

Forest Health in Oregon: State of the State 2018

Performance of Mixed Species Stands:

Relative Productivity and Response to Disturbances



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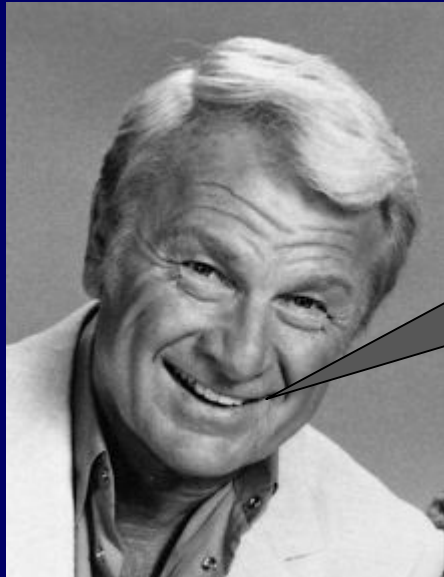
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Forest Health in Oregon: State of the State 2018

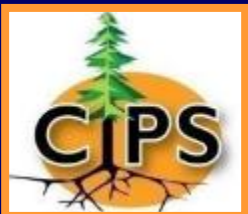
... but this forest
is dying ...





Performance of Mixed Species Stands

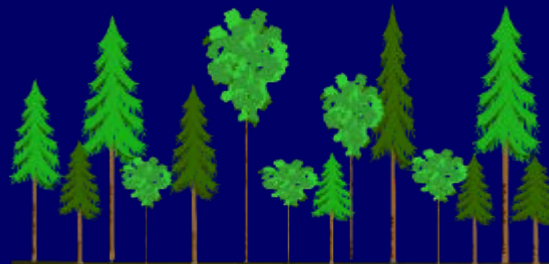
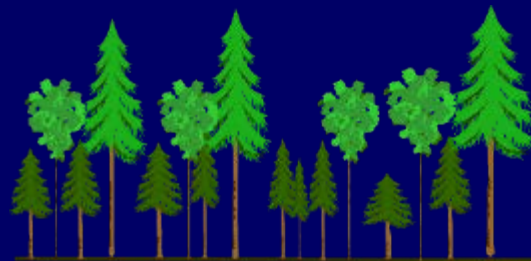
- *What is the potential range of stand structures in mixed-species stands?*
- *Does productivity of mixed-species stand always/ever exceed that of single-species stands?*
- *Are mixed-species stands more or less resistant/resilient to health threats than single-species stands?*
 - *Insects*
 - *Disease*
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 - *Climatic fluctuations or extremes*
- *What is the role of mixed-species stands in minimizing risk versus minimizing resistance and/or resilience?*

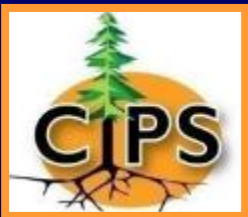


Varieties of mixed species stands

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- Single cohort, single canopy
- Single cohort, stratified mixture
- Multi-cohort, stratified mixture
- Multi-cohort, mixed-species cohorts

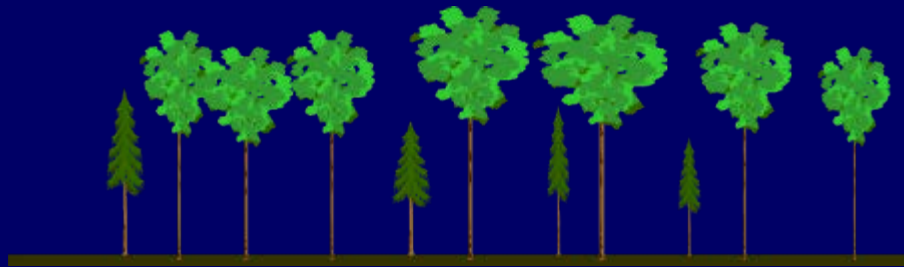




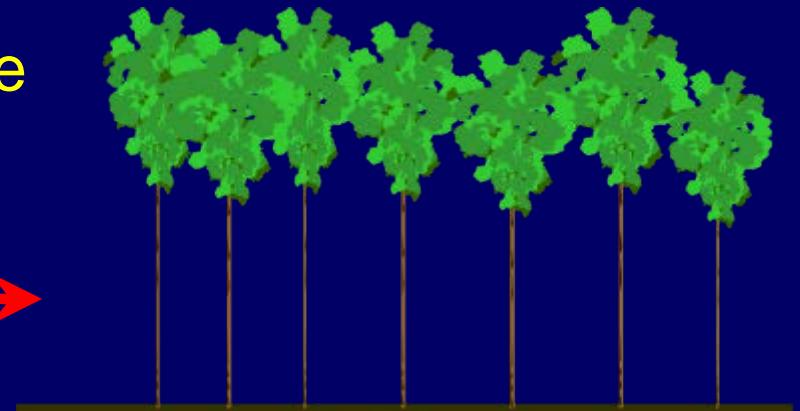
Varieties of mixed species stands

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Conventional view of an initial mix of Douglas-fir + red alder



Mixed species, before crown closure



Pure red alder - single cohort, single canopy



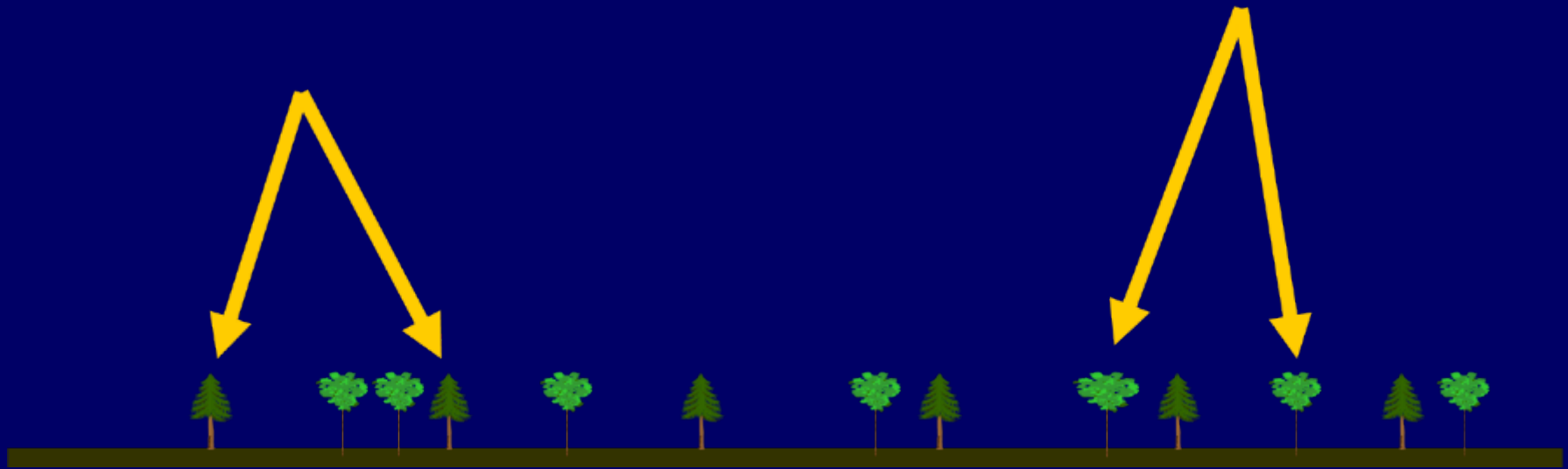
Varieties of mixed species stands

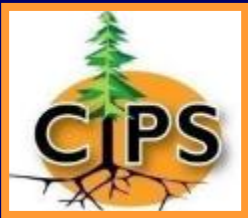
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What is the stand developmental pathway ?

Douglas-fir

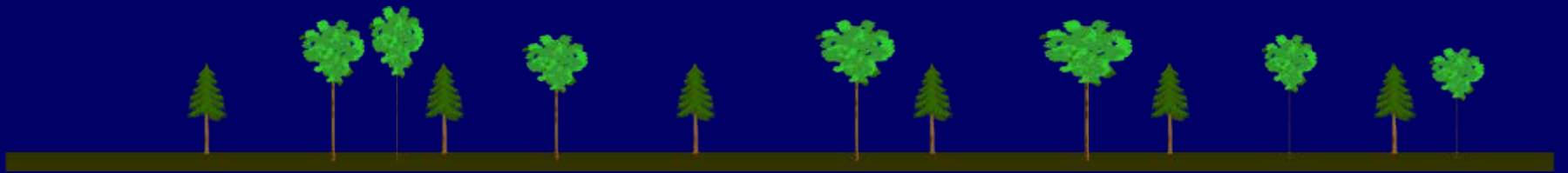
Red alder





Varieties of mixed species stands

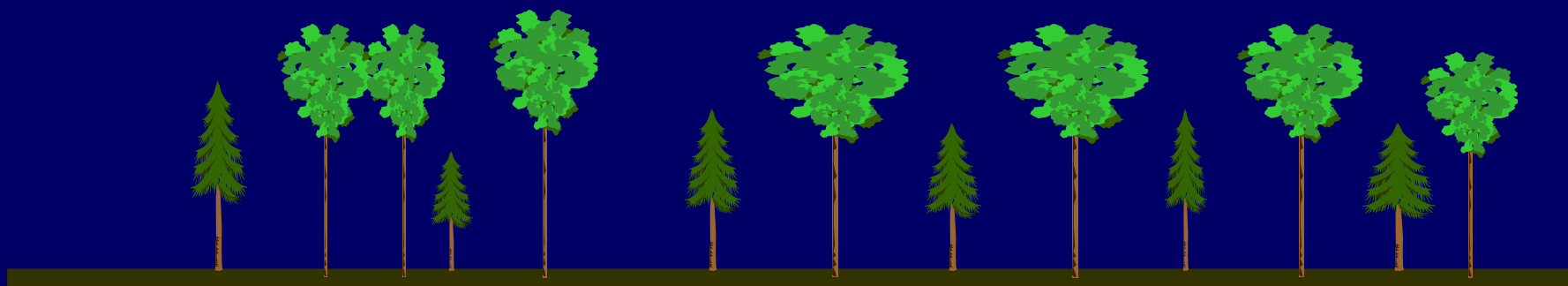
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Varieties of mixed species stands

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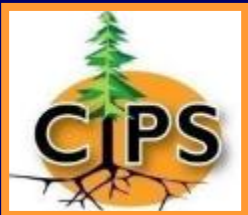


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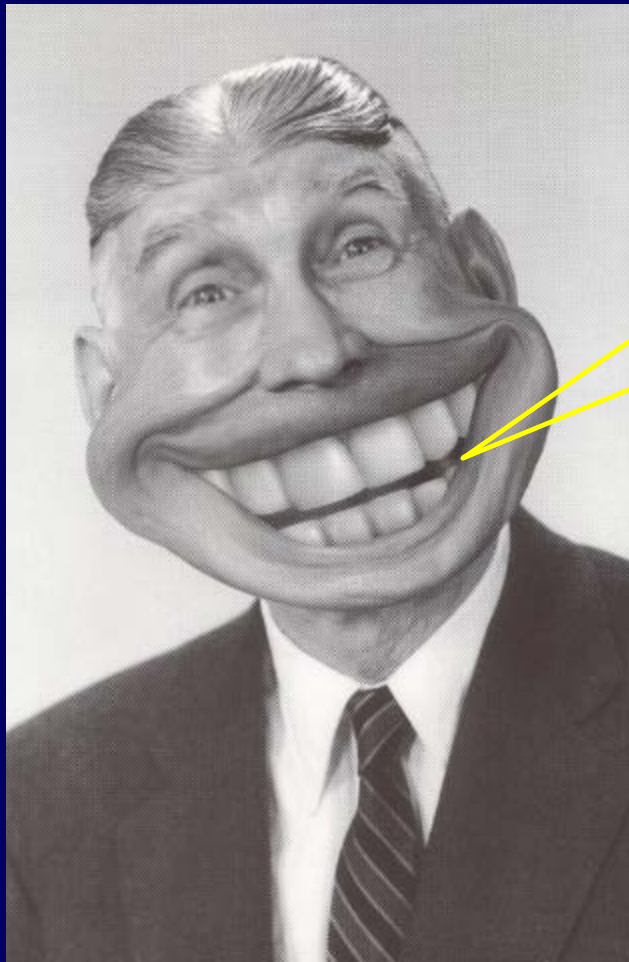


single species (red alder), single cohort, single canopy

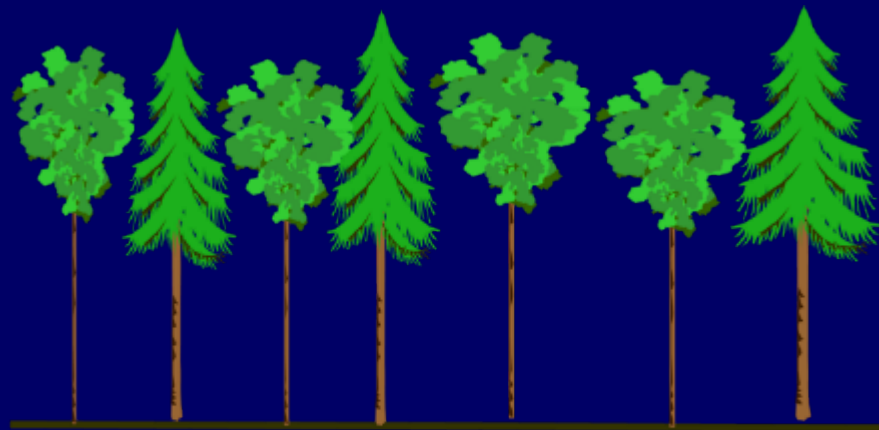


Varieties of mixed species stands

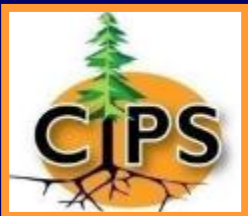
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Is an alternative pathway possible?



Douglas-fir / red alder - single cohort, single canopy

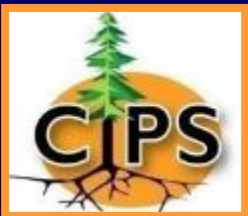


Varieties of mixed species stands

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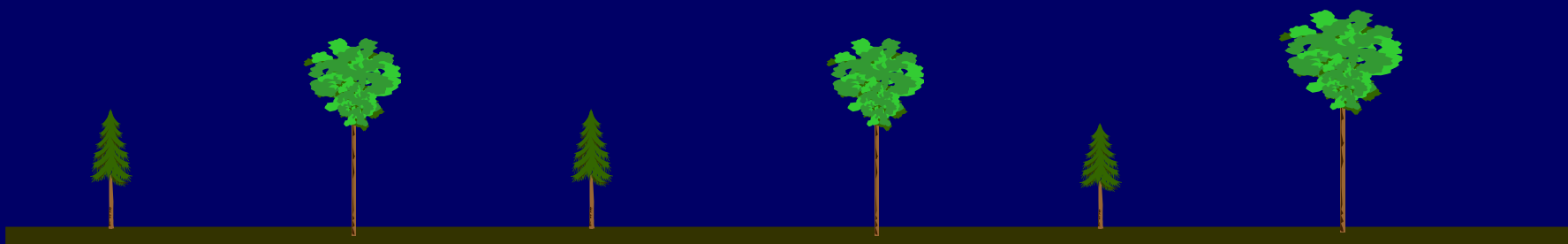
Start with wider spacing →

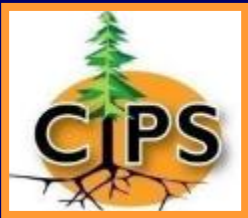




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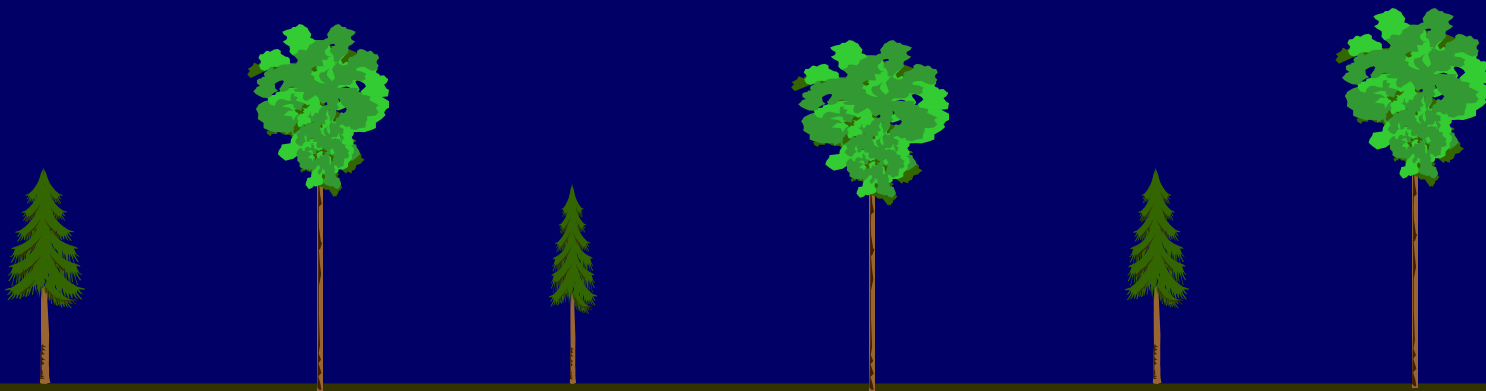
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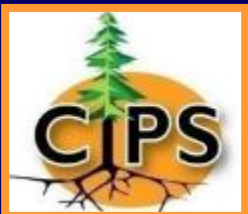




