GROUND-BASED SYSTEMS

The overwhelming majority of wood harvested in the eastern United States is produced by ground-based systems. Only in extremely rugged or environmentally sensitive areas where there is a substantial amount of high quality timber are other systems used to a widespread extent today. Ground-based systems, despite some flaws and shortcomings, are by far the most popular and most economical mechanized logging systems used throughout the world.

However, simply because ground-based systems are commonly used does not mean that they are easy to run in an economical fashion. Such systems are sensitive to a variety of factors which can affect their safety, productivity, and cost of operation. Before we discuss these factors in detail, we first need to understand the types of ground-based systems and their components.

Ground-based systems range in complexity from the most primitive of systems to the most capital-intensive and complex of systems. However, all ground-based systems have at least one thing in common -- they move logs from the neighborhood of the stump to the landing at roadside by something which moves on the ground. This movement is called skidding if logs drag on the ground and forwarding if logs are carried completely off the ground. Other systems to be discussed later move wood by means of cable or airship.

There are six basic means of moving wood on the ground to the landing (Table 1):

- animals
- crawler tractors
- rubber-tired tractors (straight-frame)
- rubber-tired, articulated skidders
- track-laying skidders
- forwarders (or prehaulers)

Animals

Animal power is by far the most primitive means of moving wood. While several types of animals have been used to move wood, most logging used either (1) oxen , (2) mules, or (3) horses. Oxen are strong, reliable animals but are slow moving. In hot climates such as the South, oxen must be worked in pairs and rested on alternate days. Mules are well suited to the warmer climate of the South where they once were the workhorse of southern industry and agriculture. Horses are better suited to more moderate northern climates and are more easily excited than either oxen or mules. Common breeds of horses useful for logging are Belgian and Clydesdales.

Finding an operation today that uses animals to skid may be extremely difficult. In some locales, animal skidding has recently received renewed interest since it causes little site disturbance. Today, draft animals may be difficult and expensive to obtain. Strong, even-tempered animals are most desirable for logging. Skidding with animals is best suited to relatively small timber and moderate slopes with little underbrush. Slopes should not allow logs to overrun the animals (or operator). This usually means less than 30-35 percent. This slope may be much less during winter when snow and ice are present. Skidding distances are short, usually under 500 feet when skidding downhill and 300 feet on level ground. Uphill skidding is usually not practiced and should be limited to less than 6 percent slopes and 150 foot distances. A horse can pull up to 80 percent of its weight.

Harnesses attach to a single- or double-tree and logs are attached by means of chokers, chains, or tongs. Chains and tongs are most often used with animals. When using animals, logging should begin at the extremity of the tract and skidding inward. Skidding is therefore performed through the uncut portion of the stand, keeping the animals away from the logging slash. Use of animals for skidding usually requires a large deck. Animals naturally require food, water, and shelter. Generally a corral and crude shelter are provided near the logging site. Prompt attention to animal needs and condition will maintain production and prevent hostile visits from animal welfare groups.

Table 1. Capabilities of skidding methods on flat to gently rolling areas.

Method	HP	Payload (tons)	Skidding Distance	Average Utilization	Tons per Hour
Animal (draft horse)	1	0.3	500	30-50	3-6
Crawler (JD 450)	80	0.4-0.8	500	60	8-15
Farm Tractor (Log Hog)	40	0.3	500	50	5-8
Rubber-tired Skidder (CAT 515)	140	2-3	1500	75	14-30
Track-laying Skidder (FMC 210)	200	4-6	1000	70	14-30
Forwarder (Timberjack 1410)	168	14-16	2000	75	20-30

Crawler Tractors

Crawlers are multipurpose machines which are available in a wide range of sizes. Crawlers use tracks instead of wheels, with the track driven by the rear sprocket. This keeps the bottom portion of the track rigid. Units range in horsepower from 20 to 230 horsepower (drawbar) and weigh anywhere from 2 to 30 tons. Crawlers are slower than other mechanical means of skidding but often cause less environmental damage. Crawlers often have better traction and flotation than standard skidders and are better at maneuvering in muddy or slick conditions. An added plus is that crawlers can double as earthmoving equipment when not needed for skidding.

Skidding with a crawler can be performed in a variety of ways. In drawbar skidding the logs are attached to the drawbar of the tractor and lie completely on the ground. This type of skidding is extremely slow and hard on the machine. Several attachments are available to improve the performance of crawler tractors. Logging arches (tracked) or sulkies (wheeled) are towed behind a crawler and lift one end of the logs, thereby reducing resistance to skidding and increasing production. These attachments are now almost obsolete. Today most crawlers configured for skidding are equipped with an integral logging arch which consists of a winch and fairlead. Most crawlers have earthmoving blades mounted on the front of the machine. This helps balance machine weight when loaded and improves traction.

Chains or chokers may be used to attach logs. With drawbar skidding, chains often readily attach to chain hooks on the drawbar. With winch skidding, chokers made of wire rope or chain are usually used. A wire rope (or cable) choker is a short segment (4-10 feet) of wire rope with a ferrule on each end. Sliding between both ferrules is a choker hook. Logs are attached by wrapping the choker around the log and locking the ferrule into the choker hook. Chokers are attached to the winch line by means of a sliding hook (bull hook). Bull hooks stack on the mainline to prevent chokers from becoming tangled.

