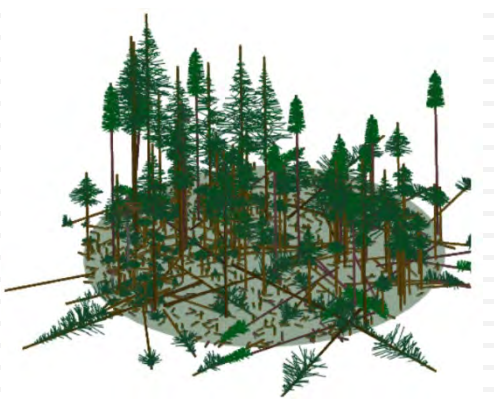
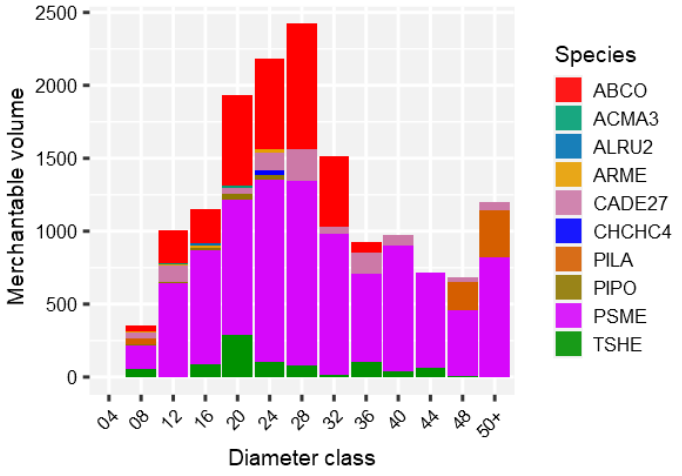
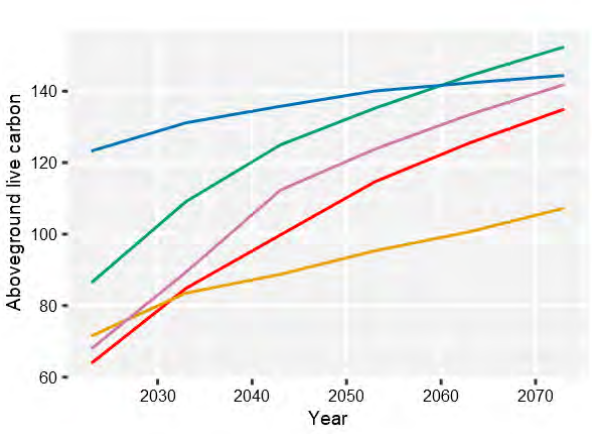
USING FOREST VEGETATION PREDICTION MODELS TO INFORM DECISIONS







Erin Smith-Mateja, USDA-FS

National Advanced Silviculture Program

September 12, 2024

Why use a model?

All Models are wrong, but some are useful.

- George E.P. Box

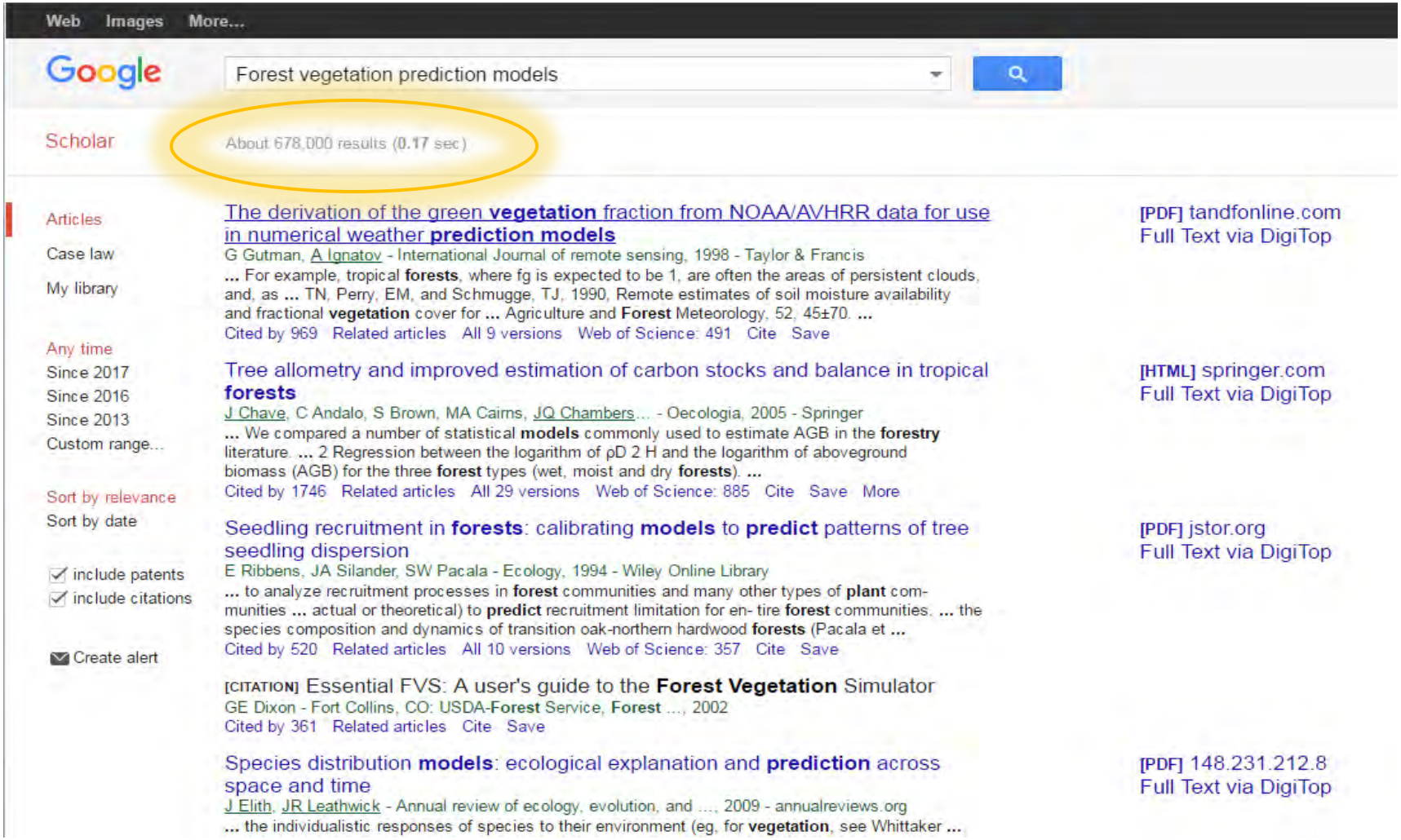
Models are an abstraction from reality that attempt to conceptualize key relationships of a system.

- Weiskittel et al. (2011)

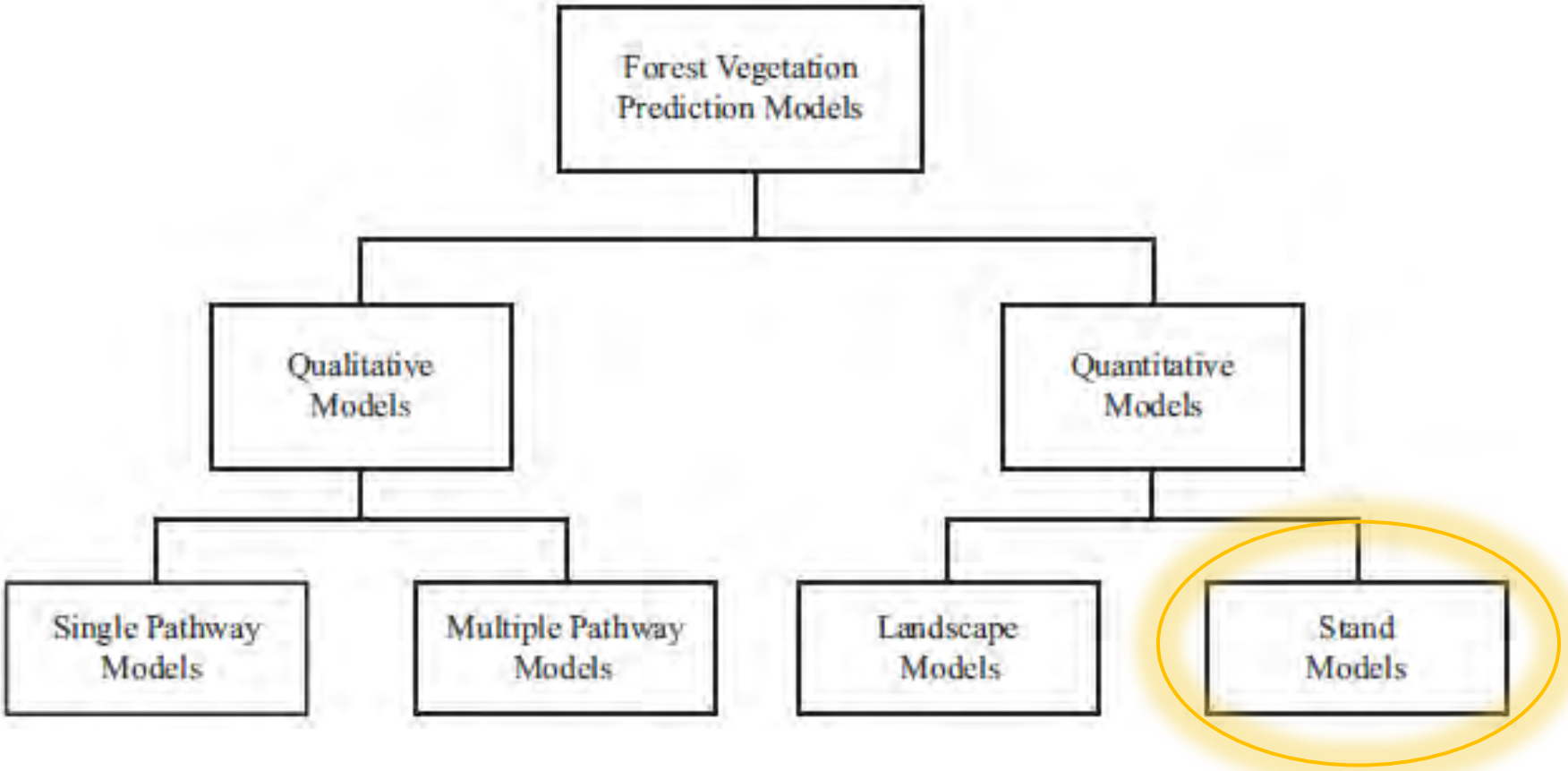
Why use a model in forestry?

