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Wetland Harvesting Systems—
Developing Alternatives for Sustainable Operation

Bob Rummer, USDA Forest Service
Auburn, Alabama

Bryce J. Stokes, USDA Forest Service
Auburn, Alabama

and

Alvin Schilling, International Paper Co.
Hattiesburg, Mississippi

ABSTRACT: Wetland forests represent some of the most productive forest lands in the southeast. They are also an environmentally sensitive ecotype which presents unique problems for forest operations. Sustaining active management in these areas will require systems which can operate on weak soil conditions without adversely affecting soil properties or stand regeneration. The systems must also operate economically. This paper reviews current investigations of alternative systems including large-capacity forwarders, clambunk skidders, and the skidder/shovel logger system in the southeastern U.S. The systems are compared in terms of production, cost, and potential site impacts.

Key Words: wetland harvesting, forwarders, site impacts

INTRODUCTION

Forested wetlands are an important natural resource in the southern United States. McWilliams and Faulkner (1991) estimate that bottomland hardwood forests cover 10 million hectares of the southern coastal plain. These forested sites provide significant ecological values in modifying hydrology, improving water quality, and life support. The unique hydrology and soils of wetland forests also make them highly productive in terms of wildlife, aquatic habitat, and plant communities. McWilliams and Faulkner (1991) note that bottomlands contain over half the hardwood timber resource in the south-central United States.

The ecological value and productive potential of bottomland hardwood forests reveal two constraints. First, the economic incentive to maintain these areas in forest cover depends on cost-effective forest operations. Secondly, however, productive use must not compromise the ecological functions of these sites.

The soft soils of typical wetland sites make it difficult to achieve either objective. Low-bearing-capacity soils impede access and extraction and increase harvesting costs. Soft soils are also more sensitive to disruption, magnifying the impacts of ground operations.

In 1986, an industry task force conducted a survey of southeastern wetland loggers (Stokes 1988). The most common system configuration averaged six workers and had one tracked feller-buncher and two rubber-tired skidders. Production averaged 350 cords per week. A survey of Mississippi Delta loggers (Jackson 1990) found 98% using rubber-tired skidders for extraction. Wide tires and dual tires were commonly applied to enhance trafficability.

While rubber-tired skidders are common, many of the problems in wetland logging are tied to this extraction function. Rubber-tired skidders can cause rutting and puddling of soils. Aust *et* al. (1993) also found changes in subsurface hydrology associated with the impacts of skid trails on wet pine flats. Skidders operating in these conditions typically have lower productivity and higher operating costs than similar machines working on dry sites. The combination of reduced productivity and the limited load capacity of the skidding function establishes the economical skid distance. This in turn determines road and landing spacing.

Several papers (Jackson and Stokes 1990, Reisinger and Aust 1990) briefly reviewed alternative technologies for wetland operations. They described a range of equipment including tracked skidders, large-capacity forwarders, cable systems, and helicopters. However, their report did not address system configurations.

The contractor working on wet sites faces the challenge of developing an integrated system of equipment and methods that will (1) operate effectively on wet soils, (2) minimize ecological impacts which include rutting, soil disturbance, and hydrologic alterations, and (3) provide a reasonable economic return. With increasing market demands in the South for hardwood fiber, forest operations are extending into more adverse sites. Under today's social pressures to protect sites and ensure sustainability, it is more difficult to harvest such areas cost effectively. It is also apparent that conventional harvesting systems do not adequately address the needs of the wetland logger.

This paper is a review of some currently operating and evolving hardwood, wet site harvesting systems: (1) conventional grapple skidding, (2) clambunk skidding, (3) high-capacity forwarding, and (4) shovel logging. Helicopter and cable systems are briefly described.

WETLAND LOGGING EQUIPMENT

A wetland logging system has to perform the functions of felling, limbing and topping, primary transport, and loading. Such equipment is often conventional forest machinery with special adaptations to enhance operability in wet terrain.

Feller-bunchers

Felling trees on wet sites requires moving a felling machine to the tree, making the cut, and directing the placement of the fallen tree. These tasks are complicated in wetlands by soft soils and large trees with extreme butt swell. Within the last few years, many operators have replaced chainsaws or rubber-tired, drive-to-tree feller-bunchers with tracked, swing-to-tree feller-bunchers. Swing feller-bunchers may reduce site disturbance by limiting travel and by the use of wide flotation tracks. On extremely wet sites, swing feller-bunchers may even use felled trees or constructed mats for support. By bunching felled trees, swing machines help increase extraction productivity and reduce the amount of traffic on the site.

Swing feller-bunchers have higher initial and operating costs than rubber-tired equipment. Historically, this option was the least preferred because of these high costs. However, Increasing emphasis on reducing site disturbance and the cost of workman's compensation are offsetting the additional capital costs of swing machines.