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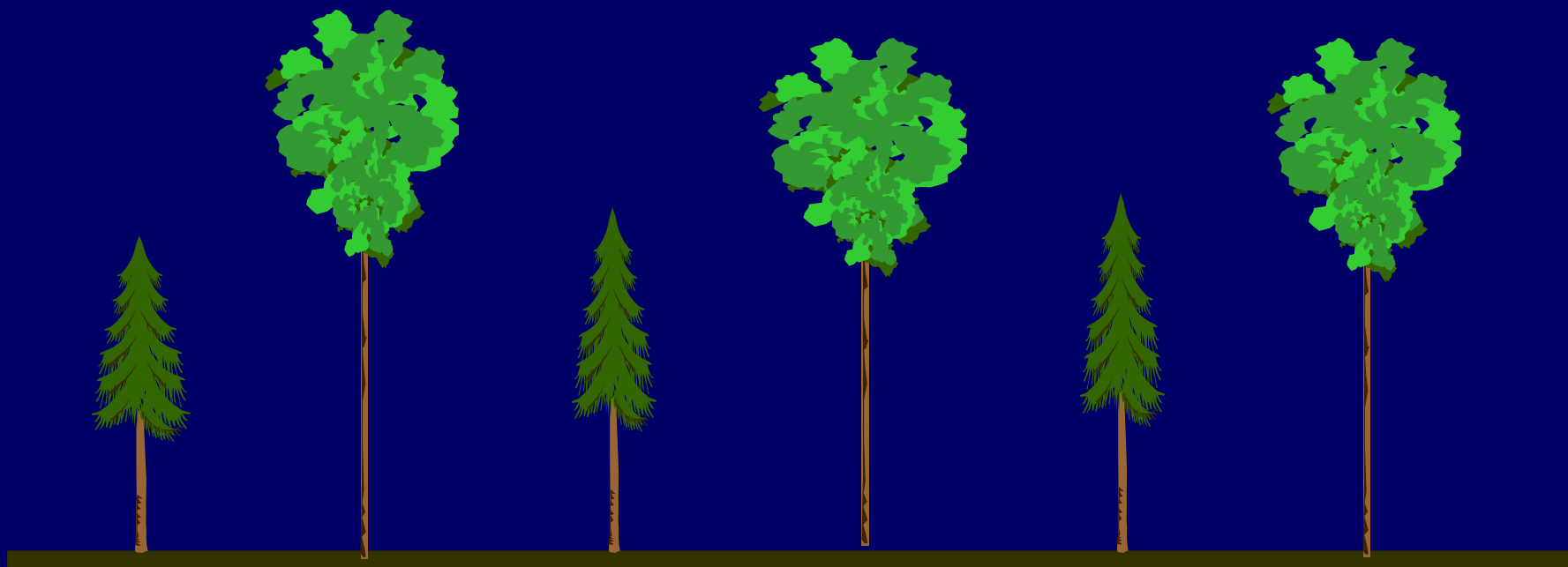
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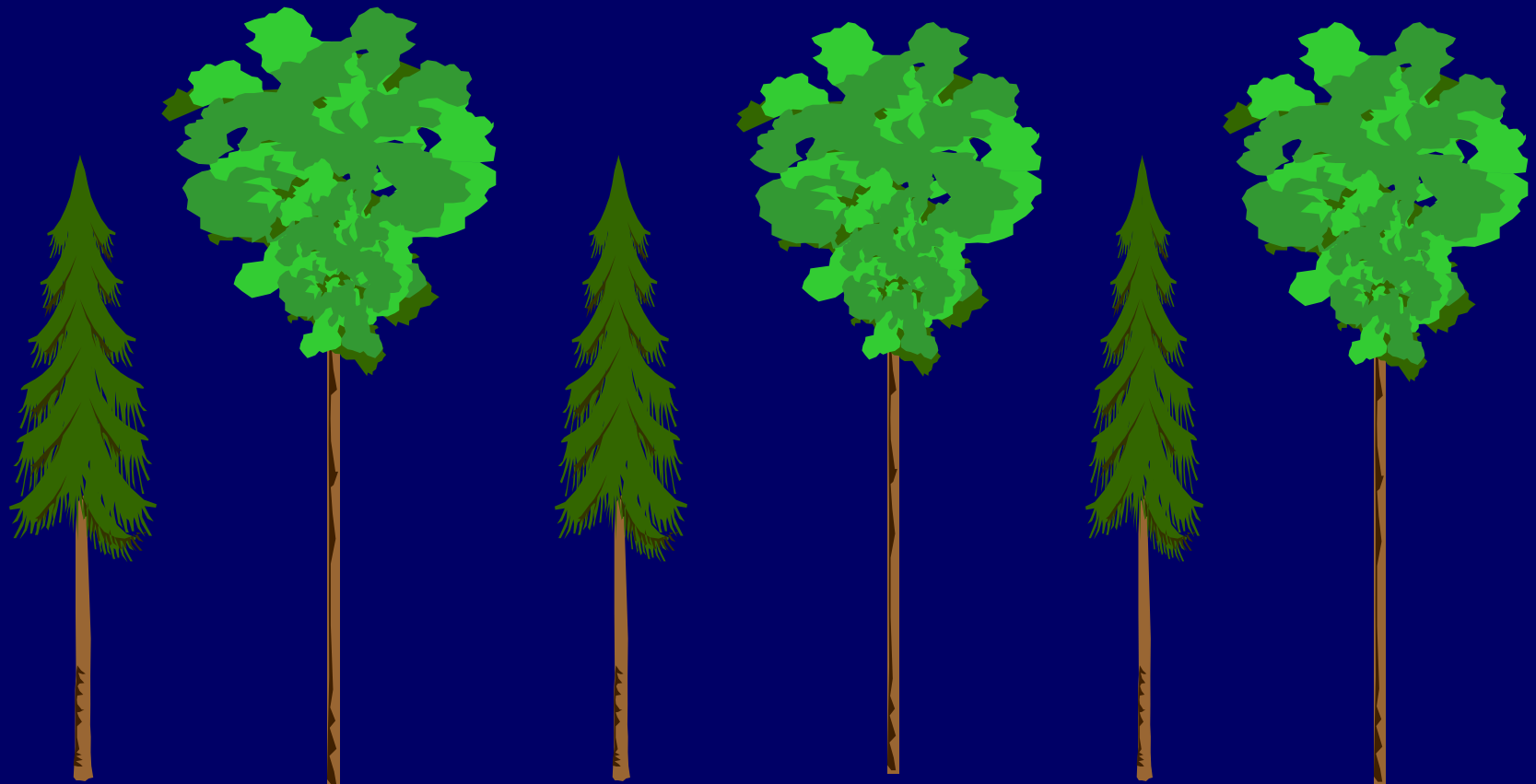
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Varieties of mixed species stands

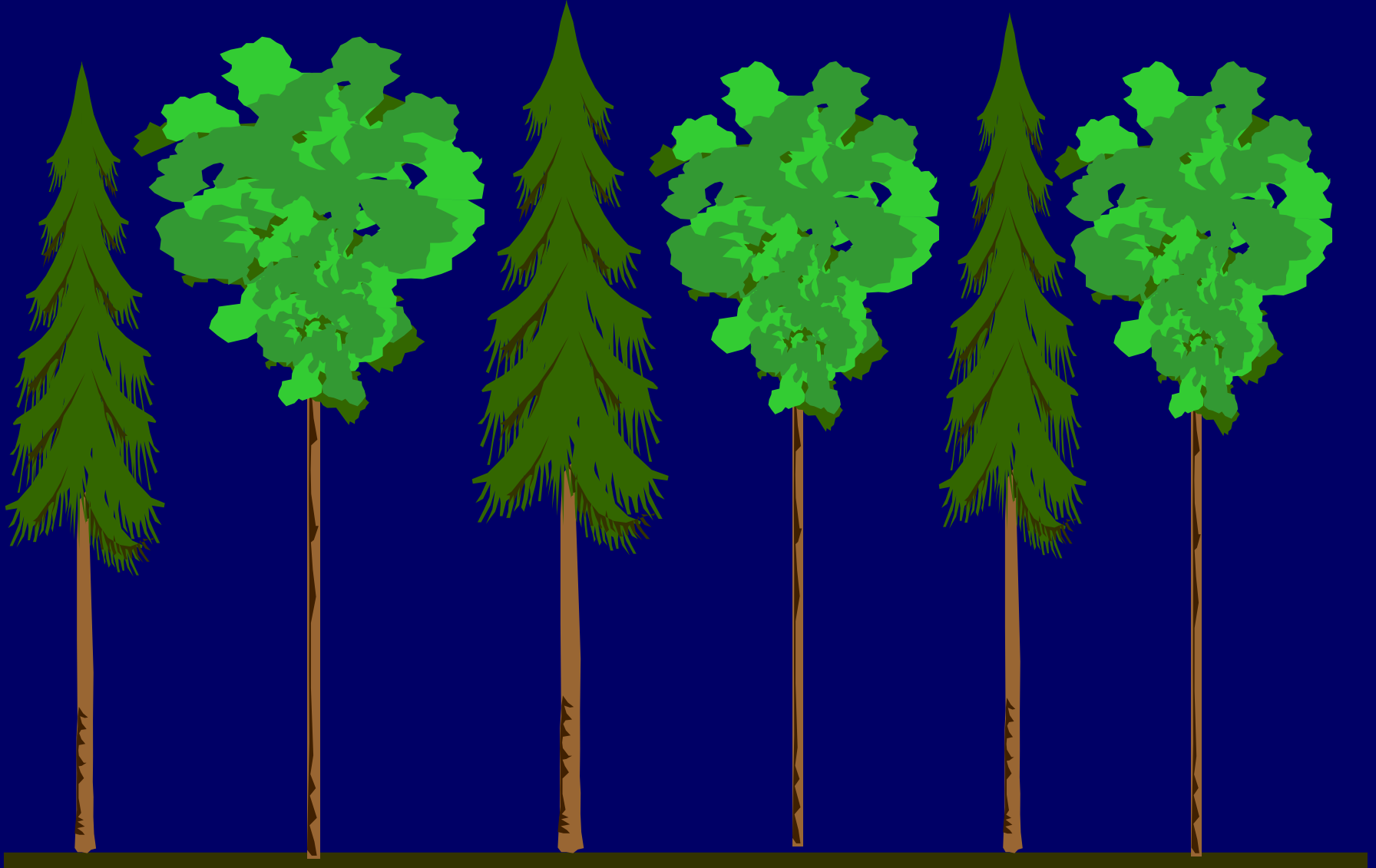
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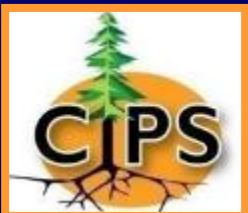




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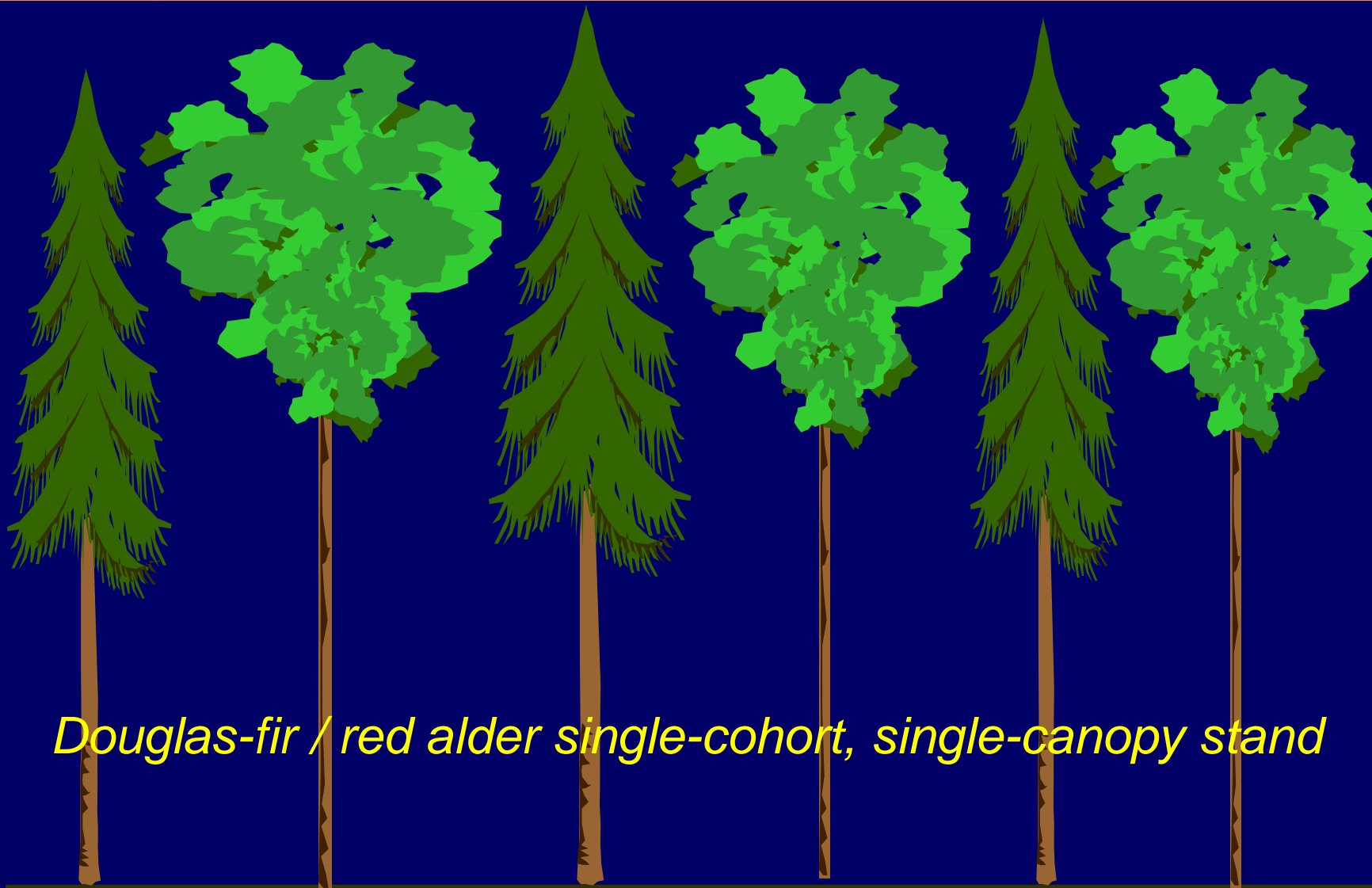
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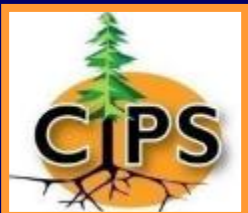


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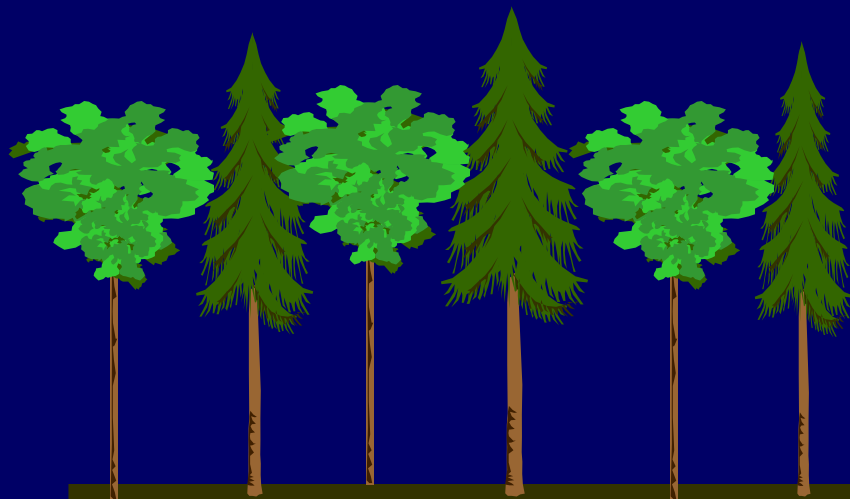


Douglas-fir / red alder single-cohort, single-canopy stand



Varieties of mixed species stands

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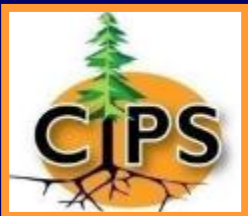


Low initial density: Douglas-fir spaced away from red alder

versus

High initial density: Douglas-fir close to red alder





Varieties of mixed species stands

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Douglas-fir / red alder mix, as single cohort, single canopy stand, can be a transient phase itself, depending on the spacing relative to height growth rates





