Presentation Outline

- Brief Review of “Precision Agriculture”
- Review of “Precision Forestry” Concepts
- Overview of Developments at Auburn

GPS, GIS and other geospatial technologies are driving “Precision Agriculture”

Yield Monitoring

- As the product is harvested, sensors measure yield and location

Yield Mapping

- Yield data are used to develop a yield map

Yield maps illustrate:

- Yield variation in the field
- Potential causes of yield variation
  - Soil type differences
  - Fertility differences
  - Weed control issues
  - Soil moisture characteristics
  - Soil compaction
  - Equipment malfunction
Soil fertility maps explain:

- Variation in growth and yield

Using GPS for Guidance and Control

- GPS and Variable Rate Controllers can control application of herbicides, insecticides, fertilizers, etc.
- Based on pre-defined management zones

Variable rate operation

- Variable Rate Controllers customize fertilizer application rate for each of the management zones in the field and adjust for changes in ground speed

New Applications in machine guidance:

GPS-based steering system
GPS-based steering system for subsequent operations based on original map created during tillage or planting

“Precision Forestry”

- Precision Forestry is the use of geospatial-based tools and technologies
  - for planning and conducting site-specific and condition-specific forest management activities and operations
  - to improve wood product quality and utilization, reduce waste, increase profits, and maintain environmental quality

- Three main areas of Precision Forestry:
  1. Using geospatial-information to assist forest management and planning
  2. Site-specific silvicultural operations
     - site preparation
     - regeneration
     - stand management
  3. Advanced technology to meet market demands
     - product identification during harvest
     - optimizing transportation systems

Site-Specific Information

- Users
  - Landowners
  - Consultants
  - Contractors

- Information
  - Verification of provided services
  - Input to management decisions
  - Audits for SFI compliance
  - Certification

Profit Map

“Profit in Field K - 1998 (Soybeans)”

Legend
- Profit
- Cost
- Variable Costs
- Fixed Costs
- Profit
- Profit per Acre

Users
- Landowners
- Consultants
- Contractors

Information
- Verification of provided services
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Precision Forestry at Auburn

- **Goal**
  - Develop geospatial technologies to acquire site-specific data to help landowners, foresters, loggers, etc. improve forest management decisions for reducing costs while increasing productivity.

- Establishing appropriate practices to control costs and inputs

- Using geospatial data for adaptive management
  - Automated data collection
  - Adjust inputs or practices based on geospatial data

1. Using geospatial-information to assist forest management and planning

- Includes many current forest management activities that employ geospatial technologies as management tools

- Site-specific emphasis

Mapping Harvesting Traffic Impacts

- GPS receivers placed on feller bunchers and skidders

- Position data recorded during harvest operations

Skidder Traffic Density Map

Untrafficked Area
Untrafficked Area

Machine Path

Automated Time Study

Automating Time Study

Time Study of Feller-Bunchers

Additional Instrumentation

- Two stages:
  - 'State' changes
    - Reversal in direction
    - Cross a boundary
  - Sequences of states
    - Leave 'deck' polygon, reverse direction = travel empty

- At least 90 percent success rate in identifying skidder cycles
- Can measure:
  - Elemental times
  - Distance

- Not just position
- Need to know
  - When tree cut
  - When and where laid down
- GPS + other instrumentation
Time Study Results

- 238 of 240 trees cut detected
- 47 cycles (cut/dump) - 53 detected

Mapping mechanical site preparation operations

<table>
<thead>
<tr>
<th>D6</th>
<th>AVG Speed (MPH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 6</td>
<td>1.6</td>
</tr>
<tr>
<td>Aug 7</td>
<td>1.3</td>
</tr>
<tr>
<td>Aug 9 (PM)</td>
<td>1.9</td>
</tr>
<tr>
<td>Aug 9 (AM)</td>
<td>1.7</td>
</tr>
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</table>

Commercial GPS-based mapping of site preparation

Productivity measurement of site preparation operations

Location of delimbing area during harvesting operation

PLow DOWN

Location of wet area

PLow UP
**Productivity measurement of site preparation**

<table>
<thead>
<tr>
<th>Time Element</th>
<th>Time (min)</th>
<th>Percent of Time</th>
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</thead>
<tbody>
<tr>
<td>Plowing</td>
<td>223</td>
<td>61%</td>
</tr>
<tr>
<td>Turning</td>
<td>110</td>
<td>30%</td>
</tr>
<tr>
<td>Avoiding Obstacles</td>
<td>20</td>
<td>5%</td>
</tr>
<tr>
<td>Stopped</td>
<td>14</td>
<td>4%</td>
</tr>
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</table>

**Yield Maps in Forestry?**

- Can we develop and use yield maps in silvicultural operations?
- Cut-to-length vs. tree-length harvesting systems

Cut-to-Length harvesting equipment is already equipped with sensors for log diameter and length.

