.6	6.8	16
IIA	146.7	6.3	144.0	8.0	136.9	9.5	130	123	142.5	7.4	17
IIB	120.2	5.4	123.4	5.7	114.3	5.4	95	91	119.3	5.4	18
IIIA	113.0	7.2	119.5	5.3	111.1	7.6	101	103	111.7	5.8	17
IIIB	122.0	9.1	125.5	6.8	124.2	9.8	111	101	123.9	6.5	14
IVA	102.1	8.7	98.8	6.3	102.6	9.5	94	84	101.2	6.1	14
IVB	107.1	6.1	106.6	2.5	105.4	6.4	101	97	106.4	3.8	15
Av. *Keskim.*	118.2	15.0	118.5	14.5	115.6	13.3	105.5	100.5	117.5	13.4	125

M= Mean – *Keskiarvo* STD=Standard deviation – *Keskihajonta*

where

HRTTC is heart rate in timber cutting, P/min
VO_2-max maximum oxygen uptake, L/min
TID ordinal number of tree in day
DIFdeb work pace in debranching, ordinal class

This indicates that

- the heart rate decreases progressively as the workers' working capacity increases. Working capacity is the main factor
- the heart rate decreases about 1 beat/min for every tree towards the end of the day (but all the workers did not react this way). This is mainly due to the cutting of larger trees in the morning
- work pace in debranching seems to influence total heart rate
- production rate did not seem to influence the heart rate.

When analyzing the variation by men the following model was assumed:

HR= f(tree size, production rate, tree in day)

The analysis revealed that generally the prediction power of the developed models was low (R^2= 72.8 %, 28.1 %, 49.3 %, 21.7 %, 28.0 %, 44.5 %, 51.6 %, 18.0 %, N= 14–18), and usually only one variable entered into the models. Tree size was a determining factor for two workers (IIB, IIIB), production rate for three workers (IIIA, IVA, IVB) and tree in the day for three workers (IA, IB, IIA). In addition production rate entered into the model of worker IA and tree in day for worker IVA, curiously enough, now as positive. If the workers are divided into two working capacity classes:

group 1: four highest VO_2-max values,
group 2: four lowest VO_2-max values,

it can be seen that three of the four workers in group 1 showed increasing heart rate as a function of increasing production rate, but only one without. In group 2 only one worker's heart rate correlated with production rate, and three of them showed either decreasing heart rate towards the end of the day or heart rate increased as a function of tree size (time). It can be concluded that the heart rate of the workers with higher physical working capacity tended to correlate with the production rate, but the heart rate of workers with lower working capacity was influenced mostly by other factors.

362. Minimum and maximum heart rate

Minimum heart rate was the lowest pulse recorded for one tree, usually it was the first heart rate observation when installing the recorder after reading. Maximum heart rate was the highest recorded pulse during timber cutting. Minimum and maximum heart rates are given in Table 8. The low average minimum pulse of workers IA, IIB, IIIB, IVA and IVB suggests that they had apparently recovered during the reading time. Workers IB and IIIA showed some accumulated stress because of elevated minimum pulse, and it seems that the reading time was not long enough for them to recover completely. Worker IIA showed high accumulated stress, and he was not able to recover during the reading time. Further analysis revealed that the average minimum pulse rate was significantly dependent on worker's maximal oxygen uptake, see Fig. 3.

There exists some evidence that the minimum pulse is correlated with the constant "a" in walk test, eq(38). Also at 90 % probability level, we can assume that lowest pulse depends on the worker's rest pulse, eq(39):

$$HRmin = 11.50 + 1.07 \cdot HRa \qquad R^2 = 58.5\ \%\ N = 8 \quad (38)$$

$$HRmin = -63.10 + 2.34 \cdot HRrest \qquad R^2 = 48.6\ \%\ N = 8 \quad (39)$$

where

HRmin is minimum pulse at the tree, P/min
HRa constant "a" in walk test equation
HRrest rest pulse, P/min

It can be concluded that the physical working capacity plays an important role in the recovery of workers. It might be possible to predict the minimum pulse and thus have some guidelines to estimate the necessary break time based on worker's rest pulse only, as shown by equation (39). In fact, there is some evidence that the work load index (see Section 37) and average minimum heart rate are correlated, and the work load can be predicted based on minimum heart rate, see equation (40):

Table 8. Minimum and maximum heart rate in timber cutting.
Taulukko 8. Syketaajuuden minimi- ja maksimiarvot puuttain puutavaran teossa.

Worker *Tekomies*	Average minimum *Keskim. minimi*	Maximum, *Maksimiarvo* Absolute *Absoluuttinen*	Average *Keskim.*
IA	97.6	154	141.4
IB	104.8	157	134.0
IIA	122.8	172	157.4
IIB	84.9	158	140.7
IIIA	100.4	170	133.4
IIIB	96.4	162	150.9
IVA	76.0	139	126.9
IVB	92.2	150	128.0
Mean *Keskimäärin*	97.3	172	139.3

$$WLI = -5.60 + 0.47 \cdot HRmin \quad R^2 = 52.4\ \%\ N = 8 \qquad (40)$$

where
WLI is work load index
HRmin minimum heart rate, P/min

The average maximum pulse varied from 68 to 81 % (73.5 % in average) and the absolute maximum pulse from 74 to 89 % (83.3 % in average) from the theoretical maximum pulse, (see eq(44)). When analysing the factors affecting the maximum pulse, the following model was assumed:

HRmax = f(working capacity, experience, tree size, production rate, total time).

The maximun heart rate increased as an inverse function of working capacity and linearly as a function of timber cutting time. Time had better explanation power than tree size, and work rate did not enter into the model at all, see eq (41):

$$HRmax = 92.30 + \frac{105.12}{VO_2\text{-}max} + 0.273 \cdot TTC \quad R^2 = 20.4\ \% \qquad (41)$$

where
HRmax is maximun heart rate, P/min
VO_2-max maximum oxygen uptake, L/min
TTC timber cutting time, min

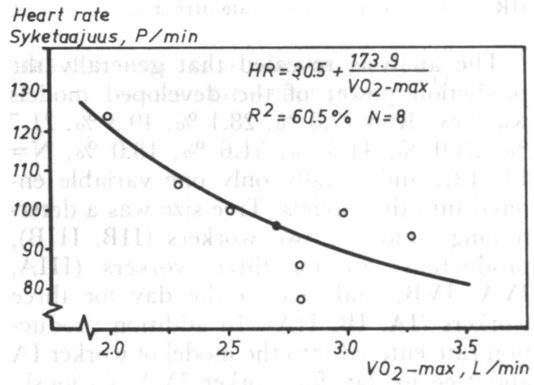

Figure 3. Average minimum pulse rate as a function of maximum oxygen uptake.
Kuva 3. Minimipulssin riippuvuus työntekijän hapenottokyvystä.

37. Work load in timber cutting

Work load can be assessed directly on heart rate or by calculating relative work load index. Work load index (WLI) was computed using the following equations (42) (Mälkiä 1973, 1974) and (43) (based on Lange Andersen's et al. 1978 data):

$$WLI(a) = \frac{HR - HRrest}{HRmax - HRrest} \cdot 100 \qquad (42)$$

$$WLI(b) = -57.5 + 0.76 \cdot HR + 0.000266 \cdot HR \cdot A \qquad (43)$$

where
WLI is work load index, %
HR heart rate, P/min
HRmax maximum heart rate, P/min
HRrest rest pulse, P/min
A age, a

The rest pulse (HRrest) was assessed using Sport Tester after at least 10 min rest in lying position. Maximum pulse was a calculated value, eq (44):

$$HRmax = 220 - A \qquad (44)$$

where
HRmax is maximum heart rate, P/min.
A age, a

In this report WLI(a)-values are generally discussed, and WLI(b)-values appear only in Table 9 for comparison. There is no meaningful difference between the calculation methods a and b. Work load index in timber cutting was in average about 41 %, see Table 9.

The work load is related to the heart rate, which depends on worker's working capacity (see eq (36)). It is thus evident that the work load depends mainly on worker's maximum oxygen uptake. Tree in the day entered also significantly into the model, but production rate or tree characteristics did not:

$$WLI = 8.35 + \frac{92.60}{VO_2\text{-}max} - 0.73 \cdot TID \quad R^2 = 30.2\ \%\ N = 125 \qquad (45)$$

where
WLI is work load index, %
VO_2-max maximum oxygen uptake, L/min
TID ordinal number of tree in a day

On individual basis it was found that the three first worker's (IA, IB, and IIA) work load was highest in the morning. Workers' IIB, IIIA, IVA and IVB work load increased as function of production rate, and workers' IA and IIIB as a function of total timber cutting time.