- Quickly summarize existing stand conditions
  - QMD, TopHt, TPA, BA, volumes and carbon stocks
  - DWD, snags, canopy cover, habitat indices
  - Fire, insect and pathogen hazard ratings
- Help develop prescriptions and demonstrate their effects on forest vegetation at various spatial and temporal scales
- Compare trade-offs
  - Timber production vs. wildlife habitat vs. fire hazard…

What models are available?

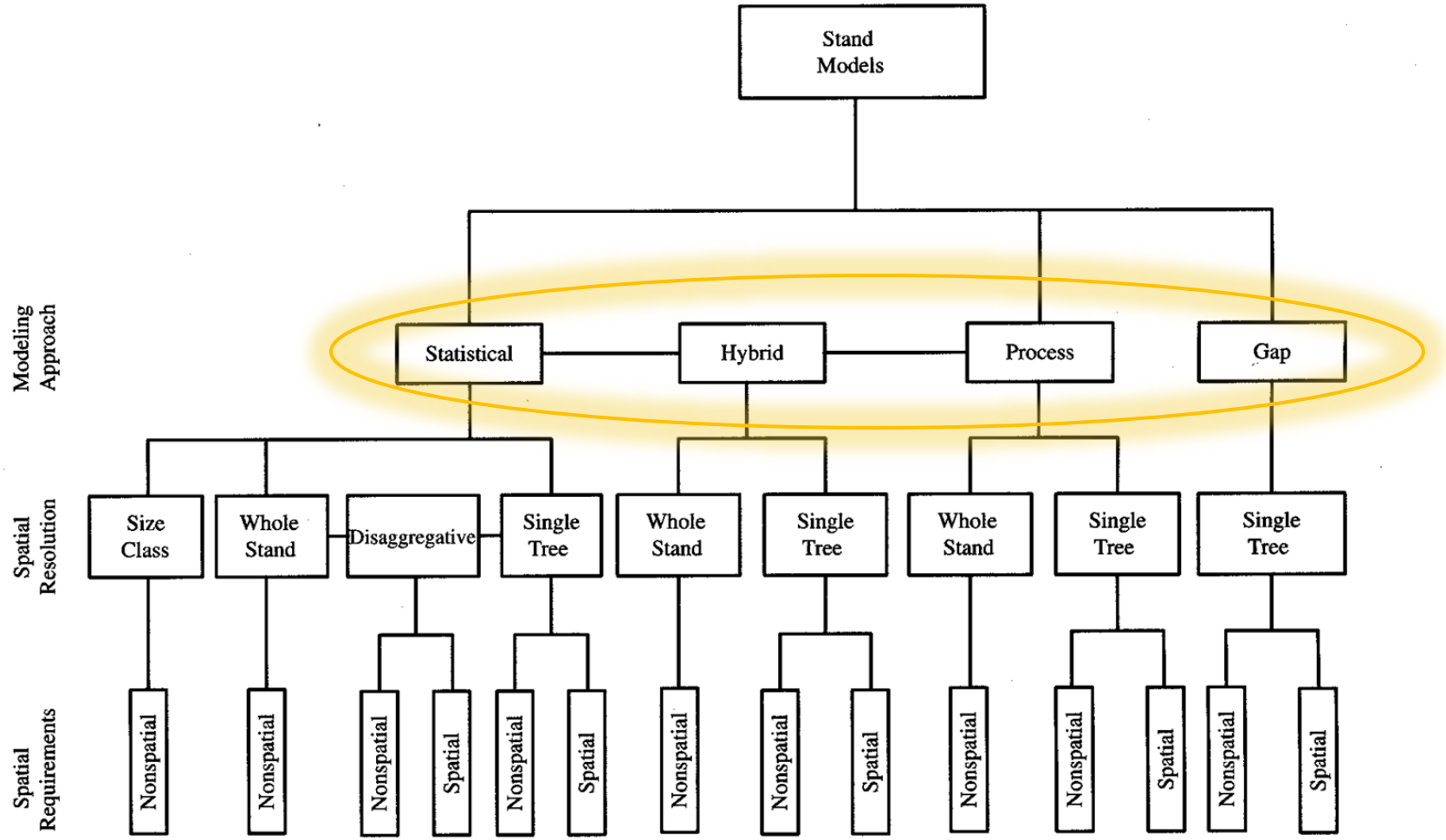


Forest Vegetation Prediction Models



Weiskettel et al. 2011

Modeling Approaches



Spatial Resolutions

- Whole Stand: basic units of modeling are stand parameters such as age, tpa, basal area and site index.
- Disaggregative*: links stand and individual tree models. Predicts stand growth and disaggregates to individual trees.
- Size Class: employ a class of trees as the basic unit for modeling, a compromise between stand and tree models.
- Individual Tree*: basic units of modeling are tree parameters such as dbh, height and crown.

* Can be spatially or non-spatially sensitive (are your plots/stands stem-mapped?)

Ok, so which model do I use?

- Many choices
  - Whole stand models (and yield tables)
  - Individual tree models
- It really just depends… on your needs, capabilities, timeframe and most importantly, how well the model is supported!

Whole Stand Models

- Easy to develop and apply
- Limited ability to represent complex composition / structure / silvicultural prescriptions
- Highly accurate in single species, even-aged stands
- Have gone out of style, but yield tables are still used in higher level planning

Yield Tables

- A yield table typically relates volume to age and site index, for typically an even-age, single species stand.
  - Normal yield tables (full stocking)
  - Empirical yield tables (average stocking)
  - Variable density tables (uses a density variable as an independent variable)
- Use data, individual equations or models to create yield tables

Yield Tables (Publications)

Table 37.—*Cubic-foot yield of wood only to a 4-inch top, outside bark, for unthinned yellow-poplar stands of various stand densities, site indexes, and ages*[1]

Trees per acre (number)	Age (years) 20	30	40	50	60	70
	Cubic feet per acre					
Site Index 90						
50	—	—	1,220	1,700	2,240	2,840
100	520	1,140	1,790	2,480	3,200	3,950
150	590	1,340	2,110	2,870	3,620	4,360
200	650	1,480	2,300	3,090	3,820	4,490
250	720	1,600	2,460	3,240	3,930	4,520
300	800	1,710	2,590	3,360	—	—
350	890	1,840	2,730	—	—	—
Site Index 100						
50	—	—	1,500	2,150	2,880	3,700
100	600	1,380	2,230	3,150	4,150	5,220
150	690	1,640	2,640	3,680	4,760	5,860
200	760	1,820	2,920	4,010	5,090	6,140
250	840	1,990	3,150	4,260	5,320	6,300
Site Index 130						
50	—	—	2,650	4,000	5,630	7,590
100	920	2,300	3,990	6,010	8,410	11,230
150	1,070	2,800	4,870	7,280	10,060	10,060
200	1,200	3,200	5,580	8,260	—	—
250	1,370	3,640	6,250	9,160	—	—
300	1,570	4,090	6,940	—	—	—
350	1,800	4,580	7,640	—	—	—

[1]Only trees 4.5 inches d.b.h. and larger are included.
Source: Beck and Della-Bianca (1970).

