# Harvesting Systems Evaluation in Caspian Forests

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## ABSTRACT

A project, "Logging System Evaluation", was initiated by the Iranian Forest Service and Teheran University in 1988. The objective is to develop a quantitative basis for job layout and planning, operations management, and forest management. Initial work is focusing on transportation functions, the largest single cost component. A brief discussion of harvesting conditions in the Caspian forest is followed by the results of initial investigations of rubber-tired skidding.

## INTRODUCTION

A project, "Logging System Evaluation", supported by the Logging Department and the Forest and Range Research Institute of the Iranian Forest Service, was initiated by the Teheran University in 1988. Harvesting, perhaps the most important and expensive of forest operations, had previously received scant attention from the forestry profession. Some functions, such as transport, have been mechanized for more than 20 years. The equipment mix available is cosmopolitan, North American, Scandinavian, continental European, and of local manufacture. Logging systems as a consequence are often assembled to meet the challenge of a specific tract; with only anecdotal information on equipment performance and operation. The objective of this study is to develop a standard unified method of data collection to be used to improve the efficiency of current operations and improve the quality of harvesting cost and productivity information available for use in forest management plans and decisions.

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## LOCATION

The Caspian forest in Iran covers roughly 18 million hectares, of which only 2 million, near the Caspian Sea, can be regarded as commercial. The remainder has been degraded to grassy pastures, fields, and grazing land. The Iranian government nationalized all forests and pastures in 1967. A forest service, employing 3,000 rangers and guards by 1970, was established to protect, manage and rehabilitate the forest.

The forest includes the lowlands along the southern shore of the Caspian Sea, the northern slopes of the Alburz Mountains and the upper reaches of the Atrak River. The Hyrcanian Forest type is predominantly hardwood with vigorous growth, tall trees, and a multistoried structure. Genera encountered include: **Tilia, Fraxinus, Ulmus, Carpinus, Juglans, Acer, Prunus, Bwais, Ruscus**, and **Ilex**. Relic species of the genera **Parrotia, Pterocaryo, Zelkora, Albizzia**, and **Gleditschia** are also present. The mountain forests are dominated by **Fagus orientalis** in the lower elevations and by **Quercus macranthera** above 1800 meters.

### Climate

Rainfall ranges from 760 to 2000 mm/year, with the heaviest precipitation in the summer and fall. Temperatures are moderate, ranging from a few degrees below 0°C in December, January, and February to 25+°C during the summer. Snowfalls occur during January and February.

## HARVESTING SYSTEMS

The combination of timber type and topography limit harvesting mechanization to the transport function. Felling, limbing, topping, and bucking are motor manual. Rubber-tired skidders are used on the more gentle slopes and on bladed trails on steeper topography. Crawler tractors are used on steeper topography to skid direct to the landing or to bunch material at bladed trails for further transport by skidder. The steepest, most difficult terrains are logged with cable systems.

Skidding and yarding are the most expensive components of logging in this environment and the most sensitive to timber stand characteristics and topography. These functions also offer the greatest opportunities for cost reduction through careful planning and application. Wheeled skidders were selected as a starting point for the evaluation project because they are the most common and versatile method of transport. Similar investigations of tracked skidding and yarding are planned as the project matures.

While the equipment can be considered conventional by most standards, and a sizable body of literature exists concerning the use of these types of systems around the world, there is surprisingly little concerning the application on topography and in timber types similar to those found in Iran.

## STUDY OBJECTIVES

Only anecdotal information was available on job organization, machine application, and the effects of job layout, slope, soils, species and tree size on skidder performance in this region at the time the study was initiated. The objectives of the larger project are to capture data which would support (1) harvesting systems management; (2) job layout and planning; and (3) productivity and cost development for forest planning. This study was a first step in identifying parameters of importance for subsequent data collection activities rather than an attempt to develop predictive equations for a particular application. The methodology used included a variety of data types and collection techniques. A more complete discussion of the methodology, procedures, and background is given in Sobhany [1] and Sobhany and Stuart [2].

