

Linking LP Models with Spatially-Explicit Models for Forest Planning

Presented by Michael Buell R.P.F., Dipl., GIS, IT
14 June 2007

Presentation Outline

- Background
 - **Why both model types?**
 - **What dictates model use?**
 - **Case study**
- Technology
- Analytical Framework
- Summary

Background

Why LP *and* spatially-explicit models?

■ Optimization models:

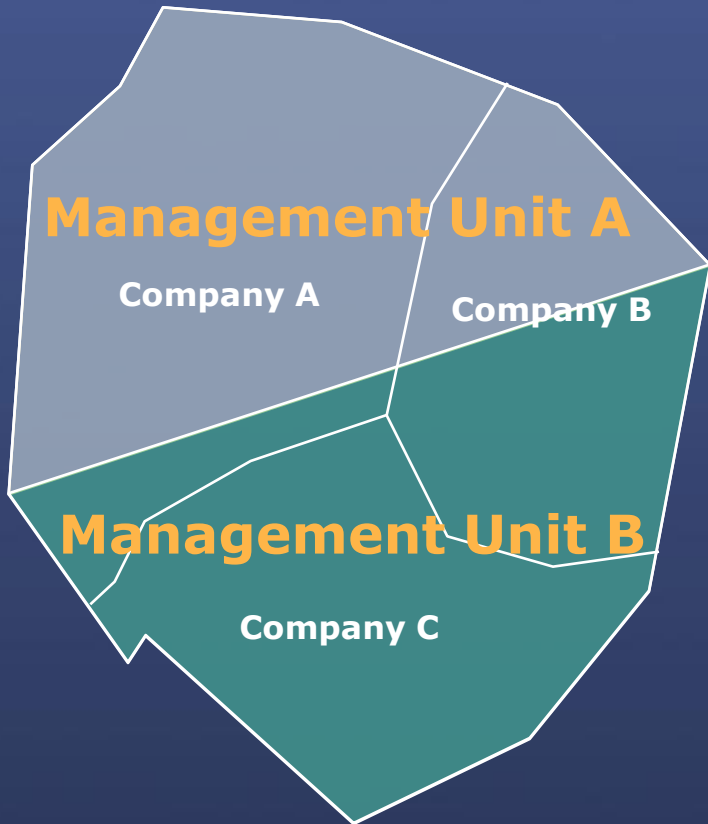
- are efficient and can deal with complex problems
- cannot carry spatial detail for large, complex problems, use strata for a quasi-spatial approach

■ Raster-based simulation models:

- can bring in spatial details (e.g., roads) and spatial constraints (e.g., maximum block size and adjacency)

Background

Forest modeling considerations



Scope and Complexity

- 1.2 million ha parcel made up of management units A and B
- overarching policies guide management units A and B
- management units A and B have separate policies on young and old forest as well as the amount of harvesting that can occur
- companies A, B, and C have different harvest policies and product objectives

Background

Alternative model structures

Optimization

- polygon based
- quality of solution is known
- efficient, inexpensive
- extensible to log allocation analyses
- aspatial (quasi-spatial)

Simulation

- raster based
- quality of solution unknown
- lengthy, multiple simulations to obtain a solution
- not extensible to log allocation analysis
- spatial

Linking LP Models with Spatially-Explicit Models for Forest Planning

Background – Our case study

- Select the proper technology to solve the problem
 - select an aspatial optimization model that can be linked to a raster-based simulation model
- Technologies selected in this case study
 - ESRI's Spatial Analyst
 - Remsoft's Spatial Planning System (RSPS)
 - MOSEK
 - SELES

Linking LP Models with Spatially-Explicit Models for Forest Planning

Technology – ESRI Spatial Analyst

- Produces the ascii grids used in SELES
- Spatial resolution is dependent on the size and complexity of the land base
- SELES exports temporal ascii grids which are then imported using Spatial Analyst

Linking LP Models with Spatially-Explicit Models for Forest Planning

Technology – RSPS

- Allows the problem to be represented aspatially
- Can model multiple objectives
- Builds the LP model that will be solved
- Converts the solution from the solver software to an activity schedule that will be linked to the spatial simulation model

Linking LP Models with Spatially-Explicit Models for Forest Planning

Technology – MOSEK

- Solves the LP matrix produced by RSPS
- Shadow prices provide insight into the importance of strata and constraints in the model

