

# Precision Forestry: Operational Tactics For Today And Tomorrow

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**ABSTRACT** - The term "Precision Forestry" is being used more frequently in the forest products industry. This paper defines two broad categories of precision forestry as 1) using geospatial information in forest management and planning, and 2) site-specific silvicultural operations. One case study is presented for site-specific application of herbicides and fertilizers in herbaceous weed control activities. In this case study, the operational characteristics and application costs are discussed for a new machine capable of applying both broadcast and banded herbicides and fertilizers. When compared to conventional systems, the precision forestry techniques reduced herbaceous weed control costs by as much as 47% and chemical use by one-third.

## INTRODUCTION

"Precision forestry" is a relatively new term that is undergoing a rapid increase in use in the forest engineering - forest operations community. This term is similar to those frequently used in agricultural production circles, i.e. "precision agriculture" or "precision farming." Over the last 20 years, the concepts of precision agriculture have been refined into a definition that most people will accept. That is, precision agriculture can be defined as managing crop inputs, such as fertilizer, herbicide, etc. on a site-specific basis to reduce waste, increase profits, and maintain the quality of the environment.

To bring together researchers and practitioners to discuss precision forestry, the first International Precision Forestry Symposium was held one year ago in Seattle, Washington (Farnum, 2001; Becker, 2001). Initially, one would think that the term "precision forestry" should have a very similar meaning to the frequently used "precision agriculture" term. Yet, as the symposium attempted to synthesize the current body of knowledge on precision forestry, it became evident that the term precision forestry has many different meanings depending on who uses the term. While many of the aspects of precision agriculture can be applied to forest management, the considerable differences between the two industries require a different, broader definition for precision forestry. The objectives of this paper are to:

- 1) Discuss and define the term precision forestry in the context of forest operations, and

- 2) Present one precision forestry case study for the application of fertilizer and herbicides.

## BACKGROUND

Precision agriculture techniques are centered around a database of geospatial information including soil fertility, crop yield and in some cases crop quality. Many harvesting machines now have yield monitors that collect continuous data on the amount of the crop being harvested as a function of location in the field. When yield maps are combined with soil fertility and soil type maps, management units within a field can be defined. Then, each management unit can have its own prescribed rates of fertilizer, herbicide, and pesticide. Using variable rate controller technology, the rates at which these inputs are applied can be changed as the applicator moves across the field. The ability to change fertilizer and herbicide application rates to suit the needs of each management unit leads to a more efficient use of these inputs and therefore reduced production costs and environmental impacts.

## PRECISION FORESTRY DEFINED

Since there are many differences between the forest products industry and the agricultural sector, all of the concepts of precision agriculture are not directly applicable to forest production systems. Moreover, there are different applications in forest management that can be considered part of precision forestry. We propose to define precision forestry as planning and conducting site-specific forest management activities and operations to

improve wood product quality and utilization, reduce waste, and increase profits, and maintain the quality of the environment. Further, we propose that the general field of precision forestry be separated into two main categories:

- 1) using geospatial-information to assist forest management and planning, and
- 2) site-specific silvicultural operations.

### **Geospatial-Information-Based Forest Management and Planning**

This area of precision forestry encompasses a wide variety of activities that use geospatial information to assist in the site-specific management of forests and planning of future operations. This actually encompasses many current management and planning activities since many industrial and private landowners use geospatial tools to manage their landbases. Traditional examples would include using GIS to help develop management plans for forested areas; however, what makes these activities fit under the precision forestry would be an emphasis on site-specific management.

New examples of this type of precision forestry include the use of information technology to optimize the transportation of wood products from the forest to their most appropriate processing location. Advances in wireless communication are at the point where much of this information can be shared from the harvesting machine directly to transportation dispatching services and to the manufacturing facilities.

### **Site-specific silvicultural operations**

Site specific silvicultural operations involve the use of geospatial technologies, such as GPS and GIS, to improve operational efficiency and reduce the cost of wood fiber. This involves using much of the technology developed for precision agriculture. Example technology includes using GPS and variable rate controllers to improve the efficiency of herbicide spraying or fertilizer application. This technology is readily available and is currently being used in forest operations on a limited basis. New technology has been developed to provide automated machine guidance for agricultural tractors that could also be adopted in certain forest operations.

Although the concept of yield maps as used in agriculture has not been attempted in forest production, it is technically feasible given the advanced product size sensors used on current cut-to-length harvesting systems. Also, research at Auburn has been developing similar instrumentation that can be placed on traditional wheeled

feller bunchers to measure tree size. Combining the tree or log size data with GPS position will make possible the development of forest yield maps.

