Argonne NATIONAL LABORATORY

Dynamic Roots in CLM: a new approach for root distribution

Beth Drewniak

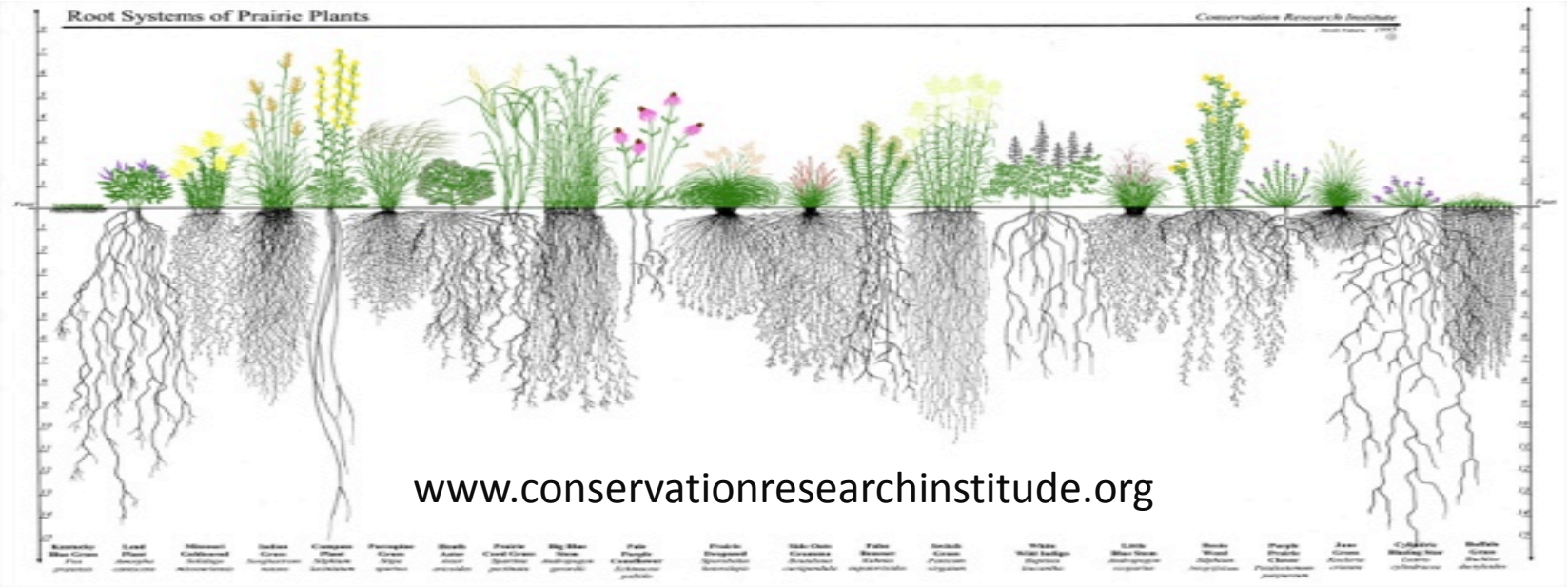
U.S. DEPARTMENT OF ENERGY

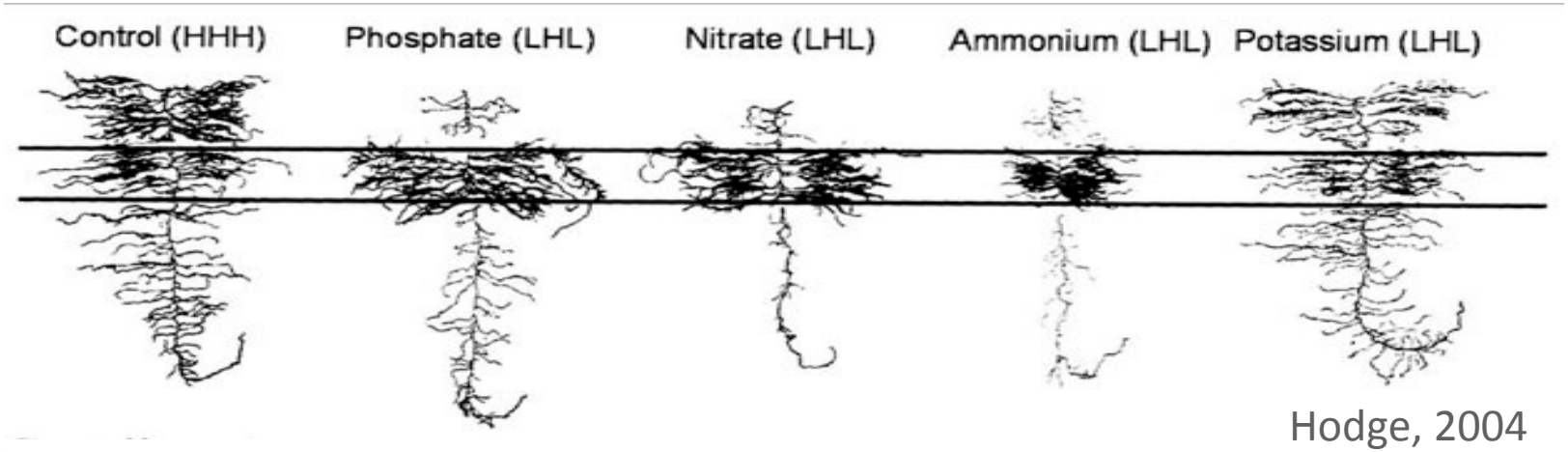
Motivation

- Roots are responsible for water and nutrient uptake
- Important drivers of above ground processes
  - photosynthesis and transpiration
- Key component in carbon, nutrient, and water cycling

- So why is root distribution static when above ground vegetation component has time-varying structure?

