

Feasibility of Excavator-Based Harvester in Thinnings of Peatland Forests

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ABSTRACT

In the next twenty years in Finland, annual cuttings on peatland forests are foreseen to increase by up to 30 % of the total cuttings. Cost effective harvesting methods on low yield peatland forests coupled with low ground bearing capacity are required. One solution to improve the feasibility of harvesting could be excavators tailored for forestry use and equipped with a harvesting head.

In the study, cost competitiveness and productivity of the excavator-based harvester were investigated. The cost analysis focused on operating hours of harvester use, shift arrangements and purchase prices for the base machine and harvesting equipment when the base machine was used partly as a harvester and an excavator. Results were compared to conventional wheeled harvesters.

If the base machine is used more than 3 working months as a harvester in addition to normal (6-8 months) excavator work, the harvesting method would be cost competitive compared to purpose-built harvesters (if 1½ and 2 shift arrangements were used). The 25 % increase of the base machine's and harvester equipments' purchasing costs did not eliminate the cost competitiveness of harvesting, when harvesting was carried out in 1 ½ shifts for at least 4 months.

It would be feasible and profitable to invest in harvesting equipment for the excavator and therefore diminish the winter lay-days of the base machine by utilizing it in logging operations. Conditions on peatland sites mean that during the winter time the use of the excavator-based harvester is ideal, when the utilisation of all logging machines is at its highest.

Keywords: *excavator-based harvester, single-grip harvester, peatland, thinning, CTL-method, cost analysis, operating hourly cost, Finland.*

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INTRODUCTION

In Finland, ditched peatland forests represent 24 % of the total forestland and in some provinces their share amounts to 40 % or more of the productive forest area [1]. During the 1960s and 1970s in particular, there was a significant effort to increase production of round wood on peatlands, due to an increased demand for timber and pulpwood by the forest industries [11]. The expected intensive utilization of peatland forests has not taken place mainly due to the associated expensive harvesting and logistic costs and the availability of more attractive alternative wood supply lines. Today, most of the peatland forests are at a young stage and in need of first thinnings and reditching [10].

In recent years, the amount of annual cuttings has been less than 10 million m³ in peatland forests in Finland, but scenarios based on the National Forest Inventory data suggest that annual cuttings can increase up to 15-20 million m³ within the next two decades [12]. This figure corresponds to about 30 % of total annual cuttings in Finnish forests. In order to meet the yield expectations, there is an apparent need for the large-scale application of first thinnings and other forestry operations on peatland forests.

The low harvesting yield and small size of the trees, pose a large challenge on mineral and peat soils. In addition, there are factors that weaken the economics of logging on peatlands. Loggings are mainly carried out during the wintertime on frosted and snowy peatlands due to the low bearing capacity of the ground and the location of tree roots close to the soft soil surface during the unfrozen period. Timber hauling faces difficulties with the ditch network, which determines the main moving direction and the locations of the thinning tracks resulting in longer hauling distances. In addition, tree distribution is uneven, since most of the merchantable trees are located close to the ditches. Therefore it is necessary to employ cost-effective harvesting equipment to accomplish the expected work effort on peatland forests.

Excavators are commonly used world-wide for earth moving on various construction sites. Base machines are mass produced on assembly lines using standard components. When compared to conventional harvesters, the excavators' lower investment costs have been a major reason to use them as base machines equipped with a harvester head. Excavators have been used as a base machine to carry out various logging operations for a long time in, e.g. Canada, USA and New Zealand [5]. In recent years the popularity of excavators as harvesters has increased in Great Britain [4] and Ireland [8] where CTL method has been the main logging method. Corre-

spondingly, in Finland, it is estimated that approximately 10 to 15 excavator-based harvesters will be employed in logging operations during the forthcoming winter season (2003-2004) [7].

New innovations and solutions have been created for excavators to improve the working ability of forestry operations. Excavator manufacturers have improved the ergonomic aspects of the machine resulting in better ergonomic conditions close to conventional harvesters [5]. Nevertheless, difficulties in regards to cabin access and ergonomics are assessed as "less good" [5]. Excavators equipped for forestry operations have an undercarriage with high ground clearance, which improves the mobility in stands with large obstacles (stumps, stones etc.) [9]. These undercarriages can be equipped with wider tracks to further diminish their impact on the ground.