### **Discussion**

There are several key components of both of these two categories. The primary component that is common to all forms of precision forestry is the use of geospatial technologies such as GPS, GIS, remote sensing, LIDAR, etc. as tools to assist in site-specific forest management, planning or silvicultural operations.

A second component in precision forestry is the development and use of an extensive information base to help make management and operational decisions. This information base could include data on product growth and yield, product quality, and environmental conditions as a function of location and time. A critical part of this use of information is the feedback mechanism that is possible. In other words, it is possible to take the spatially attributed data on yield and use it to validate and refine growth and yield models so that future management strategies can increase return on investment for the landowner.

A final concept in precision forestry is that of defining the the most appropriate management unit. As a start, this would involve examining stand maps, terrain information, soil maps, and soil fertility maps along with other information such as wildlife habitat, etc. Eventually, this should incorporate the development of yield maps but with additional information on product quality. Once the size or number of management units is determined, more focused management and operational decisions can be made on site-specific bases.

Precision forestry should not mean that every operation is computerized or automated. Many site-specific silvicultural operations can be conducted in a cost effective manner without being automated. What it should mean is that the management process or operational activity is focused on making decisions for the smallest practical management unit area or number of management units within a given tract or management area. For example, this could determine how much fertilizer or which herbicide is applied at a particular location on a tract.

Using many of the methods from precision agriculture, we can envision that these geospatial technologies can help the forest products industry adopt a scenario like the following :

- 1) Develop yield maps during harvesting operations. From the yield maps, begin to quantify variability in wood

quality and wood fiber production rates as a function of location.

- 2) Once variability is quantified, identify site conditions that contribute to that variability (e.g. soil type, soil fertility, moisture conditions, etc.).
- 3) Track the types and dates of operational practices and prescriptions that are carried out during the rotation (fertilization, herbicide application, seedling quality, planting methods, etc.). It may be possible to track tree growth during the rotation using remote sensing data or other methods on the ground.
- 4) With a record of these data, begin to conduct comprehensive analyses to determine what contributes to spatial and temporal variability in seedling survival rates, wood fiber growth rates, and final wood quality.
- 5) Using these conclusions, determine the most appropriate management unit size or number of management units for the operations.
- 6) Using these management units and the previously collected data, plan future silvicultural operations for the same rotation or the subsequent rotations. Fertilizer and herbicide application rates, planting density, etc. can be varied as a function of location depending on the site conditions.
- 7) At the time of the next harvest, product type and quality can be recorded and even used in determining the optimal use for the product as well as the optimal destination for further processing of the product.

### **CASE STUDY: SITE-SPECIFIC APPLICATION OF FERTILIZER AND HERBICIDES**

A case study is presented here as an example of the use of precision forestry techniques for site-specific silvicultural operations. This example shows how herbaceous weed control costs can be reduced and chemical use efficiency improved by using precision forestry techniques.

#### **Operational Description**

During 1999 and 2000, Woodlands Specialists, Inc. in Chapman, Alabama began developing the concepts for a new type of sprayer for application of herbicides and liquid fertilizers. Tigercat of Bradford, Ontario, Canada performed the detailed design and subsequent fabrication of the machine during 2000, with delivery and first use of the machine occurring in the fall of 2000.

The machine, referred to as the WS Sprayer, is shown in Figure 1 and is constructed on the same chassis used for a wheeled feller buncher. Using the feller buncher chassis provides several advantages. First, the cab-forward design inherent in a feller buncher allows greater visibility for the operator. Second, the weight distribution of the feller buncher chassis allowed the designers to place a

large water tank on the front of the machine where tanks and pumps are more accessible.

Herbicides are not tank mixed, rather the machine contains one main 500 gallon water tank with chemicals injected at the nozzles. This design allows many different chemicals to be placed on the machine and used only when determined by the operator or the spray controller. Variable rate pumps are used to deliver chemicals to the spray nozzles.

An additional 250 gallon tank is mounted on the rear of the machine. This tank allows liquid fertilizer to be applied. When not in use for fertilizer, the tank can hold additional water for herbicide spraying.

A Midtech spray control system is used to monitor navigation of the machine and control injection of chemicals. The controller uses GPS to determine the location and speed of the machine. The controller also monitors water flow rate, band width, and herbicide application rate. Using these inputs, the control system then determines how much herbicide to inject into the spray pump for application to the site. This variable rate control is critical to efficient use of the chemical as the ground speed of forestry sprayers can be highly variable.

