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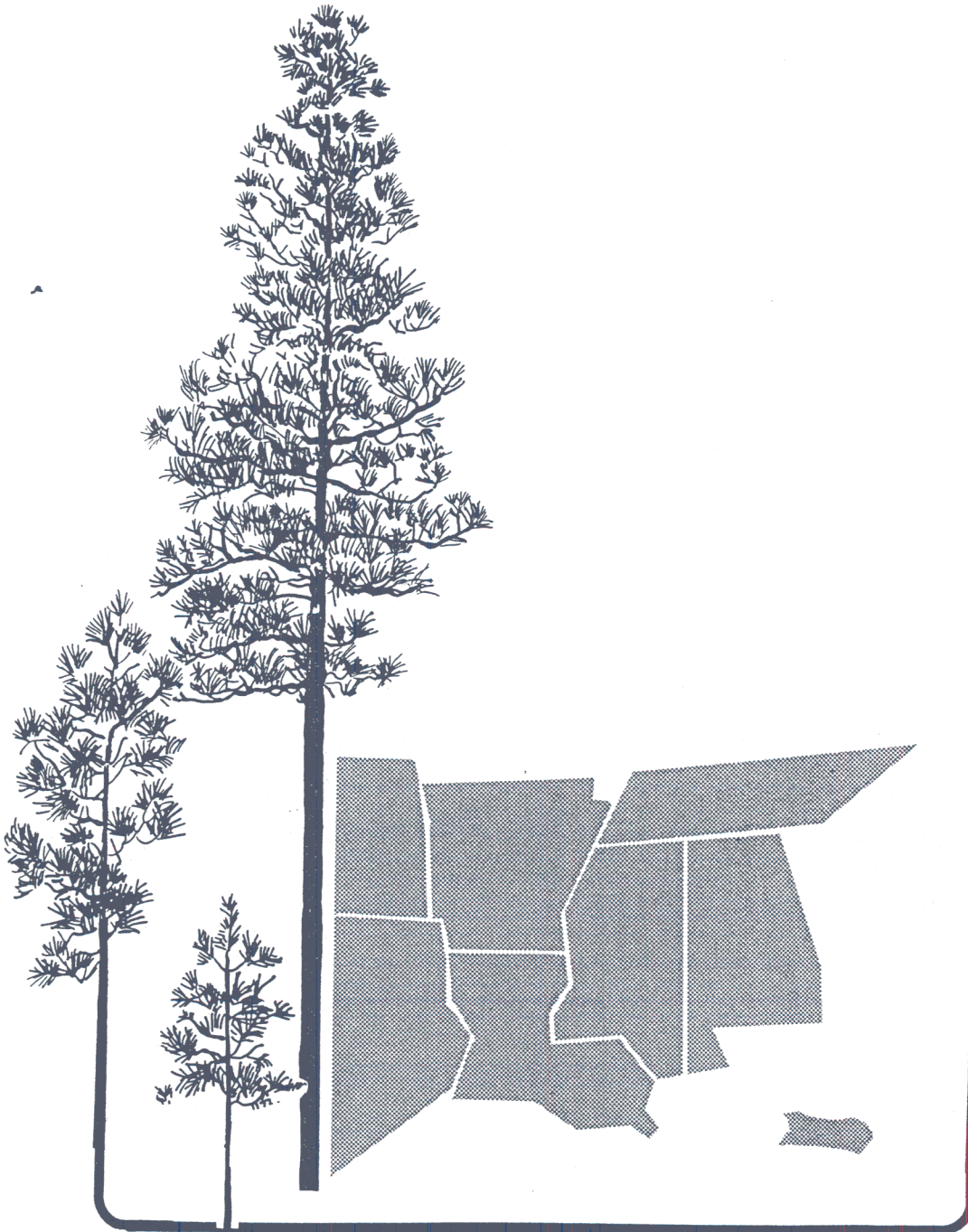
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# COMPARISON AND FEASIBILITY OF NORTH AMERICAN METHODS FOR HARVESTING SMALL TREES AND RESIDUES FOR ENERGY

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## ABSTRACT

A database of North American harvesting systems was developed. Parameters for each system included site, material and product characteristics, equipment mix and production rate. On-to-truck and delivered costs per green tonne, and breakeven oil prices were developed using standard costing methods. Systems costs were compared over the ranges of piece size, volume per unit area removed, capital/labor ratio and other variables. Feasibilities of various systems were also compared.

