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PROJECT RECORD

Grapples for Forest Residues Concentration and Removal



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GRAPPLES FOR FOREST RESIDUES CONCENTRATION AND REMOVAL

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INTRODUCTION

Forest residues generated during timber harvesting, thinning, and other forest activities are a continuing fuels and timber management problem. Removal of forest residues can be a costly undertaking and, in many instances, the only feasible method is by hand. The treatment and removal of residues are specified in timber sale contracts. However, for contracts to be realistic and enforceable, methods that are cost effective must be identified and developed.

Forest Service user reports indicate tractor-mounted grapples of various configurations are being successfully employed for residues cleanup. Machines in current use are tractors with front-end grappling devices (or clamp rakes). Some have been conceived and custom-fabricated by clean-up contractors and are not commercially available for purchase. A large variety of grappling devices are available—mostly designed for log pickup and handling. Grapples designed for log handling, for the most part, are inefficient when used on the odd-sized and -shaped materials that constitute forest residues.

Engineers at the San Dimas Equipment Development Center (SDEDC) searched for and found suitable commercially manufactured grapples for tractor mounting and field tested them to define their efficiency and economics of operation during residues handling on moderate (less than 35 percent) slopes.

SELECTION OF GRAPPLES FOR FIELD TESTING

A market search to define commercially manufactured grapple devices for field testing was conducted. The criteria for selection were as follows:

1. Configured in a manner suitable for residues handling.
2. Adaptable to prime movers commonly in Forest Service use.
3. Capable of picking up, moving, and piling residues with a minimum amount of soil disturbance.
4. Capable of multiple use applications (i.e., roadside cleanup, fire danger reduction following a timber harvest or timber stand improvement (TSI), etc.).

Grapples were categorized into two basic types:

1. **LGR—LOADER GRAPPLE RAKES (or clamp rakes)**, which are devices that attach to the front end of a standard tracked loader or dozer.
2. **EGR—EXCAVATOR GRAPPLE RAKES**, which are devices that adapt to a small excavator or crane and, in some instances, a backhoe on a conventional tractor.

Three grapples were located and considered for testing. In the LGR category, a commercially available rake manufactured by Young Corporation, Seattle, Wash. (fig. 1) and a custom-fabricated clamp rake (fig. 2). Both the LGR selections were in use on the Pineridge Ranger District of the Sierra National Forest, California Region.

