**3PG Class Notes | Gabby John | Fall 2024**

Week 1

* Richard Waring (!!!!!!) and Joe Landsberg’s initial 3PG paper (FORECO 1997 95:209-228) was the most cited paper in the journal of forest ecology and management for 10 years until carbon sequestration.
  + <https://3pg.forestry.ubc.ca/> is from UBC and takes the model and incorporated GIS stuff into it
* Basic schematic diagram of 3PG : LIGHT
  + sunshine provides energy for the forest canopy (per **Beer’s Law**) to do photosynthesis and produce carbohydrates (per LUE = **light use efficiency or canopy quantum yield/efficiency** [amount of carbon fixed per unit of light intercepted]) that are then partitioned to new foliage, stems, and roots. The roots uptake the water to do this.
    - LUE unit is molC/molPAR or g/mJ
    - LUE = ac = alpha c
  + Leaves are like the solar panels of plants
  + On a light response curve (x axis light flux, y axis Photosynth amount), there is a light saturation point where no more CO2 can be absorbed to do photosynthesis at one time
  + On the light response curve, the light compensation point is the light amount where plants switch from respiration and photosynthesis is triggered
    - The more to the left on the x axis this point is, the more shade tolerant the species is
  + On the light response curve, the LUE is the slope of the curve before the saturation point is reached (photosynth/light) in units of micromole/megajule
    - More practically, we use mol C / mol light
* Crown vs. canopy
  + Trees have crowns; forests have canopies
  + Denser forests with more crowns are rich environments with many collectors (AKA site has higher leaf area)
* Leaf area index
  + Area of leaves in m^2 per m^2 of ground
    - AKA density of foliage per area of ground
    - 1 m2/m2 LAI means the leaf area fits flat on the ground area
    - LAI is usually more than 1. Younger pine forests for example can reach 4-ish. Eucalyptus is less because they have smaller crowns. But! They are efficient and allocate more carbon to their stems. Without thinning and at a productive site, **PNW DF** can be 10-12 and **coastal WH** can be 14----max LAI is 16.
      * DF needles live for an average of 4 years
  + More LAI = more intercepted radiation = more **GPP** in micromol
    - GPP can be predicted through beer’s law and light use efficiency – remember that GPP does not include respiration but **NPP** does, which is about half of GPP
    - This is why we often see a linear relationship between accumulated biomass and light absorbed by leaves
  + This is related to Beer’s Law:
    - fraction of light absorbed = (1-e^(-k(LAI)))
      * k is light extinction(?) coefficient, a stable number that is affected by angle of foliage relative to position of sun. Most absorption is perpendicular to sun. Angle also changes with seasons
        + Most conifers have k=~0.52
    - This results in a Up-right exponential curve with layers of leaves (LAI) on the X axis and % light absorbed on y. LAI of 1=40%; LAI of 4>80%; LAI of 10=100%.
* Types of mortality
  + Density-independent
    - 1-2% of mortality
      * Wind, predators, etc.
      * EG frost freezes sap so water transport cannot happen
  + Density-dependent
    - Not enough space for all the trees or intra-specific competition per self-thinning law
      * Tends to be that smaller, younger trees get outcrowded
* Basal area (m^2/ha) or (ft^2/acre)
  + Hectare is 10,000 m^2 (100x100m)
    - This is why 10,000 is maximum theoretical BA. Max observed in high latitude conifer forest is less than 200 (this is 2% of the ground area).
      * For DF, max is 100 and this is old, productive
      * For loblolly, max is 50 (can get higher in some non-native areas like Hawaii)
      * For radiata, max is 70 in super successful plantations
  + Indicates productivity and stocking of a stand
  + Over time, as a stand ages, basal area will have a similar shape to the LAI curve. These relationships are related to environmental resources and the carrying capacity of. Over even more time, the BA will begin to decrease because space runs out.
    - Related to SDI – stand density index: max number of trees of 10-in diameter allowed in a site using the self-thinning law
  + With BA, you can solve for quadratic mean diameter.
    - This is NOT the same as the average dbh
* Precipitation
  + 1 mm rainfall = 1 liter of rainfall per 1 m^2 ground
    - The model does not consider organic matter in soil on water holding capacity
  + gc=canopy water conductance
    - gc and LAI directly affects et=evapotranspiration
      * is also directly affected by environmental conds. e.g., temperature, VPD, FR=fertility rating=nutriends, rainfall, frost, etc. These are all accounted for in the model
  + gs=stomatal water conductance
* Running the model
  + Step 1: GPP = APAR x LUE in Mg/ha or tonnes/ha