## STUDY SITE

Compartment 113 of the Shafarood Forest, chosen for this initial study, is typical of the tracts being harvested in the region. The 68 ha compartment has an average elevation of 300 meters and lies on an eastern aspect. Soils have developed from cretaceous rock and are deep heavy clays with weak drainage and a high hydromorphology. Eighty-two percent of the stand was low-quality wood of the **Carpinus, Parrotia, Diaspyros** and **Gleditschia** genera. The remaining valuable 18 percent included species of the **Quercus, Alnus, Fagus, Ulmus, Tilia, Fraxinus, Zelkova,** and **Prunus** genera.

## HARVESTING SYSTEM

The harvesting system selected was also typical. Landing locations accessible by truck were identified, and a network of skid trails laid out from them. Skidding by rubber-tired skidders was predominantly downhill. Slopes of the skid trails averaged 13.7 percent, with sections exceeding 18 percent.

Trees to be removed were felled, limbed, and topped motor-manually, well ahead of the tree-length skidding activity. Stems deposited on the landing were reduced to log lengths and loaded out or inventoried for later transport.

## METHODS AND PROCEDURES

Organizational delays (those arising from local custom, social, legislative, or business structure) and operational delays (those associated with the application of the machine) were of equal concern to mechanical delays and productivity. Elemental level deci-minute time study techniques were interspersed with work sampling and other data collection techniques to assure complete coverage of the operation.

Thirty machine cycles for a Clark 66BDS choker skidder were selected for intensive study. Elements of the machine cycle were measured with a deci-minute stop watch. Independent variables expected to affect machine productivity were documented. Skid distances, empty and loaded, were recorded to the nearest meter. Slope was recorded to the nearest percent. The number, diameter, length, species, and form of each stem were documented.

## RESULTS AND DISCUSSION

The primary factors affecting skidding performance are shown in Table 1. Skid distances were long by most standards (averaging 608 meters) with some well in excess of one kilometre. Favourable slopes in the loaded direction were between 10 and 20 percent, which aided machine performance. Tree size was in excess of one tonne per tree.

**Table 1** — Selected independent variables affecting skidding performance.

| Variable | Median | Mean | S.D. |
|---|---|---|---|
| Distance | 570 m | 608 m | 302 |
| Slope | -12% | -14% | 4 |
| Volume | 2.94 $m^3$ | 3.43 $m^3$ | 11.1 |
| Stems/turn | 2 | 2.77 | 1.70 |

Time per turn averaged 26.36 minutes. Approximately 90% of each machine cycle was devoted to productive activities: travel loaded, 33%; travel

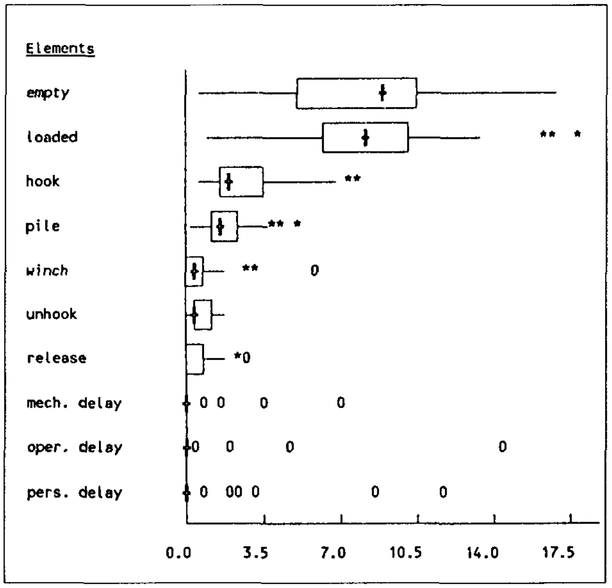


**Figure 1.** Distribution of elemental times per machine cycle. (mins).

empty, 33%; hook, 11%; piling, 7%; bunch and release, 6%; and unhooking, 2%. The distribution of elemental times per machine cycle are shown in Figure 1. [For those not familiar with box plots, the symbol within the box identifies the median of the data set, the box spans the middle 50% of the data — 25% on either side of the median — often referred to as the Inter Quartile Range (IQR). The whiskers extend to the furthest data value lying within 1.5 times the IQR to either side of the box. Asterisks (*) are used to identify values lying within ∓3 of the IQR beyond the box, and zeros (0) for outliers.]

Only three of the variables of interest — travel empty, travel loaded, and unhook — tended toward symmetrical distributions. All of the independent variables, the other productive elements, and all of the delay elements were skewed to the right. Skewness is not uncommon in production studies of forest operations where a single, lengthy occurrence can raise the mean well above the median and reduce predictive power.