Roots respond to their environment

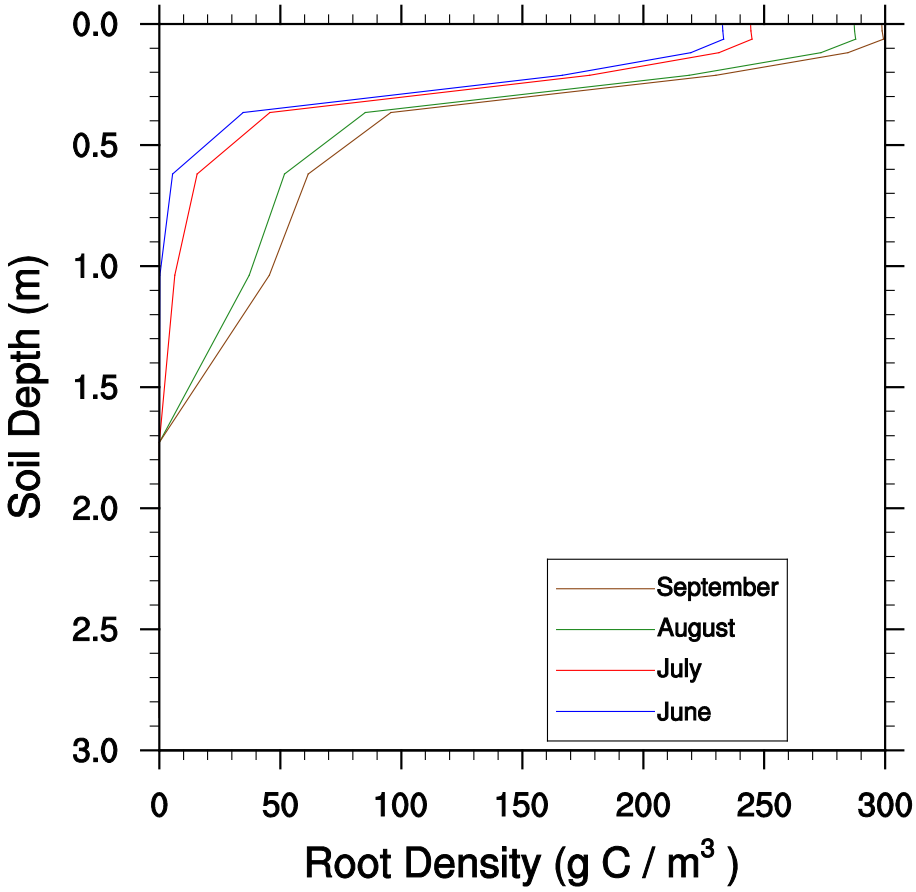




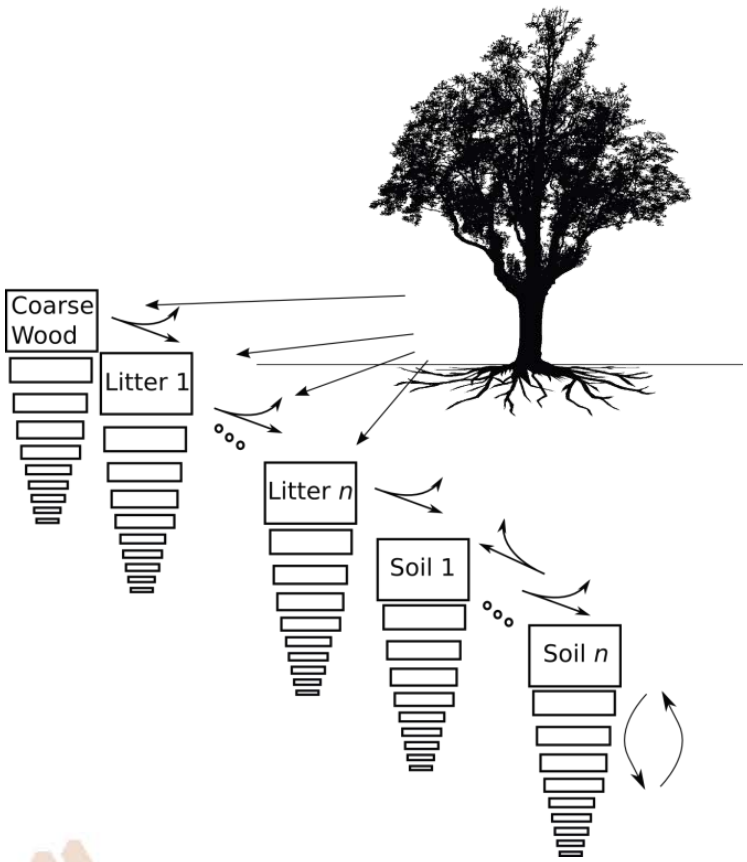
Hodge, 2004

Dynamic root scheme

- Two Parts:
  - Root fraction (density)
  - Rooting depth (crops only)
- Crop roots grow linearly with Growing Degree Days (GDDs), maximum depth at grain fill
- Root Depth for Crops:
  - Maize: 1.2 m
  - Wheat: 0.9 m
  - Soybean: 1.6 m



Root Fraction Weight Factors



First, calculate the water stress in the root zone:

$$w_{limit} = \sum \frac{\log\left(\frac{minpsi}{psi}\right)}{\log\left(\frac{minpsi}{maxpsi}\right)} * fr$$

Next calculate the water (rswa) and nitrogen (rsmn) availability in each soil layer:

$$rswa_j = \frac{\log\left(\frac{minpsi}{psi}\right)}{\log\left(\frac{minpsi}{maxpsi}\right)} * dz_j$$

$$rsmn_j = sminn\_vr_j$$

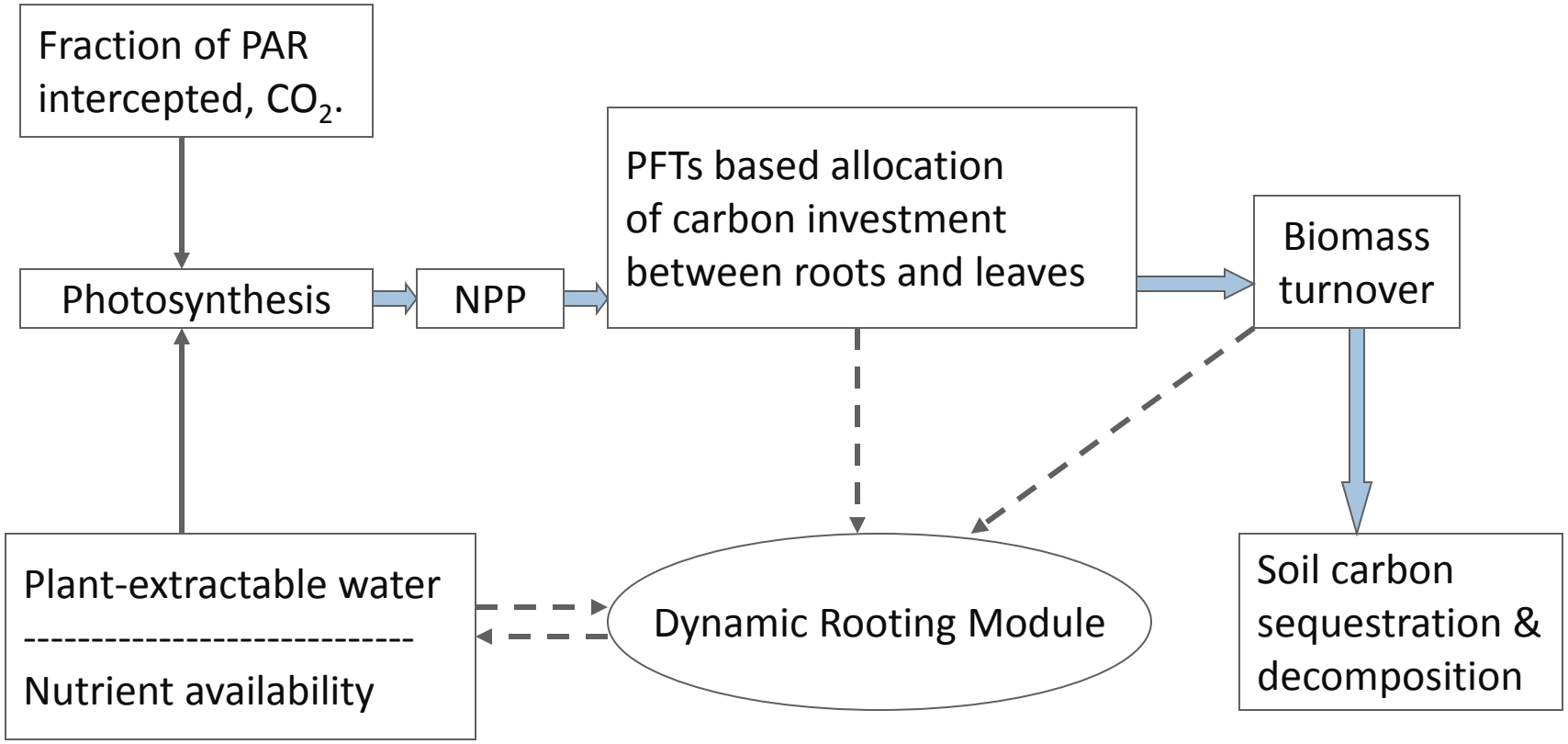
Calculating Root Fraction

Finally, calculate the root density in each soil layer:

$$\rho_j = C * fr + C_{new} * ((1 - w_{limit}) * \frac{rswa}{\sum rswa} + w_{limit} * \frac{rsmn}{\sum rsmn}) - C_{lost} * fr$$

