International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

Stand-scale modelling with 3-PG

Andrey L. D. Augustynczik

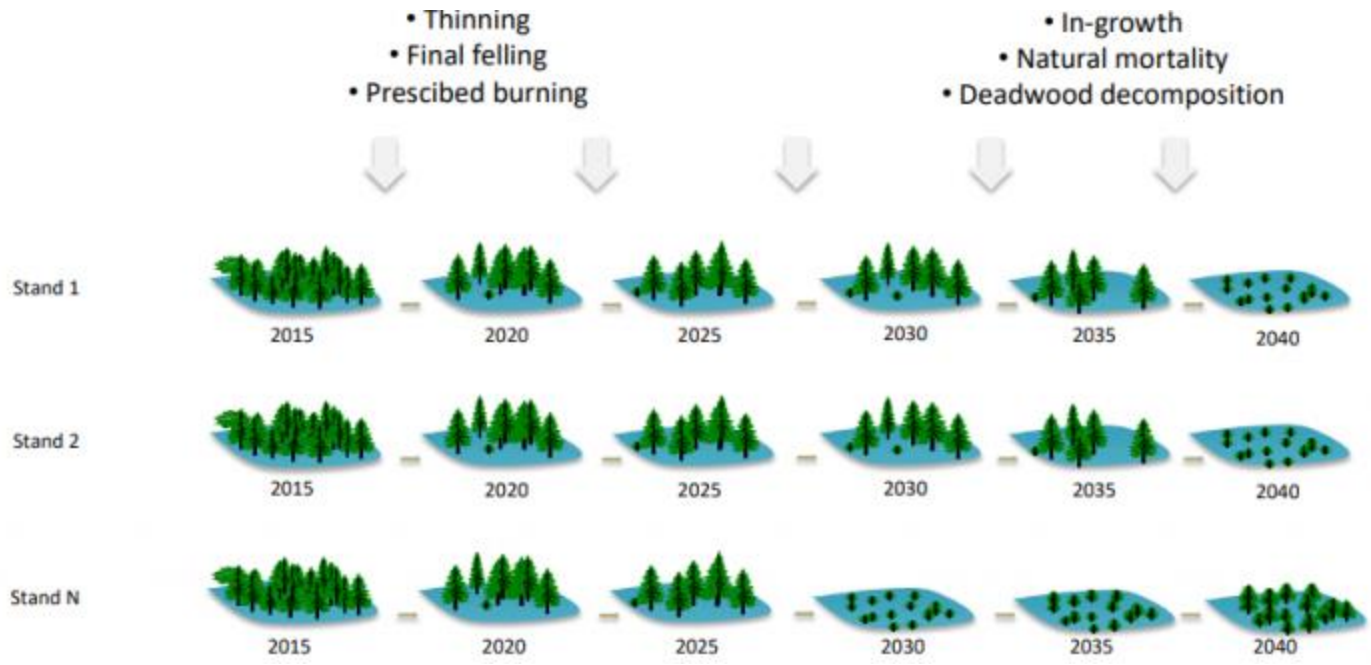
Stand-scale modelling

Simplified representation of forest stands

- Representative tree
- Less data intensive
- Easier to parametrize

- Limited silvicultural operations
- Work better in homogeneous (even-aged) structures
- Limited representation of forest structure and finer scale processes

- Well suited for large scale analyses especially dealing with production/economic goals, optimization, and less suited for answering ecological-driven questions