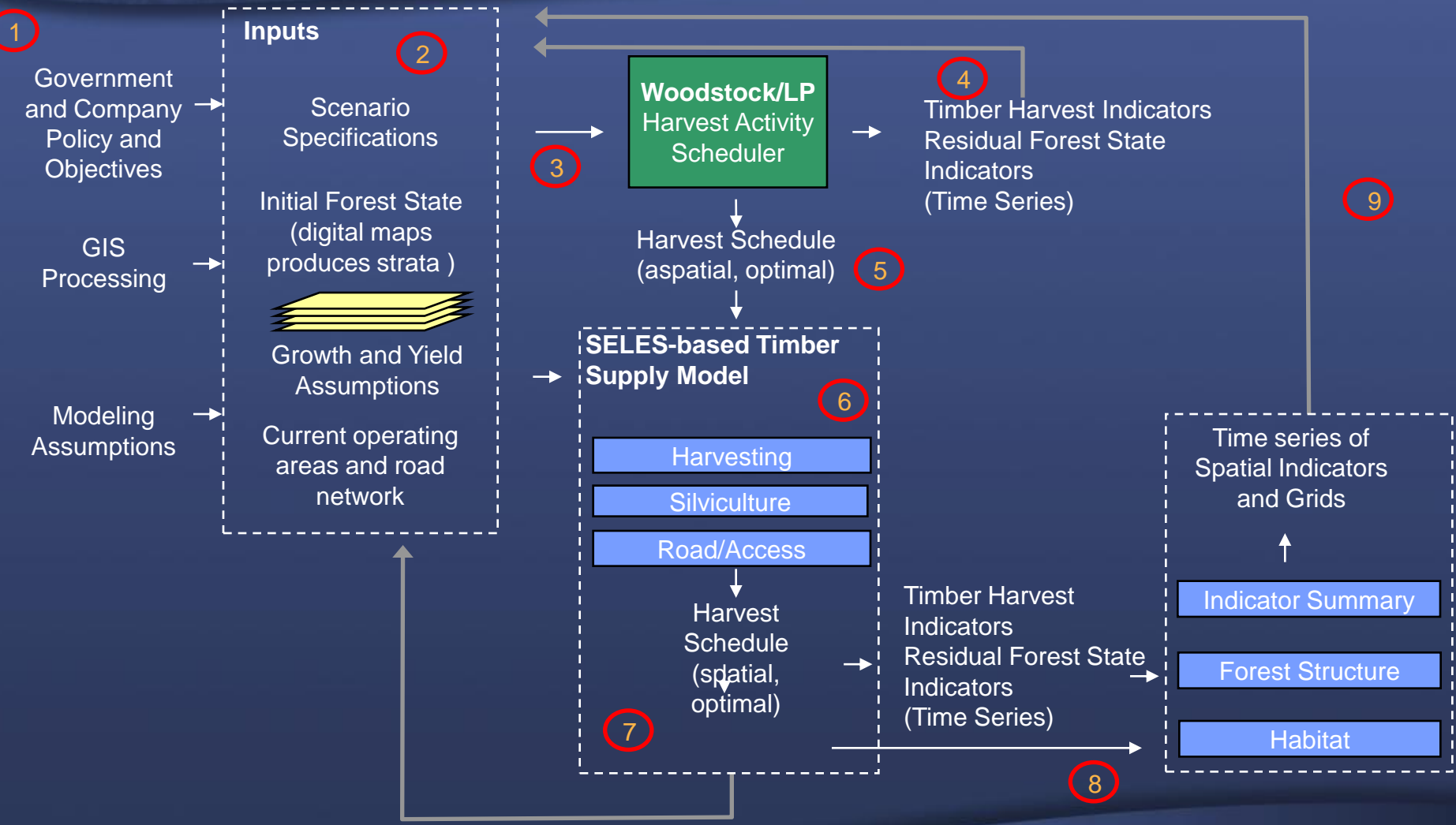
Linking LP Models with Spatially-Explicit Models for Forest Planning

Technology – SELES

- Allows the problem to be represented spatially
- Blocks the optimal aspatial RSPS harvest schedule
- Apply spatial constraints on the land base
- Build the future road network
- Adjust the schedule using a cost surface

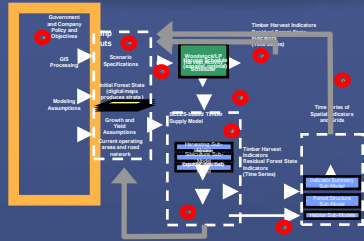
Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework



Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 1



Government and Company Policy, Objectives

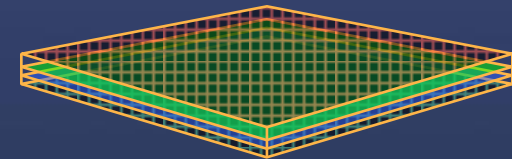
- company objectives: maximize net revenue
- company policy: ensure 70% of harvest volume from Fir
- government policy: ensure a minimum income to government
- government objectives e.g. ensure a minimum area of old-growth forest

GIS Processing

- ESRI Spatial Analyst produces the ascii grids
- check existing and predicted data

Modeling Assumptions

- operability and growth and yield
- forest cover and critical habitat constraints
- length of the planning horizon will be determined by consensus



1

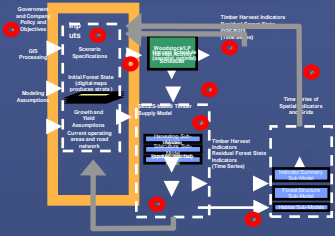
Government and Company Policy and Objectives

GIS Processing

Modeling Assumptions

Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 2



Scenario Specifications (examples)

- scenario 1: maximize net revenue while ensuring that old growth forest \geq 30% of land base
- scenario 2: maximize net revenue while ensuring that old growth forest \geq 70% of land base

Inputs

2

Scenario Specifications

Initial Forest State
(digital maps produces strata)

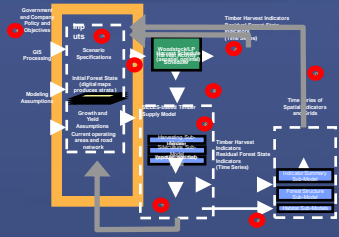


Growth and Yield Assumptions

Current operating areas and road network

Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 2 continued



Initial Forest State

- SELES produces the aspatial inventory file for Woodstock
- strata are produced that provide a link between SELES and Woodstock

