

# **Savanna**

## Savanna Submodels

## Weather Modeling in Savanna

Savanna uses temperature and rainfall extensively in modeling. Weather stations from throughout the region provide these data.

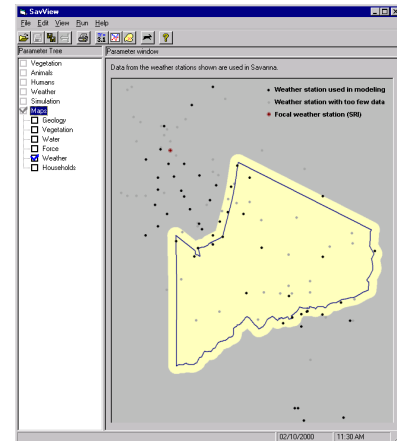
Every cell in the map of the study area must have weather information, but each cell does not contain a weather station. Values for cells must therefore be estimated.

*Different* methods are used to estimate temperature and rainfall because of their different properties.

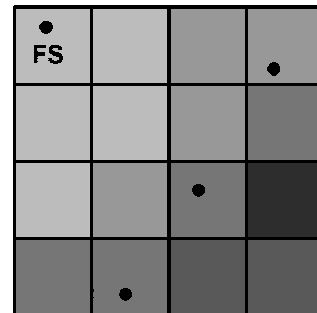
Temperature varies closely with elevation, so temperature is calculated based upon values from a focal weather station and a *lapse rate* with elevation. Values are also adjusted for slope and aspect.

Precipitation often does not relate as well with elevation. If so, precipitation is estimated by smoothing data from many weather stations.

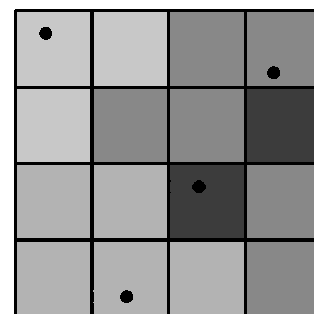
Other weather-related values are included in WEATHER.PRM, such as the lapse rate, humidity, wind speed, radiation values, information to model potential evapotranspiration, and CO<sub>2</sub> concentration.



For each cell:  
Temp. = FS \* (Lapse rate)



For each cell:  
Rain = S1 \* Dist.<sup>-1</sup> + S2 \* Dist.<sup>-1</sup> +  
S3 \* Dist.<sup>-1</sup> + S4 \* Dist.<sup>-1</sup>



**Exercise:** Look at the weather stations map for Ngorongoro Conservation Area.

**Method:** Use the method described on page 17, clicking upon “Weather” under the heading “Maps”. Some stations were excluded because of too little data. The remaining 55 stations were used in modeling Ngorongoro in Savanna. The weather station at Seronera Research Institute provided temperature information.

**Exercise:** Look at the BASESTN.DAT file in the “parms” directory.

**Exercise:** Look at the files PPT6392.MRG and SR356392.MRG in the “parms” directory. Notice the differences.

**Exercise:** Look at the WEATHER.PRM file in the “parms” directory.

**Exercise:** Look at INTERCEP.PRM. Look at the SNOW.PRM file in the “parms” directory. Not of great use in East Africa, but ...

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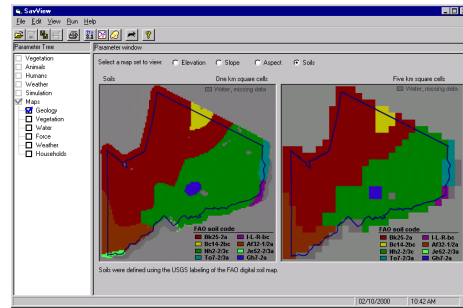
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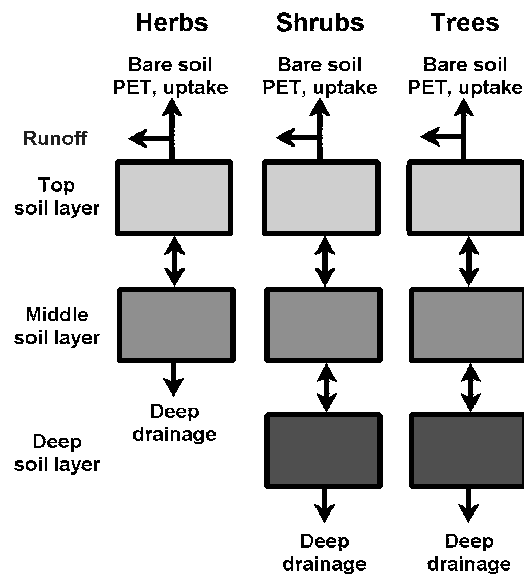
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## Soil Modeling in Savanna