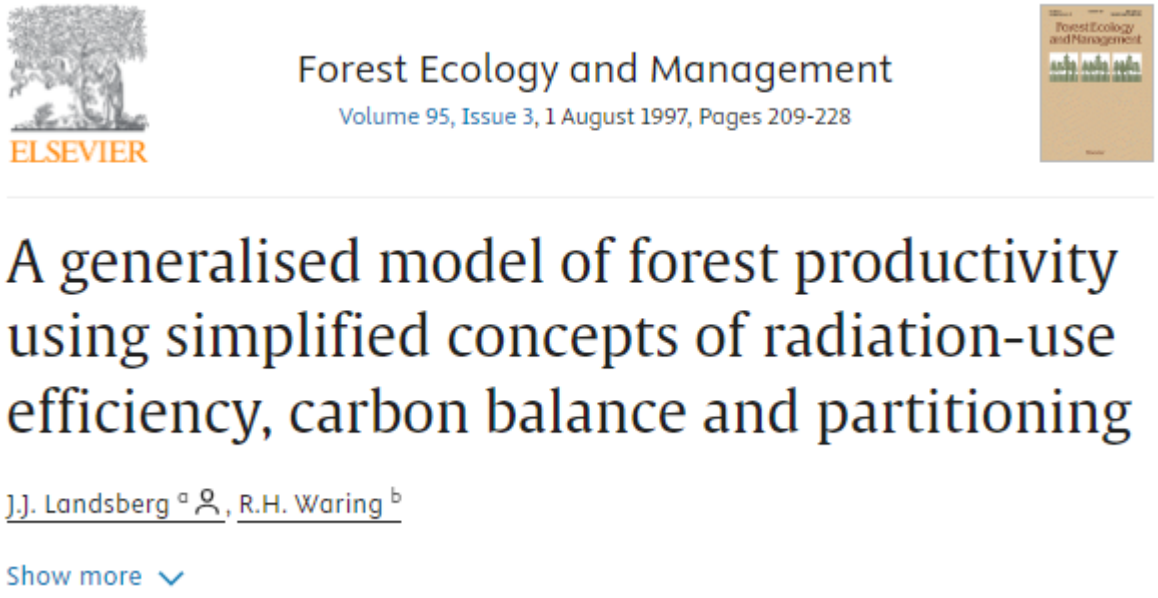
Nazari, https://nobel.boku.ac.at/

3-PG

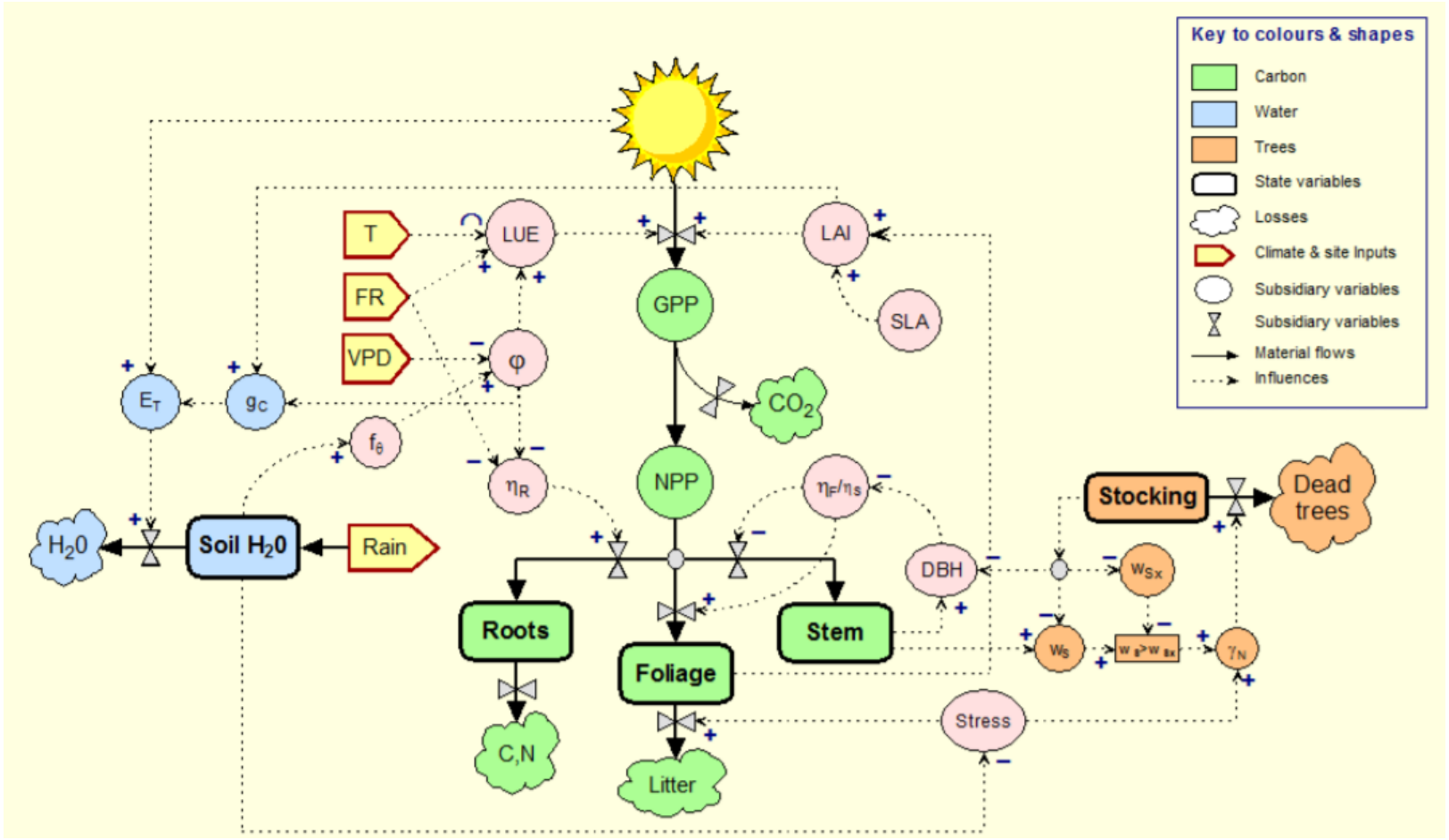
Simplified process-based (or hybrid) model that has been widely used and well validated for all the processes it considers, such as growth, biomass partitioning, light absorption, water balance, responses to CO2, diameter distributions and mortality.