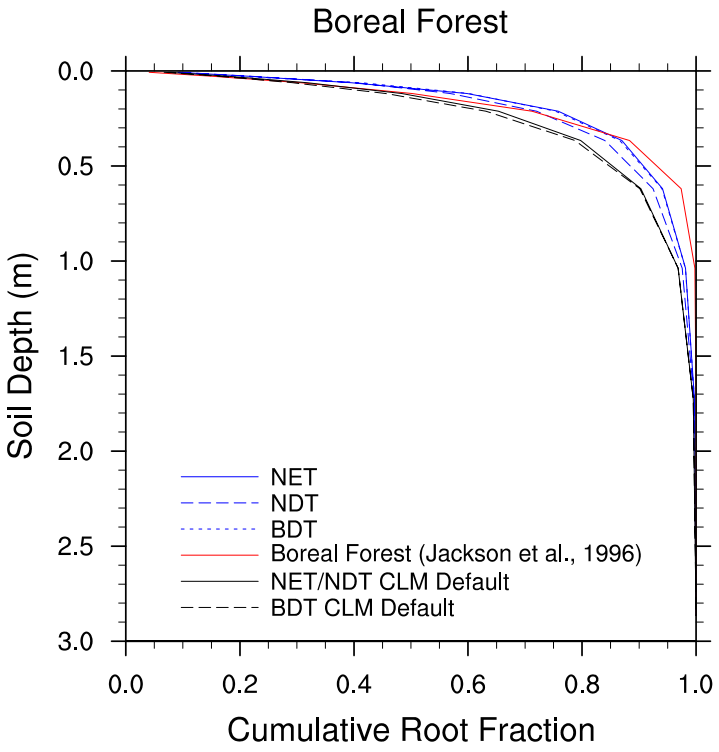
And convert to the new root fraction:

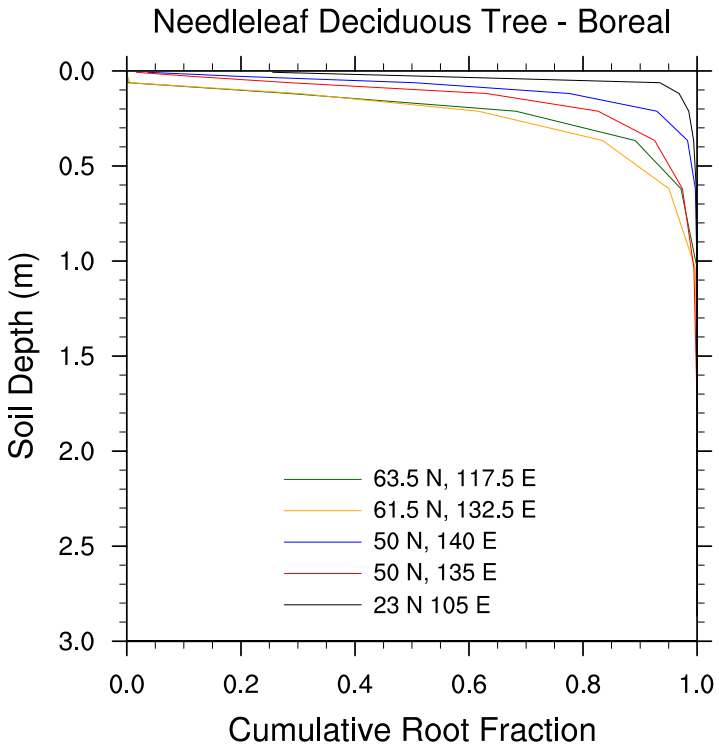
$$fr = \frac{\rho_j}{\sum \rho_j}$$



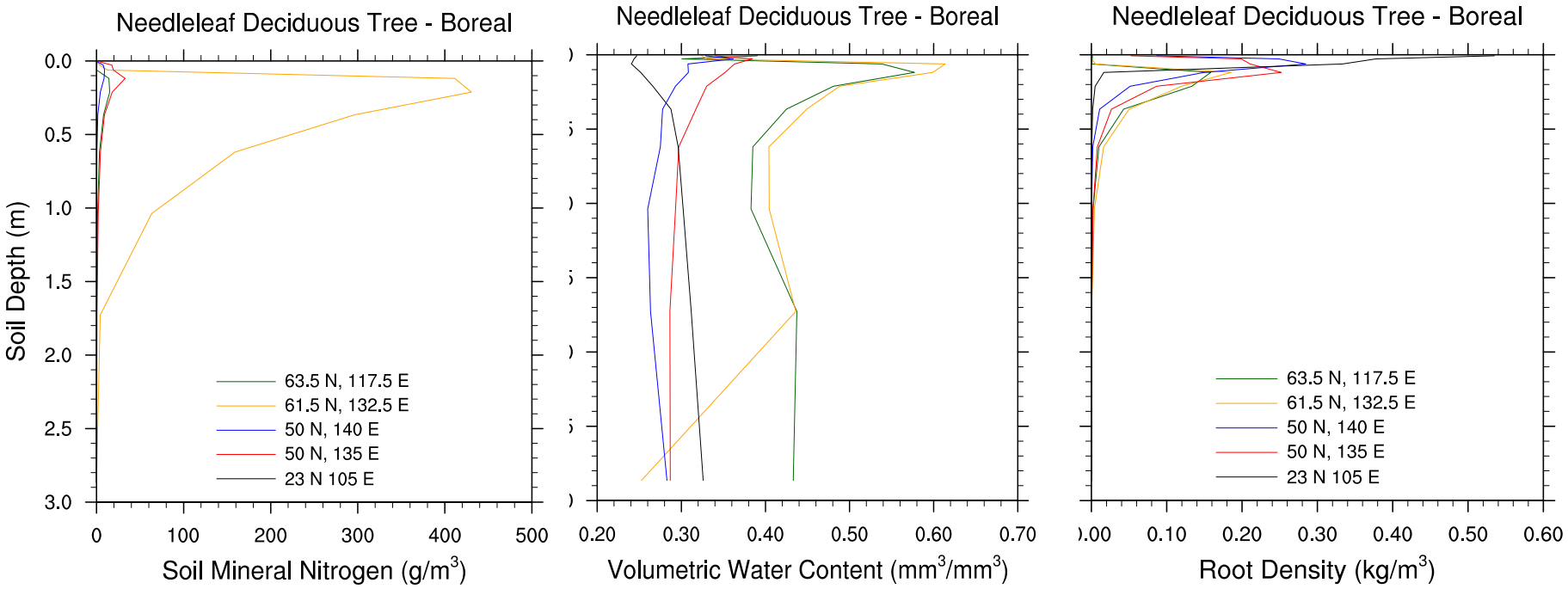
Taking advantage of the new biogeochemistry model (BGC) with vertically resolved carbon/nitrogen/water, this root distribution can pull nitrogen and water from the correct layer(s) of the soil profile.