GPP also = IPAR x alphaCx in MJ/m^2/day or Mg DM/ha/month

* + - Input 1 = GR = global radiation = incoming total radiation = insolation = daily solar radiation income (MJ/m^2/day)
      * 3PG runs monthly
      * Closer to equator = higher insolation – but max will never reach 25. Main latitudinal differences are in winter
      * PAR = Q0 = incoming photosynthetically active radiation = 0.5GR
        + Photosynthesis happens with a certain range of light frequences – PAR is about 50% of total light
        + Absorbed PAR = APAR = Qint = Q0(1-e^(-k(LAI)))
        + Remember that the part in parenthesis represents the fraction of light absorbed by the plant-it will be between 0 and 1.
  + Step 2 : NPP is in g C / MJ IPAR and is about 47% of GPP so NPP = 0.47GPP. This represents biomass. To get straight carbon we take the NPP / 2.
    - We can calculate NPP from GR which we can multiply by k to get PAR which we can multiply by LAI (AKA absorption fraction) to get APAR which we can divide by 30 to get a monthly value
    - Maximum quantum yiekd = alphaCx in mol C / mol IPAR
    - 3PG does unit conversions
      * DM = dry matter
  + Biomass allocation
    - 50% of NPP biomass is allocated to stem, and 50% of that biomass is straight C.
      * Another way to put this is that dry mass is double C allocation
    - Wood specific gravity (not unit) = ~ wood density / density of water (which is 1)
      * Specific gravity for DF = 0.45; loblolly = more dense at 0.52
    - In excel, “EXP” is “e to the X”
    - It’s 0.86 for the loblolly pine in our exercise 1 for all months
    - Pay attention to units – march is 7.48 then 2.76 5h3n 20.64 then 9.7 then 4.85 then 9.7 then times wsg for 5.05 eg APAR factors are 24 qand 2.3
    - April 10.55 0.86 9.12 2.76
    - Highest GMO eucalyptus volume production recorded
    - On average mean annual increment in PNW DF is 25 m^3/ha/yr
  + The fact that we are doing these calculations only with radiation information assumes perfect conditions for other environmental variables eg precip and temp,
    - SEND BEFORE MIDNIGHT

Week 2: Growth Modifiers

* The basis of 3PG is the idea that GPP is proportional to intercepted radiation: P=ac(1-e-kL)Q0
  + This is the maximum theoretical yield of production but is impossible in nature because environmental factors reduce the optimization of growth – AKA there are growth modifiers! We can account for this in 3PG
* Remember that canopy conductance is a stand-level attrivbute whereas stomatal conductance is an individual leaf-level attribute.
  + Canopy stomatal conductance drops in an exponential way as VPD increases
    - Lloyd et al. 1995
* New versions of 3PG include the following growth modifiers for stomatal conductance:
  + CO2
    - Relative LUE exponentially increases but relative stomatal conductance exponentially decreases with increasing atmosphere CO2 (for broadleaf)
      * Waring and Landsberg 2011
        + Their CO2 pumping study ranged from 0-1,000 ppm. Today’s emissions are a little over 410 ppm…not good
        + Stomatal conductance for conifers will be more stable amidst rising CO2
  + Soil and atmosphertic moisture
    - Remember VPD is the difference between vapor on leaves (inside stomatal chamber) vs the air surrounding the leaf
      * So VPD=0 when it is raining
    - Soil moisture is measurement ibn either gravimnetric grams of soil before and after drying to get water percentage of soil in grames
      * + Also measured in volumetric units which requires one to know soil type because lower bulk density soils can store more water since more space. With increasing soil moisture, fraction, we have sand, sandyt loam, ckat ka=i=oam, ckas
        + This is hekpfuyl bc precipoitation is recorded volumetrically eg mm which is an input for 3PG
    - Despite the different units, it is important to transport soil moisture to matric potential
      * Should be measured pre dawn bc stomata are closed and no transpirastion is happening so esyrt potential in plant is in equilibrium with watr potentiak in the soil so they should be equal
      * Water potential becomes more negative with dreying soil AKA more drought because the plant needs to use more energy to suction water into transpiration and because it is suction that’s why the valiue is negative
      * Plants start to freak out and drop stomatal cobnducations when water potential approaches -1.5 MPa por soil
      * Some molecules are attached to soul aparticles and this is why soil moisyure modifier changes with soil types – this is also why soil moisture modifier can never be 0
      * Soil moisture ratio if the volumetric water content relative to the maximum
        + EG soil moisture ratio of 0.4 = 40% of total capacity
        + SWC is more similar to VWC but tricky bc units can be weird LIKE FRACTION ):
  + Temperatures
    - No growth during frost acc to Hadley 2000 and in fact carbon exchange can be negative which is attributed to plant respiration
    - Teskey et al. 1987 found that fractional leaf conductance exponentially decreases with magnitutde of frost eg more negative temperature = more reduced leaf conductance
      * Eg if FLC=1 at 0 deg C, it’ll be 0.5 at -3C and 0.2 at -9
    - What I study! Growth
      * Landsberg and WRING 201X discusses cardinal optimal temp that is the inflection point between when growth increases with temp before it starts decreasing—curve peaks at 20C-25 for most conifers in cool temperate regions and “peaks at about 30 for tropical species, which would be unlikely to compete with better adapted trees where average max temperatures are less than 25C”
        + 3PG has been parameterized for a lot of species and we can ese how growth just quits and super drops beyond 30C but some species can go up to 40
        + See also Yury Llancari MS project of DF
        + How to isolate just effects of temperature?