Inputs

2

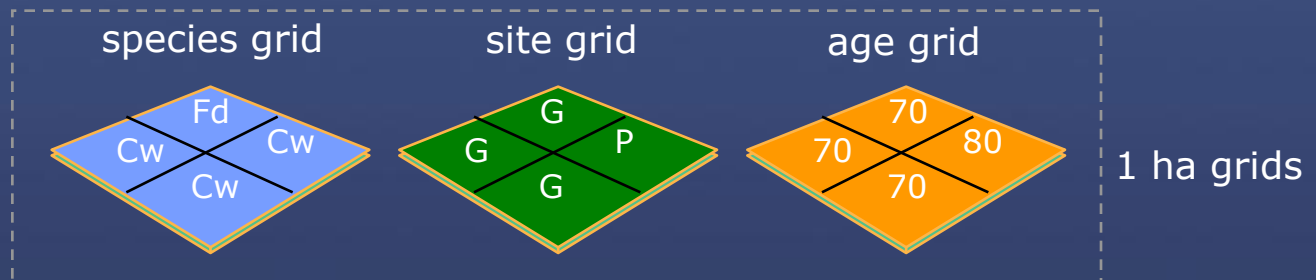
Scenario Specifications

Initial Forest State
(digital maps produces strata)



Growth and Yield Assumptions

Current operating areas and road network

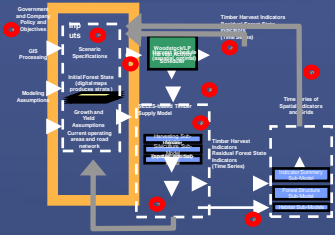


Woodstock aspatial inventory file

Strata_ID	Species	Site	Age	Area
1	Fd	G	70	1
2	Cw	G	70	2
3	Cw	P	80	1

Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 2 continued



Growth and Yield Assumptions

- growth and yield models are used to produce yield curves that predict forest products outputs
- prices are attached to the product curves

Inputs

2

Scenario Specifications

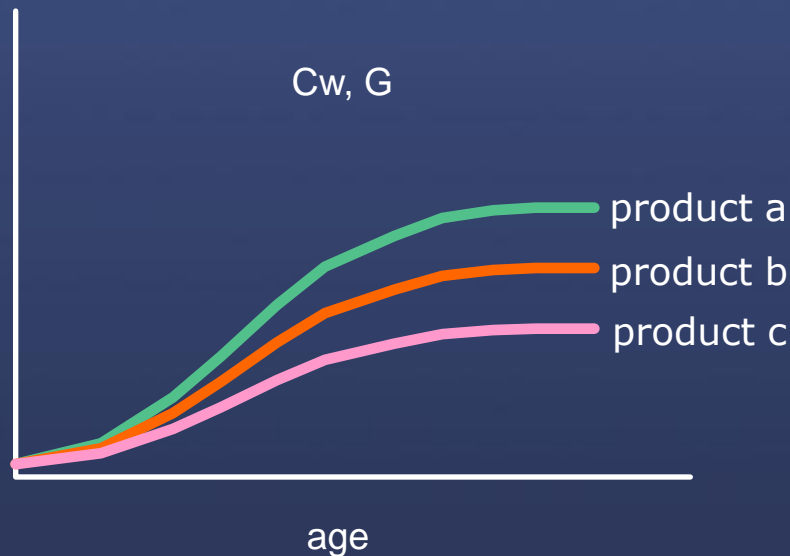
Initial Forest State
(digital maps produces strata)



Growth and Yield Assumptions

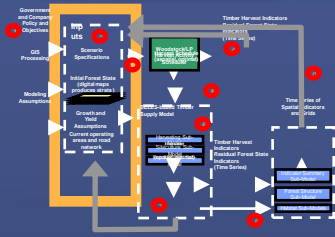
Current operating areas and road network

vol / ha



Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 2 continued



Current operating areas and road network

- current operating areas and existing road network is provided
- operating areas and existing roads are included when formulating the strata
- costs are associated with operating areas
- inoperable areas are identified and included when formulating the strata

Inputs

2

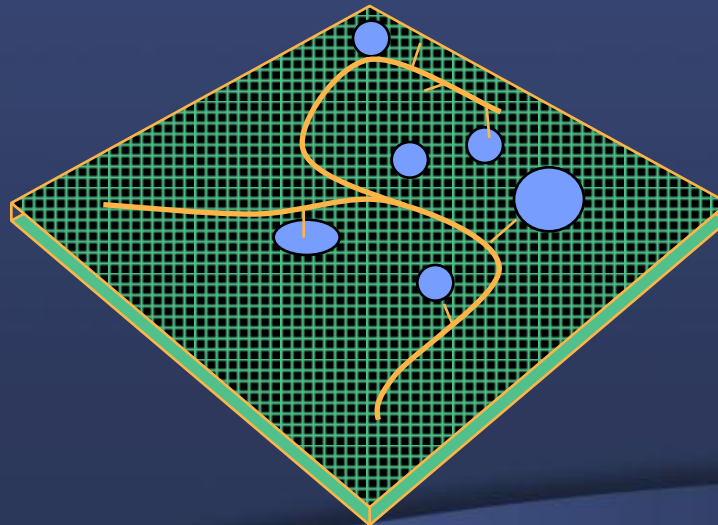
Scenario Specifications

Initial Forest State
(digital maps produces strata)