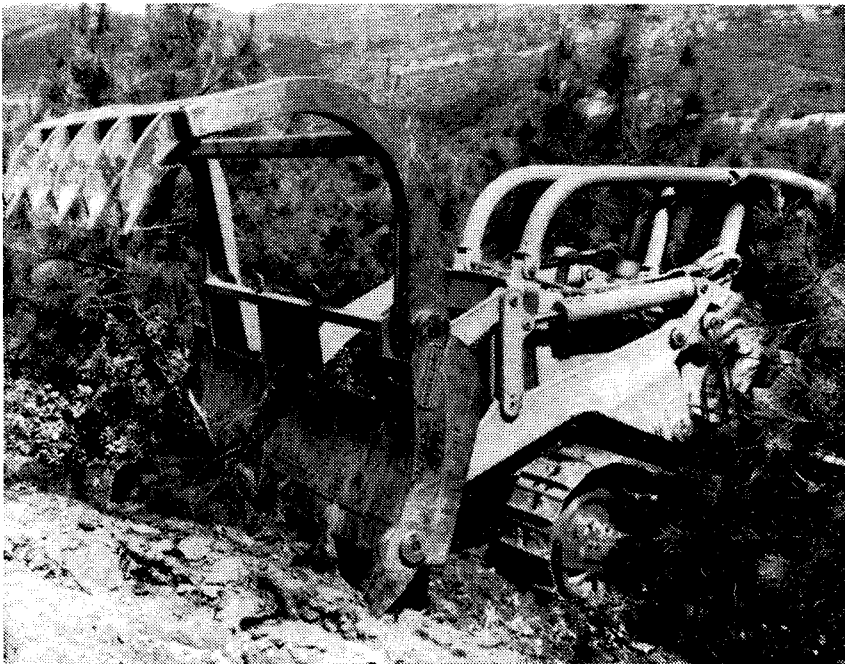
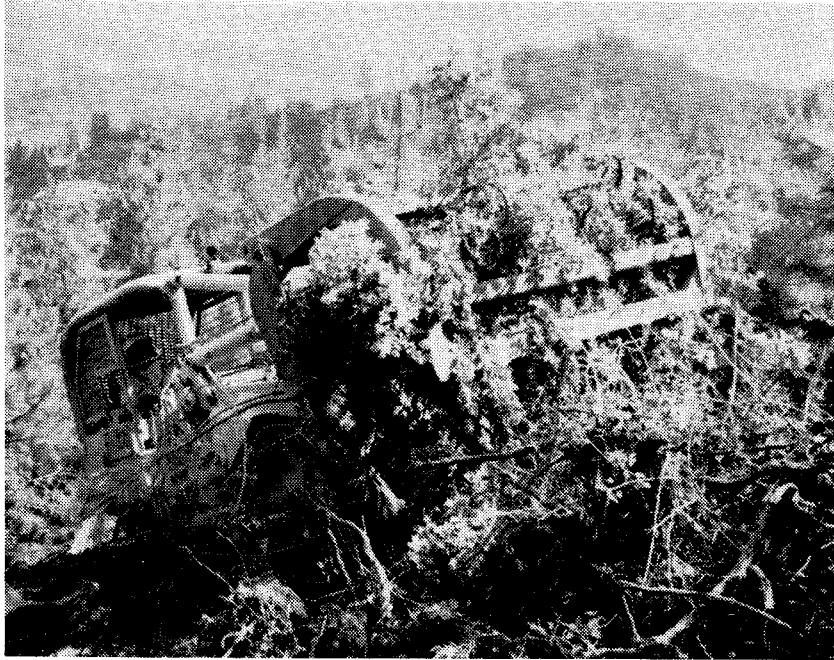


Figure 1. Case 1150 crawler loader with Young grapple rake.



Figure 2. International Harvester TD-7 crawler dozer with prototype clamp rake.

The Young grapple was mounted on a Forest Service-owned Case 1150 crawler loader and the clamp rake on a contractor-owned International Harvester TD-7 crawler dozer. Reports from the Sierra National Forest indicate that both versions worked very well.

In the EGR category, one configuration was selected—a grapple for backhoe or small excavator mounting, manufactured by La Bounty Manufacturing, Inc., Two Harbors, Minn. (fig. 3). Arrangements were made with the Sierra National Forest to purchase a La Bounty grapple suitable for mounting on the Case 1150 backhoe attachment owned by the Forest, and to test that combination in conjunction with the LGR test.



Figure 3. Case 1150 loader with backhoe and La Bounty grapple.

PRIME MOVER SELECTION

The Young LGR selected for testing is adaptable to a variety of loaders—both tracked and rubber tired. For the Young LGR testing, a Case 1150 tracked loader was used because of its availability.

The clamp rake was built especially for the International TD-7 dozer selected for the testing. Dozers in the TD-7 size class are in common usage throughout the Forest Service. The La Bounty grapple used in the EGR tests is adaptable to a variety of excavators. Excavators are not in widespread Forest Service use; for that reason the Case 1150 backhoe was used to mount the EGR test grapple.

FIELD TESTING OBJECTIVES

The primary objectives of the field testing were to:

1. Determine the capabilities and limitations of both types of grapples (i.e., LGR and EGR) in terms of:
 - (a) Production rate in acres/day (hectares/day) and \$/acre (\$/hectare) as a function of residues loading in tons/acre (tons/hectare).
 - (b) Material size limitations (length and diameter).
 - (c) Mechanical reliability.
2. Determine the suitability of each grapple rake for specific field uses (i.e., slash from TSI thinning, road construction, logging, etc.).
3. Establish what modifications, if any, would improve each grapple and make it a more effective tool.

