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Equipment and Processes for Removing and Utilizing Biomass from Central Sierra Nevada Forests

Review conducted for the
State of California Department of Forestry
and Fire Protection
through the
California Biomass Collaborative

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What would you do
if you could begin from scratch?

Basic Design Principles

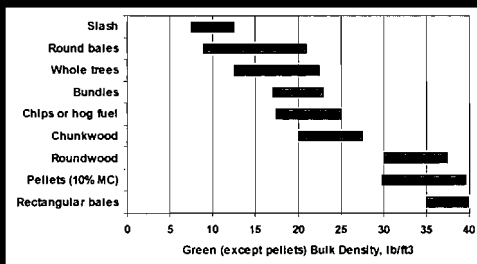
- Use human brain & machine brawn
- Take advantage of economies of scale
- Fully utilize payload weight capacities (in contrast to volume capacities)
- Densify on-highway loads, to a point
- Handle small pieces in bulk or in big packages

Basic Design Principles

- Minimize rehandling
- Fully utilize humans, and machine power and components
- Move continuously rather than starting and stopping
- Use human for decisions/actions that can't be automated & computer for others
- Tradeoffs always exist

Density of Woody Biomass

(assuming 50% MC wet basis except for pellets)



Equipment, Past & Present

- Comminution
- Densification
- Extraction (primary transport)
- Felling
- Loading
- Processing
- Transport

Comminution

- Chipper-forwarder
- Chipper, based at the landing
- Chipper, woods-mobile
- Chunker
- Grinder/hog
- Logging residue processor
- Residue shear
- Roll splitter
- Stump splitter

Densification

- Baler/bundler
- Chip densifier

Extraction (primary transport)

- Agricultural tractor
- ATVs and smaller vehicles
- Brush transport system
- Cable yarder with carriage and chokers
- Cable yarder with grapple
- Cable yarder, zig-zag
- Chip forwarder
- Conveyer

Extraction (continued)

- Crawler tractor
- Forwarder
- Helicopter
- Prebunching winch
- Residue collector-forwarder
- Skidder, clambunk grapple
- Skidder, cable
- Skidder, grapple

Felling

- Chainsaw
- Combi harvester-forwarder (harwarder)
- Feller-buncher, drive-to-tree
- Feller-buncher, swing-to-tree
- Feller-bundler
- Feller-chipper
- Feller-chipper-forwarder
- Feller-forwarder
- Feller-skidder
- Harvester
- Tree puller

Loading

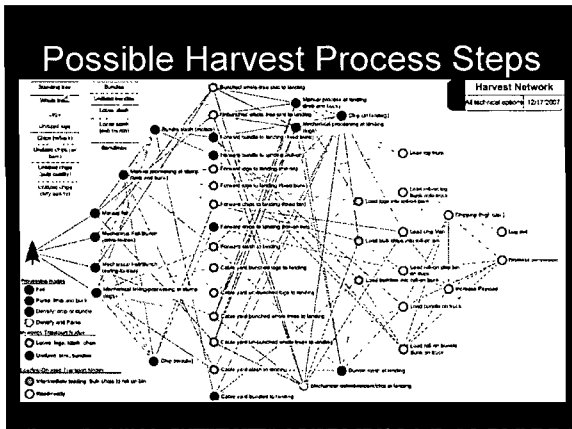
- Chip dump/van loader
- Loader, front-end
- Loader, swing/excavator-based

Processing

- Chainsaw
- Logging residue processor
- Residue shear
- Stump splitter
- Topwood processor
- Topwood processor-skidder

Transport (secondary)

- Chip van
- Log truck
- Multi-use trailer
- Rail
- Residue trailer
- Roll-on/roll-off container
- Self-loading log truck
- Setout trailer