Varieties of mixed species stands

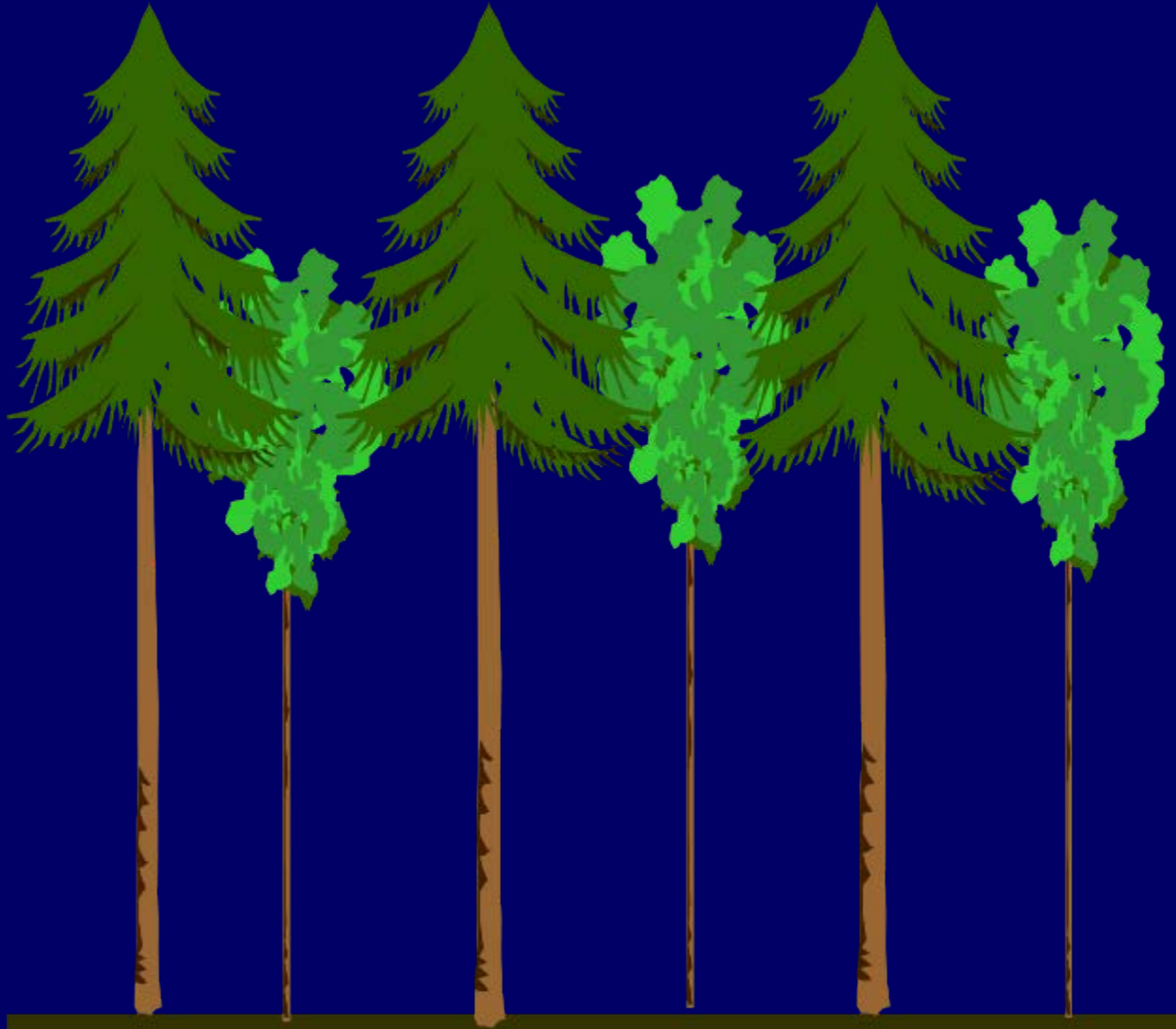
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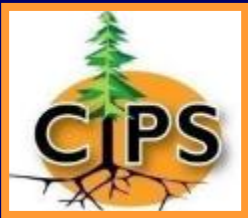




Varieties of mixed species stands

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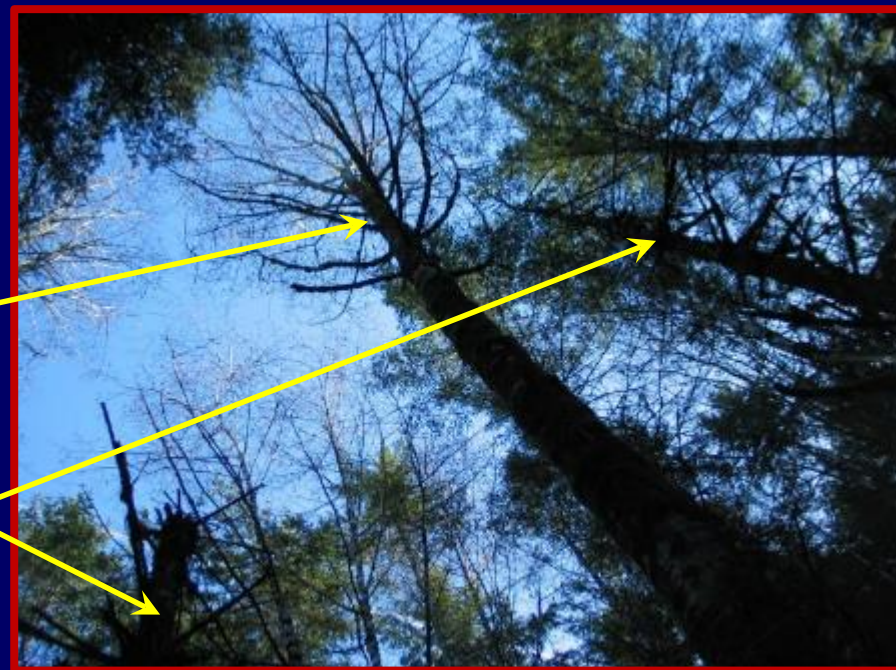


RA

struggling
DF

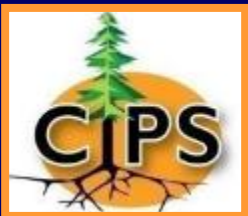
Risley Creek Douglas-fir / red alder study (Miller et al. 1999)

- 300 planted DF per ac
- Leave 0, 20, 40, 80 natural red alder per ac



RA

dead DF

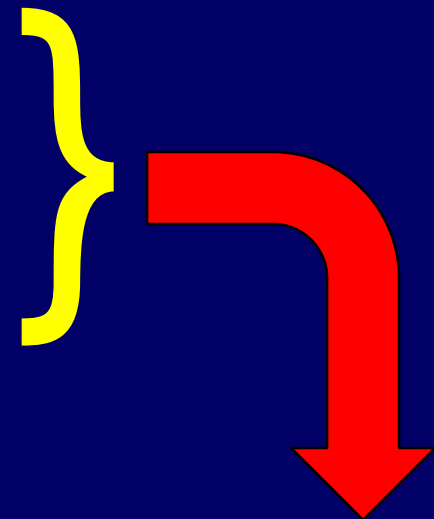


Varieties of mixed species stands

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What are the key attributes driving the dynamics of species mixes ?

- 1) Height growth patterns*
- 2) Relative shade tolerance*
- 3) Potential crown width*



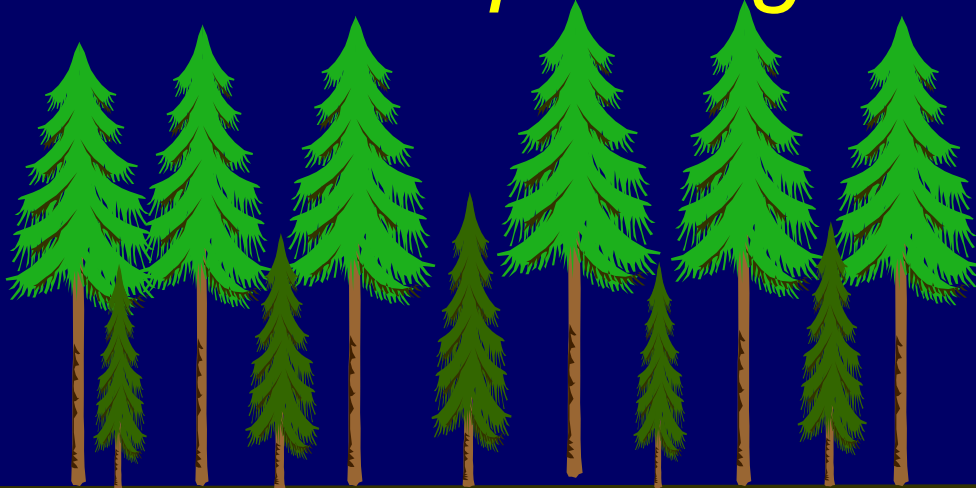
**SPACING X SPECIES COMPOSITION
INTERACTIONS**



Varieties of mixed species stands

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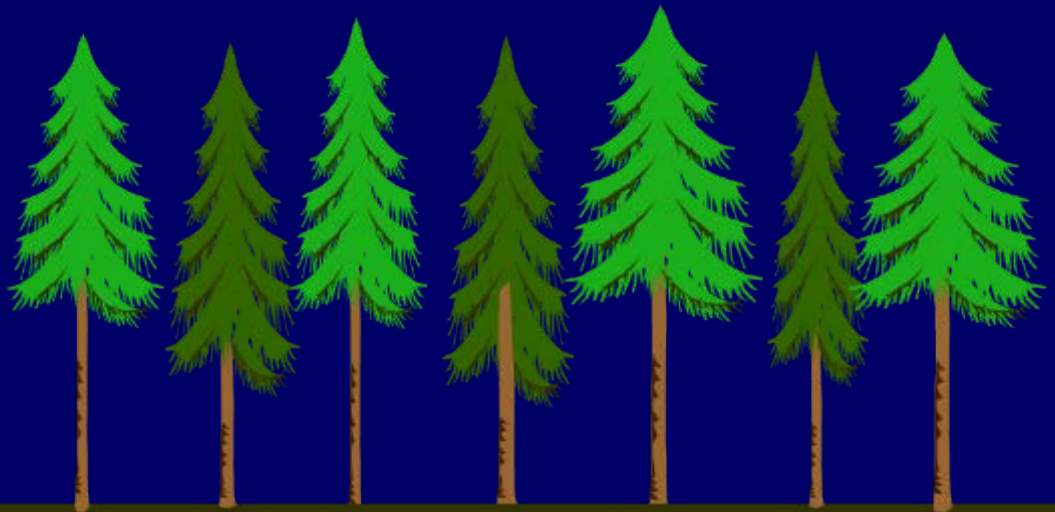
Ponderosa pine / grand fir spacing trials

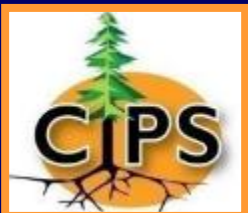


6 x 6 ft initial spacing

Now 44 yrs old !!

18 x 18 ft initial spacing



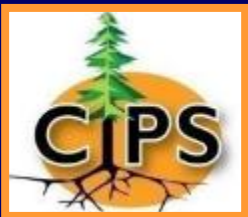


Varieties of mixed species stands

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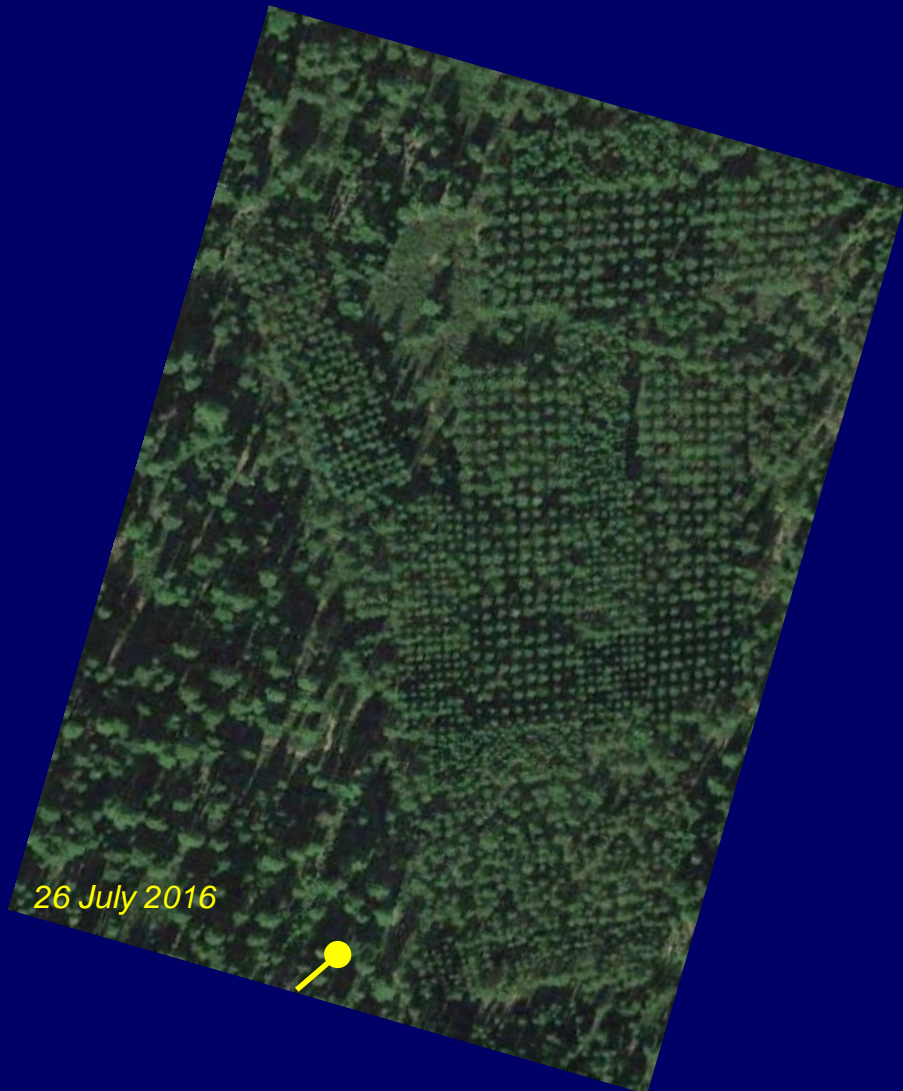
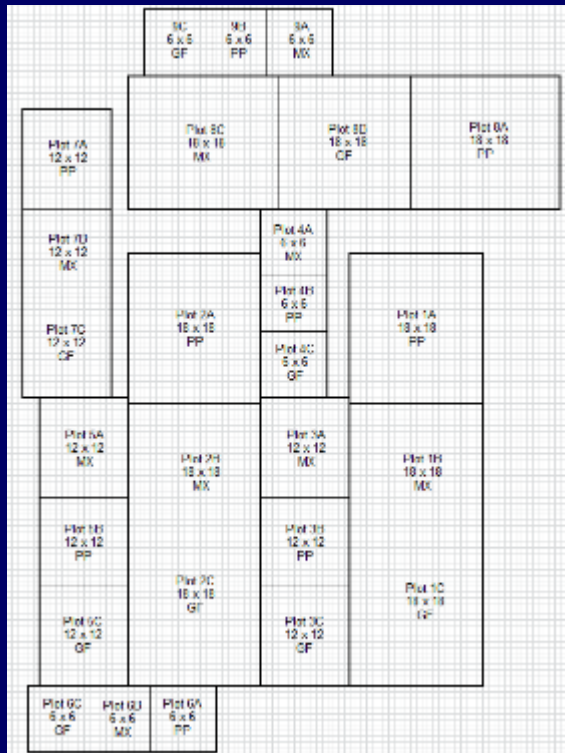
Lookout Mountain PP-GF spacing trial

- Three initial spacings: 6, 12, 18 ft
- Three species mixes:
 - pure PP
 - pure GF
 - 50:50 mix PP/GF
- Planted in 1974 (44 yrs old in 2018)
- Mixed conifer/snowbrush/chinkapin plant association
- Site index approximately 90 ft at 50 years
- Elevation ~ 5100 ft
- Annual precipitation ~39 inches

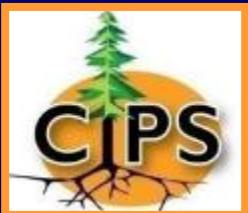


Varieties of mixed species stands

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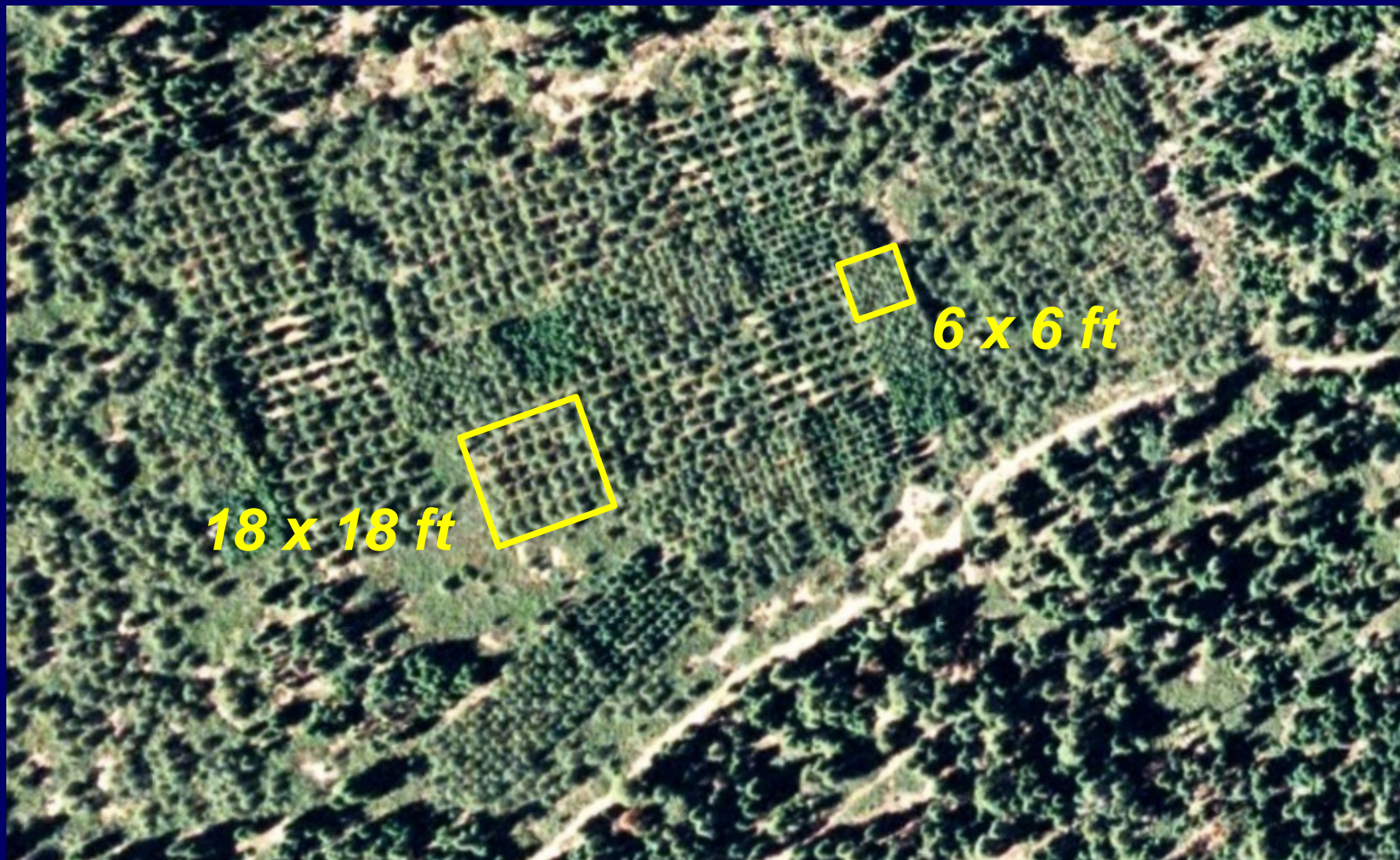


