Production, Harvesting, and Sustainability of Woody Biomass

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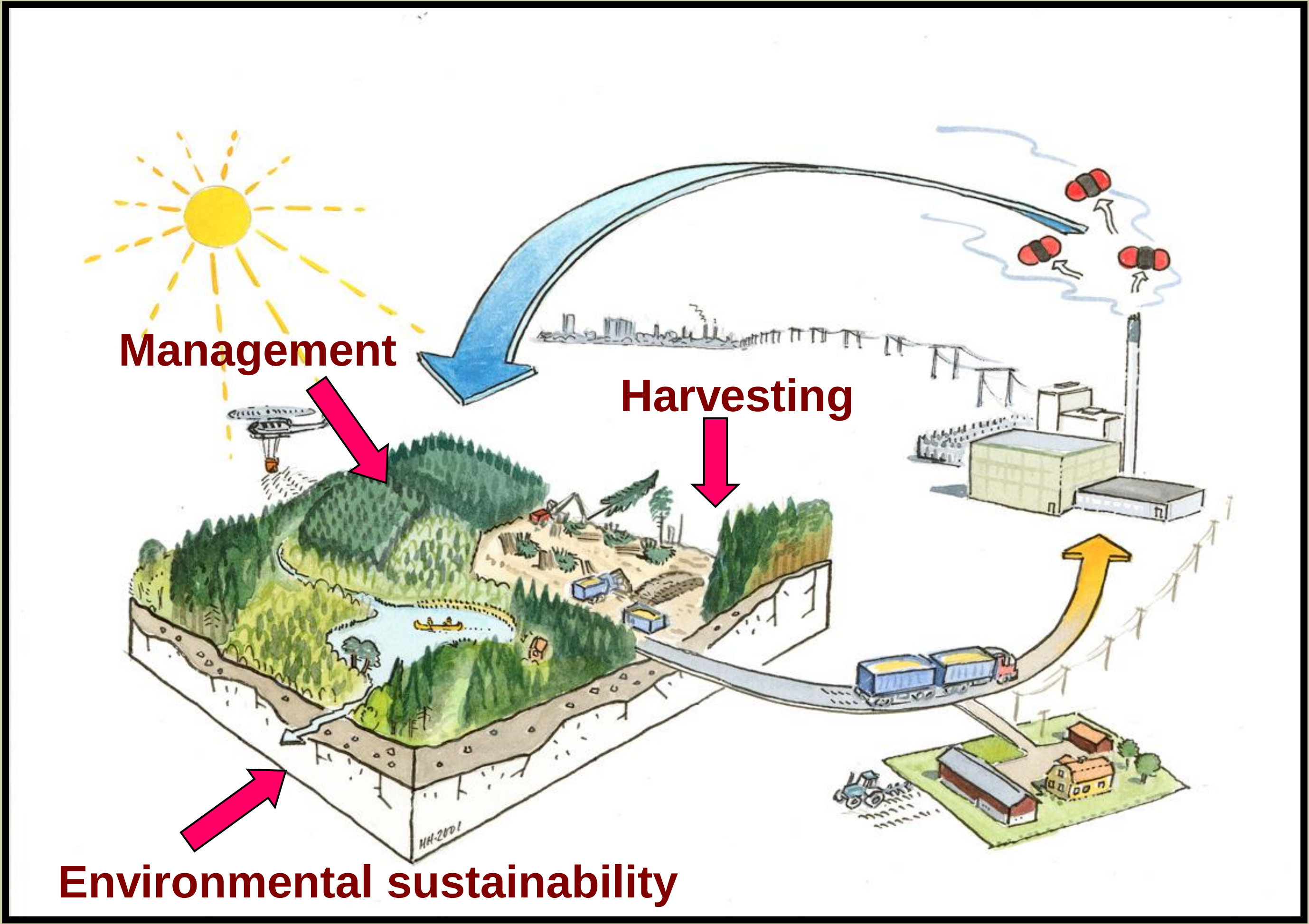
Outline

- Introduction
- Forest Management
- Harvesting
- Low Impact Operations

Objectives

- Describe the silvicultural practices appropriate for biomass production in the southern forest
- Describe the biomass harvesting and pre-processing operations used in the southern forest
- Describe low-impact management operations that enable sustainable biomass production