From the point of view of thinning operations some excavator manufacturers offer a concept of maincarriage having no tail swing extension. Tail swing has been the primary reason for not utilizing the excavator-based machines in thinnings [5]. The implementation of an additional boom, with integrated aiding device, at the end of the main boom provides greater reach of the harvester head and a possibility to help the motion with the boom, when conditions impede the movement of the base machine [10].

In Finland, excavators have been used mainly in ditching operations, but also in soil preparation work, forest road construction and tree planting. For various forestry operations, excavators have been used also in other countries such as Ireland [3, 8] and Sweden [17]. Wintertime ditching is restricted in Finland by regulations and so a large number of excavators are idle. Instead of winter laydays there is a possibility to use the excavator as a base machine for a harvester and thereby provide a feasible solution for wintertime-stressed loggings on peatlands.

The aim of this study is to illustrate the feasibility of utilising the excavator as a harvester on its lay days, with it continuing its basic excavator work the rest of the time. The cost-competitiveness of an excavator-based harvester was compared to thinning harvesters and midsize harvesters. Additionally, a trend setting unit cost calculation was formulated from one operator's productivity values in thinnings with excavator-based harvester [10] and was compared to the thinning harvesters.

MATERIALS AND METHODS

Cost-calculations were based on the methods used by Salo and Uusitalo [14], where the costs of the forest

machines were calculated based on the wood harvesting cost calculation model. Total machine costs included capital costs, operator's salary cost, operating and maintenance costs and overhead costs. In addition to the total cost, 5 % was added to take into account entrepreneurship risk. The values of cost elements used 2001 as a base level. Costs were calculated without value added tax (VAT 0 %) and an interest-rate of 5 % was applied. In the cost calculations the currency conversion rate 1 € = 1.1672 US\$ was used.

Cost comparisons were made for harvesters specially designed for thinnings and conventional midsize harvesters. The cost values of thinning specific harvesters, which are also capable of harvesting standard sized clear-cuttings, were referred from the publication of Rynnänen & Rönkkö [13], where the productivity and costs of different wheeled thinning harvesters were studied. An entrepreneurship risk of 5 % was added to the referred costs of thinning harvesters in order to make the costs of the machines more comparable. In the cost calculations, the values of the harvesting cost factors were calibrated to the same level for as the excavator-based harvester and the midsize harvester (Appendix 1). An exception was repair and service costs, which were 5.8 US\$/operating hour for the excavator-based harvester and 8.2 US\$/operating hour for the midsize harvester. Table 1 highlights some of the basic values of the studied machines.

The purchase prices of the excavator and its harvester equipment were attained from the Kobelco excavators dealer (Kesko Ltd. Konekesko) in Finland. The excavator used in the cost calculations was the Kobelco SK135SRL equipped for forestry use with the Foresteri 22 harvester head and the Epec 50 measurement system. Additionally, in this case, harvesting equipment includes an extra boom, cabin safety glasses, extra lights (and charger) and hydraulic pipe installations. Some technical data about the excavator is presented in Table 2.

Both excavating costs and harvesting costs, were included in the cost calculation model of the excavator-based harvester. Costs of excavating and harvesting were separated to ensure that all costs were divided into different work types by their actual work time. Work type specific equipment capital costs and its operating costs were applied only to the appropriate work element. E.g. harvester equipment costs applied only to the harvesting element. An example of the cost division to different work and hourly cost calculation is expressed in Appendix 2. With the installations, the harvesting equipment's total purchase cost was 65 713 US\$ (VAT 0 %). Additionally for the excavator, costs included two different ditching buckets totalling 6 303 US\$ (VAT 0 %). For the calculations machine utilization was 88 %. In addition relocation com-

Table 1. Basic values of the studied machines and the cost calculation.