TESTING PROCEDURE

The testing of the LGR and EGR were conducted separately, since each was considered to have unique capabilities. The testing was conducted on the Sierra National Forest in areas where the Forest had scheduled TSI slash for piling and burning. Specific test sites were jointly selected by personnel from both SDEDC and the Pineridge Ranger District.

Prior to testing, the following were done at each test site:

1. The perimeter of the site was measured and flagged for identification.
2. A fuels inventory was compiled and a treatment prescription furnished to SDEDC by the Ranger District.
3. Percent slope was measured and average slope calculated.
4. Photographic records were made of the site's appearance prior to testing.
5. A map was drawn of the site and its gross area determined.
6. The site was rated by SDEDC in accordance with the "point of view acceptability" criteria listed in the appendix of ED&T Report 7120-7, "Slash—Equipment and Methods for Treatment and Utilization," April 1975.

The test site chosen for the LGR according to the site prescription was one where TSI thinning had been done and the resulting slash was to be piled for burning. There was dense brush on the site that was considered to be both undesirable competition for the leave trees and a severe fuels problem. This brush was to be uprooted and piled for burning. The thinning slash on the site represented a fuels loading of around 10 tons/acre (24.7 tons/

hectare). The biomass of the brush was not measured. However, it could be classified as very dense, dominated by manzanita.

The estimated average height of the brush in the most dense areas was 4 ft (1.2 m). The average slope on the site was 20 percent, with maximums to 35 percent. The approximately 7-acre (2.8-hectare) site was divided in half. The International TD-7 with clamp rake was tested on the eastern half. The Case 1150 with Young LGR was tested on the western half. The portion chosen for the TD-7 had an average slope of 22 percent and the Case 1150 portion had an average slope of 12 percent. The TD-7 was chosen to work on the steeper terrain because the Case 1150, being a tracked loader and front heavy with the Young grapple, did not handle well on slopes greater than 20 percent.

The EGR site was a part of a 9-acre (3.6-hectare) area which had undergone TSI thinning. The fuels loading was approximately 12 tons/acre (29.7 tons/hectare). The site prescription specified that the slash on the site be piled for burning. The slopes on this site averaged less than 20 percent. The EGR was used to move materials to a point where the crawler dozer with brush rake could easily push them into piles. The treated area was measured after the testing and production rates estimated. The balance of the site was completed by the Case 1150 loader and Young LGR working in conjunction with the Caterpillar D-5 crawler dozer with brush rake (fig. 4). This operation was also time studied and the results measured.