Buchberger (1984) classifies the work component of heart rate 30–40 P/min as the limit for "heavy" – class. Singleton (1972) suggests that for the normal work the heart rate should not rise by more than 40 pulses per minute above the resting rate. Lower limits have also been used, for example 30 P/min by Moens et al. (1979). If we assume 40 P/min over rest pulse as an alarm-limit only worker IVA was under the limit in all the timber cutting ele-

Table 9. Work load index in timber cutting.
Taulukko 9. Kuormittuneisuusaste puutavaran teossa.

Worker *Tekomies*	Felling *Kaato*	Debranching *Karsinta*	Bucking *Katkonta*	Total timber cutting *Puutavaran teko* Eq. (42) *Yhtälö (42)*	Eq. (43) *Yhtälö (43)*
IA	39.3±5.8	39.9±3.7	39.0±5.9	39.4±4.4	39.4±4.6
IB	36.9±4.2	39.6±4.4	35.0±3.8	37.5±3.2	41.2±3.1
IIA	60.8±2.7	58.5±3.5	52.4±4.1	57.2±3.2	61.0±3.2
IIB	44.2±2.2	46.8±2.2	39.5±1.4	43.5±1.4	42.7±1.4
IIIA	36.3±3.0	35.1±2.2	34.8±3.2	35.2±2.4	35.7±2.5
IIIB	46.8±4.2	49.6±3.2	48.6±4.5	48.3±3.0	47.2±3.2
IVA	28.6±4.2	25.9±3.0	29.1±4.6	27.9±2.9	28.3±2.9
IVB	35.0±2.8	34.7±1.1	33.6±3.0	34.5±1.7	32.1±1.7
All *Kaikki*	41.3±2.0	41.6±1.9	39.1±1.8	40.7±1.8	41.3±1.8

ments as well as in timber cutting as a whole. In timber cutting workers IA, IB, IIIA and IVB exceeded the limit by less than 10, so their work load was not yet too heavy. Workers IIB and IIIB exceeded the limit by 10–20 and their work load was nearly over the limit. Worker IIA exceeded it by more than 30 and his work load was excessive.

Staaf (1972) suggests that heart rates over 125 are excessive for longer periods. Only worker IIA exceeded the limit in timber cutting.

Lange Andersen et al. (1978) give the following limits for moderate and heavy work load:

Work load class	WLI	HR P/min.
moderate	26–50	100–124
heavy	51–75	125–150

Again worker's IIA work load class was heavy for all the work elements. Worker IIIB was close to the upper limit in all the active elements, and even exceeded it slightly in debranching. Workers' IVA and IVB heart rate was near the lower limit of moderate work load. Worker's IVA class in debranching was light. Other workers' work load was moderate.

Regardless of the method used for judging, worker IIA exceeded the recommended work load limit. Worker IIIB also seems to be rather stressed, but all the other workers were safely under excessive work load. Worker IVA seems to be very fit and his work load was really low. However, he belonged to high producers, as seen from Table 6.

4. Study on sulky skidding

41. Introduction

There are several studies concerning the production rate in sulky skidding (Skaar 1973, 1981, Fosser 1974, 1976a, Ole-Meiludie and Omnes 1979, Ole-Meiludie 1984), but except Fosser (1976a) the sulky skidding is not studied from an ergonomic point of view. In thinnings sulky skidding has proved to be more economical than tractor skidding (Ole-Meiludie 1984).

42. Data presentation

The sulky used in this study is so called "skidding sulky" (Fosser 1976b), see Figure 4, an implement made of inversed U-form steel tube frame, fitted with two rubber tyres of 400 mm diameter, and a 5 m long steel tube handle with cross-bar. The empty weight of the sulky is 25 kg. The load is connected to the frame with a steel chain. The work cycle consists of the following elements:

- return: One worker pulls the empty sulky to the loading area. The other worker usually walks independently carrying the chain.
- loading: One worker piles an appropriate load (1–4 logs) on the chain and the other worker pulls the sulky over the load. The chain is attached to the frame and the load is lifted off the ground by pulling the handle into the horizontal position.
- travel: One worker is pulling the sulky from the handle and the other is helping by pushing from the frame (on easy sections) or by turning from a wheel (on difficult sections).
- unloading: The workers unhook the load and push the sulky aside.
- piling: takes place occasionally when the workers have to pile logs for larger storing units.

After unloading or piling, a new cycle starts. A cycle may contain different kinds of delays, necessary and unnecessary.

During the study, which lasted for 9 days a total of 17.6 m^3 of logs or poles were skidded over an average distance of 46 m. Total skidding time was 1093 min, and the average daily workplace time was 2h 01 min. Average daily production was 1.95 m^3. Total number of loads was 194 and the average load 0.084 m^3, corresponding to about 80 kg. Slope varied from +10 to −25 %. Sulky skidding data was collected in two different compartments, which are presented in Table 10. It can be seen that from the point of view of work difficulty the Pine compartment was easier. The teams and slopes were not randomly distributed, team S3 working only on the most favourable slopes. This causes multicollinearity, due to different working capacities and motivation. Workers' anthropometric data is given in Table 11. The crew worked on a daily task basis, the average number of loads being 20–35 per day depending on the skidding distance. The averages of different variables are presented in Table 12.

Figure 4. Skidding sulky.
Kuva 4. Sulky-juontokärry.

Table 10. Sulky skidding compartments.
Taulukko 10. Sulky juonnon puusto- ja maastokuvaus.

Variable *Muuttuja*	Compartment, *Palsta* 9A	15A
	Stand – *Puusto*	
Species *Puulaji*	Cupressus *Sypressi*	Pinus *Mänty*
Age, *Ikä, a*	7	19
Cutting *Hakkuu*	First selective thinning, *Valikoiva ensiharvennus*	
	Terrain – *Maasto*	
Surface *Pinta*	Rough with plenty of debris *Epätasainen, runsaasti hakkuutähteitä*	Even, hard surface without debris *Tasainen, kova, ilman hakkuutähteitä*
Slope, *Kaltevuus, %*	+10 to − 18	−19 to − 25

Table 11. Anthropometric data of workers in sulky skidding.
Taulukko 11. Juontomiesten henkilötietoja.

Worker *Juontomies*	Age *Ikä*	Weight *Paino*	Height *Pituus*	Experience *Työkokemus*	VO_2-max *Hapenottokyky*	
	a	kg	cm	a	L/min/kg	mL/min/kg
S1	21	58	175	2.0	2.80	48
S2	30	58	173	2.0	2.54	44
S3	21	52	176	0.2	2.28	43

Table 12. Daily averages in sulky skidding.
Taulukko 12. Päivittäiset keskiarvot eri muuttujista.

Crew *Työryhmä*	Day *Päivä*	Production *Tuotos* m^3	Nb of Loads *Kuormia*	Nb of Logs *Pölkkyjä*	Distance *Juontomatka* m	Slope *Kaltevuus* %
S1	1	2.22	26	41	45.5	+2.0
	2	1.55	25	25	67.0	+8.6
	3	1.87	21	33	38.4	−18.0
S2	1	1.83	18	32	38.3	+4.3
	2	1.56	27	29	61.0	+5.3
	3	1.60	22	43	28.0	−22.0
S3	1	2.59	25	50	42.8	−21.0
	2	2.47	31	46	42.0	−20.5
	3	1.92	21	52	60.5	−23.8
All *Kaikki*		1.96	24	40	45.6	−9.5
Total *Yhteensä*	9	17.61	216	357		

43. Time equations

The average cycle time in sulky skidding was 4.68 ±0.17 min, see Table 13. Loading was the most time consuming element, occupying more than one third (36 %) of total time. The share of travel and return times were about a half of the total time, and unloading took about 10 %. Delay times played a very small role in sulky skidding during this study, their share being only 2 %, as seen from Table 13.

Return time was influenced by distance and slope:

$$TR = 0.30 + (0.0162 - 0.00020 \cdot S) \cdot D \qquad R^2 = 36.0\ \% \quad (46)$$

where
- TR is return time, min
- S slope, %
- D distance, m

Loading time was highly dependent on load size:

$$LT = 0.41 + 15.55 \cdot V \qquad R^2 = 45.6\ \% \quad (47)$$

where
- LT is loading time, min
- V load size, m^3

Table 13. Time breakdown in sulky skidding, min.
Taulukko 13. Ajan jakautuminen osa-aikoihin juonnossa, min.