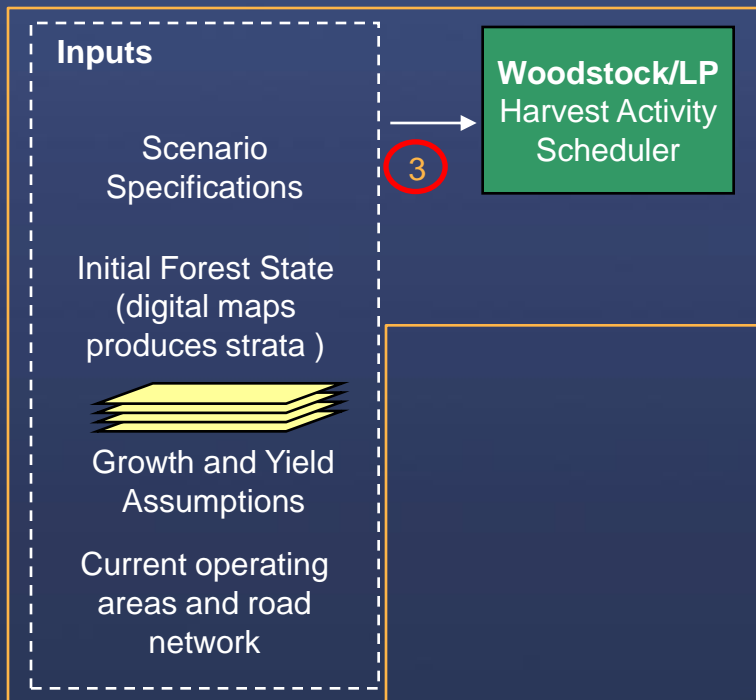
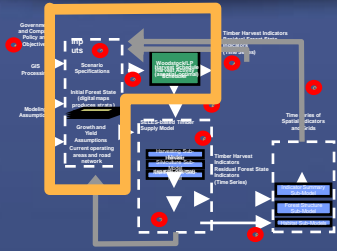
Growth and Yield Assumptions

Current operating areas and road network



Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 3 – Build the model



- Inventory File
 - strata based inventory records

- Yields File
 - yield tables linked to strata - product yield, price and costs

- Actions File
 - activities and timings, e.g. clearcut if age \geq 80 years

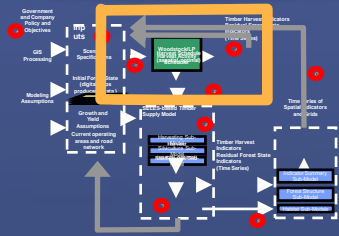
- Transitions File
 - what happens after an action, e.g. plant clearcut stands

- Outputs File
 - user defined outputs

- LP File
 - objectives and constraints

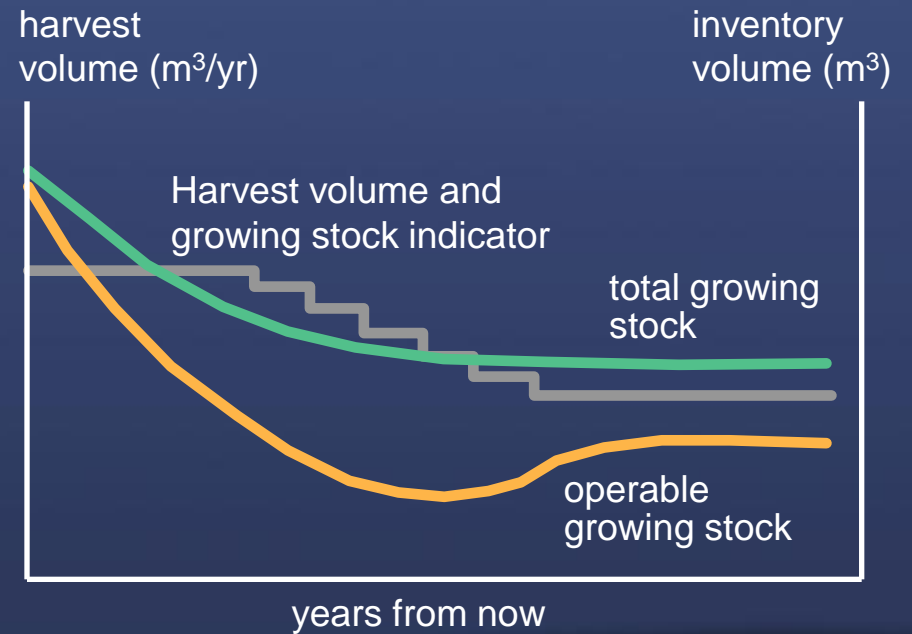
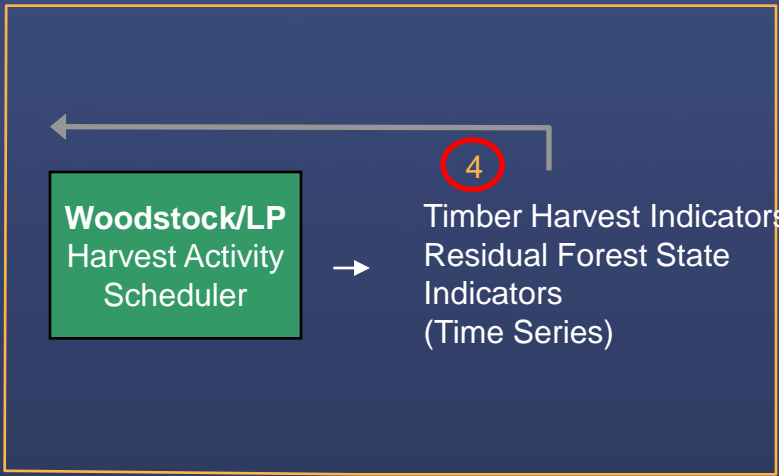
Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 4