	Excavator-based harvester	Thinning harvester	Midsize harvester
Purchase price, US\$ (VAT 0 %) (+ harvesting equipment, VAT 0 %)	122 603 (65 713)	260 904	385 916
Service life, hours (SL of harvester head)	12 000 (6 000)	12 000	15 000
Operating hours annually, h	2450 (in 1½ shifts and 11 work months)	2570	2600
Machine utilization, %	88	Not mentioned	88
Interest rate, %	5	5	5
Entrepreneurship risk, %	5	5	5
Weight level of machine, tonnes	14-16	11-12	13-16

Table 2. Technical data of the Kobelco SK135SRL and the Kobelco SK135SRLC excavators.

Characteristics	Kobelco SK135SRL	Kobelco SK135SRLC
Weight, tonnes	16.2	14
Engine power, kW	70.1	62.5
Ground clearance, mm	600	455
Pulling force, kN	157	127
Overall width, mm (with 900 mm width tracks)	2940	2940
Tail swing, mm	5	5

prised 5% of the time, with the remaining 7% being repair and maintenance.

For formulating a trend-setting estimation of the unit costs of harvesting with an excavator-based harvester, productivity levels of the excavator-based harvester were

taken from the publication of Niemi et al. [10], where an excavator-based harvester (Kobelco SK135SRLC) was employed in peatland thinnings during the winter of 2001 (Figure 1). A harvesting cost comparison was made among purpose built thinning harvesters and an excavator-based harvester (Table 2).

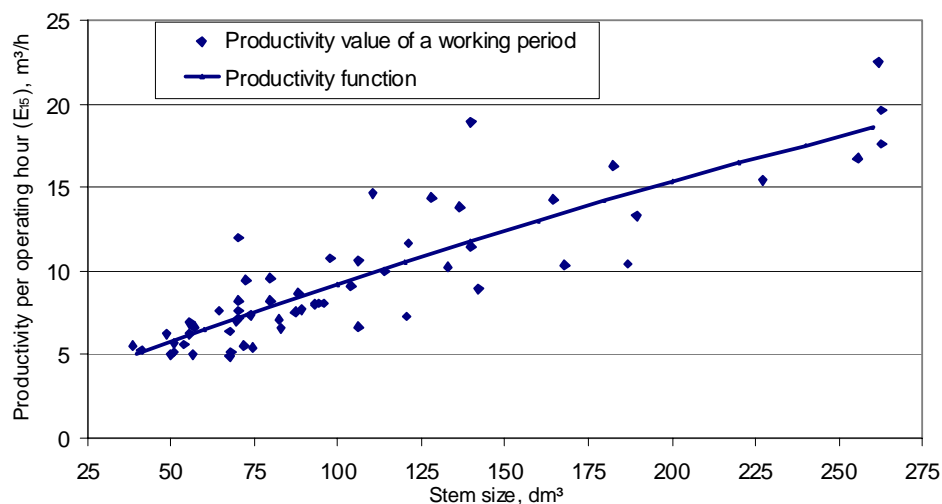


Figure 1. Productivity per operating hour (E_{15}) of 14 tonne's excavator-based harvester in a wintertime (3 months) peatland thinnings [10].

RESULTS

Results of the excavator-based harvester's operating costs were expressed using different work shift arrangements, when the share of harvesting and excavating works differs in months (Figure 2). Same shift arrangements were used for excavating and harvesting. The maximum working time for the excavator was set at eight months per annum. The operating hourly costs of the purpose built thinning and midsize harvesters were 74.1 US\$ and 78.4 US\$, respectively, when the annual work time was 11 months.