Team *Työryhmä*	Loading *Kuormaus*	Travel *Kuljetus*	Unload *Purkaminen*	Piling *Pinoaminen*	Return *Paluu*	Delays *Keskeytykset*: Necess. *Välttämätön*	Delays *Keskeytykset*: Unnec. *Tarpeeton*	Total *Yht.*
S1	1.46	1.40	0.43	0.27	1.03	0.01	0.08	4.69
S2	1.73	1.42	0.41	0.11	1.04	0.02	0.10	4.83
S3	1.83	0.99	0.35	0.00	1.26	0.02	0.09	4.54
Average *Keskim.*	1.68	1.26	0.39	0.12	1.12	0.02	0.09	4.68
St.Dev *Hajonta*	0.63	0.57	0.17	0.19	0.40	0.12	0.27	1.24
%	36	27	11		24	2		100

Loading time was about 1 s per one litre of log volume (plus 25 s fixed time).

Travel time depended on slope (r = 0.495***) and on distance (r = 0.450***), both variables being intercorrelated. Also load size entered into the best model:

$$TS = 0.67 + (0.200 + 0.00435 \cdot S) \cdot V \cdot D \qquad R^2 = 42.0\ \% \quad (48)$$

where
- TS is travel time, min
- S slope, %
- V load size, m^3
- D distance, m

About half a minute was needed for handling loads on the yard. Unloading and piling times were independent of studied variables, and can be considered as constants:

$$TU = 0.39 \quad (49)$$
$$TP = 0.12 \quad (50)$$

where
- TU is unloading time, min
- TP piling time, min

Delay times were randomly occurring times, and they can be considered as constant:

$$TDU = 0.09 \quad (51)$$
$$TDN = 0.02 \quad (52)$$

where
- TDU is unnecessary delay time, min
- TDN necessary delay time, min

Total delay time was short, 0.11 min.

Total cycle time in skidding (TT) varied from 2.23 to 8.35 min the average being 4.68 min. It was influenced by volume, slope and distance, the product V · D being the most important factor (r = 0.771***):

$$TT = 1.93 + 5.53 \cdot V + (0.646 + 0.005\,65 \cdot S) \cdot V \cdot D \qquad R^2 = 57.4\ \% \quad (53)$$

where
- TT is cycle time, min
- S slope, %
- V load size, m^3
- D distance, m

44. Production rate in sulky skidding

The average production rates by elements are given in Table 14. Production rate was calculated as per total time. Loading rate is 60 · V/LT, and it is expressed in m^3/h. It can be seen that team S2 had lowest loading rate and average speed, and can be considered as low producer. Team S1 and S3 seem to be rather equal in production. Production rate varied from 0.41 to 2.53 m^3/h the average being 1.07 m^3/h. Load size was the single

Table 14. Production rates in sulky skidding.
Taulukko 14. Tuotoslukuja sulky juonnossa.

Crew *Työryhmä*	Production rate *Tuotos* m^3/h	Load size *Kuormakoko* m^3	Loading rate *Kuormaustuotos* m^3/h	Travel speed *Kuljetusnopeus* m/s	Return speed *Paluunopeus* m/s	Average speed *Keskinopeus* m/s
S1	1.01±0.08	0.078±0.007	3.33±0.25	0.68±0.06	0.86±0.07	0.73±0.05
S2	0.96±0.09	0.074±0.006	2.70±0.20	0.58±0.06	0.73±0.05	0.61±0.03
S3	1.23±0.06	0.091±0.006	3.14±0.17	0.87±0.06	0.68±0.05	0.75±0.04
Average *Keskim.*	1.07±0.04	0.082±0.004	3.07±0.12	0.72±0.04	0.76±0.03	0.70±0.25

Table 15. Production rate correlation matrix.
Taulukko 15. Juontotuotoksen ja eri muuttujien väliset korrelaatiot.

Variable, *Muuttuja*		V	D	S	P
Volume, *Kuormakoko,*	V	1			
Distance, *Matka,*	D	–0.302	1		
Slope, *Kaltevuus,*	S	–0.261	0.456	1	
Prod. rate, *Tuotos,*	P	0.614	–0.606	–0.463	1

Test-value t*** = 0.223 N = 216
t-testiarvo

most influencing factor, see Table 15, the correlation coefficient being somewhat higher than that with the distance. However, the load size and distance were correlated, so that there is multicollinearity on the production rate model eq(54).

$$PRT = 3.09 - (0.545 + 0.001\,69 \cdot S) \cdot \ln D \qquad R^2 = 44.2\ \% \qquad (54)$$

where
PRT is production rate as per total time, m^3/h
S slope, %
D distance, m

Because the load size model developed from total data was not satisfactory, the multiple correlation coefficient being low, and the model biased, the analysis was continued by pooling the data into adverse slope (+2 to +10 %) and favourable slope (–18 to –25 %) groups. On adverse slopes load size was strongly correlated with distance and slope. Distance and slope were correlated, as shown by the following correlation matrix:

	Load	Distance	Slope
Load	1	–0.599	–0.369
Distance		1	0.779
Slope			1

On favourable slopes there was no correlation between load and terrain factors.

On adverse slopes the average load size varied from 0.30 to 0.146 m^3 the average being 0.074 m^3. The load size decreased as an inverse function of distance. Because the distance and slope were correlated the influence of slope cannot be detected.

$$PLa = 0.012\,5 + \frac{3.14}{D} \qquad R^2 = 39.3\ \%\ \ N = 90 \qquad (55)$$

where
PLA is load size on adverse slopes, m^3
D distance, m

On favourable slopes the load size was somewhat larger varying from 0.037 to to 0.161 m^3 the average being 0.087 m^3. The load size can be considered as constant.

$$PLf = 0.087 \qquad (56)$$

where
PLf is load size on favourable slopes, m^3

Travel speed which is the skidding distance divided by travel time, varied from 0.19 to 1.52 m/s. The average travel speed 0.72 m/s corresponds to 2.6 km/h. All the factors, load size, distance and slope influenced the travel speed:

$$PT = 1.058 - 4.72 \cdot V - 0.000\,207 \cdot D \cdot S \qquad R^2 = 37.7\ \% \qquad (57)$$

where
PT is travel speed, m/s
V load size, m^3
D distance, m
S slope, %

Return speed varied from 0.32 to 1.94 m/s the average being 0.76 m/s, corresponding to the speed of 2.7 km/h. It is of the same magnitude as the travel speed. The best model included both slope and distance, the slope being the most influencing single factor (r = 0.485):

$$PR = 0.708 + 0.002\,6 \cdot D + 0.007\,78 \cdot S \qquad R^2 = 25.3\ \% \qquad (58)$$

where
PR is return speed, m/s
D distance, m
S slope, %

Because the averages of travel and return speeds are nearly the same, but the slope influencing inversely, it can be assumed that the average moving speed, $(2 \cdot D)/(TS+TR)$, is independent of the slope. It would then be easier to use average moving speed instead of travel and return speeds in production estimation. Average moving speed varied from 0.28 to 1.23 m/s, the average being 0.70 m/s. It was independent of slope (r = 0.059 N.S.), but increased degressively as a function of distance:

$$PA = -0.103 + 0.210 \cdot \ln D \qquad R^2 = 11.2\ \% \qquad (59)$$

where
PA is average speed, m/s
D distance, m

Table 16. Production rate in sulky skidding expressed in $m^3 \cdot m/h$.
Taulukko 16. Tuntituotos sulky-juonnossa, $m^3 \cdot m/h$.

Crew *Työryhmä*	Mean *Keskiarvo*	STD *Hajonta*	N
S1	48.2	9.98	72
S2	38.1	7.95	67
S3	57.2	11.99	78
Average *Keskim.*	49.0	13.0	195

Production rate can also be expressed as the product of volume and distance per unit of time ($m^3 \cdot m/h$). This production rate can be assumed to be independent of volume and distance, the only independent variables being slope and work pace. The latter is assumed to correlate with heart rate, even though sulky skidding might contain more static work than timber cutting. The highest correlation coefficient between VD/T-production rate and other variables was, in fact, with heart rate (r = 0.460***). The second highest was that with the product slope · distance, showing, that the VD/T production rate is somewhat dependent on distance too. The best model was as follows:

$$VD/T = 10.4 + 0.233 \cdot D + 0.706 \cdot S - 0.0205 \cdot S \cdot D + 0.253 \cdot HR \qquad R^2 = 37.0\ \%\ \ N = 195 \qquad (60)$$

where
VD/T is production rate, $m^3 \cdot m/h$
D distance, m
S slope, %
HR heart rate, P/min

The average VD/T production rate was 49.0 $m^3 \cdot m/h$, and the production rates as per team are given in Table 16.

