ECONOMICAL HARVESTING SYSTEMS FOR SCATTERED STANDS OF COTTONWOOD IN CENTRAL OKLAHOMA

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CHAPTER I

INTRODUCTION

Natural stands of eastern cottonwood (Populus deltoides, Marsh.) occur on many bottomland sites along the five major river systems and their tributaries in Oklahoma. These natural stands have produced, and can in the future produce good form despite adverse climatic conditions. The eastern cottonwood is one of the fastest growing species in North America. Fast growth and good form makes cottonwood a tree of high value. The species is used for sawlogs, rotary cut veneer stock, and box stock.

In the years since 1960, demand had developed for cottonwood as a pulping species. Pulpwood buyers from outside the State are searching for cottonwood stumpage. As the pulp and paper industry in southeast Oklahoma develops, the demand for cottonwood stumpage will increase in all bottomland areas of the state. The demand situation for cottonwood as a raw material will place central Oklahoma in a position to improve its economic future through new market outlets for this timber species.

Thousands of acres of bottomlands in central Oklahoma meet the requirements for cottonwood production. Local farmers and land owners will be able to secure additional incomes from land types that are classified as marginal for annual crop production. Farmers and land owners will need professional advice and guidance to enable them to establish proper management of these bottomlands and marginal annual croplands. Forest industry can ensure a future supply of cottonwood stumpage by helping local farmers and land owners develop management plans for production of cottonwood.

The forest enterprise must be planned carefully to match new demands to new sources of cottonwood stumpage. Marketing in a forest enterprise is the process of planning and managing sales in order to tie supply and demand together. Administrative decisions on the organization of executive and staff functions must be made in order to ensure smooth functioning of planning and management. Production must satisfy consumer demand of the finished product and at the same time it must satisfy its own need through procurement of the raw material. Three executives are directly involved in satisfying the double utility mentioned above. The marketing manager is responsible for capturing sales to the ultimate consumer. The forest manager is responsible for ensuring the maintenance of future potential cuts as well as providing for current yields. Finally, the harvesting manager is responsible for a regular flow of raw material to the mill.

While a regulated cut may be agreed upon as a result of joint planning by the marketing manager and the forest manager, circumstances may arise where the harvesting costs incurred in delivering the agreed volumes are so high as to make the working of stands unprofitable. It is necessary therefore for all three managers to be aware of the interactions between logging conditions, the harvesting process, and sales.

The main concern of this study will be the development of harvesting systems for the production of pulpwood from cottonwood stands in central Oklahoma. Individual farmers and land owners will be considered as producers who perform the functions involved in operating the harvesting systems. Graphs will be developed from the total costs of the harvesting systems to determine which of the systems would be most economical at specified levels of production. In addition the minimum acreage needed to support each of the systems will be determined.

At the beginning of the study certain basic assumptions must be made. Equipment capacities and time requirements in different phases of harvesting will be taken from manufacturers specifications. The round trip hauling distance is assumed to be 50 miles. The current selling price at the delivery point or concentration yard is $20.00 per cord. Finally, the going stumpage price is taken to be $4.00 per cord, and the owner-operator therefore has the alternatives of selling stumpage at the $4.00 rate, or harvesting his own wood crop.

CHAPTER II

LITERATURE REVIEW

Selection of a harvesting system and the appropriate machinery for that system are the most important decisions a producer must make. Such decisions should be based on sound information for the area of operation. Information concerning timber availability, average tree size, average cut per acre, size of tracts, type of cutting practices, topography, and quality and quantity of available labor are some of the factors that enter into the decisions. Also, the producer must take an objective look at himself to determine his managerial capabilities for operating any new equipment at its maximum efficiency. Finally, he must have the finances available to purchase equipment (7).

Before the logger can decide how much he can afford to spend on a piece of equipment he must be sure the machine will operate at a reasonable cost in the type of timber available. A harvesting machine that is not used to its maximum efficiency or capacity is draining away potential profits (7).

In the early 1960's, Catawba Timber Company ran a short term comparison study between a tree-length skidding operation and a stump-to-stump pallet operation using a small crawler tractor and cart in the pine areas of the Carolina Piedmont. The work was done in comparable topographic conditions with the same crew, and identical skid or prehaul distances. All wood was measured after it was loaded into pallets. Tree-length production with the skidder was as high as 0.6 cords per man hour in the larger timber but dropped off sharply with a decline in timber size. The pallet prehaul operation with hand loading reached its maximum production in smaller timber with 0.5 cords per man hour.

The fact that logging cost research is the key to progress in southern pulpwood production was brought out by Holekamp (5) in a forestry sumposium in 1962. He stated that today most foresters and logging engineers know that the cost of harvesting can account for as much as 70 per cent of all costs incurred in producing and delivering a cord of southern pine pulpwood. Additionally, they show that the cost of this same cord of roundwood, which constitutes the principal raw material for pulp and paper, can account for as much as 60 per cent of the total cost of producing a ton of unbleached kraft pulp. Thus, the cost of extraction of the pulpwood from the forest has become the major expense involved in manufacturing pulp and paper.

Winer (24) pointed out that neither in the South nor elsewhere can the practice of forestry really come of age until logging and the costs of logging are recognized as integral parts of forest management. Among the many problems faced in attempting to determine logging costs more accurately than in the past, a few may be profitably investigated. First of all, it is necessary to know accurately the effect of major stand variables on actual logging costs, apart from the obscuring influences of averages and the real or implied task system that still affects many southern operations. Secondly, an accurate knowledge of the real costs of labor, machines, and other principal cost items is needed. Thirdly, the nonphysical and noneconomic factors, that research and experience have shown may influence logging productivity, need to be evaluated carefully. More attention should be given to the institutional framework in which logging takes place. Winer further suggested that gross studies offer great promise, particularly as first steps in approaching a rational determination of logging costs. The gross study measures over-all production in terms of cords per man-day or man-hour.

In most pulpwood operations, six basic steps are included in the harvesting cycle: (1) felling, (2) limbing, (3) bucking, (4) pre-hauling or skidding, (5) loading, and (6) hauling.

For felling, limbing, and bucking, power saws have taken the place of cross-cut saws in the woods since the early 1950's. For felling and bucking, Gardner (4) estimated the man-minutes required to handle 1M feet to be 60.50. Tufts (18) shows in a table of cutting times that in timber averaging 5 to 14 inches in diameter contractors estimate one cutter can fell, limb, measure, and buck eight cords per day or forty cords per week.

Skidding is the next step within the harvesting cycle. In this operation, the trees, logs, or bolts are moved over unimproved terrain to a skidway, landing, deck rollway, or banking ground. (Wackerman et al., 19). Studies have been conducted which show time requirement and operating costs for certain harvesting operations where skidders are used.

A three-year study of the logging operations of Container Corporation of America at Circleville, Ohio, was conducted by Lucas (9). Four different skidding methods were analyzed. Cost breakdowns included fixed and variable costs as well as operator's wages. A summary of costs from this study is given in Table I.

TABLE I

PULPWOOD SKIDDING COSTS*

Operating Method	Cost/Hour dollars	Production/Hour tons	Cost/Ton dollars
Animal	1.60	2.4	0.75
Farm Tractor	2.97	3.5	0.85
Crawler Tractor	3.81	4.1	0.93
4 Wheel-Drive Skidder	5.10	7.5	0.68

*From a Study by Lucas (9) of the Container Corporation of America Operation at Circleville, Ohio.

Meyer, et. al (11) conducted a study comparing rubber-tired skidders and crawler tractors. Skidding damage to the residual stand was compared for an articulated rubber-tired tractor skidding long or tree-length loads and a small crawler tractor skidding log-length loads from a selective cutting in an all-aged northern hardwood stand. The rubber-tired tractor, skidding tree-length loads, caused somewhat greater damage than the crawler tractor with log-length loads. Nevertheless, the system using the rubber-tired skidder was considered to be acceptable, especially when its economic advantages were taken into account.

Silversides (15) stated that skidding of pulpwood in tree lengths is the method currently in favor. The rapid development of the wheeled skidder has resulted in this machine gaining favor over the crawler tractor.

Time studies made for Logging Research Associates (15) on machine skidding operations have shown that hand-choking required up to 6.0 minutes per cord. During this period the skidding machine was idle although the operator was working. If a standard rate of $8.00 per hour was allowed for the skidder, including operator, the choking operation cost $0.80 to $0.85 per cord. As long as this operation was carried out by hand there was little opportunity to reduce the cost. The development of chokerless skidders was based upon a recognition of the above unsatisfactory condition, and was an attempt to reduce costs in the woods.