Table 38.—*International 1/4-inch board-foot yield to an 8-inch top, outside bark, for unthinned yellow-poplar stands of various stand densities, site indexes, and ages*[1]

Trees per acre (number)	Age (years) 20	30	40	50	60	70
	Board feet per acre					
Site Index 90						
50	—	—	5,180	8,490	12,240	16,480
100	260	2,480	6,260	10,750	15,670	20,920
150	140	2,090	5,960	10,690	15,730	20,830
200	80	1,630	5,210	9,750	14,530	19,120
250	40	1,230	4,370	8,540	12,920	17,000
300	20	880	3,520	7,230	—	—
350	10	590	2,670	—	—	—
Site Index 100						
50	—	—	7,120	11,590	16,790	22,830
100	460	3,760	9,020	15,270	22,270	29,990
150	290	3,420	9,100	15,940	23,370	31,170
200	180	2,930	8,540	15,430	22,770	30,150
250	120	2,460	7,780	14,510	21,580	28,460
Site Index 130						
50	—	—	15,160	24,950	37,190	52,270
100	1,600	9,500	21,120	35,590	53,220	74,650
150	1,310	10,070	23,880	40,940	61,220	—
200	1,100	10,270	25,560	44,350	—	—
250	990	10,470	26,960	47,180	—	—
300	940	10,740	28,320	—	—	—
350	920	11,050	—	—	—	—

[1]Only trees 11 inches d.b.h. and larger are included.
Source: Beck and Della-Bianca (1970).

Yield Tables (from USFS Forest Plans)

- Expands the concept of yield to many forest attributes by age
- Usually created for some combination of forest type, site class and density class stratification scheme
- Embedded within planning software to help determine SYL and PWSQ/PTSQ
- Typically use an individual tree model (FVS) to create

Individual Tree Models

- Current standard in forest modeling!
- Expensive to develop/maintain and generally harder to use
- Produce detailed outputs of trees, plot and stand attributes
- Can incorporate many types of silvicultural prescriptions and other disturbances
- Able to represent single species, even-aged stands as well as mixed species, uneven-aged stands

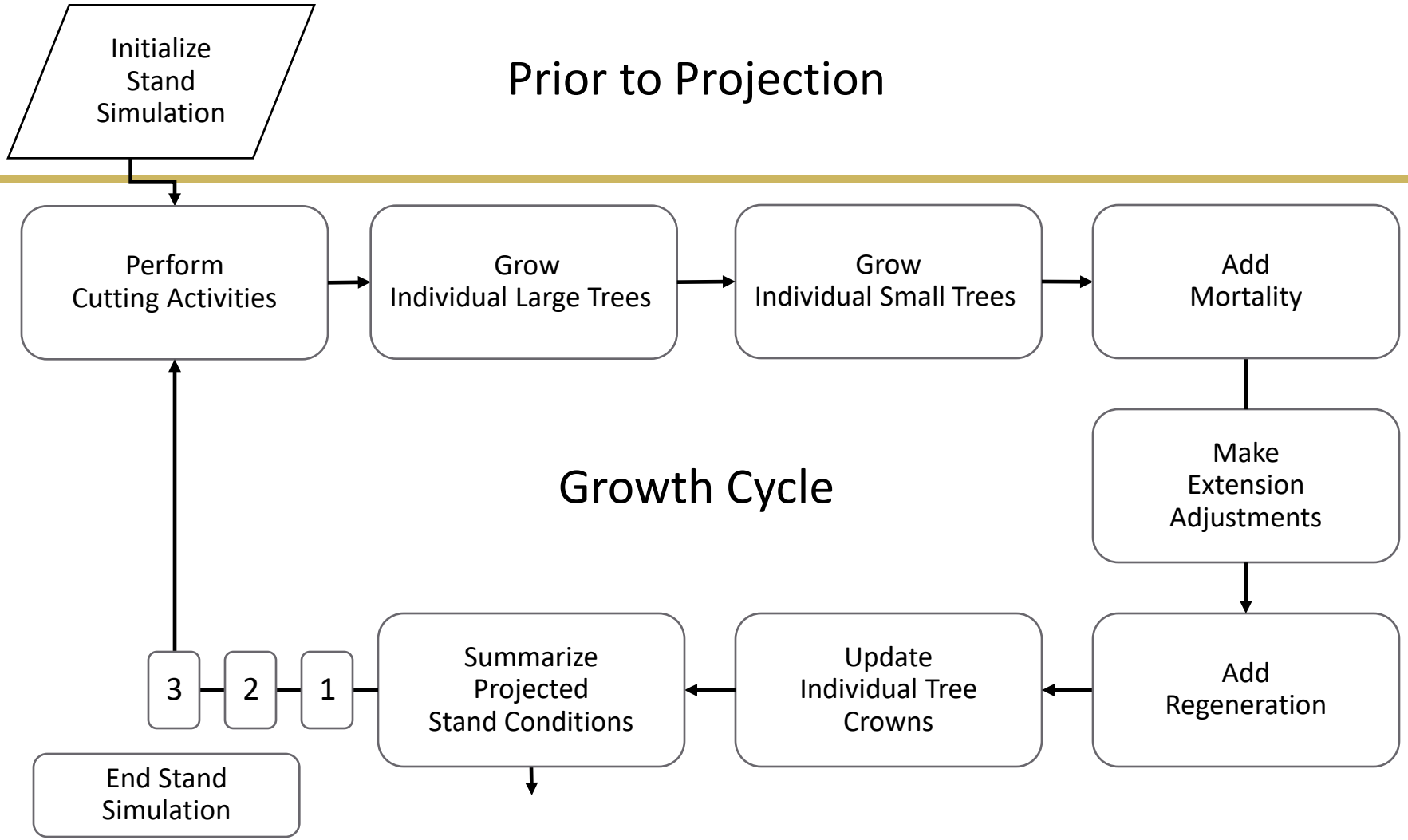
Forest Vegetation Simulator

- Individual-tree, distance-independent growth and yield model
- Responsive to site, structural differences and management actions common to forest stands found throughout the United States
- Inventory-based system that can accommodate a variety of inventory designs in projecting stand development

FVS Development Guidelines

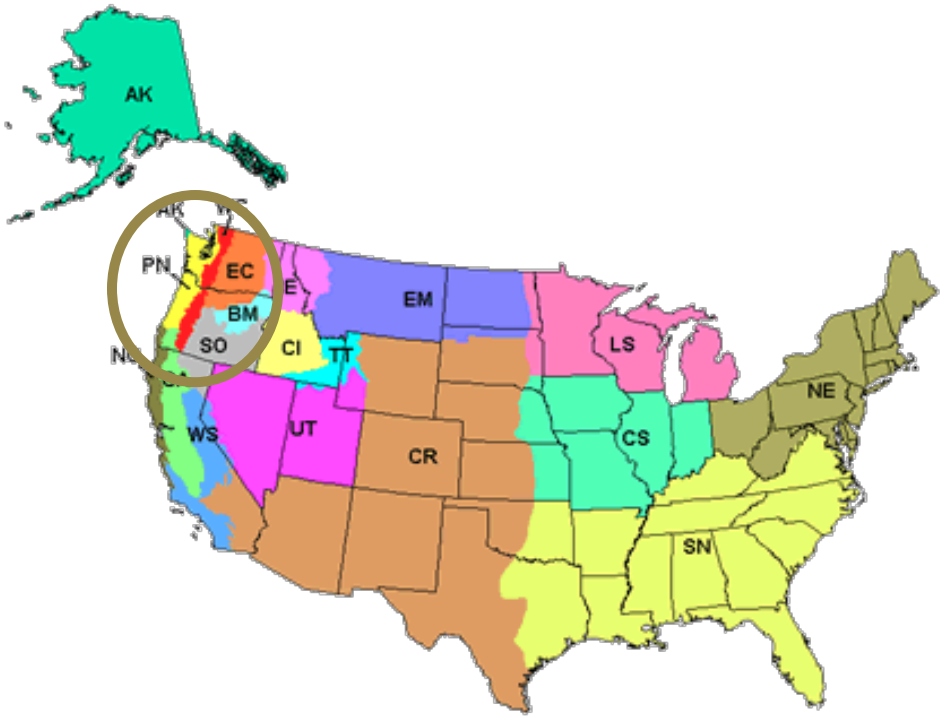
- Use existing inventory methods as sources of input in model development
- Apply to forest stands containing any mixture of species, age structures, and site conditions
- Ensure growth projections are dependent on interactions between trees within stands
- Incorporate growth of current inventory into projections
- Provide links to other ecosystem components

FVS Model Structure



Geographic Variants of FVS

- Represent species commonly found in a geographic region
- Local Data are used to create models that predict tree growth, mortality, and regeneration
- Focus on variants in Oregon and Washington