With all of the datapoints, find the perimeter / boundary of the points

“table 6.2 optimu temperature for photosynthesis compared with actual mid-summer temperature for five genera of native new zealand and north American tree species. From Hawkins and sweet 1989”

Pseudotsuga 21 vs 20

Tsuga hetero 19.6 vs 19,4 (these are average for the whole day) – we have probably gone up 2 degrees since (look!)

* + VPD (3PG uses mb. Mb/10=kpa)
    - Waring and franklin 1979 sees big drop in max stomatal conductances (value 0-1) around 2kpa: drops from 0.4-0.2. slowly then goes below 0.1 toward 5 kpa with less variability among species/genetic families
    - Can predict other values with a growth chamber. We have measured 7.5 kpa during heat wave!!!
    - negative correlation (straight line) between growth and VPD sensitivity taken as slope of gs vs vpd – those slope values become the y axis and gsmax becomes the x axis
  + Age
    - Waring et al 2016 for ecol and mgmt. as tree aboveground biomass increases it puts more energy in branches than in foliage
      * This measn photosynthesis is constrained by less efficiencty plumbing as expressed by a drop in the total Ga=hydraulic conductance AKA xylem and phloem becomes more complicated/hard to transport
  + Waring and Fraklin 1979 Science
    - Main differences in theoretical (just radiance and LAI) photosynthesis vs. more realistic photosynthesis occur during the summer growing season because higher VPD and lower soil moisture which affects a large portion of the growing season
      * Some differences in winter too because of frost
* All modifiers affect canopy production and transpiration
  + NPP = R x Q0 x (1 – e^kLAI) x acx x fi
  + NPP = respiration x
  + Fi is a combination of many equations, temp, frost, nutrition, VPD, ASW (available soil water, age, CO2
    - F will be between 0 and 1.
      * If one factor is 0, everything else will be 0 bc 0x0=0
    - Similarly, stomatal conductance, Gcmax, is affected by VPD,ASW,age,CO2 so those are the fs for that in Gc=Gcmax x fi