Planning for Sustainable Systems



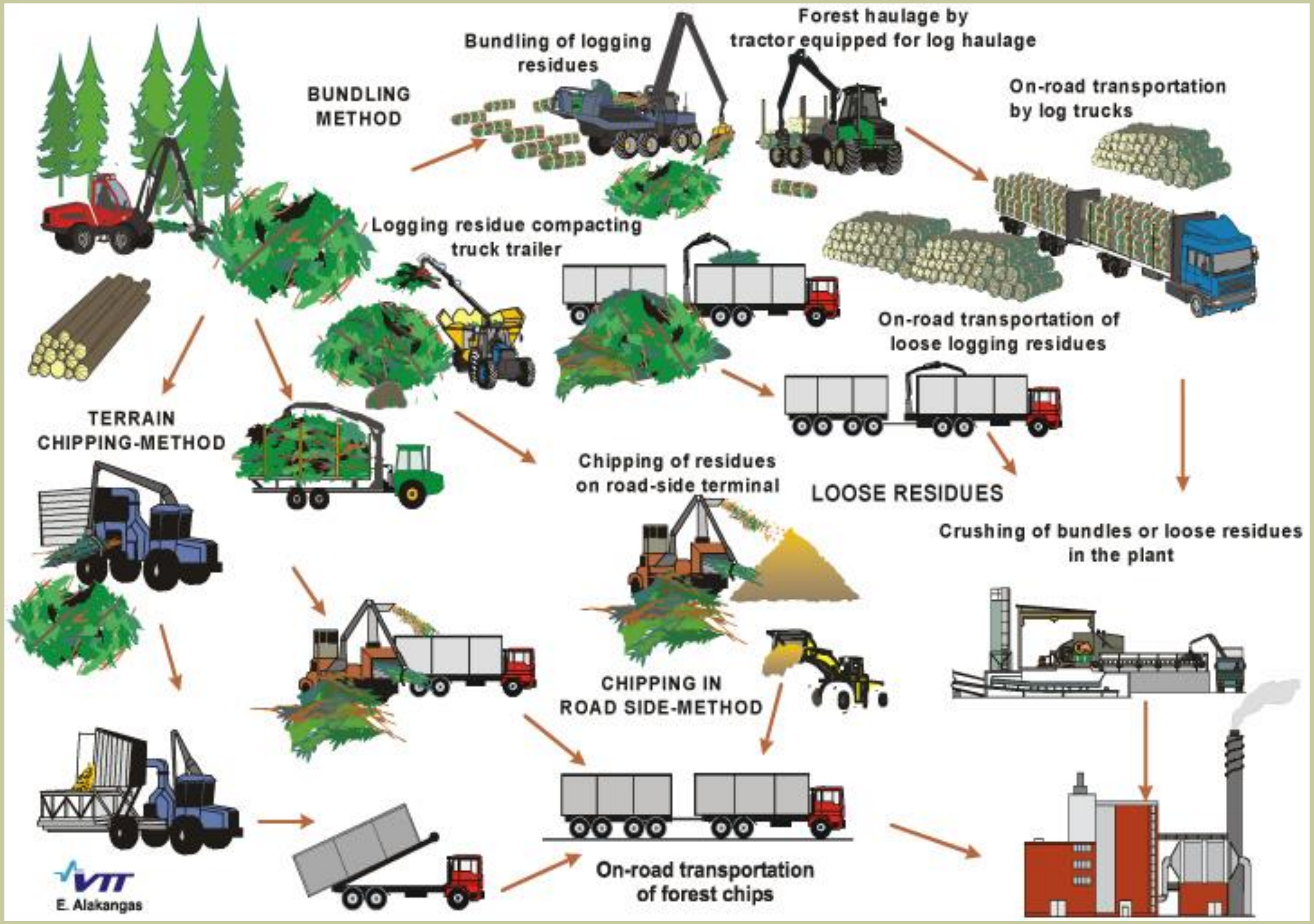
Source: Martin Holmer

Forest Management

Introduction

- Largest potential is from residues or underutilized forest biomass
  - Short-rotation bioenergy plantations more limited
- Currently constrained by lack of markets
- Relatively low-valued product
- Integrate production into silviculture and harvesting practices

Forest Management for Bioenergy



Source: Eija Alakangas, VTT Energy

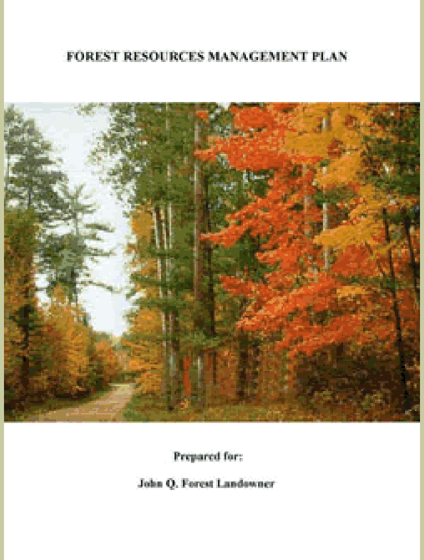
Sources of Woody Biomass

- Logging residues
- Thinnings and other stand improvement operations
- Underutilized species
- Stands severely damaged by climatic events, fires, insect or disease
- Bioenergy plantations