45. Heart rate in sulky skidding

Due to short elementary times, the heart rate was calculated as an average over a cycle. The average cycle time being 4.7 min, and readings taken at 30 s intervals the average heart rate is then the average of 9 readings. Due to technical problems the heart rate recording was unsuccessful during the third day. Therefore the heart rate data matrix consists of only 8 days corresponding to 195 loads. The average heart rate in sulky skidding was 106 P/min, which is lower than in timber cutting, Table 17. Maximum heart rate, which is the highest single observed reading during a cycle was 123 P/min in average, varying between 99 and 153.

As mentioned earlier, see eq(60), heart rate and production rate VD/T were correlated (r = 0.460***), indicating that the heart rate increased as a function of production rate:

$$HR = 92.9 + 0.270 \cdot D \cdot V/T \quad R^2 = 21.1\ \%\ N = 195 \quad (61)$$

where
HR is heart rate, P/min
D distance, m
V load size, m^3
T cycle time, min

However, the model was not satisfactory, and when analysing the heart rate on adverse and favourable slopes separately, it was found, that the heart rate on favourable slopes was rather constant:

$$HRf = 107 \quad (62)$$

where
HRf is heart rate on favourable slopes, P/min

but on adverse slopes it was strongly correlated with the product of production rate · slope. Also the physical working capacity of the workers entered into the model:

$$HRa = 18.48 + \frac{177.3}{VO_2\text{-max}} + 0.011\,35 \cdot V \cdot D \cdot S/T$$
$$R^2 = 47.8\ \%\ N = 99 \quad (63)$$

where
HRa is heart rate on adverse slopes, P/min
VO_2-max maximum oxygen uptake, L/min
V load size, m^3
D distance, m
S slope, % (adverse slope +2 to + 10)
T cycle time, min

We can see that on adverse slopes the heart rate increased if the load size, distance, slope or production rate increased.

There was a remarkable variation between days, within teams which might originate in:

- the afternoon-evening history of the previous day
- different sequences in pulling-pushing the sulky and/or setting choker-waiting etc.
- the fact that the correlated energy expenditure/heart rate becomes more regular at higher heart rate levels only, and sulky skidding contains static muscular work.

Therefore the models developed using regression analysis might mechanically explain the variation in heart rate during the study, but they cannot be considered as perfect sulky skidding heart rate models.

The maximum heart rate was mostly influenced by the product V·D.

Table 17. Average and maximum heart rate in sulky skidding, P/min.
Taulukko 17. Keskimääräinen ja maksimi syketaajuus sulky-juonnossa, P/min.

Worker *Juontomies*	Average heart rate *Keskim. syketaajuus* Mean *Keskim.*	Range *Vaihteluväli*	Maximal heart rate *Maksimi syketaajuus* Mean *Keskim.*	Range *Vaihteluväli*
S1	105.2±1.1	99–118	119.9±2.1	107–141
S2	102.0±1.7	88–125	122.8±2.8	99–153
S3	110.2±1.8	92–132	125.7±2.1	103–149
Average *Keskim.*	106.1±1.1	88–132	123.0±1.4	99–153

46. Work load in sulky skidding

Work load index was computed using eq(43). The average work load index in sulky skidding was 30 %, see Table 18. Because based on the heart rate, the variations in work load follows the same irregularities as encountered in analysing the heart rate. The most influencing single factor was the worker's maximum oxygen uptake, VO_2-max (r = 0.310***). Also the distance was significantly correlated (r = 0.271***). The best model was:

$$WLI = -24.34 + \frac{66.3}{VO_2\text{-max}} + 7.20 \ln D$$
$$R^2 = 23.5\ \%\ N = 195 \quad (64)$$

where
WLI is work load index
VO_2-max maximum oxygen uptake, L/min
D distance, m

The variation in work load was rather small, and the workers seemed to adjust their work pace at about 30 % WLI level at all slopes. This stress level was lower than in timber cutting.

Table 18. Work load in sulky skidding.
Taulukko 18. Kuormittuneisuusaste sulky-juonnossa.

Worker/crew *Juontomies*	Work load index *Kuormittuneisuusaste* Mean *Keskim.*	St. Dev. *Hajonta*	Number of observations *Havaintoja*
S1	28.4	3.11	51
S2	28.2	5.86	66
S3	32.5	6.57	77
All *Kaikki*	29.9	5.95	195

5. Energy expenditure in forest work

51. Introduction

Working efficiency of an individual is not only dependent on his working capacity, but is also largely influenced by his food intake (FAO 1976b). Therefore it is important to know the daily energy consumption of the workers. It can be used as a work load indicator too, as well as a basement for planning a better diet to increase the productivity. This sector is less studied, and there is only one energy balance study on forest workers in Tanzania (Abeli and Ndossi 1985).

52. Energy expenditure in different operations

521. Calculation method

The energy expenditure calculations are based on recorded heart rates using the following method (Saarilahti 1986):

The heart rate-walking speed ratio is assessed by walk test, and the specific coefficients a and b have been developed using regression analysis for every worker. The following heart rate model is assumed:

$$HR = a + b \cdot V^2 \quad (65)$$

where
HR is heart rate, P/min
a, b specific coefficients
V walking speed, km/h

From the literature the following energy expenditure-walking speed relation can be calculated (Lange Andersen et al. 1978):

$$EE = W \cdot (0.08 + 0.007\,77 \cdot V^2) \quad (66)$$

where
EE is energy expenditure, kJ/min
W body weight, kg
V walking speed, km/h

Table 19. Energy expenditure by workers during different timber cutting operations.
Taulukko 19. Energian kulutus työvaiheittain puutavaran teossa.

Subject *Tekomies*	Felling sawing *Kaatosahaus*	Notching with axe *Kaatokolo kirves*	Debranching *Karsinta*	Bucking *Katkonta*	Clearing *Raivaus*	Walking *Siirtyminen*	Total timber cutting *Puutavaran teko*
	Energy expenditure – *Energian kulutus, kJ/min*						
IA	25.0	22.5	24.0	23.0	18.5	16.0	23.5
IB	20.3	17.2	19.9	17.2	15.4	13.6	18.3
IIA	27.6	26.4	26.4	23.1	20.3	17.4	25.4
IIB	26.9	26.6	26.2	23.2	16.3	15.0	24.6
IIIA	18.0	18.9	16.6	18.0	11.9	12.9	16.9
IIIB	28.2	30.7	26.8	25.3	19.0	14.2	25.3
IVA	19.6	17.9	16.2	17.5	14.1	9.8	17.2
IVB	24.6	20.7	20.7	19.4	16.7	14.1	21.4
Average *Keskim.*	23.8	22.6	22.1	20.8	16.5	14.1	21.4

Combining the two equations the following energy expenditure model can be written:

$$EE = (0.08 + 0.007\,77 \cdot (HR - a)/b) \cdot W \qquad (67)$$

where

EE is	energy expenditure, kJ/min
HR	heart rate, P/min
a, b	specific coefficients
W	body weight, kg

Equation (67) is used to convert the average heart rate of different elements into energy expenditure.

522. Energy expenditure in timber cutting and sulky skidding

Energy expenditure estimates by elements in timber cutting are given in Table 19 and the average energy expenditure in sulky skidding is given in Table 20. The energy expenditure was highest in felling, about 24 kJ/min and was somewhat lower in other operations. The average energy expenditure rate over all timber cutting operations varied between 17.2–25.2 kJ/min and was 21.4 kJ/min as an average. The estimated values are low in comparison with figures given by FAO (1976b):

Felling with axe	36.0 kJ/min
Debranching	36.1 kJ/min
Sawing, hand saw	36.0 kJ/min
Walking	15.5 kJ/min

but close to the values given by Abeli and Ndossi (1985), whose energy expenditure values during timber cutting vary from 15.4 to 30.0 kJ/min, the average being 22.1 kJ/min. Saarilahti and Ole-Meiludie (1987) also give lower energy expenditure values obtained in cutting of pine, energy expenditure being

- 25.1 kJ/min in felling
- 21.2 kJ/min in debranching
- 23.7 kJ/min in bucking and
- 21.8 kJ/min in total timber cutting

Hansson et al. (1966) measured in Indian logging values close to this study:

- 21.2 kJ/min in felling
- 21.2–22.9 kJ/min in crosscutting

Maybe FAO values are measured over the main time only, but in this study they contain by-times too.

The energy expenditure in sulky skidding (16.3 kJ/min) is lower than in timber cutting.

Table 20. Energy expenditure in sulky skidding.
Taulukko 20. Energian kulutus sulky-juonnossa.

Subject *Juontomeis*	Energy expenditure, *Energian kulutus,* kJ/min
S1	18.1
S2	15.6
S3	15.3
Average *Keskim.*	16.3

53. Daily energy expenditure

Four of the eight loggers and two of the three sulky skidding workers were picked up for further studies. Their daily activities were investigated by interviews. Some time studies, incorporated with heart rate recording were carried out to assess the average heart rate and time spent in non-salaried activities. Average daily energy consumption between different activities and corresponding heart rate and energy expenditure is presented in Table 21.