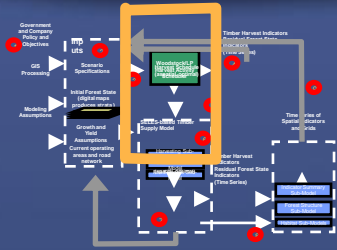
Confirm timber and residual forest indicators

- check that results are in line with what is expected; if not go back to Step 2
- timber indicators
- residual forest state indicators



Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 5



Build the activity schedule to be used in SELES

- Woodstock produces the activity schedule that is linked by Strata_ID to SELES

**Woodstock/LP
Harvest Activity
Scheduler**

Harvest Schedule
(aspatial, optimal)

5

Woodstock harvest schedule

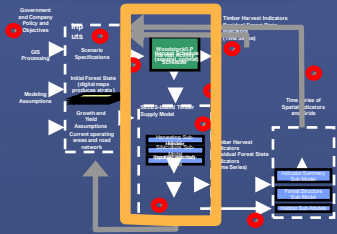
Strata_ID	2007	2008	2009	2010
1	1	0	0	0
2	1	0	0	0
3	0	0	0	1

Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 6

Produce the spatial harvest schedule and time series of timber indicators

- set up the SELES model to reflect spatial considerations



Woodstock/LP
Harvest Activity
Scheduler

Harvest Schedule
(aspatial, optimal)

SELES-based Timber
Supply Model

6

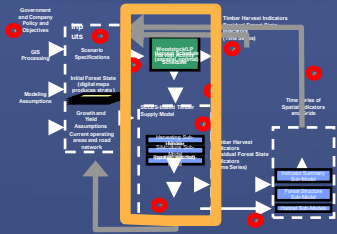
Harvesting

Silviculture

Road/Access

Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 6



Produce the spatial harvest schedule and time series of timber indicators

- set up the SELES model to reflect spatial considerations
- set maximum block size and adjacency
 - max block size may be 2 ha
 - adjacency e.g., blocks harvested in the same year must be 100 m apart
- ensure blocks are within 200 m of an existing road
- limit road building costs by year

Woodstock/LP
Harvest Activity
Scheduler

Harvest Schedule
(aspatial, optimal)

SELES-based Timber
Supply Model

6

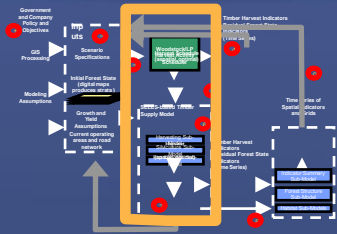
Harvesting

Silviculture

Road/Access

Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 6



Produce the spatial harvest schedule and time series of timber indicators

- set up the SELES model to reflect spatial considerations
- set maximum block size and adjacency
 - max block size may be 2 ha
 - adjacency e.g., blocks harvested in the same year must be 100 m apart
- ensure blocks are within 200 m of an existing road
- limit road building costs by year

Woodstock/LP
Harvest Activity
Scheduler

Harvest Schedule
(aspatial, optimal)

SELES-based Timber
Supply Model

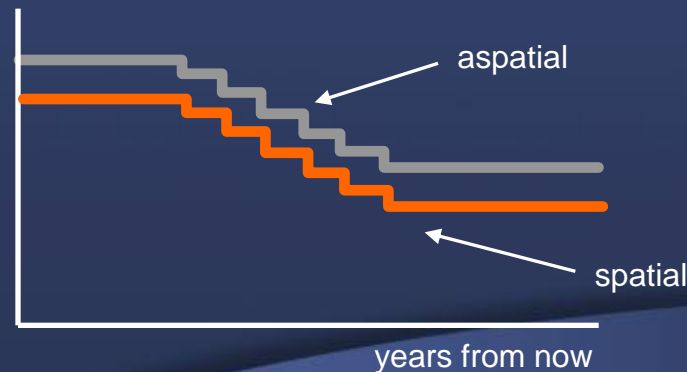
6

Harvesting

Silviculture

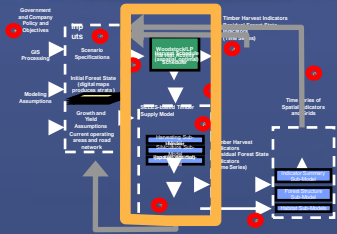
Road/Access

harvest volume (m³/yr)



Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 6 continued



Why the loss in harvest volume between the aspatial and spatial model?