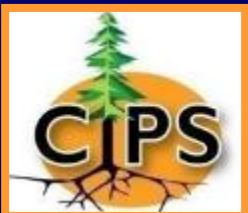
26 July 2016



Varieties of mixed species stands

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Varieties of mixed species stands

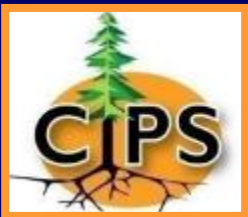
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2004

2016





Varieties of mixed species stands

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Varieties of mixed species stands

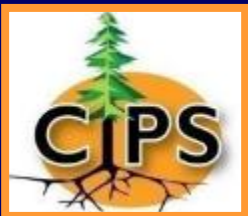
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PP

GF

PP/GF: 6-ft



Varieties of mixed species stands

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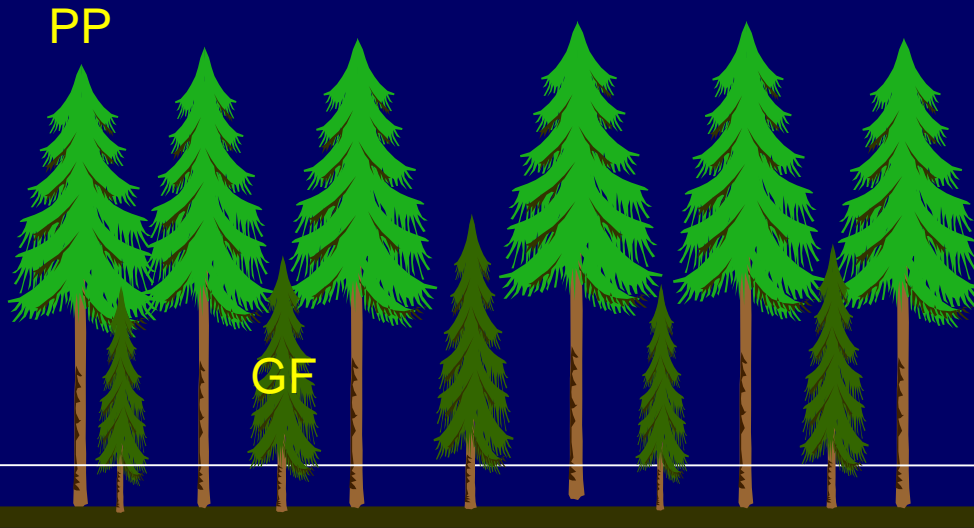


PP GF
18-ft spacing



Varieties of mixed species stands

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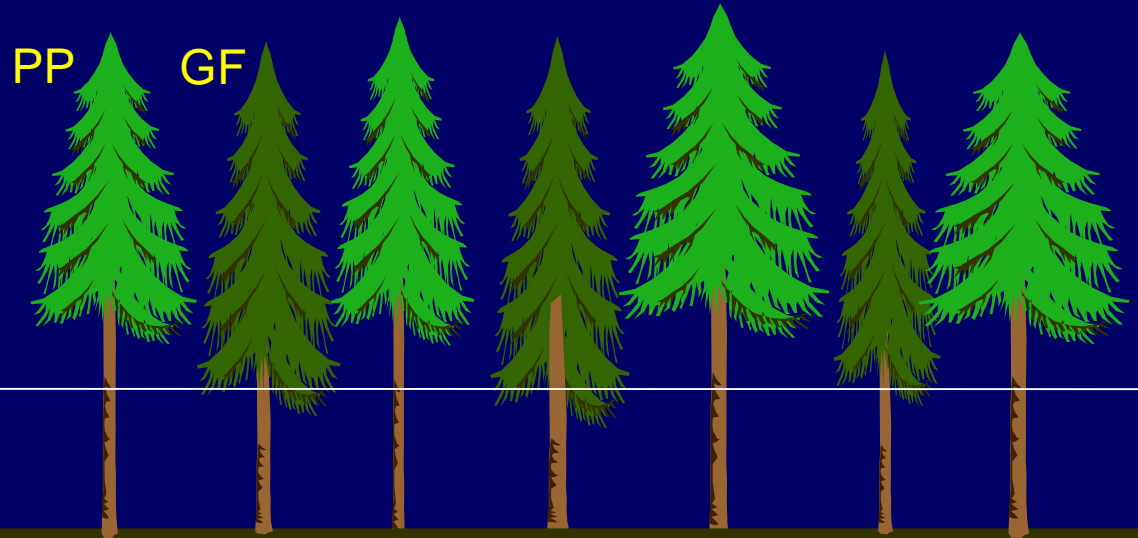


Implications for relative size and relative vigor attained by each species.

← crown base

versus

crown base





Varieties of mixed species stands

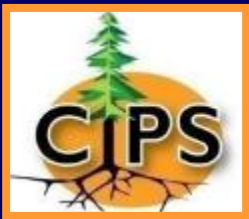
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In mixed species stands, have to pay attention to stand density management because there are consequences for:

- Individual tree health and vigor (just as in a single-species stand);

but also

- Consequences for stand dynamics and resulting stand structure (with a feedback to individual tree health and vigor).



Varieties of mixed species stands

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At some stage in designing silvicultural regimes for mixed-species stands, particularly from the viewpoint of pest resistance, the question of selecting target stand densities emerges

Several approaches have been taken, for example, to estimate a maximum SDI for a given species mix:

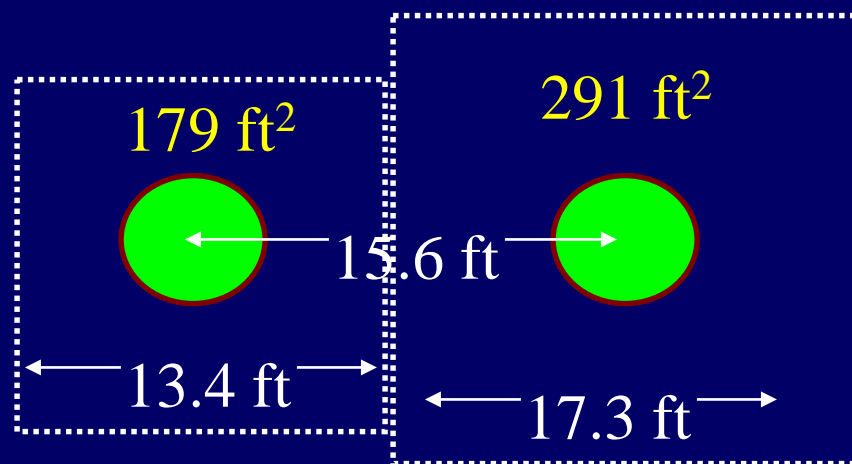
- 1) Stand maximum SDI corresponding with the species with the LOWEST maximum SDI (Cochran et al. 1994)
- 2) Basal area weighted maximum SDI (e.g., Hann / ORGANON)
- 3) Maximum SDI based on stand mean specific gravity (available at species level; Woodall et al. 2011)
- 4) Modification of basal area weighted maximum SDI that takes into account vertical structure, i.e., vertical position of the constituent species?



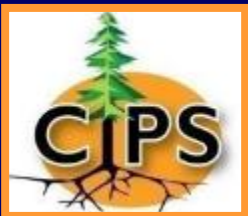
Varieties of mixed species stands

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Douglas-fir would need 179 ft² to grow to 12 inches within recommended density management limits, and ponderosa pine will need 291 ft² to grow to 12 inches



Implies 63% more space is needed by ponderosa pine (before even considering their relative height growth).



Varieties of mixed species stands

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Cochran et al. (1994). Suggested stocking levels for forest stands in northeastern Oregon and southeastern Washington. PNW-RN-513

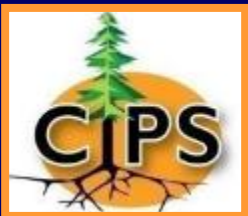
Recommendations for Upper Management Zone (UMZ):

ponderosa pine ($SDI_{UMZ} = 365 \cdot [-0.36 + 0.01 \cdot SI]$)

and

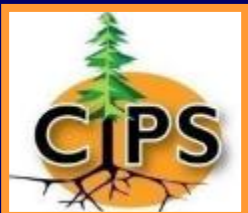
lodgepole pine ($SDI_{UMZ}=170$)

are based partly or entirely on keeping susceptibility to bark beetles at low level.



Performance of Mixed Species Stands

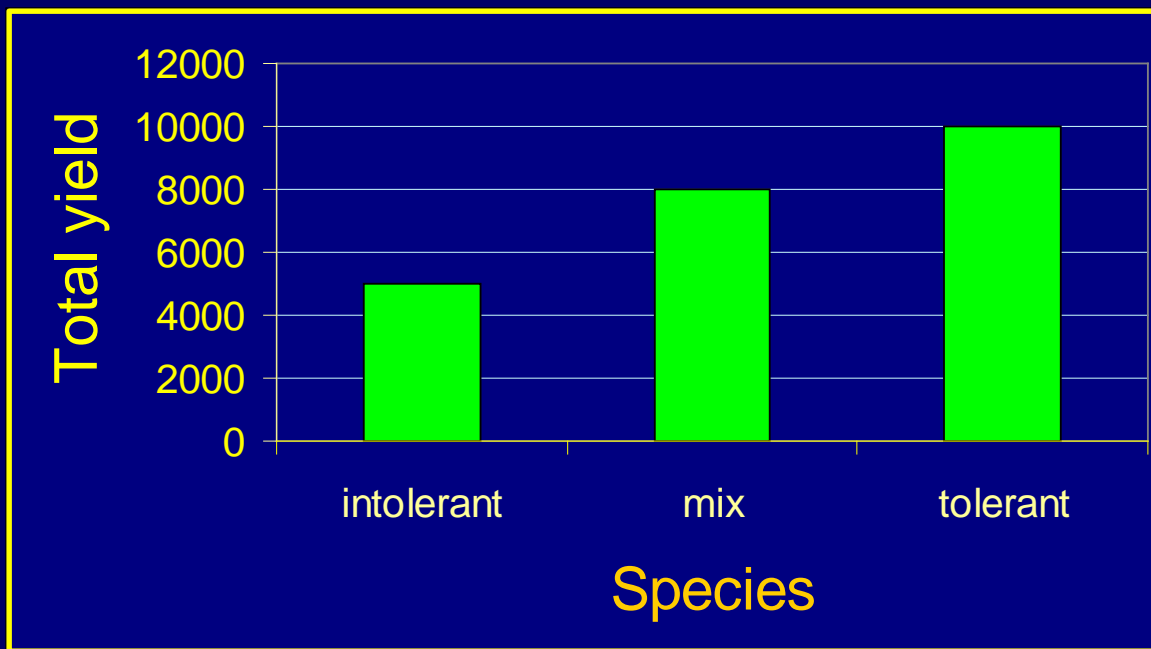
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Relative productivity

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- Relative yields
 - Typical patterns in absolute yield:
 - Controlled spacing trials
 - Observational studies

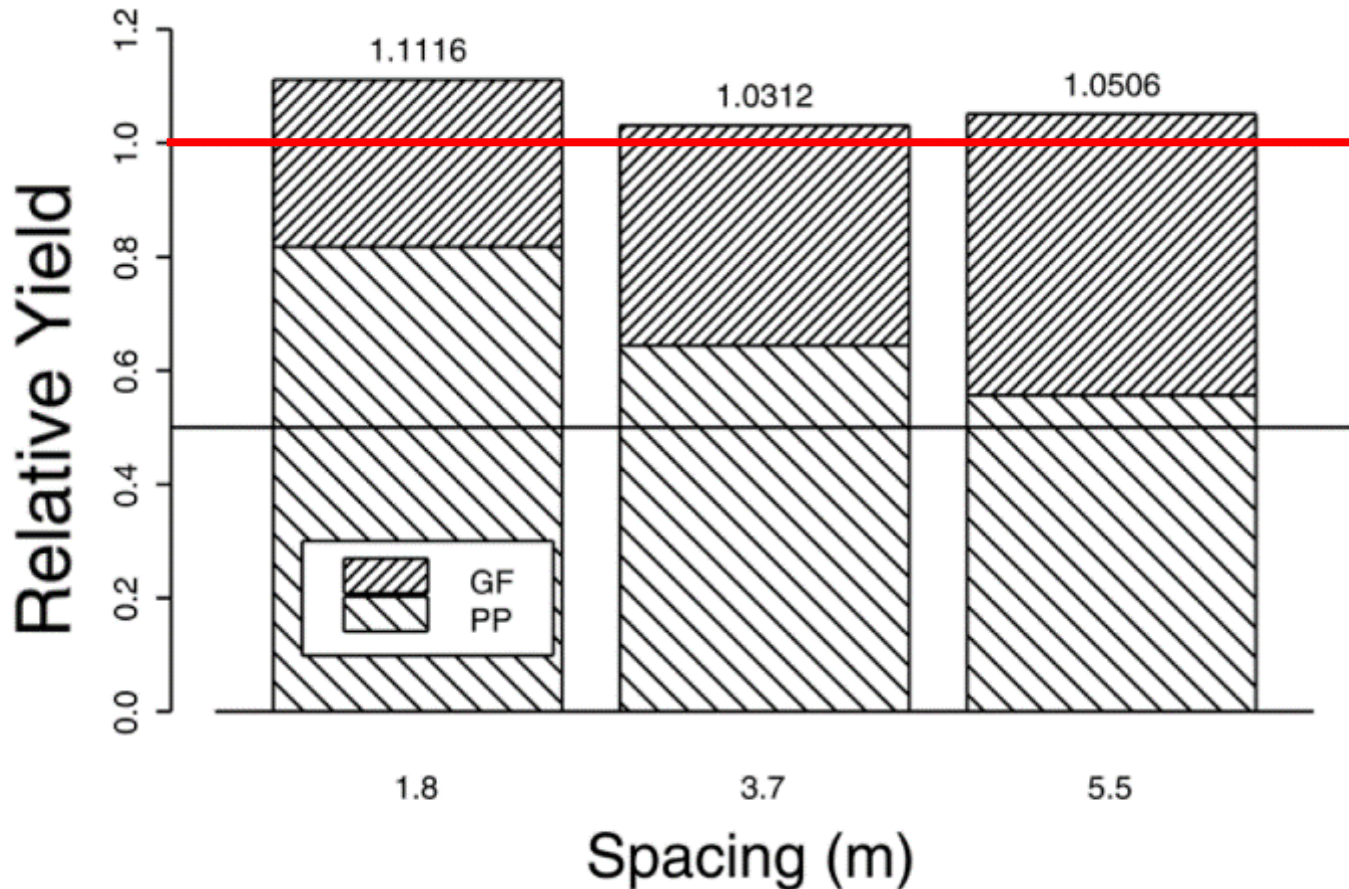




Relative productivity

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Considering *RELATIVE YIELDS*, Ponderosa pine is over-yielding (>0.5), and grand fir is under-yielding (<0.5) in mixtures



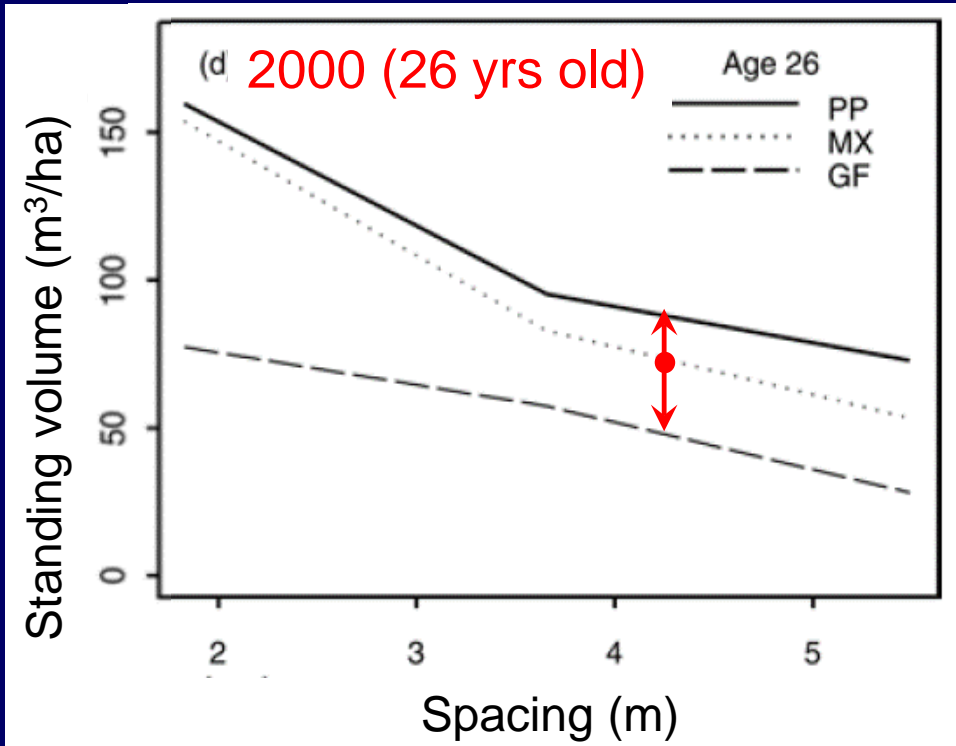


Relative productivity

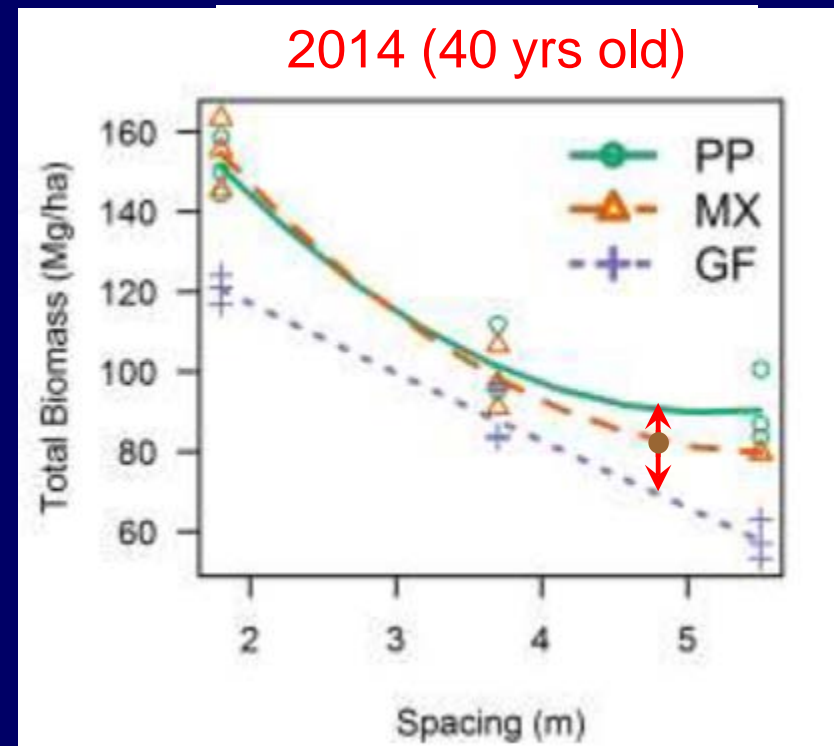
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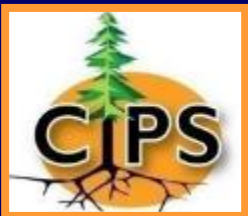
Volume & total above-ground biomass of 50:50 mix \leq pure plots of ponderosa pine (PP) and grand fir (GF)