## INTRODUCTION

Several reviews of studies of wood harvesting for energy have been published. Wellwood (1979) analyzed the harvesting literature during the 1970's. McKenna (1984) summarized the state of the art. Pottie and Guimier reviewed methods for harvesting and transport (1986) and for preparation (1985). Johnson (1989) summarized equipment studies on recovery, collection and processing. Hakkila (1989) reviewed harvesting systems as part of an extensive work on utilizing residues.

Differences in site conditions, material characteristics and other factors such as labor rates make it difficult to directly apply the costs reported in a review or single study to a situation in another area. This problem can be partially remedied by incorporating basic characteristics and production information into a computer database. Studies with characteristics approximating those of a given situation can be identified, and local hourly cost rates applied to generate estimates of harvesting costs. Koten (et al. 1984) developed a database of conventional stump-to-truck harvesting equipment suitable for harvesting biomass. It was implemented on a mainframe computer, and used the Statistical Analysis System (SAS) to evaluate the data and generate graphical output. The database included information on over 150 site/harvest system combinations in the eastern United States. Many of the included systems harvested multiple products. Guimier (1985) developed a biomass equipment database using dBase II on an HP-150 personal computer. Information on each machine included functions performed, type of material handled and purchase price, as well as many other attributes. Production rates and operating costs were not included within the scope of the database.

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<sup>1</sup> Presented at the International Energy Agency, Task VI, Activity 3 Workshop, "Harvesting Small Trees and Forest Residues," Copenhagen, Denmark, May 28-29, 1990.

The current study combined the benefits of both the Kotten and Guimier efforts to generate specifications for a database for non-integrated harvesting of small trees and residues for energy. The goals were to evaluate the onto-truck costs and feasibility of systems used in North America, and provide a flexible database implemented on a personal computer for use by others.

## METHODOLOGY

A review of the literature identified equipment and systems which have been tested and/or used commercially to harvest small trees and/or forest residues in North America. Systems for simultaneous harvesting of multiple products were generally excluded, except for cases where the activities could have produced solely energy product. Short rotation plantation equipment was not included.

The database template was developed using the Microsoft Excel spreadsheet program because of the portability it allowed between DOS-based and Macintosh personal computers.

One database record was generated for each reported site/system combination. The data on each record included:

- A. Site characteristics
  - Harvest type (clearcut, thin, preharvest or postharvest)
  - Slope
  - Skid distance
  - Removals per hectare (dry weight, green weight, volume, pieces)
- B. Material characteristics
  - Type (whole trees, complete trees, trees and residues, residues)
  - Size (diameter, dry weight, green weight, volume, moisture content)
  - Species group (hardwood, softwood, mixed)
  - Location (standing, down in-woods, piled in-woods, landing)
- C. Product characteristics
  - Form (unprocessed, baled/unitized, short bolts, chunks, chips)
  - Location (down in-woods, piled in-woods, landing, truck)
- D. Equipment mix and crew
  - Year of purchase price estimates
  - For each of up to four equipment types:
    - Type (a code was used for each unique type)
    - Number of machines
    - Purchase price per machine
    - Power
    - Utilization (productive time/scheduled time)
    - Crew size
- E. Productivity
  - Units (green weight, dry weight, volume)
  - Rate (units per scheduled hour (SH), units per productive hour (PH))
- F. Study information
  - Productivity equations reported (yes or no)
  - Number of days of observation (zero if a simulation)
  - Year in which data was collected
  - Location (state, province or region)
  - Authors and dates for source publications

Through the use of macros, the spreadsheet program adjusts equipment purchase prices to reference year dollars using the Producer Price Index for industrial machinery (USGPO 1990), then hourly costs are generated for each system by the machine rate method (Miyata 1980). Calculations are based on a table of machine cost parameters (life, salvage, repair and maintenance, etc.) which expands upon those reported by Brinker (et al. 1989). An hourly labor rate, including loading, is specified separately.<sup>2</sup>

Cost per metric green tonne (mgt) is calculated from the hourly cost and production figures. Where the source document did not state production in green weight units, assumed default values are used to convert from dry weight or volume units. Many studies reported on only partial systems. Since onto-truck costs are desired, assumed costs for the missing activities are added to the reported costs. Assumed transport, processing and handling costs are added to the onto-truck costs to give delivered costs. Figure 1 shows, for a sample of the studies, costs for the reported activities, added costs to bring material onto truck, and added costs for transport, processing and handling at the biomass facility.