Week 3

* remember that most radiation data in met stations is global radiation - PAR is 50% of GR.
* if a leaf is perfectly parallel to a sunbeam the intercepted light will be 0 (k will be 0).
  + same consequence if LAI =  bc then no leaf!
  + realistically you can get 97% IL if LAI is 10
  + linear relationship between IL and production (any metric egg NPP; aboveground biomass)
* 0.52 is typical k used for conifers
* remember that water potential is the energy potential of water to do work \
  + water conductivity better at higher elevation
* 7 growth modifiers in 3PG (these fs)
  + vpd
  + asw
  + age
  + co2
  + temperature
  + frost
  + nutrition
  + relationships here: NPP vs...
    - VPD: negative linear curved toward vertex
    - temp: upside down U with 3 cardinal temps: min temp (x int); optimum (max NPP; 20-25C); max  (x int)
    - soil moisture = soil moisture ratio = fraction of available soil water; 0-1 fraction of available water based on saturdation point: positive curve to asymptote
      * most C3 points reach their peak between 0.3 and 0.4
      * water logging is not addressed in 3pg
      * same shape when precip instead of SWC
      * wherever tempoerature permits growth, water availability is a factor xontrolling plantn distribution and productivity
    - frost: negative linear
    - nutrition: positive linear
    - age: flat then negative curve after ccertain age
    - CO2 alpha: positive also linear
    - CO2 Cg: negative almost linear
* water moves from high to low water potential (less neg - more neg) : E = ksubh x delta trident
  + e=rate of transpiration
  + ksubh is hydraulic conductivity
    - when we are dealining with gaseous water, E = delta wat pot = Gsubs x VPD
      * gsubs stomatal conductance
      * trees with higher gsmax have higher sensitivty to vpd varying by species
    - Leaf tridents then =  soil trident - (e/Kh)
    - E is in units of per leaf area so if we multiply E by LAI we can extrapolate this to ground coverae per acre
  + delta trident = trident of soil - trident of leaf
    - trident = wat pot
    - soil = -0.3-0.5 MPa
    - leaf = -1
    - outside air = -100
    - delta trident here then is +0.5
  + this is why transpiration works bc wat pot more neg in air than leaf
  + leaf water potential is influenced by 3 main things
    - soil water potential
    - rate of transpiration
    - resistance of hydraulic pathways between roots and leaf
  + all of this to say...transpiration dictates water potential as per cohesion tension theory
    - look at sperry and pockman 1993 for figures showing linear curved relationship bt vpd and Gc (stomatal conductace)
    - see also "combining drought and vpd effects on stomatal conductance fig 4.10 as predawn water potentials decrease young seedlings of DF close stomata more at a given VPD, here expressed in grams of water per cubic centimeter of air (after lassoie 1982) descrption of leaf conductance v preedaw nseedling water pot
      * stomata may still be sclosed when it is hot and dry in the air even if high SWC because some species are more sensitive to vpd changes
      * at predawn delta trident is 0 and predawn trident is therefore a good indicator of
        + see also sun et al 1995 figure 2.13
      * this varies more precisely based on soil texture
  + water release curve shows tension of water at different oressures based on soil type : relationship between soil moisture tension and Soil moisture content
  + a basic equation is that soil is 25% air; 25% air; 45% minerals; 5% organic matter
    - 2.65 is density of...????
    - the air and water part is what dictates soil porosity ; full of water --> full of air
    - downward entry of water into soil is called infiltration
    - downward movement of water into the soil profile once it has already entered the soil is called percolation
    - pore spaces is what allows water to move and also where water can be stored.
    - see landsberg and sands 2011 table 7.1 values of a range of soil properties for a number of soil texture classes for more precise percentages ased on many soil types
    - saturation is when all pores are filled and no air
    - field capacity is after saturated water has drained through ; maximum capacity to retain water based on strength of pores AKA structure of soil texture
    - permanent wilting point is not 0
    - diff between max and min (fc and wp) is the available water fraction AKA available water holding capaicity. usually 12-13%
    - remember that 1 mm rain = 1 liter rain / 1 mm^2 = 10m^3 / 1 ha; 10m^3 in a hectare so 100 mm rain = 1,000m3/ha; 10,000 square m in a hectare
      * rain vol/soil vol = 1000m3 / 10,000 m3 = 10%
      * assuming 1 m deep soil, this is 1000 mm. rain/soil = 100/1000 = 10% ( another way to calculate this)
    - water holding capacity: expressing water volume as a % of soil volume
      * if sandy soil is 1 m deep, AWHC is 4.2%, what is AWHC in mm? 1000 mm x 0.042 = 42 mm water
        + this means
      * if clay loam with AWHC 13.8%, this is now 138 mm
    - in 3pg, soil water balance is based in 1 homogenous soil horizon although newer versions includes other soil layers
      * this is calculated on a monthly basis with inputs being rain and irrigation and loss is accounted for in interception of leaves = f(LAI); evapotransspiration using energy balance equation from penman-monteith (1965); and drainage - only accounted when the precip exceeds field capacity
        + crux of monteith 1965 equation is that it is directyly related to vpd and radiation through it we conclude vpd is the major driver of evapotranspiration especially in needle leaf conifers
        + boundary layer = Ga = 0.2 m/s this is a constant
      * [Scholarly Presentation Award | Graduate School | Oregon State University](https://nam04.safelinks.protection.outlook.com/?url=https%3A%2F%2Fgradschool.oregonstate.edu%2Fawards%2Fscholarly-presentation-award&data=05%7C02%7Cgabhriel.john%40oregonstate.edu%7C3d466f1f24cb4188de7708dced4a819f%7Cce6d05e13c5e4d6287a84c4a2713c113%7C0%7C0%7C638646151455099182%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=Sq9NebZJI%2B%2Ff73KKkU%2Fp9vQSU%2FwL9lJfU4cMwSUcO9c%3D&reserved=0)
      * [Professional Development Award | Graduate School | Oregon State University](https://nam04.safelinks.protection.outlook.com/?url=https%3A%2F%2Fgradschool.oregonstate.edu%2Fawards%2Fprofessional-development-award&data=05%7C02%7Cgabhriel.john%40oregonstate.edu%7C3d466f1f24cb4188de7708dced4a819f%7Cce6d05e13c5e4d6287a84c4a2713c113%7C0%7C0%7C638646151455124181%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=1sY5ihQ%2B%2BxpvvHAMbD2G1OFYxTMu%2FgneZNpGH4JoXlw%3D&reserved=0)