Using volume and GPS location, we can develop the yield map.

Optical Diameter Sensor Development

Current research at Auburn has developed yield sensors for use by feller-bunchers.

Optical sensors in felling head measure tree diameter

Prototype Sensor Testing
Prototype Sensor Field Testing

Test Stand for Yield Mapping

- ~9 ac. site
- Located north of Auburn at Caterpillar Forest Pro Training Center
- Hand and sensor measurement of DBH
- Generation of a "yield" map

Test Stand - Topography

52 ft elevation change

Test Stand Map

Merchantable Timber Map

Merchantable Timber Assessment

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>AVG DBH</td>
<td>9.4 inches</td>
</tr>
<tr>
<td>Range of DBH</td>
<td>4.0 - 20.4 inches</td>
</tr>
<tr>
<td>AVG Height</td>
<td>38.2 ft</td>
</tr>
<tr>
<td>Basal Area</td>
<td>146.9 ft²/acre</td>
</tr>
<tr>
<td>Stand Density</td>
<td>291 trees/ha</td>
</tr>
</tbody>
</table>

Additional data:
- Harvest rate
- Machine audit
- Electronic file of harvest
Value Map

AVID Value $13.74 per tree
Total Value $19,809

Next Steps in Yield Mapping
- Extensive field testing of optical sensor
- Testing of different sensing techniques
- Refinement of yield mapping methods
- Extension activities to transfer technology to loggers and landowners

2. Site-specific silvicultural operations

Using GPS, GIS, and variable rate controllers to assist in regeneration (site preparation, planting), thinning, harvesting, etc.

- More efficient herbicide and fertilizer application
- Marking tree location for planting and subsequent operations
- “Smart” backpack spraying systems
- “Smart” hand planting systems

Site-specific herbicide application

- Banded spraying and variable-rate technology
- Manual or Automated control

Site-specific herbicide application

- Pre-plant:
  - Banded spraying
  - Variable-rate technology
  - Marks location of trees

As-applied map of herbicide application

<table>
<thead>
<tr>
<th>Acres</th>
<th>Owner GIS</th>
<th>Herbside</th>
<th>Tractor GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>82</td>
<td>79</td>
<td>77</td>
<td></td>
</tr>
</tbody>
</table>
WS Sprayer – banded spraying configuration

- Control system monitors navigation and chemical injection
- GPS determines machine speed and location
- Controller monitors water flow rate, chemical application rate
- Map display and light bar used for guidance
- "As-applied" maps can be downloaded for import to GIS

"As-applied" map shows areas sprayed
Backpack Concerns

Barriers
- Worker Safety & Compliance
  - Walking Through Contaminated Vegetation All Day (Reentry Issues)
  - Improper Personal Protective Equipment
- Quality Issues
  - Ground Speed
  - Skips and Double Sprayed Rows
  - Tank Mix Not Correct
  - Dumping Product
  - Wand Height Not Correct

Solutions
+ Meet and exceed all standards for safety
- Nozzle at the rear of sprayer
- Battery-powered pump unit at same weight to decrease worker energy output requirements
- High-quality backpack frame and harness available
+ Use GPS data collection for worker production
  - Real-time ground speed feedback for worker
  - Data collection for evaluating and reporting actual ground speed, product dumping, skips, and double sprayed rows
  - Rear adjustable fix mount wand to assure proper wand height