- Stand level
- Monthly time step
- Application in a variety of forest types (tropical, temperate and boreal conditions)

- Open access
- Not so demanding in terms of input data
- Derivation of parameters relevant for management



3-PG


Key to colours & shapes
Carbon
Water
Trees
State variables
Losses
Climate & site Inputs
Subsidiary variables
Subsidiary variables
Material flows
Influences
T
FR
VPD
LUE
φ
LAI
SLA
GPP
CO2
NPP
ηR
ηF/ηS
ET
gC
fθ
H20
Soil H20
Rain
Roots
Foliage
Stem
C,N
Litter
DBH
Stocking
Dead trees
wSx
wS
γN
Stress

3-PG

GPP

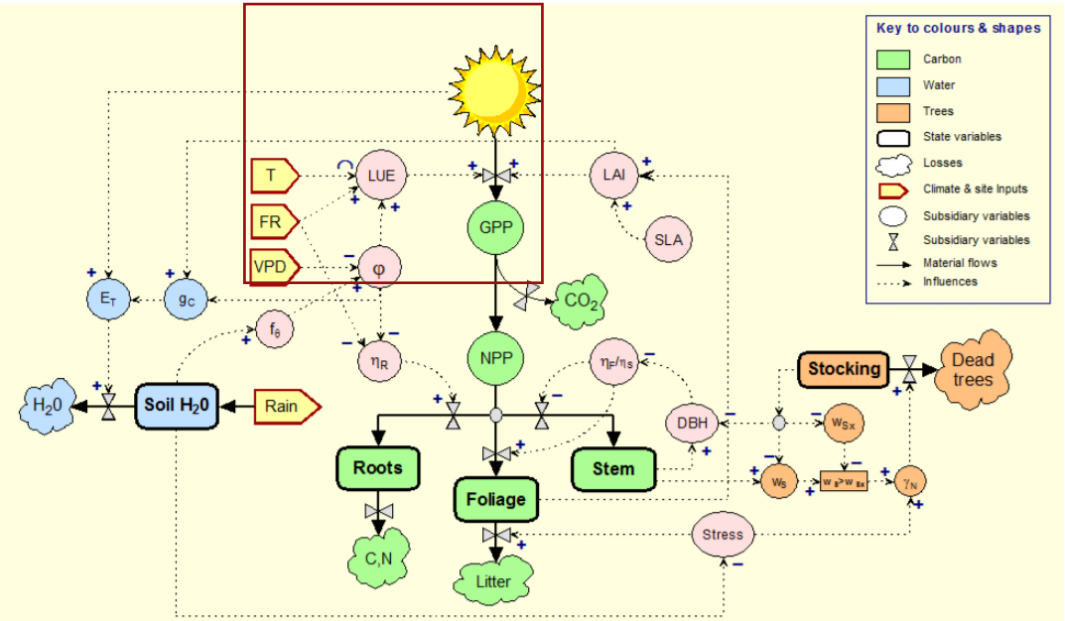
Solar radiation

PAR
- 0.5 * RAD