Organizational delays encountered were largely of local origin and interest. Operational delays, however, were common to skidding operations regardless of location. These were kept to a minimum by having the timber prepared for skidding well ahead of the operation and keeping the landings clean.

Regression models were developed for production-related elements as a method of identifying casual relationships. Only those relationships with a correction coefficient greater than 0.10 are shown in Table 2.

As expected, distance proved to be a strong predictor for travel activities. Since travel loaded and travel empty accounted for nearly two-thirds of the total cycle time, distance was also the strongest predictor of summary measures such as productive

**Table 2. Regression models for tree length skidding.**

| Dependent Var. | Intercept | Distance | Slope | Stems | Volume | R^2 |
|---|---|---|---|---|---|---|
| Travel empty | 1.93934 | 0.010927 | | | | 0.84 |
| Hook | 0.86458 | | | 0.712 | | 0.33 |
| Travel loaded | 2.73933 | 0.009795 | | | | 0.58 |
| Travel loaded | 15.942 | | 0.5270 | | | 0.37 |
| Travel loaded | 4.2745 | | | | 1.2884 | 0.13 |
| Pile | 0.6222 | | | | 0.3599 | 0.16 |
| Productive time | 12.52948 | 0.019003 | | | | 0.64 |
| Productive time | 34.22970 | | 0.7401 | | | 0.21 |
| Total turn time | 15.06248 | 0.018575 | | | | 0.54 |
| Total turn time | 35.52132 | | 0.6662 | | | 0.15 |
| Time/unit volume | 3.57540 | 0.00657 | | | | 0.45 |
| <u>Multiple Regression Models:</u> | | | | | | |
| Productive time | 0.5159 | 0.0203 | | 1.394 | 2.1494 | 0.84 |
| Time/unit volume | -0.579 | 0.0076 | -0.1691 | 0.4347 | | 0.56 |

time per turn, total turn time, and time per unit volume.

Multiple regression efforts yielded only two models which met the correlation coefficient criteria, one for estimating the productive time per turn and one for estimating the time per unit volume. The variability in volume per turn in stands composed mainly of broad-leaved species lying on difficult terrain frustrate attempts to develop predictors of machine productivity. The multiple regression equation for productive time per turn, for example, accounted for 80% of the variability in the data set. The companion equation, incorporating volume, only accounted for 54% of the variability.

### Job Layout and Planning

The regression models did provide some insight concerning the increase in cycle time associated with skid distance and slope. The fact that travel empty accounted for a slightly larger percentage of the total cycle time than travel loaded was a function of downhill skidding layout. Unladen machines had difficulty travelling up average slopes in the unloaded direction of 13.7%, with steeper sections ranging up to 18%. These slopes, coupled with good rainfall, a heavy clay soil, lack of drainage, and heavy shade on some sections of the skid trail, resulted in significant slip, slowing machine travel.

### Forest Management Planning

The regression models demonstrated the difficulty of predicting machine and job productivity for mechanized systems in extensively managed broadleaf forests from work study measurements. Comparing the models developed here with previous similar exercises, especially that of the American Pulpwood Association Harvesting Research Project (APAHRP) in the 1970's, found similar problems. The APAHRP model predicting skidding time per 100 cubic feet of solid wood used distance, distance$^2$, equipment size, and average stand DBH as independent variables. The fact that volume per turn did not enter those equations is an indicator that tree size may have been such that a reasonably constant turn volume could be assembled from smaller stems.

## CONCLUSIONS

This study is the first in a series being conducted to establish a quantitative base for harvesting management and planning in Iran. Work is currently underway expanding the size and scope of the rubber-tired skidder investigations, developing similar information for crawler and yarder systems, and other harvesting functions.

Information on the productivity, cost, and applications of harvesting equipment and systems is a key component in the evolution of management plans for the rehabilitation and utilization of the Caspian forests.

## REFERENCES

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[2] Sobhany, Hooshang, and W.B. Stuart. 1984. A Date Collection Handbook for the Evaluation of Forest Harvesting systems. Industrial Forestry Operations, School of Forestry and Wildlife Resources, Virginia Tech., Blacksburg, Virginia, USA.