Many northern loggers prefer chain chokers since they do not freeze stiff as does wire rope. In addition, chain grips frozen and icy logs better than wire rope. Chain chokers are difficult to get under logs without some sort of assistance. Many loggers use a short piece of steel with a hook on one end. Even Yankee ingenuity has yet to devise a way to push a chain.

Rubber-Tired, Non-Articulated Tractors

Farm-type tractors may be used for logging on a part-time basis and similar tractors are adapted and strengthened to perform logging full-time. These tractors involve a lower investment than dedicated logging skidders. They are sometimes used by a landowner to log their own timber or by a small independent logger. A higher percentage of the weight of a farm tractor is supported by the rear wheels than on a logging skidder. This may cause problems while skidding since the front-end of the machine may lift off the ground when trying to skid logs. To prevent this, weight might be added to the front of the machine, the logs could be lowered (however this can increase skidding resistance), or the logs may be moved top first.

These machines often do not stand up well under the rigors of full-time logging or when logging sizeable timber. Furthermore, these machines usually do not have any of the protective structures required by OSHA to reduce the hazards of logging. Logs are usually attached by means of chains, chokers, or tongs.

Several manufacturers offer tractors which are designed for logging. Many of these small tractors are imported. Such machines have a more robust construction including more four-wheel drive transmissions, FOPS, ROPS, belly pans, heavier axles, larger tires with suitable tread and ply ratings, and additional weight on the front of the machine. Most of these machines use a PTO-driven winch although they often also provide chain hooks on the winch frame.

Rubber-Tired, Articulated Skidders

These types of machines perform the majority of skidding in North America today. First developed in the late 1950's, these machines became accepted in the 1960's and today are the standard ground skidding machine throughout the world. Skidders range from 70 to 200 hp and weight from 6 to 18 tons. Most skidders have a fixed rear axle and a center-hinged front axle. Steering is performed by hydraulic cylinders to twist the frame of the machine. This design provides extremely good maneuverability and easily accommodates a rugged four-wheel drive system. Skidders are classified by their method of holding logs as either a (1) cable, (2) grapple, and (3) clam-bunk machines.

Cable skidders use a powerful winch and wire rope chokers to assemble and hold logs during skidding. The skidder operator (or occasionally a separate choker setter) attaches chokers to the logs, the logs are then winched up to the skid plate on the skidder, and skidding begins. At the landing, the logs must also be unchoked by hand. Cable skidders are the least expensive of skidders but require the most labor to operate since loads are assembled by choking logs by hand. These skidders can be highly productive in larger timber where only one or two logs will create a large load. Cable skidders also work better than most skidders on adverse slopes or in wet areas. Should the skidder become bogged down, the operator can free-spool the winch, drive to a firmer piece of ground, re-winch the load and continue.

Grapple skidders use a hydraulically operated grapple to assemble and hold logs during skidding. Use of the grapple prevents the operator from dismounting the machine to choke logs, thereby creating a safer work environment. While the grapple adds both weight and expense to the machine, it often pays for itself through higher production.

If wood has been felled and bunched by a feller-buncher, grapple machines are much more productive than cable skidders. In large timber which has been manually felled, productivity of cable and grapple machine are nearly equal. In fact, grapple skidders were developed almost 15 years before reliable feller-bunchers became available. Once small trees could be bunched to take advantage of the grapple capabilities, systems using both feller-bunchers and grapple skidders quickly became popular.

Clam-bunk models are the least popular type of skidder. These skidders use an inverted grapple found on the rear of the machine to hold large loads of wood while skidding. The grapple is loaded using a small hydraulic loader attached to the machine. Since butts of the logs rest upon the rear portion of the skidder, traction is greatly improved. This permits larger payloads allowing clam-bunk skidders to economically skid long distances. They are most popular in the large unroaded areas of Canada where road building costs are high.

Track-Laying Skidders

Track laying skidders appear similar to crawler tractors at first glance. However, there is one important difference. Crawler tractors use the rear sprocket to drive the machine, resulting in the lower portion of the track being rigid. Track-laying skidders use the front sprocket to drive the machine, with the upper portion of the track rigid and the lower portion flexible. This permits higher speeds and reduces site damage. As a result, these machines are often used on sites with environmental concerns or poor traffic ability.

The most popular of these machines was originally made by FMC Corporation and is now made by KMC of Canada. This machine is expensive to purchase and maintain but can skid large payloads and negotiate otherwise unaccessible tracts. As a result, it is often used on slopes or in swamps. As with rubber-tired machines, track-laying skidders are made in cable, grapple, and clam-bunk versions.

Forwarders

Forwarders (or prehaulers) differ from skidders in that their payload is carried entirely off the ground. Most forwarders can only move cut logs. Since the entire weight of the load is borne by the machine, forwarders exert relatively high pressures to the ground beneath them. As a result, these machines are commonly used in areas with glaciated soils which have high soil strength or on prepared skid trails.