APAR
- Beer-Lambert law

$$Q_{int} = (1 - e^{-kL}) Q_0$$

GPP
- APAR*LUE



Waring & Gonzalez-Benecke

3-PG

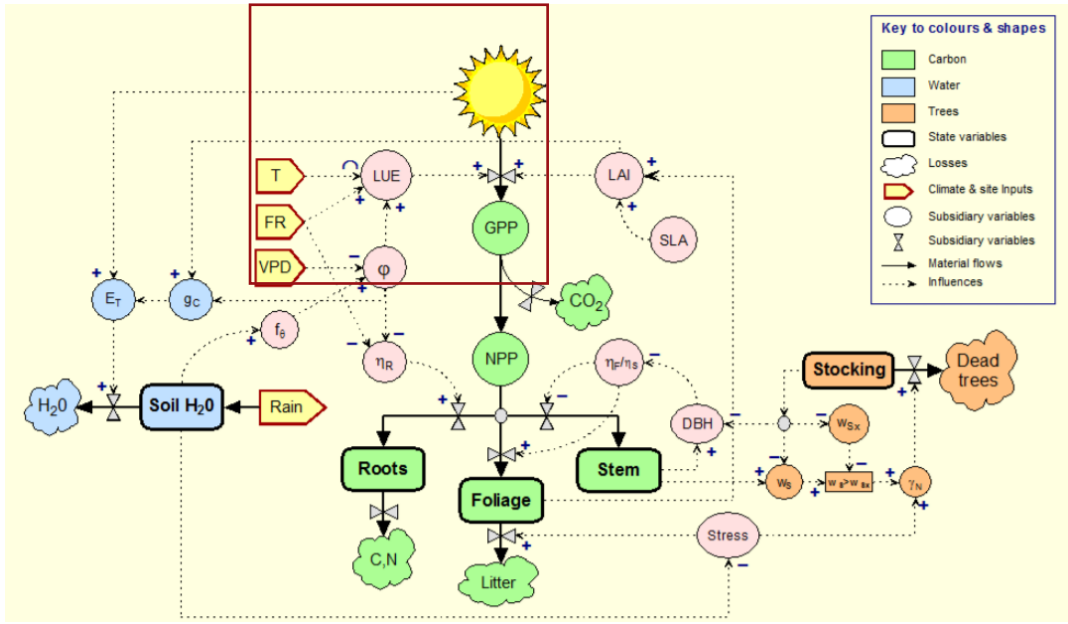
LUE

Canopy quantum efficiency

$$LUE = \alpha Cx \prod f_i$$

- Species specific
- Depends on climate and site conditions

$f_T = temperature$
$f_{VPD} = vapor\ pressure\ deficit$
$f_F = frost$
$f_N = nutrition$
$f_{ASW} = available\ soil\ water$
$f_A = age$
$f_{Ca} = CO_2$



Waring & Gonzalez-Benecke

$$Gc = Gcx \prod f_j$$

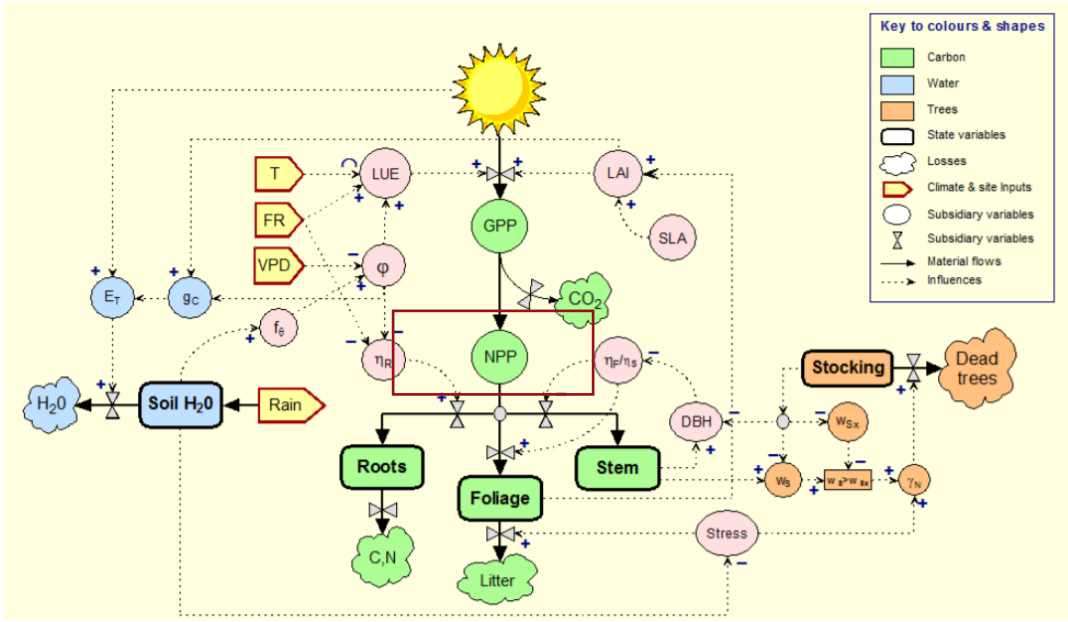
$f_{VPD} = vapor\ pressure\ deficit$
$f_{Cg} = CO_2$
$f_F = frost$
$f_{ASW} = available\ soil\ water$