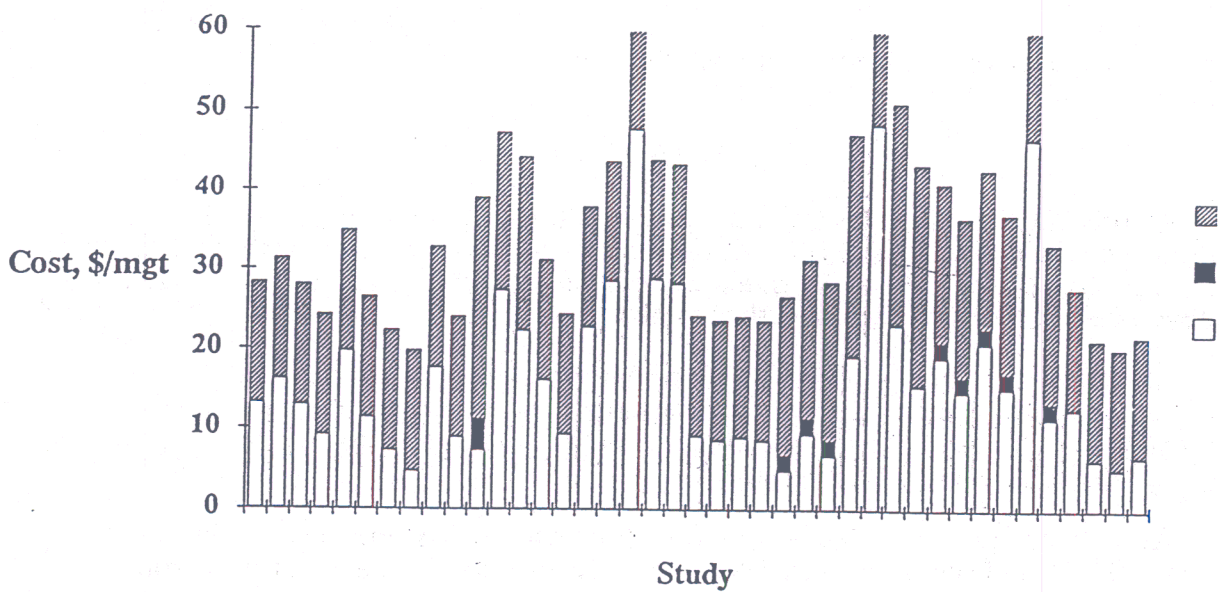


Figure 1. Delivered costs for a sample of studies. Delivered costs include costs for reported activities (white) plus costs onto truck (black) plus transport, additional processing and handling costs (hatched).

As a measure of feasibility, the breakeven price for oil is calculated for the material produced by each system. Recoverable heat energy is derived (Ince, 1979) from an assumed higher heating value of the recovered biomass and the reported or assumed moisture content of the material. Figure 2 displays example breakeven prices for the same group of studies as in Figure 1.

<sup>2</sup> The machine parameters, labor rate and other assumed values are tabulated separately from the system records in the database so they can be easily adjusted by the user if desired.

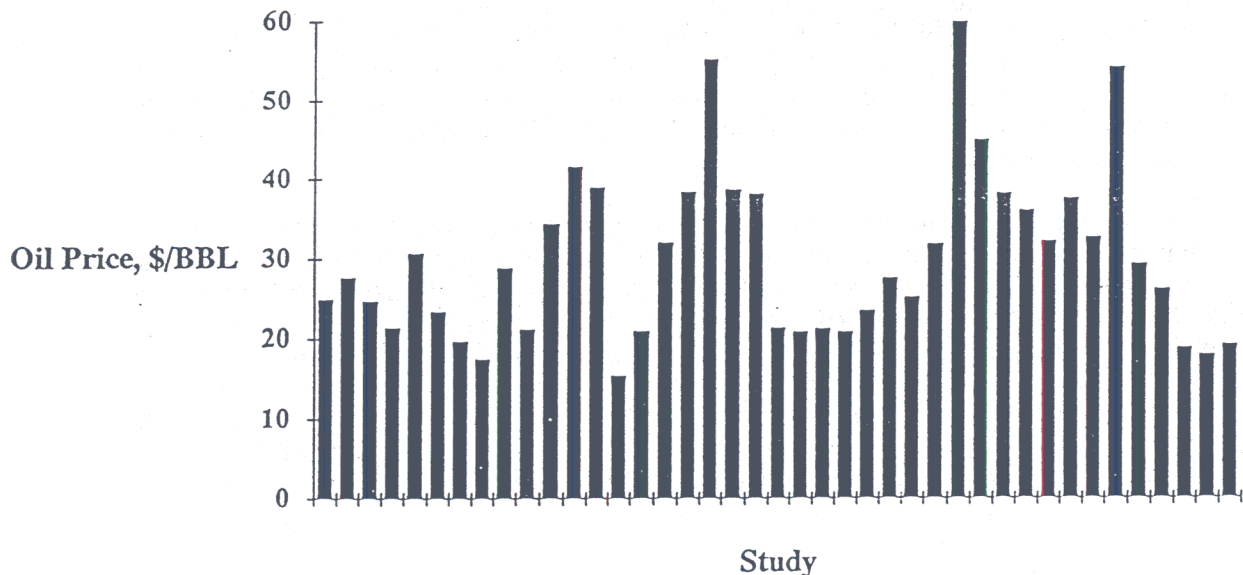


Figure 2. Breakeven oil prices for a sample of studies.