Week 4: Uses for the Model

* Remember that
  + radiation is intercepted by the canopy per beer’s law
  + the radiation is converted to assimilates per LUE=canopy quantum yield=alphacx based on LAI and via GPP. Max aphlacx is 0.05 and most people use this as it doesn’t change by more than 20%
  + these assimilates are allocated to foliage, stem, and roots
    - carbon stock = mass/area
    - carbon sequestration is mass/area/time
  + some assimilates are lost to respiration, litterfall, and root turnover
    - NPP is 47% of GPP. Can be estimated by taking height and diameter of tree and maybe even age to take an allometric function e.g. general biomass function. Can be extrapolated to any type of tree. This requires estimation of litterfall which can be done by weighing lost litter in a given area – root turnover is more complicated and is usually ignored
    - Stomata opening and closing is an active process regulated by potassium movement in and out of the guard cells
      * Potassium outside the guard cell = water from guard cell vacuole leaves = shrinks = stomata open
        + Other way around = guard cell inflates with water and now stomata is closed

This is why potassium is such an important macronutrient for plants

* Based on the above, we can use the model to estimate where the biomass allocation is going to go based on age and environmental conds
  + Every species has a different allocation ratio
    - Biomass sub s = a sub s \* b D^(nsub s)
    - Shade tolerant trees tend to put a lot in foliage
  + We always need a starting point. Site index, age, env conds., etc.
    - **Idea for final project** : use 2021 heat wave conditions to see how growth would change in just drought vs just heat and see how growth would have changed bc can contribute to argument on which is major driving factor
      * stand dynamics class to learn more about self thinning laws etc eg relationship between size of trees and number of trees per ha
* avg leafycycle for DF foliage is 4 yrd and optimum demo is 18 and max is 40 and min is -07’
* max tree age is age where tree starts declining
* Recap of inputs – REMEMBER THAT MODEL IS STAND-LEVEL NOT INDIVIDUAL TREE LEVEL
  + Climate
    - Monthly mran
      * max temp (1 value per month of average of max temps),
      * min temp
      * daily global radiation MJ/sq m/day,.
      * Total Rain in mm/month, ang daily vpd (not required)
    - Observed or long-term average data
  + Site and soil descriptions
    - Latitude decimal– needed for calculating light extinction constant, k
    - Soil texture and water holding capacity mm
      * Min asw assune 0 if no water table or irrigation mm
      * Max asw
    - Fertility rating – hard part. Modifier between 0-1 (eg 0.3) associated with availability of nutrients – like a site index for a growth and yield model
      * Maybe use site index instead?
      * Trial and error using different FRs and modeling biomass and compare with real observed biomass
      * Eg height of tallest trees reflect the productivity of the stand and that the height of the dominant trees is (kind of) independent of density this is based on relative age of the stand
    - CO2 concentration in ppm
      * Can simply use rcp 4.5 bc model knows the climate scenarios
  + Initialization data
    - Foliage, stem, and root biomass (to estimamte size of trees) in Mg/ha
      * Knowing stocking, diameter, and height of tree, biomass functions calculate the ratio to get these specific values
    - Stocking = trees per hectare
    - Available soil water in mm at starting date
      * If you put starting date in winter that is likely when the ASW is at its maximum so you can put the max value
    - Planting month and year yyyy/mm
    - Starting age in years
    - Starting month of model
  + Looking at the model in excel
    - Be sure to enable macros in the workbook
    - Output details frequency
      * M=mponthlyu
      * A=annually
    - See lecture slides for output acronyms and explanaations – ther eare many! R
      * Cateogries include
        + Production infor
        + Mortality
        + Water use