Garber (2002)



Terroba (2014)





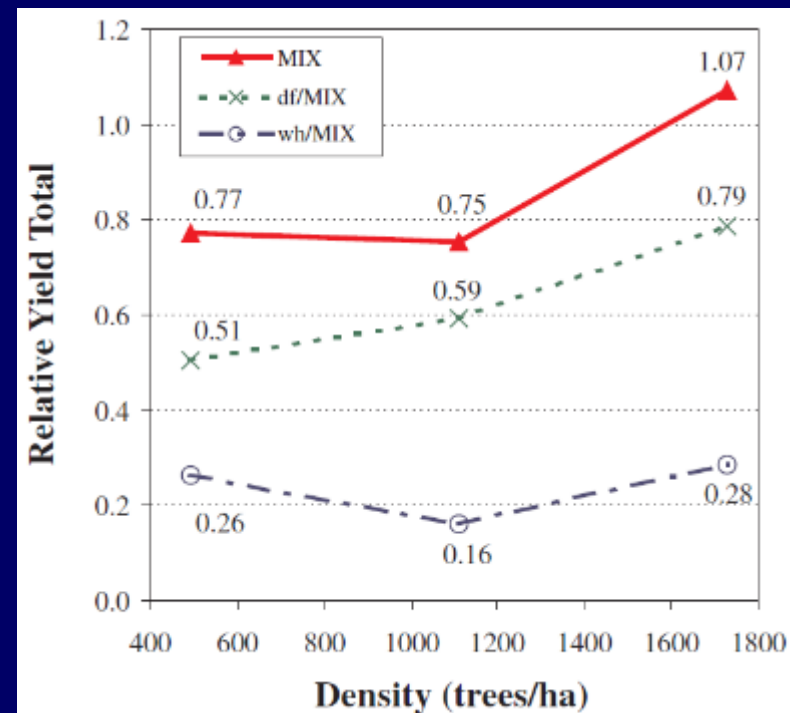
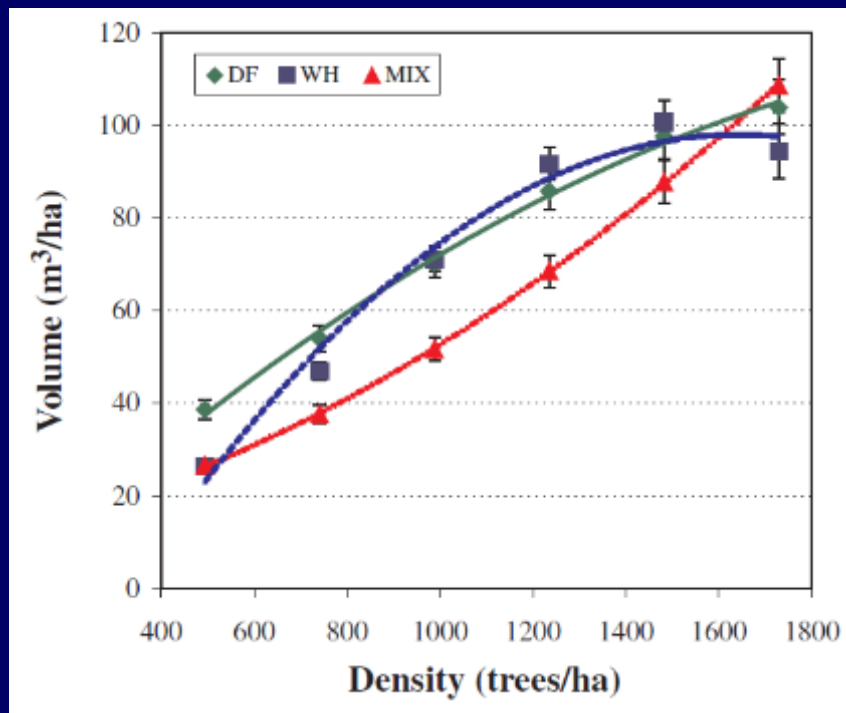
Relative productivity

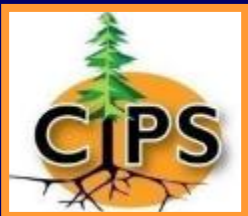
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Stem volume of 50:50 mix \leq pure plots of Douglas-fir (DF) and western hemlock (WH): underyielding, negative “mixing effect”

Amoroso & Turnblom (2006):

Mixed species spacing trials at plantation age 12



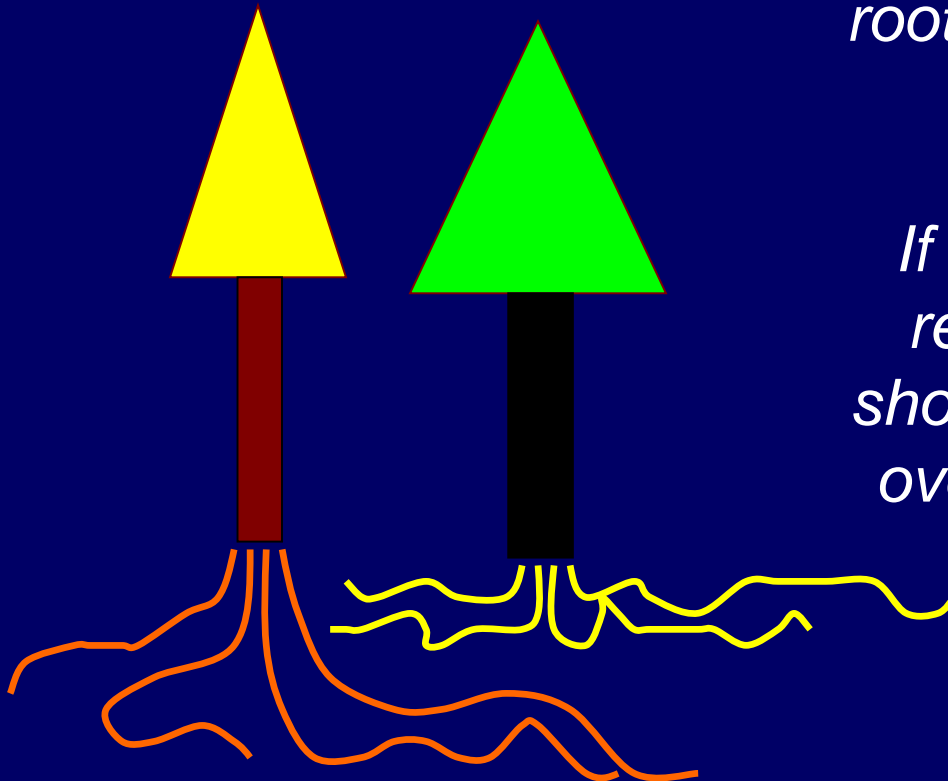


Relative productivity

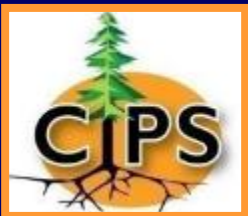
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- Potential drivers of increase in yields
 1. Niche separation

For example, different rooting depths



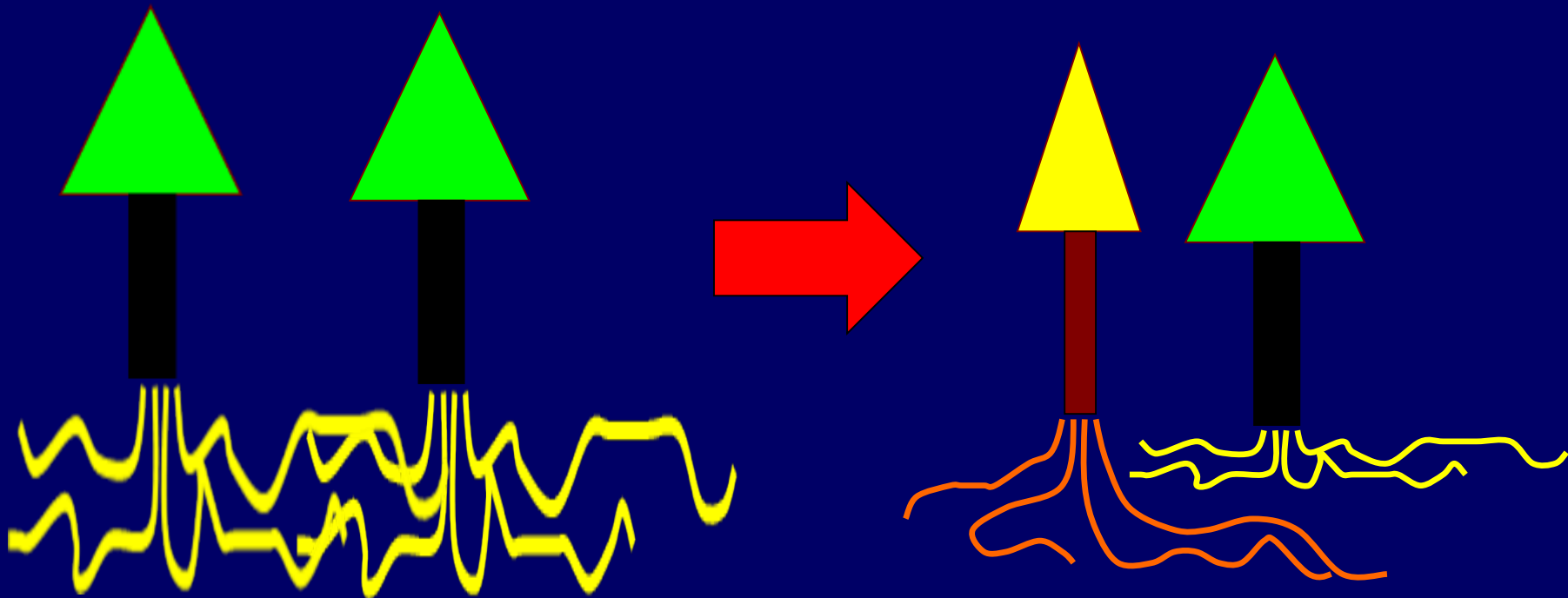
If utilizing untapped resources, mixture should out-produce, or over-yield, relative to pure stand



Relative productivity

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- BUT, research on root distribution in pure and mixed stands (Schmid and Kazda 2002) suggests spatial partitioning of soil resources is a response to competition between species (→ poorer tree vigor and health; e.g., loblolly pine susceptibility to bark beetle with intercropped oaks)





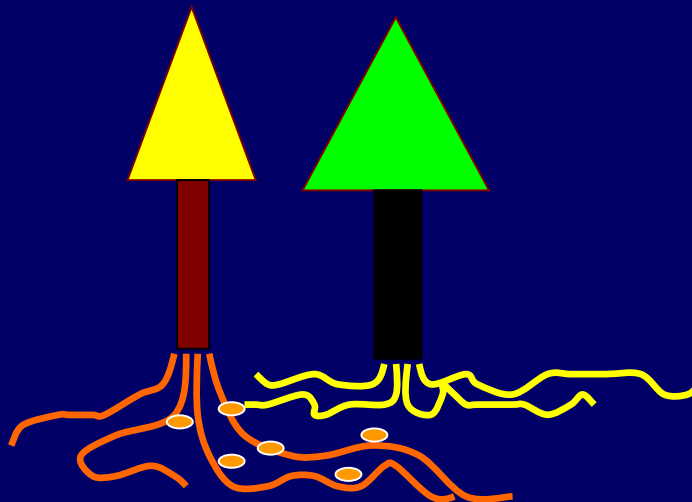
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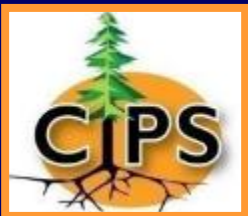
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- Potential drivers of increase in relative yields

- 2. Facilitation

- Red alder fixes nitrogen, particularly on poor sites
 - If fixation by alder increases nitrogen available to Douglas-fir, could result in an increased yield of mixed stands
 - BUT, trade-off against competitive effect of red alder





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- *What is the role of mixed-species stands in minimizing risk versus minimizing resistance and/or resilience?*



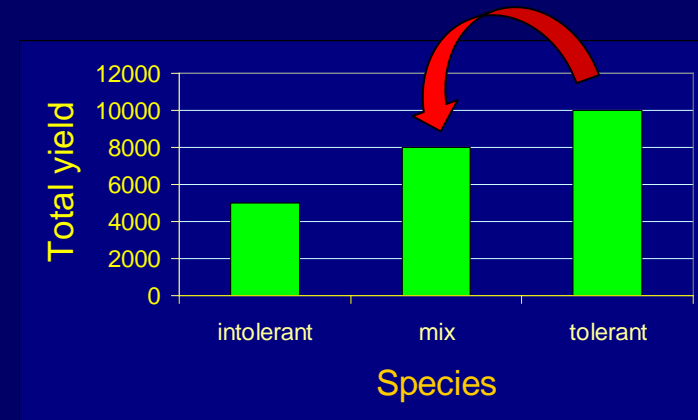
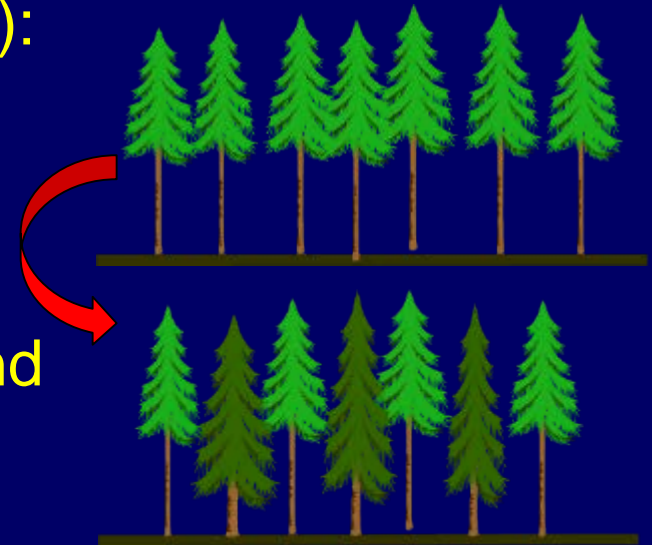
Sources of stress and disturbance

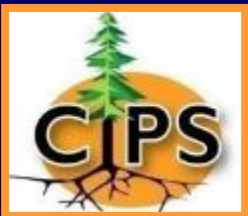
Forest Health in Oregon: State of the State 2018

Integrated management for maintaining healthy forests west of the Cascade Crest (Edmonds et al. 2000):

Recommend that we:

- “Shift from single species to multiple species to reduce insect outbreaks and proliferation of diseases”
- “This involves tradeoffs between maximizing timber production and minimizing insect and disease management”



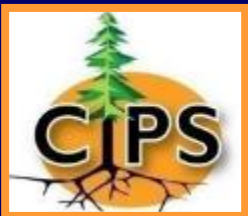


Sources of stress and disturbance

Forest Health in Oregon: State of the State 2018

Potential effects of stand density and/or species composition on risk of insect damage (as summarized by Berryman 1986):

Insect	Tree species	Stand density	Species composition
Mountain pine beetle	Lodgepole pine	High	<i>% pine</i>
Mountain pine beetle	Ponderosa pine	High	<i>% pine</i>
Fir engraver beetle	Grand fir	High	<i>% grand fir</i>
Spruce beetle	Engelmann spruce	High	<i>% spruce</i>
Budworm	Balsam fir/spruce	High	<i>% fir</i>
Balsam woolly adelgid	Balsam fir	High	<i>% fir</i>
Pine leaf aphid	Pine and spruce	-	<i>Equal % pine and spruce</i>



Sources of stress and disturbance

Forest Health in Oregon: State of the State 2018

Management

- Plant fir in sites that receive adequate moisture
- Manage for root disease
- Thin overstocked stands and reduce competing vegetation
- Remove damaged or less vigorous trees (those with weak crowns)
- Remove infested trees and avoid creating >4" slash Jan. - July to reduce beetle populations

Fir Engraver Beetle. 2017. ODF Forest Health Fact Sheet.



Figure 4.
Red foliage
stage on
grand fir.
Photo by
Dave Powell.

- Beetle outbreaks often follow period of subnormal precipitation or harvesting activity.
- Thinning of a stand can temporarily lower the vigor of residual trees by sudden exposure.
- Timber harvesting can create slash, a preferred material for fir engraver.
- Slash does not predispose a stand to fir engraver outbreaks, but may cause some increase in fir engraver populations.