Stand Inventory Data

Stand /Site Conditions

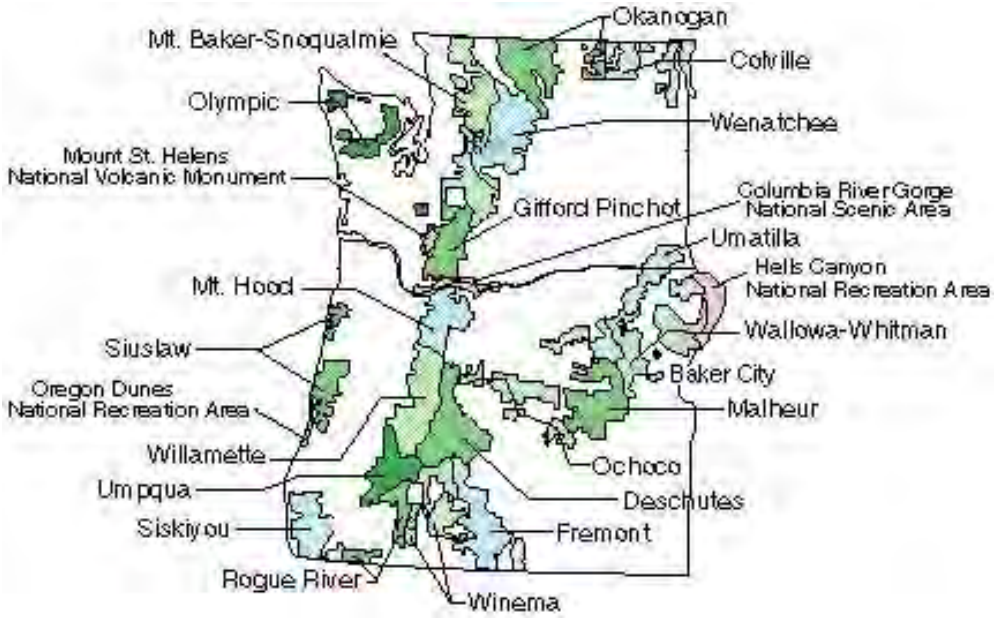
- Location
- Plant Association
- Slope
- Aspect
- Elevation
- Site Index
- Carrying Capacity (Max SDI)

Tree Characteristics

- Species
- DBH
- Height (total)
- Crown Ratio
- Past Growth Increment
- Tree Count (from inventory design)

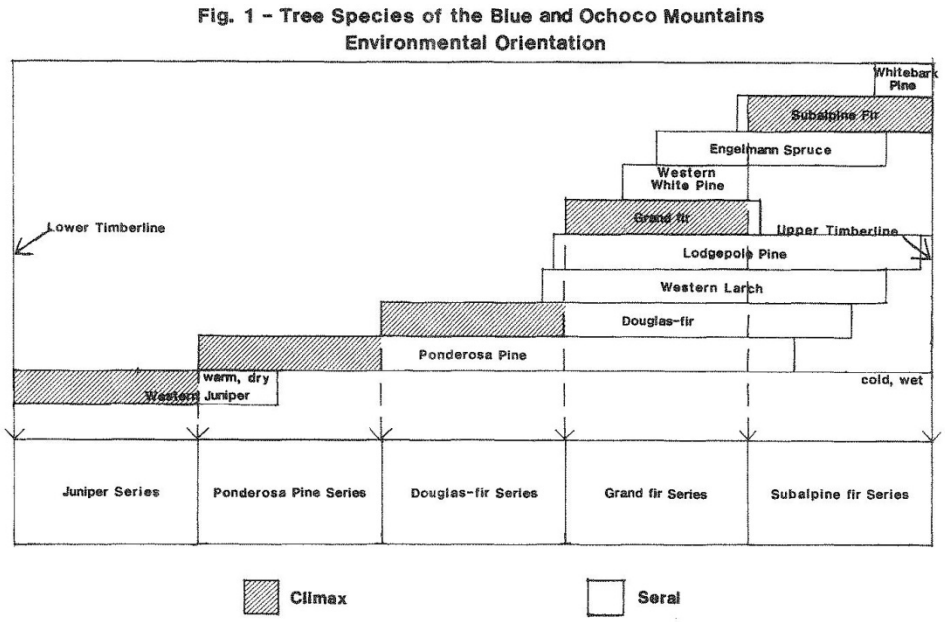
Site Conditions

- Location
  - US Forest Service National Forest
  - code is based on Region, Forest



Site Conditions

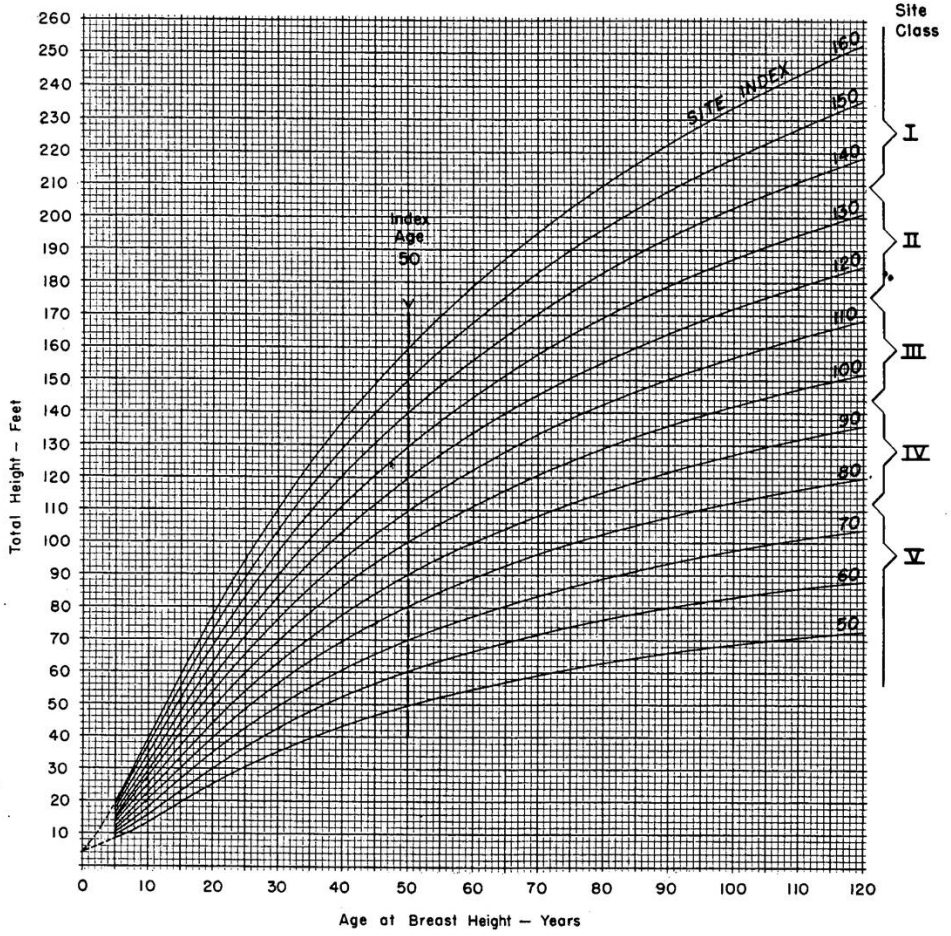
- Plant Association
  - Washington/Oregon (R6)
  - Sets default Site Index and Maximum SDI
  - Each R6 variant has its own list of acceptable PA codes
  - List are in the back of the variant overviews



Johnson and Clausnitzer 1992, R6-ERW-TP-036-92

Site Conditions

- Site Index
  - single measure that integrates the effects of soil and climate on tree growth for a given site
  - used to identify potential height growth and affects diameter growth
  - Variants may use different SI curves for the same species.



Site Index Curves for Douglas-fir in the Pacific Northwest, King, 1966

Site Conditions

- Slope, Aspect, Elevation
  - combined measures that integrate the effects of topography on tree growth for a given site
  - can identify an optimal location for growth
  - affects diameter growth

