# An Overview of Harvest Scheduling Models

Formulated using Woodstock

April 15, 2023

KR Walters
Consulting Services

## What Is Harvest Scheduling?

- A planning tool that prescribes what areas of forest to harvest and when
- Choose among harvest methods and criteria for selection
  - Clear cutting, selection harvests, commercial thinning, shelterwood method
- Choose among reforestation methods and other silviculture
  - Natural seeding, hand planting, machine planting
  - Conventional open pollinated stock, genetically improved and clonal stock
  - Fertilization at reforestation, post-thinning or mid-rotation
- Every choice needs yield information to choose among the alternatives
  - For each activity, a yield table predicts growth with and without the treatment
- Problem size can grow very large if number of choices grows very large

KR Walters Consulting Services

Although it is called harvest scheduling, a better term would be forest management scheduling because harvesting is only one activity that can be considered in these models.

# Model Components

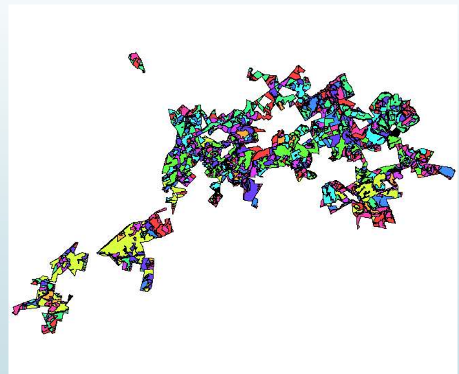
| Model Section | Purpose |
|---|---|
| LANDSCAPE | Way to describe current stand state |
| AREAS | Initial condition of forest by stand/area |
| ACTIONS | Activities to be considered by stand |
| TRANSITIONS | Identify new stand after treatment |
| OUTPUTS | Key performance indicators (KPIs) |
| – Inventory-based | – Forest conditions |
| – Action-based | – Commodities produced by activities |
| OPTIMIZE | Defines the type of solution desired |
| – Objective function | – KPI to be maximized or minimized |
| – Constraints | – Restrictions on KPIs |

KR Walters Consulting Services

A Woodstock model is basically a state model for a collection of forest areas called development types. While these can be stands, there is no requirement that they be so. A development type is a unique piece of ground that we can describe in a systematic way, based on species composition, age, site productivity, density, administrative boundary, etc. To effectively model outcomes for development types, we need to be able to predict future states such as volume, height, basal area, etc. If we clearcut a development type, the volume standing in that planning period is the harvest volume. However, if we only partially harvest a stand, we need to predict the volume removed and the residual state after treatment (again, volume, height, basal area, etc.). If we consider all the possible states of the development types in all planning periods, an optimization solver can choose those treatments that represent future outcomes that we desire. What we need to tell the solver is the kind of solution we seek: to maximize harvest volume or minimize costs, and what conditions to place on forest states or output flows (e.g. greater than some value, equal to some value, or less than some value).