Gardner (4) prepared tables with skidding equipment listed and specifications for average production and costs. For a 3-ton tracked vehicle with 25 drawbar horsepower, an average man-day production of 7.8 cords was shown, with an estimated cost of $3.35 per cord. A 3½ ton rubber-tired tractor with 48 horsepower showed an average man-day production of 15.0 cords at a cost of $3.20 per cord.

Some operators choose to buck the trees into pulpwood lengths and load pallets in the woods. Tufts (18) reported a study where this type of operation was used. Woods conditions usually determine the type of operation that was used. A medium-size crawler tractor equipped with a big stick loader and skid pan proved to be practical for pulling pallets from stump to stump on wet ground. For dry ground skidding, a pallet tilt-ford truck with a big stick loader was more economical than the crawler tractor. The time required per cord to pick up, load, and return a pallet to the truck-loading site for the crawler tractor is shown in Table II.

TABLE II

CREW HOURS PER CORD REQUIRED FOR TWO-MAN CREW FOR PALLET LOADING AND SKIDDING*

	Skidding Distance in Feet									
	100	200	300	400	500	600	700	800	900	1000
Time in Hours (Dry Ground)	.41	.42	.43	.44	.45	.46	.47	.48	.49	.50
Time in Hours (Wet Ground)	.52	.53	.56	.58	.60	.62	.64	.66	.67	.70

*From Tufts (18)

Loading is the next phase of the harvesting cycle. Lucas (9) reported that loading accounts for 33% of the cost of pulpwood production in the southeastern United States. This same function took up 45% of the man hours. The trend toward mechanical loading was due, of course, to labor costs and shortage of manual labor.

TABLE III

PULPWOOD LOADING COSTS*

Operating Method	Cost/Hour dollars	Production/Hour tons	Cost/Ton dollars
Hand	2.28	5.4	0.67
Light Industrial Front-End Loader	3.70	10.0	0.37
Hydraulic Knuckle-Boom	3.26	25.0	0.15

*From Lucas (9)

Gardner (4) reported on a hydraulic loader with a per hour capacity of 8 cords of 8-foot wood averaging 10" in diameter. The cost per cord, including operators' wages, was $0.35. A winch-operated cable-boom jammer, including hooker or choker, produced 6 cords per hour of 8-foot wood averaging 10" diameter at a cost of $0.70 per cord.

Walbridge (20) pointed out that manual loading of the prehauler, pallet, or haul truck continues to be the most physically difficult phase of the harvesting system. Despite many efforts toward mechanization, it remains the most common method for performing this function.

Hauling ends the harvesting cycle. Coordinating the hauling vehicle or vehicles with the cutting and skidding is very important in balancing the pulpwood production cycle.

The truck design is of utmost importance. If loading is done in the woods, then a winch is needed either to pull the wood to the truck and load it, or to pull loaded pallets to the truck for loading. Walbridge (20) described such a system. The truck consisted of a simple mechanical winch powered by the truck engine, an all steel frame, and a center section which contained a hydraulic boom. Equipped with 150-250 feet of 5/16 inch wire rope, it was capable of simultaneously skidding and loading bundles of wood on even the steepest terrain. The usual procedure was to pile bolts into one-tenth cord bundles at or near the stump then, skid and load them directly onto the truck.

Tufts (18) described a truck with larger capacity hauling pulpwood pallets which were pre-loaded in the woods. The unit consisted of a three-pallet, tandem drive axle bob-truck capable of hauling 4.5 cord loads. The initial cost of the truck and 6 pallets was $9,720. This truck completed a twenty mile round trip in which were encountered wood roads, gravel roads, and paved roads, in a period of 79.1 minutes. This travel time in addition to time for loading, unloading, and delays, gave a total round-trip time of 119.1 minutes.

Regeneration of cottonwood (Populus deltoides, Marsh.) from natural seedfall requires that certain conditions exist. Walker and Craighead (21), report that natural seedling stands of cottonwood are obtained only if (1) the land is bare and exposed at the time of seed-fall in the spring and if (2) such exposed soil is fresh or wet at the time the seed falls on it. Conditions such as those reported above have in the past been present in bottomland areas of Oklahoma. As a result many acres are covered with natural stands today.

There has been an interest in cottonwood growth and yield for many years as evidenced by different studies of natural stands. Swenning (16), in studies conducted in 1924 with cottonwood and silver maple, concluded that:

(1) The rotation for cottonwood for pulpwood purposes had been placed empirically at 20 years.

(2) The underplanting of cottonwood with silver maple showed evidence of good future possibilities.

(3) Fair stands of 12-year old cottonwood have yielded 1.36 cords per acre per year.

(4) Average stands have produced yields of 1.5 cords per acre per year.

Bull and Muntz (2) found that cottonwood is a relatively short-lived tree but grows so rapidly that it soon reaches a large size. In natural stands and plantations on better sites, cottonwood commonly increases 2/3 inch to 1 inch in diameter and 5 feet in height annually up to 10 to 15 years of age, and grows at only a slightly slower rate up to 30 or 35 years. Well stocked natural stands in the Mississippi Valley have been found to contain trees averaging 20 inches in diameter and 120 feet in total height when 35 years of age. The growth rate begins to decrease sharply at about this age, however, so it is probably best to harvest the entire stand at about 35 years of age and replant.

Fully stocked natural stands on good sites have been estimated to yield about 6 cords of pulpwood at 5 years, 24 cords at 10 years, and 50 cords at 15 years. The volume in board feet per acre, Doyle rule, in similar stands has been estimated at 5,200 at 20 years, 10,700 at 25 years, 19,200 at 30 years, and 27,500 at 35 years.

Switzer (17) in his studies in Illinois estimated that fully stocked natural stands of cottonwood on good sites will produce 10,700 board feet per acre, Doyle rule, in 25 years, and 27,500 board feet in 35 years. In the latter case the growth was at the rate of 785 board feet per acre per year. From observations in Southern Illinois it is believed that this growth can be readily equaled, and perhaps even surpassed, with proper tree farming. Two 71 year-old plantations in Illinois have averaged 975 board feet, International Rule, per acre per year. This growth is approximately equal to 750 feet, Doyle rule.

Individual trees whose tops have a good supply of sunlight increase in volume at the rate of 12-15 percent a year when they are 14 to 15 inches in diameter. This rate of growth gradually decreases to 3-4 percent per year for trees 30 inches in diameter.

Careful growth measurements on two small areas of nearly fully stocked cottonwood indicate an average annual growth of 640 board feet per acre, Doyle Rule. The stand is now 26 years old, has about 17,000 board feet per acre, and is currently growing 1500 board feet per acre per year. There are approximately 100 trees per acre, averaging 16.8 inches in diameter. Partially stocked cottonwood stand, 20-25 years old have averaged 3,000-8,000 board feet per acre, depending on the stocking, over large areas. An annual growth of 650 board feet per acre per year for a well stocked 30 year old stand on a good site is not unusual.

Minckler and Lamendola (12) report that a cottonwood stand, twenty-five years of age in 1949, measured 14,401 board feet per acre. In 1953 it had 21,503 board feet per acre, a periodic growth of 1,663 board feet per acre per year. Mean annual growth over the twenty-nine years was 726 board feet per acre.

Walker (22), in his study of natural stands of cottonwood in Central Oklahoma, found that although the technical rotation for pulpwood production has not been identified positively, the leveling off of mean annual gross production at age 20 and the trend of the curve of current growth suggested that culmination of mean gross growth in cubic feet (technical rotation) would occur at age 22 or 23. Whether stands should be held any longer would be dependent upon increasing unit values for larger timber and in declining unit costs in converting standing trees to pulp. In other words, the net stumpage value (above costs of production and carry-costs) would determine whether stands should be held past the technical rotation age. The natural or planted stands on good, well-drained bottomland soils in Central Oklahoma, when properly managed, will produce about forty cords of pulpwood per acre in twenty to twenty-two years.

McKnight and Biesterfeldt (13) reported that it was too early to estimate the precise yields to be expected from the commercial cottonwood plantations in the South. For cost computations, one company assumed a yield of 2.5 cords per acre per year for a 20-year rotation. It was estimated that the management system will produce wood for $3 per cord during the first rotation. A yield of 2.5 cords per acre per year would be reasonable from clones currently being planted. With the clones research scientists are now testing, yields of 4 cords per acre per year seem entirely possible.