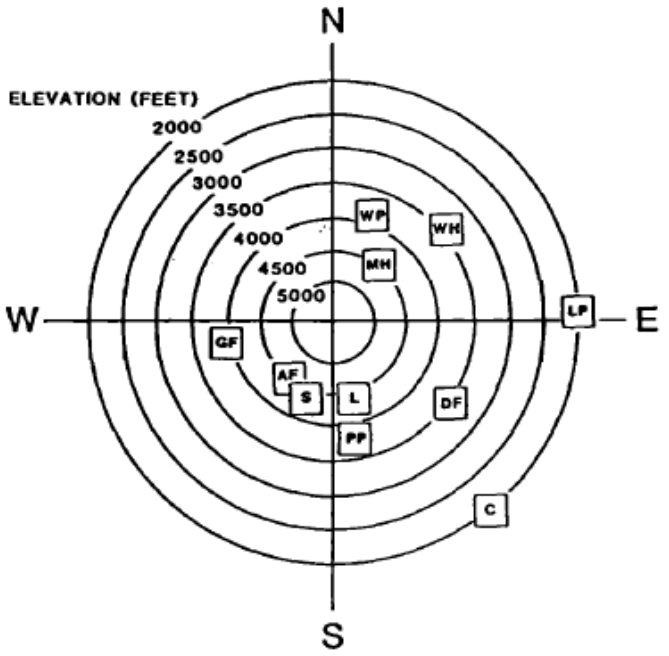
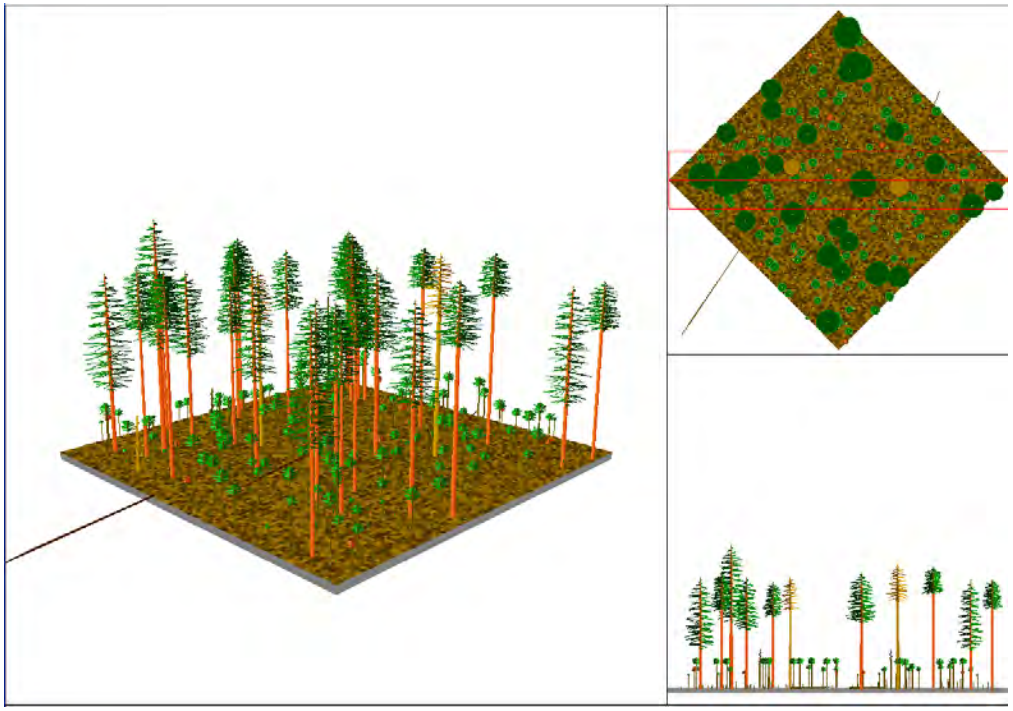


FIGURE 10. Elevation and aspect associated with maximum predicted increment with all other effects held constant. Species codes are listed in Table 1.

Wykoff 1990, Forest Science 36(4): 1077-1104

Tree Characteristics

- Species
- Size
  - dbh
  - ht
- Vigor
  - crown ratio
  - social position
- Density
  - basal area
  - sdi



FVS Model Behavior

- **Diameter Increment**
- Height Increment
- Crown Change
- Regeneration
- Impacts from other ecosystem attributes
  - insects
  - pathogens
  - fire
  - climate change

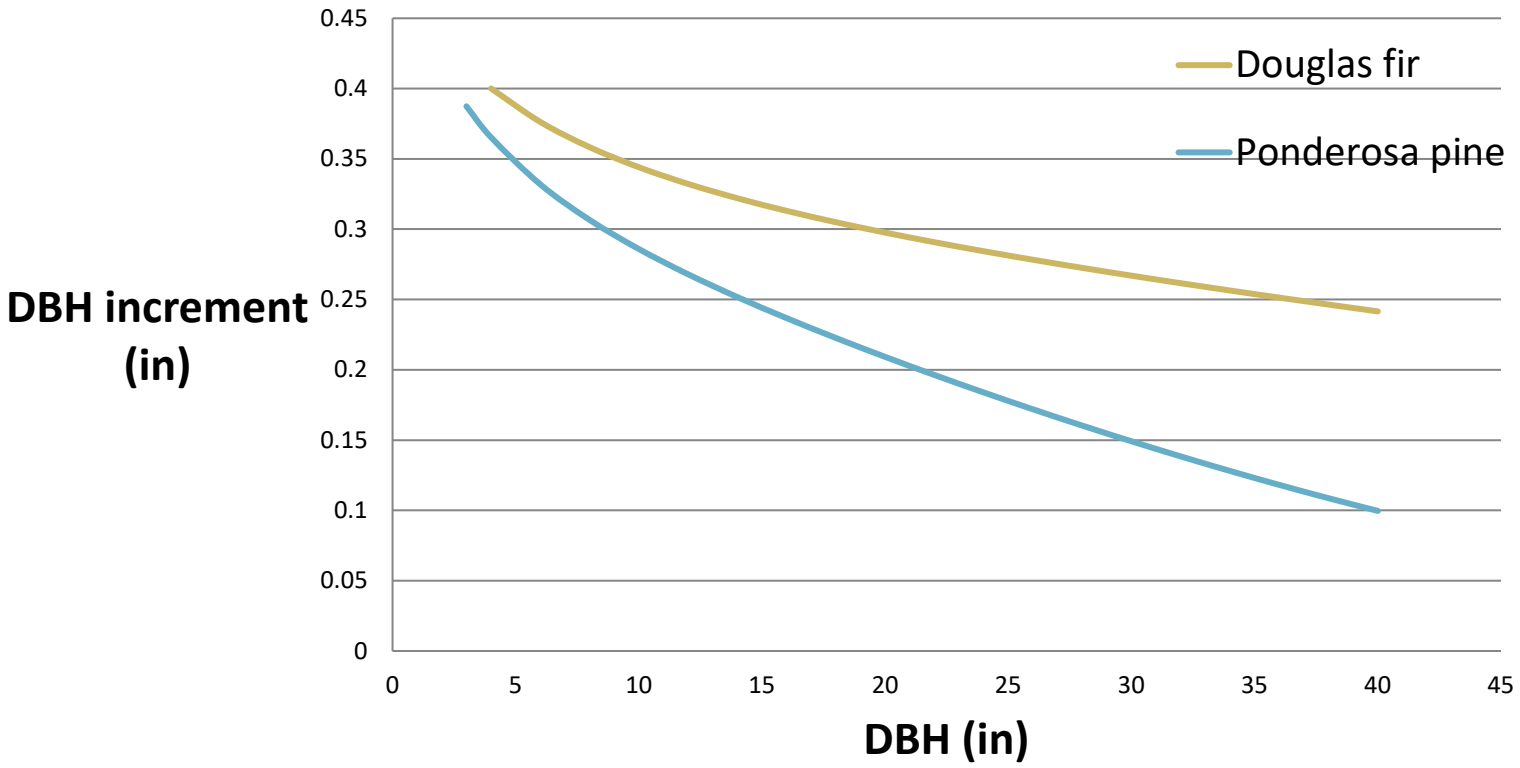
Diameter Increment Model

- Based on a prediction of a mean growth rate that is corrected for tree size, site quality, and the level of competition
- Derive diameter increment (*DG*) from predicted periodic change in squared inside-bark diameter (*DDS*)
  - equivalent to a basal area increment model
  - linear relationship between ln(*dds*) and ln(*DBH*)