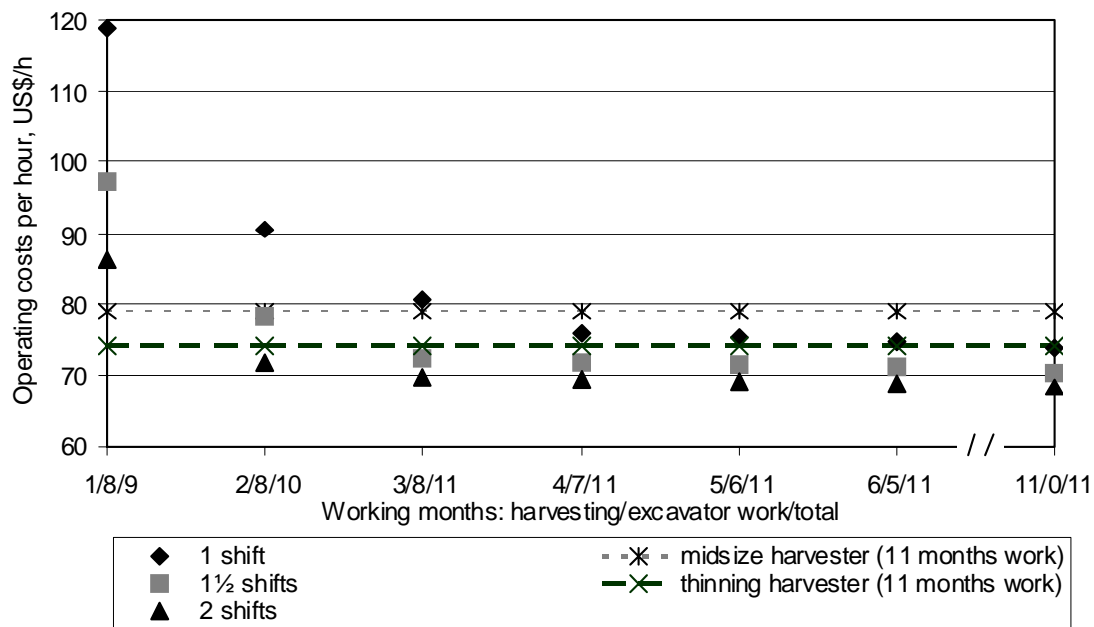


Figure 2. The effects of work shift arrangement and harvesting month changes to operating costs per hour of the excavator-based harvester.

There is a significant decrease in the operating hourly costs of harvesting. This varies from one to three months depending on the work shift arrangements. The excavator-based harvester's hourly costs undercuts the thinning harvesters' hourly costs, when excavator-based machine is used for harvesting for at least three months in either 1½- or 2-shifts. A single shift's operating hourly cost is 8.1 US\$ higher than operating as 1½ - shift arrangement, when harvesting was done for 3 months. If harvester work is carried out over a period of 11 months annually with a 1 work shift arrangement, operating costs per hour are the same as the thinning harvester with 1½-work shifts. Additionally, the basic excavator's operating cost per hour decreases 3.2 US\$, when base machine's annual work time increases from 8 to 11 months.

The effects of the excavator's purchase price change regarding the operating costs of harvesting are presented

in Figure 3, when the base price of the excavator (122 603 US\$) varied $\pm 25\%$ and 1½-work shift arrangement was used in the calculations. The additional cost of harvester equipment remained constant at 65 713 US\$.

With 1½-shift work arrangements, the 25% increase of purchase price only increased the operational hourly costs of harvesting by 3.4% (2.5 US\$). Therefore, the 25% more expensive excavator with a purchase price of 153 253 US\$ undercuts the operational hourly cost level of thinning harvesters after four months of harvester work.

The results of the changes of the harvester equipment's purchase price are reflected in the operating costs, when the price of the excavator remains at the initial value (Figure 4). The $\pm 25\%$ price change applicable to the initial harvesting equipment price is more sensitive on the operational costs than the price changes of the excavator, when harvesting is carried out for only one or two months. At a feasible level of harvesting work time (3 months), the operational hourly costs are competitive compared to the thinning harvester's costs, even if the cost of harvesting equipment is 25% higher than the initial value.