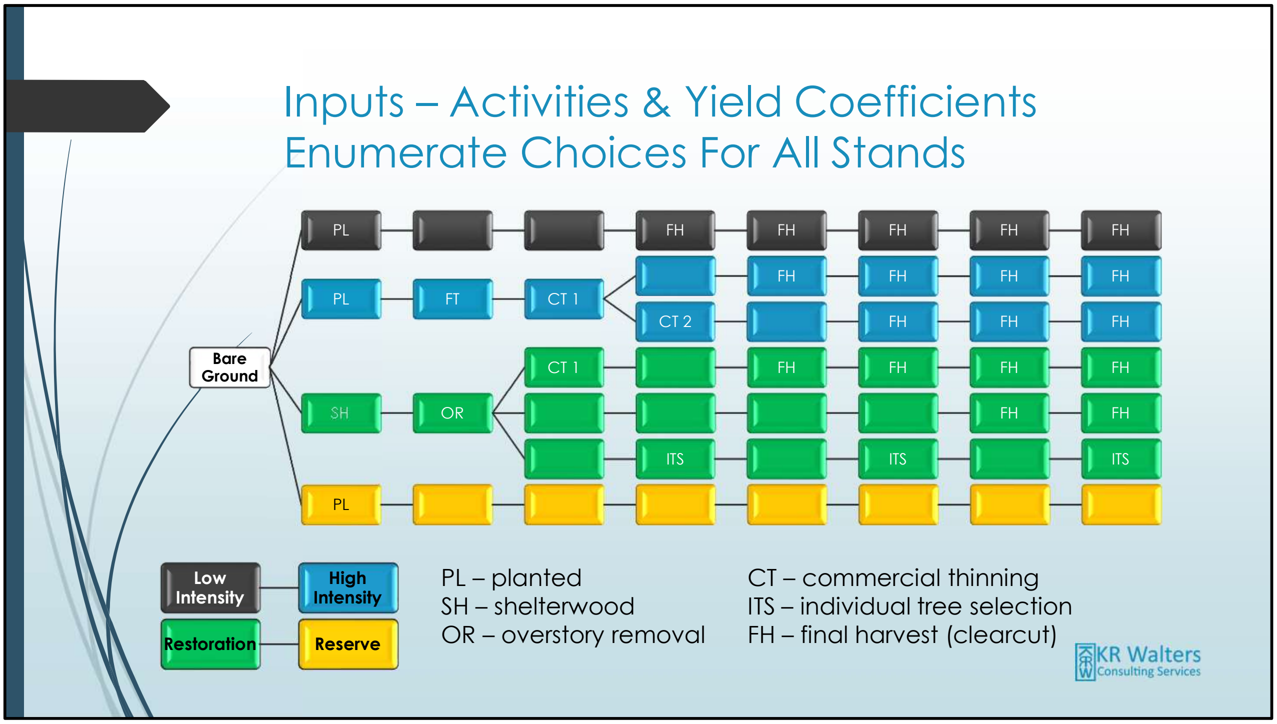
## Inputs – Forest Area

- Mapped planning layer characterized by
  - Forest type
  - Age
  - Site Index
- Intersection of layers = forest development type (e.g., stand)
- Map represents current condition of the forest estate