Forwarders spend a substantial amount of their cycle time assembling a load with their knuckleboom loader. As a result they can benefit from wood which has been felled in bunches or piled after bucking. Forwarders can economically move wood long distances and often compete directly with clam-bunk skidders in areas where they are used.

Forwarders either unload wood at roadside to the ground or directly onto a truck. This may simplify a logging systems since a separate loader is not necessary. Forwarding systems are common where roadside wood markets are popular. Forwarders may perform other functions as well. Instead of a simple grapple, a delimbing/bucking head may be used to allow the forwarder to process trees into logs prior to loading and forwarding. One manufacturer sells a huge forwarder which fells and then forwards full trees. Most forwarders used in the United States simply move wood and do no processing.

Forwarders are often widely used for thinnings or partial cuts of timber. The rear tires on most forwarders follow the tracks made by the front tires. This permits an operator to easily maneuver the machine through the residual stand while damaging a minimum number of crop trees.

Factors Affecting Ground-Based Systems

Several factors affect the productivity and cost of ground-based systems. These include: (1) average tree size (typically measured by dbh); (2) stand volume per acre; (3) extraction distance; (4) extraction payload; (5) type of harvest (thinning or clearcut); and (6) species harvested.

Proper planning can permit harvesting systems to economically log many different types of tracts. However, the limitations of each system and the sensitivity to the above factors must be understood to develop a sound logging plan.

Average Tree Size

Tree size can be measured in many ways, including dbh, average volume per tree, and number of trees per cord or ton (Table 2). The most common measure is dbh. In many respects, timber harvesting is a materials handling problem. In typical materials handling situations (e.g., a warehouse), items are combined into larger units to minimize the number of times a product must the handled and to maximize the amount of product moved in a given unit of time.

With small trees, harvesting equipment typically tries to handle several stems at once to offset the extremely small volume associated with each stem. Where this is not possible, the productivity of the machine or system declines significantly, raising per unit costs substantially. Harvesting functions which often deal with single stems, such as felling and processing, are particularly sensitive to stem size. If stems cannot be bunched for skidders or forwarders, their productivity and cost can also be quite sensitive to stem size.

Table 2. Effect of tree size on productivity of a cable skidder when skidding 0.5 cords at a distance of 750 feet.

DBH (inches)	Tree Volume (CFob)	Trees per Cord	Trees per Turn	Minutes per Turn	Cords per PMH
6	3.87	24	12	11.79	2.54
8	8.45	11	5	8.41	3.57
10	15.06	6	3	7.45	4.03
12	23.65	4	2	6.97	4.30
14	33.94	3	1	6.48	4.63
16	45.52	2	1	6.48	4.63

Stand Volume per Acre

In dense stands of uniform trees such as plantations, volume per acre often has a greater effect on system productivity and cost than does individual tree size. This is especially true when using a harvesting system designed for handling stems within a relatively small range of size. For highly mechanized systems using feller-bunchers and grapple skidders in plantations, the effect of volume per acre diminishes once volumes exceed 20 cords per acre (Figure 1).

Extraction Distance & Payload

The two factors which most affect the productivity and cost of ground-based systems are extraction distance and payload (Figure 2). These factors are controlled to a great degree by the planning and execution of the logging operation. The number and location of landings determine the average extraction or skidding distance. Payload is determining by the type and size of timber harvested, the type of extraction method used, and the method of felling. Naturally, a logger seeks to move the maximum payload over the shortest possible distance in order to maximize productivity and minimize costs. These two factors receive an great deal of attention when discussing logging systems since skidding is the major cost component in getting wood to roadside.