Forest Management Plans

- Define objectives and goals
- Prioritize objectives and goals

Source: Darwin Foster



Source: Darwin Foster

Long-term Management Goals

- Common Goals
  - Timber production
  - Firewood
  - Non-timber forest products
  - Forest health
  - Clean water
  - Amenity/recreation/ lifestyle
  - Conservation/biodiversity
  - Spirituality

Source: Chyrel Mayfield

Integrating Bioenergy Production into Forest Management Objectives

- Does bioenergy production assist another objective such as stand improvement for high-value log production?
  - *Note:* bioenergy production may help meet non-timber goals such as fire protection, amenity values or wildlife enhancement.
- Integrate! Evaluate the whole management package, not just the biomass production part.

Site and Stand Attributes

- Many but not all forest stands will
  have biomass
  readily available
- Topography and other physical factors may constrain biomass utilization

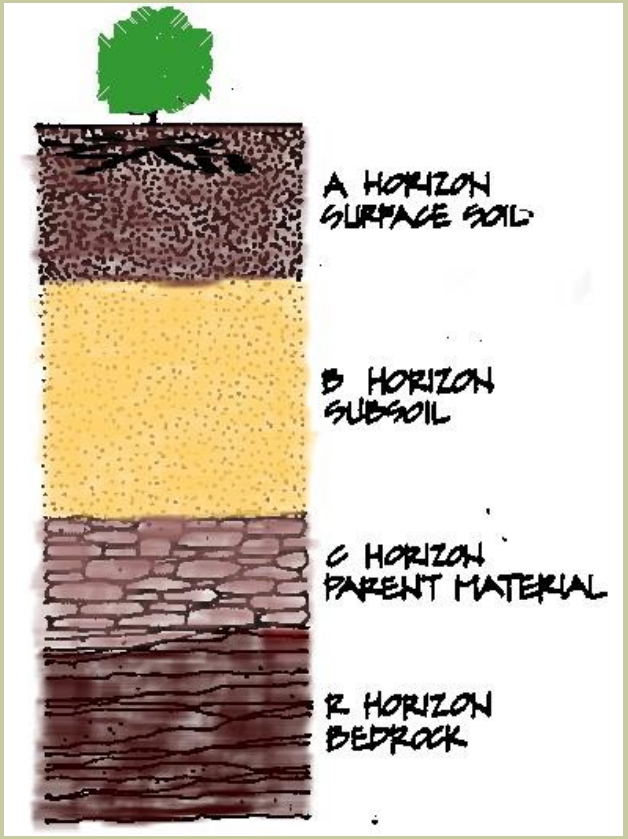
Source: Darwin Foster

Favorable Site Attributes

- Easy site access and adequate road infrastructure
- Close to bioenergy utilization plant
- Gentle topography
- Resilient soils

In addition:

- Is suitable harvesting equipment available?
- Is there enough biomass available in the vicinity?



Source: Darwin Foster

Favorable Stand Attributes

- Stands being managed with an even-aged structure
- Stands where a high amount of otherwise unusable biomass is available
- Trees and shrubs with high wood density
- A rule of thumb is a minimum of 6-7 tons dry weight per acre

Source: Darwin Foster

Biomass Harvesting and Silvicultural Implications

1. Timber harvesting residues
2. Small diameter woody biomass
3. Sanitation and salvage
4. Low value species
5. Short-rotation woody crops

Timber Harvesting Residues

- During a harvesting operation, often 25 to 45% of the tree's biomass is left on site as residues.
- About 65% of total logging residues can easily be recovered for use as bioenergy
- This is about 20-40 tons per acre, on a green basis

Source: Darwin Foster

Timber Harvesting Residues

- Easier when using even-aged silvicultural prescriptions, for example clearcutting.
  – Whole tree vs. log harvesting followed by residue collection
  – Transpiration drying

- May be less feasible and profitable with uneven-aged silvicultural systems, for example single-tree selection.
  – Group selection is an intermediate option

Advantages of Residue Removal

- Reduces the visual impact of harvesting
- Allows better access to the site
- Improves seed bed by exposing mineral soil
- Reduces fire risk
- Allows for easier selection of planting spots
- Reduces site preparation needs and costs
- May reduce some insect problems

Source: Darwin Foster

Potential Disadvantages of Residue Removal

- Removal of nutrients
  - Returning ash is often advocated.
  - Retaining leaves and twigs reduces nutrient removals
- Biological diversity
  - Can be affected by management
- Erosion and sedimentation
  - Site specific; minimize through planning etc
- Damage to advanced regeneration

Small Diameter Woody Biomass

- Material from thinnings
- Possible when thinned material cannot be sold to higher value market
- Often more costly biomass and more likely to be limited by site factors
- More care needed with nutrient removal

Source: Darwin Foster

Sanitation and Salvage

- Material from sanitation or salvage cuts
- Possible when sanitation or salvage material cannot be sold to higher value market


Source: Darwin Foster

Low Value Species

- Need for restoration due to mismanagement and high-grading
- Material generated by restorative silvicultural techniques could be used for bioenergy.