Grapple Skidders

Rubber-tired skidding has been and continues to be the most widely used and cost-effective wood extraction method in most situations. By eliminating choking, the grapple skidder has higher productivity than a cable skidder. In wetlands, however, this advantage is reduced if the machine cannot drive to each turn. Wider tires or dual tires increase payload and improve flotation. The dual-tire combination has proven to be a cost-effective alternative to single, wide tires (Table 1).

Table 1. Skidder tire costs for wetland logging.

Tire size	*Ground pressure (psi)* [1]	*Total cost*
Singles		
23.1x26	7.1	$8,600
28Lx26	5.9	$9,800
30.5x32	5.3	$ 12.400
66/43.00-26	4.1	$14.800
72x68-28	2.6	$39.400
Duals		
23.1 (2)	4.0	$17,200
28L (2)	3.4	919,600
34.00 (2)	3.2	$28,000
24.5 + 30.5	3.4	$23.000
28L + 43.00	2.8	$24,600

[1] based on a John Deere 548G

An alternative approach to improving skidder trafficability is the recent innovation of a hydrostatic grapple skidder. By powering the wheels independently, the machine can better control torque and slip to match the ground conditions. Reduced wheel slip can result in less site disturbance by reducing rutting from wheels spinning and displacing soil.

High-Capacity Forwarders

High-capacity (over 11t) forwarders are also being used to extract wood on wet sites. Tree-length forwarders can move payloads of up to 23 t. Large loads reduce the total number of trips into the stand. The forwarders may be self-loading, but to reduce weighr and increase payload, they are usually loaded and unloaded by knuckle-boom loaders. Roads are not necessary, but forwarder trails are generally wider and straighter than skid trails to improve travel speed and accommodate the long loads. Self-loading forwarders require pre-bunched wood along the main trail. Forwarders without loaders requrre an In-wood< knuckleboom loader and a roadside loader

The large capacity may also extend the economic skid distance compared to skidders. This is a critical part of the evaluation of these machines. Longer extraction distance reduces roadbuilding costs. Fewer roads also reduce the overall site disturbance. Systems using tree-length forwarders may also be less sensitive to wet weather since highway haul trucks are not operating on unimproved woods roads. High capacity forwarders can work at very long distances; one study observed extraction at 8 km.

Clambunk Skidders

Clambunk skidders are another alternative to conventional skidders. Like tree-length forwarders. clambunks extend extraction distance and reduce travel by having a larger payload. Six- and eight-wheel drive clambunks have been manufactured by various companies for a long time but have not been widely accepted due to their overall large size and high price. The large size makes them difficult to move over the road to different locations. A smaller, less expensive four-wheel-drive clambunk capable of skidding 15-ton loads was introduced in 1993 (Schilling 1993).

Clambunks generally are self-loading. However, with limited maneuverability as the load accumulates, clambunks need to work from pre-bunched material along a main trail. Effective extraction distance lies between conventional skidders and tree-length forwarders.

Shovel Loaders

Shovel loaders are hydraulic knuckleboom loaders adapted to heavy swing applications. Shovel loaders have been used in the Pacific Northwest (Andersson and Jukes 1995. McNeel and Andersson 1993) to extract wood short distances to roadside. Typically, the tree-length stems or logs are picked up, swung 180 degrees toward the deck or roadside, perpendicular to the direction of travel of the shovel. In effect, the wood is moved two lengths of the boom; this distance is increased by grappling longer stems near the end.

On wet sites in the southern U.S., the procedure is significantly different. Shovel loaders are used to pile felled trees in a “road” of stems. The trees are laid down end-to-end which provides a continuous mat to support skidders. The shovel machine builds the mat, pre-bunches stems to load skidders, and loads out the “road” as it works from the back of the corridor out of the stand. With long reach and wide tracks, shovel loaders minimize site disturbance. Corridor spacing can be two to three times the boom reach.

Aerial

Cable systems and helicopters have also been used in wetlands on a limited basis. The primary advantage of these systems is a reduction in site disturbance and the ability to extract wood in areas which will not support ground systems. Such systems are also employed to provide woodflow during wet winter months.

Murray (1996) describes a cable system operating in Georgia which uses mobile intermediate supports for a multi-span standing skyline. A tracked feller-buncher cuts the timber which is forwarded 100 m to the skyline corridor by a shovel loader. The Christy yarder carries enough skyline to reach 760 m.

Helicopters are used more frequently on wet sites but require larger tree sizes and short distances to be economical. This system causes the least disturbance except for the building of decks and roads.