Type of Harvest

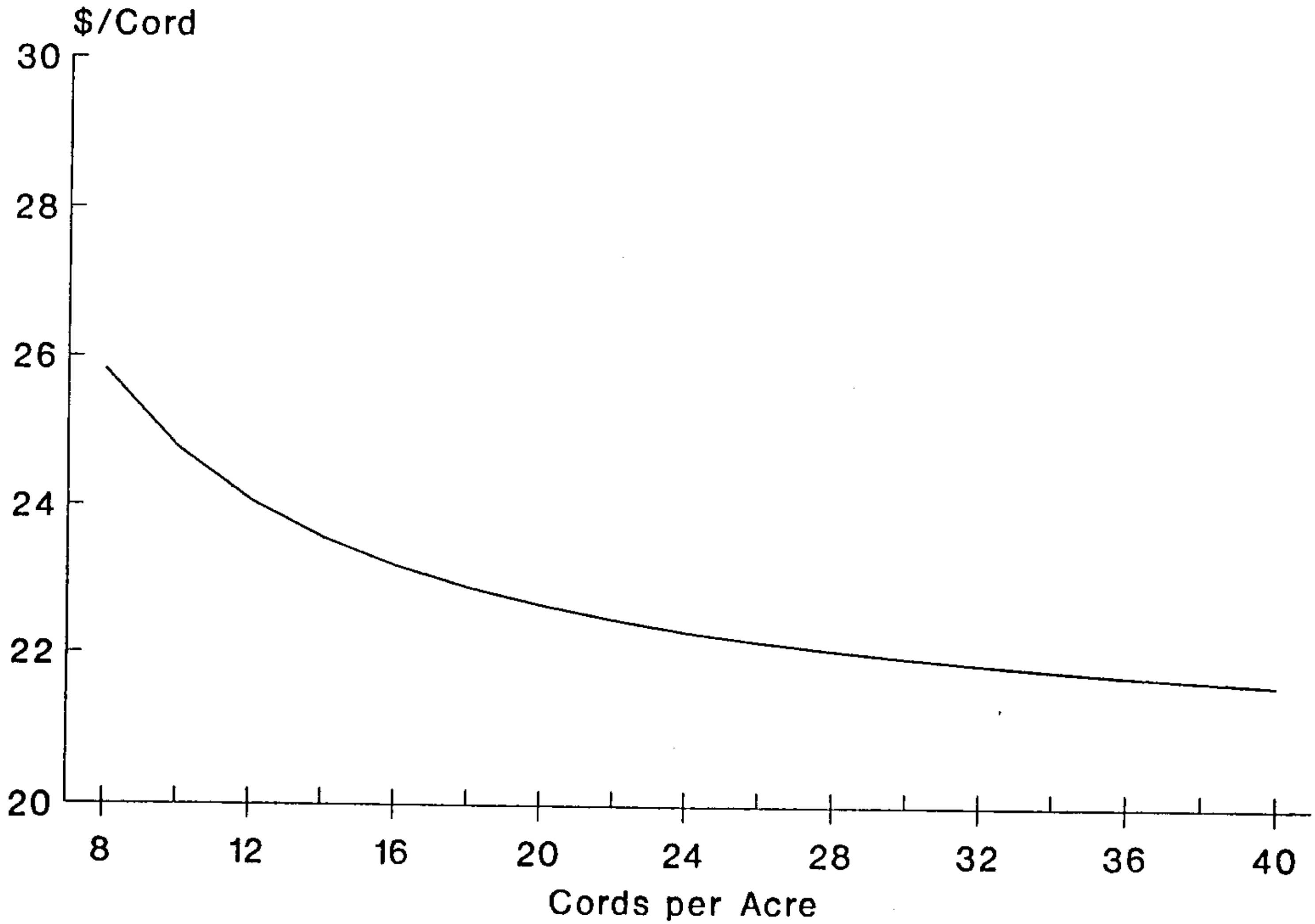
Clearcuts present fewer constraints to a harvesting system than do thinnings or partial cuts. Thinnings often require smaller equipment or radically different operating strategies than clearcuts. Residual trees not only represent an obstacle to be avoided, they must not the excessively damaged in order that the thinning be silvicultural beneficial. In addition, thinnings often remove small, deformed trees in order to improve the residual stand. These small stems often make the harvest expensive since large equipment payloads are difficult to achieve. First thinnings of a stand create the most problems while second and later thinnings are much easier to mechanize since trees are larger and stand density is lower.