$$\ln(dds) = SIZE + SITE + COMPETITION$$

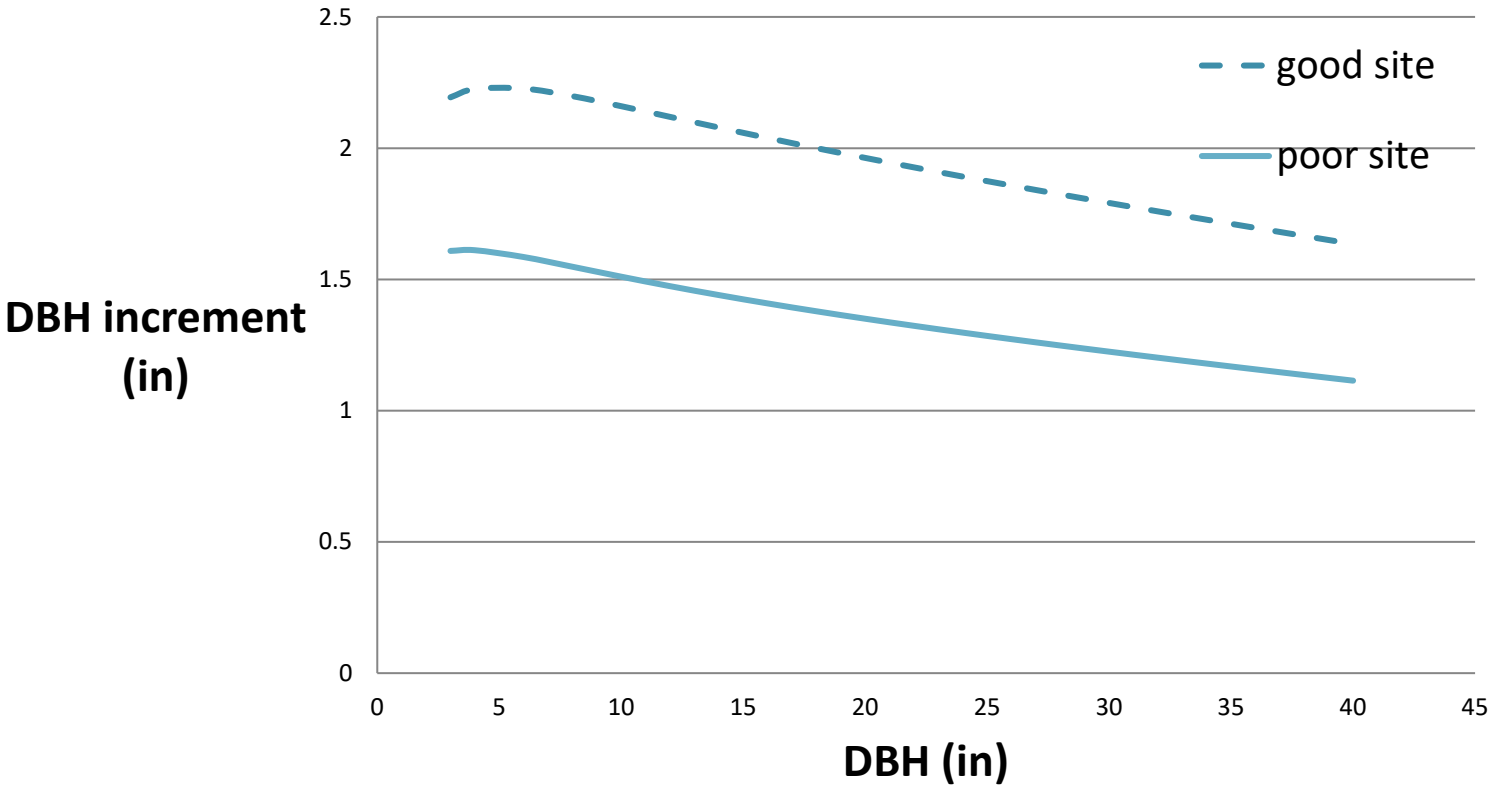
$$DG = \text{sqrt}(dib^2 + dds) - dib$$

Tree Size Effects



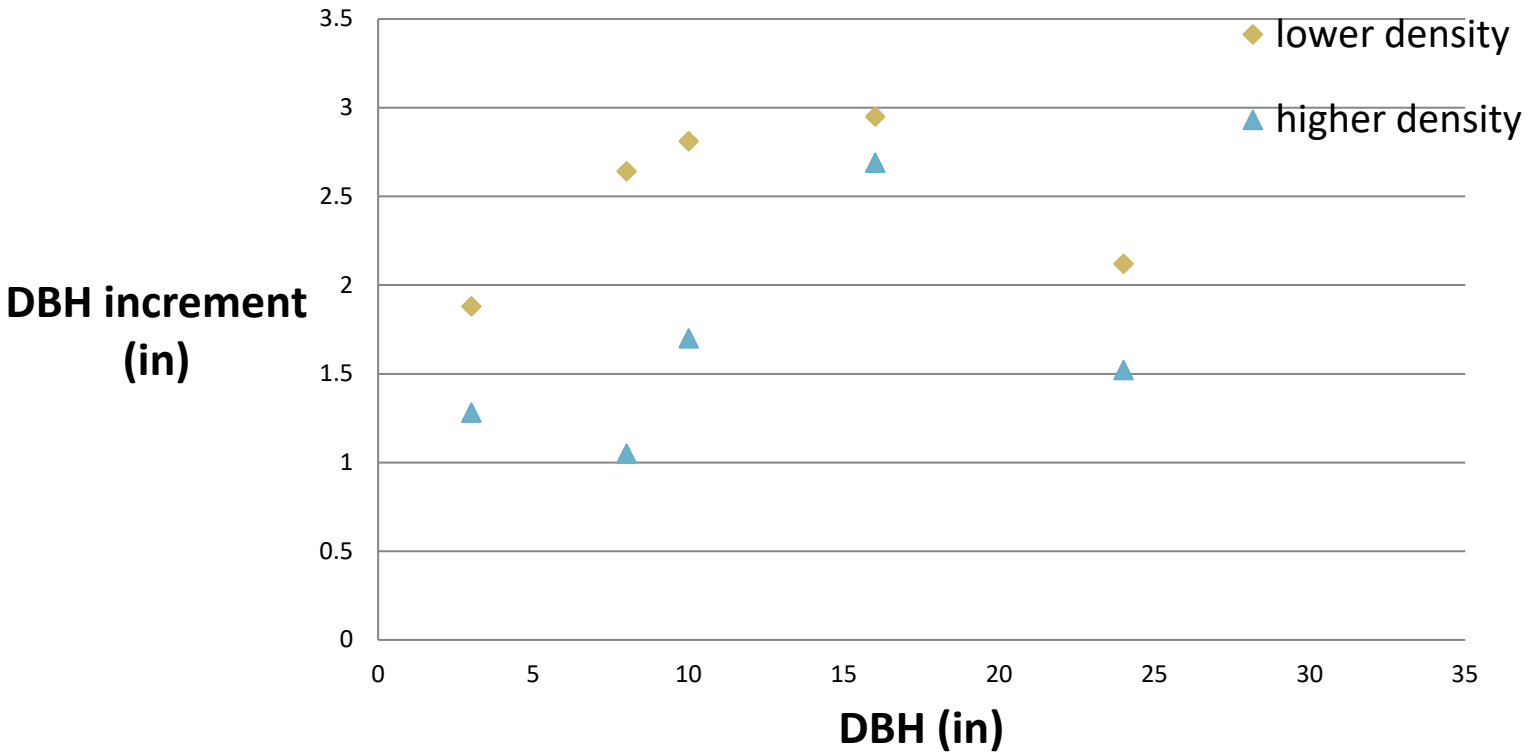
$$Size = \ln(DBH) + DBH^2$$

Site Effects



Site = Site Index + Elevation+ Elevation^2 + *Slope* + Cos(*Aspect*) + Sin(*Aspect*))

Competition Effects



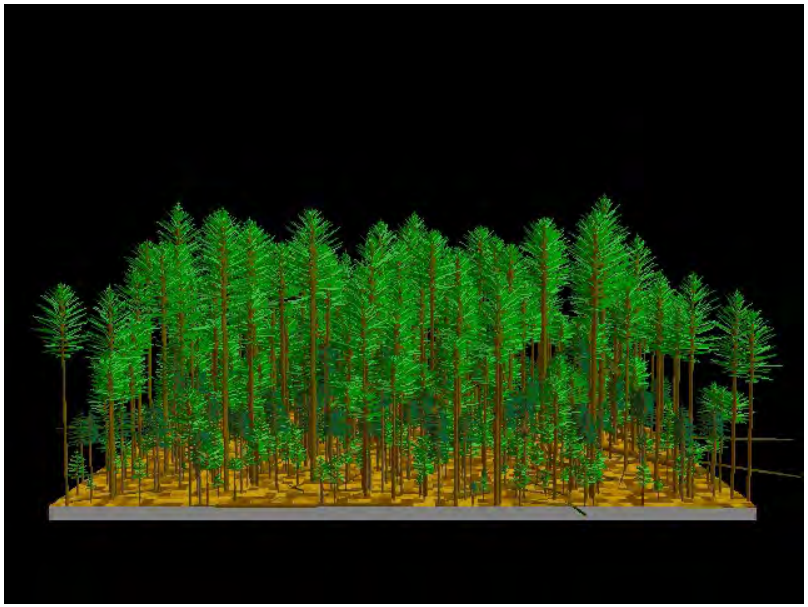
Competition = Crown ratio + Relative height + Basal Area + Basal Area in Larger Trees

FVS Model Behavior

- The diameter increment model shows how FVS is designed to handle differences in tree size, site quality, and stand structure
- Focusing on the growth of individual trees allows FVS to handle most stand structures
  - even-aged stands
  - two-aged stands
  - uneven-aged Stands