### ANALYSIS

At present, the database has records for 160 site/system combinations. The raw data file can be reviewed with EXCEL on a computer equipped with 640k of memory. An additional 512k of expanded memory is needed to perform the cost and breakeven calculations and to review the results.

As noted by Guimier (1985), the primary value of a database lies in its interactive use on a computer. For example, an individual might select all systems that included a chunker, adjust the cost and other parameters to suit his or her situation, then calculate costs per tonne.

As an overview of the data, a general comparison of systems was carried out. Hakkila (1989) listed several factors which can affect the performance of harvesting options: properties of biomass, scale of operation, logging conditions, etc. Indicators of several of these factors were included in the analysis:

- Material type (trees vs residues),
- Piece size, kg green
- Amount removed, mgt/ha
- Harvesting system for trees (clearcut, thin, prelog, postlog)
- Material location for residues (in-woods vs landing)
- Productivity, mgt/SH
- Capital/labor ratio, \$1000/crewmember

All cost figures were brought to year 1990 dollars. Major assumptions for the analysis included:

Labor rate of \$15/SH

Round-trip transport time of 3 hours per truckload

Handling cost at the biomass facility of \$10/mgt for chips

Higher heating value for biomass of 20 MJ/kg

Boiler efficiencies of 70% for wood and 80% for oil

## RESULTS

As expected, the average of the costs for the various studies decreased as piece size increased (Fig. 3).<sup>3</sup> There were however several instances where costs for small pieces were as low as for larger material. On the average, costs for residues were similar to those for trees. Two notes: (1) the data pool for residues is small because many studies did not report piece size, and (2) many of the residues cases dealt with materials at a landing, so stump-to-landing costs are not included.

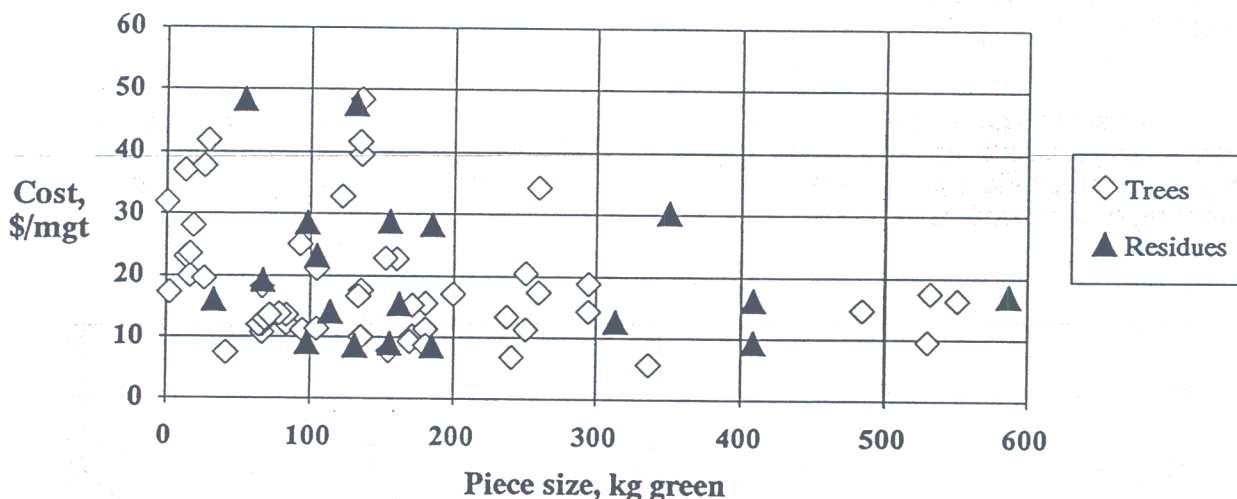


Figure 3. Onto-truck cost versus piece size for small trees and residues.

In general, costs decreased as the amount of material removed per unit area increased (Fig. 4). Some low costs were reported for low removal levels.

<sup>3</sup> Figure 3 and many of the following figures have been truncated at \$60/mgt to allow expanded display of the data of most interest. Several records with onto-truck costs between \$60/mgt and \$200/mgt are in the database.