Species Composition

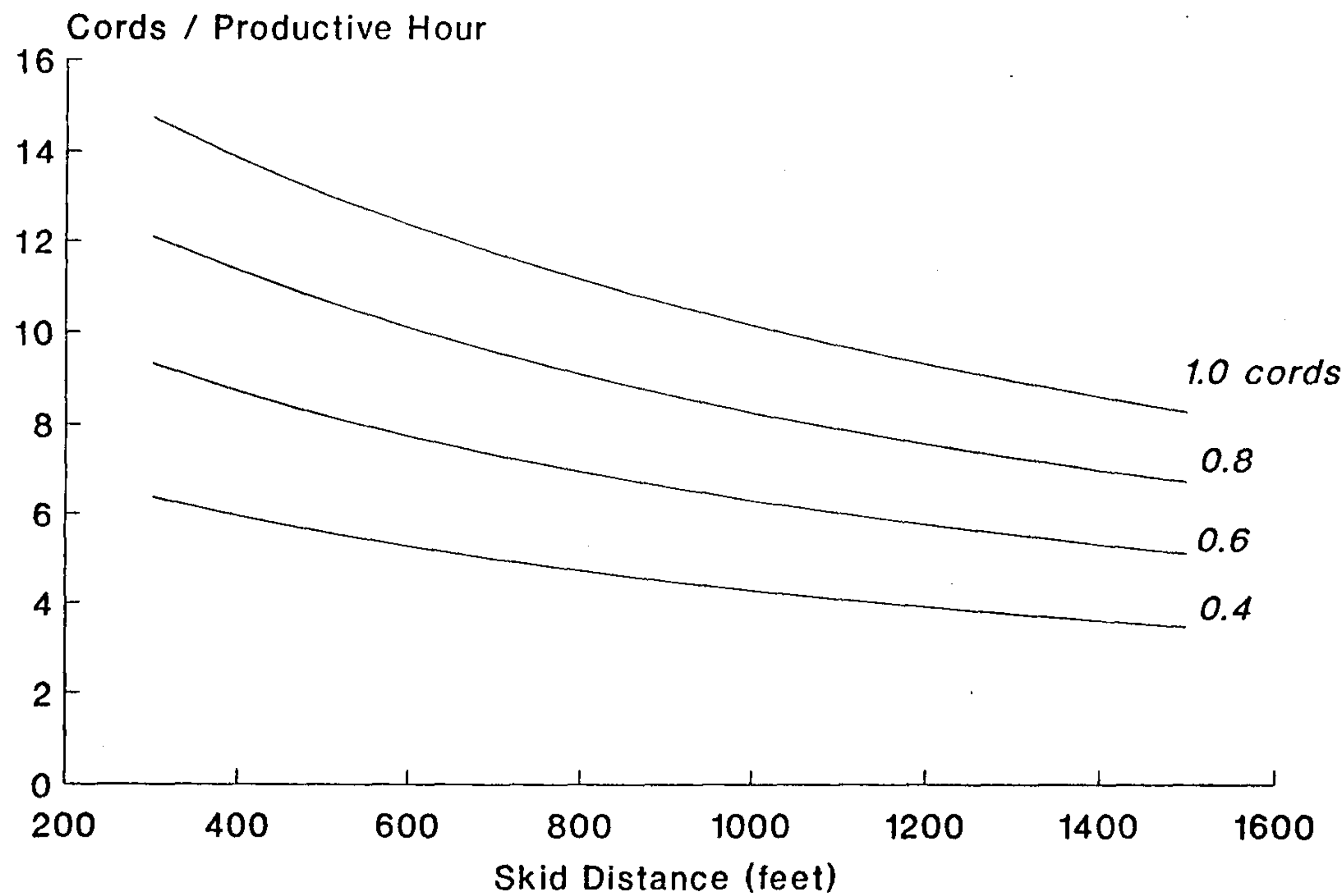
In the major timbered regions of North America, conifers are the preferred timber species. In the South, southern yellow pine is the primary species harvested followed by various hardwoods. Harvesting of hardwood species are generally more difficult to mechanize due to several factors. Hardwoods often occupy difficult sites, such as slopes or poorly drained stream bottoms or swamps. In addition, hardwoods are heavier and generally of poorer form, making large payloads more difficult to obtain. Processing of hardwoods is almost entirely manual with the use of a chainsaw. The large, non-uniform limbing pattern of chainsaws makes mechanical delimbing difficult. The dense wood and large, heavy crowns often reduce mechanical felling productivity with hardwoods. These factors combine to make hardwood harvests more expensive (Figure 3).

Figure 1. Effect of volume per acre on cost per unit volume.

Figure 2. Effect of volume per turn on hourly productivity.


$/Cord
30
28
26
24
22
20
8
12
16
20
24
28
32
36
40
Cords per Acre

2



Cords / Productive Hour
16
14
12
10
8
6
4
2
0
200
400
600
800
1000
1200
1400
1600
Skid Distance (feet)
1.0 cords
0.8
0.6
0.4

Figure 3. Effect of hardwood composition on per unit cost.

MECHANIZED SYSTEMS

Logging systems are collections of people and machines which produce wood or fiber to be transported from the woods. These systems are composed of several functions including:

(1) felling,

(2) processing (delimbing, bucking, or chipping),

(3) woods transportation (skidding, forwarding, or yarding),

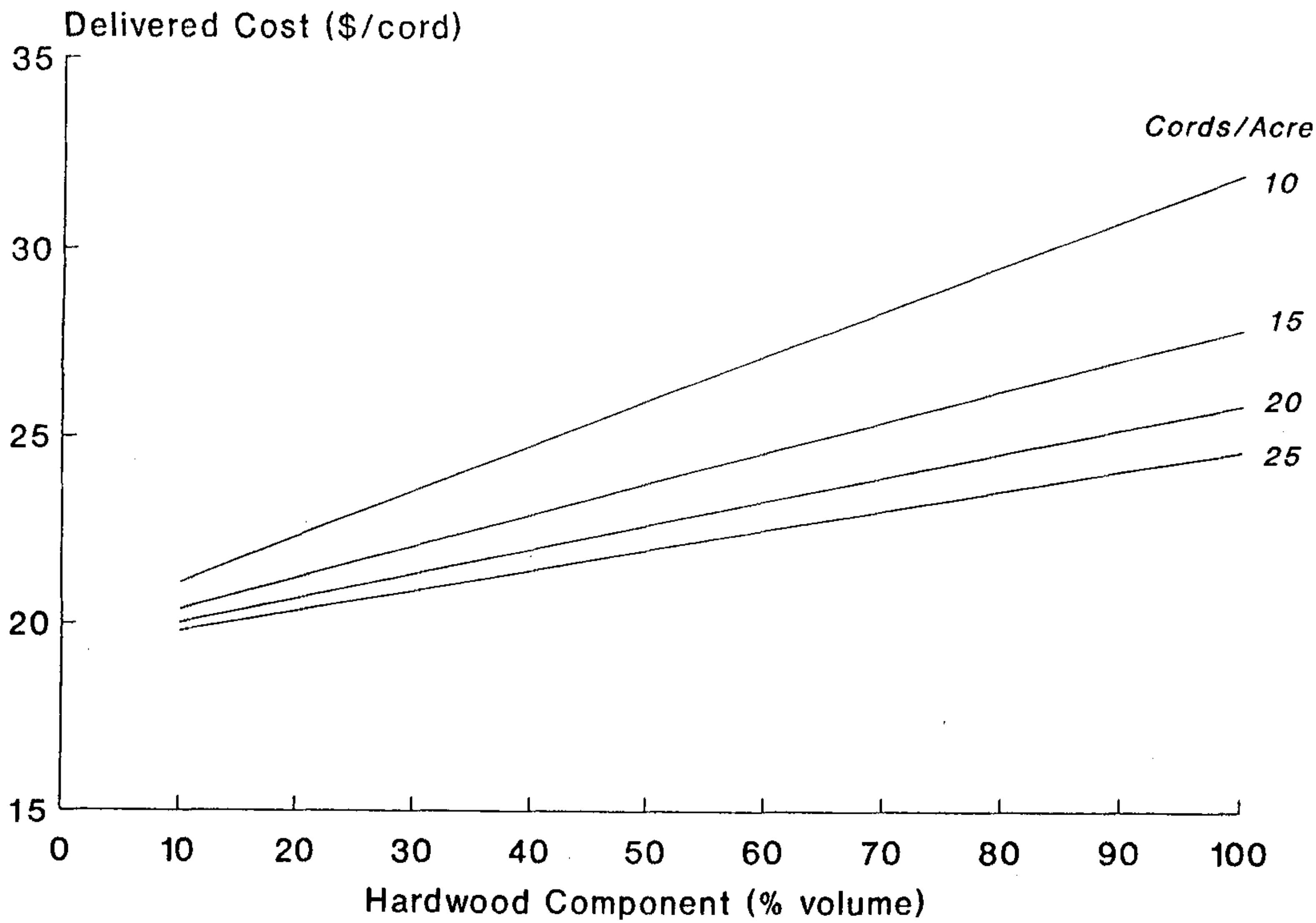
(4) loading, and

(5) highway hauling.

These functions do not have to occur in any certain order. In fact, the distinguishing feature of many logging systems is the order in which these activities occur. However, the order of functions often affects the logging plan and the layout of the sale, roads, and landings.

Logging systems have become increasingly mechanized in recent years. A mechanized logging system has one or more of the above functions performed by a piece of equipment

3



Delivered Cost ($/cord)
35
30
25
20
15
Cords/Acre
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100
Hardwood Component (% volume)

instead of a person using a manual technique. A fully mechanized system has all functions performed by equipment. Use of increased mechanization increases safety and productivity of the system, but also increases the capital investment required and the hourly fixed costs. As a result, the system must produce more wood than a similar less mechanized system to break even financially.

Mechanized systems are in widespread use throughout the eastern United States. They are particularly popular in the major timbered regions of the Northeast and Maine, the Lake States, and the South. The following sections will describe common mechanized systems and their cost and productivity.

Lake States

Table 3 contains descriptions of five mechanized timber harvesting systems in widespread use in the Minnesota, Wisconsin, and Michigan. The five systems in the table are listed in order of capital requirement. In general, as the capital investment increases the labor efficiency (cords per man-hour) increases. The exception to this trend is the forwarder system (A) which requires less capital than system (B) but is a more efficient user of labor.

Systems (A) through (C) are most common. Highly capital-intensive systems such as (D) and (E) are less common. Chipping systems, while greatly increasing the utilization of fiber from a site, are expensive to own and operate and require a large labor force and tract size.

Southern USA

Six systems used in the South are listed in the Table 4. With the exception of system (C) which uses a grapple processor, each of these systems is in widespread use. The system which accounts for the majority of pine produced in the coastal plain of the South is system (E) which uses a feller-buncher, grapple skidder, and delimbing gate. Loading is usually performed by a 30,000-lb hydraulic knuckleboom loader. Other systems using cable skidders are more common where wetland harvesting, slopes, or hardwood logging is involved. Comparisons of labor and capital efficiency between systems indicates trends similar to those noted for Lake States systems.

The majority of loggers in the South are independent contractors who use a highly mechanized system producing tree-lengths. Most harvested volume is pine although hardwood removals are increasing. Clearcuts are the predominate harvest type. Over the past 20 years, southern loggers have changed from being dependent on wood dealers and labor-intensive operations to becoming innovators with mechanized systems.

Table 3. Productivity and cost measures of five mechanized logging systems operating in the Lake States.