Boreal Forest

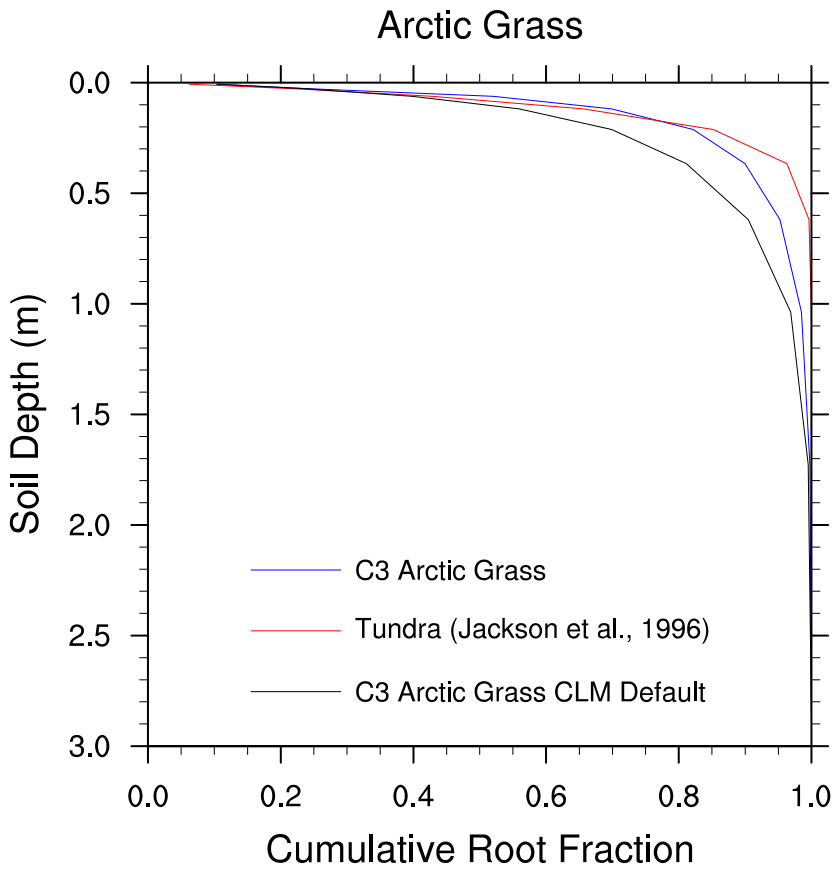




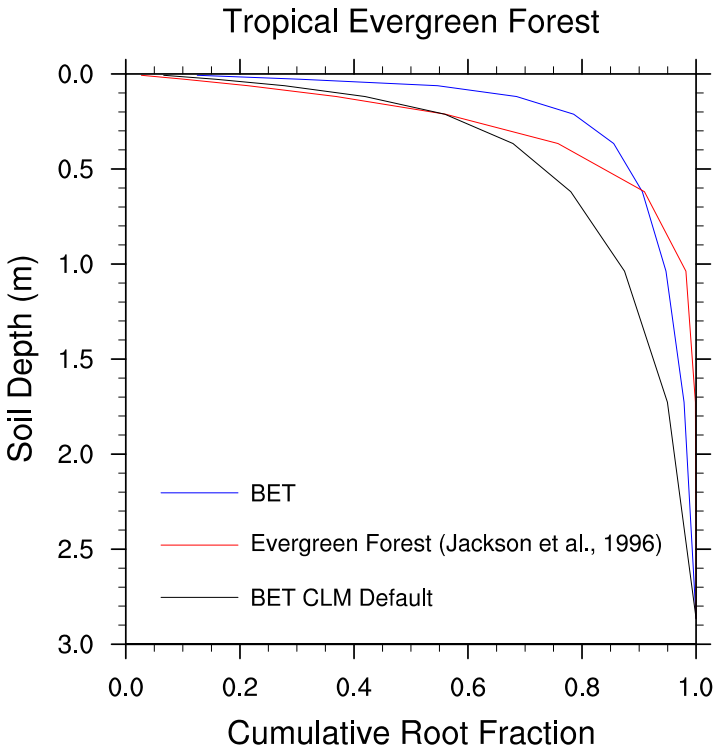
Root density and nutrients (Boreal)

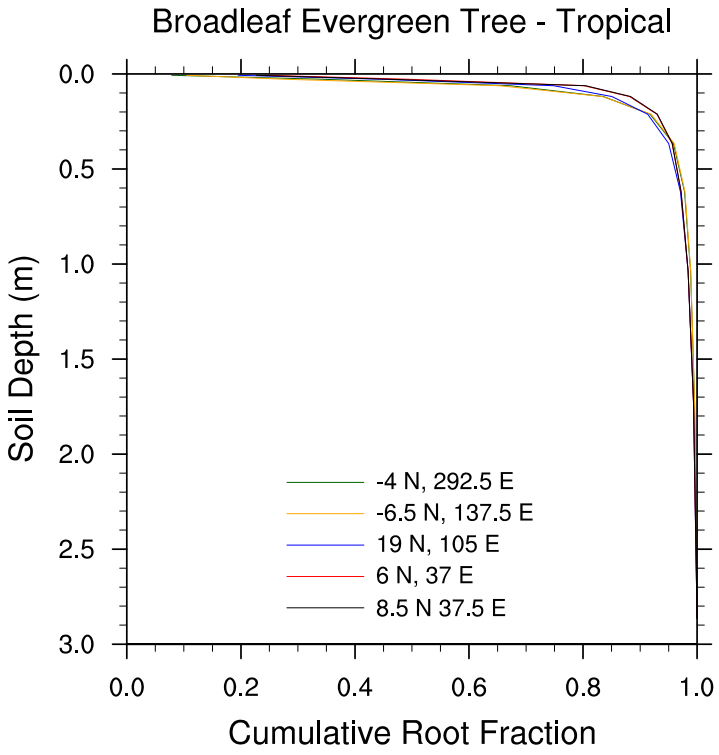


Grass (Boreal)