The unit costs of cutting were formulated for the excavator-based harvester with the aid of Niemi et al's [3] productivity values. Unit costs were calculated with 1 and 2 - shift work arrangements, when cutting was made for 4 months and excavation for 7 months. The unit costs of excavator-based harvester were compared to those of

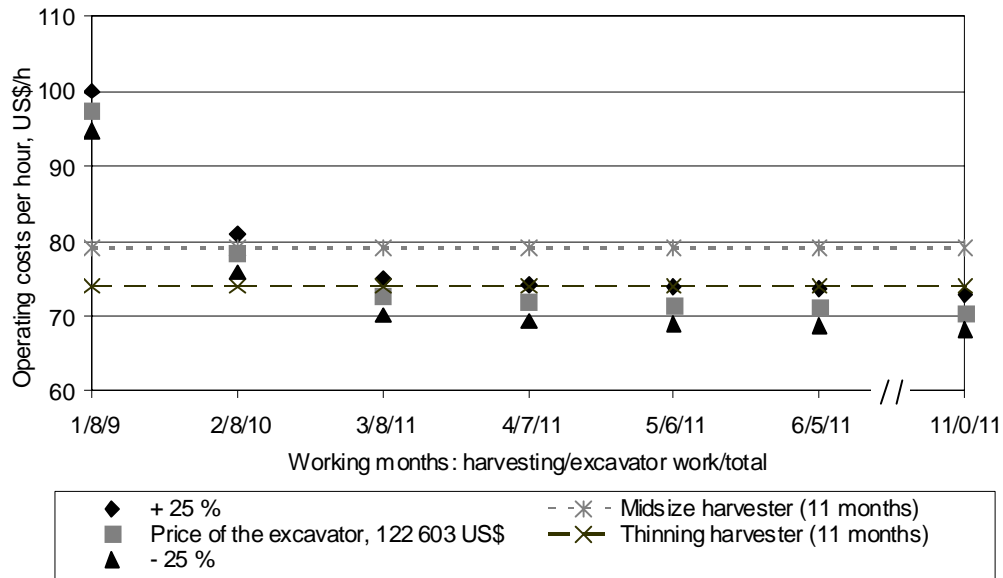


Figure 3. The effects of excavator’s price and harvesting month changes to operating costs per hour of the excavator-based harvester. 1½-work shift arrangement was used in the calculations.

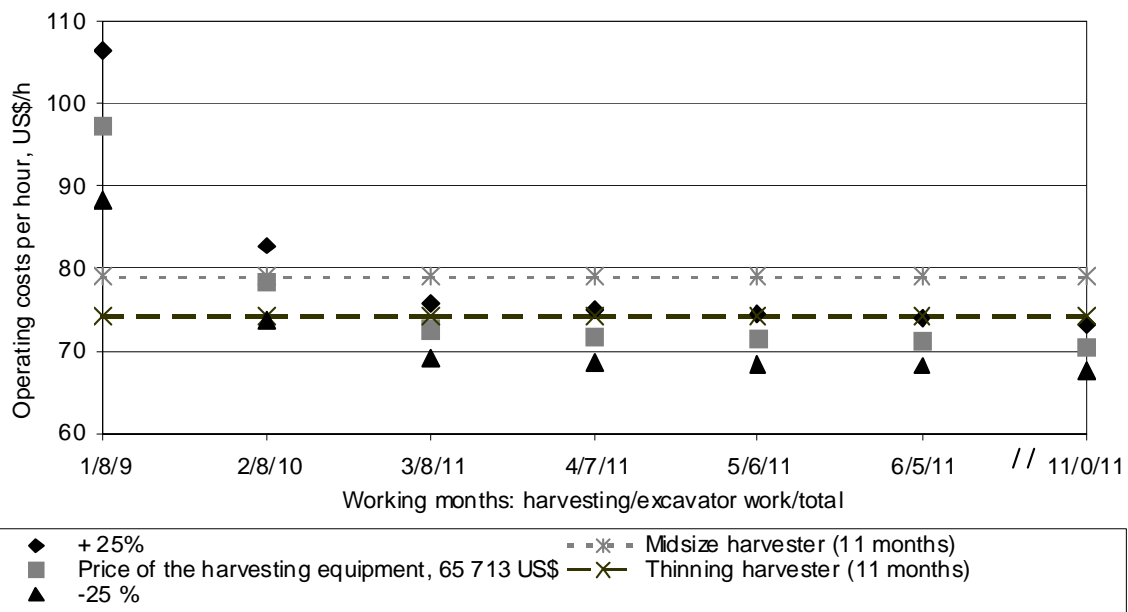


Figure 4. The effects of harvesting equipment’s price and harvesting month changes to operating costs per hour of the excavator-based harvester. 1½-work shift arrangement was used in the calculations.

thinning harvesters. unit costs based on productivity and cost studies of thinning harvesters with the purchase price level presented in this paper [12, 15].