The average work day length, the time spent in forest (work + lunch) was about 4.0 h (240 min). If we compare the day length to Scandinavian forest workers' day it is short. In Finland the length of the 25–35 years old forest workers' work day was 7.1–7.6 h/d (Heikinheimo 1984). But for Tanzanians we have to add more than 2 h for the walking to forest and home (136 min) into the total work day length. Because the own food production is a must for most forest workers, shamba work (agricultural work), 2.7 h/d as an average, must be added to their effective day length. Then totally the Tanzanian forest worker uses nearly 9 h (538 min) for salaried work and food production.

Table 21. Average daily activities, heart rate and energy expenditure of forest workers.
Taulukko 21. Metsätyömiesten keskimääräinen ajankäyttö, syketiheys ja energian kulutus.

Activity *Toiminta*	Time *Käytetty aika*	Heart rate *Syketiheys*	Energy expenditure *Energian kulutus*		Share *Osuus*
	min	P/min	kJ/min	kJ/d	%
Sleeping *Nukkuminen*	580	N.A.	4.6[1)]	2668	18
Walking to forest *Kävely metsään*	73	90	10.9	783	10
Walking to home *Kävely kotiin*	63	91	11.1	676	
Forest work *Metsätyö*	240	116	21.0	5061	34
Shamba work *Peltotyöt*	162	105	16.8	2665	18
Light home activities *Kevyet kotiaskaret*	137	89	10.2	1460	10
Leisure *Vapaa-aika*	185	85	8.9	1666	11
Average/Total *Keskim/Yht.*	1440	–	10.4	14979	100

1) From Lange Andersen et al. (1978)

The generally recommended maximum daily energy expenditure is 20 MJ/d (McCormic 1957, Grandjean 1982). This value is for European males which generally are heavier than Tanzanians (see Table 2). FAO (1976b) gives following indicative values, kJ/d/kg of body weight, for different activity categories, see Table 22. Class "Exceptionally active" can be kept as recommended maximum daily energy expenditure. Three timber cutters belonged to the class "Exceptionally active" and only one into "Very active" class. One of the sulky workers belonged into "Very active" and the others into "Moderately active" classes. The workers seem to "work hard", most being close the recommended upper limit.

Table 22. Daily (24 h) energy expenditure kJ/d/kg in different activity classes, after FAO 1976b.
Taulukko 22. Päivittäinen energiankulutuksen luokitus (kJ/d/kg) FAOn (1976b) mukaan.

Energy expenditure, *Energian kulutus,* kJ/d/kg	Activity class *Aktiviteettiluokka*
176	Light activity – *Vähän aktiivinen*
193	Moderate activity – *Kohtalaisen aktiivinen*
226	Very active – *Hyvin aktiivinen*
260	Exceptionally active – *Poikkeuksellisen aktiivinen*

6. Performance rating

Performance rating is not used in comparative time studies, and no performance rating of the workers was made beforehand. In order to get an idea of the work performance, the following approach, even though not a standard method, can be used (Saarilahti 1986). In the British rating method (Scott 1973) walking speed of 6.4 km/h corresponds to the rating 100 (piecework performance) and walking speed 4.8 km/h to 75 (time work performance), the relation walking speed/rating index being linear:

$$RI = 15.625 \cdot V \quad (68)$$

where
RI is rating index
V (comparable) walking speed, km/h

Using walk test a relation between heart rate and walking speed can be established. The comparable walking speed of an element can be assessed using eq(69):

$$V = \sqrt{(HR - a)/b} \quad (69)$$

where
V is comparable walking speed of an element, km/h
HR heart rate, P/min.
a, b walk test coefficients for an individual

Combining equations (68) and (69) we can write

$$RI = 15.625 \cdot \sqrt{(HR - a)/b} \quad (70)$$

Average comparable walking speed of the felling sawing, axe notching, debranching and bucking elements was 6.2 km/h corresponding to the rating index 97. We can thus assume, that the workers' performance corresponds to the rating index 100, which is normal piece-work performance.

In sulky skidding the comparable walking speed was only 5.6 km/h corresponding to the rating index 87. The performance in sulky skidding seems to be in between piece-work and time work performances.

7. Discussion

71. Sources of errors

Time and production studies might contain some minor recording and copying errors which increase variation but do not influence the conclusions. Average heart rate over a tree is rather reliable because the recorder was read after every tree. Averages by elements are more sensitive to allocation error, but reliable enough.

The energy expenditure calculation method is only indicative having many possible source of errors. In fact, the heart rate is influenced by many factors other than the work component, as assumed in this study. The work component of heart rate depends on ratio static/dynamic work, which varies between timber cutting elements (Cermak 1977), and is not the same as in walking, as assumed in this study. Some authors give different values for energy expenditure in walking at different speeds as used in this study. When analysing the results, we can conclude, that the energy expenditure tends to become too high because the heart rate may contain larger stress + static work component in forest work than in walking. Therefore the given figures are rather overestimations than underestimations.

72. Comparison with previous studies

721. Studies on timber cutting

Production rates reported by different authors are presented in Table 23. Drugge's (1984) original figures refer to daily task (in m^3) divided by 6 hours work day length. Drugge's modified figures refer to the daily task divided by the actual day length of this study, 3.39 h/d. Ole-Meiludie's (1984) figures refer to thinnings, where hangup time is remarkable, about 10 % of total time. In the light of Table 23 we can conclude, that the production rate of this study is high, but falls close to the previous studies.

It is also interesting to compare the production rate of Tanzanian forest workers with production rates obtained in Northern hemisphere. FAO's (1976a) handbook gives some data on felling, debranching and bucking times measured in Norway (Samset 1950), in Sweden (Järvholm and Kilander 1965) and in Canada (Cunia 1960), see Fig. 5. Järvholm and Kilander's (1965) study concerns 1-man crew, which usually is more effective (per man) than a two-men crew. Also we have to note that there might be differences in recording by-times in different reports. It seems that the effective times of Scandinavian workers are shorter, but those recorded in Canada are closer to those obtained in this study, specially in felling and bucking.

Table 23. Production rate in cutting of cypress, m^3/manhour, proposed by different authors.
Taulukko 23. Tuntituotos sypressin hakkuussa, m^3/miestyötunti eri lähteiden mukaan.

Source *Lähde*	Diameter DBH, cm *Rinnankorkeusläpimitta, cm* 15	20	25	30	35	40	45	50	55
Drugge, orig.	–	–	0.45	0.55	0.60	–	–	–	–
modif.			0.80	0.98	1.06				
Ole-Meiludie	0.16	0.40	0.62	0.83	1.05				
Saarilahti & Abeli	–	–	1.48	1.44	1.41	1.39	1.38		
This study	0.70	0.89	1.05	1.18	1.28	1.35	1.41	1.46	1.49

Sources–Lähteet: Drugge (1984), Ole-Meiludie (1984), Saarilahti & Abeli (1985).

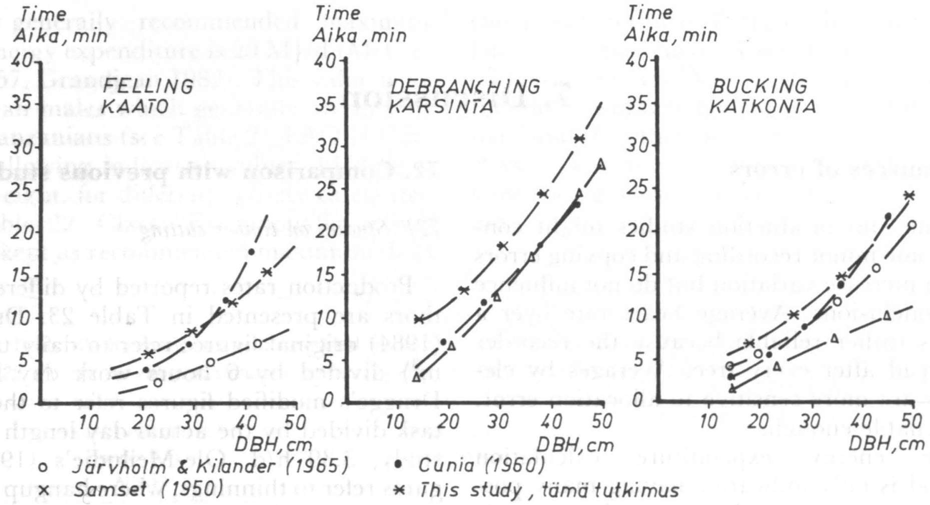

Figure 5. Effective time as a function of DBH after different authors.
Kuva 5. Työvaiheittainen tehoaika eri lähteiden mukaan.