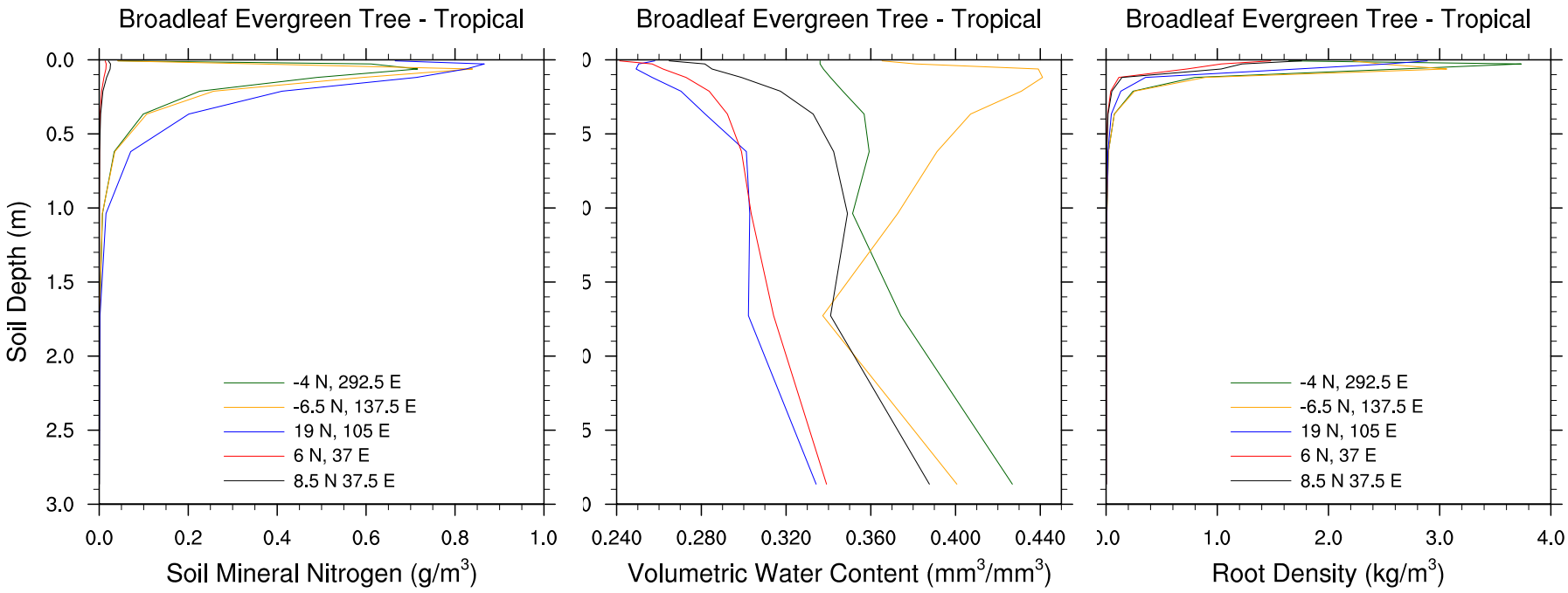


Tropical Evergreen

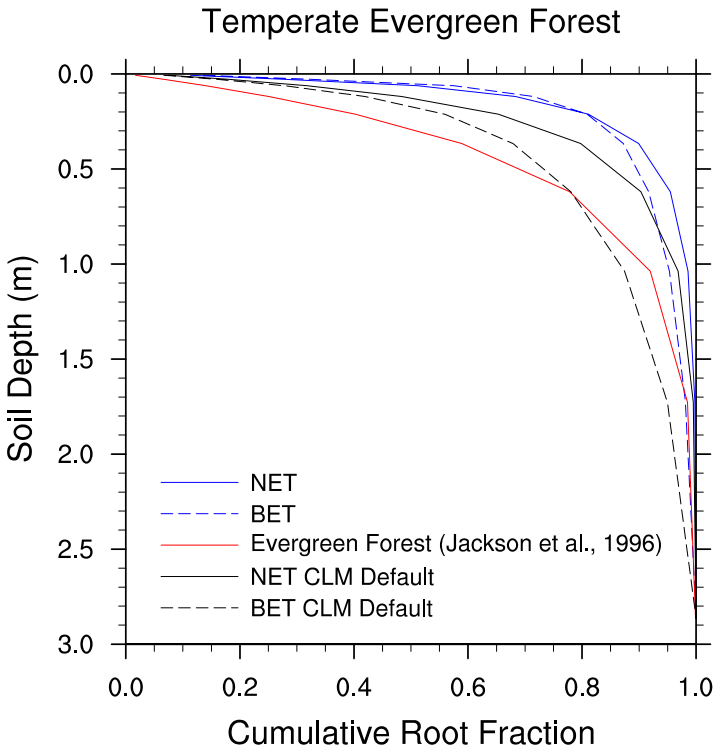


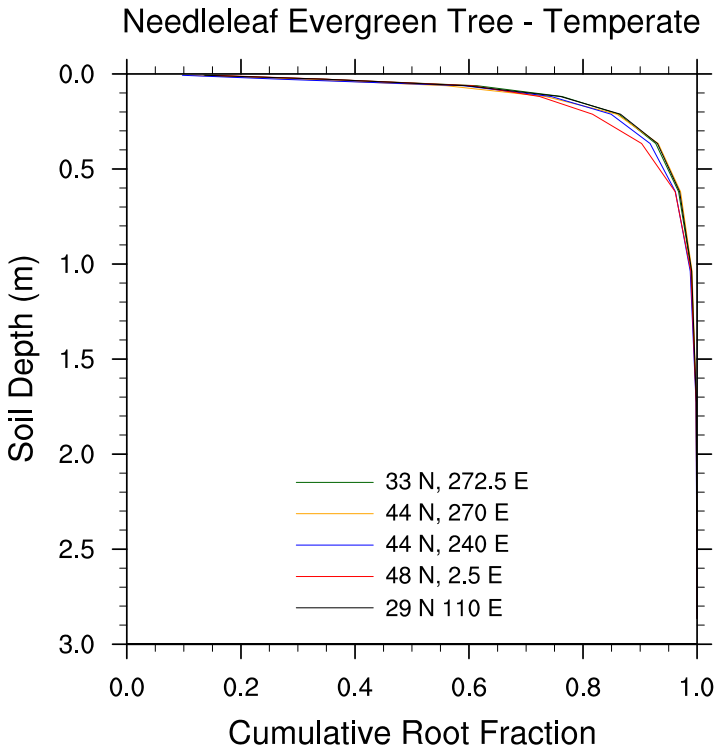


Root density and nutrients (BET Tropical)