With the expressed work shift arrangements, unit costs are 9.7% higher, when operating in one shift instead of two shifts. In this comparison the excavator-based harvester seems to be cost-competitive and a feasible solution in all stem sizes showed in Figure 5.

DISCUSSION

The operating hourly cost of the machine is a suitable factor for analysing cost fluctuation of a certain machine in a changing working environment and for finding economically feasible work concepts for the studied machine system. For comparing the cost competitiveness of different machines, the unit costs should be used. In this study both methods were used in the cost analysis. The excavator-based harvester’s cost-competitiveness comparison with the unit costs was made to the thinning

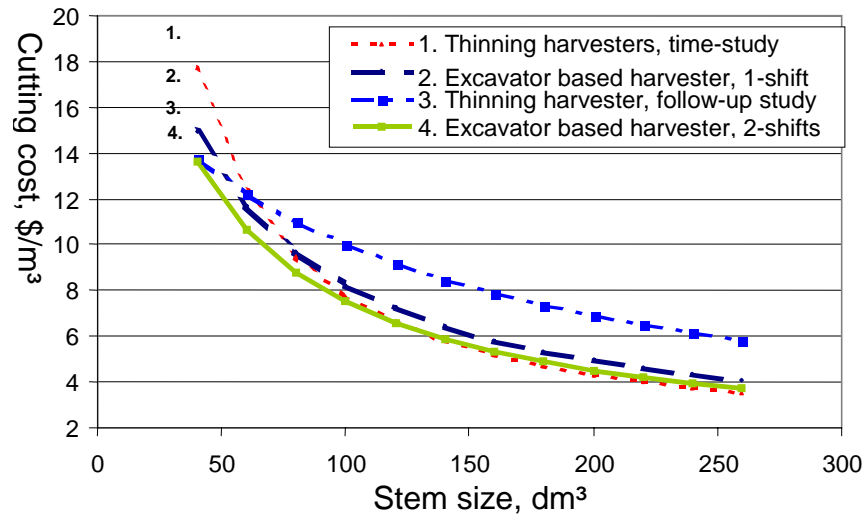


Figure 5. The unit costs of cutting for excavator-based harvester and thinning harvesters (values from the studies of Rynnänen and Rönkkö [13]* and Siren and Aaltio [16]**).

harvesters, which could potentially be used for peatland thinnings but are also capable for use in clear cuttings. In this case the unit cost comparison of machine works gives only trend setting results and the generalisation value is very low.

The productivity function of the excavator-based harvester [10] was formulated from the work performance of only one operator in peatland thinnings during the wintertime. The machine operator greatly affects the output of the harvester. In recent work studies of single grip harvesters the difference between experienced harvester operators' work output has been as much as 40 % or more [6,13,15,18].

The operating costs of harvesting during the maximum number of working months (11 months) were also included in the cost calculation figures. It revealed that hourly operating costs were only slightly reduced when harvesting was increased to the maximum number of working months. In Finland, for excavator-based harvesters to be operational all year, additional harvesting on mineral soils will be required.

In addition to normal excavator work, 2-4 harvesting months were needed to keep the excavator-based harvester's costs at an economically feasible level, since it is dependent on the work shift arrangements. As a result of increased base machine utilization, operating hourly costs for the excavator work also diminishes. Additionally, ± 25 % changes to the initial purchase prices of the excavator or harvester equipment did not significantly affect the operating hourly costs, if harvesting was done for at least 4 months. The main reason for having feasible operating costs for the

excavator-based harvester was the lower purchase price compared to purpose built harvesters and therefore even with lower productivity the unit costs of harvesting are still cost-competitive.