Source: Chris Evans, University of Georgia, www.forestryimages.com (1378140)

Short-Rotation Woody Crops

- Willow and poplar hybrids extensively researched
- Loblolly and sweetgum researched in South
- Short-rotation willow ranges from 3-7 oven-dry tons per acre per year
- Higher with irrigation and fertilization

Source: Donald J. Mead

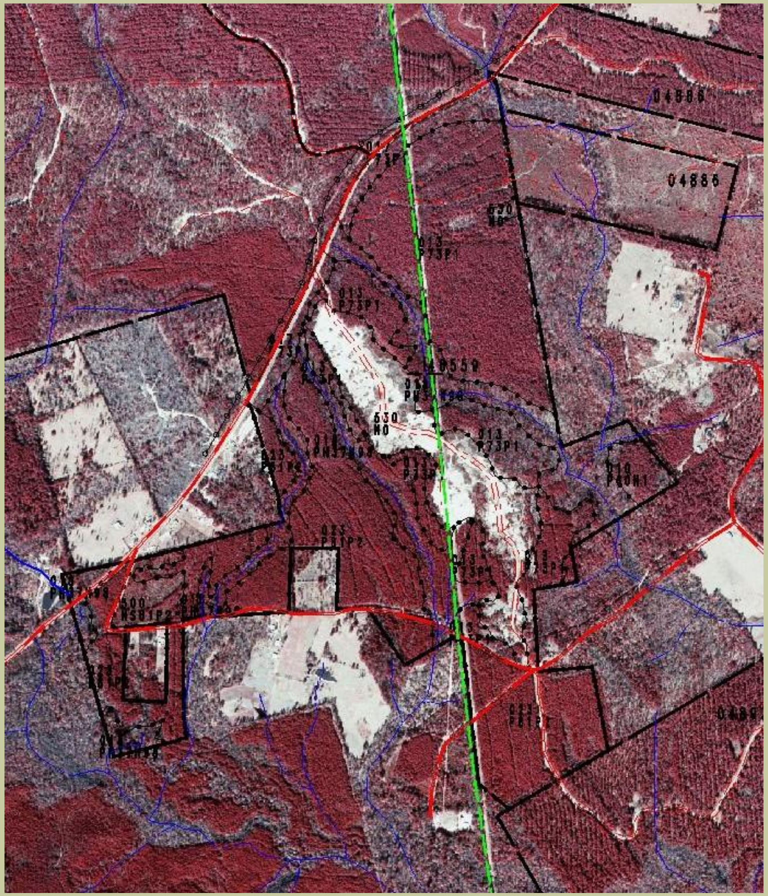
Short-Rotation Woody Crops

Source: Oak Ridge National Laboratory

- Expensive
- Adoption depends on alternative energy costs or other financial mechanisms
- Energy costs are double that of coal
- Land prices dominate Energy input:output ratio is good (typically 10 to 20:1)

Biomass Production by Southern Forest Type

- Planted Pine
- Natural Pine
- Mixed Oak-Pine
- Upland Hardwoods
- Lowland Hardwoods



Source: Darwin Foster

Planted Pine

- Will account for 1/4 of the South's forests by 2040.
- Most plantations are owned by industry or TIMOs
- About 25% owned by NIPFs
- Often intensively managed

Source: Darwin Foster

Planted Pine and Bioenergy

- Collect biomass during scheduled thinnings and clearcuts.
- Intensive silvicultural techniques vary in their energy balance