A map of soils represented by codes is used by Savanna in modeling water and nutrient transfers. Each soil type may have a different suite of properties.



Soils are represented in three layers in Savanna, with their thicknesses set by parameters. Water passes through each layer in a tipping-bucket model, from the top to the middle, to the deep soil layers. If the soil is saturated, water passes on to deep drainage. Herbs may use water from the top two layers, whereas woody plants may use water from all layers.



### Soil.prm sample

Soil attributes such as depth, wilting point, and water capacity are set in the SOIL.PRM parameter file.

```

8,3 //nsoil,nlay
1 //isoipto
0 //i50bar
1 //isoilnin
0 //icrack - flag to use crack
0 //iwttable - flag to use water
300. //biogood -biomass good cond
5. //wdreten - reduction in run
1 75.0 100.0 750.0 1000.0 .09
2 75.0 100.0 750.0 1000.0 .09
3 75.0 100.0 1000.0 1500.0 .17
4 75.0 100.0 1000.0 1500.0 .17
5 75.0 100.0 750.0 1000.0 .09
6 75.0 100.0 750.0 1000.0 .12
7 75.0 100.0 750.0 1000.0 .12
8 75.0 100.0 750.0 1500.0 .21
n,edep,depl,hdep,depth,wilt1 wilt2,
    
```



**Exercise:** If you haven't done-so, look at the soils maps used as input into the default model for Ngorongoro Conservation Area.

**Method:** Use the method described on page 17, clicking upon "Geology", then in the large window to the right, select the button that displays the soils. Most other applications of Savanna have a more detailed soil layer.

**Exercise:** Look at the SOIL.PRM file in the "parms" directory.

**Exercise:** Look at the SOILN.PRM file in the "parms" directory. You may look at WTABLE.PRM and CRACKFLW.PRM as well, although these are not used in NCA-Savanna.

**Method:** Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown.

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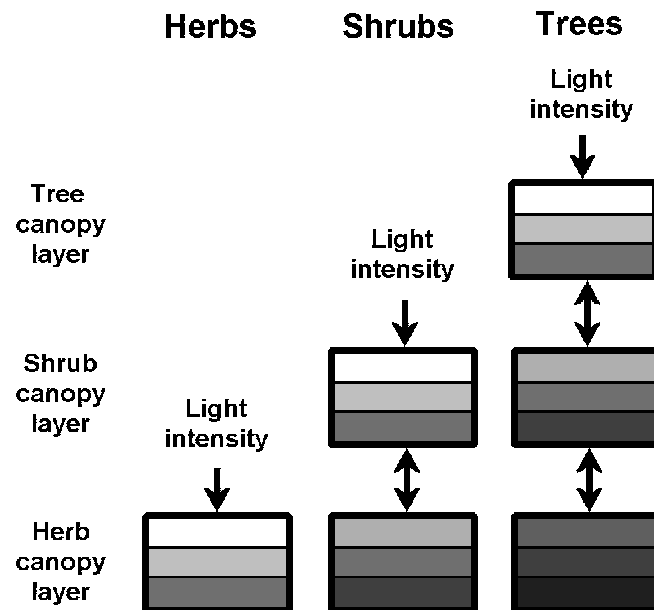
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## Light Modeling in Savanna

Global shortwave radiation is reported to Savanna in the WEATHER.PRM parameter file, as is the base latitude of the study site. From mathematical equations, Savanna calculates a day length for each time period throughout the year, based upon the latitude provided. Equations are then used to calculate *photosynthetically active radiation*, the portion of incoming light potentially available to plants.