- maximum block size is 2 ha
- blocks formed in the same year must be 100 m apart

**Woodstock/LP
Harvest Activity
Scheduler**

Harvest Schedule
(aspatial, optimal)

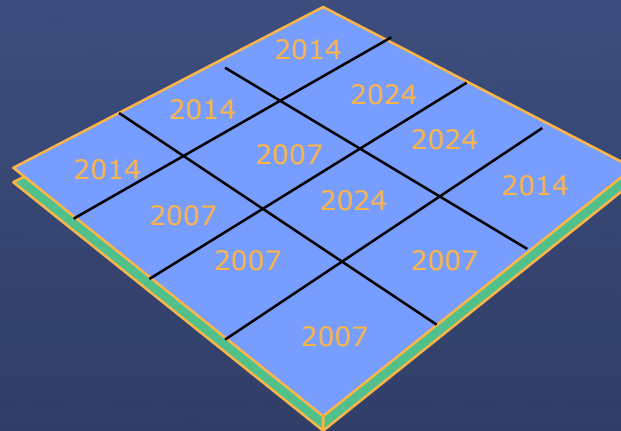
**SELES-based Timber
Supply Model**

6

Harvesting

Silviculture

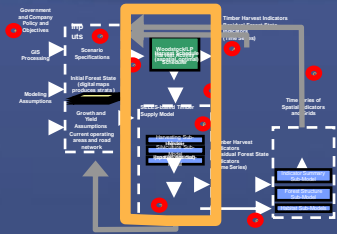
Road/Access



1 ha cells

Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 6 continued



Why the loss in harvest volume between the aspatial and spatial model?

- maximum block size is 2 ha
- blocks formed in the same year must be 100 m apart

**Woodstock/LP
Harvest Activity
Scheduler**

Harvest Schedule
(aspatial, optimal)

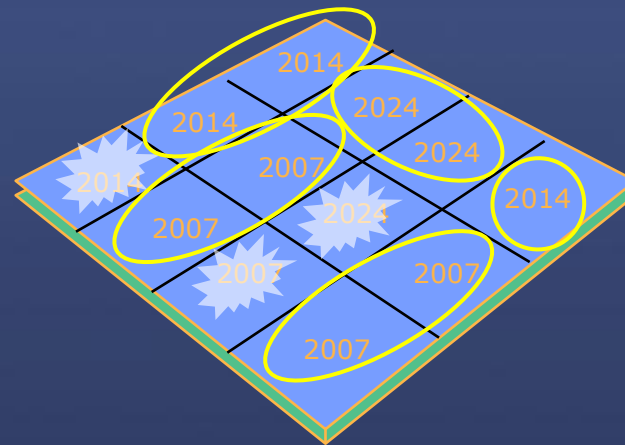
**SELES-based Timber
Supply Model**

6

Harvesting

Silviculture

Road/Access



block formed



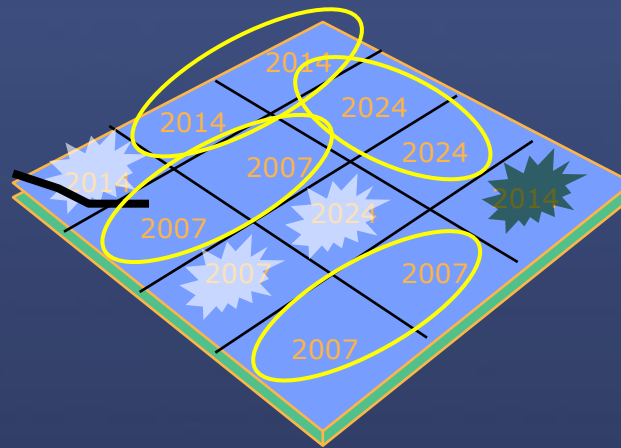
potential block
within 100 m

Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 6 continued

Why the loss in harvest volume between aspatial and spatial model?

- blocks must be 200 m to road



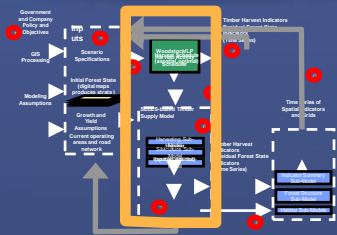
block formed



potential block within 100 m



potential block not within 200 m of road



**Woodstock/LP
Harvest Activity
Scheduler**

Harvest Schedule
(aspatial, optimal)

**SELES-based Timber
Supply Model**

6

Harvesting

Silviculture

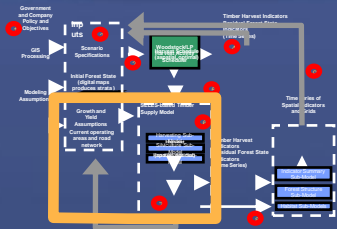
Road/Access

Linking LP Models with Spatially-Explicit Models for Forest Planning

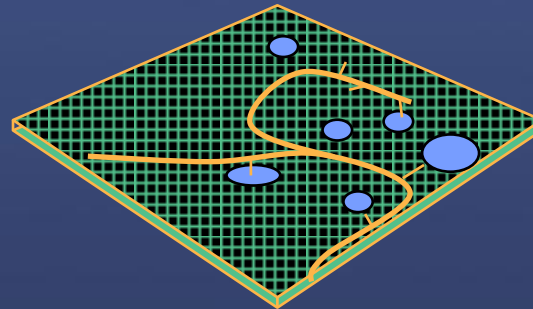
Analytical Framework – Step 7

Review the feasibility / desirability of the spatial schedules and indicators

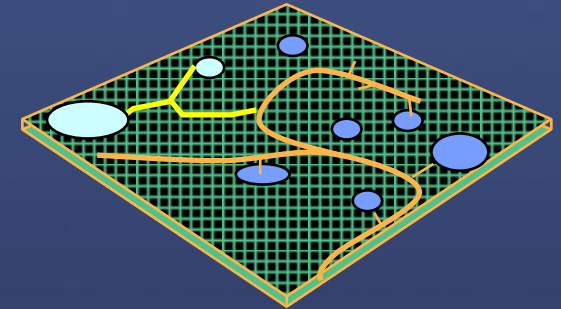
- if necessary go back to Step 2 and make adjustments to input data or model parameters