Productivity & Cost

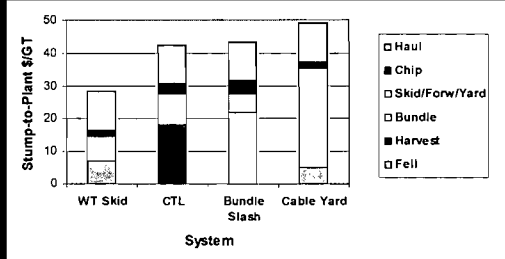
- Productivity
 - Based on results of empirical studies where available
 - Simulated where necessary
 - Covered a range of tree sizes: 4-10" dbh
 - Slopes as relevant for specific equipment: 10, 30, 60%
- Hourly cost
 - Used standard machine-rate approach

Base Case Woods to Landing Systems

1. Ground-Based Whole Tree
 - Swing-boom F-B, Grapple Skidder, Chipper*
2. Ground-Based Cut-to-Length (CTL)
 - Harvester, Forwarder, Chipper*
3. Cable Yarding Whole Tree
 - Chainsaw Fell, Skyline Yarder, Chipper*
4. Removing Surface Fuel
 - Slash Bundler, Forwarder, Chipper

* or Delimber-Debarker-Chipper for clean chips

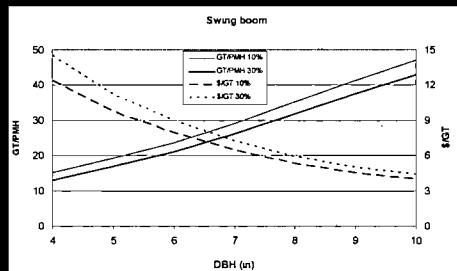
Base Case Woods to Landing Systems



- Removals: 45 GT/ac (190-7" trees/ac)
- 500' skid, 30% slope (60% for cable), 50-mi haul