FVS Extensions

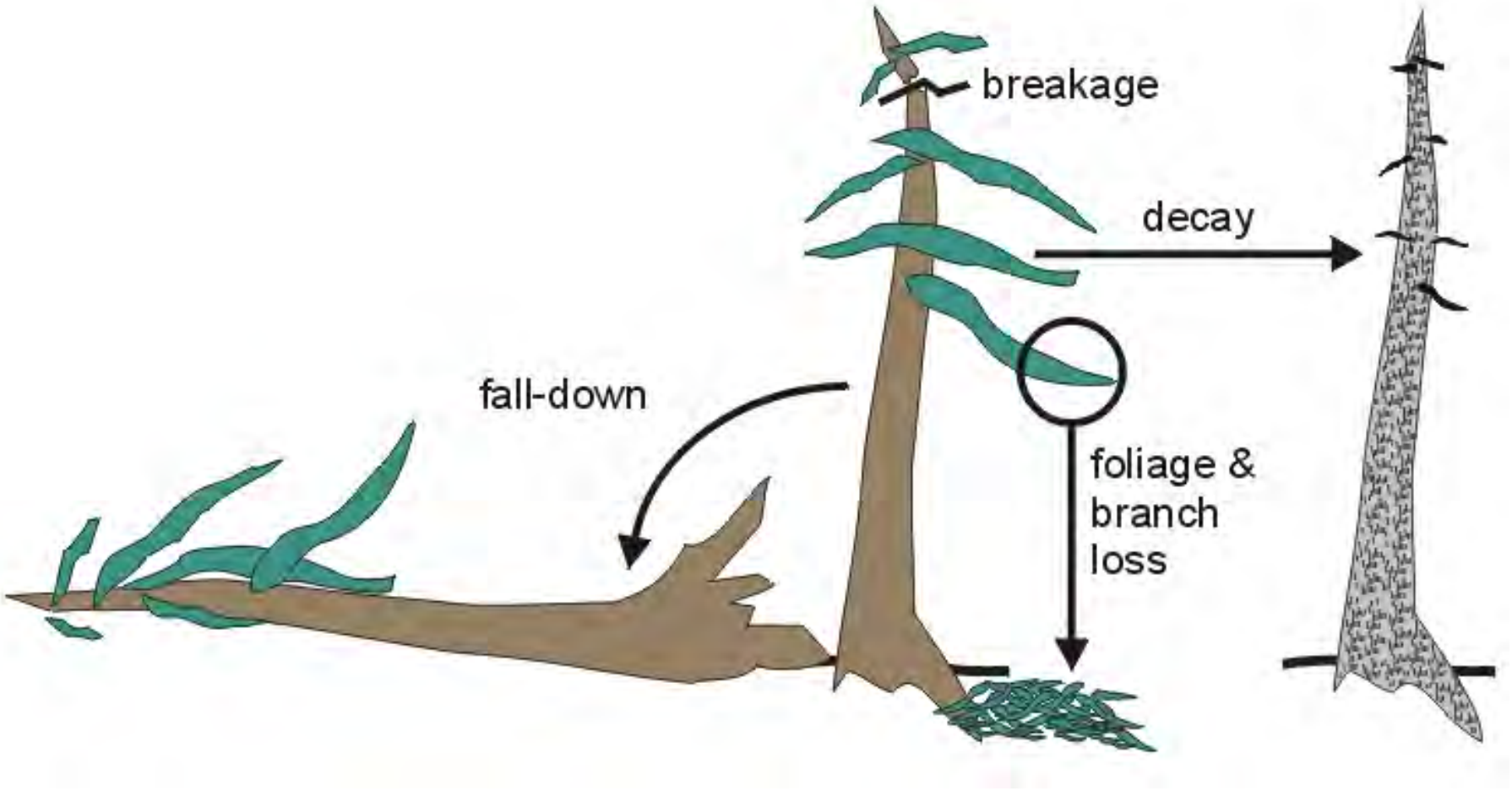
- Models that interact with base FVS variants
- Simulate the effects of various ecological disturbances
  - Insects and Diseases
  - Fire and Fuels (FFE)
  - Climate Change



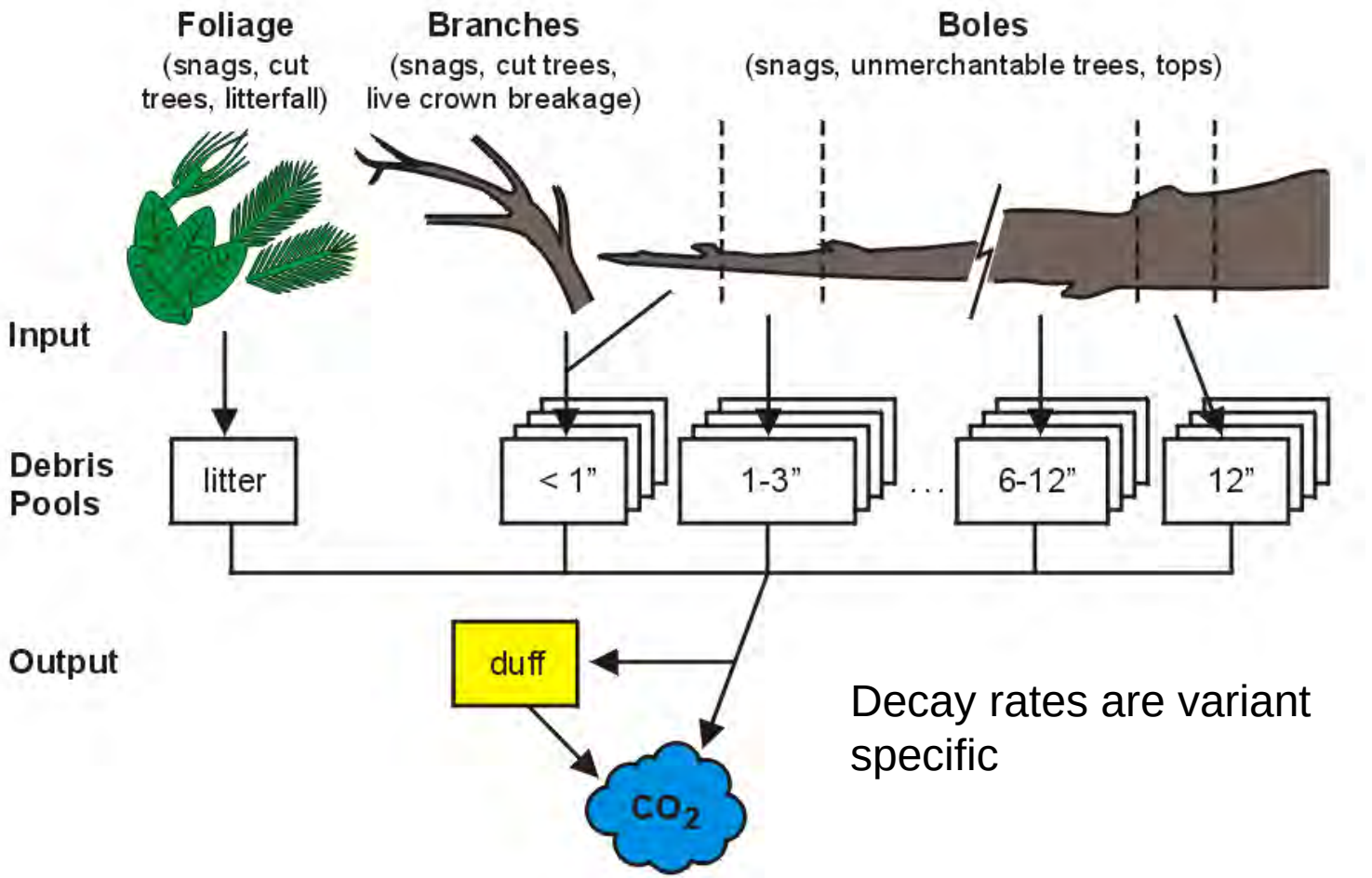
FFE-FVS *CAN*:

- Simulate additional stand biomass dynamics over time
  - standing trees (boles and crowns)
  - live and dead surface fuels
  - coarse roots
- Predict or simulate the effects of fire on stand components
- Convert biomass into carbon estimates