Source: Darwin Foster

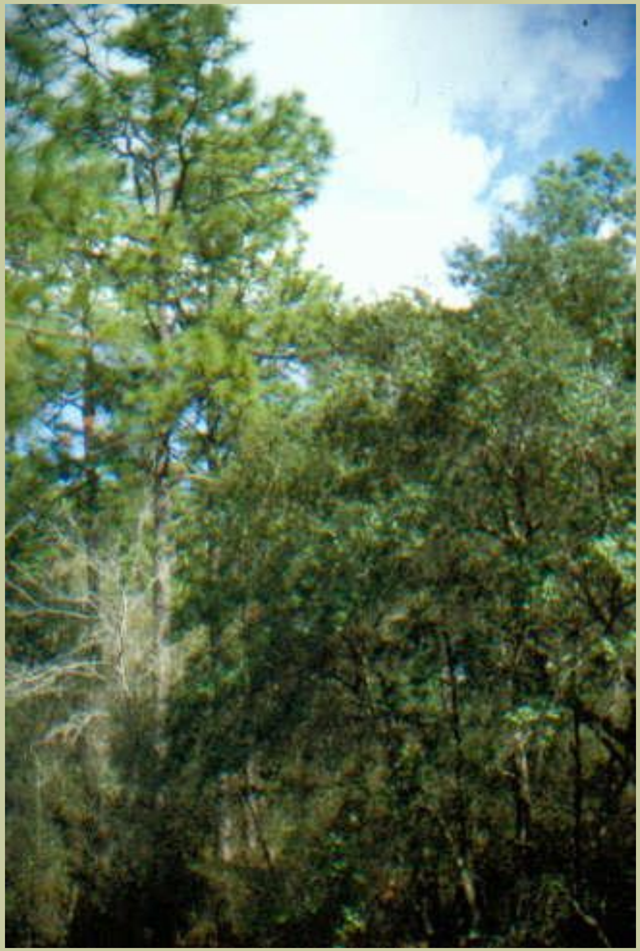
Natural Pine and Bioenergy

Source: Darwin Foster

- Even-aged silviculture provides biomass opportunities
- More difficult with selection system
- Useful in degraded stands

Mixed Oak-Pine and Bioenergy

- Clearcutting
- Poor quality sites
- Thinning and other timber stand improvement (TSI) cuts
- Limited by topography and road systems



Source: Donald J. Mead

Upland Hardwoods

Source: Brian Lockhart, USDA Forest Service, www.forestryimages.com (1118144)

- Oak-hickory or maple-beech-birch
- Cover approximately 64 million acres
- Second growth, often even-aged
- Often high-graded

Upland Hardwoods

- Intensive thinning, cleaning, and clearcuts
- Regeneration of poor quality sites e.g. using shear/chip methods
- Costs, transport and topography could be limiting factors

Source: Brian Lockhart, USDA Forest Service, www.forestryimages.com (1118184)

Lowland Hardwoods and Bioenergy

- Biomass potential unclear
- High wood density advantageous
- Main opportunities with restoration or regeneration of stands
- Not applicable on extremely wet sites.

Source: Paul Bolstad, University of Minnesota, www.forestryimages.com (1437191)

California Case Study

Source: Donald J. Mead

Source: Donald J. Mead

- Sierra Pacific Industries
- Improvement of degraded stands
- Integrated with traditional operations

Source: Darwin Foster

Benefits

- Improves access for site preparation, establishment and weed control
- No need to pile and burn residues for fire control
- Reduces costs of establishing the new crop by as much as $150 per acre
- More environmentally friendly than other alternatives

Main Biomass Operations

- Occurs before and after clearcutting
  - Biomass felled before the main harvest is piled and allowed time to dry
  - Residue remaining after clearcut is collected and chipped
  - 15 to 25 dry tons per acre removed

Other Biomass Operations

- Occur when thinning or establishing fuel breaks
  - Ensures growth is concentrated on crop trees
  - A bioenergy market allows for earlier thinnings and overall reduced costs by about $50 per acre
  - Reduces fire risk

Conclusions

- Biomass harvesting can and should be integrated into traditional forest management schemes in the South.
- Use of short-rotation woody crops are currently restricted, but this could change.

Harvesting Woody Biomass

Recovering Woody Biomass

- Logging residue represents great potential
- 41 million dry tons of logging residue
- Needs to be augmented by other wood sources

Source: Michael Westbrook

Recovering Woody Biomass

- Similar technology to timber harvesting
- Similar processes to timber harvesting

Source: OSHA

Feedstock Forms-Unconsolidated

- Raw form
- Non-merchantable
- Bulky
- Expensive to transport

Source: Sarah Ashton

Feedstock Forms-Comminuted

- Reduced in size
- Various methods
- Occurs at harvesting site or at end-use facility
- “Clean” or “Dirty”

Source: Rien Visser

Source: Shawn Baker

Feedstock Forms-Bundled

- New material concept
- Compaction of biomass
- Specialized bundling equipment
- Expensive

Source: Bob Rummer

Harvesting Systems for Recovery of Woody Biomass

Source: Michael Westbrook

- Two basic types
  - Conventional
  - Small-scale

Source: Harry Groot

Choosing an Appropriate System

- Social acceptability
- Environmental impact
- Economic viability
- Operator safety