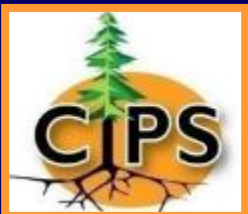
Sources of stress and disturbance

Forest Health in Oregon: State of the State 2018

- Beetle outbreaks often follow period of subnormal precipitation.

Compensatory growth in mixed species stands:

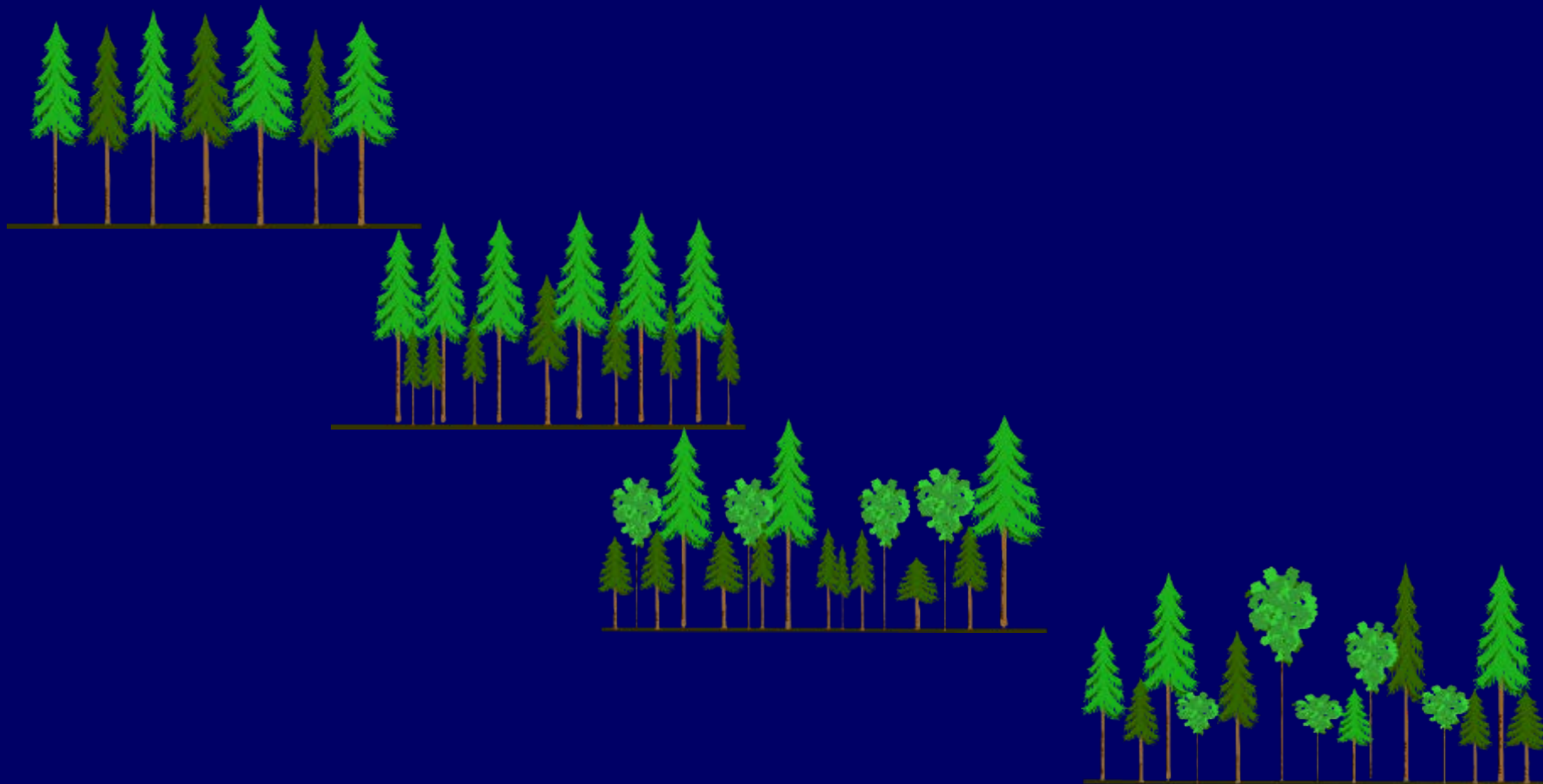
- If species have different temperature-precipitation optima, then stand-level growth should be maintained over climatic fluctuations (Forrester and Pretzsch 2015)
- Does that enhance or diminish individual tree vigor and pest resistance/resilience (or simply maintain productivity)?

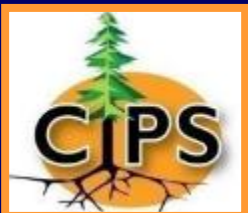


Sources of stress and disturbance

Forest Health in Oregon: State of the State 2018

Implications of stand structure for fuel ladders and risk of stand-replacing fire (or other stand-replacing disturbances)





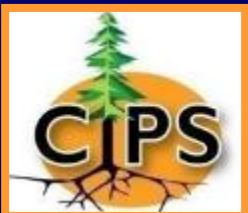
Sources of stress and disturbance

Forest Health in Oregon: State of the State 2018

Implications of stand structure for fuel ladders and risk of stand-replacing fire (or other stand-replacing disturbances)

Control plot at
Finley Butte
installation of
uneven-age
ponderosa pine
study





Sources of stress and disturbance

Forest Health in Oregon: State of the State 2018

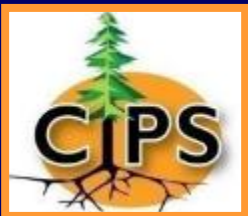
Implications of stand structure for fuel ladders and risk of stand-replacing fire (or other stand-replacing disturbances)

Conventional B-D-q uneven-age regime at Finley Butte



Overstory removal + thinning at Finley Butte





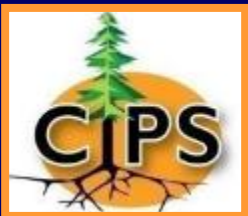
Sources of stress and disturbance

Forest Health in Oregon: State of the State 2018

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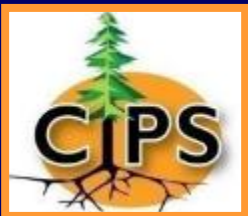
Very different level of fire risk with and without layering from mix of species or ages





Performance of Mixed Species Stands

- *What is the potential range of stand structures in mixed-species stands?*
- *Does productivity of mixed-species stand always/ever exceed that of single-species stands?*
- *Are mixed-species stands more or less resistant/resilient to the following health threats than single-species stands?*
 - *Insects*
 - *Disease*
 - *Fire*
 - *Climatic fluctuations or extremes*
- *What is the role of mixed-species stands in minimizing risk versus minimizing resistance and/or resilience?*



Risk, resistance, resilience

Forest Health in Oregon: State of the State 2018

Advantages and disadvantages of species mixes

- Reduce insect/disease susceptibility (“reduce insect outbreaks and proliferation of diseases”?)

or

- Reduce economic/environmental risk of loss to insects and disease?

Both influential in different forest types, but growing consensus is that the latter dominates.

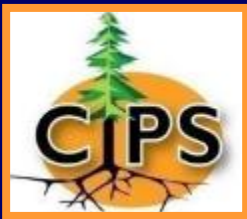


Performance of Mixed Species Stands: Relative Productivity and Response to Disturbances

Forest Health in Oregon: State of the State 2018

Conclusions:

- Mixed species stands can be successfully managed for a wide variety of structures*

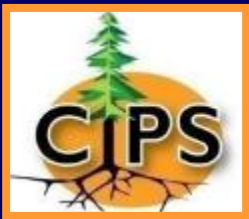


Performance of Mixed Species Stands: Relative Productivity and Response to Disturbances

Forest Health in Oregon: State of the State 2018

Conclusions:

- *Mixed species stands can be successfully managed for a wide variety of structures*
- *The structure of a mixed species stand (horizontal and vertical) has a strong influence on:*
 - *Relative growth and vigor of constituent species*
 - *Stand-level productivity and economic performance*
 - *Susceptibility to stand-replacing fire*
 - *Resistance to some insects (tree vigor, perhaps spatial arrangement)*
 - *Possible resistance to some diseases (e.g., spread of root rot?)*
 - *Buffering of stand-level growth over weather/climatic cycles (compensatory growth)*



Performance of Mixed Species Stands: Relative Productivity and Response to Disturbances

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Performance of Mixed Species Stands: Relative Productivity and Response to Disturbances

Forest Health in Oregon: State of the State 2018

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 - Buffering of stand-level growth over weather/climatic cycles (compensatory growth)*
- A mix of species reduces economic and environmental risk of forest loss due to a species-specific forest insect or disease*
- Many examples where resistance/resilience is implied; but huge literature on diversity/stability/productivity relationships*

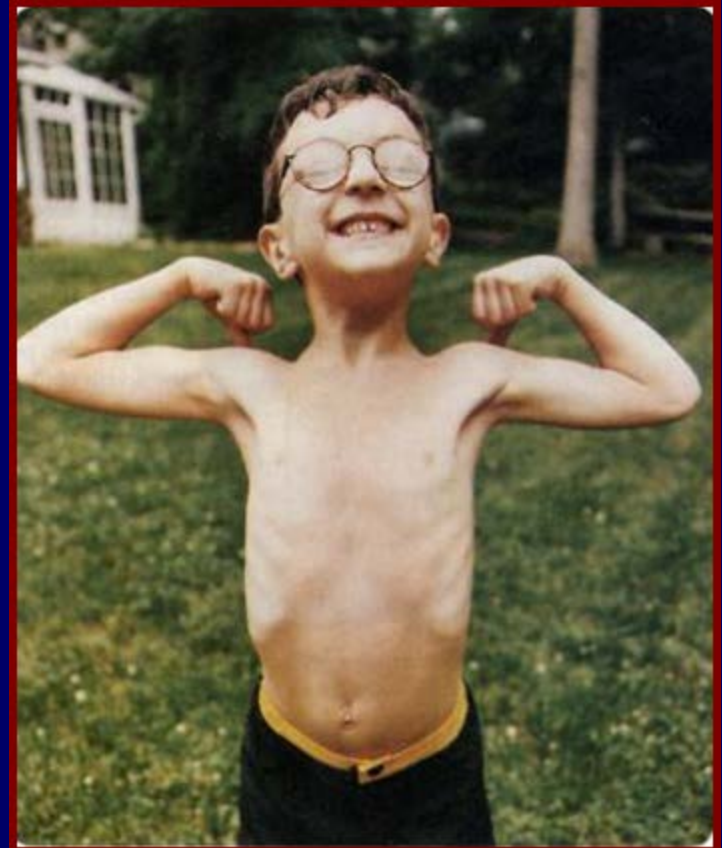


Performance of Mixed Species Stands: Relative Productivity and Response to Disturbances

Forest Health in Oregon: State of the State 2018

Conclusions:

- To a large extent, it's about tree vigor*
 - Ability to maintain healthy level of photosynthesis and growth rate to overcome attack*
 - Ability to generate sufficient reserves to allocate carbohydrates to defensive chemicals*
 - Ability to generate sufficient reserves to get through periods of climatic stress, without compromising defense*





*Thanks for
your attention!*



Performance of Mixed Species Stands: Relative Productivity and Response to Disturbances

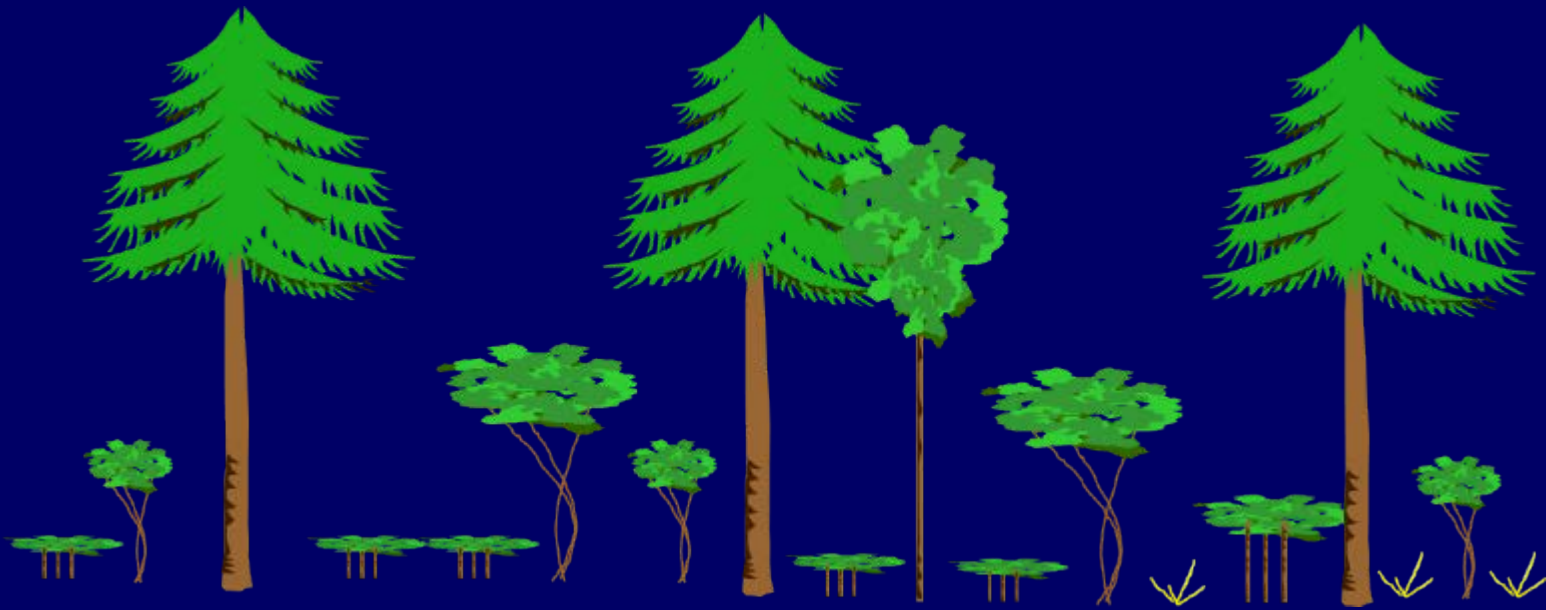
Forest Health in Oregon: State of the State 2018



Performance of Mixed Species Stands: Relative Productivity and Response to Disturbances

Forest Health in Oregon: State of the State 2018

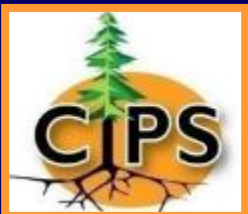
Understory growth in thinned stand





Forest Health in Oregon: State of the State 2018

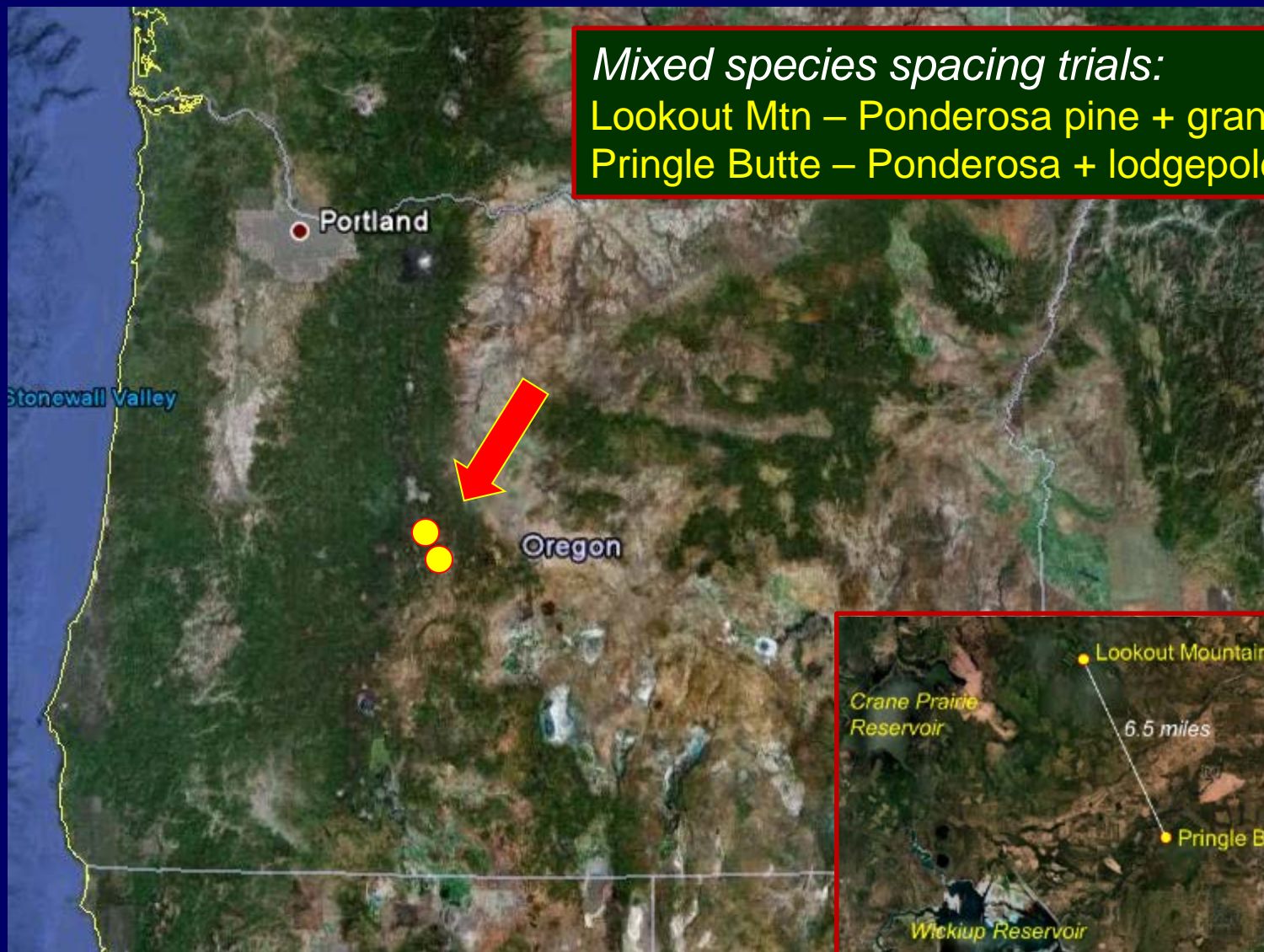




Varieties of mixed species stands

Forest Health in Oregon: State of the State 2018

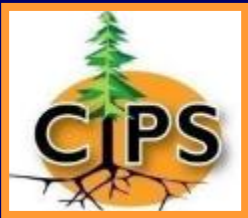
Mixed species spacing trials:
Lookout Mtn – Ponderosa pine + grand fir
Pringle Butte – Ponderosa + lodgepole pine