CHAPTER III

METHODS AND PROCEDURES

Guidelines for Developing Harvesting Systems

In developing a system of operation, the producer must examine certain factors that will influence his choice of equipment. He must first determine the characteristics of the stand of timber with which he will be working. The information thus gained will provide the producer with a basis to judge the size of equipment he will need to carry out the functions of the harvesting operation. Walker and Craighead (21) show that at age 22, an acre in central Oklahoma should support, on the average, about 180 trees. Those trees would range in size from 4 inches to 17 inches, and average 9 to 10 inches in diameter 4.5 feet above ground level.

The producer should examine the topography of the area where the timber is to be harvested. Most of the cottonwood producing areas will be in the bottomlands, which indicates that equipment of the type that works well on wet soils will have to be selected. Through selection of proper equipment the operator will be able to increase the number of days per year he can work.

The producer will need men to help in operating the equipment. Since he is a local man, he will be in a position to know where he may obtain labor.

Delivery of the pulpwood will be made to a concentration yard located along a railroad siding. Access will be available from the cutting site to the concentration yard through the use of open field roads, county road systems, and paved public highways.

When the producer has determined the type and size of equipment needed to complete the cottonwood harvesting operation, he must design a total system. Such a system must be designed so that the producer can make a profit. Many operators incur losses by failing to design efficient systems and by failing to operate equipment in optimum ranges for given conditions. It proves to be helpful, in solving problems of system design, if the producer has natural managerial and technical skill in developing an operation. Gardner (4) states several objectives which should be met in designing a total system. First, the design must include equipment that produces at the lowest unit costs. Second, the design must hold investment costs to the minimum level for a balanced system. Third, the operator must give adequate attention to the coordination of equipment used. Fourth, a system must be built around the key piece of equipment, which is usually the skidder. Fifth, it is virtually impossible to balance perfectly all operations in any system. The objective is to approach the balanced condition as nearly as possible.

Although this procedure is simple, it is often bypassed in favor of the educated guess, which usually requires considerable adjustment in the field.

Most harvesting operations consist of six basic steps, of which felling, limbing, and bucking constitute the first three phases. Gardner (4) says that the slope of the ground, if extremely steep terrain is excluded, has little effect on total production. Time is usually saved if bucking is done at the landing rather than in the woods.

Skidding is the fourth phase of an operation. The type of skidding applicable to a given harvesting chance depends on slope, soil, tree size, season of the year, distance, amount of brush and down timber, silvicultural requirements, and logging methods. Loading and hauling, the fifth and sixth phases, are controlled by such principal variables as delay and standby times, length of haul, road standards, season of the year, and loading and unloading methods.

For purposes of this study, a basic round-trip hauling table similar to one developed by Gardner (4) will be used. In order to obtain comparable cost estimates in different systems, a standard 8-hour day is used. Where minor differences exist in the daily operating capacities between two or more specific phases of an operation, it is assumed that the phase showing the lower capacity will be operated for more hours per day, or more days per week, or more total days, than the phase which has a higher daily production. Thus, if a skidder in a given system can handle 15 cords per day, but the associated hauling equipment can deliver only 14 cords, then the hauling rig must operate 15/14 = 1.071 times the total hours required by the skidder to complete a given job.

TABLE IV

ROUND-TRIP HAULING TIMES USING A 25-MILE HAULING DISTANCE (50-MILE ROUND TRIP) WITH ASSUMED MILEAGES IN EACH ROAD CLASS

Road Class	One-Way Distance miles	Speed Loaded	Speed Empty	Round Trip Time Loaded	Round Trip Time Empty	Total minutes
		miles per min.	miles per min.	minutes	minutes	
Woods	0.25	0.08	0.10	3.13	2.50	5.63
Field	1.00	0.16	0.20	6.25	5.00	11.25
County	10.00	0.40	0.50	25.00	20.00	45.00
Highway	13.75	0.90	1.00	15.28	13.75	29.03
Total	25.00					90.91

90.91 minutes equals	1.52 HOURS
Plus 10% Delay Time	.15
Total	1.67 HOURS

Descriptions of Harvesting Systems

Five systems have been developed for examination in this study. System 1 is the simplest in terms of equipment used. More sophisticated systems will be designed around the use of more equipment and larger units of equipment in order to increase daily production and reduce the man-hours required per unit of production.

System 1 predominates in the pulpwood harvesting business in the southern and southeastern parts of the United

States. Preparation of the pulpwood bolt takes place at the stump. The truck used for hauling is driven from stump to stump and the pulpwood bolts loaded with the help of an A-frame and winch equipped with cable and tongs. Much of the loading is done by hand. The total operation has a 4-man crew. The producer drives his own truck and three men prepare the bolts and load the truck. Equipment consists of two power saws, one used in case of a breakdown, and a bob-tailed truck with a 2-cord load capacity. The round-trip time for the truck in System 1 is given in Table V.

TABLE V

ROUND-TRIP TIMES FOR TRUCK IN SYSTEM 1

Activity	Time (hours)
Loading	0.50
Unloading	0.25
Travel	1.67
Total*	2.42

*For an 8 hour day, 8/2.42 = 3.31 round trips, hauling two cords per trip. Daily Production = 3.31 (2) = 6.60 cords.

System 2 is similar to System 1 in that it also has a hauling truck moving from stump to stump to load the pulpwood bolts. The truck uses an A-frame and winch with cable to load the pulpwood. Crew organization is similar to that of System 1. The producer drives the truck and uses four men in the woods preparing the bolts. The addition of one man to the woods crew results in more efficient pulpwood bolt loading. Equipment consists of two power saws and a larger bob-tail truck with a three cord load capacity. The woods crew stacks the bolts in order to reduce movement of the truck in the woods. The result is a reduction in loading time. The round-trip time for the truck in System 2 is shown in Table VI.

TABLE VI

ROUND-TRIP TIME FOR TRUCK IN SYSTEM 2

Activity	Time (hours)
Loading	0.75
Unloading	0.375
Travel	1.67
Total*	2.79

*For an 8 hour day, 8/2.79 = 2.86 round trips, hauling 3 cords per trip. Daily Production = 2.86 (3) = 8.58 cords.

System 3 is implemented with a skidding unit. At the felling site trees are felled and limbed. A farm tractor equipped with a logging arch then skids tree-length material from the stump to the woods landing. After the tree length material arrives at the woods landing, it is bucked into pulpwood bolts and stacked. Loading is accomplished through the use of a hydraulic loader which is mounted on the hauling vehicle. The truck has a load capacity of three cords. In the routine of the operation the producer drives the truck and loads the cordwood on the truck at the woods landing. The three other crew members work at the cutting site. One man fells and limbs the trees and helps with hooking the tree lengths to the skidder. A second worker drives the farm tractor with logging arch, and skids the tree-length material from the stump to the woods landing. The third man works at the landing bucking the tree length material into pulpwood bolts, and he also helps unhook tree lengths from the skidder. The skidding time and hauling time for System 3 appears in Table VII.

TABLE VII

SKIDDING TIME, SYSTEM 3

Activity	Time (minutes)
Skidding (Loaded, 4 mph covers 1320' in 0.0625 hours)	3.75
(Outrun, 5 mph covers 1320' in 0.05 hours)	3.00
Hook-up (Including 25% Delay Time)	5.06
Unhook (Including 25% Delay Time)	3.38
Total*	15.19

*For an 8 hour day, 480 min./15.19 = 31.59 round trips, hauling 0.30 cords per trip. Daily Production = 31.59 (0130) = 9.50 cords.

ROUND-TRIP TIME FOR TRUCK IN SYSTEM 3

Activity	Time (hours)
Loading	0.63
Unloading	0.21
Travel	1.67
Total*	2.51

*For an 8 hour day, 8/2.51 = 3.20 round trips, hauling three cords per trip. Daily Production = 3.20 (3) = 9.6 cords.

In System 4, increased production is obtained through the use of a small rubber-tired skidder. This skidder hauls tree-length material out of the woods to the woods landing. At the landing, tree lengths are bucked into pulpwood bolts and stacked. Two trucks would be coordinated in hauling the amount skidded. One truck has a 3-cord load capacity and the second a 2-cord load capacity. On the larger truck is mounted a hydraulic loader. On the smaller truck is mounted an A-frame, winch, and cable. In this system the producer drives the larger truck and operates the hydraulic loader. The smaller truck is driven and the winch operated by a second member of the crew. The remainder of the crew, consisting of three men, fell and limb the trees, skid the tree-length material to the woods landing, and buck the tree-lengths into pulpwood bolts. The skidding and hauling times of the two trucks are given in Table VIII.