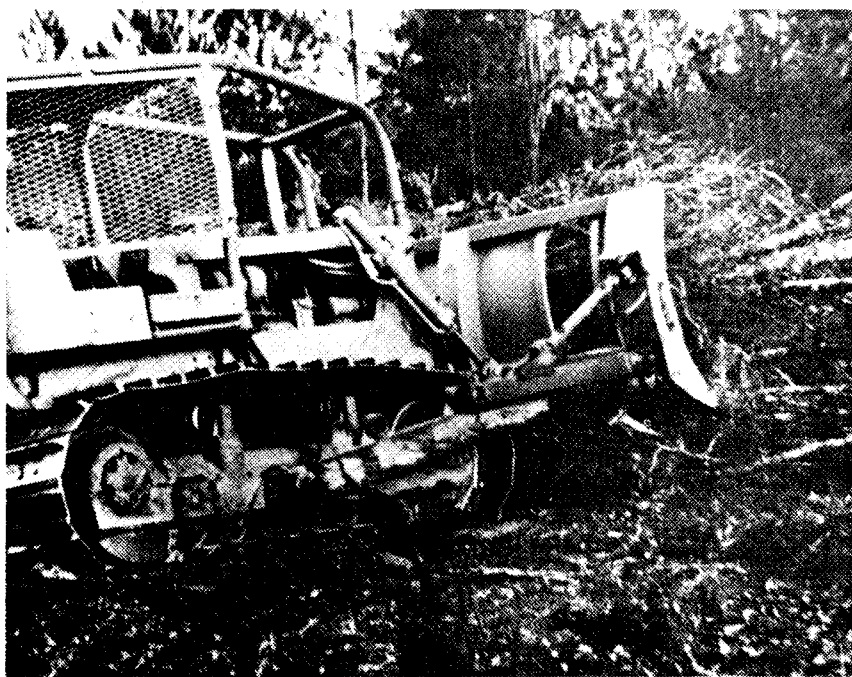


Figure 4. Caterpillar dozer with brush rake.

During the testing, each grapple was evaluated for its ability to pick up and handle slash materials. Motion pictures were taken of the operating characteristics of each grapple system. Notes were kept on any modification to the equipment that would improve its operational efficiency or slash-handling abilities. The data collected during the testing were as follows:

1. Total time to treat the test area (hours)
2. Actual machine operating time during the testing (total time minus downtime, lunch breaks, etc.)
3. Quantities of fuel, lube oil, hydraulic oil, and any maintenance items
4. Number, type, and position of support equipment and personnel required to perform the work.

The data taken after the testing was completed are as follows:

1. Number of piles constructed and their spacing
2. Height and base area of each pile
3. Estimated average diameter and length of materials in each pile
4. "Point of view acceptability" rating after treatment, by Ranger District personnel.

TESTING RESULTS

LGR Testing

The Case 1150 with Young grapple and the International TD-7 with clamp rake test results are summarized in table 1. Comparative photographs of the test site before and after testing are shown in figures 5 and 6. Operational illustrations of both machines are in figures 7 and 8.

Case 1150 with Young Loader Grapple Rake

The site prescription called for the salvage of as much material as possible for use as firewood. After thinning the area, hand crews limbed and bucked the tree stems into 6 to 7 ft (1.8 to 2.1 m) lengths and hand piled them prior to the machine piling operation. The machine then piled the remaining slash and brush on the site. After the testing the machine moved the salvage materials up to a nearby road, where they were decked. Although the machine time required to do the salvage work is not included in the time study (table 1), it took approximately ½ hour to accomplish.

During the testing, the grapple rake was used in a manner similar to a brush rake. It had the additional advantage of the grapple fingers, which allow buildups of material to be clamped against the face of the rake and, thus, larger loads can be handled than with a brush rake.

Table 1. LGR testing results summary

	CASE 1150 WITH YOUNG GRAPPLE	INTERNATIONAL TD-7 WITH CLAMP RAKE
<u>SITE DESCRIPTION</u>		
Area treated	3.34 acres (1.35 hectares)	3.30 acres (1.34 hectares)
Slope—average	12%	22%
Slope—maximum	25%	35%
Slope—minimum	0%	10%
Trees/unit area—after thinning	200/acre (494/hectare)	200/acre (494/hectare)
<u>AMOUNT AND TYPE OF RESIDUE</u>	10 tons/acre (24.7 tons/ hectare) TSI slash and brush	10 tons/acre (24.7 tons/ hectare) TSI slash and brush
<u>POINT OF VIEW ACCEPTABILITY</u> ^{1/}		
Before testing:		
Aesthetics	4	4
Watershed	2	2
Fire Management	5	5
Timber Management	N/A	N/A
After testing:		
Aesthetics	1	1
Watershed	3	3
Fire Management	1	1
Timber Management	1	1
<u>FUELS MANAGEMENT EVAL- UATION AFTER TREATMENT</u>	The 1-hr fuels were 90% removed; large tree trunks and tops were removed	The 1-hr fuels were 90% removed; large tree trunks and tops were removed
<u>PILE DATA</u>		
Number	10	12
Spacing—average	119.4 ft (36.4 m)	94 ft (28.7 m)
Volume—average	2,832 cu ft (80.2 m ³)	1,518 cu ft (43.0 m ³)
Total volume piled	23,820 cu ft (674.6 m ³)	18,216 cu ft (515.9 m ³)
Height—average	6.6 ft (2.0 m)	4.8 ft (1.5 m)
<u>MACHINE DATA</u>		
Production rate	0.96 acre/hr (0.39 hectare/hr)	0.40 acre/hr (0.16 hectare/hr)
Estimated hourly cost (by SDEDC) ^{2/}	\$39	\$39
Hourly cost charged to Forest ^{3/}	\$39	\$25
Estimated area treated cost (by SDEDC) ^{2/}	\$41/acre (\$101/hectare)	\$93/acre (\$230/hectare)
Area treated cost charged to Forest ^{3/}	\$41/acre (\$101/hectare)	\$63/acre (\$156/hectare)