Current



10 years from now



SELES-based Timber Supply Model

Harvesting

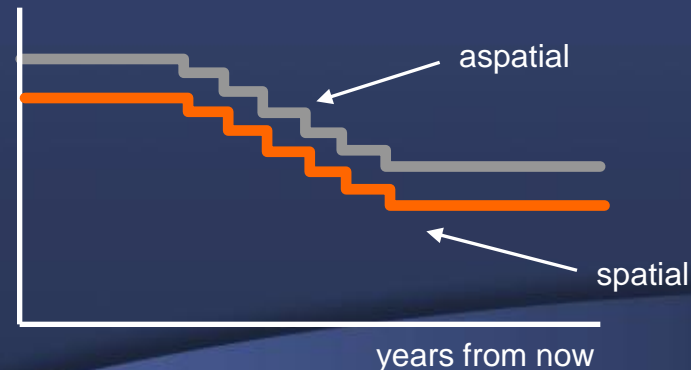
Silviculture

Road/Access

Harvest Schedule
(spatial, optimal)

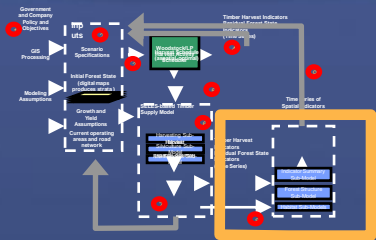
7

harvest volume (m³/yr)

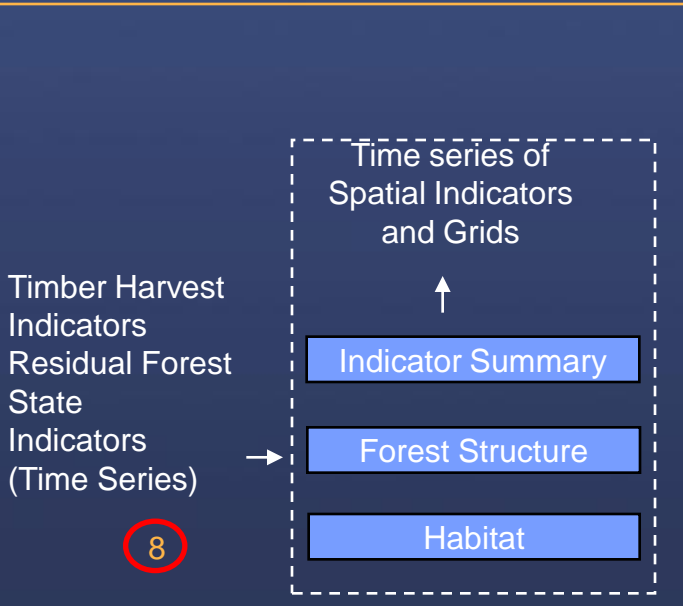
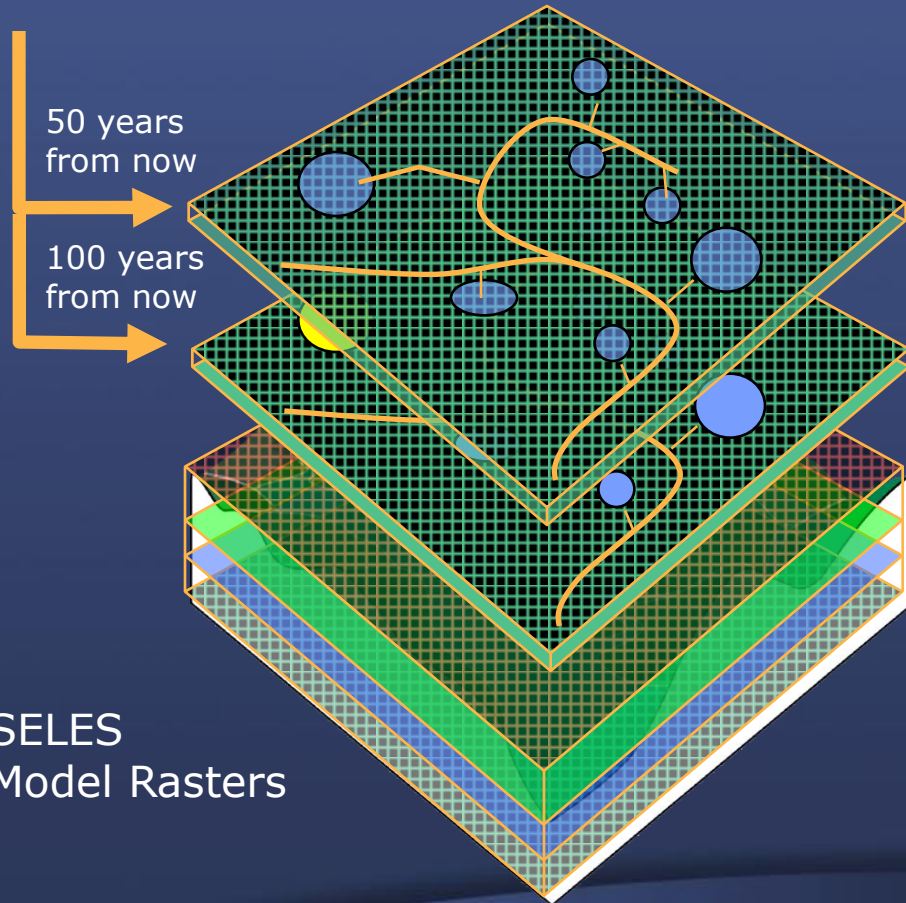