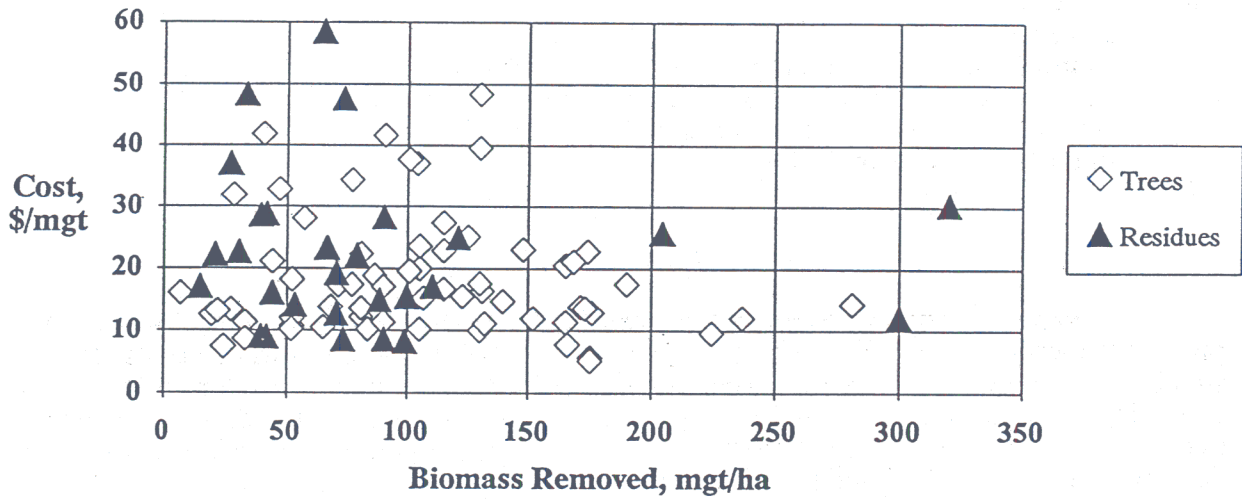


Figure 4. Onto-truck cost versus amount of biomass removed for small trees and residues.

Costs for harvesting small trees varied widely between studies. The range of costs for clearcutting and thinning was greater than for preharvesting and postharvesting (Fig. 5). This is due to the inclusion of a few studies of clearcutting or thinning of extremely small trees.

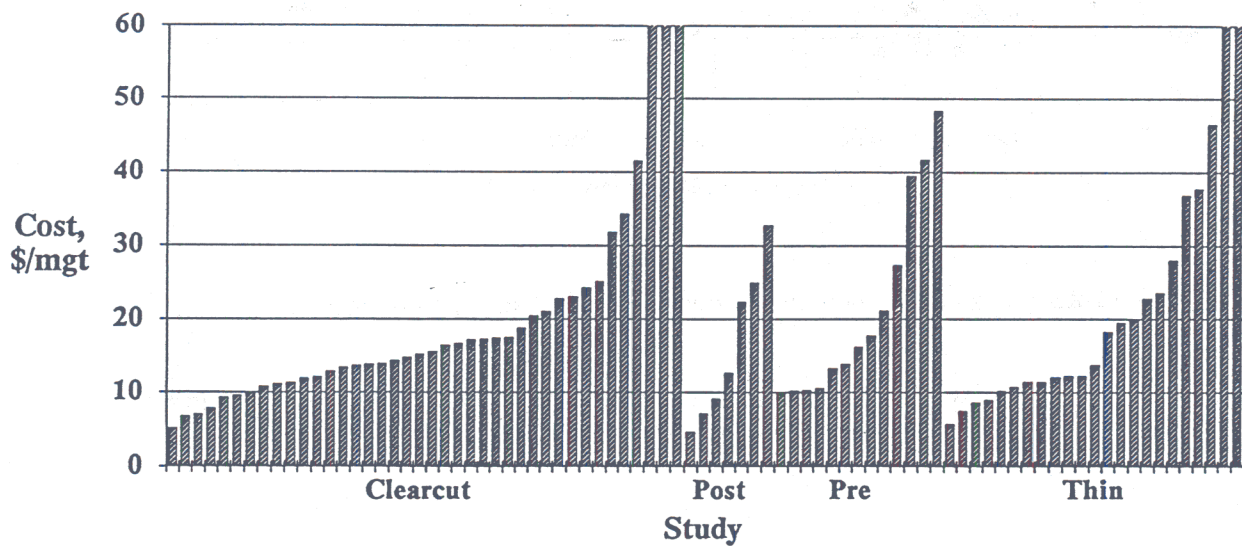


Figure 5. Onto-truck costs for small trees by harvest type.