^{1/} See: ED&T Report 7120-7.

^{2/} Charges estimated by SDEDC were done by conventional economic analysis methods, based on those given in "Fundamentals of Earthmoving," Caterpillar Tractor Co.

^{3/} Charges to Forest were based on WCF Forest rates and use rates, or direct contract charges.



Figure 5. Test site prior to LGR treatment



Figure 6. Test site after LGR treatment

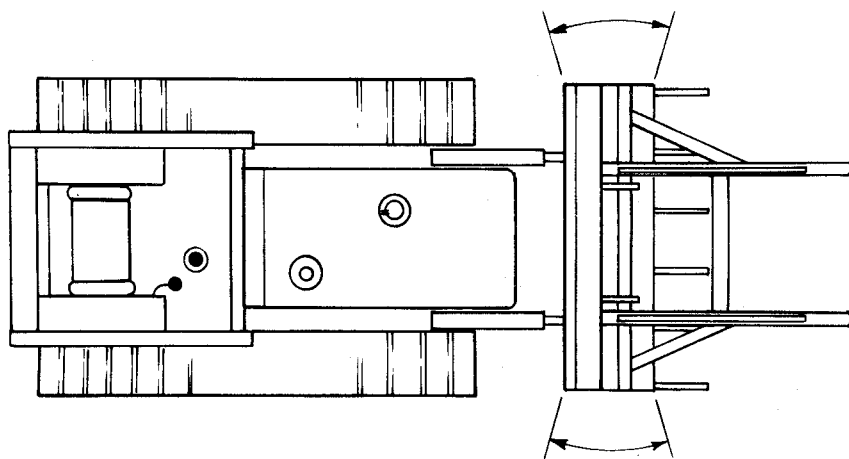
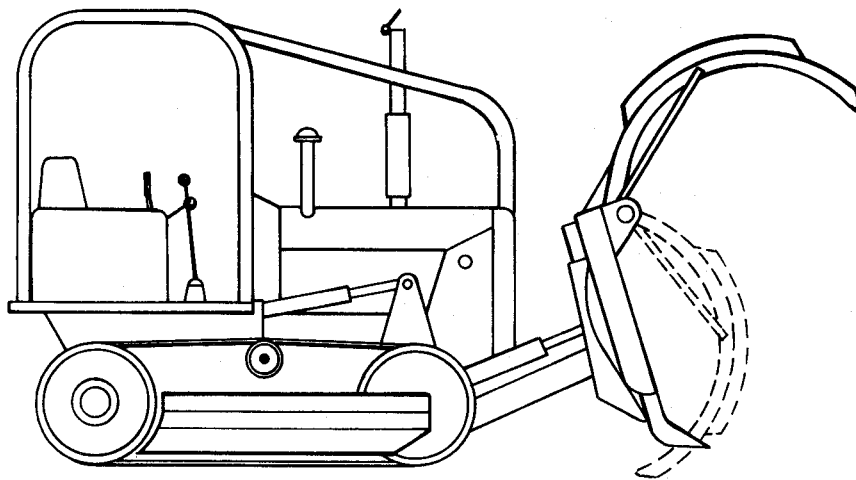


Figure 7. International Harvester TD-7 with clamp rake.