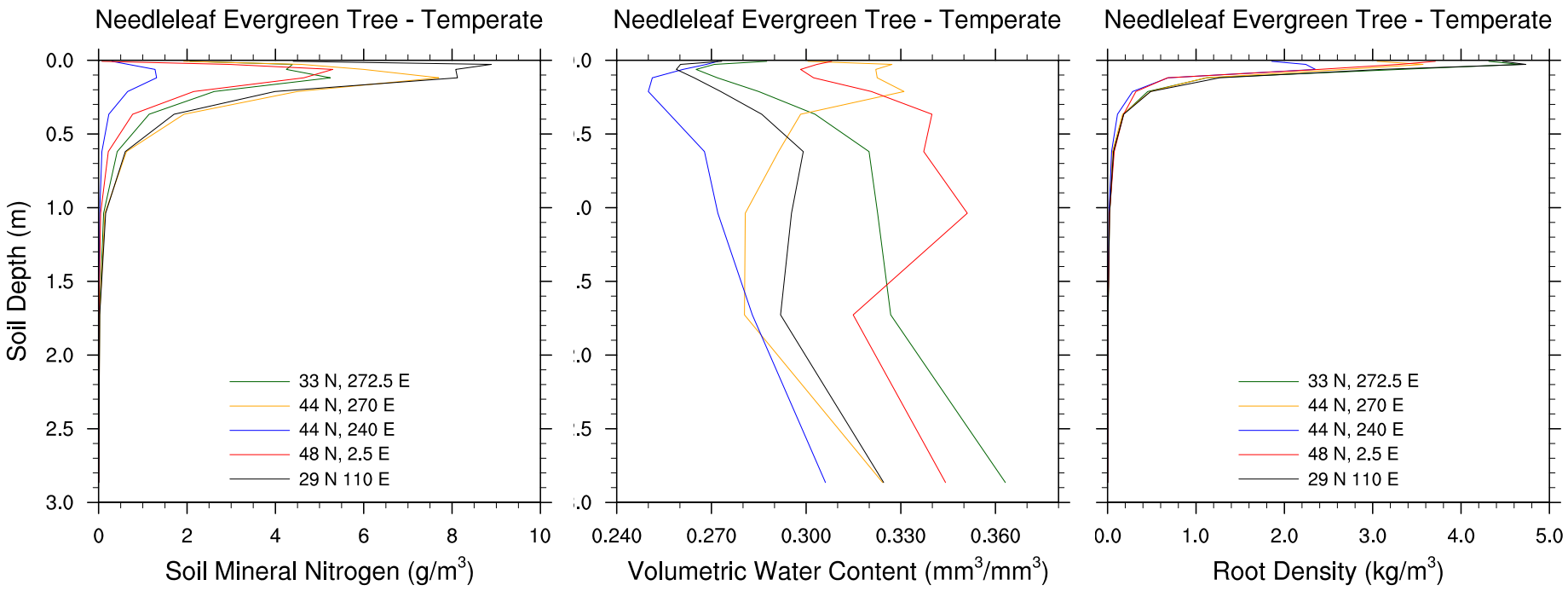


Temperate Evergreen

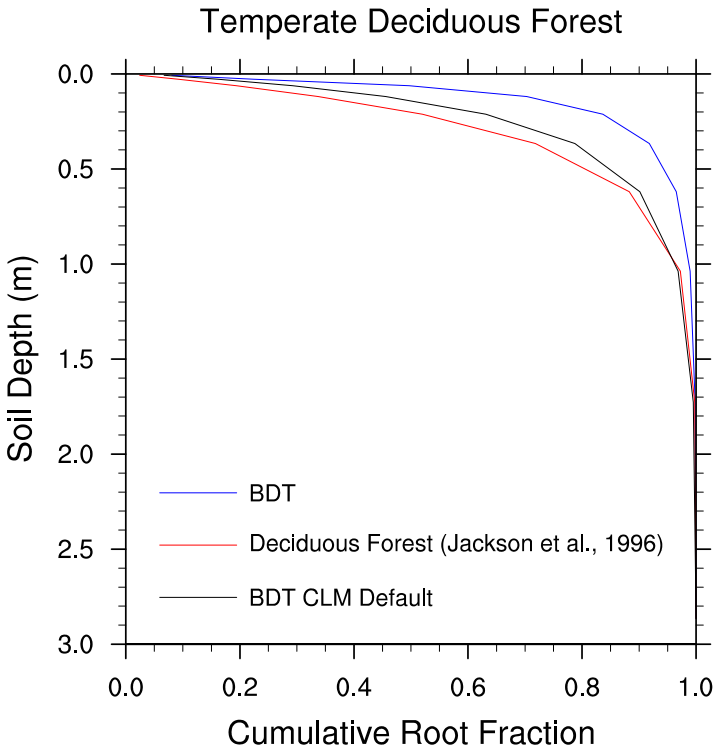


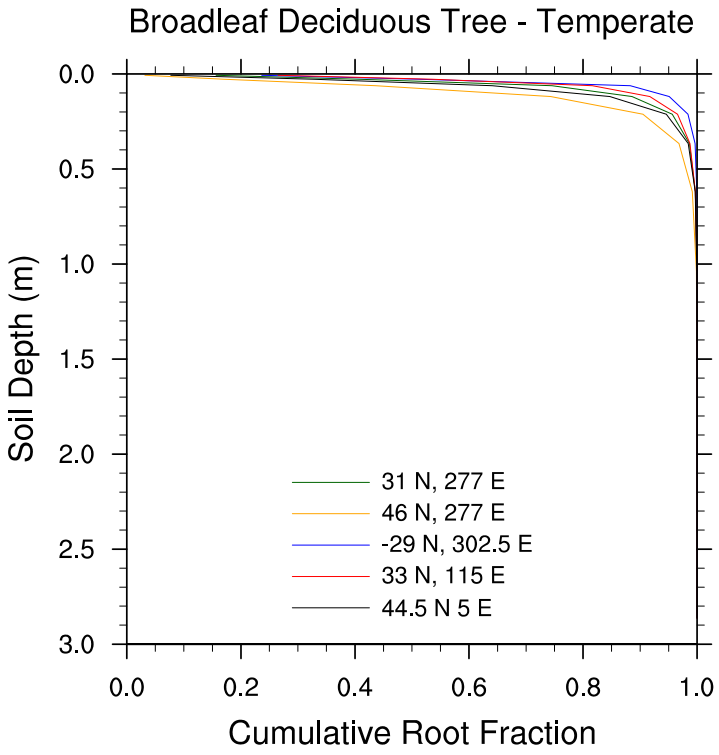


Root density and nutrients (NET Temperate)