System 5 uses a large rubber-tired skidder to haul tree-length material from the stump to the woods landing. One man is employed to fell and limb at the cutting site. At the woods landing one man works at bucking the tree-lengths into pulpwood bolts. A small crawler tractor is also used to coordinate the bucking and loading at the landing. The crawler is equipped with a hydraulic loader to load the hauling vehicle. In addition to loading the truck, the crawler keeps the landing clear of debris. Hauling is accomplished with a large tandem-axle truck equipped to handle seven cords per load. Crew size in System 5 totals six men. The

TABLE VIII

SKIDDING TIME, SYSTEM 4

Activity	Time (minutes)
Skidding (Loaded, 4 mph covers 1320' in 0.0625 hours)	3.75
(Outrun, 5 mph covers 1320' in 0.50 hours)	3.00
Hook-up (Including 25% Delay Time)	5.40
Unhook (Including 25% Delay Time)	4.05
Total*	16.20

*For an 8 hour day, 480 min./16.20 = 30 round trips, moving 0.50 cords per trip. Daily Production = 30 (0.50) = 15.0 cords.

ROUND-TRIP TIME FOR LARGE TRUCK IN SYSTEM 4

Activity	Time (hours)
Loading	0.48
Unloading	0.25
Travel	1.67
Total*	2.40

*For an 8 hour day, 8/2.40 = 3.30 round trips, hauling three cords per trip. Daily Production = 3.30 (3) = 9.90 cords.

ROUND-TRIP TIME FOR SMALL TRUCK IN SYSTEM 4

Activity	Time (hours)
Loading	0.50
Unloading	0.25
Travel	1.67
Total*	2.42

*For an 8 hour day, 8/2.42 = 3.31 round trips, hauling two cords per trip. Daily Production = 3.31 (2) = 6.60 cords.

operator drives the truck from the operating site to the concentration yard. The remainder of the crew works at the operating site. One man works in the woods felling and limbing. Another operates the skidding unit between the stump and woods landing, while a third works at the landing bucking the tree lengths into pulpwood bolts. A fourth man works half time felling and limbing, and half time bucking at the landing. The last member of the crew operates the small crawler tractor used for loading and maintenance at the woods landing. The skidding and hauling times are listed in Table IX.

In each system considered in this study, one to three saws are used. The cost of operating the power saw is a portion of the total costs in any system. For each saw in operation a stand-by saw must be available in the event of a breakdown. Such a stand-by saw is usually an old saw that is kept in good condition. The fixed costs of this saw are included in the total costs of saw ownership.

The specifications and costs of each piece of equipment in the five systems and development of those costs into total costs are shown in the Appendix, Tables XIV-XXI.

Total costs of an operation allows the producer to determine his costs per unit of production. Both fixed and variable components are included in total costs. For the systems considered in this study, equipment, wages, social security, and workman's compensation are the components that are included in the total costs. Fixed costs include

TABLE IX

SKIDDING TIME, SYSTEM 5

Activity	Time (minutes)
Skidding (Loaded, 4 mph covers 1320' in 0.0625 hours)	3.75
(Outrun, 5 mph covers 1320' in 0.50 hours)	3.00
Hook-up (Including 25% Delay Time)	3.44
Unhook (Including 25% Delay Time)	0.34
Total*	10.53

*For an 8 hour day, 480 min./10.53 = 45.5 round trips, hauling 0.50 cords per trip. Daily Production = 45.5 (0.50) = 22.75 cords.

ROUND-TRIP TIME FOR TRUCK IN SYSTEM 5

Activity	Time (hours)
Loading	0.87
Unloading	0.13
Travel	1.67
Total*	2.67

*For an 8 hour day, 8/2.67 = 3.04 round trips, hauling seven cords per trip. Daily Production = 3.04 (7) = 21.28 cords.

equipment ownership costs only. Variable costs include wages, equipment operating costs, and any other costs that are associated with the amount of time worked or to the production per day.

From the total cost analysis, the graphs in Figures 1 and 2 have been developed for the five systems. In Figure 1 the wage component has been placed in the variable costs, on the assumption that the workers are paid in accordance with the volume produced. If less than an optimum amount is produced, or if less than 8 hours per day are worked, the wages decline proportionately. Figure 2 shows the systems layout with wages entered as fixed costs, and the assumption is that employees are paid for 8 hour days regardless of the amount produced.

An important part of analyzing total costs is in accounting for each worker's time in each phase of an operation. Such a cost break-down greatly facilitates the analysis of the total costs. Fixed and variable costs of equipment also are more easily analyzed when this same procedure is followed. By combining the percentages of wages with fixed and variable cost percentages of equipment, total costs of each phase of an operation can be analyzed separately. Table 10 shows development of total costs through each phase of harvesting for the five systems.

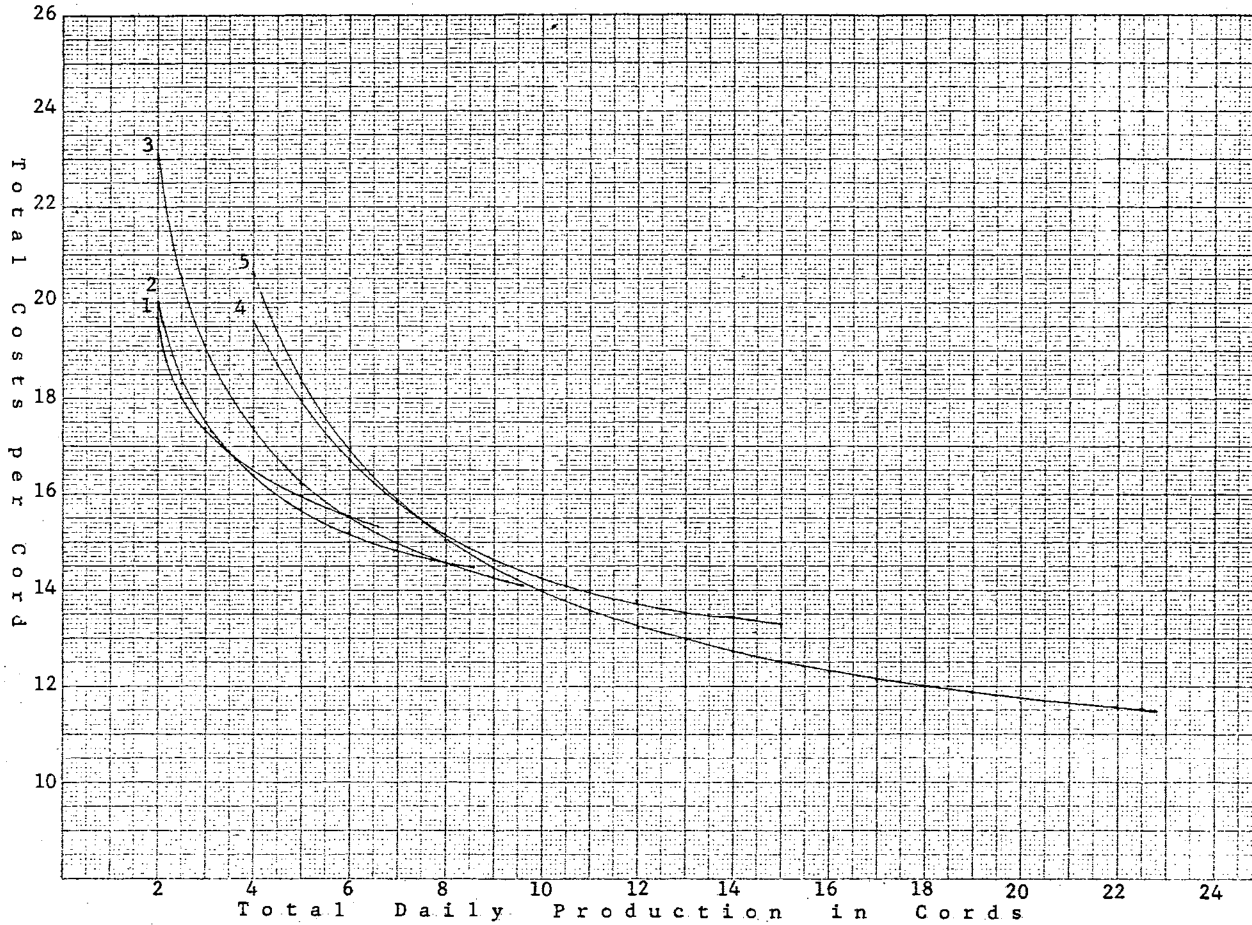

Figure 1. Total Costs Per Cord of Production for 5 Systems
Variable Costs Include the Wage Component