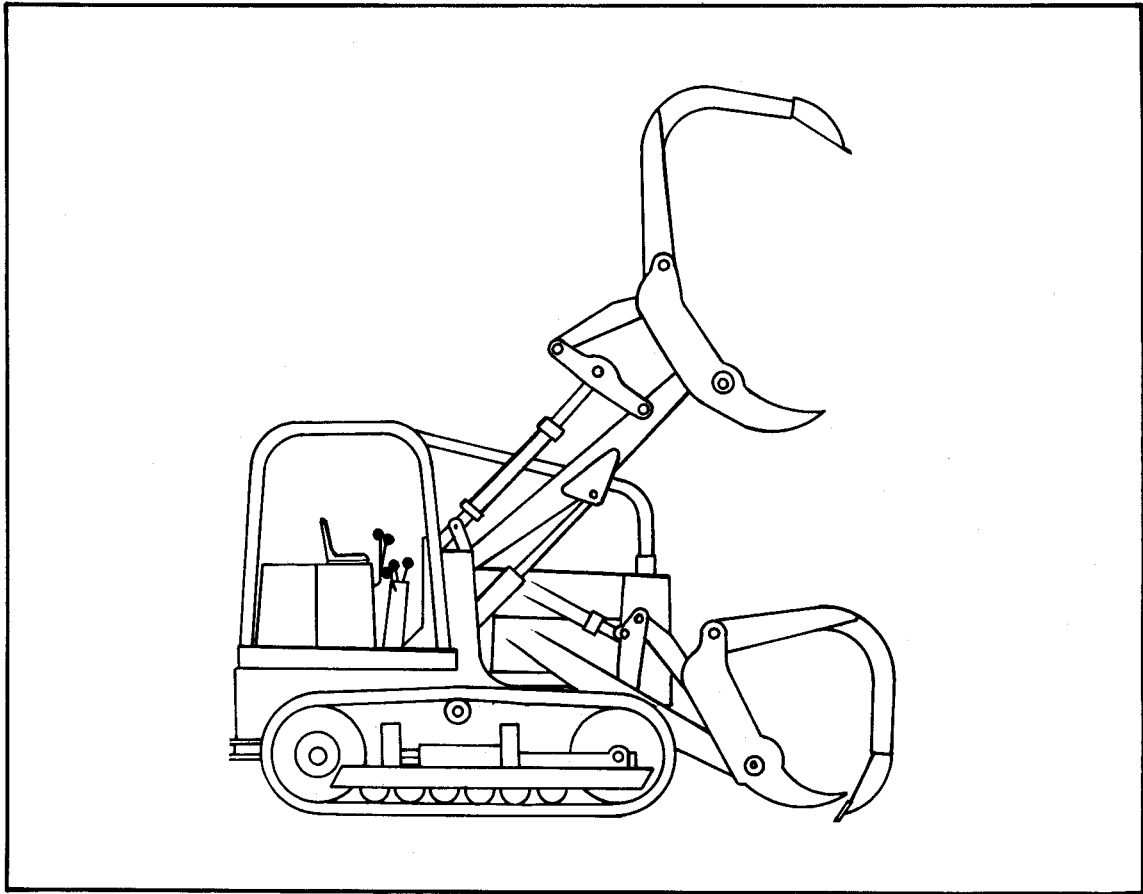


Figure 8. Case 1150 with Young rake.

The fingers also make construction of piles simpler than with a brush rake. The ability to lift up slash and brush by use of the grapple fingers allows the dirt collected to shake out. This results in a relatively dirt-free pile, which aids burning. The grapple fingers are also used to compress the materials prior to piling. Compression greatly aids in constructing piles of higher density than is feasible with a brush rake.