As expected, the average costs for residues at the landing were less than for in-woods residues (Fig. 6). A few cases of in-woods recovery at less than \$10/mgt were reported.

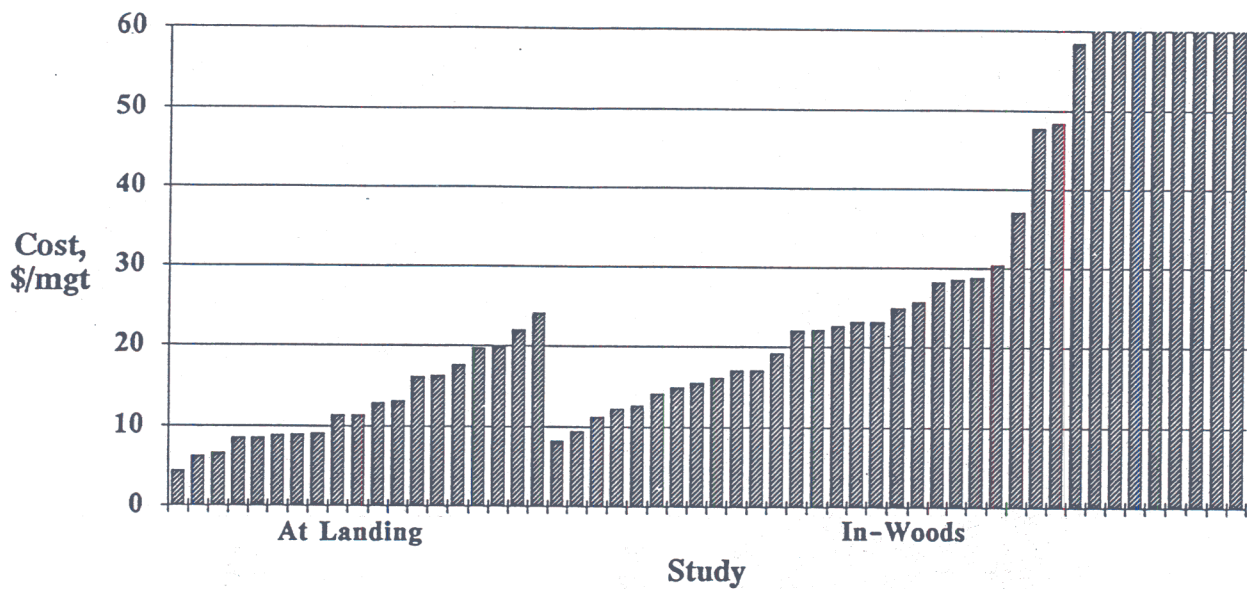


Figure 6. Onto-truck costs for residues by location.

There was a strong negative trend between cost and productivity (Fig. 7), although some low-production systems had low costs. A caution: productivity does not have consistent meaning for the partial versus complete systems. For example, a study focusing on a single machine skidding residue might report one-third the productivity of another study of a complete onto-truck system consisting of three skidders and one chipper.