Eg SMPot=soil matric potential

* + - Can set defaults in parameters hseet in he excelfikle
  + Quadratic mean diameter of tree isn’t the most accurate bc it related noire tithe wight rther thnab tghesuze if tge tree
  + When a species reaches its max biomass it begins self thinning from there
  + Canopy closure in normal spaced DF usually occurs when three is about 9 m high (27 ft)
  + Fir this stem biomass = sny [paty ofg the tree thatid woody eg branch and bole
  + Rememnber the conversion factor of mol to jule
  + ClkijateNA gives climate data PRSM gives climae day as we;; amd NOAA
  + USDA-NRSC gives soil info [Web Soil Survey - Home (usda.gov)](https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm)

**Week 5: using the model when it comes to forest thinning**

* Summarizing up to now:
  + Linear relationship between LAI and photosynthesis because light interception
    - Every species has a different way to do this via LUE
      * Max LUE will never happen because env. factors eg temp, VPD, nutrient availability, age, SWC, CO2, etc
        + This is why every species has preferred habitats
  + Stems are the bole + branches + bark
  + Based on age, size, species, and env.conds., trees will allocate a certain amount of carbohydrates to stems, roots, and leaves
  + If you only have a single 3PG value that is the monthly mean
    - E.g. can estimate number of frost days in a month based on this value but ofc it is better to have actual data
* The stocking part of the model is relevant for forest thinning management. Less trees = less stand-level LAI
  + Important because remember that 3PG is a stand-level model
* Fractional ASW max – min
* In Excel model…
  + Species name has to match name format in parameters tab
  + Do not change formats and do enable macros
  + Cliate data = name of sheet with climate data
  + Met station is from “station =” in climate sheet tab eg station =summit
  + “end age” determines how long the model is going to run for
  + Output data tells the model what aparameters you care about using the language/formatting specified
    - Eg if we do ET that is evapotranspiration that it predicts using the penman monteith equation
    - Max LAI is end of summer – august
    - Min LAI is right before growing season – march
    - LAI will also decline cyclically as a result of litterfall
  + Output frequency: a = annual m = monthly
  + Output sheet lets you name the new sheet tab it will spawn
  + You run by going to add-ins and clicking run under 3pgpjs 2.7
  + The silvicultural options tab tells you all the things you can do
* Model assumes even stand spacing and therefore consistent LAI
* Ecological effects of thinnings
  + Reduced LAI and therefore lower intercepted radiation
  + More resources available for residueal (leftover) trees
    - As a result individual trees may grow bigger but at a stand level there will not be more growth (biomass) because of the reduced intercepted radiation
      * May be affected tho by efficiency
  + Increased vigor
    - Graphically this is age x axis and y axis is wood production growth efficiency (grams / m^2 LAI / yr)
      * More efficiency = more vigor
  + More potential for understory growth
  + More thinning resides (eg lost branches/leaves)
  + Increased soil temperature
* Water yield = water not used by forests = difference between precip and evapotranspirated water
  + Fractional. WY = 1 = no ET. WY = 0 = ET is equal to or exceeding amount of rainfall the site received
  + Related parameter = Water deficit = potential ET – ET
    - If water deficit that means not enough water to support the amount of ET the stand is capable of
    - This has nothing to do with rainfall: you CAN have a water deficit AND water yield
* No matter what unthinned stands will reach a point where there is densirty-related mortality and self thinnings will occur due to resource competition
* Max LAI isn’t necessarily the best LAI because maybe too much resource hogging. Managers may want to thin within a safe LAI range to not allow max LAI but not go below a safe threshold that will limit Photosynth too much
  + In place of LAI you can use basal area
  + Safe determined by critical LAI aka the LAI needed to achieve a certain water yield
  + Remember that reducing LAI means reducing # trees
* In the silvucultural events what the thinning box looks like
  + Thinning
    - * Age stocking F r s
      * Age is age at thinning event
      * Stocing is density we are thinning TO
    - Frs relates to biomass allocation to foliage roots and stems
  + Quadratic mean diameter as 3pg parameter is avDBH; transpiration is Transp;
    - Transpiration may stall because the max LAI has been reached ; there is no more work to be done
    - For exercise 5 we are doing 40 years and there is a water use every year. The sum of all of this is the total cumu water use. Compare the unthinned vs one thiunned vs multiple thinned values
    - Look at last slides in powerpoint for more instructions and details
    - Remember that water use efficiency is either as production per unit of water used or timber production per unit of water usesd (volume of growth per year = difference in one year of growth vs previous = annual increment = volume growth = timber production)
      * So we can then calculate this by the annual increment divided by transpiration or flipped as that would be amount of water required to make 1 unit of timber?????
    - Gross efficiency = timber production/LAI
    - Do not count CAI or GE for years when the thinning event occurs