The grapple rake causes about the same amount of soil disturbance as a brush rake. However, the ability to shake out the dirt from the slash or brush prior to piling results in less overall soil displacement than a brush rake.

Fitting the Young grapple to the Case 1150 (approximate weight of the Young grapple is 3,000 lb; or 1361 kg), creates a problem in the overall weight distribution of the total assembly. The Case 1150 ran mostly with its front end down. The back one-third of the tracks was off the ground or had relatively small effect on the mobility of the machine. This front-heavy problem made it difficult (and sometimes impossible) to back the machine uphill when the grapple was raised off the ground. Consequently, the operator had to compensate for the problem by pushing the grapple (loaded or unloaded) into the ground to jack up the front of the machine high enough to make contact on the back one-third of the tracks to achieve the traction required to move back up the hill. To

correct this problem, the machine should be counterweighted to maintain proper balance when lifting materials with the grapple.

Despite the weight distribution problem, the testing showed that the operator can safely compensate to overcome the problem and inconvenience. However, the balance problem limited the machine during the testing to work on side slopes of less than 20 percent. This limitation in maneuverability due to machine balance also was observed to be a contributing factor to leave-tree damage.

The overall size of the Case 1150 seemed optimal for maneuvering in and out of tight spots that were created by the tree spacing at the test site. The minimum tree spacing for an economic production rate using the 1150 appeared to be 12 ft (3.7 m). In some instances, the spacing on the test site was 10 ft (3.0 m). The machine handled 10-ft (3.0-m) spacing, but leave-tree damage was more frequent and the operation slowed down significantly.

International TD-7 with Prototype Clamp Rake

This machine constructs looser piles than the Case 1150 with the Young rake. The operator had a difficult time shaking out the dirt from materials being piled and compressing the piles as they were being constructed. The balance of this machine was much better than the Case 1150. The superior balance should render this machine more efficient than the Case; however, due to the variations in terrain and tree spacing between the two test sites a direct comparison can not be made. Slopes were much steeper than the Case 1150 test site, and tree spacing was tight—8 to 10 ft (2.4 to 3.0 m) in places. The compounding of steep slopes with tight tree spacing had a marked effect on production rate and leave-tree damage.

This machine maneuvered well on 25 to 35 percent slopes. The clamp rake requires more maneuvering to construct a pile than was required with the Young rake. However, again, steeper slopes on the test site may have been the governing factor. This machine works better in tight tree spacing than the Case. Soil disturbance from each machine was comparable.

EGR Testing—Case 1150 with Backhoe and La Bounty Grapple

The tree spacing on the test site, in some locations, was less than 10 ft (3.0 m) apart. This made the collection and handling of residues difficult. On this test site, about 10 percent of the downed stems had not been bucked. This slowed the piling operation considerably and contributed significantly to leave-tree damage. The test objective here was to use the La Bounty grapple to move residues from locations that were inaccessible to an LGR or brush rake to locations where they could be reached.

The backhoe could not swing around readily at the point of pickup without encountering trees and inflicting damage to them. The Case 1150 had to pull out into an open location, after a load was picked up, to allow the backhoe boom to swing around. This was inconvenient and very slow with a single operator on the machine. The operator would have to move from the backhoe seat to the tractor seat each time a load was picked up. Testing was terminated after only a few minutes of operation when it was found to be impractical to operate with a single operator.

Testing was then resumed using two operators; one man operated the La Bounty grapple while the other operated the Case 1150 tractor. A load was picked up by the grapple and

the tractor moved to a location where the backhoe boom could swing around freely and unload the grapple. This method of operation also proved to be inefficient for the following reasons:

1. Communications between the backhoe operator and tractor operator were poor due to machine noise. Efficiency could have been improved if radio or intercom communications were established between the two men.
2. The cost of machine operation increases substantially with two operators.
3. After a ½ hour of operation, less than 0.1 acre (0.04 hectare) had been satisfactorily treated.
4. The backhoe operator did not have seat belts or adequate rollover protection.