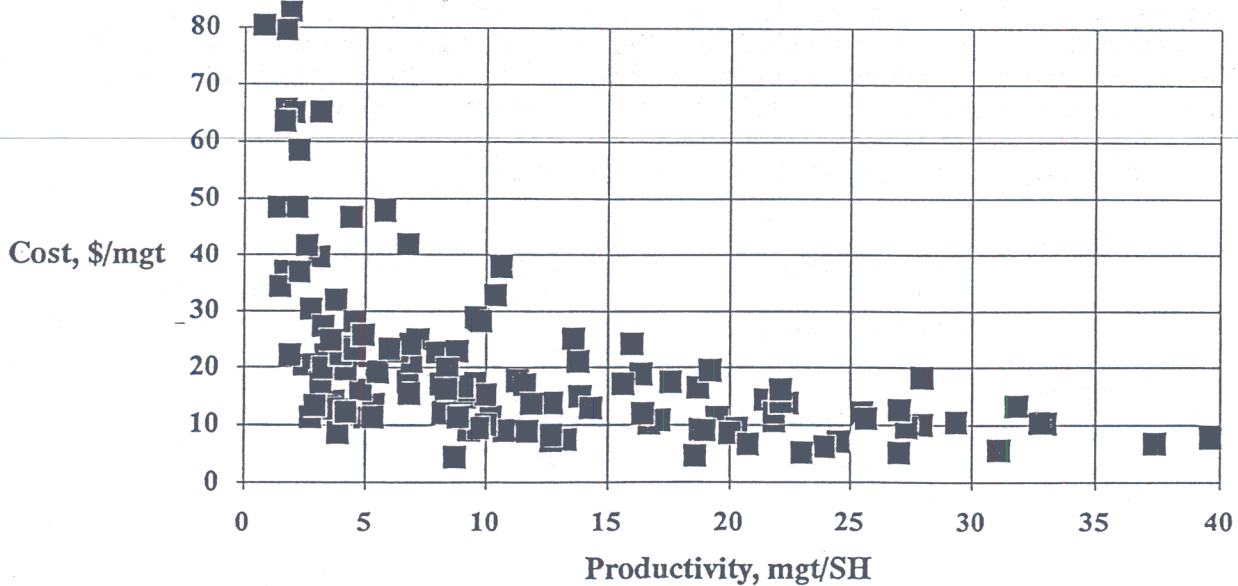


Figure 7. Onto-truck cost versus productivity.



At the assumed labor rate (\$15/SH including loading), there appeared to be a negative trend between cost and capital/labor ratio. This trend would be more extreme at higher labor rates, and flatter or even positive at low labor rates.

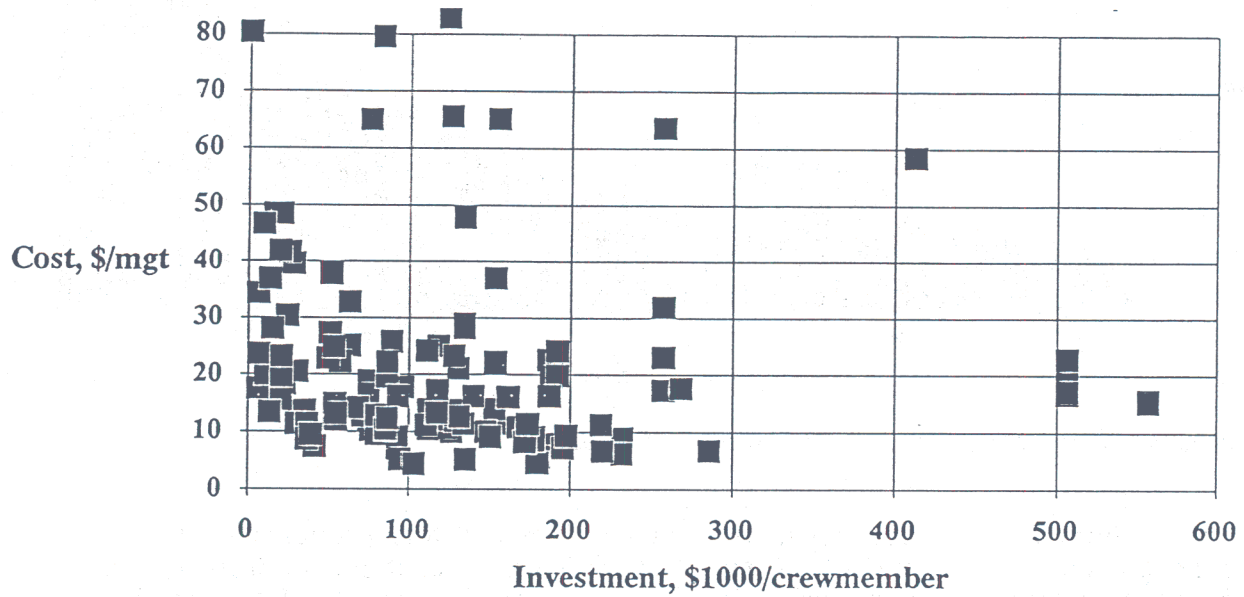


Figure 8. Onto-truck cost versus capital/labor ratio.

Feasibility of small tree and residue systems depends on their competitiveness with alternative fuels. Assuming that oil is the fuel to be replaced, the price of oil must exceed the breakeven price for a system to be feasible. Breakeven prices for the various small tree systems are displayed in Figure 9, and prices for residue systems in Figure 10. Under the stated assumptions, the median breakeven prices for studies within the various categories of small tree and residue systems were:

<u>Material</u>	<u>System/Location</u>	<u>Breakeven Price, \$/BBL</u>
Small Trees	Clearcutting	30.
	Thinning	30.
	Preharvesting	26.
	Postharvesting	30.
Residues	In-woods	38.
	At landing	25.