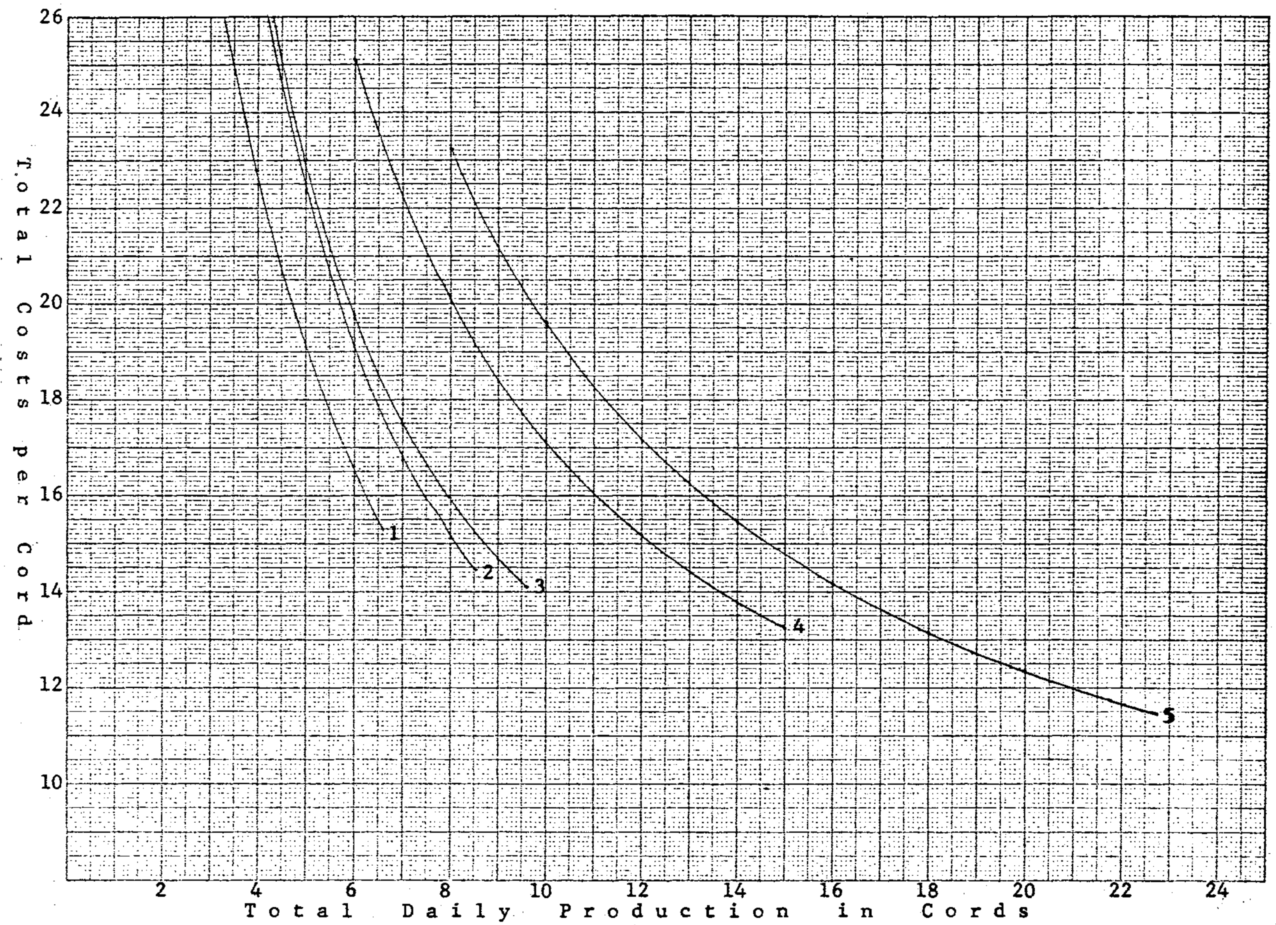

Figure 2. Total Costs Per Cord of Production for 5 Systems
Fixed Costs Include the Wage Component

TABLE X

TOTAL DOLLAR COSTS PER CORD BY PHASE OF OPERATION

System	Cutting	Prestacking	Skidding	Loading	Hauling	W.C.*	Total
1	3.03	4.22		2.25	5.02	0.80	15.32
2	2.90	3.86		2.91	4.02	0.80	14.49
3	4.33		3.96	1.27	3.76	0.80	14.12
4	3.75		2.78	1.19	4.70	0.80	13.22
5	4.22	1.11	2.75	1.24	1.37	0.80	11.49

*Workman's Compensation

Production per man-day is an important key in the analysis of the systems. As a labor-intensive operation such as System 1 is transformed into the successively more capital-intensive systems, production per man-day must increase. In fact, this increased production per man-day is the primary reason for acquiring heavy equipment and increasing daily production. Table XI gives the listing by systems of the cords per man-day production.

TABLE XI

CORDS PER MAN-DAY PRODUCTION BY SYSTEMS

System	Production cords	Workers' number	Production cords	Wage dollars	Total Cost dollars
1	6.60	4	1.65	64	9.70
2	8.58	5	1.72	80	9.32
3	9.60	4	2.40	64	6.67
4	15.00	5	3.00	80	5.33
5	22.75	6	3.79	96	4.22

Operating and Profit Ratios in The Harvesting Systems

Operating and profit ratios, as developed by Rothery 14), may be used to compare these systems. The operating ratio is defined as the relationship existing between total costs of operation plus stumpage value and the selling price of products. For example, if X = stumpage value, CO = total cost of operation, and SP = selling price, then the operating ratio equals (CO + X)/SP. The profit ratio is defined as the relationship between the operator's profit margin and the costs of operation plus stumpage. That is, the profit ratio equals MARGIN/(CO + X). In this study, a constant $4.00 per cord is used for stumpage, and a constant $20.00 is used for selling price. The costs of operation vary from system to system. By way of example, the ratios for System 3 are computed. Total operating costs at optimum production of 9.6 cords per day are $14.12 per cord. The difference between the selling price and costs of operation ($20.00 - $14.12 = $5.88) is the conversion return for that system. Of the $5.88 conversion return, $4.00 is allotted to stumpage, leaving $1.88 designated as the operator's profit margin. The calculated operating ratio is

$$OR = (\$14.12 + \$4.00)/\$20.00 = 0.906,$$

and the calculated profit margin is

$$PR = \$1.88/(\$14.12 + \$4.00) = 0.104.$$

Table XII shows the operating and profit ratios of the five systems.

TABLE XII

OPERATING AND PROFIT RATIOS BY SYSTEM

System	Operating Ratio	Profit Ratio
1	0.966	0.035
2	0.925	0.082
3	0.906	0.104
4	0.861	0.161
5	0.775	0.291

Acres Required to Support Each Harvesting System

One of the objectives in this study was to determine the number of acres that would be required to support each of the designed systems. To determine the number of acres required to support a system, the annual production must be figured and then divided by the growth per acre per year. It has been shown by Walker and Craighead (21) that an acre in Central Oklahoma will produce forty cords in twenty to twenty-two years, or approximately two cords per acre per year. The annual production of a system can be divided by 2 to determine the number of acres required to support that system.

TABLE XIII

ACREAGE NEEDED TO SUPPORT SYSTEMS

System	Annual Production (cords)	Requirement (acres)
1	1254	627
2	1630	815
3	1920	960
4	3150	1575
5	5005	2502

The acreage requirement as indicated in Table XIII ranges from 627 acres in System 1 to 2505 acres in System 5. Most individual ownerships of potential cottonwood producing land are not large enough in size to support these harvesting systems. The individual land owner is therefore prevented from harvesting with any one of the five systems. The acreage required to support any of the systems could be met if a farmers cooperative were organized. Such a cooperative would guarantee a producer the acreage required to support his harvesting system. At the same time the existence of this cooperative would assure the timber owner that he could sell his cottonwood. A stable market for the timber would provide incentive for better management practices in the future and ensure the operator future cuts.