722. Studies on sulky skidding

Production rate as a function of distance recorded by different authors is given in Fig. 6. When compared with previous studies we can see, that the production rate of this study is lower than in most of the other studies. It is mainly due to differencies in load size, the load size being:

0.081 m^3 in this study compared with
0.109 m^3 in Ole-Meiludie and Omnes (1979)
0.202 m^3 in Skaar (1973) and
0.101 m^3 in Ole-Meiludie (1984)

It is uncertain if the difference in load size is due to differences

- in stand characteristics (smaller logs), or
- in work organisation and payment (task as loads/d in this study), or
- in working capacity of the workers.

Because of low work load index we can assume, that the low production rate is not due to working capacity of workers, but rather to the motivation or stand characteristics.

The average times match better with previous studies, showing the importance in controlling the load size when increasing the productivity.

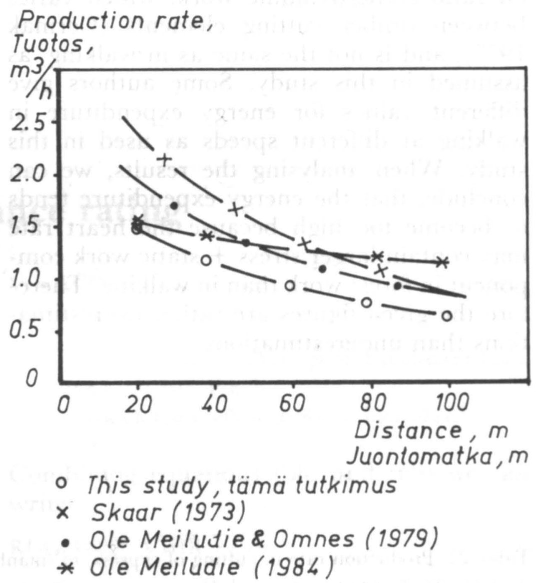

Figure 6. Production rate in sulky skidding, m^3/h.
Kuva 6. Tuntituotos sulky-juonnossa, m^3/h.

73. Fair daily task

The most interesting question from the Forest Manager's point of view is usually, what should be the fair daily task.

731. Fair daily task in clearcutting of Cypress

The work pace maintained by the workers during the study seems to correspond with piece work rate, see section 6. Generally it is approved, that piece work performance is 30 % higher than time work performance. The reading time (10 % or total time) seems to be long enough for an experienced worker to recover. The rest factors 7 % to 10 % are recommended in calculating British Standard time tables for axe work (Scott 1973). If we assume the normal work day length 7 h, of which 30 min is allocated for lunch and 30 min for preparation time (WPT in this study did not contain preparation time) the total WPT becomes 6×60 minutes. For calculating daily production rates for time work performance combine eq. (1) and eq (20) and allocate 10 % rest and 30 % for time performance the following equation is obtained:

$$PR = \frac{22.75 + 0.280 \cdot DBH^2}{10.12 + 0.0196 \cdot DBH^2} \qquad (71)$$

where

PR is daily production of a crew, m^3
DBH breast height diameter, cm

New daily tasks are computed in Table 24. Current task is based on West Kilimanjaro and Meru Forest Project's norms (Drugge 1984). The increase in daily production is about 25 % and the total timber cutting time will increase from 3.09 h to 4.20 h and WPT from 3.37 to 4.62 h.

There exist some possibilities to increase the daily task, purely based on analyzing the worker from the point of view of salaried work only. The new daily task does not increase the work load, only the work day length is increased. The work load being under recommended maximum, it is possible to expect a longer work day. The increase in production increases the energy expenditure in work, average increase being 0.75 MJ/d if the workers take the time from their leisure time, and 0.25 MJ/d if the shamba work is reduced. In the previous case the workers achieve the recommended maximum daily energy expenditure limit (260 kJ/d/kg).

If the increase in salaried work output exceeds the worker's habitual energy intake, or his overall capacity, he has to decrease his other activities, mainly the shamba work. It leads to an interesting socio-economic decision making problem: does the increase in salaried work compensate the losses in other activities? The high labour turnover permits us to conclude, that the actual utility of forest work is rather low for the workers and if the increase in daily task is applied without increase in other benefits (salary, security, agroforestry permit etc.) it will only lead to larger labour turnover and no real increase in production can take place. Also it can be seen how difficult it is to reduce timber cutting labour costs, the actual salary being close to "utile".

Table 24. Recommended daily task for timber cutting crew in clearcutting of Cypress.
Taulukko 24. Suositeltu päivätyötuotos työryhmää kohti sypressin hakkuussa.

DBH $D_{1.3}$ cm	Recommended task *Suositeltu normi*		Actual task *Nykyinen normi*	
	m^3/d	Tree/d *Puuta/d*	m^3/d	Tree/d *Puuta/d*
15	5.9	24.8		
20	7.5	20.0		
25	8.8	16.1	5.35	13
30	9.9	13.0	6.60	10
35	10.7	10.5	7.12	8
40	11.3	8.7		
45	11.8	7.2		
50	12.2	6.1		
55	12.5	5.2		

732. Fair daily task in sulky skidding

The work load in sulky skidding is lower than in timber cutting (see Section 46) and also the comparable walking speed and performance rating are lower (see Section 6). The production rate in sulky skidding is apparently too low, and it should increase.

As seen in Section 44 the load size seems to be the reason for low production rate. The theoretical load is calculated assuming (Saarilahti 1985):

- the pulling force of a man to be 1/5 of his gravity, crew factor 0.9. The weight of a worker 60 kg
- rolling resistance to be 0.15 . . . 0.20, density 1000 kg/m^3.

Because the gravitational component overcomes the rolling resistance steeper than –10 % slope, the maximum load is put to 0.175 m^3. It can be seen, that the load size is close to the "normal" on adverse slopes, but too small on favourable slopes as seen from Fig. 7.

The work performance being 87 (see Section 6) the time work performance could be lower. If adding 10 % rest allowance then the "standard time" should be about 25 % longer than calculated using eq. 53. If considering 6 h effective work day to be sufficient, following recommended daily task targets can be calculated, see Table 25. The maximum load size should not exceed more than 20 % of the average load size given in Fig. 7. Therefore sulky skidding is not very suitable on adverse slopes except for first thinnings.

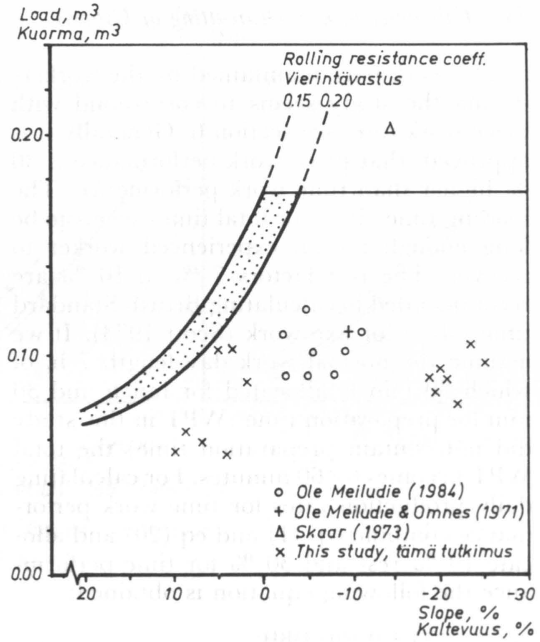

Figure 7. Load size on different slopes.
Kuva 7. Kuormakoko eri rinnekaltevuuksilla.

The new target is 2–3 times higher than the actual daily production, see Table 12, and the increase is more pronounced than in timber cutting. The application of the new norms will have the same consequences discussed in timber cutting. However, the current sulky skidding production rate is very low, so increasing the productivity should start by increasing the productivity in sulky skidding first and later in the timber cutting.

Table 25. Recommended daily task for sulky skidding, 2-men crew.
Taulukko 25. Ehdotettu sulky-juonnon päivänormi 2-miehen työryhmälle.

Slope *Kaltevuus* %	Distance – *Juontomatka*, m 25	50	75	100	125
	Daily task – *Päivänormi, m/d*				
+10	5.0	4.0	3.0	2.5	2.0
+ 5	6.0	4.5	3.5	3.0	2.5
0	7.0	5.0	4.0	3.5	3.0
Steeper than –5 *Jyrkempi kuin –5*	9.0	6.5	5.0	4.0	3.5

74. Recommendations

How important it is to respect the recommendations concerning work load is shown by the case of the worker IIA. His work load index was 57 %, and he often complained of being tired and he resigned his work soon after the study.