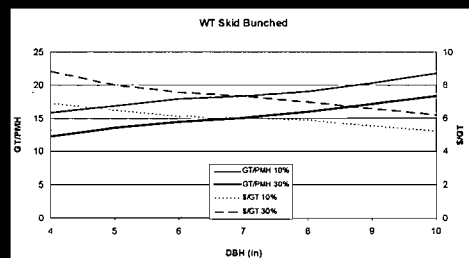
1. Ground-Based Whole Tree

- Swing-to-Tree Feller-Buncher



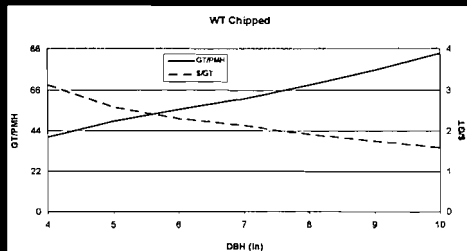
1. Ground-Based Whole Tree

- Grapple Skidder



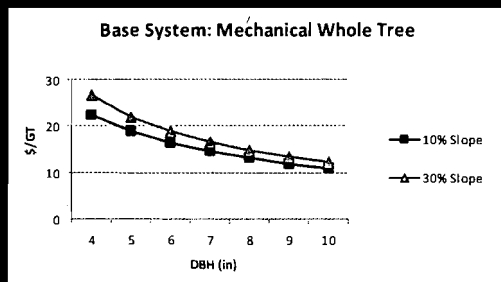
1. Ground-Based Whole Tree

- Chipper



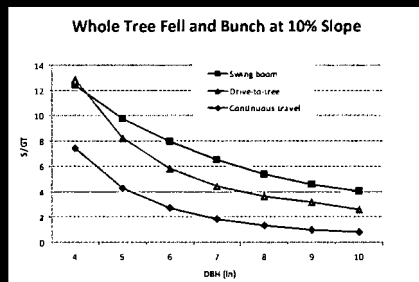
1. Ground-Based Whole Tree

- Stump to Truck



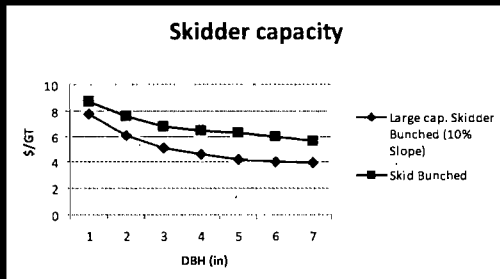
Changes to Ground-Based Whole Tree

- Felling & Bunching



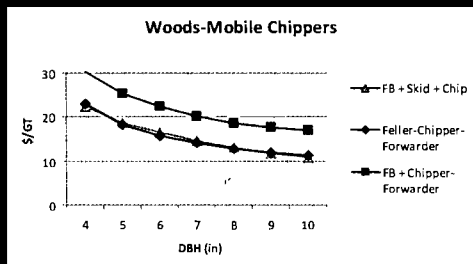
Changes to Ground-Based Whole Tree

- Skidding: Large Grapple



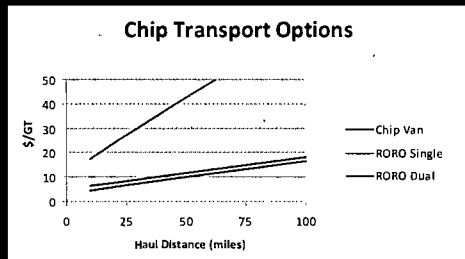
Changes to Ground-Based Whole Tree

- Woods-Mobile Chippers



Transport Options

- Roll-on/off Containers



Transport Options

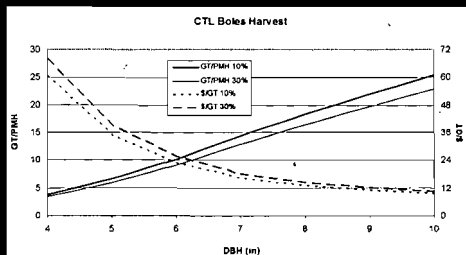
- Dry trees before chipping and hauling
 - MC can be reduced to ~ 40% (wet basis) before van volume becomes more limiting than weight
 - On a 50-mile haul, drying from 50% to 40% might save \$2/GT
- Increase Legal GVW
 - If increase from 80,000 lb to 97,000 lb by adding a sixth axle, might reduce costs by 9% (Eason & Greene 2006)

Transport Options

- Use a Stinger-Steered Chip Van
 - On roads where can't use standard vans
 - Preferable to smaller trucks