A Farmer's Labor-Intensive System

Most individual owners of farms will have fewer than 100 acres of potentially productive cottonwood land. Lacking cooperatives through which they might work, these individuals could produce their own pulpwood on a small scale during their off-season from annual crop production. Only a small investment in equipment would be required. Most farmers own a chainsaw for clearing brush. This saw can be used to prepare the pulpwood bolts. Most farmers also own a 2-ton truck which could be converted to haul one pallet with a one-cord load capacity. A tubular steel pallet could be acquired, and a winch operated from the power take-off unit on the truck. This equipment would enable the land owner to produce the pulpwood bolts.

The preparation of the bolts, hand loading of the pallet, winching of the pallet onto the truck, and the hauling of the load to the concentration yard, would take 5.06 hours. In an 8-hour day the operator could produce 1.58 cords.

Assuming that the timber grower has the necessary equipment, and uses it only during his off-season, he would need to charge off the equipment operating costs against his timber harvesting business but might ignore the fixed costs of ownership. The variable costs would amount to $6.32 per 8-hour day, exclusive of any wage components. The land owner producing 1.58 cords per day would have an expense of $4.00 per day to produce the 1.58 cords. With a maximum cost limitation of $16.00 per cord, a wage return of $12.00 per day would be obtained.

The acreage needed to produce 7.9 cords per week for a maximum of sixteen weeks per year would be 63.20 acres of cottonwood producing land.

The Effect of Hauling Distance on System Analysis

The operating systems developed in this study are based on a constant 50-mile round-trip hauling distance. (Table IV, page 19). An increased hauling distance would result in a decreased volume hauled per day, and would disturb the balance in other phases of the designed system. The system might be redesigned, or, as an alternative, the hauling hours or number of days might be increased to offset properly the increased round-trip hauling time. It would be necessary to use care in keeping woods inventories balanced.

Shorter hauling distances would increase the daily volume hauled and would require greater output at the cutting site. Achieving more production requires the addition of men or equipment, or both, to the operation.

By way of example, if the round-trip hauling distance is reduced from 50 miles to 20 miles, total daily production in the farmer's labor-intensive system will increase from 1.58 cords to 1.88 cords per day. The total variable costs would increase to $4.72 per 8-hour day. If the maximum cost limitation of $16.00 per cord is used, a wage return of $13.49 per day could be shown. A decrease of 30 miles in the round trip hauling distance would increase the farmer's production per week by 1.50 cords to a total of 9.4 cords and increase his weekly profit. The acreage needed to produce 9.40 cords per week for a maximum of sixteen weeks per year would be 75.20 acres of cottonwood-producing land.

CHAPTER IV

RESULTS AND DISCUSSION

From the total cost curves graphed in Figures 1 and 2, pages 28 and 29, it may be observed that four out of the five systems are operative when the wage component is placed in the variable costs. System 1 shows operability up to 3.50 cords of production. The cost to operate System 1 at the 3.5 cords level of production is shown to be $16.90 per cord, which is above the $16.00 maximum cost allowable under the assumptions of this study. From 3.50 cords to 8.0 cords, System 2 would be the most economical system to use. At the 8.0 cords production level the cost of production with System 2 is $14.55, with an indicated profit of $1.45 per cord. System 3 picks up the production at 8.0 cords and could be used up to a maximum of 9.70 cords. At the 9.7 cords production level the total cost would be $14.10 per cord, and a profit of $1.90 is indicated at that level of production. At any daily production above 9.70 cords System 5 proves to be least expensive. The indicated profit ranges from $1.90 per cord at 9.70 cords production to $4.51 per cord at 22.75 cords production.

System 4 does not have a place among the other systems, if wages are considered as variable costs. If the wages are considered as fixed costs, System 4 minimizes costs between the production levels of 13.4 and 17.8 cords per day.

The total costs of production per cord decrease from System 1 to System 5. This trend is to be expected as the systems become less labor-intensive and more capital-intensive. Production increases must be sufficient to offset the increased investment required in the more sophisticated systems. A major portion of the difference between production and costs is accounted for by the increase, from system to system, of the cords per man day production.

It is shown from various time and cost studies that problems develop if equipment is tied up in performing jobs other than the specific work it was designed to do. Some of the equipment used in the five systems designed in this study reflects such problems, as indicated in Table X, page 30. The hauling vehicles in each operation have been plagued by inefficiencies in that they cannot be used fully for their designed functions. In the first four systems loaders are mounted on the hauling vehicles. When the hauling vehicle is enroute between the cutting site and concentration yard the loader on that vehicle is not in use. This situation causes the fixed costs associated with the loader to be charged against the hauling vehicle when it is enroute to or from the cutting site. When the truck is stationary and loading, the fixed costs of the truck are charged against the loader. The average loading time for the five systems is shown to be 25.20% of an eight hour work day of the hauling vehicle. The costs of loading from System 1 to System 5 show a general decrease.

Hauling costs in the five systems explain why System 4 does not become a working system. (Figure 1, page 28). System 4 shows a hauling cost of $4.20 which is higher than any except that of System 1, and it is caused by combining the use of trucks from System 1 and System 3. The hauling costs for System 4 must therefore fall between costs shown for Systems 1 and 3. Otherwise, there is a decline from system to system.

Costs associated with the other phases of the operations show decreases from system to system. Cutting costs decrease by systems until additional saws are needed. For example, cutting costs in System 2 are less than those in System 1 because one saw is used more efficiently. When additional saws are used in Systems 3 and 4, cutting costs increase because the additional saws are not used to their full capacity. Three saws are used in System 5, and again the cost of felling increases. Hand pre-stacking of the pulpwood bolts is introduced as a phase of the operation in Systems 1 and 2. A decline in the pre-stacking cost occurs in System 2, since the production increases sufficiently to offset the addition of one man. Skidding costs are encountered in Systems 3, 4, and 5. Succeeding systems are characterized by declining skidding costs.

Operating and profit ratios shown in Table XI, page 30, give an idea of how efficient each of the five systems is. In System 1, \$0.966 of each income dollar is taken in costs of operation, and for each dollar of operating cost, the operator receives \$0.035. In System 2, which achieves a cost and profit level characteristic of many operations, \$0.925 of each income dollar is taken in operating costs, and \$0.082 of each cost dollar is returned as profit. Progressively lower operating ratios and higher profit ratios characterize succeeding systems. System 5, with operating ratio of \$0.775 and profit ratio of \$0.291 appears to have a considerable edge over all other systems.

The operating ratio for System 1 (0.966) is ridiculously high. No timber contractor would work under such a situation. What this figure reveals is that no such value as \$4 per cord can be assigned to stumpage where this system is used under the assumptions made in this study. If a reasonable operating ratio, such as 0.87, is used, System 1 may be evaluated as follows:

$$\text{Operating Ratio} = \frac{(\text{Costs of Operation} + \text{Stumpage})}{\text{Selling Price}}$$

and

$$\text{Selling Price X Operating Ratio} = \text{Costs of Operation} + \text{Stumpage}$$

$$\$20\ (0.87) = 15.32 + \text{Stumpage}$$

$$17.40 - 15.32 = \text{Stumpage}$$

$$\text{Stumpage} = \$2.08$$

The Operators Profit Margin = Selling Price - (Costs of Operation + Stumpage)

$$\$20 - (15.32 + 2.08) = \$2.60$$

$$\text{Profit Ratio } 2.60/17.40 = 0.149$$

Conversely, the operating ratio in System 5 is far too low. If again the ratio 0.87 is used, the evaluation becomes:

$$20(0.87) = 11.49 + \text{Stumpage}$$

$$17.40 - 11.49 = \text{Stumpage}$$

$$\text{Stumpage} = \$5.91$$

$$\text{Operators Margin} = \$20 - (11.49 + 5.91) = 2.60$$

$$\text{Profit Rate} = 2.60/(11.49 + 5.91) = 0.149$$

Thus, the use of a reasonable operating ratio of 0.87 and profit ratio of approximately 0.15 indicate that stumpage values increase from about $2 per cord when System 1 is used to $6 per cord when System 5 is used.

CHAPTER V

SUMMARY AND CONCLUSIONS

The results obtained for the five harvesting systems show that operations which are labor-intensive are not as profitable as those that are capital-intensive. Coordination of equipment use is essential for the success of any operation. If coordination is to be achieved equipment must be used as fully as possible to do the work it is designed to perform.