Linking LP Models with Spatially-Explicit Models for Forest Planning

Analytical Framework – Step 8



Pass spatial schedule to sub-models for use by other domain experts

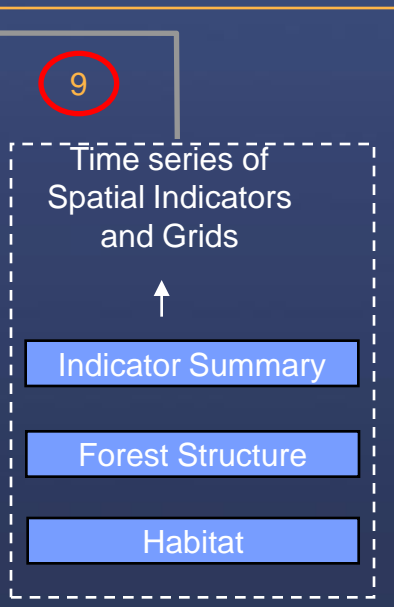
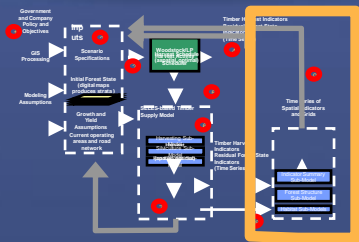


Linking LP Models with Spatially-Explicit Models for Forest Planning

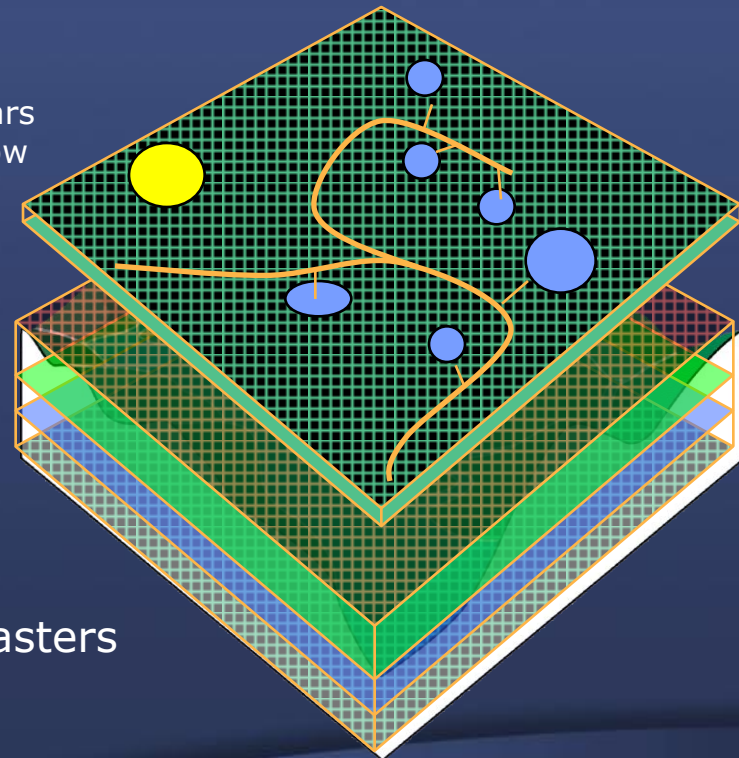
Analytical Framework – Step 9

Check spatial indices and indicators generated by sub-models

- if necessary go back to Step 2 and make adjustments to input data or model parameters



100 years from now



SELES
Model Rasters

Linking LP Models with Spatially-Explicit Models for Forest Planning

Summary

Efficient

- LP requires one run that optimizes the schedule as opposed to simulation where multiple runs are required to find a good schedule

Cost Effective

- allows user to quickly run multiple scenarios

Spatially Feasible

- brings in operational / policy rules to ensure a spatial, feasible solution

Linking LP Models with Spatially-Explicit Models for Forest Planning

Summary

Applicable to multi-stakeholder planning

- sub-models can be developed and implemented that provide input / control to multiple stakeholders

Feedback loop

- solution can be adjusted to meet the needs of all stakeholders

Extendible to other industries

- e.g., oil and gas, transportation
- simultaneous modeling of multiple industries on same land base

Linking LP Models with Spatially-Explicit Models for Forest Planning

Contact Information

Michael Buell R.P.F., Dipl. GIS, IT
Programmer/Analyst
Cortex Consultants Inc.
Suite 2a-1218 Langley Street
Victoria BC, Canada V8W 1W2
Tel:(250)360-1492 ext. 223
Fax:(250)360-1493
web: <http://www.cortex.ca/>
email: mbuell@cortex.ca