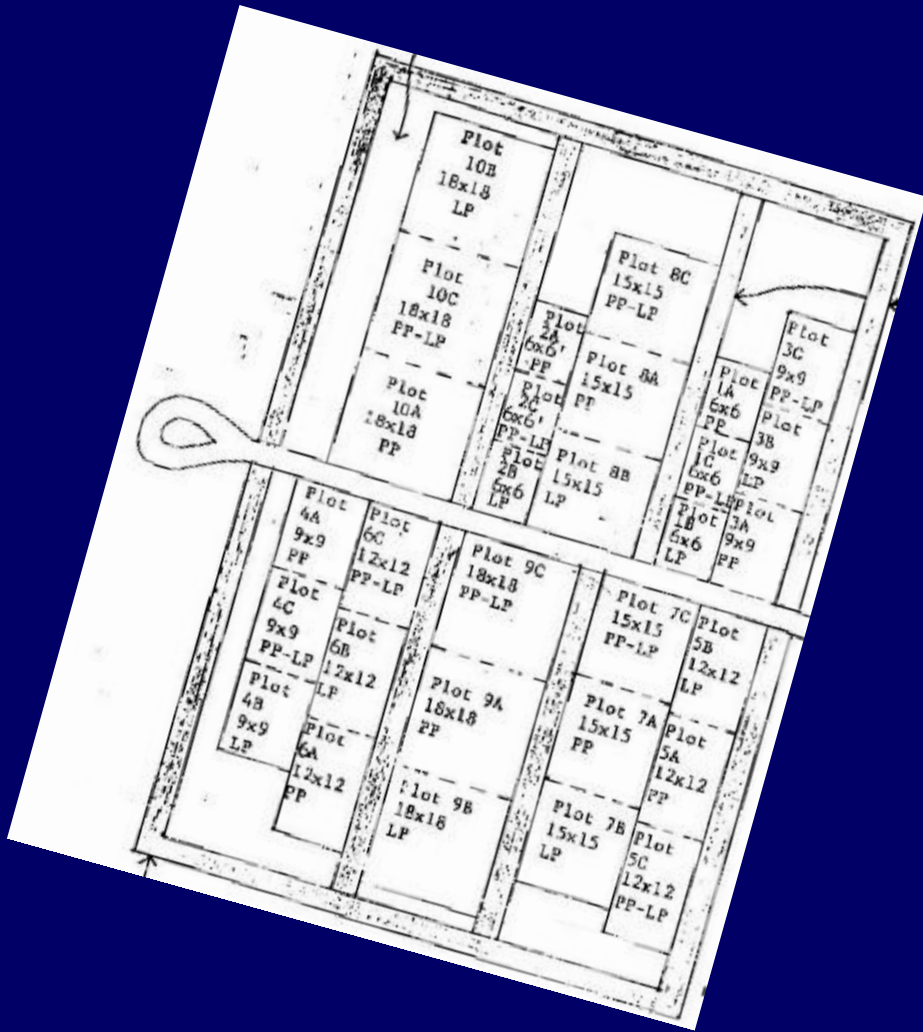
Advantages and disadvantages of species mixes

- Relative yields (yield in pure vs. mixed stands)
 - Niche separation
 - Facilitation
 - Typical patterns in relative yield
- Insect/disease susceptibility
- Insect/disease risk
- Stability
- Biological diversity
- Investment/economic diversity



Varieties of mixed species stands

Forest Health in Oregon: State of the State 2018



26 July 2016



Varieties of mixed species stands

Forest Health in Oregon: State of the State 2018

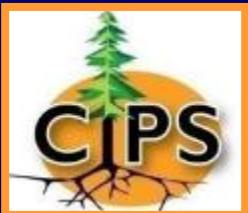




Varieties of mixed species stands

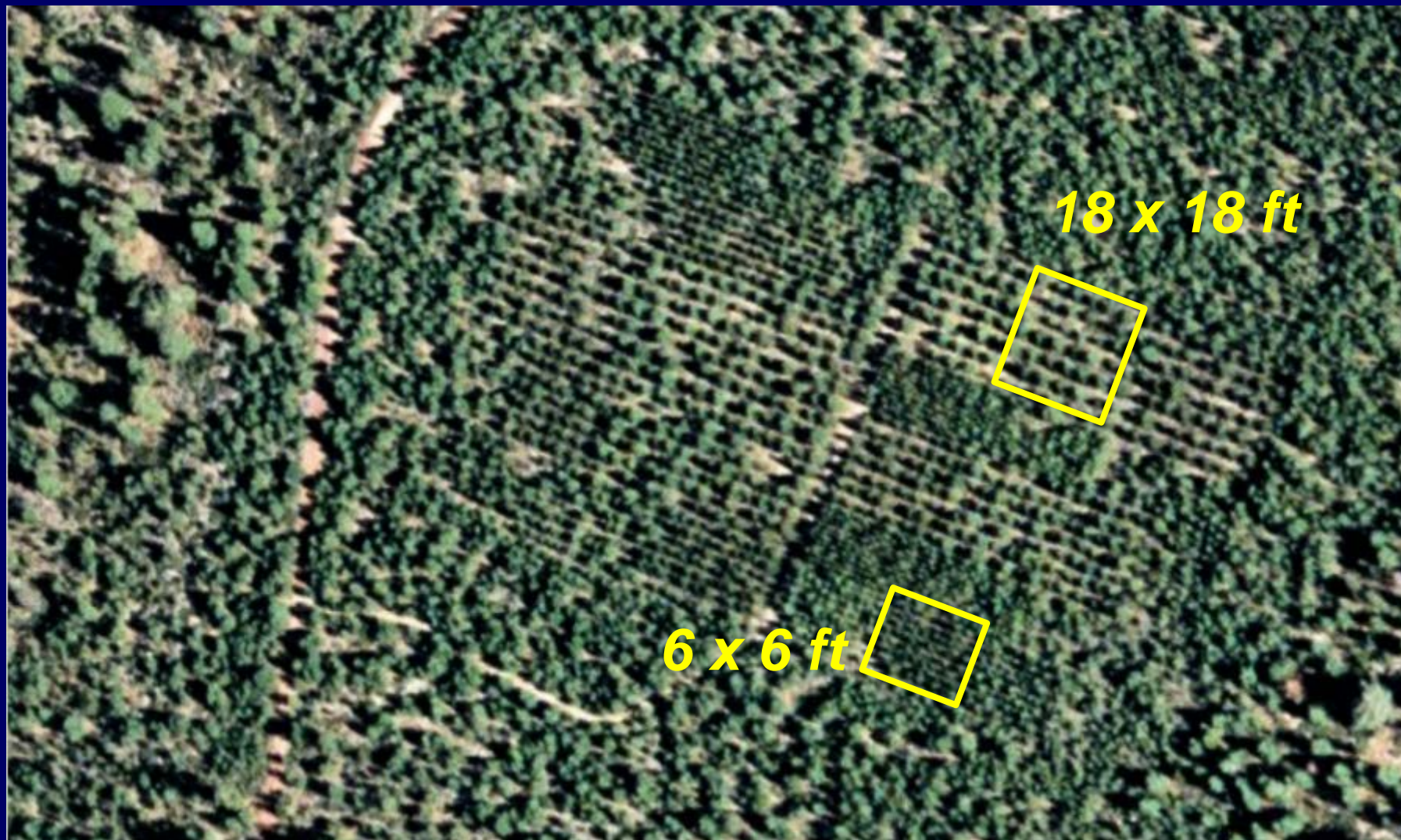
Forest Health in Oregon: State of the State 2018

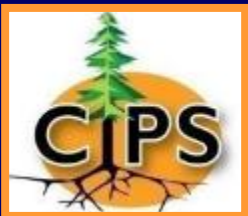
- Five initial spacings: 6, 9, 12, 15, 18 ft
- Three species mixes:
 - pure PP
 - pure LP
 - 50:50 mix PP/LP
- Planted in 1967
- PP/bitterbrush/snowbrush/sedge plant association
- Site index approximately 60 ft at 50 years
- Elevation ~ 4600 ft
- Annual precipitation ~24 inches



Varieties of mixed species stands

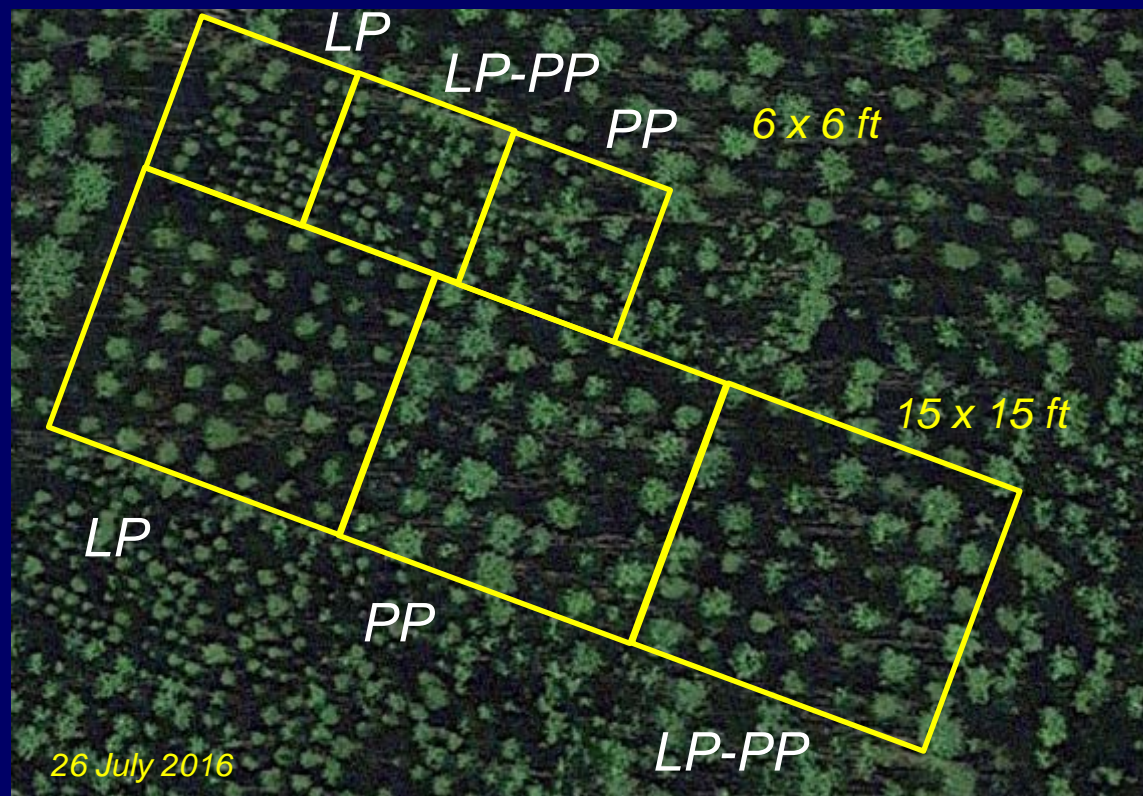
Forest Health in Oregon: State of the State 2018





Varieties of mixed species stands

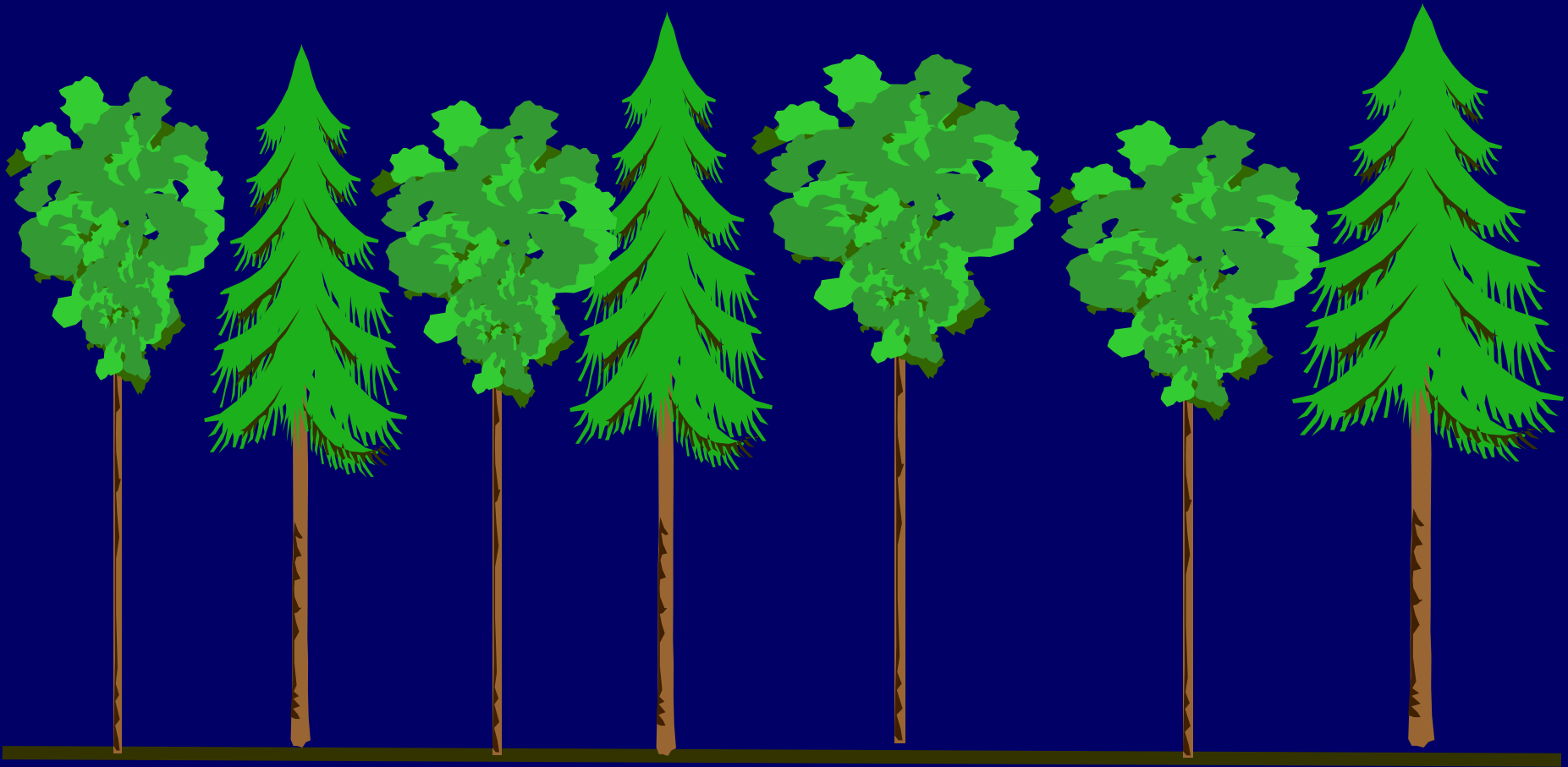
Forest Health in Oregon: State of the State 2018





Varieties of mixed species stands

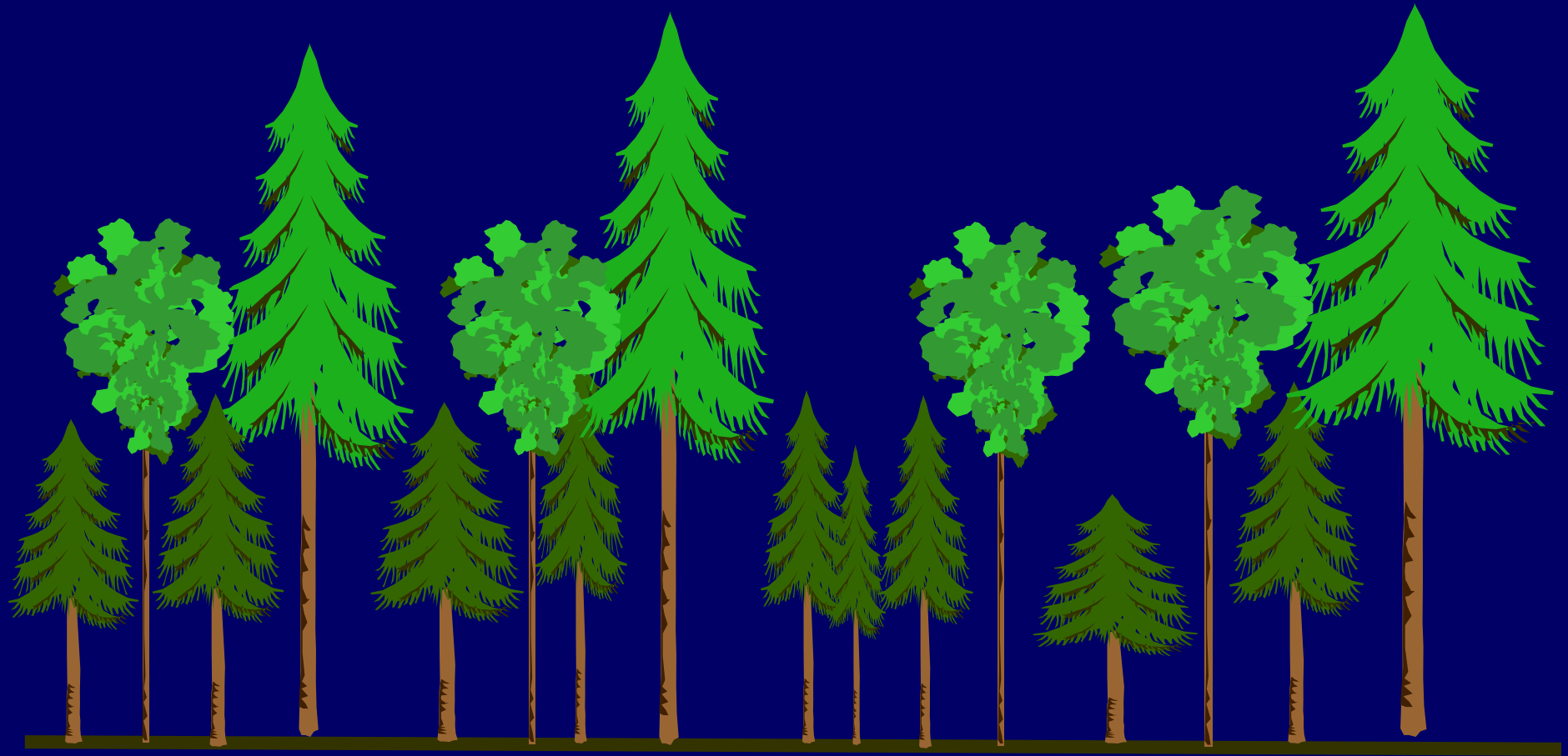
Forest Health in Oregon: State of the State 2018