Source: Chris Schnepf

Source: Sarah Ashton

Conventional Timber Harvesting Equipment

Source: Sarah Ashton, Rien Visser, Christian Kanzain

Advantages

- An option for generating additional income
- Favored by conventional loggers
- Safer than alternative systems
- Cost savings in reforestation efforts

Disadvantages

- High capital, operational, and transport costs
- Operators willing to work energy projects hard to find when fossil fuel prices are low
- A strong market for woody biomass must exist

Two-pass Systems

- Types
  - Pre-harvest
  - Post-harvest
- Expensive
- Time consuming
- Uncommon

Source: Shawn Baker

One-pass Systems

- Types
  - Feller/buncher-skidder
  - Harvester-forwarder/skidder
- Highly integrated
- Cost effective
- Less time consuming

Source: Sarah Ashton

Small-scale Timber Harvesting Equipment

- Low capital costs
- Low overhead
- Low transportation costs
- Maneuverability
- Minimal access requirements
- Ability to handle small-diameter and irregular woody material

Advantages

- Lower capital, operational, and transport costs
- Optimize at lower levels of productivity
- More socially acceptable

Disadvantages

- Not economical when removing smaller amounts of lower value material
- Quality control problems
- High levels of operator skill
- Environmental impacts questionable
- Do not meet OSHA safety standards

Mechanized

Source: www.forestryimages.net

Source: Chris Schnepf

- Systems
  - Modified agricultural tractors
  - Small excavators
  - Small skid-steers
  - Small cable-yarding systems
  - ATVs

Animal-Powered

- Systems
  - Horses
  - Mules
  - Oxen
- Contractor availability
- Willingness to pay

Source: Tat Smith

Pre-processing Woody Biomass

Grinding

- Advantages
  - Accept a wide range of material
  - More forgiving of contamination
- Disadvantages
  - Uses more energy than chippers
  - Susceptible to internal wear

Source: Dale Greene

Source: Sarah Ashton

Shredding

- Advantages
  - Appropriate for contaminated material
- Disadvantages
  - Expensive
  - Material often requires further size reduction

Source: Ben Jackson

Chipping

- Advantages
  - Well integrated
  - Cost effective
- Disadvantages
  - Susceptibility to wear from contamination

Source: Michael Westbrook

In-woods Chipping

- Advantages
  - Well integrated
  - Cost effective
  - No need for on-site storage
- Disadvantages
  - Down-time costly
  - Low energy density

Source: Michael Westbrook

Off-road Chipping

- Advantages
  - Transpiration drying
  - Higher energy density
  - Control supply
- Disadvantages
  - Lose track of inventory
  - Storage Issues
  - Costs of forgoing reforestation

Source: Rien Visser

Chipping at the Plant

- Advantages
  - Economies of scale
  - Robust, powerful
- Disadvantages
  - Increased noise levels
  - Storage of uncomminuted material
  - Expensive to transport low bulk density material

Source: Dale Greene

Factors Affecting Harvesting Costs

- Stand size
- Tree species
- Volume removed
- Degree of difficulty
- Type of equipment

Costs and Harvesting System Size

- Conventional Systems
  - Range from $ 600,000 to $2 MM
- Small Scale Systems
  - Less than $60,000

Conclusions

- Modification of conventional one-pass harvesting system is most common system in the South – usually an in-woods chipper
- Most common Pre-processing is in-woods chipping, delivered immediately to the end user
- New harvesting systems using bundlers or CRL have potential but are not now feasible

Georgia-Case Study

- Study
  - Adding a small chipper to a tree-length operation
  - Chip during downtime (between trucks and during equipment maintenance)

Findings

- If a load of chips is produced from 12 or fewer loads of roundwood, chips can be competitive.
- Chip costs increase as the volume chipped decreases.
- Fuel chip prices have ranged from $14-21 per ton in the South in 2006.
- As fuel chip prices increase, logging residue chips get more competitive.