Herbicides are injected in their original concentration from the manufacturer, except for dry flowable formulations such as Oust, Oustar, and Velpar. Using the injection system means that there is no measuring or mixing of chemicals, which minimizes exposure to the operator. Also, there is no leftover tank mix solution to dispose of at the completion of the tract; only the amount of product needed on the tract is applied. In its current configuration, the sprayer can inject three different products; however, up to six injection pumps can be used on the machine. Spraying prescriptions can be easily changed using the control console.

The spray control system provides a field computer display and a light bar so the operator can see where they have sprayed and where they need to steer the machine. By comparing this real time map to maps provided by the customer, the operator can insure that all designated areas are treated. There is also the capability to download a digital tract map from the customer to the field computer before beginning the tract. Finally, an "as-applied" map is stored in the controller that can be downloaded and provided to the customer for incorporation into a GIS database. A typical spray map is shown in Figure 2. This map shows the machine path as it is spraying and it indicates areas that were not sprayed.

The machine has been configured for two types of operation: 1) broadcast spraying and 2) banded spraying.

In broadcast spraying, two Radiarc nozzles are mounted on the upper rear portion of the machine so that a 50-ft-wide strip can be sprayed during chemical site preparation or during understory release spraying. The Radiarc nozzles provide a uniform spray pattern and they provide uniform droplets of large diameter to reduce drift. In banded spraying, booms with six Teejet spray nozzles on a common manifold are mounted on the front of the machine. These nozzles are shielded, positioned close to the ground, and operated at low pressures to reduce drift. The booms are configured to spray a band of herbicide directly over each of three rows. Also, liquid fertilizer can be applied along the row using the same booms.

### **Cost Comparison of Herbaceous Weed Control Methods**

Table 1 contains a comparison of costs for the WS Sprayer to those of three other herbaceous weed control methods. These methods are: 1) helicopter broadcast application of herbicide and fixed wing aircraft broadcast application of fertilizer, 2) a single pass of a modified skidder applying herbicide and liquid fertilizer in a band on a single row, 3) a combination of banded backpack sprayer application of herbicide and fixed wing broadcast application of fertilizer, and 4) a single pass of the WS sprayer applying herbicide and fertilizer in bands over three rows.

The cost data in the table are based on herbicide application rates of 48 oz/acre for Velpar and 3 oz/acre for Oust. Herbicide costs were assumed at \$0.39/oz and \$10.50/oz for Velpar and Oust, respectively. Fertilizer was assumed to be either DAP or Liquid Green applied at rates of 125 lbs/treated acre and 155 lbs/treated acre, respectively, which results in 57 lbs of phosphorous per treated acre. Unit costs of the fertilizers were assumed at \$0.11 and \$ 0.12 per lb for DAP and Liquid Green, respectively.

By applying the herbicides and fertilizer in a band over the row, only those areas close to the tree are treated, thereby reducing by approximately 2/3 the amount of herbicide and fertilizer that is applied to the tract. Studies have shown that by applying the herbicide in a 4-ft-wide band around the tree, the growth response is the same as in broadcast herbicide applications. Also, by applying the fertilizer in a band, it is left in a concentrated stream a few inches from the tree, where it will be most effective. In addition, by applying the fertilizer in a band, the total amount of fertilizer applied to the tract will be much less than needed in a broadcast application. The effect of this method of fertilization on growth rates has not been quantified.

The data in the table indicate that an operation like the WS sprayer combined herbicide and fertilizer treatment has the lowest total cost of the four methods. The estimated cost for the WS Sprayer was \$48 per acre compared to \$91 per acre for the aerial applications of herbicide and fertilizer. If the objective was only to apply herbicide, the backpack sprayer method has a lower cost. However, this method has several issues that relate to health concerns for the workers. Clearly, by performing a more site-specific application of herbicides and fertilizers, and by combining operations to limit machine passes, the cost of herbaceous weed control can be reduced significantly. Perhaps just as important as reducing cost, the use of herbicides and fertilizers can be reduced by two-thirds in this operation.

An additional benefit of this type of operation is that the locations of the rows are established by the GPS track of the sprayer. This map can now serve as the beginning of the complete geospatial history for the tract. In fact, the machine is capable of using a dye to mark the potential locations of tree seedlings and record this in the GPS map. This ability to mark the recommended tree location is important for manual tree planting operations since during winter planting operations, it is often difficult to distinguish the location of the herbicide treated row because all the surrounding vegetation is dead as well.

### **SUMMARY**

Precision forestry is a rapidly developing field but there is no universally-accepted definition of precision forestry. We defined precision forestry as planning and conducting site-specific forest management activities and operations to improve wood product quality and utilization, reduce waste, increase profits, and maintain the quality of the environment. Precision forestry can be categorized into two main areas: 1) using geospatial-information to help make forest management and planning decisions; and 2) conducting site-specific silvicultural operations. Finally, we reviewed one case study of a sprayer performing herbaceous weed control that uses many of the site-specific silvicultural operations techniques. In this case, the precision forestry techniques resulted in cost savings up to 47% and chemical use reductions of two-thirds when compared to traditional application methods of herbicide and fertilizer.