System 5 proved to be most productive with an optimum capacity of 22.75 cords per day. Production may be reduced considerably below optimum without increasing costs greatly because in the design of the system, each piece of equipment is performing its designated function to capacity. The skidder is skidding tree-length material for 8 hours per day. The truck is hauling its loads for 8 hours per day and is idle only when being loaded or unloaded. The small crawler tractor is in operation loading the truck when the truck is at the landing, or stacking wood at the landing when the truck is enroute from the cutting site to the concentration yard. If the loader is not in use, the crawler tractor with blade is being used to keep wood available for loading.

The acreage needed to support any one of the five harvesting systems is prohibitive to most farmers and land owners. By their grouping together and forming cooperatives, the farmers could make cottonwood-producing land a profitable part of their farms. A farmers' cooperative could ensure good management of those sites and obtain a market for cottonwood in the future.

The use of the off-season system could be confined to almost any arbitrarily-chosen shorter period per year, and could therefore be made to fit in with any smaller acreage of timber land. The economic justification for a system of this kind is found only where the needed equipment is already owned, and where there is no better alternative use for the equipment in the farmer's off-season. If any equipment must be acquired solely for use in timber work, then the fixed costs of ownership must be charged against the timber project.

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LITERATURE CITED

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A P P E N D I X   A

TABLE XIV

SYSTEM 1 EQUIPMENT SPECIFICATIONS AND HOURLY OWNERSHIP AND OPERATING COSTS

SYSTEM 1 TRUCK SPECIFICATIONS		dollars
Truck With A-Frame and Winch (Initial Cost)		$ 5100
Insurance		180/year
License		280/year
Estimated Salvage (10% of I.C.)		510
Depreciation Period--4.8 Years @ 1520 hours/year (190 x 8)		
Fixed Costs		dollars/hour
Depreciation--(5100-510)/7296		$ 0.63
APBI* [(5100-510) (4.8 + 1) + 510]/2(4.8) = $2,826.25		
Interest & Tax -- 8% ($2826.25)/1520		0.15
Insurance -- $180/1520		0.12
License -- $280/1520		0.18
Total		$ 1.08
Variable Costs		dollars/hour
Fuel @ 7 mpg for 150 miles-- 21 gallon x 0.30¢	$ 6.30	
Loading--10 gallon x 0.30¢	3.00	
	$ 9.30	$ 1.16
Lubrication (25% of fuel)		0.29
Repairs -- $1800/7296		0.25
Tires -- $2500/7296		0.34
Total		$ 2.04

*APBI--Average profit bearing Investment formula according to Allis-Chalmers Mfg. Co. (1)

APPENDIX B

TABLE XV

SYSTEM 2 EQUIPMENT SPECIFICATIONS AND HOURLY OWNERSHIP AND OPERATING COSTS

SYSTEM 2 TRUCK SPECIFICATIONS		dollars
Truck With A-Frame and Winch (Initial Cost)		$ 6400
Insurance		200/year
License		350/year
Estimated Salvage (10% of I.C.)		640
Depreciation Period--4.8 Years @ 1520 hours/year (190 x 8)		
Fixed Costs		**dollars/hour**
Depreciation--(6400-640)/7296		0.79
APBI--[(6400-640)(4.8 + 1) + 640]/2(4.8) = $3,546.67		
Interest & Tax--8% ($3546.67)/1520		0.19
Insurance--$200/1520		0.13
License--$350/1520		0.23
Total		$ 1.34
Variable Costs		**dollars/hour**
Fuel @ 6 mpg for 150 miles-- 25 gallon x 0.30¢	$ 7.50	
Loading--10 gallon x 0.30¢	3.60	
	$11.10	$ 1.39
Lubrication--(25% of fuel)		0.35
Repairs--$2200/7296		0.30
Tires--$3100/7296		0.42
Total		$ 2.46

A P P E N D I X   C

TABLE XVI

SYSTEM 3 EQUIPMENT SPECIFICATIONS AND HOURLY OWNERSHIP AND OPERATING COSTS

SYSTEM 3 SKIDDER SPECIFICATIONS	dollars
Farm Tractor (Initial Cost)	$ 2,600
Logging Arch	365
Freight	200
Estimated Salvage (20%)	630
Depreciation Period--5.8 Years @ 1600 hours/year (200 x 8)	
Fixed Costs	dollars/hour
Depreciation--(3165-630)/9280	0.27
APBI--[(3165-630)(5.8 +1) + 630]/2(5.8) = $1,540.34	
Interest, Tax & Insurance--10% ($1540.34)/ 1600	0.10
Total	$ 0.37
Variable Costs	dollars/hour
Fuel--25 horsepower x 0.100 gallon/hour x 0.25¢	0.63
Lubrication--(25% of fuel)	0.16
Parts, Repair, & Labor (100% Depreciation)	0.27
Tires--$536.56/9280	0.06
Total	$ 1.12

TABLE XVI

(Continued)

SYSTEM 3 TRUCK SPECIFICATIONS		dollars
Truck & Loader (Initial Cost)		$ 8,000
Insurance		200/year
License		350/year
Estimated Salvage (10% of I.C.)		800
Depreciation Period--4.8 Years @ 1600 hours/year (200 x 8)		
Fixed Costs		dollars/hour
Depreciation--(8000-800)/7680		0.94
APBI--[(8000-800) (4.8 + 1) + 800]/2(4.8) = $4,433.33		
Interest & Tax--8% ($4433.33)/1600		0.22
License--$350/1600		0.22
Insurance--$200/1600		0.13
Total		$ 1.51
Variable Costs		dollars/hour
Fuel--6 mpg for 150 miles--		
25 gallon x 0.30¢	$ 7.50	
Loading--12 gallon x 0.30¢	3.60	
	$ 11.10	1.39
Lubrication--(25% of fuel)		0.35
Repair--$2200/7680		0.29
Tires--$3100/7680		0.40
Total		$ 2.43

A P P E N D I X   D

TABLE XVII

SYSTEM 4 EQUIPMENT SPECIFICATIONS AND HOURLY OWNERSHIP AND OPERATING COSTS

SYSTEM 4 SKIDDER SPECIFICATIONS	dollars
Small Skidder (Initial Cost)	$ 7,700
Resale (20% of I.C.)	1,540
Depreciation Period--5.8 Years @ 1680 hours/year (210 x 8)	
Fixed Costs	dollars/hour
Depreciation--(7700-1540)/9744	0.63
APBI--[(7700-1540)(5.8 + 1) + 1540]/2(5.8) = $4,523.75	
Interest, Tax, & Insurance--10% ($4523.75)/1680	0.27
Total	$ 0.90
Variable Costs	dollars/hour
Fuel--38.38 Horsepower x 0.105 gallons/hour x .25	1.01
Lubrication--(25% of fuel)	0.25
Parts, Repair, & Labor (100% Depreciation)	0.63
Tires--$3200/9744	0.33
Total	$ 2.22

SYSTEM 4 TRUCK SPECIFICATIONS	dollars
Truck with Hydraulic Loader (Initial Cost)	$ 8,600
Insurance	200/year

TABLE XVII

(Continued)

License		$ 350/year
Estimated Salvage (10% of I.C.)		860
Depreciation Period--4.8 Years @ 1680 hours/year (210 x 8)		
Fixed Costs		dollars/hour
Depreciation--(8600-860)/8064		0.96
APBI--[(8600-860)(4.8 + 1) + 860]/2(4.8) = $4,765.83		
Interest & Tax--8% ($4765.83)/1680		0.23
License--$350/1680		0.21
Insurance--$200/1680		0.12
Total		$ 1.52
Variable Costs		dollars/hour
Fuel--6 mpg for 150 miles-- 25 gallon x 0.30¢	$ 7.50	
Loading--12 gallon x 0.30¢	3.60	
	$ 11.10	1.39
Lubrication--(25% of fuel)		0.35
Repairs--$2200/8064		0.27
Tires--$3100/8064		0.38
Total		$ 2.39

SYSTEM 4 TRUCK SPECIFICATIONS	dollars
Truck with Winch (Initial Cost)	$ 5,100
Insurance	180/year
License	280/year

TABLE XVII

(Continued)

Estimated Salvage (10% of I.C.)		$ 5.0
Depreciation Period--4.8 Years @ 1680 hours/year (210 x 8)		
Fixed Costs		dollars/hour
Depreciation--(5100-510)/8064		0.57
APBI--[(5100-510)(4.8 + 1) + 510]/2(4.8) = $2,826.25		
Interest & Tax--8% ($2,826.25)/1680		0.13
License--$180/1680		0.11
Insurance--$280/1680		0.16
Total		$ 0.97
Variable Costs		dollars/hour
Fuel--7 mpg for 150 miles--		
21 gallon x 0.30¢	$ 6.30	
Loading--10 gallon x 0.30¢	3.00	
	$ 9.30	1.16
Lubrication--(25% of fuel)		0.29
Repairs--$1800/8064		0.22
Tires--$2500/8064		0.31
Total		$ 1.98