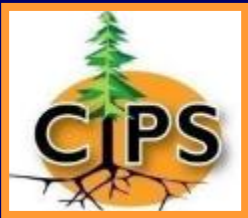




Varieties of mixed species stands

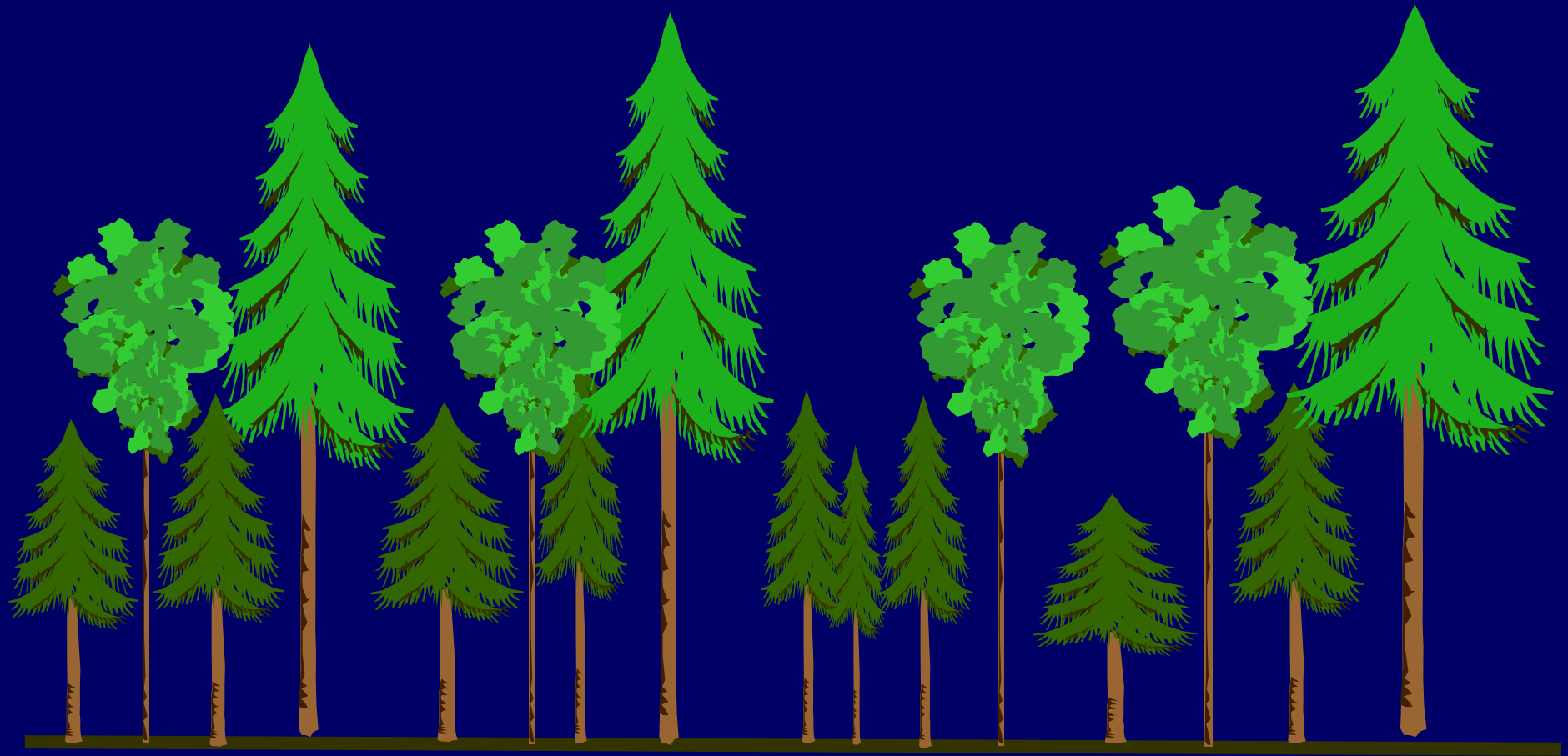
Forest Health in Oregon: State of the State 2018





Varieties of mixed species stands

Forest Health in Oregon: State of the State 2018





Varieties of mixed species stands

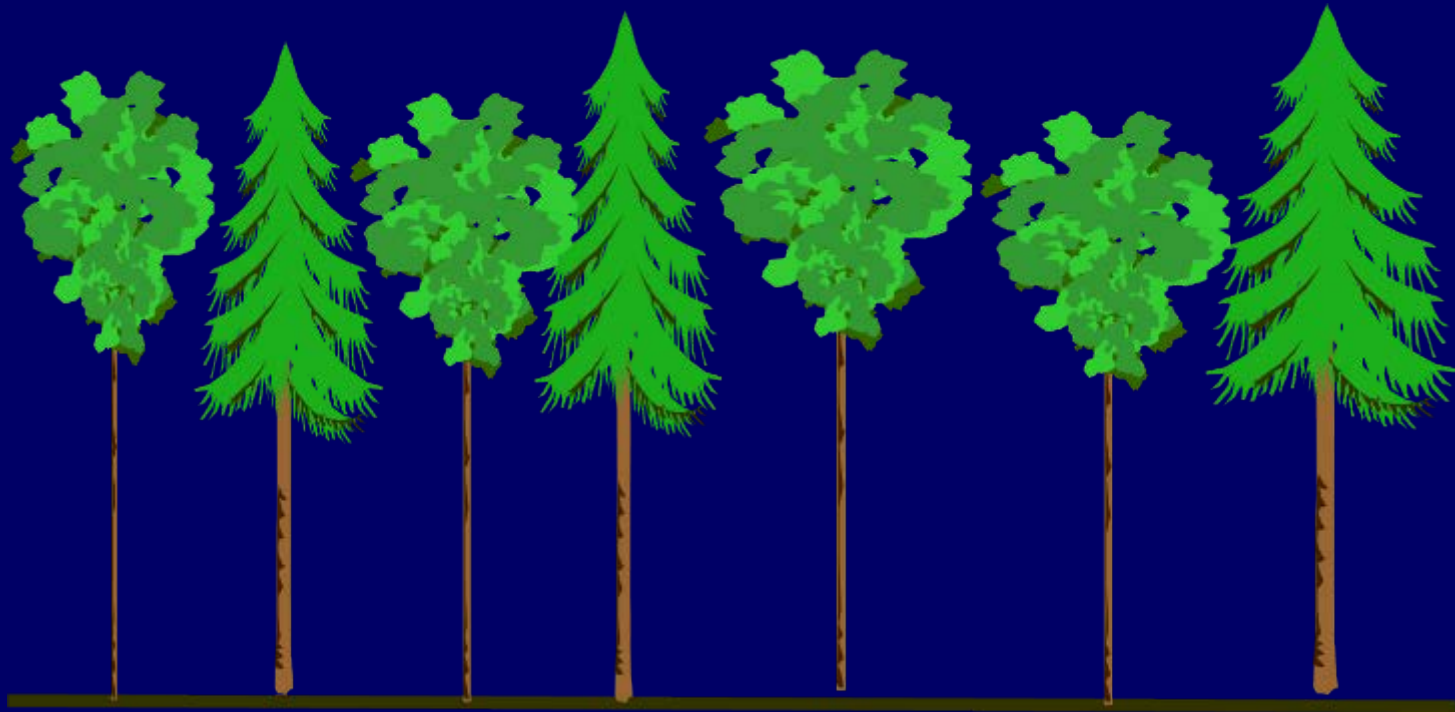
Forest Health in Oregon: State of the State 2018





Varieties of mixed species stands

Forest Health in Oregon: State of the State 2018



Douglas-fir / red alder - single cohort, single canopy



Varieties of mixed species stands

Forest Health in Oregon: State of the State 2018

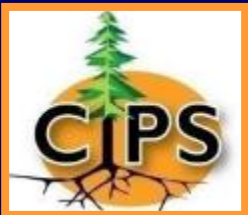




Varieties of mixed species stands

Forest Health in Oregon: State of the State 2018

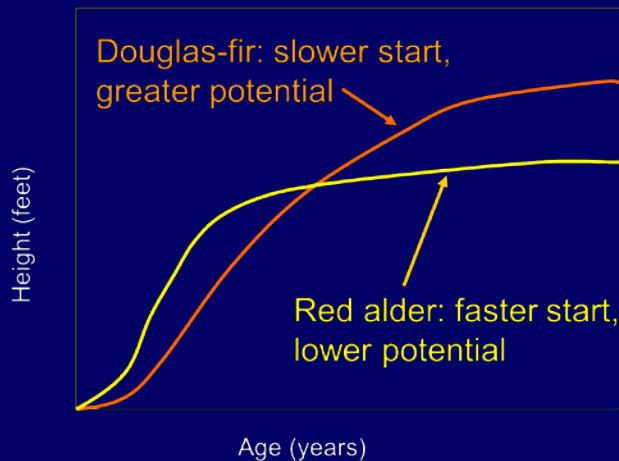




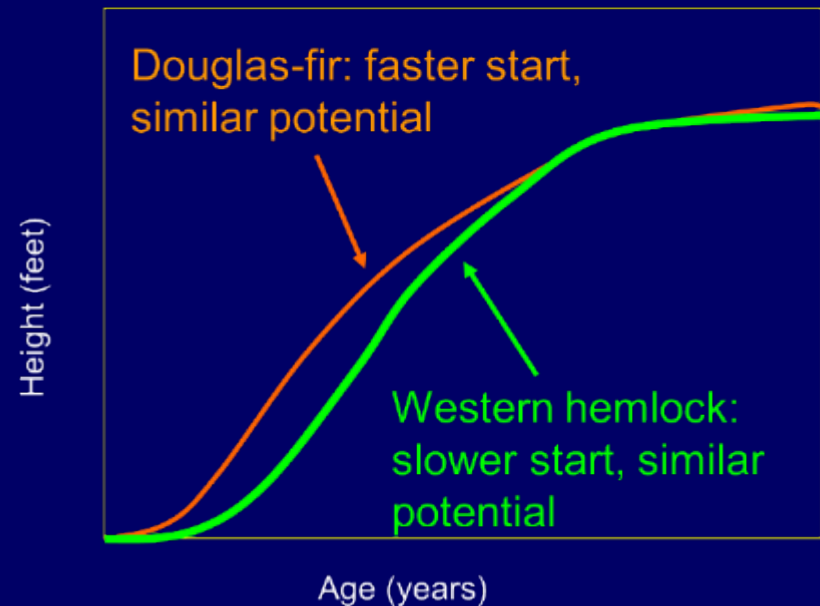
Varieties of mixed species stands

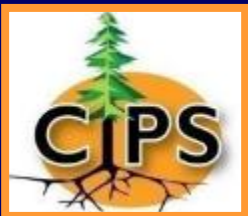
Forest Health in Oregon: State of the State 2018

Height growth pattern



Height growth pattern

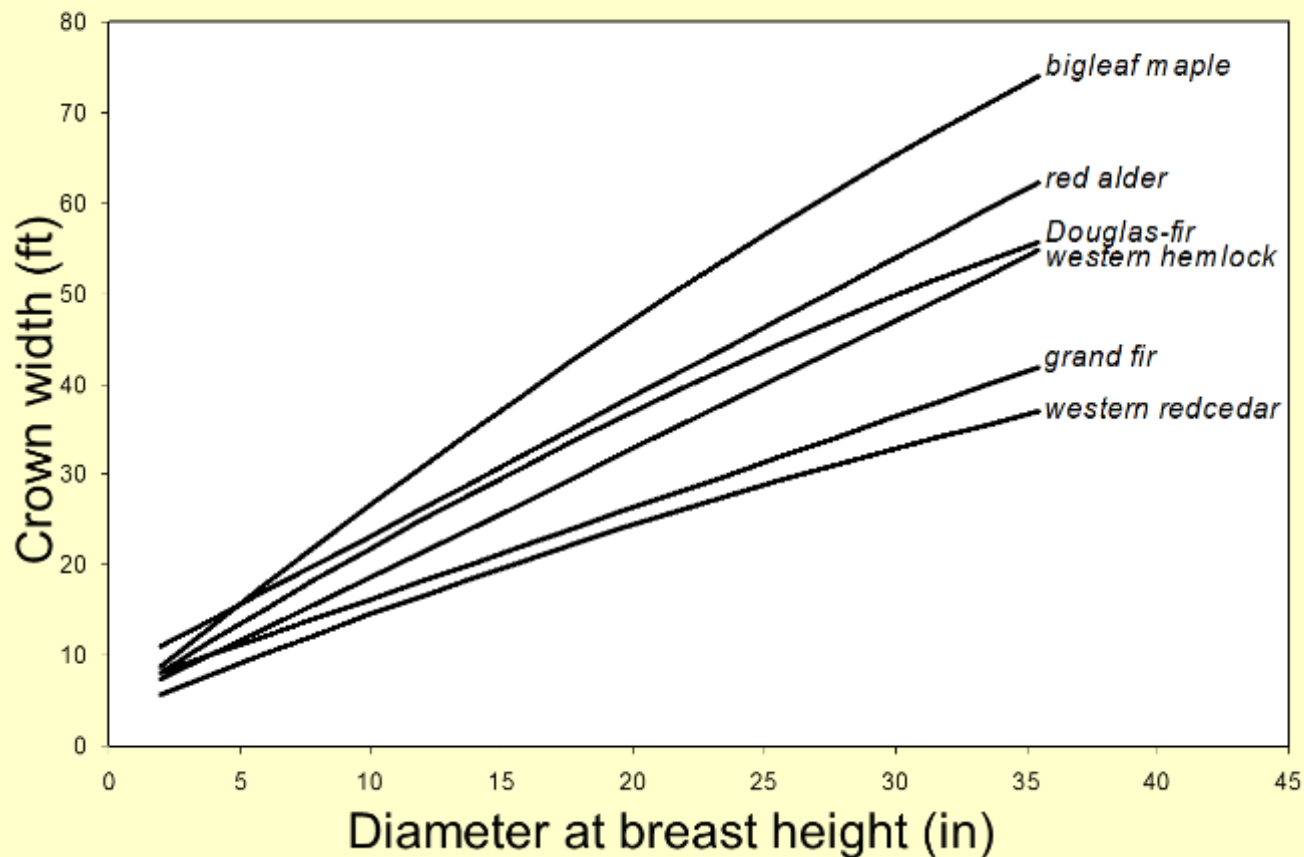


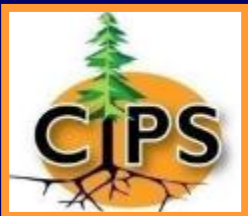


Varieties of mixed species stands

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Crown width of selected species





Varieties of mixed species stands

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Target: Relative SDI = 55% when mean DBH = 12 inches

NOW, if half Douglas-fir AND half ponderosa pine,

Max SDI = average of 595 and 365 = 480

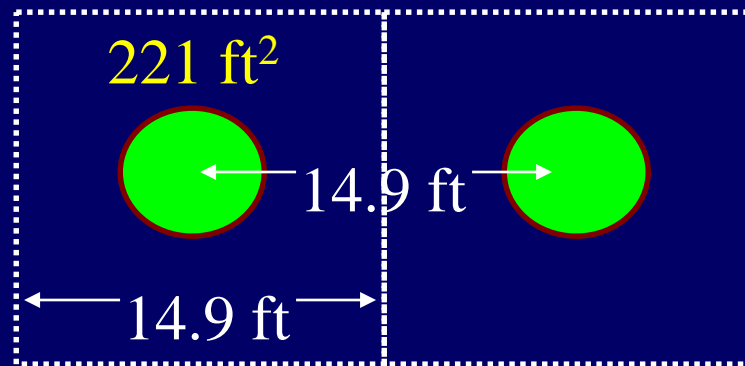
$0.55 \times 595 = 264$

$264 = tpa(12/10)^{1.605}$

So, $tpa = 197$

$ft^2/tree = 43560/197$
 $= 221$

$\Rightarrow 14.9\text{-ft spacing}$





Performance of Mixed Species Stands

- *Varieties of mixed species stands*
- *Silvicultural strategies*
- *Relative productivity*
- *Sources of stress and disturbance*
 - *Climate*
 - *Insects*
 - *Disease*
 - *Fire*
- *Response to stress and disturbances*
 - *Resistance*
 - *Resilience*
 - *Risk*



Performance of Mixed Species Stands: Relative Productivity and Response to Disturbances

Forest Health in Oregon: State of the State 2018