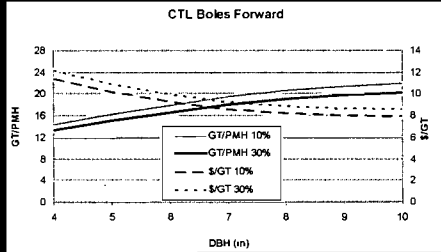
2. Ground-Based CTL

- Harvester



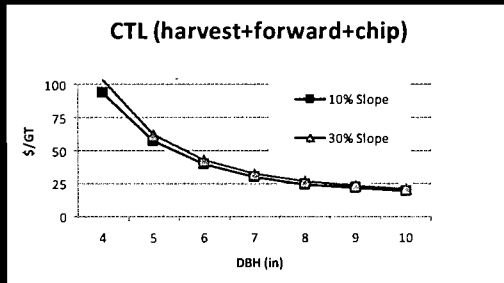
2. Ground-Based CTL

- Forwarder



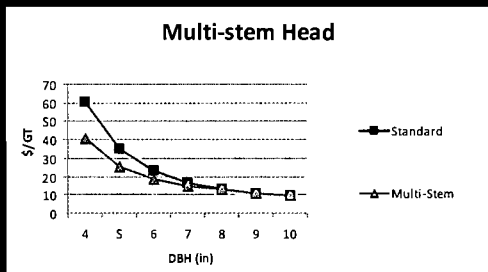
2. Ground-Based CTL

- Stump to Truck



Changes to CTL

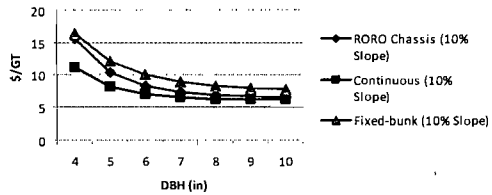
- Multi-Stem Head



Changes to CTL

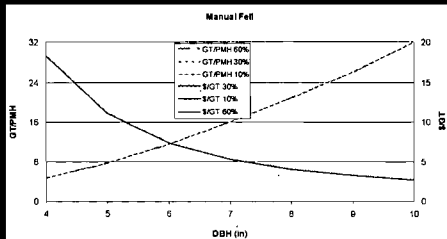
- Forwarding

Forwarding options



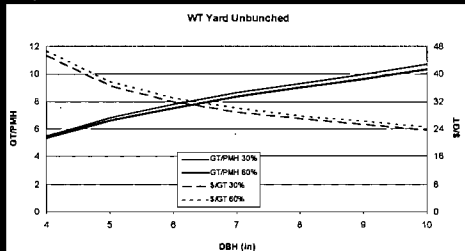
3. Cable Yarding Whole Trees

- Chainsaw Fell



3. Cable Yarding Whole Trees

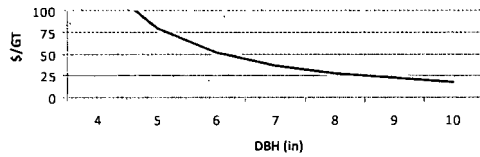
- Skyline Yarder



3. Cable Yarding Whole Trees

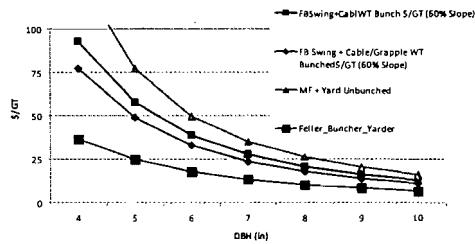
- Stump to Truck

Cable yarding chainsaw felled whole trees on 60% slope

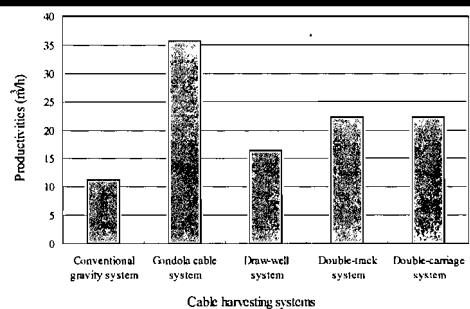


Changes to Cable Yarding

Cable systems

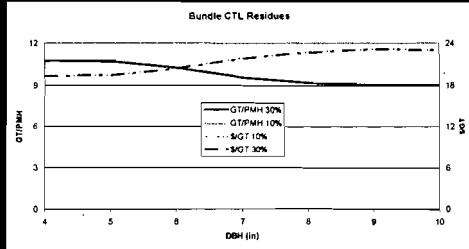


Comparison of productivities for cable harvesting system concepts



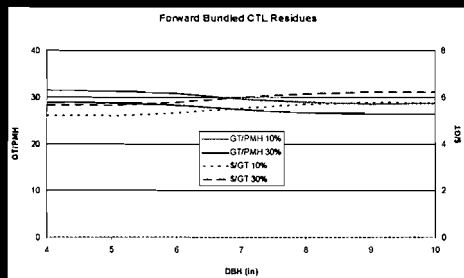
4. Removing Surface Fuel

- Slash Bundler



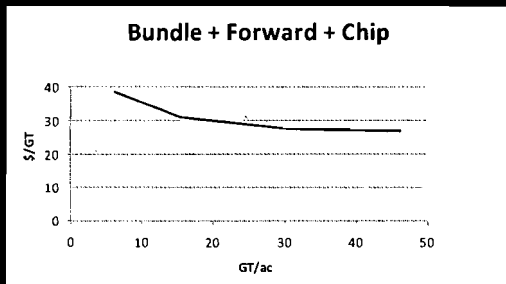
4. Removing Surface Fuel

- Forward Handling Bundles



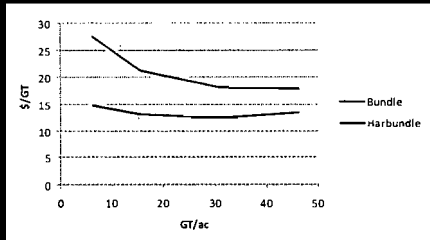