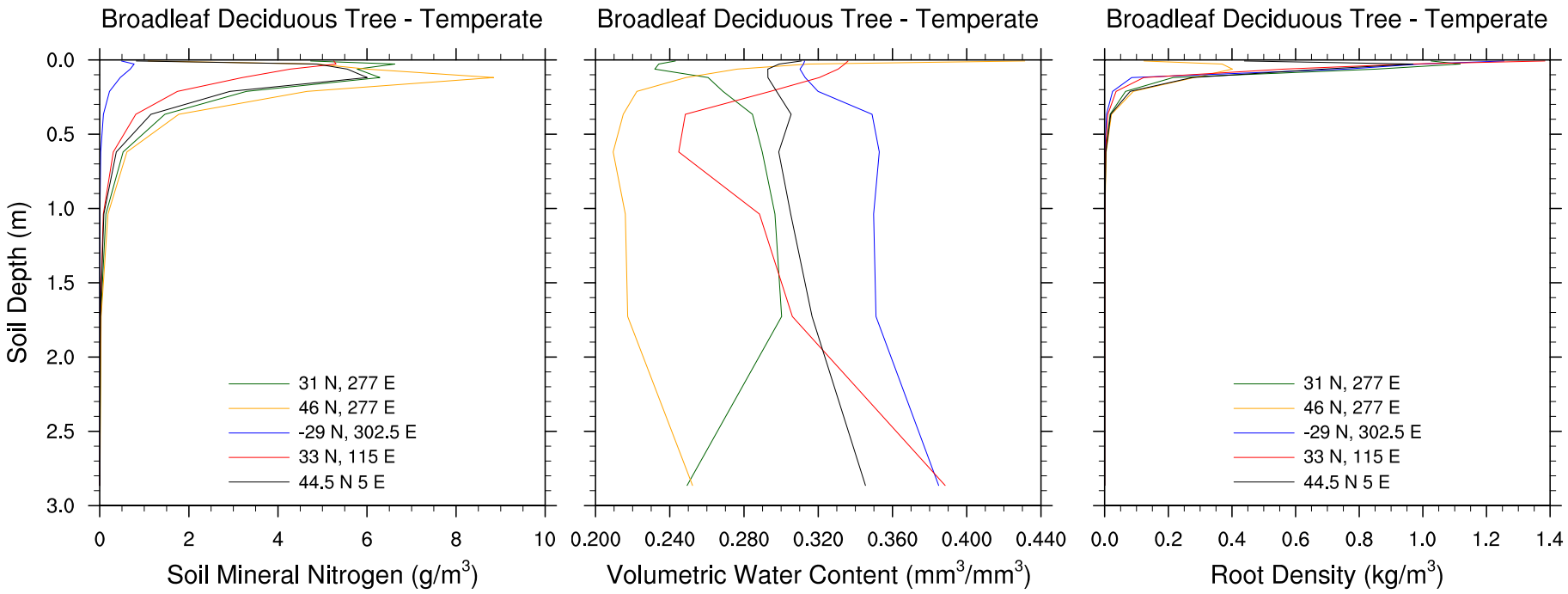


Temperate Deciduous

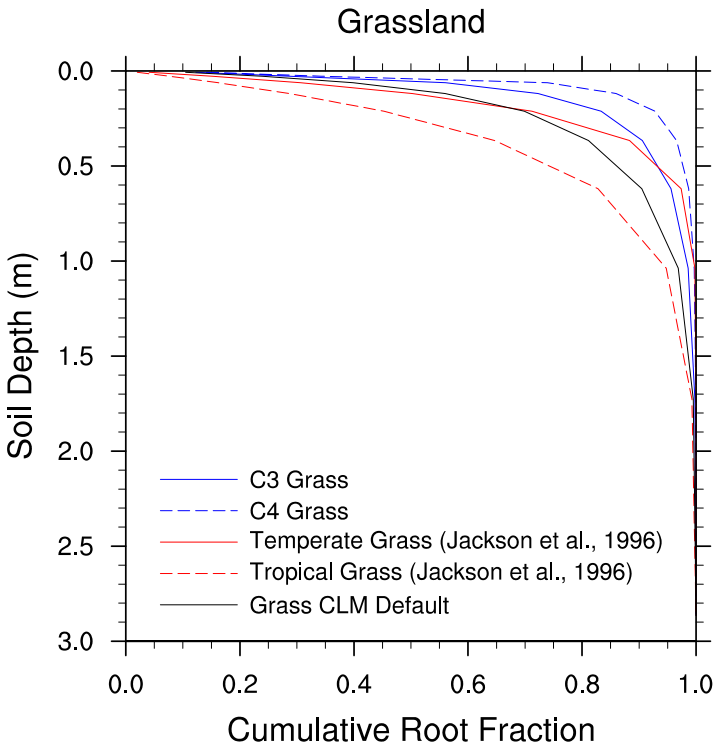


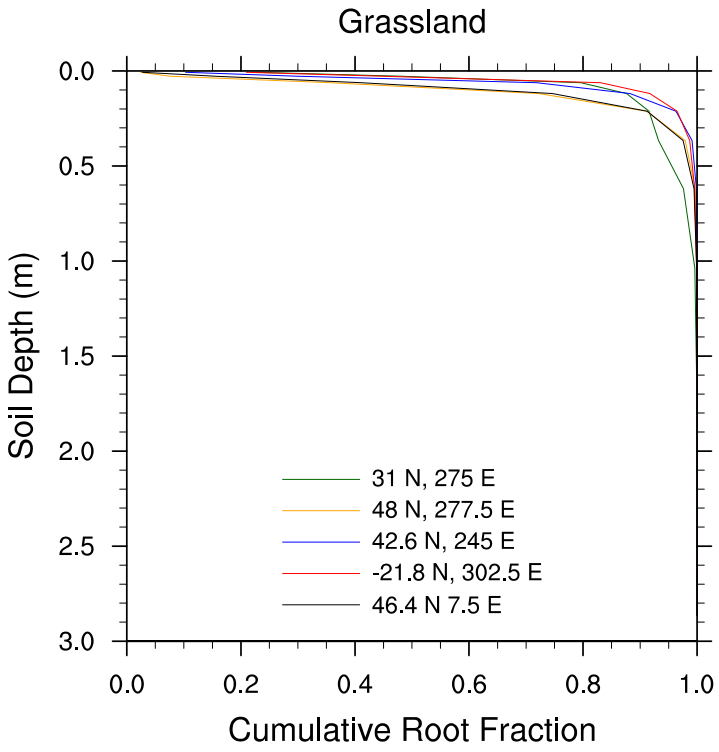


Root density and nutrients (BDT Temperate)