**REFERENCES**

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Table 1. Cost comparison of various herbaceous weed control methods.

<i>Application &amp; Materials - Cost Per Acre(US Dollars)</i>				
	<b>Helicopter &amp; Fixed-Wing</b>	<b>Skidder Single Row Combo</b>	<b>Back Pack &amp; Fixed Wing</b>	<b>WS-Sprayer Three Row</b>
<b>2-Pass</b>	<b>Broadcast</b>	<b>Banded</b>	<b>Banded</b>	<b>Banded</b>
<b>Helicopter</b>				
<b>Application</b>	<b>\$19.00</b>			
<b>Velpar</b>	<b>\$18.75</b>			
<b>Oust</b>	<b>\$31.50</b>			
<b>Subtotal</b>	<b>\$69.25</b>			
<b>Farm Tractor</b>				
<b>Application</b>			<b>\$17.00</b>	
<b>Velpar</b>			<b>\$6.25</b>	
<b>Oust</b>			<b>\$10.50</b>	
<b>Subtotal</b>			<b>\$33.75</b>	
<b>Fixed Wing</b>				
<b>Application</b>	<b>\$8.00</b>		<b>\$8.00</b>	
<b>Fertilizer</b>	<b>\$13.44</b>		<b>\$13.44</b>	
<b>Subtotal</b>	<b>\$21.44</b>		<b>\$21.44</b>	
<b>1-Pass Banded</b>				
<b>Application</b>		<b>\$32.00</b>		<b>\$25.00</b>
<b>Velpar</b>		<b>\$6.25</b>		<b>\$6.25</b>
<b>Oust</b>		<b>\$10.50</b>		<b>\$10.50</b>
<b>Fertilizer</b>		<b>\$4.48</b>		<b>\$5.94</b>
<b>Total</b>	<b>\$90.69</b>	<b>\$53.23</b>	<b>\$55.19</b>	<b>\$47.69</b>
<b>WS Sprayer Savings</b>	<b>47%</b>	<b>10%</b>	<b>14%</b>	



Figure 1. Photograph of WS sprayer configured for banded spraying. Inset shows the cab with field computer and other spray controller equipment.

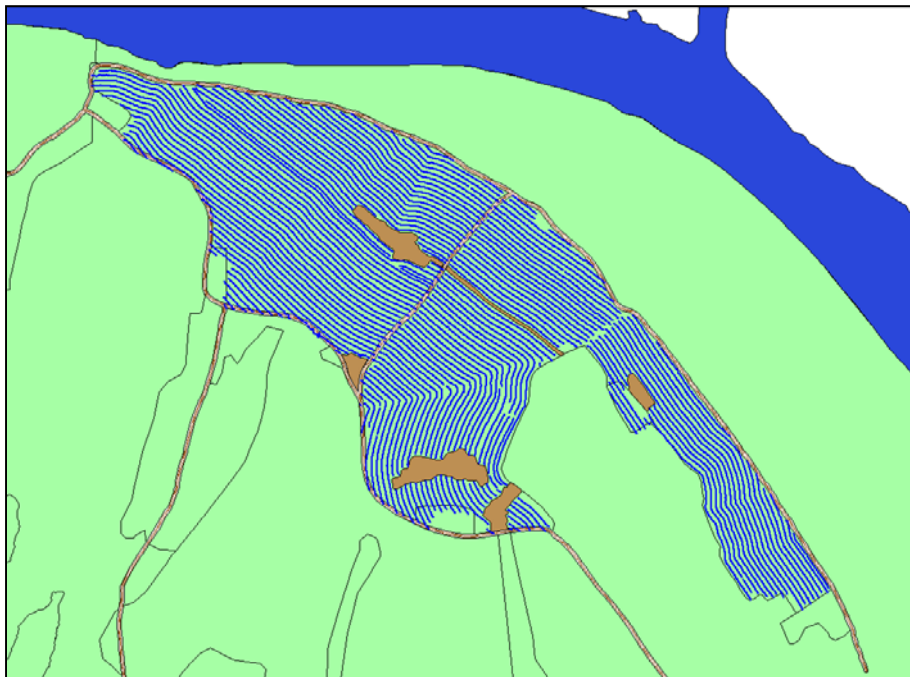


Figure 2. Typical "as-applied" map showing results from spraying operations. The blue line indicates sprayer path when spraying activated. Brown regions show areas not sprayed.