**Week 6: using the model with new parameters and multi site**

* q quadratic mean diameter?
  + We always need a starting point. Site index, age, env conds., etc.
    - **Idea for final project** : use 2021 heat wave conditions to see how growth would change in just drought vs just heat and see how growth would have changed bc can contribute to argument on which is major driving factor
      * stand dynamics class to learn more about self thinning laws etc eg relationship between size of trees and number of trees per ha
    - talk with chris and carlos about this for help
* 3pg final project maybe tree survival given climate we have real climate variables
* younger needles are less heavy than older trees if the same size
* pulpwood = pw; cns=ship and saw; sawtimber = st
  + see lecture for equations for each of these relative to stands vol and other parameters
* climate change scenarios are available at climatology lab . org and university of alberta Canada ClimateNA

**Week 7: EFFECT OF ROOT SIZE ON asw for younger stands**

* Remember that younger trees allocate more biomass to foliage
* 1500 is around av planting
* **54 total site runs; 27 per site**
* Limitations of the model is that max ASW is constant but a younger seedling in a stand cant access all of that mpoisture because smaller roots haven’t developed yet. The result of this is that the model does not recognize water stress for the seedling because it thinks it is getting more wate than it actually is
* For example we can modify max ASW under specific lateral root extensions; max root depth
  + Lateral root extension 10,30,50 cm
  + Root depth 10,30,50 cm
  + From these assukptions, we can…
    - Calculate root volume in m^3 for each root size assuming volume as a cylinder where r=hortiz and h=depth (v=)
    - Calculate water volume for each root size which depends on soil type
    - Calculate root volume as a fraction of initial spacing for each root size under 3x3 m initial spacing
      * For 10x10 it will be less than 1 percent
    - T
    - AKA 9 runs of the model and 1 additional run with theoretical non modifications where max asw = 123 and rain fraction = 1 this is like the control group
    - Remember 50cm soil depth with 15% WHC = 75 mm ASW bc 50x15
  + For exercise 7
    - Q1: 3PG calculates tonnes/ha so to get to g/seedling we divide by number of living seedlings and get to tonnes to grams by multiplying by 1 mil bc tonne=megagram
    - fSW is easily output in the model
    - month x axis q2 and 10 different lines for each scenario.
    - ONLY max ASW is changing which is based on the root mods . ni climate is when we are changing rainfall bc remember it will be a fraction of the horizontal root area the model has a column to calculate available rain vs actual rain eg if available rain is 215 but the fraction is 0.2 the rain in the climate table will be 43.2
    - Assuming scenario 10 with roots everywhere would be 15 0rad and 100 length so before we click run the model each time we need to repace the available rain fraction and the max ASWand the outputs will be transp ASW and fSW
    - Then just select biomass at the end when seedlings are 1 yr old and do a surface or contour plot in sigmaplot which will require downloading model version in assignment for exercise 7 – **one plot AGB g/tree all scenarios and one plot fSW all scenarios and one plot x root lateral length y vertical length and what shows up is a colorful figure that represents biomass eg 10-15cm lateral has between 60 and 80 biomass grams and it looks like the bviomass goes indepevent al,ost of vertical root length** 
      * To make biomass v month in sigma plot we take the 3pg output and put it in singma lot whjich I free as a student – maybe see if can be done in r check it out . anyway after pasting then click graph page om sog,a and then choose line/scatter and pick straight line with multiple lines and scatter and for data format pick XY category if column is joining the two eg 1-10 = January(category)-biomass category is radius by depth? After this figure double click and where it says symbols click and pick color schemes and pick incrementing because each category is different and size 0.015
      * Second max asw2 0.0492
      * In sigma plot if you want to combine two graphs that have the same x axis you can right click to object properties to position and change the area / shape of the figure and switch the shape you want then you can copy paste the graph and only change the y axis to keep the look the same eg we can switch bioass to LAI and that’s it you already did the rest of the hard work
    - To make the rainbow figure discussed above you filter the last month
    - at seedling age of 1 year and then still keep your column of combined number in this canse now radius-depth eg 50-10 then create graph but now pick contour graph and pick if you want BW or color and do XYZ triplet where x is radius y is depth and z is biomass (response variable) then it creates it : you can change legend parameter values and colors and stuff by double clicking the dfifure and chanfginf the scaling and conrour scale number of intervals for example abd nu,mber of minor lines etc
    - FUTURE WORKSHOP OPPORTUNITY TO HAVE CARLOS DO SIGMA PLOT WORKSHOP
* pasting will do a column but you can do paste as values and transpose and it will do a row these values are coming from sibngle site teskey I think
* more productive sites start showing mortality sooner bc more growth and more comp
* in the output you can insert filters and filter blanks and words and delte those rows and then unfilter and that's how you have a full and complete data set in the output tab this is good for making our plots