3-PG

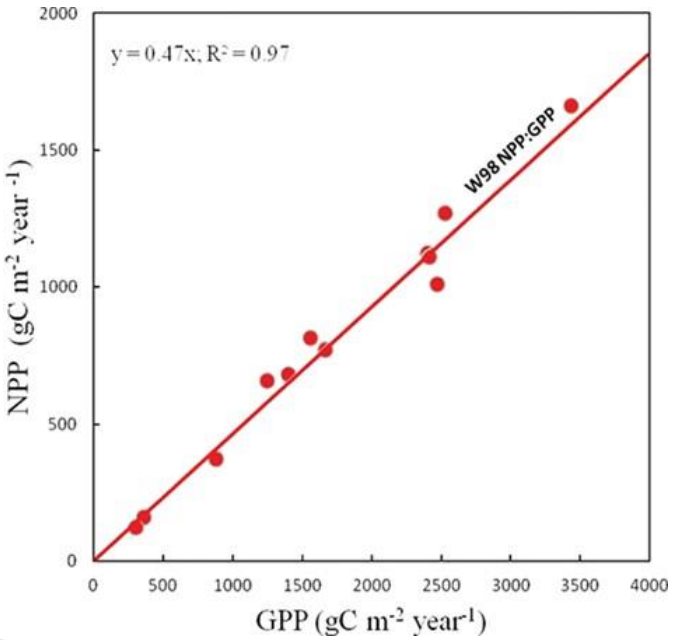
NPP

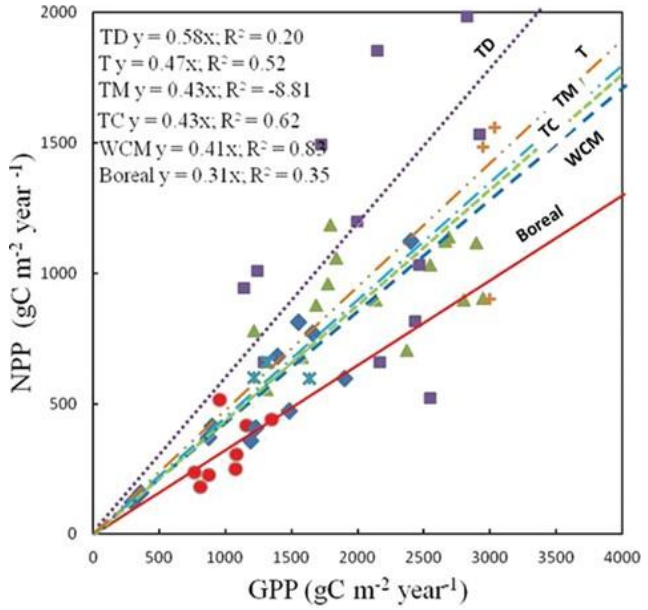
Fixed ratio of GPP

$$NPP = GPP * 0.47$$



Waring & Gonzalez-Benecke





Collalti et al. 2019

3-PG

Water balance

Canopy conductance

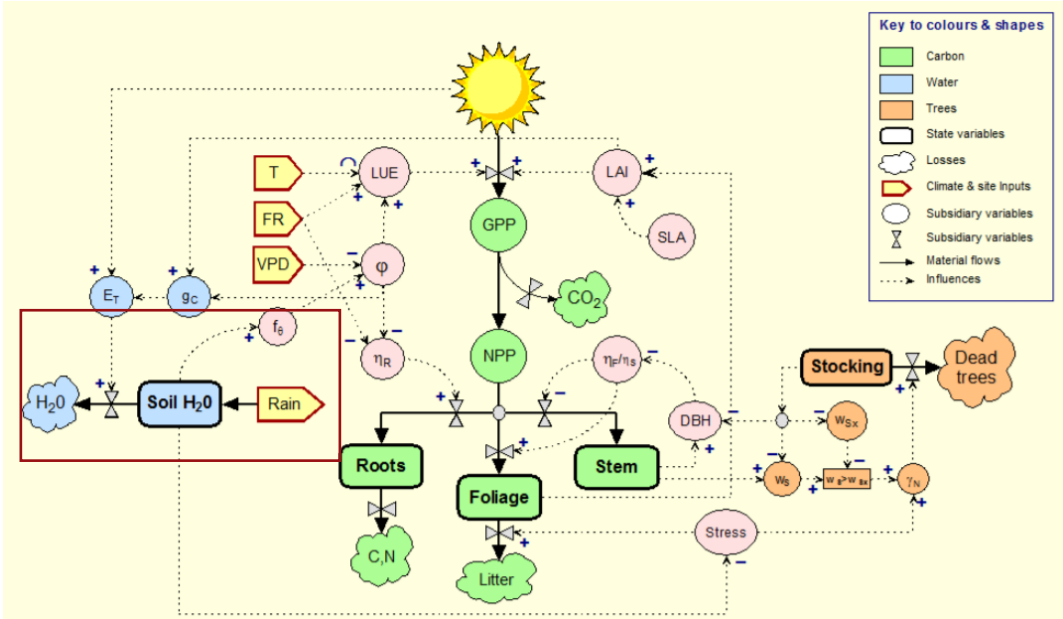
$$Gc = Gcx \prod f_j$$

$f_{VPD} = vapor\ pressure\ deficit$

$f_{ASW} = available\ soil\ water$

$f_F = frost$

$f_{Cg} = CO_2$



Waring & Gonzalez-Benecke

ET: Penman-Monteith

$$\lambda_v E = \frac{\Delta(R_n - G) + \rho_a c_p (\delta e)\, g_a}{\Delta + \gamma(1 + g_a/g_s)} \iff ET_o = \frac{\Delta(R_n - G) + \rho_a c_p (\delta e)\, g_a}{(\Delta + \gamma(1 + g_a/g_s))\, L_v}$$