“SmartPack” Solutions

SmartPack

Example SmartPack Data

```
<table>
<thead>
<tr>
<th>Worker</th>
<th>No. Packs Sprayed</th>
<th>Rate of Application</th>
<th>Total Gadgets</th>
<th>Weld Arcs</th>
<th>Feet of Row Sprayed</th>
<th>Feet of Row Double Sprayed</th>
<th>Acres Double Sprayed</th>
<th>% of Row Double Sprayed</th>
<th>% of Time Within 15% of Target Speed</th>
<th>Actual oz/acre Spyder</th>
<th>Actual oz/acre Velpar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeronimo Rodriquez</td>
<td>2</td>
<td>0.8825</td>
<td>100</td>
<td>2.0</td>
<td>10,736</td>
<td>126</td>
<td>0.84</td>
<td>92%</td>
<td>85%</td>
<td>2.13</td>
<td>26.04</td>
</tr>
<tr>
<td>Arcadio Perez</td>
<td>3</td>
<td>0.75</td>
<td>100</td>
<td>2.4</td>
<td>10,061</td>
<td>137</td>
<td>0.89</td>
<td>92%</td>
<td>84%</td>
<td>1.80</td>
<td>21.61</td>
</tr>
<tr>
<td>Marcos Pastor</td>
<td>4</td>
<td>0.74</td>
<td>100</td>
<td>2.1</td>
<td>7,490</td>
<td>88</td>
<td>0.85</td>
<td>92%</td>
<td>83%</td>
<td>2.42</td>
<td>29.03</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>18.645</td>
<td>100</td>
<td>2.1</td>
<td>28,283</td>
<td>350</td>
<td>0.85</td>
<td>92%</td>
<td>84%</td>
<td>2.13</td>
<td>29.03</td>
</tr>
</tbody>
</table>
```

SmartPack Activity Report (Landowner)

```
Contractor: [Name]
Date of Application: 9/15/2004
Amount of Product Used:
  - 2.13 oz/acre Spyder
  - 2.2 oz/acre Velpar
Total Acres Covered: 7.0 acres
```

“Smart” Hand Planting

- Spatially marking trees during planting using GPS and sensors on dibble
- Spatial inventory of trees planted
- Quality assurance data for landowner
  - Planting density
  - Within-row spacing
  - Row spacing
- Errors
- Worker payment (trees/day)
- Survival rates
- Patent pending
Quality Assurance Data for Landowner

• **Target**
  - 545 trees/ac
  - Tree spacing = 6 ft
  - Row spacing = 12 ft

• **Actual**
  - 551.7 trees/ac (CV = 12%)
  - Tree spacing = 6.2 ft (CV = 18%)
  - Row spacing = 11.3 ft (CV = 24%)

As-Planted and SmartPack Application Map

How do we use yield maps?

• How can we use yield maps in the next rotation?
  - Site-specific fertilization
  - Site-specific herbicide application
  - Site-specific planting density

Management philosophies for site-specific silvicultural operations

• Manage soil fertility to optimize profit
  OR
• Manage vegetation to optimize profit

Site-specific fertilization

• Yield maps can be combined with soil fertility maps to develop management zones

• Different rates of fertilizer can be applied at different locations

Vegetation Mapping

• Vegetation maps can be used to control herbicide application

• Site-specific herbicide application may offer more opportunities for forest productivity gains
Competing vegetation may be mapped using Remote Sensing techniques.

3. Technology to meet market demands
- Product identification in the woods:
  - Detect wood quality and determine most appropriate final product
  - Combine product identification with market demands to determine optimal transportation scheduling and routing

Improved Selection of Higher Quality Products
- Assess mechanical properties of trees at harvest
- Quality map
  - Stiffness
  - Defects
- Segregation of trees to different markets

Tree-length feller bunchers may be able to measure log stiffness by ultrasonics or vibration techniques.

GPS / GIS – based systems can schedule and transport wood directly to optimal processing location.

Summary
Precision Forestry is:
- The use of geospatial-based tools for planning and conducting site-specific and forest management activities and operations

Auburn’s goals:
- Develop technologies for acquiring data to help landowners improve management of their forests
Summary

Precision Forestry focus at Auburn:

- GPS-based tracking and monitoring systems developed and tested in forest operations
  - Site preparation and harvesting
  - Harvesting impacts on soil compaction measured
- Basic components of yield mapping techniques have been developed for tree-length harvesting systems
  - Optical diameter sensor developed and tested
  - Other sensing systems under development

- Techniques have been refined for site-specific herbicide and fertilizer application (with industry collaborators)
  - Mechanical and manual spraying systems
- New technology has been developed for quality assurance in manual tree planting operations
  - “Smart” dibble