APPENDIX E

TABLE XVIII

SYSTEM 5 EQUIPMENT SPECIFICATIONS AND HOURLY OWNERSHIP AND OPERATING COSTS

SYSTEM 5 SKIDDER SPECIFICATIONS	dollars
Large Skidder (Initial Cost)	$14,900
Freight	500
Resale--(20% of I.C.)	3,080
Depreciation Period--5.8 Years @ 1760 hours/Year (220 x 8)	
Fixed Costs	dollars/hour
Depreciation--(15,400-3080)/10,208	1.21
APBI--[(15,400-3080)(5.8 + 1) + 3080]/2(5.8) = $7,487.59	
Interest, Tax, & Insurance--8% (47487.59)/1760	0.34
Total	$ 1.55
Variable Costs	dollars/hour
Fuel--63.05 Horsepower x 0.133 gallon/ hour x 0.25¢	2.10
Lubrication--(25% of fuel)	0.53
Parts, Repairs, and Labor (100% Depreciation)	1.21
Tires--$3312/10,208	0.32
Total	$ 4.16

SYSTEM 5 SMALL CRAWLER SPECIFICATIONS	dollars
Small Crawler with Blade (Initial Cost)	6,500
Hydraulic Loader	2,800

TABLE XVIII

(Continued)

Resale--(20%)	1,860
Depreciation Period--5.8 Years @ 1760 hours/year (220 x 8)	
Fixed Costs	dollars/hour
Depreciation--(9,300-1860)/10,208	0.73
APBI--[(9300-1860)(5.8 + 1) + 1860]/2(5.8) = $4,521.72	
Interest, Tax, & Insurance--10% ($4521.72)/1760	0.26
Total	$ 0.99
Variable Costs	Dollars/hour
Fuel--3 gallon/hour x 0.25¢	0.75
Lubrication--(25% of fuel)	0.19
Parts, Repairs, & Labor--(100% of Depreciation)	0.73
Total	$ 1.67

SYSTEM 5 TRUCK SPECIFICATIONS	dollars
Large Tandem-Axle Truck	$10,000
Insurance	250/year
License	410/year
Estimated Salvage (20% of I.C.)	2,000
Depreciation Period--4.8 Years @ 1760 hours/year (220 x 8)	

TABLE XVIII

(Continued)

Fixed Costs	dollars/hour
Depreciation--(10000-2000)/8448	0.95
APBI--[(10000-2000)(4.8 - 1) - 2000]/2(4.8) = $5,041.67	
Interest & Tax--8% ($5041.67)/1760	0.23
License--$410/1760	0.23
Insurance--$250/1760	0.14
Total	$ 1.55

Variable Costs	dollars/hour
Fuel--5 mpg for 150 miles-- 30 gallon x 0.30¢ = $9.00 =	1.13
Lubrication--(25% of fuel)	0.28
Repairs--$2750/8448	0.33
Tires--$3875/8448	0.46
Total	$ 2.20

A P P E N D I X   F

TABLE XIX

COST OF OWNING AND OPERATING A POWER SAW*

Chainsaw With Automatic Oiler and 28" Chain	$ 225.00
Extra Sawbar and Chain	38.25
Axe	6.70
Wedges (4)	11.30
Gas Can	2.95
Files (2)	2.50
Fire Extinguisher	8.00
Shovel	6.50
Total Cost	$ 301.20
Depreciation Period--1.0 Years or 1640 hours	
Resale Value (Residual)--$54.00 (18%)	
Fixed Costs:	
Depreciation-- $\frac{301.20 - 54.00}{1640}$ =	$ 0.15/hour
APBI--60% of Actual ($301.20) = $ 180.72	
Interest & Tax-- $\frac{10\% (180.72)}{1640}$	0.01/hour
Total Fixed Cost	$ 0.16/hour
Variable Costs:	
Saw Gas--2 gallon/day x 0.43¢/gallon-- 7 hours/day	0.12/hour
Chain Oil--1 quart/day x 0.43¢/gallon-- 7 hours/day	0.04/hour
Repairs and Maintenance (90% of Depreciation)	0.15/hour
Replacement Equipment	0.19/hour
Total Variable Cost	$ 0.50/hour
COST OF SECONDARY SAW	
Fixed Costs:	
Depreciation-- $\frac{54.00}{1640}$	$ 0.03/hour
APBI--60% of Actual--$32.40	
Interest & Tax	0.002/hour
Total Fixed Cost	$ 0.032/hour

*Table Taken from Conway (3).

A P P E N D I X G

TABLE XX

TOTAL DAILY COSTS OF SYSTEMS

Total Daily Costs for System 1:	
Fixed Costs:	
Truck with A-frame and Winch	$ 8.64
Power Saw	3.84
Total	$ 12.48
Variable Costs:	
Truck with A-frame and Winch	$ 16.32
Power Saw	3.30
Wages	60.80
Social Security	2.92
Workman's Compensation	5.28
Total	$ 88.62
Total Daily Costs for System 2:	
Fixed Costs:	
Truck with A-frame and Winch	$ 10.72
Power Saw	3.84
Total	$ 14.56
Variable Costs:	
Truck with A-frame and Winch	$ 19.68
Power Saw	4.29
Wages	75.20
Social Security	3.48
Workman's Compensation	6.86
Total	$ 109.51
Total Daily Costs for System 3:	
Fixed Costs:	
Farm Tractor	$ 2.96
Truck and Loader	12.08
Power Saw	7.68
Total	$ 22.72
Variable Costs:	
Farm Tractor	$ 8.96
Truck and Loader	19.44
Power Saw	9.60
Wages	64.00
Social Security	3.07
Workman's Compensation	7.68
Total	$ 112.75

TABLE XX

(Continued)

Total Daily Costs for System 4:	
Fixed Costs:	
Small Skidder	$ 7.20
Truck with Loader	12.16
Truck with Winch	7.76
Power Saw	7.68
Total	$ 34.80
Variable Costs:	
Small Skidder	$ 17.76
Truck with Loader	19.12
Truck with Winch	15.84
Power Saw	15.00
Wages	80.00
Social Security	3.84
Workman's Compensation	12.00
Total	$ 163.56
Total Daily Costs for System 5:	
Fixed Costs:	
Large Skidder	$ 12.40
Small Crawler with Blade	7.92
Large Tandem-axle Truck	12.40
Power Saw	11.52
Total	$ 44.24
Variable Costs:	
Large Skidder	$ 33.28
Small Crawler with Blade	13.36
Large Tandem-axle Truck	17.60
Power Saw	34.13
Wages	96.00
Social Security	4.61
Workman's Compensation	18.20
Total	$ 217.18

A P P E N D I X   H

TABLE XXI

PERCENTAGE OF TIME SPENT BY WORKERS ON PHASES OF OPERATION

System	No. of Men	Cutting	Prestacking	Skidding	Loading	Hauling	Total
1	1 Cutter	76.88	23.12				100%
	2 Helpers		79.31		20.69		100%
	1 Driver				20.69	79.31	100%
2	1 Cutter	100.00					100%
	3 Helpers		73.19		26.81		100%
	1 Driver				26.81	73.19	100%
3	1 Cutter	66.75		33.25			100%
	1 Skidder			100.00			100%
	1 Bucker	77.75		22.25			100%
	1 Driver				25.20	74.80	100%
4	1 Cutter	100.00					100%
	1 Skidder			100.00			100%
	1 Bucker	100.00					100%
	2 Drivers				20.25	79.75	100%
5	1 Cutter	100.00					100%
	*1 Cutter	50.00					
		50.00					100%
	1 Skidder			100.00			100%
	1 Bucker	100.00					100%
	1 Crawler		66.94		33.06		100%
	1 Driver				33.06	66.94	100%

*This man falls and limbs 50% of the time and bucks 50% of the time.

Percentages established on an 8-hour work day.

VITA

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Candidate for the Degree of

Master of Science

Thesis: ECONOMICAL HARVESTING SYSTEMS FOR SCATTERED STANDS OF COTTONWOOD IN CENTRAL OKLAHOMA

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