The light that reaches the upper canopies (herb, shrub, or tree, depending upon the facet) passes through layers of vegetation. Each layer is further divided into at least three sublayers. For each sublayer, a mathematical formula (Beer's Law) is applied, calculating how much light reaches each layer.



From these methods, light within a given layer of vegetation is determined by leaf area in the layers above. In addition, for the woody facets, taller types of trees and shrubs may shade shorter types of trees and shrubs.



**Exercise:** Look at the WEATHER.PRM file within the “parms” directory.

**Method:** Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown. The WEATHER.PRM parameter file includes global radiation values and the latitude of the study area.

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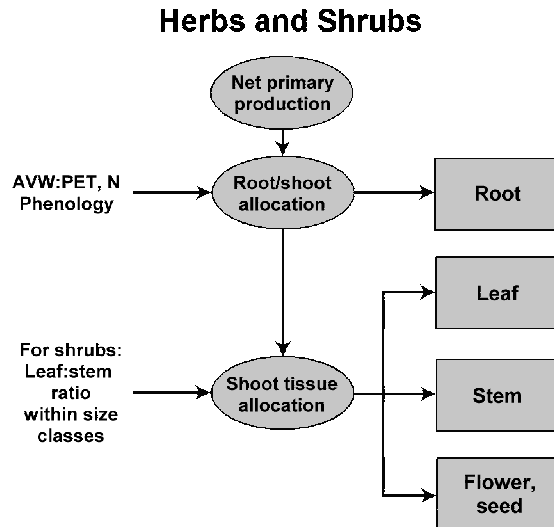
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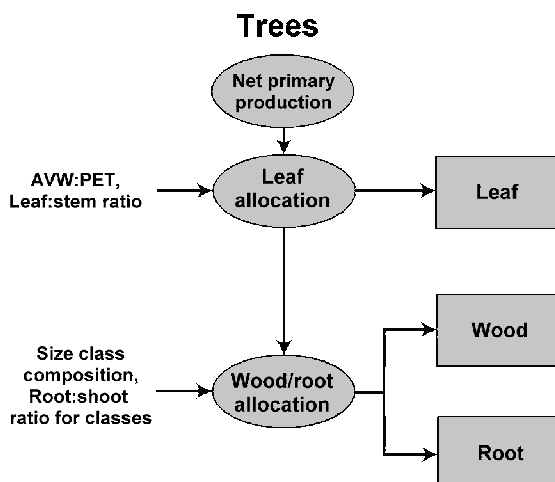
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## Biomass Allocation in Savanna

For herbs and shrubs in Savanna, plant resources are allocated first between roots and shoots, then the portion going to shoots is allocated between stems, leaves, and flowers and seeds. Allocation to roots versus shoots is determined by water availability, nitrogen balances, and the phenology of the plant. Allocation to portions of shoots is determined by the ratio of leaves to stems (in shrubs). At first, leaves are favored over stems, until a given ratio is met, then resources are divided based upon maintaining that ratio.



For trees, resources are allocated first to leaves, then the remaining resources go to growing roots and wood. As for shrubs, leaves are favored over stems when allocated resources, until a given leaf to stem ratio is met. The ratio used is specific to the size class of the plant being modeled. Then resources are partitioned based upon maintaining that ratio.