Environmentally Sustainable Bioenergy Production Systems

Ecosystem Components

- Operational intensity of management and biomass utilization can affect:
  - Soil health and productivity
  - Forest hydrology
  - Biodiversity

Source: Alabama Cooperative Extension, Vale of Glamorgan Council, Universities Space Research Association

Important Functions of Forest Soils

Soils provide the **biophysical foundation** of forests and are important to the hydrologic cycle, productivity and biodiversity, acting as:

- A medium for plant growth
- A recycling system
- A water supply regulator
- Soil organism habitat
- An engineering medium

Source: The Nitrate Elimination Company

WOOD to ENERGY

Potential Impacts of Operations on Soils

Issues	Contributing activities
Exposure of soil surface → drying of surface layers, temperature extremes, erosion	**•Exposure through removal of protective litter layer, dead wood, slash**
Compaction → decreased soil oxygen and soil porosity → decreased infiltration, waterlogged ruts	**•Removal of slash and loss of protective roadbed** **•Time of year and soil conditions during harvest** **•More frequent and/or intensive entries than conventional harvesting**

Potential Impacts of Operations on Soils

Issues	**Contributing activities**
Reduction in total capital and availability of nutrients	•Intensive biomass removal
Accumulation of toxic substances	•Use of harvesting machinery (e.g., leaking lubricants and hydraulic fluids)

Value of Water to Forests and People

The quality and quantity of water in a forest ecosystem is essential for providing and supporting:

- Tree growth and survival
- Habitat
- Drinking water
- Recreation

Source: University of Minnesota

Potential Impacts of Operations on Water

Issues	Contributing activities
Soil exposure → increased overland flow → erosion and sedimentation → increased turbidity	•Harvesting intensity and forest floor retention •Selection and use of equipment
Effectiveness of SMZs	•Road building •Stream crossings

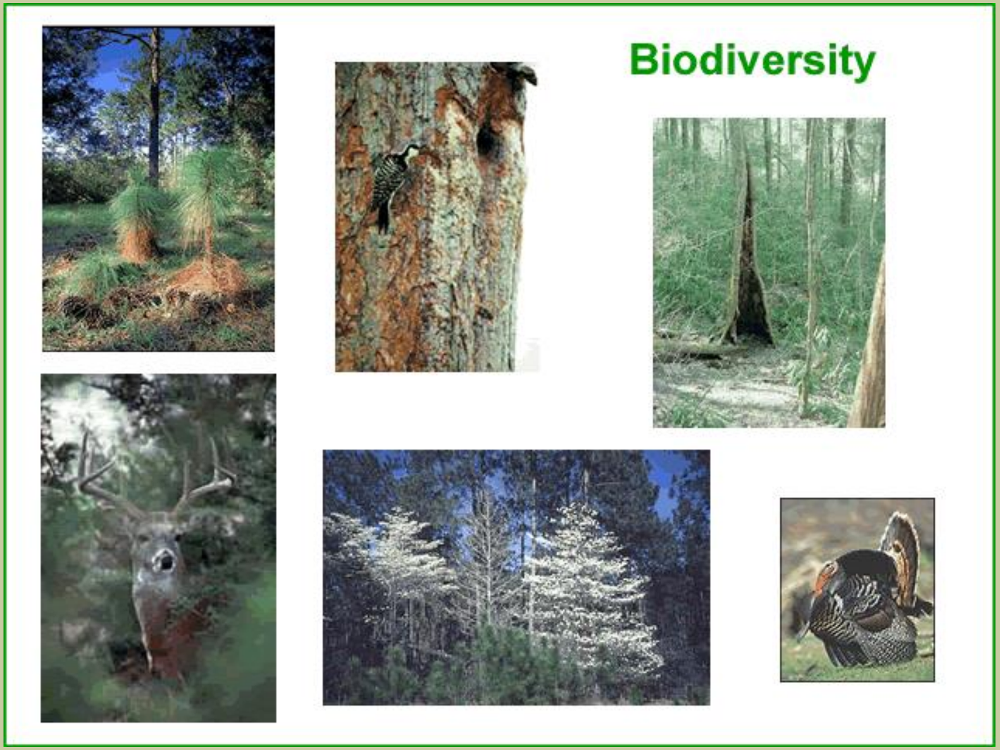
Potential Impacts of Operations on Water

Issues	**Contributing activities**
Changes in ecosystem hydrologic flux	**•Changes in vegetation** **•Practices leading to compaction** **•Irrigation**
Changes in water chemistry (pH, nutrients, toxic compounds, oxygen)	**•Management practices leading to excessive leaching** **•Inappropriate application of fertilizers and pesticides**

Importance of Forest Biodiversity

High diversity of species, genes, ecosystem functions, and habitats:

- Heightens ecological resilience
- Helps to ensure long-term productivity
- Enhances recreational experiences