System	People	Capital	Cords per Week	Cords per Man-Hr	Capital per Cord
A - Chainsaw fell, limb, buck and top, forwarder	7	$110,650	235	0.83	$10.07
B - Chainsaw fell, limb, and top, cable skidder, chainsaw buck	5	$130,400	155	0.77	$18.00
C - Chainsaw fell, limb, and top, cable skidder, chainsaw buck logs, slasher for pulpwood	5	$180,500	220	1.08	$17.92
D - Feller-buncher, chainsaw limb and top, grapple skidder, chainsaw buck logs, slasher for pulpwood	9	$438,000	425	1.18	$21.97
E - feller-buncher, grapple skidder, whole tree chipper	7	$669,500	690	2.45	$20.32

Source: Blinn, C.R., S.A. Sinclair, C.C. Hassler, and J.A. Mattson. 1986. Comparison of productivity, capital, and labor efficiency of five timber harvesting systems for northern hardwoods. For. Prod. J. 36(10): 63-69.

Note: All costs are to roadside and do not include highway hauling.

Table 4. Productivity and cost measures of six mechanized logging systems operating in the South.

System	People	Capital	Cords per Week	Cords per Man-Hr	Capital per Cord
A - Feller-buncher, grapple skidder and gate, chainsaw buck	8	$340,400	560	1.75	$12.14
B - Feller-buncher, chainsaw delimb and buck, forwarder	6	$183,300	300	1.25	$12.18
C - Feller-buncher, grapple processor, forwarder	4	$307,000	325	2.04	$18.95
D - Chainsaw fell and delimb, cable skidder, chainsaw buck	12	$267,800	340	0.70	$15.94
E - Feller-buncher, grapple skidder and gate	5	$338,600	575	2.86	$11.80
F - Chainsaw fell and delimb, cable skidder	10	$266,600	336	0.84	$15.87

Source: Greene, W.D., B.L. Lanford, and R.A. Tufts. 1987. Evaluation of harvesting systems for the second thinning of pine plantations. For. Prod. J. 37(6): 9-14.

Note: All costs are to roadside and do not include highway hauling.

Maine and eastern Canada

Due to the unroaded nature of many areas in Maine and eastern Canada, logging systems operating in those areas differ considerably from those observed in other areas of the country. Use of large forwarders capable of moving tree-lengths or large clam-bunk skidders is common. Most of these systems operate in a COLD logging fashion as opposed to the HOT logging found in the South (see definition below). Large tract sizes, long skid distances, and high road building costs are characteristic of these areas. Multifunction machines are often used in this part of the continent due to the conditions, the uniform tree sizes, and the high labor costs.

Hot vs. Cold Logging

"Cold Logging" refers to a system where there is a significant inventory of wood and/or period of time between functions of a harvesting system. "Hot Logging" on the other hand refers to systems where the harvesting functions follow each other closely with little buildup of inventory between functions.

Cold logging is more easily used in areas which are largely unroaded since they require large tracts to operate efficiently. In addition, if loading can occur directly at roadside, these systems are much easier to implement. Machine breakdowns and inclement weather are more easily handled by a cold system.

Hot logging is more commonly used in areas such as the South where hauling is performed over public highways and tract sizes are smaller. Hot systems suffer when one machine breaks down or is slowed by weather since all machines in the system work together closely.

Product Type

The type of product produced by the logging operation also has a great effect on its performance (Table 5). In general, systems are usually designed to handle the largest piece possible since this minimizes the processing required and the number of pieces handled. However, handling larger pieces can have detrimental impacts as well. Handling whole trees or tree lengths requires larger equipment or additional machine passes across the site to remove the harvested wood. These larger machines and/or additional traffic may disturb or damage the site beyond acceptable levels. However, in other instances, the additional traffic may improve the ability of the site to produce natural regeneration since additional mineral soil will be exposed. The type of system to match to the site will depend on the silvicultural objectives, site conditions, stumpage markets, and the logging systems available.

Table 5. Comparison of features associated with different logging systems (1=best, 3=worst).

Issue	Method of Extraction from Woods		
	Whole-tree	Tree-length	Cut to length
Residual tree bole damage	3 control difficult	2 control difficult	1 less damage
Residual tree root damage	3 variable	2 variable	1 slash mat helps
Detrimental soil impacts	3 more trips	2 some slash	1 fewer trips, slash
Site prep scarification	1 slash removed	2 skidding actions	3 little bared soil
Serotinous cones	3 moved to landing	1 in unit	1 in unit, disturbed
Nutrient recycling	3 limbs at landing	2 varies by method	1 limbs in unit
Slash and residue	1 piled at landing	2 in the unit	2 in the unit
Landing size	3 large	2 medium	1 smallest
Truck road density	2 economic skid	2 economic skid	1 longer econ skid
Small animal habitat	2 little control	2 little control	1 more control
Wood product potential	1 complete range	2 no tops/limbs	3 cut lengths only
Cost	1 variable, depends on situation for all systems		

Whole-tree: trees with limbs and tops attached.
Tree-length: trees delimbed and topped at the minimum top diameter.
Cut-to-Length: trees delimbed, topped, and cut into random or fixed log lengths, typically from 8-20 feet.

Mountain Ground-Based Systems

Ground skidding on steep slopes can greatly reduce productivity over that obtainable on more level ground. In most areas of the East, ground-based systems operating in mountainous areas are smaller and less productive than systems operating in flatter areas. Mountain systems tend to be less capital-intensive and more labor-intensive than their flatland counterparts.