LGR Compared to Brush Rake

To complete the remaining cleanup work on the test site as planned, comparative studies of the Case 1150 with Young LGR and D-5 with brush rake working together were conducted. The D-5 with brush rake was too wide for the tree spacing on the site, causing a great amount of leave-tree damage. Moving material around with the brush rake proved to be difficult. The D-5/brush rake combination was a good supporting tool when used with the Case 1150 and Young LGR. The Case 1150 with Young LGR pulls material out to locations where the brush rake can push it easily into piles. The brush rake pushes a significant amount of dirt into the piles it constructs. The Young LGR constructs relatively clean piles and has the ability to construct larger and denser piles than the brush rake—a consideration when the time comes to burn the piles. However, the economics of this type of operation is questionable, considering the cost of using both these machines to work the same site—close to \$100/hour.

The testing was stopped after 3 hours of operation due to soil conditions. There was underground water close to the surface. After a few minutes of operation, the vibration induced by the machine tracks would cause the soil to turn to mud, making it difficult to operate on. The machines periodically became severely bogged down, making the treatment of this site much slower than expected.

Because of the soil conditions on the test site, exact production measurements were not made. However, under more ideal conditions it appeared that a production rate of 1 acre/hour (0.4 hectare/hour) could have been possible with both machines working. The Case 1150, working by itself on this site under ideal conditions, could have treated approximately ¾ acre/hour (0.3 hectare/hour). This estimate is based on the measurements made during the previous LGR testing.

CONCLUSIONS

Testing indicated that, for moderate-slope (up to 35 percent) applications the LGR appears to be an economical and viable way to accomplish the job. Of the LGR alternatives considered and tested, the Case 1150 loader with Young LGR was the better. A dozer fitted with a clamp rake in the same size class as the International TD-7 is a viable alternative. Dozers have superior handling and balance on steep slopes. If properly balanced, the Case 1150 loader may perform as well as a dozer on slopes. A loader with a grapple rake can

construct denser, higher, and cleaner piles than possible with a dozer/clamp rake combination or brush rake. The EGR idea, although an alternative, did not appear to be economical or practical for use in residual stands.

RECOMMENDATIONS

Prior to the establishment of absolute selection criteria for land managers, more testing and observation of grapple systems is recommended. Land managers can use the information presented herein as a guideline until more extensive data become available.

Careful consideration should be given to thinning specifications (tree spacing and bucking of downed materials) when the use of a machine is planned for the final cleanup of residues. For the machines tested, 12 to 18 ft (3.7 to 5.5 m) tree spacing after thinning is recommended. Also, due consideration should be given to slope and soil conditions on a site prior to specifying a treatment method.

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EQUIPMENT DEVELOPMENT AND TEST

The Forest Service's Equipment Development and Test (ED&T) program, conducted by two Equipment Development Centers (San Dimas, Calif., and Missoula, Mont.), provides systematic application of scientific knowledge to create new or substantially improved equipment, systems, materials, processes, techniques, and procedures that meet the objectives of advanced forest management and utilization in the United States. The ED&T effort, featuring Mechanical Engineering activities, encompasses projects in forest engineering, aviation and fire management, recreation, timber, range, wildlife, occupational safety and health, forest insect and disease, and forest residues to enable forest work to be performed more efficiently, at less cost, with minimum hazard.

As needs for field development services are identified and defined, the Centers determine if already available commercial products are suitable as is or if they require modifications necessitated by the forest environment. On the other hand, sometimes needs can only be met by the Centers taking advantage of the latest technology to create new concepts through a step-by-step product development program. These developments are typically achieved by active ED&T involvement with disciplines found throughout the Forest Service. The new equipment is field tested and demonstrated and user feedback is obtained to evaluate results. The role of the Centers is not considered complete until project output is implemented in the field.