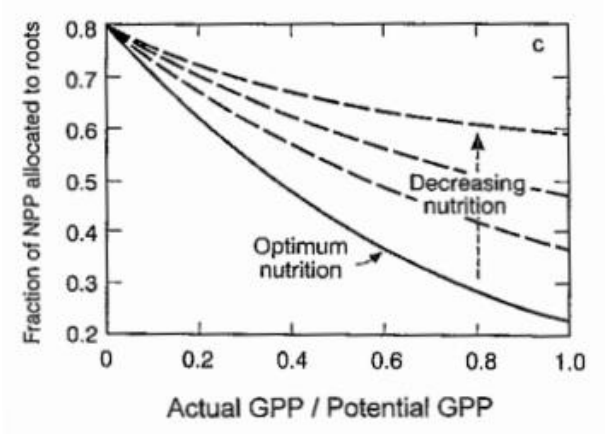
Energy flux rate

Volume flux rate

3-PG

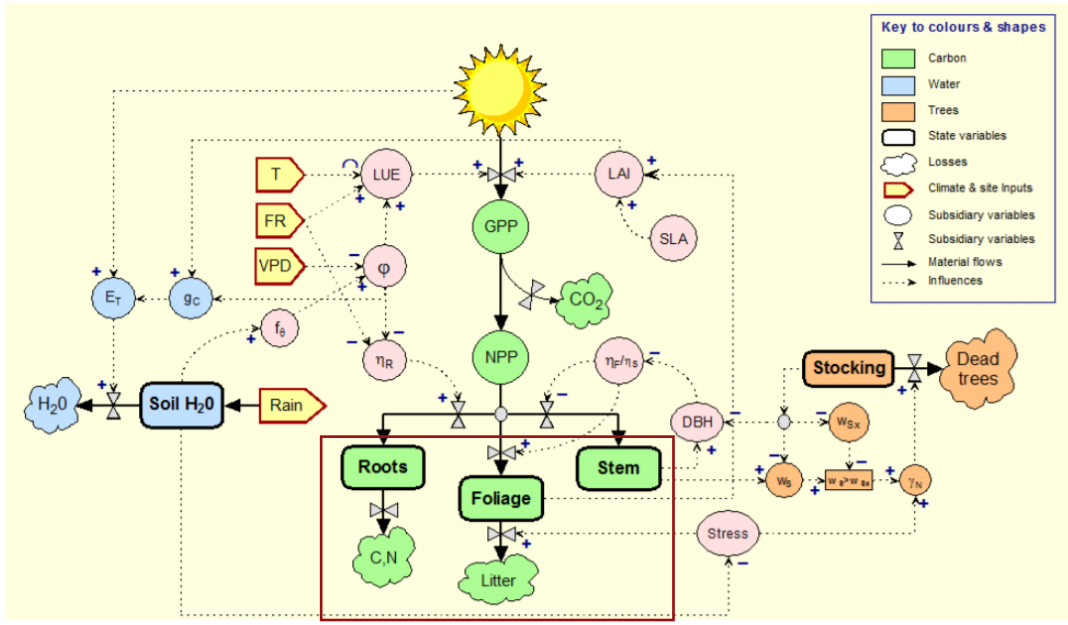
Allocation

- Priority is given to allocation to roots
- Assumes that harsher growing conditions increase allocation to roots



Waring & Gonzalez-Benecke

- Partition between stem and foliage maintains the balance between the increments of these compartments and is implemented according to allometric relation with DBH



Waring & Gonzalez-Benecke

3-PG

Mortality and turnover

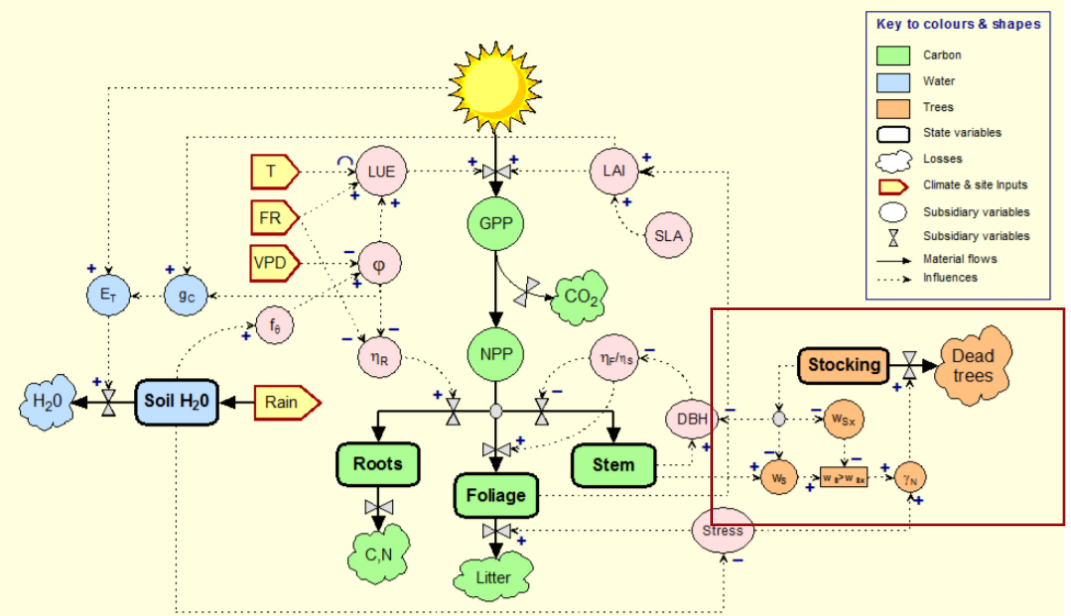
Fine roots and foliage have specific turnover rates (monthly)