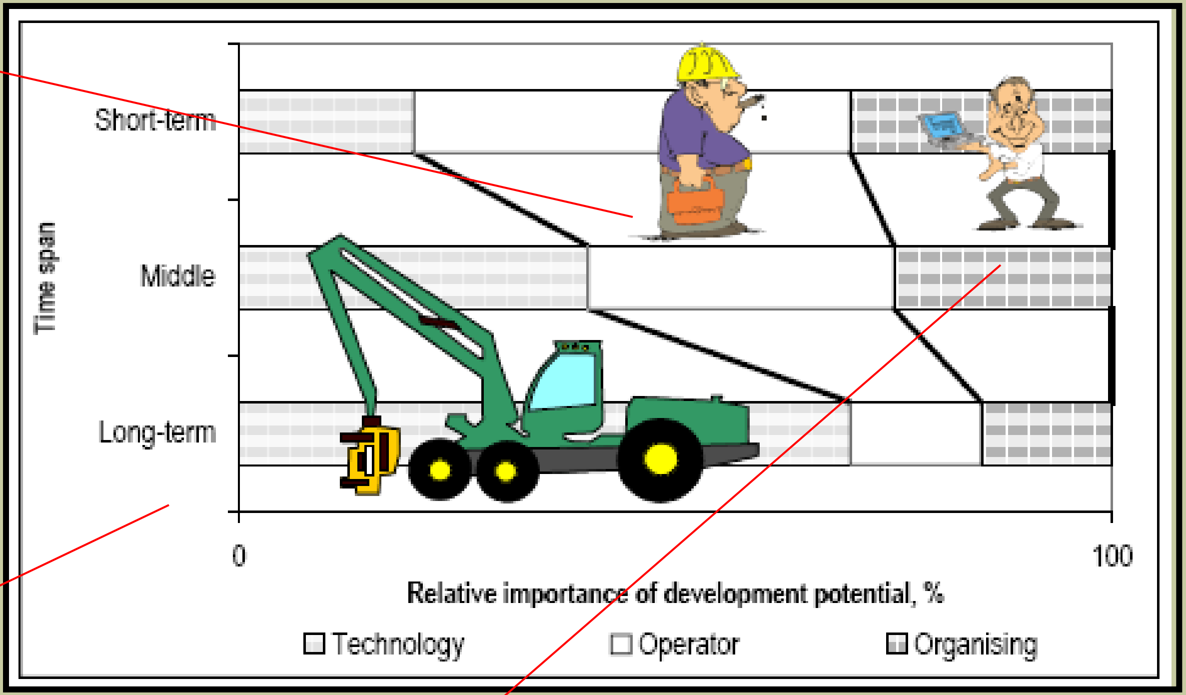
Source: Chyrel Mayfield

Potential Impacts of Operations on Biodiversity

Issues	Contributing activities
Loss of DWD and dead wood needed for survival of some species	Removal of dead wood and DWD
Changes in forest composition	Replacement of natural forests with mono-specific plantations
Species loss due to habitat degradation	•Extensive clearing •Land conversion

Designing sustainable systems requires:

•Operator training and provision of guidelines



Source: K. Rieppo

•Technology choice

•Planning and organization of operations

Practices to Mitigate Soil Damage

- Use BMPs for your area (www.forestrybmp.com)
- Restrict operations to seasons when soil moisture is low
- Minimize interventions e.g. one-pass harvesting
- Retain nutrient-rich crown biomass onsite
- Maintain protective roadbed

Source: C. T. Smith

Source: B. Titus

Technology to Mitigate Soil Damage

Source: Valmet

Source: John Deere

Source: C. T. Smith

- Choose the most efficient and low-impact equipment possible

Planning and Practices to Mitigate Negative Hydrologic Impacts

- Know local hydrology and practice site-specific management

- Develop effective streamside management zones

- Use Best Management Practices for road construction and stream crossings

- Manage for healthy soils

Source: www.forestryimages.com

Source: U. S. National Park Service

Landscape and Stand-level Planning to Mitigate Biodiversity Loss

- Use landscape analysis techniques to assess patch size and shape, connectivity, etc.
- Apply umbrella species concept
- Incorporate well-planned protected areas and buffer zones

Source: Al Lucier
National Council for Air and Stream Improvement

Source: Joe Kosack

Practices to Mitigate Biodiversity Loss

- Retain residual trees
- Retain DWD/deadwood
- Encourage structurally complex stands
- Create habitat
- Restrict operations during nesting/calving/breeding periods

Source: U. S. Fish and Wildlife Service
U. S. Forest Service

Conclusions

- Like other forms of forest management, biomass production systems can have positive and negative ecological impacts on soils, water and biodiversity
- Mitigating negative impacts is important to producing energy that is truly renewable and sustainable
- Low-impact operations can be designed through careful planning, practice and technology choice

Summary

- Biomass harvesting can and should be integrated into traditional forest management schemes in the South.
- Modification of conventional one-pass harvesting system is most common system in the South – usually an in-woods chipper.
- Low-impact operations can be designed through careful planning, practice and technology choice.