Cost calculations verify the assumption that it would be feasible and profitable to invest in harvesting equipment for the excavator which would reduce the winter lay-days of the base machine by utilizing it in logging operations. However, harvesting and especially thinning with a single grip harvester is demanding work with several aspects simultaneously influencing the decision making during operation. Attainment of an adequate performance level in thinnings, education and practical experience is needed over some years, regarding to work productivity and quality [2].

The expressed concept is an option for wintertime stressed harvesting on peatlands, where the base machine can provide work opportunities all year round. It also provides possibilities to reduce logistical costs by combining forestry projects on peatland forests, where both thinning and re-ditching are made by the same base machine, thereby reducing operational and translocation costs.

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Appendix 1. Cost calculation values of the excavator-based harvester (VAT 0 %).

Purchase price of excavator, US\$	122 603	Consumption; units/hour	
Service life, hours	12 000	Tracks (once per 5 000 hours)	0.0002
Depreciation (per year), %	25	Salary (piece and hourly wages), US\$/h	11
Purchase price of harvesting equipment (installed), US\$	65 713	Extra for evening shifts, US\$/h	1.41
Service life, hours	6 000	Indirect salary costs, %	67
Depreciation per year, %	25	Costs;	
Excavating buckets (2 units), US\$	6 303	Fuel, US\$/l	0.47
Interest rate, %	5	Motor and gear oil, US\$/l	1.17
Working time; hours/shift	8	Hydraulic and chain oil, US\$/l	1.52
days/month	21.1	Colour-marking paint, US\$/l	1.63
Machine utilization, %	88	Chain, US\$/unit	14.5
Share of relocation, %	5	Chain plate, US\$/unit	45.1
Share of repair and maintenance, %	7	Tracks, US\$/unit	3 922
Consumption; litres/hour		Transport-to-work expenses, US\$/km	0.42
Fuel	12	Average distance, km	40
Motor and gear oil	0.1	Maintenance expenses, US\$/day	26.8
Hydraulic oil	0.25	Transferring expenses, US\$/km	1.17
Chain oil	0.53	Average distance, km	50
Colour marking paint	0.3	Repair- and service costs, US\$/E ₁₅	5.8
Consumption; units/hour		Insurance costs, US\$/year	2 043
Chains	0.1	Administration costs, US\$/year	2 918
Chain plates	0.02	Maintenance costs, US\$/year	1 167

Appendix 2. Cost calculation of an excavator-based harvester, when work distribution is 4 months (891 operating hours) and 7 months (1560 operating hours) for harvesting and excavating, respectively, at a 1½-work shift arrangement.

Salary costs, US\$/year	Harvesting	Excavating	Total
Piece wages	9 779	17 113	26 891
Hourly wages	1 333	2 334	3 667
Evening shift extra	238	417	656
Indirect salary cost	7 605	13 308	20 913
Salary costs totally, US\$/year	18 955	33 172	52 127
Variable costs, US\$/year			
Fuel costs	4 993	8 738	13 732
Motor oil costs	104	182	286
Gear oil costs	104	182	286
Hydraulic oil costs	338	592	930
Chain oil costs	717		717
Colour marking paint costs	437		437
Chain costs	1 290		1 290
Chain plate costs	803		803
Tracks	699	1 223	1 922
Buckets for excavation		1 287	1 287
Travelling expenses	4 561	7 982	12 544
Maintenance expenses	195	342	537
Repair and service costs	5 201	9 102	14 304
Transferring costs	1 478	2 586	4 064
Variable costs totally, US\$/year	20 921	32 217	53 138
Fixed costs, US\$/year			
Salary costs	18 955	33 172	52 127
Depreciation costs	15 662	12 854	28 516
Interest costs (5 % interest rate)	3 194	2 527	5 720
Insurance costs	743	1 300	2 043
Administration costs	1 061	1 857	2 918
Maintenance costs	424	743	1 167
Fixed costs totally, US\$/year	40 039	52 452	92 491
Entrepreneurship risk, 5 %	3 048	4 233	7 281
Total costs, US\$/year	64 008	88 902	152 911
Operating hourly costs, US\$/hour	71.8	56.1	61.8