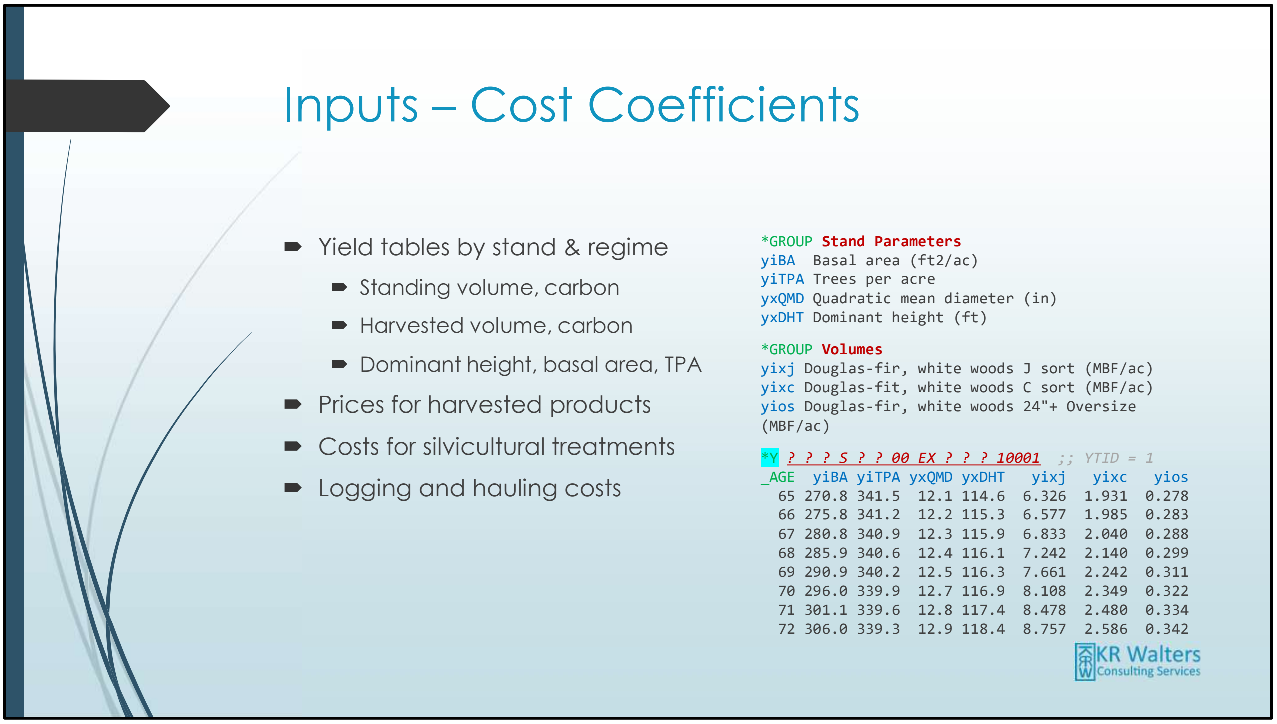


KR Walters Consulting Services

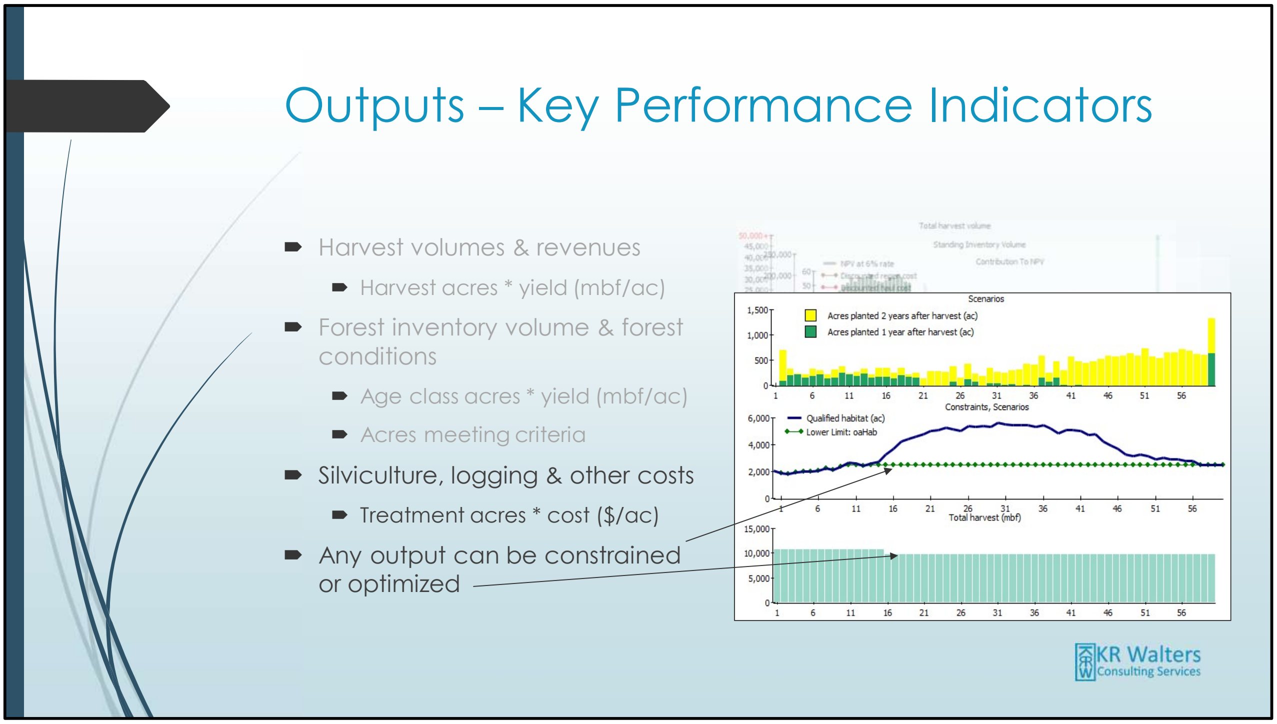
The mapped planning area represents the initial state of the forest for modeling. GIS layers are often separated by data type: stand polygons (species composition and age), soils polygons (representative of site productivity), administrative boundaries, etc. If we intersect all these layers, the resulting polygons represent unique combinations of attributes (development types), and this information is used to initialize the harvest scheduling model. Yield tables are assigned to each development type and so we can predict the future outcomes for them. Rules are applied based on attributes to determine if activities such as clearcutting, planting are allowed. The model can also choose management emphases based on certain combinations of attributes. These assignments in turn determine what types of harvesting or reforestation are permitted.




In the graphic I have identified all the possible regimes available to a particular development type. However, there is no need for every DevType to be eligible for every regime. Woodstock allows you to tailor choices based on the way you described the forest. For example, some stands may start out unassigned to any management emphasis while others may already be assigned to reserve or high intensity management. The regimes available to the pre-assigned stands will only be the ones matching the color scheme in the graphic. This can reduce the potential size of the model a great deal. For stands that are not assigned, there are many choices, and each branch of the decision tree must be projected using a growth and yield model.




Yield tables are the product of growth & yield projections. For each future period or age of the stand, standard metrics are reported such as basal area, trees per acre, quadratic mean diameter and volumes by species and log size. The YIELDS section also stores cost coefficients for log prices, hauling cost ($/mbf), planting costs ($/ac), and so forth. Yield tables are fundamental to modeling: if you cannot measure and predict a metric, you cannot model it. Sometimes a metric can be derived from or represented by other metrics (proxy) but sometimes there just is no way to predict a condition beyond its current state. Such metrics cannot be modeled.




If metrics can be predicted, then you can produce key performance indicators based on them as outputs. A Woodstock output can be anything (harvest volume, clearcut acres, acres planted, silviculture budget, etc.). Outputs in turn can be optimized:

- _MAX ohTotal 1.._LENGTH *; maximize total harvest volume*
- _MAX orTotal 1.._LENGTH *; maximize total harvest revenue*
- _MAX ordTotal – ocdTotal 1.._LENGTH *; maximize discounted revenue – discounted costs*
- _MIN ocTotal 1.._LENGTH *; minimize total costs*

Outputs can also be constrained:

- _EVEN(ohTotal, 5%) *; apply bounded even-flow to total harvest volume (maximum difference across all periods = 5%)*
- oaQHAB >= 2000 10.._LENGTH *; qualified habitat acres must equal or exceed 2000 in every planning period from 10 onward*
- orTotal – ocTotal >= 0 1.._LENGTH *; revenues must equal or exceed expenditures in every planning period*