|  |
| --- |
|  |
|  |
|  |
|  |
| trees/ha = age vs stems plot |
| can switch column to plot by just dragging to a new one |
| saw timber / total volume = proportion going to saw timber |
|  |
|  |
| for q2 pdxfr spr site 1 scenariop 1 is one value |
| pdxfr site 1 scenario 2 |
| one plot for volme and one plot for saw timber |
|  |

Lecture 7:  
Effect of root size on  
ASW for young stands

Exercise 7: Modify effect of ASW for young stands  
• 3-PG assume a constant Max ASW (e.g. 123 mm), but a young  
seedling can’t access all soil moisture due to reduced root volume  
(i.e., during first years, 3-PG underestimate plant water stress)  
• For seedlings growing during first growing season:  
• Modify Max ASW assuming:  
• Maximum lateral root extension (horizontal length): 10, 30 and 50 cm  
• Maximum root depth (vertical length): 10, 30 and 50 cm  
• 1. Calculate root volume (m3) for each root size. Assume volume as  
a cylinder (e.g. 10 cm radius x 10 cm depth).  
• 2. Calculate volume of water (mm) for each root size  
• 3. Calculate root volume as a fraction of initial spacing for each root  
size  
• Assume 3 x 3 m initial spacing  
• 4. Calculate horizontal area as a fraction of seedling spacing  
• Assume 3 x 3 m initial spacing

Exercise 7: Modify effect of ASW for young stands  
• 3-PG assume a constant Max ASW (e.g. 123 mm of available soil  
water in 1 m soil depth), but a young seedling can’t access all soil  
moisture due to reduced root volume (i.e., during first years, 3-PG  
underestimate plant water stress)  
RUN 3-PG for each root size scenario  
• Modify monthly rainfall input for each root volume (soil volume) scenario  
(as a fraction of root horizontal area)  
• Modify ASW input for each root volume (soil volume) scenario  
(as a fraction of root horizontal area)  
• Keep one scenario with theoretical Max ASW=123 mm (1 m soil depth,  
roots have access to all soil up to 1 m that have AWHC=0.123)

Exercise 7: Modify effect of ASW for young stands  
• Q1: Compare monthly total AG biomass (g/seedling) and  
soil moisture growth modifier (fSW) during first growing  
season for each scenario.  
• Show plot(s) with 10 scenarios. Please, explain your  
findings  
• Q2: Using final seedling size (age=1), plot contour (surface)  
graph  
X: Root Horizontal length  
Y: Root Vertical Length  
Z: ABG (g/seedling) at age 1 year

Exercise 7: Modify effect of ASW for young stands  
• Q3: Do you think that is important initial root growth for  
seedling performance? Explain.  
• Q4: What type of silvicultural treatments can improve initial  
root growth?  
• Q5: Do you think that is important to modify ASW for young  
seedlings? If yes, propose and explain a method to do that.

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**Week 8: EcoPhys**

* Biomass partitioning and gas exchange change based on water availabiltiy