Each of the six skidding methods discussed for flatland systems can under certain circumstances be used in mountainous areas. However, some of the methods have a much more limited application than others. Animals are limited to downhill skids of very short distances while forwarders cannot safely negotiate many slopes due to their high center of gravity when loaded. The majority of skidding occurring in mountainous areas is performed by crawler tractors, rubber-tired skidders, and track-laying skidders such as the FMC. Both the FMC and crawlers can operate with reasonable production and environmental damage on favorable slopes of up to 50 percent and adverse slopes of up to 40 percent (Table 1). Other skidding methods are hampered to a greater degree by slopes.

Systems

Almost all mountain ground-based systems in the East use chainsaw felling and processing. Feller-bunchers are generally unable to handle slopes in excess of 30 percent. A few machines can handle such slopes, but they are expensive and are currently not widely used in the East. Delimbing usually occurs in the woods but may be performed by the skidder with a gate or by chainsaw at the landing. Bucking often occurs at the landing where greater care can be taken to make good decisions to maximize product value. Eastern mountainous stands typically have an assortment of timber quality with hardwood being common. Hauling usually involves log-lengths rather than tree-lengths. Log-lengths permit use of tandem-axle trucks instead of tractor-trailers. This is often an advantage on mountain roads which have short radius curves and a shortage of areas for turning around a tractor-trailer.

Two example systems will be discussed here (Table 6). The two systems are identical except that one uses a small crawler for skidding while the other uses a rubber-tired skidder. The smaller payload and slower speed of the crawler result in a lower production for the system. Both systems employ five woods workers and load log-lengths onto straight tandem-axle trucks.

The crawler system makes less efficient use of labor, producing 0.75 cords per man-hour compared to 1.00 cords per man-hour for the skidder system. Capital requirements for both systems are substantially less than those for highly mechanized systems in flat country or cable systems operating in mountains.

Landings

Location and layout of landings are crucial to the success of any logging operation but are of even greater importance on mountainous sales. Landings should allow skidding, loading, and hauling activities to operate with a minimum of disruption. In general, the location of the landing should be selected so that there is sufficient room for the loading and skidding operations. Landings that are too small cause delays and are often unsafe. Landings should be well drained and located so that skid roads (if any) can easily access the landing with a minimum of site disturbance.

In mountainous areas, landings are often small due to the nature of the terrain. Unless a wide bench or ridge top is available, landings are often wide places in the road where truck loading can occur. Such small landings often make sorting of products or bucking of logs more difficult and hazardous. In addition, use of front-end loaders is often ruled out due to their need for large landings with little slope. Knuckleboom loaders or self-loading trucks are widely used. If possible, landings should be located so that a minimum of sorting and bucking can take place without being directly under the loader or in the path of the skidder at the landing. Truck turnarounds should be located such that trucks need only back a short distance to approach the landing.

Uphill vs. Downhill Skidding

In general, skidding is performed downhill if possible. Uphill skidding often increases soil disturbance caused by skidding and greatly limits the payloads possible with the machine. However, roads are often located on ridgetops in many areas of the East and therefore it is not uncommon for uphill skidding to be used in some areas. Uphill skidding is very sensitive to weather since snow or rain will reduce the traction possible on an adverse slope. Most loggers find themselves performing a little of both, but downhill skidding in general provides the higher productivity.

If uphill skidding is to be used, preplanned skid trails should be considered. These trails are located prior to logging and a small crawler is used to build the trails. Use of skid trails can increase payloads with uphill skidding and is an effective means of limiting the amount of soil and site damage inflicted upon a site by logging.

Downhill skidding, while preferred from an operational viewpoint, often leads to greater levels of soil erosion after logging since skid trails tend to concentrate runoff at the foot of slopes. If downhill logging is to be used, abandoned skid trails should be reclaimed to reduce such erosion.

Table 6. Capabilities of skidding methods in mountainous areas.

Method	HP	Payload (tons)	Maximum Slope (%)	Skidding Distance	Tons per Hour
Animal (draft horse)	1	0.3	30-35 D 5-10 U	500	3-6
Crawler (JD 450)	80	0.4-0.8	45-50 D 35-40 U	500	8-12
Farm Tractor (Log Hog)	40	0.3	10-20 D 5-10 U	500	5-8
Rubber-tired Skidder (CAT 515)	140	2-3	30-35 D 20-30 U	1500	14-25
Track-laying Skidder (FMC 210)	200	4-6	45-50 D 35-40 U	1000	14-25
Forwarder (Timberjack 1410)	168	14-16	15-20 D 10-15 U	2000	20-25

Table 7. Productivity and cost measures of typical ground-based systems used for mountainous logging in the East.

System	People	Capital	Cords per Week	Cords per Man-Hr	Capital per Cord
Chainsaw fell, limb, and top, small crawler, chainsaw buck	5	$75,000	150	0.75	$10.00
Chainsaw fell, limb, and top, cable skidder, chainsaw buck	5	$120,000	200	1.00	$12.00

Note: All costs are to roadside and do not include highway hauling.

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