Both cable and helicopter systems require large capital investments and well-trained, skilled crews. These systems must also maintain high production to achieve profitability. For these reasons, aerial systems tend to be associated with large contractors closely associated with major wood consumers.

Equipment Costs

While initial cost is only one component of a machine rate, it is directly related to hourly operating costs and capitalization requirements for the operation. Table 2 summarizes some current price data (Brinker 1997).

SYSTEM CONFIGURATIONS

A comprehensive evaluation of wetland logging alternatives must look at a range of combinations of equipment. To compare among alternatives. system production rates were estimated using the Auburn Harvesting Analyzer, a spreadsheet template that combines stand information, production equations, and cost information. Four systems were modeled: (1) swing feller-buncher with grapple skidder; (2) swing feller-buncher, grapple skidder, clambunk; (3) swing feller-buncher, grapple skidder, tree-length forwarder; and (4) swing feller-buncher, shovel loader, grapple skidder. All systems included manual topping with chainsaws.

Production functions were developed for a clambunk skidder, shove! loader, and swing-to-tree feller-bunchers using standard production and time study methods. Regression analysis related productivity to various stand parameters. Previous studies of tree-length forwarders, grapple skidders were used as estimators for those functions. Machine costs were estimated using the machine rate approach and current price data. A

Table 2. Costs of representative wetland logging equipment.

Machine	*Make/Model*	*Tires*	*Purchase Price*
Cable skidder	Franklin 405	23.1 x26 duals	$95,600
Grapple skidder	Timberjack 450C	28Lx26 duals	$138,915
Grapple skidder	Timberjack 480C	28Lx26 duals	$181,218
Clambunk skidder	Franklin 170	24.5x32 duals	$162.500
Clambunk skidder	Timberjack 933C	20.5x25	$417.502
Clambunk skidder ·	Ardco "N" 6x6	66/43.00-25	$460.000
Swing feller-buncher	Timbco T425-B	tracks	$23864 l
Swing feller-buncher	Timberjack 608	tracks	$248.623
Swing feller-buncher	Tigercat 860	tracks	$319,000
Drive-to-tree feller-buncher	John Deere 643D	28Lx26	$153,975
Drive-to-tree feller-buncher	Franklin C5000	28Lx26	$173500
Tree-length forwarder	Ardco "K" 6x6	66/43.00-25	$233,933
Shovel loader	Timberjack 735	tracks	$255,000

stand table was constructed from cruise plot data of an actual bottomland stand (Table 3). The stand had 344 trees per ha with a quadratic mean DBH of 28 cm. Stand volume averaged 292 t per ha.

Table 3. Bottomland hardwood stand for analyses.

DBH (cm)	*Trees/ha*	*Tons/ha*
15	86	9.7
20	69	18.6
25	42	21.1
30	37	29.9
35	35	40.0
40	27	42.7
45	20	41.6
50	10	27.4
55	10	31.9
60	5	21.1
65	0.5	2.0
70	1.2	7.2

Using the common stand table and production functions, each system was modeled at the actual observed extraction distances.

The summary data in Table 4 is based on very different extraction distances and tract configurations. The lateral distance refers to the average distance from the stump to the main trail (pre-bunch distance). The external distance is the one-way distance of primary extraction transport. The extraction distances are considered representative for each specific system.

SUMMARY

The wetland forest resource challenges forest operations from both an environmental and an operational perspective. The operating conditions in these stands push the limits of equipment capabilities. Variability in operating conditions also means that there is no single best operational approach for working in wetlands. Wet pine flats in Louisiana are very different from alluvial Delta islands and Carolina pocosins.

Resource managers and logging contractors need the capability to analyze system performance for varying conditions to minimize production costs. The approach

Table 4. Wetland logging system estimated production summary.

System	*Lateral distance (m)*	*External distance (m)*	*System Rare (t/SMH)*	*System Cost ($/SMH)*	*Unit Cost ($/t)*
Feller-buncher, grapple skidder	0	213	29.7	$17 1.77	$5 7x
Feller-buncher. grapple skidder, clambunk	107	366	32.1	$219.98	S6.85
Feller-buncher, grapple skidder, forwarder	107	1676	29.4	$213.93	57.28
Feller-buncher, shovel, grapple skidder	10	274	40.8	$237.38	$5.82

demonstrated in this report is a simple technique for addressing such questions. For example, the system spreadsheets can be iterated over distances to determine breakeven extraction distances which separate systems. Changes in stand volumes or diameter distribution can also be studied to estimate the impact of selective harvesting strategies on unit cost.

Increasing fiber demands in the South mean there will be a continuing search for better ways to work in wetlands. New equipment developments, new system combinations, and better methods of analyzing and understanding system performance will be the key to finding solutions.

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