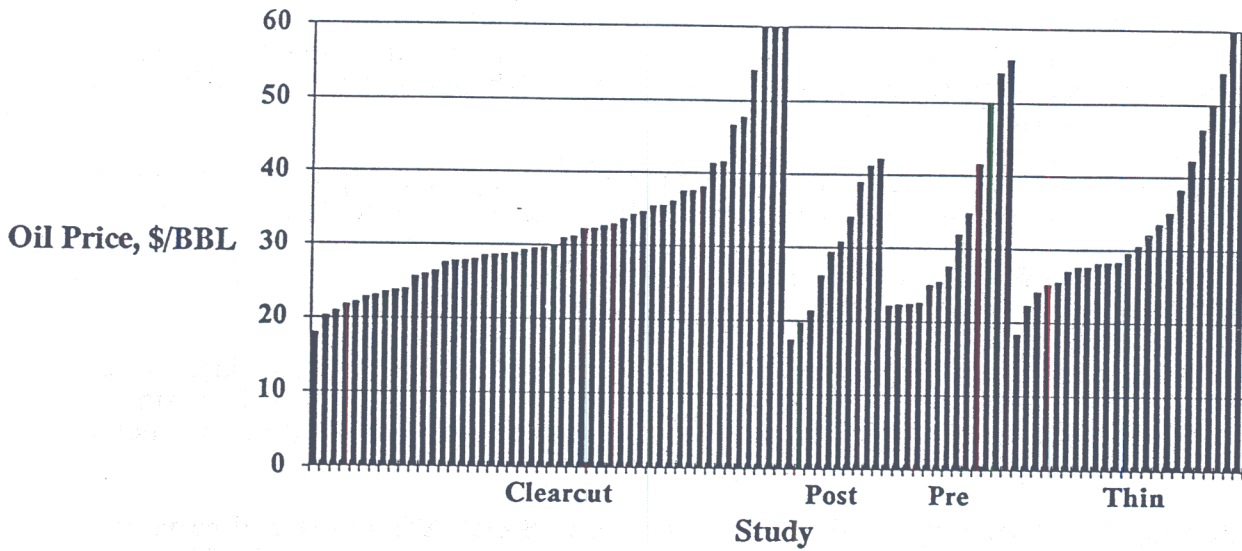


Figure 9. Breakeven oil prices for small tree systems by harvest type.

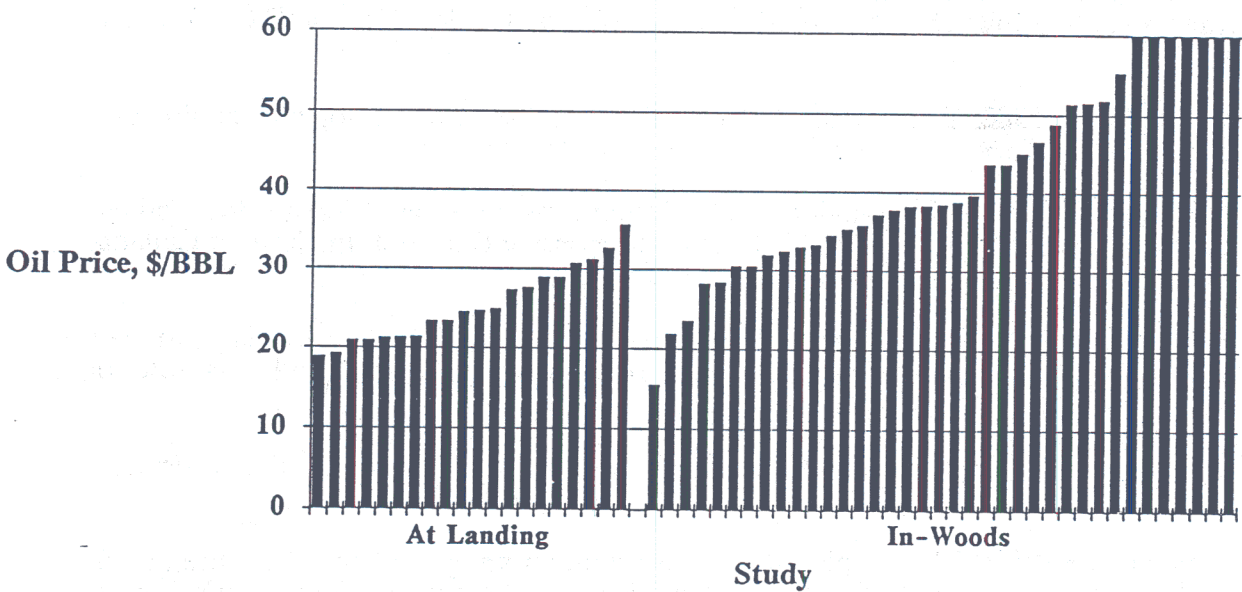


Figure 10. Breakeven oil prices for residue systems by residue location.

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