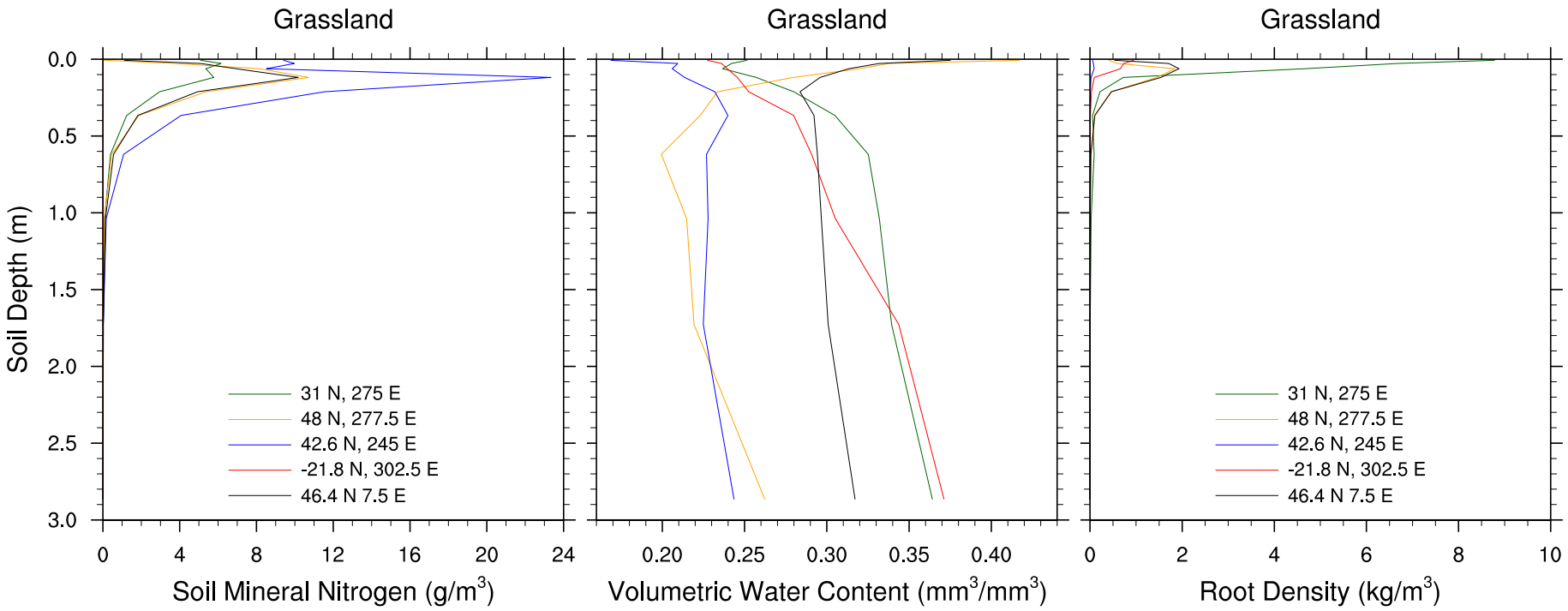


Grass

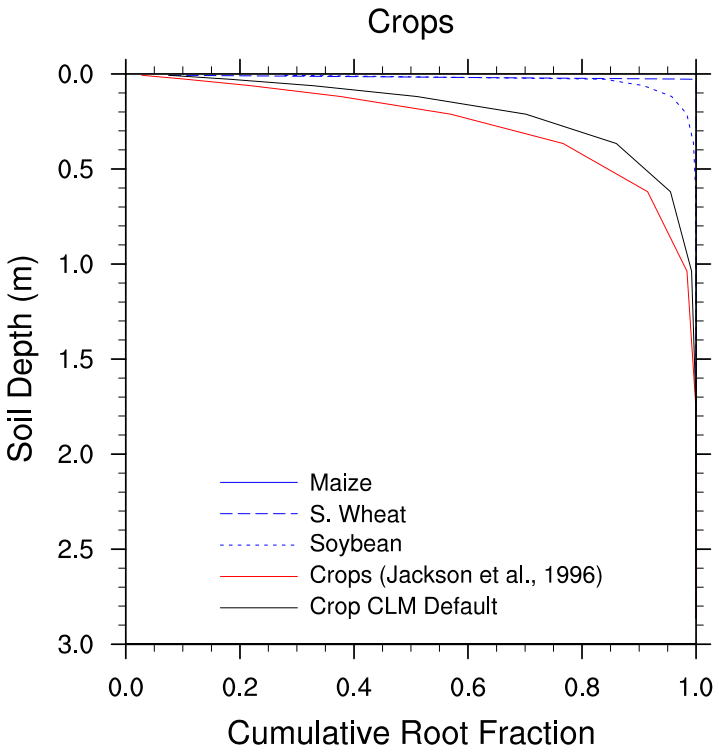

Grassland
Soil Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0.0
0.2
0.4
0.6
0.8
1.0
Cumulative Root Fraction
C3 Grass
C4 Grass
Temperate Grass (Jackson et al., 1996)
Tropical Grass (Jackson et al., 1996)
Grass CLM Default

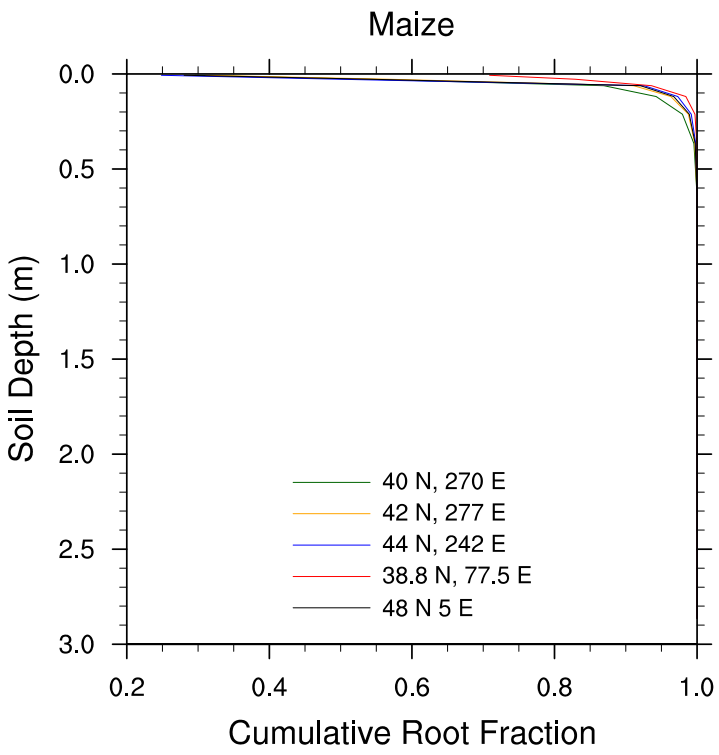

Grassland
Soil Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0.0
0.2
0.4
0.6
0.8
1.0
Cumulative Root Fraction
31 N, 275 E
48 N, 277.5 E
42.6 N, 245 E
-21.8 N, 302.5 E
46.4 N 7.5 E

Root density and nutrients (Grass)

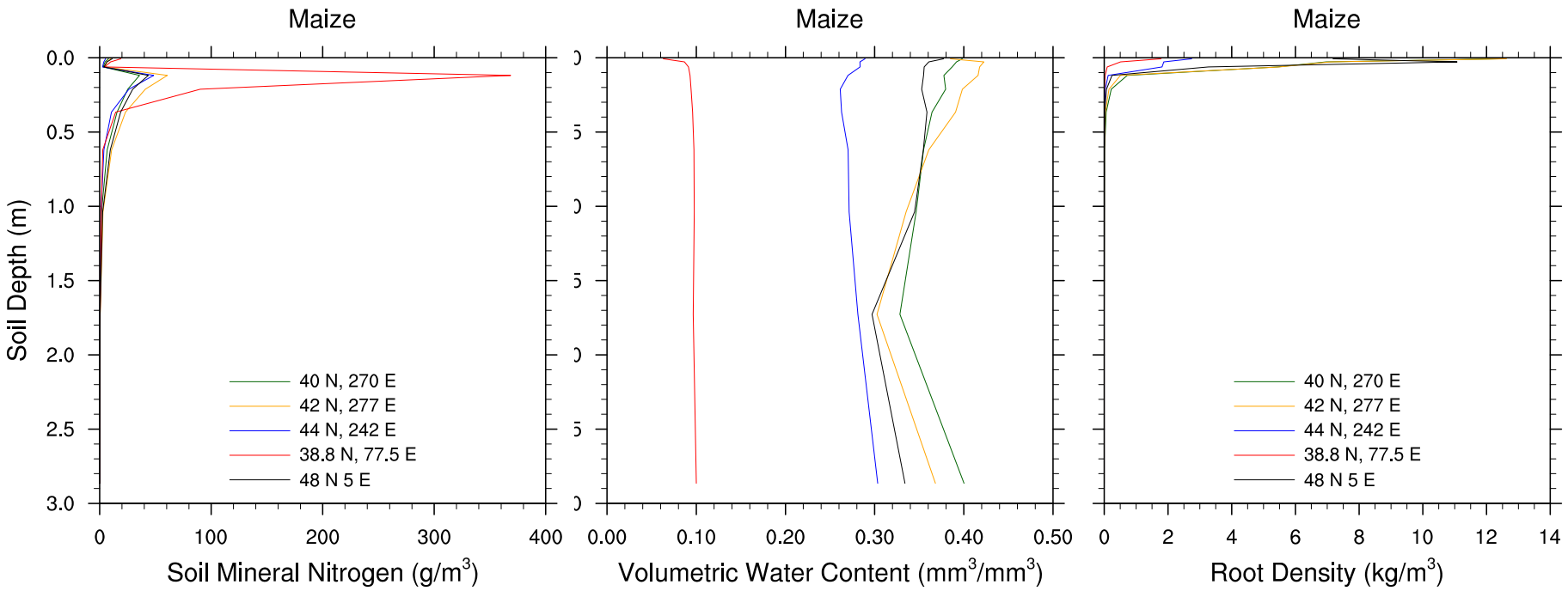


Crops


Crops
Soil Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0.0
0.2
0.4
0.6
0.8
1.0
Cumulative Root Fraction
Maize
S. Wheat
Soybean
Crops (Jackson et al., 1996)
Crop CLM Default


Maize
Soil Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0.2
0.4
0.6
0.8
1.0
Cumulative Root Fraction
40 N, 270 E
42 N, 277 E
44 N, 242 E
38.8 N, 77.5 E
48 N 5 E

Root density and nutrients (Crop)



Still to do…

- This is a work in progress
- Roots strongly follow the nutrients
- Results in shallow root profiles
  - Great for arctic
  - Poor root distribution everywhere else
  - Crops need help
- Can tweak the weight algorithm some
  - More weight on water distribution
  - Alternative nitrogen profile (worked in CLM3.5)