4. Removing Surface Fuel

- Within-Stand to Truck



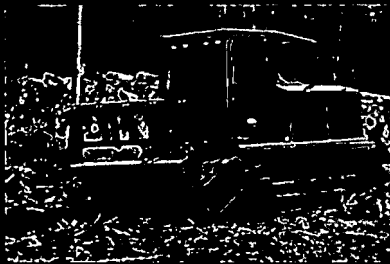
Changes to Surface Fuel Collection

- Harbundler



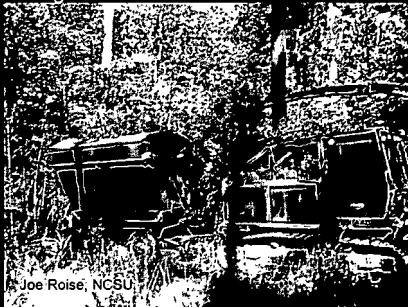
Changes to Surface Fuel Collection

- Swathing Cutter-Comminutor-Forwarder



Changes to Surface Fuel Collection

- Swathing Cutter-Comminutor-Forwarder



Changes to Surface Fuel Collection

- Swathing Cutter-Comminutor-Forwarder



Changes to Surface Fuel Collection

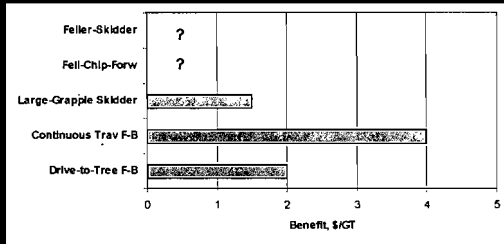
- Swathing Cutter-Comminutor-Forwarder



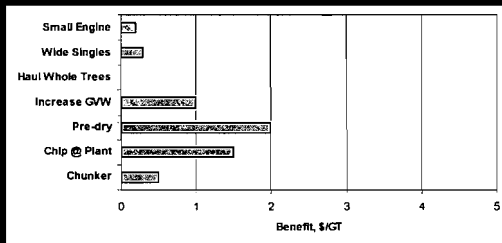
Changes to Surface Fuel Collection

- NCSU/FECON machine
 - Now producing 5-7 GT/pmh
 - At \$18/GT, anticipate breaking even at 10 GT/pmh
- Texas Ag Exp. Stn. mesquite harvester
 - Conventional brush cutter
 - Plus a towed comminutor-collector
 - Hoping for 5-10 acres/day (@15 GT/ac?)

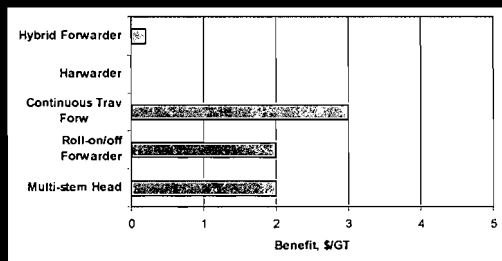
Benefits Summary: Whole Tree



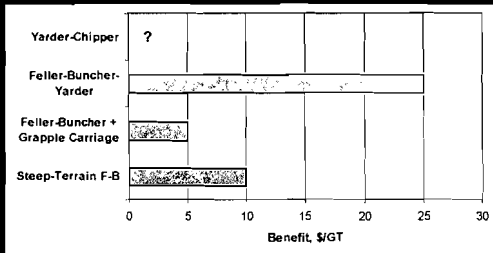
Benefits Summary: Comminution & Transport



Benefits Summary: CTL



Benefits Summary: Cable



Benefits Summary: Slash & Surface Fuels