The current training system of putting a newcomer together with an experienced worker might cause excessive stress to the newcomer, because his working capacity is lower, see Fig. 2, and his working technique is not adequate. When working under stress the risk of accidents increases. When interviewed on accidents, the same worker (IIA) had already had one accident, amputing one toe with an axe.

The investigation of accidents revealed that, in total there have been 6 accidents among studied timber cutting and sulky skidding workers, totalling 26. 3 manyears of work. The corresponding frequency rate (based on 6 h work day length) is 173, which is relatively high. After Staaf (1979) the frequency rate in Swedish forest work varied during 1968–1974 between 59 and 75. The training should emphasize reducing accidents too.

As seen from Section 352 (eq. (41)), the work load index seems to be high for the workers, whose rest pulse is high. There are thus possibilities to develop simple methods for screening the workers before recruitment, so that only physically fit workers will be contracted. At least workers with high rest pulse need special attention.

References

Abeli, W. S. 1979. A survey of ergonomic aspects in Tanzanian forestry. In: Ergonomics in tropical agriculture and forestry, edited by van Loon, Staudt and Zander. Proc. 5th Joint Ergonomic Symposium IAAMRH, CIGR, IUFRO. Wageningen. ISBN 90-220-0717-0. p. 115–118.
— & Dykstra, D. P. 1981. Logging and log transport in miombo woodland forests. UDSM, Division of Forestry, Morogoro. Record 19.
— & Ndossi, M. A. T. 1985. Physical working capacity and productivity of forest workers engaged in a cutting operation. J. of Tanzanian Association of Foresters 5(1): 39–48.
Åstrand, P. O. & Ryhming, I. 1954. A nomogram for calculation of aerobic capacity from pulse rate during submaximal work. J. Applied Physiology 7: 218–221.
Axelson, O. 1974. Heat stress in forest work. FAO, Rome. 31 p.
Bakena, E. 1985. Heart rate and workload in cutting of Cypress. A special project submitted in partial fullfilment of the requirements of the degree of B.Sc. (For.). Sokoine University of Agriculture, Morogoro. Manuscript. 30 p + appendices.
Buchberger, J. 1984. Die Beurteilung von Arbeitsbeanspruchungen aufgrund des kontinuierlich registrierten Herzschlagfrequenz. Illustrierte Zeitschrift fur Arbeitsschutz 6/84. 7 p.
Cermak, K. R. 1977. Exergie bei Buchenholzzernte mit der Einmannmotorsage. In: Ergonomics in industry, agriculture and forestry. ILO, Occupational safety and health series 35: 505–509.
Cunia, T. (1960). Production studies in cutting and horse skidding. Canadian Pulp and Paper Association. Woodlands Section Index No. 1951. In: FAO 1976a.
Drugge, U. 1984. Task work rates for logging. Forest Division, Logging and Road Building Project. Letter U/B/9/2/80. 6 p.
FAO 1976a. Harvesting man-made forests in developing countries. Rome. 185 p.
FAO 1976b. The feeding of workers in developing countries. Rome. Food and nutrition paper 6. 77 p.
Fosser, E. 1974. The sulky – working aid in conifer plantations. NORAD, TAN/70/005. Oslo.
— 1976a. Project findings and recommendations. Terminal report, Research project on skidding sulkies, Norway. NORAD, Halden. 9 p + 8 app.
— 1976b. Manual for logging sulkies. Working aid in softwood plantations. NORAD, Oslo. 8 p + 6 photos.
Grandjean, E. 1982. Fitting the task to the man. Taylor & Francis Ltd, London. ISBN 0-85066-191-9. 379 p.
Hansson, J. E., Lindholm, A. & Birath, H. 1966. Men and tools in Indian logging operations. A pilot study in ergonomics. Royal college of forestry, Dept. of operational efficiency, Stockholm. Rapporter och uppsatser 29. 27 p.
Harstela, P. 1975. Työajan menekkiin ja työntekijän kuormittumiseen vaikuttavat tekijät eräissä metsätyömenetelmissä. Summary: Factors affecting the consumption of working time and the strain on the worker in some forest work methods. Commun. Inst. For. Fenn. 87(2). 130 p.
Heikinheimo, L. 1984. Metsätyövoima. Summary: The Forest work force. Silva Fenn. 18(4): 365–375, 396.

Järvholm, A. & Kilander, K. 1965. Prestationer och kostnader vid drivningsarbete i skogsbruket. In: Skogstekniska Data 1964. In: FAO 1976a.
Lange Andersen, K., Masironi, R., Rutenfranz, J. & Seliger, V. in collaboration with Degre, S., Trygg, K. & Orgim, M. 1978. Habitual physical activity and health. WHO Regional publications, European Series 6. Copenhagen. ISBN 92-9020-106-1. 188 p.
Levanto, S. 1976. Suorityskyvyn ja kuormittumisen suhteet metsätyössä. Työtehoseuran Julk. 192. 30 p.
— & Mälkiä E. 1971. Työn vaihtelun vaikutus metsätyöntekijän kuormittumiseen. Summary: The influence of work variation on physiological strain in loggers. Työtehoseuran Julk. 152. 40 p.
Mälkiä, E. 1973. Puutavaran teon fyysisistä kuormitustekijöistä. Summary: On the physic factors of stress in making timber. Työtehoseuran Julk. 165. 32 p.
— 1974. Iän ja fyysisen suorituskyvyn vaikutus työntekijän kuormittumiseen puutavaran teossa. Summary: The influence of age and physical performance on strain of the worker in making timber. Työtehoseuran Julk. 173. 63 p.
Mboya, G. 1985. Factors influencing production rates in sulky skidding. A special project submitted in partial fullfilment of the requirements of the degree of B.Sc. (For.). Sokoine University of Agriculture, Morogoro. Manuscript. 46 p+ appendices.
McCormic, E. J. 1957. Human factors engineering. McGraw-Hill, New York. ISBN 07-044884-1. 639 p.
Micski, J. & Stridsberg, B. 1981. The shortwood method. A field study with two-man raker saw and power saw in Pinus patula plantations at Sao Hill, Tanzania. Swedforest consulting AB. 39 p + app + figs.
Migunga, G. A. 1982. Production rates and costs of different cutting methods in a Tanzanian softwood plantation. UDSM, M.Sc. thesis. Morogoro. 120 p + 6 app.
— & Dykstra, D. P. 1983. Time study on cutting with crosscut saw and chainsaw in a Tanzanian softwood plantation. UDSM, Division of Forestry, Record 30. Morogoro. 18 p.
Minja, T. 1985. Production rate in manual timber cutting of Cypress. A special project submitted in partial fullfilment of the requirements of the degree of B.Sc. (For.). Sokoine University of Agriculture, Morogoro. Manuscript. 54 p + appendices.
Moens, A., van Loon, J. H. & Hoftyzer, R. 1979. Ergonomic aspect of operating two wheeled tractors under tropical conditions. Proc. 5th Ergonomic Symposium, Wageningen, The Netherlands. 12 p.
Ngerageze, T. 1985. Daily energy expenditure of forest workers engaged in timber cutting and sulky skidding operations. A special project submitted in partial fullfilment of the requirements of the degree of B.Sc. (For.). Sokoine University of Agriculture, Morogoro. Manuscript. 29 p + appendices.
Ntahompagaze, J. B. 1985. Factors influencing the heart rate and the workload in sulky skidding. A special project submitted in partial fullfilment of the requirements of the degree of B.Sc. (For.). Sokoine University of Agriculture, Morogoro. Manuscript. 23 p + appendices.
Ole-Meiludie, R. E. L. 1984. The influence of thinning procedures on logging production rates and costs in a Tanzanian softwood plantation. UDSM. Ph. D. thesis. Morogoro. 293 p + 6 app.
— & Omnes, H. 1979. The use of sulkies in thinning softwood plantations. UDSM, Division of Forestry, Record No. 9. Morogoro. 13 p.
Saarilahti, M. 1985. Manual primary transportation. SUA, Faculty of Forestry, Department of Forest Engineering. Lecture notes, Stencil FEN 20. 9 p.
— 1986. Ergonomics. SUA, Faculty of Forestry, Department of Forest Engineering. Lecture notes, Stencil FEN 65.
— & Abeli, W. S. 1985. The use of a simple portable heart rate recorder in determining the work loads of forest workers. Proc. Finland/ILO/IUFRO Workshop on operational efficiency work study and ergonomics in forestry. Olmotonyi, Arusha.
— & Ole-Meiludie, R. E. L. 1987. Production rate and work strain on workers in cutting of pines in Tanzania. Seloste: Työn tuottavuus ja työntekijän kuormittuminen männyn hakkuussa Tansaniassa. Silva Fennica 21(1): 95–106.
Samset, I. 1950. Hogstundersøkelser i norsk granskog. Medd. Norsk Skogsforsk. 37: 397–597. In: FAO 1976a.
Scott, A. H. 1973. Work measurement: Observed time to standard time. In: Wittering. Work study in forestry. Forestry commission bulletin 47. London. 26–39.
Singleton, W. T. 1972. Introduction to ergonomics. WHO, Geneva. 143 p.
Skaar, R. 1973. Skidding of sawlogs from conifer thinnings with a locally made skidding cart. A pilot study. Makerere University, Dept. of Forestry, Kampala. Report 01–73. 18 p.
— 1981. The use of hand-sulkies in logging. Proc. XVII IUFRO World Congr. Ibaraki, Japan: Div. 3: 473–480.
Skoglig arbetsstudienomenklatur i Danmark, Finland, Norge och Sverige. 1963. The Nordic forest work study council, Bulletin No. 1. 56 p.
Sport Tester (No year). PE 2000. Leaflet. Escotek, Oulu. 16 p.
Staaf, A. 1972. Drivning – avverkning och transport i skogsbruket. LTs förslag-LTK, Borås. ISBN 91-36-00193-7. 444 p.
— 1979. Skydd och säkerhet i skogsbruket. LTs förlag, Stockholm ISBN 91-36-00268-2. 176 p.
Strehlke, B. 1971. Suggestions on ergonomic studies related to tropical forestry. In: Methods in ergonomic research in forestry. IUFRO. Norwegian Forest Res. Inst., Ås. p. 139–143.
Vik, T. 1971. Maximal aerobic power of Norwegian forestry workers. In: Methods in ergonomic research in forestry. IUFRO. Norwegian Forest Res. Inst., Ås. p. 123–128.