Snag Dynamics

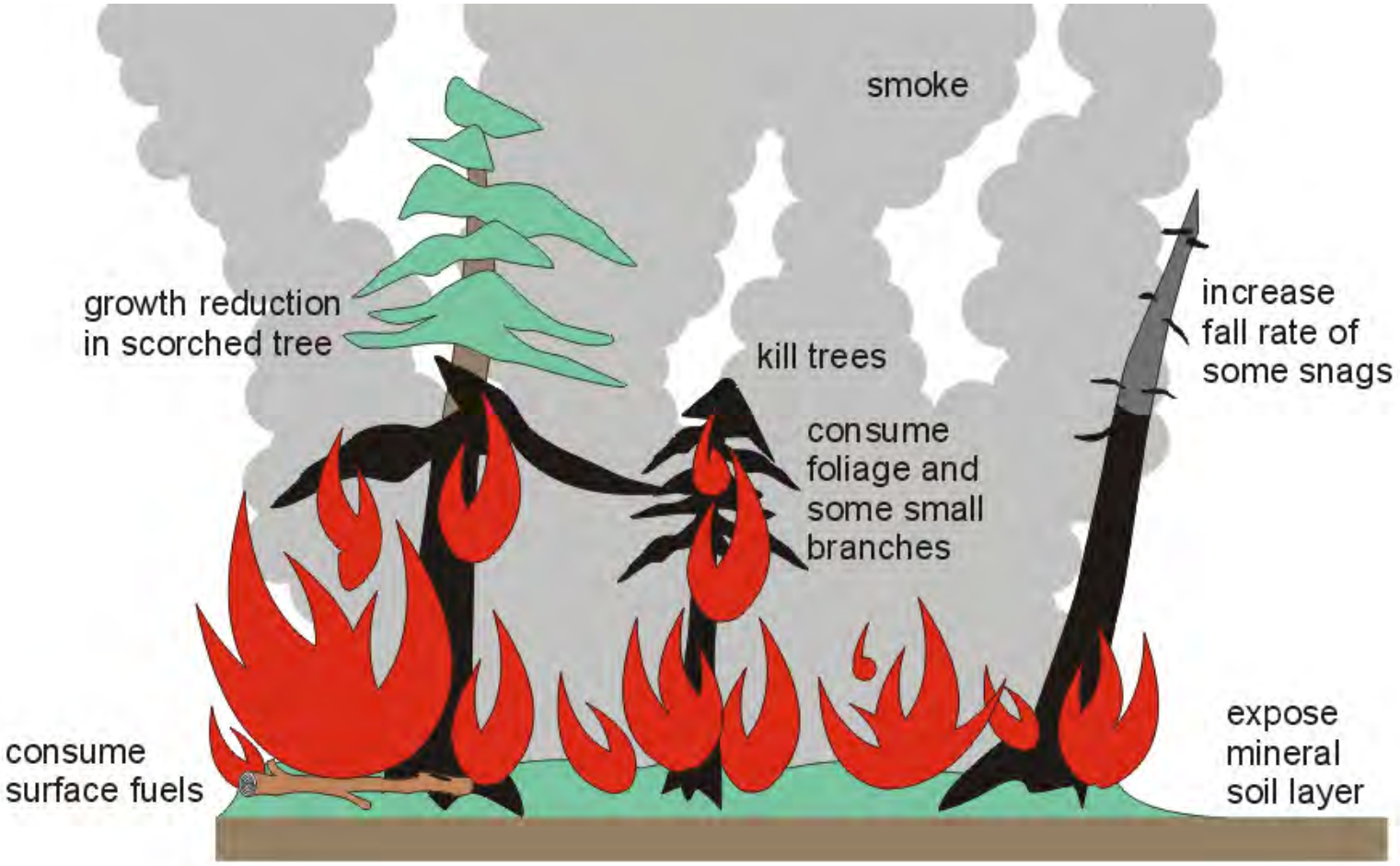


Fuel Dynamics

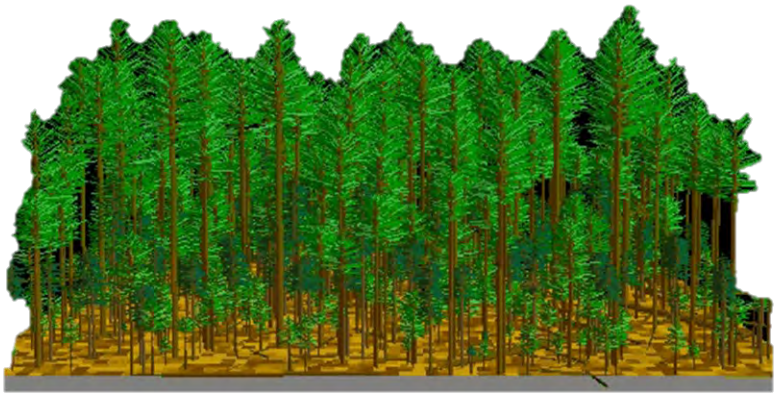


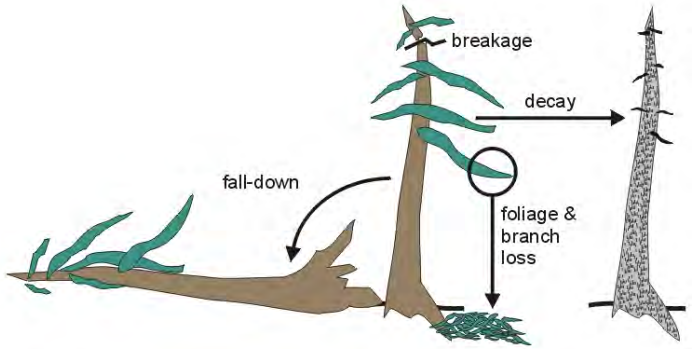
Decay rates are variant specific

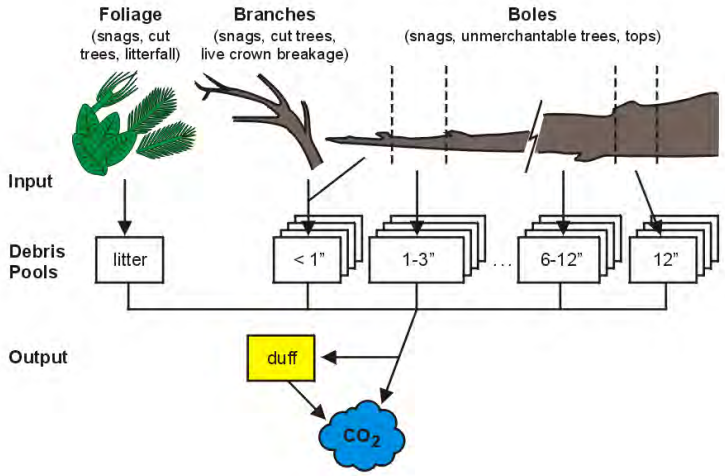
Fire Dynamics

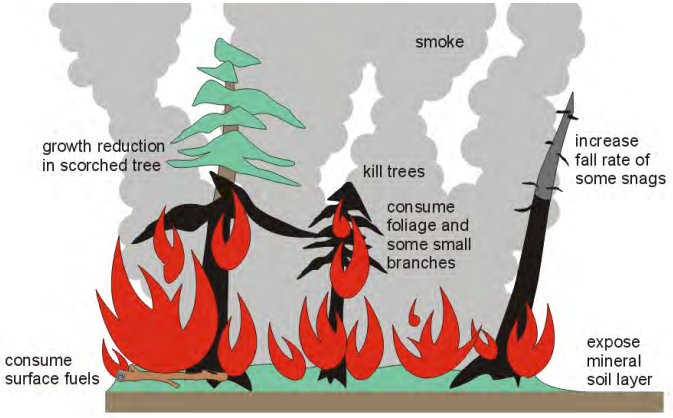


Carbon Dynamics









FVS Growth and Yield Model

- Projects single or multiple stands in a single simulation
- Models stand development with and without taking into consideration forest health concerns
- Simulates common and user-defined management actions
  - thinning methods
  - regeneration methods
  - fuels and fire management

Conclusions

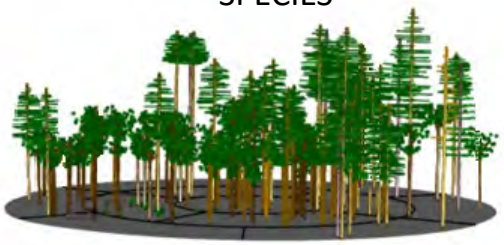
- FVS is the primary growth and yield model used throughout the United States on public lands
- FVS is used primarily by silviculturists and other forestry professionals needing to compare existing and projected stand conditions with a desired stand condition
- FVS has over 40 years of development history and is actively maintained, enhanced and supported by the FMSC and its partners.

Evaluate Alternatives

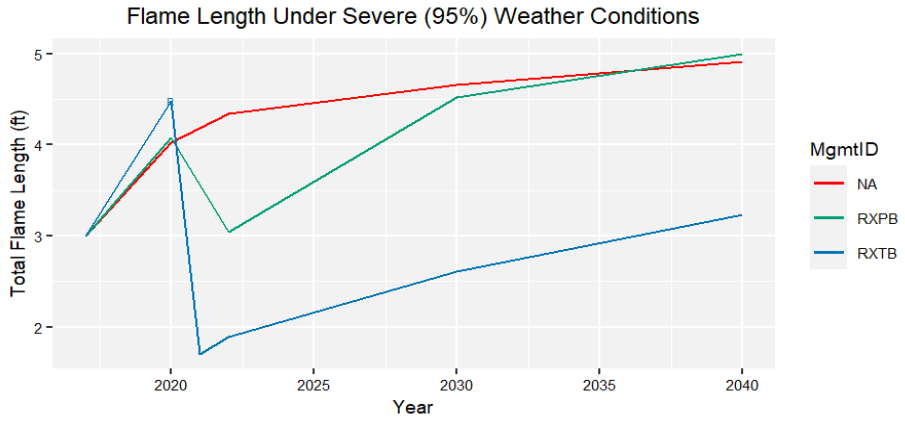
NO ACTION

PILE BURN

THIN FROM BELOW 80 BA RETAINING FIRE TOLERANT SPECIES



Stand Attributes	NA 2022	RXPB 2022	RXTB 2022
Canopy Cover %	58	47	47
Flame Length (ft) Severe	4.3	3.0	1.9
Trees per Acre	158	142	115
Basal Area (ft2/acre)	110	91	81
Quadratic Mean Diameter (in)	11	11	11
Board feet	8176	7107	6228
Board feet removed	0	0	1970



FVS Support

https://www.fs.usda.gov/fvs/