Mortality has 2 components:

- Self thinning (self-thinning law) based on stem mass
- Stress based on the mortality rate of young and old forest stands

Stand structure

- Stand average dbh is derived based on allometric relation $WS = aDBH^b$
- Stand height is based on dbh-height relationships



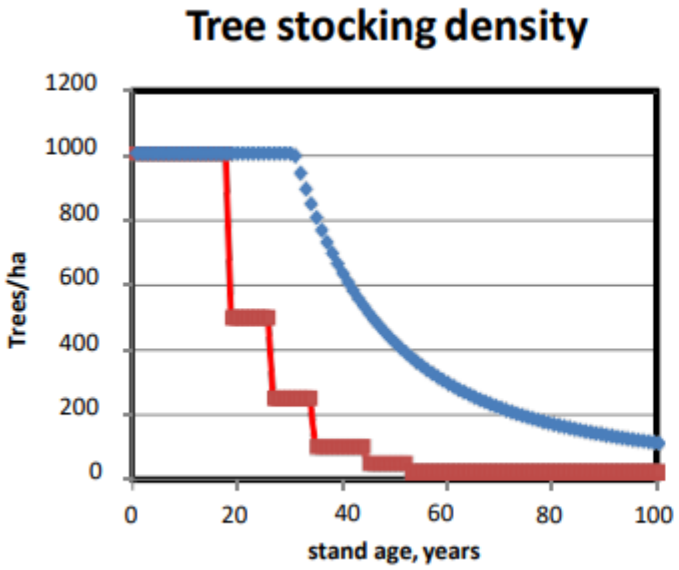
Waring & Gonzalez-Benecke

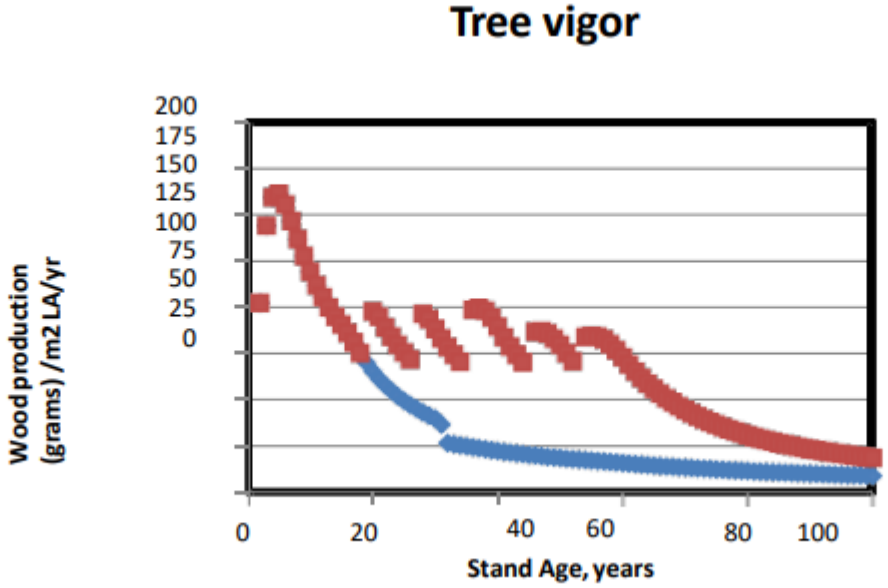
3-PG

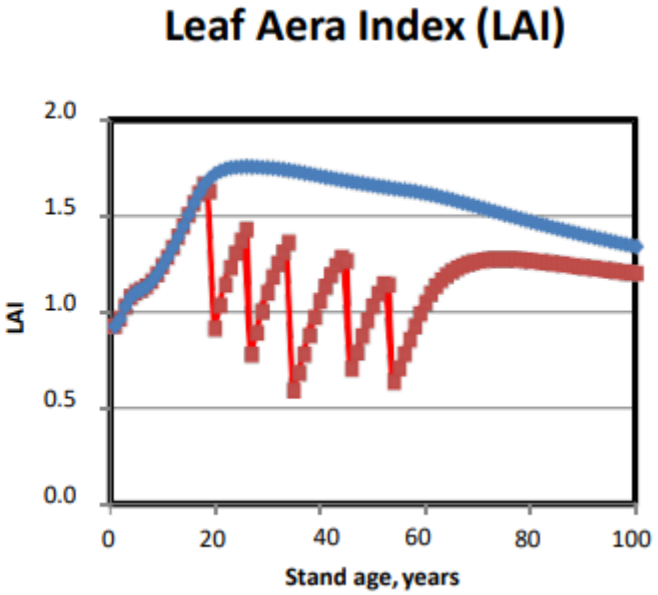
Management

- Thinning frequency: age of intervention
- Thinning intensity: number of removed trees
- Thinning concept: above, neutral, below

Waring & Gonzalez-Benecke







3-PGmix

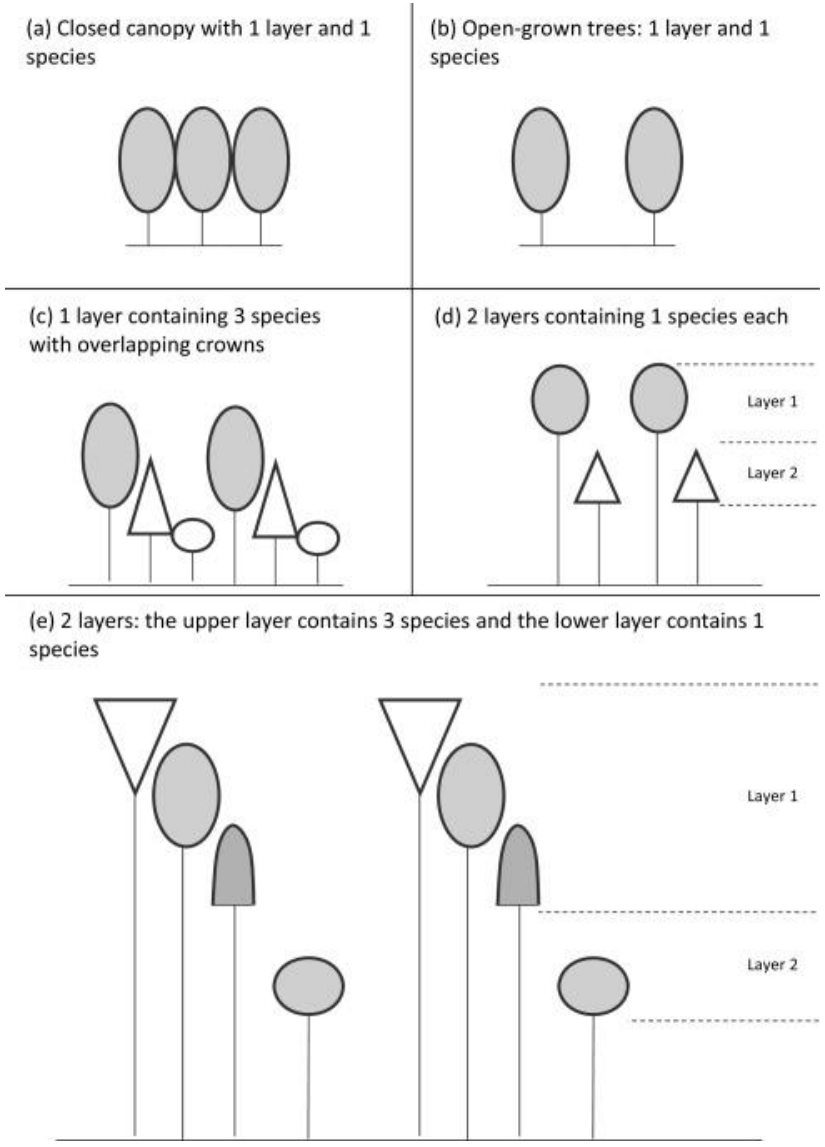
Further development of 3-PG to simulate mixed stands (Forrester & Tang 2016)

- **Alteration of light interception, based on canopy shape and size**
- **Possibility to simulate mixed and multilayered stands (e.g. Plenterwald)**

- **Richer stand structure**
  - **Weibull distribution of DBH**
  - **Weibull distribution of WS**

Other versions:

- https://3pg.forestry.ubc.ca/software/



i3PGmiX:

- https://github.com/andreyaugustynczik/i3PGmiX

Photosynthesis
- FvCB based-routines

Autotrophic respiration
- Differentiation between growth and maintenance respiration

Mortality
- Empirical and growth efficiency approaches

Soil
- ICBM/2N, Yasso20 and RothC

Management
- Additional management options

Disturbances
- Windstorms, bark beetles