Total of 51 references

Seloste

Tutkimuksia metsätyöstä Tansaniassa

Ergonomisia tutkimuksia yhdistettyinä aikatutkimuksiin tarvitaan kehitettäessä miestyövaltaisia puunkorjuumenetelmiä. Tästä syystä ergonomia on yksi Sokoinen maatalousyliopiston metsäteknologisten tutkimusten painopistealoja. Tässä tutkimuksessa esitellään opinnäytetöissä saatuja tuloksia, jotka koskevat tuotosta ja kuormittuneisuutta sypressin avohakkuussa ja sulkyjuonnossa. Lisäksi esitetään metsätyömiesten päivittäistä energian kulutusta koskevia arvioita.

Tutkimus on tehty Tansaniassa lähellä Arushan kaupunkia, 1.5–2.0 km korkeudella Meru-vuoren rinteillä sijaitsevassa istutusmetsässä. Ilman lämpötila tutkimusaikana, helmikuussa 1984, oli aamuisin työtä aloitettaessa 16–18 °C, ja keskipäivällä työtä lopetettaessa 18–20 °C. Lämpötila ei kohoa työtä haittaavan korkeaksi.

Tansanialaiset metsätyömiehet ovat ruumiinrakenteeltaan kevyempiä kuin pohjoismaalaiset metsurit tansanialaisten keskipainon ollessa alle 60 kg. Maksimi hapenottokyky ruumiin painon kiloa kohti on samaa suuruusluokkaa kuin pohjoismaalaisilla, 46 mL/min/kg, mutta suorituskyky jää alhaisemmaksi pienemmästä ruumiinkoosta johtuen. Maksimaalinen hapenottokyky lisääntyy degressiivisesti työvuosien myötä. Tästä syystä nykyinen koulutusmenetelmä, jossa kokematon tulokas pannaan työskentelemään yhdessä hyvän suorityskyvyn omaavan kokeneemman metsurin pariksi aiheuttaa sen, että uusi tulokas kuormittuu kohtuuttomasti.

Puutavaran teossa seurattiin neljää kahden miehen työryhmää siten, että yhtä työmiestä seurattiin kahden päivän ajan mittaamalla työvaiheajat ja puutavaran tilavuus sekä rekisteröimällä syketaajuus "Sport Tester"-laitteella, joka tallentaa 30 s välein 5 s syketaajuuden keskiarvon. Laite luettiin joka puun jälkeen. Tästä aiheutui n. 10 % lisäaika, jonka kuluessa suurin osa työmiehistä elpyi hyvin, ts. heidän pulssinsa laski lähelle leposykettä. Kaikkiaan valmistettiin 125 puuta joiden keskimääräinen rinnankorkeuskeskiläpimitta oli 34 cm. Työmiehet tekivät normityötä päivänormin ollessa 9 puuta työryhmää kohti (7 lauantaisin). Ryhmän työkaluina olivat hyväkuntoinen 2-miehen justeeri, joka kunnostettiin keskusvarikolla viikoittain ja 2 heikkokuntoista kirvestä, jotka kunnostettiin iltaisin kotona, sekä 2 kiilaa. Keskituotos oli 2,6±0.1 m³ työryhmätuntia kohti. Tuotoksen vaihtelu työryhmien välillä ja sisällä oli vähäistä. Eniten tuotokseen vaikutti puun koko. Työmiehet pitivät yllä urakkatyötahtia ja saivat urakkansa täyteen alle 3.5 tunnissa. Keskeytysajan osuus oli vähäinen, alle 5 % kokonaistyöajasta. Lämmin lounas, yleensä maissipuuroa, tarjottiin keskipäivällä, ja lounaan jälkeen miehet kävelivät koteihinsa.

Syketaajuus oli

kaadon aikana	118,2±2,6	P/min,
karsinnan aikana	118,5±2,6	P/min,
katkonnan aikana	115,6±2,3	P/min,
puutavaran teon aikana	117,5±2,3	P/min.

Kuormittuneisuusaste oli 41±2 %, mikä vastaa kohtuullista kuormittuneisuutta. Ainoastaan yksi työmies, joka oli työskennellyt vain 2 kk, osoitti ylikuormittuneisuuden oireita. Sekä syketaajuus että kuormittuneisuus riippuivat erittäin merkitsevästi työmiesten hapenottokyvystä.

Sulkyjuontoa tutkittiin männyn ja sypressin ensiharvennuksissa. Tutkimuksen aikana seurattiin kolmea työryhmää, joista toisen jäsenen syketaajuus rekisteröitiin. Kaikkiaan tutkimus kesti 9 päivää, jona aikana juonnettiin 216 kuormaa. Työtahti oli hitaampi kuin puutavaran teossa, sillä arvioitu joutuisuus oli 87 syketaajuuden ollessa 106,1±1,1 P/min ja kuormittuneisuusindeksin 30,3±0,8. Tuotos, 1,07 m³/h 46 m juontomatkalla, oli alhaisempi kuin muissa tutkimuksissa yleensä, pienestä kuormakoosta, 0,087 m³ alamäissä, johtuen. Teoreettisesti kuorman olisi pitänyt olla ehkä 0,175 m³.

Koska oma ruoan viljely on tärkeä tulonlähde lähes joka työmiehelle, he viettivät keskimäärin 2–3 tuntia päivässä erilaisissa maataloustöissä, joissa heidän energian kulutuksensa oli keskimäärin 16,8 kJ/min. Myös kävely rinteisessä maastossa lisää heidän päivittäistä energian kulutustaan, ja lähes kaikki tekomiehet kuuluivatkin "Erittäin aktiivinen" -ryhmään heidän päivittäisen kokonaisenergian kulutuksensa (15,0 MJ/d) perusteella. Juontomiesten kokonaisenergian kulutus oli alhaisempi.

On mahdollista lisätä päivätuotosta pidentämällä työmaa-aikaa ja/tai nostamalla työtahtia. Tilanne vaikeutuu kuitenkin, jos tarkastellaan työmiehen koko päivää. Mikäli urakkaa nostetaan, varsinkin jos siihen liittyvä rahatulon lisäys on pieni, ja työmiehet joutuvat vähentämään työpanostaan maataloudessa, hyöty heidän näkökulmastaan saattaa olla negatiivinen, mikä lisää työstä poisjääntiä ja työvoiman vaihtuvuutta. Todellista tuottavuuden nousua ei siten ehkä saavutetakaan vain normia kohottamalla. Palkkakustannuksia voidaan tuskin täten alentaa.

Tapaturmatiheys on verraten korkea indeksin ollessa 173 onnettomuutta miljoonaa työtuntia kohti, ja tapaturmatorjunta tulisi liittää koulutukseen. Koska korkea lepopulssi näyttää olevan korreloitunut alhaiseen työkykyyn näyttäisi mahdolliselta kehittää työmiesten valintaa siten, että vain fyysisesti sopivat otetaan työhön.