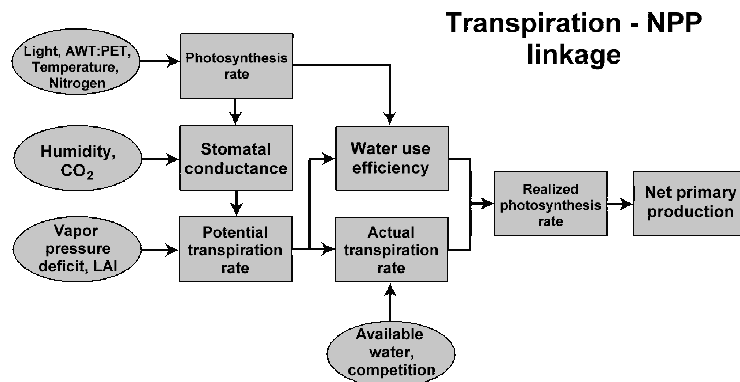


## Transpiration - Net Primary Production, Establishment

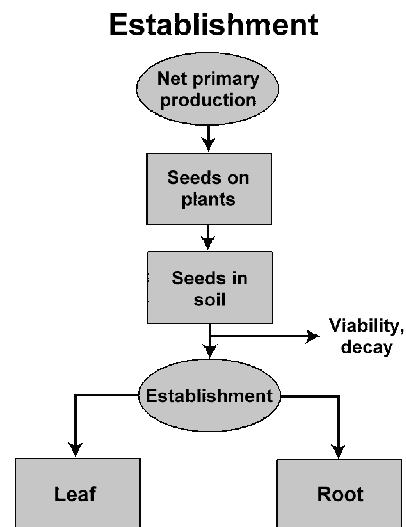
### Net Primary Production

(NPP) is dependent upon many things, but Savanna was designed, and remains, primarily a tool to model arid and semi-arid eco-

systems. With that, NPP is mainly dependent upon water availability. The *potential transpiration rate* is affected by stomatal conductance, which itself is affected by the photosynthesis rate, set by the amount of light, water, heat, and nitrogen present. The *actual transpiration rate* is controlled in-part by competition with other plants in the same or other functional groups. From this, an actual photosynthesis rate is calculated, and net primary production summed.



Establishment of young plants is related to the net primary production of the parent plants. Some portion of NPP is generally allocated to flower and seed production. These seeds drop to the soil, and some then may be nonviable or decay. For those that germinate and become established, Savanna allocated resources to leaves and roots based upon the plant size characteristics.





## Vegetation Physiology Modeling in Savanna

### Plpgrass.prm

Any number of plant types may be modeled in Savanna, but generally the number is eight or fewer. Plant physiology is described for Savanna's use in large PL\*.PRM files, where the '\*' represents a short name for the plant group of interest. The trimmed file for palatable grasses is shown.

Values within the PL\*.PRM files control the size and shape of the plants, photosynthesis rates, how nitrogen is distributed within the plants, effects of limited water availability on death rates, phenological information, digestibility rates, and other information.

The list of values for herbs and woody plants are slightly different. We will highlight those differences as a group.

```

PGRASS //plname
1 //indx
0 //nwdysp
0 //nannsp
.50 //plht
0.80,0.20,0 //proot
0. //grndwtr
42.2 //pnetmx
.10,3.23 //csfixa,
40.,6.,25. //tcsm
350.,1.,700.,1.,1000.,1. //eco2ps
77. //splwt
292 //spwwt
.2 //widlf
50. //alpha
.45 //radk
.25 //albedolf
0.,.0,.3,1.0 //ewgr
0.,1.,1.,1. //esrp
0.0091 //respnm
1.0 //respmps
0.25 //respgr
0.0,0.05,4.0,0.05 //prseed
0.67 //prlf
0.67 //shootrt
0.0 //stmperr
2.,.33,4.,.5 //epal
1.,1.,2.,1. //esral
0.,1.,.8,.7 //ewal
0.75 //enalbg
0.003 //trnmx
1.,.015,3.,.035 //rsrvf
0.018 //seednc
.02,.01 //actvnbmx,
.044,.028 //glnbmx,
.25 //varlnb
1.3,1.,1.8,1.6 //eclimnb
0.5,3.5 //phglnmx,
.0042 //dlnb
.0042 //drnb
.0042 //dwnb
0.,.010,.3,.0020 //drwat1
0.,.006,.3,.0005 //drwats
0.,.004,.3,.0005 //drwatr
0.,.0,3.,0.0 //drtmpl
0.,.0,3.,0.0 //dtrmps
0.,.0,3.,0.0 //dtrmpr
0.,0.001,4.,0.0005 //drphnl
3.,0.010,4.,0.035 //falr
0.,0.,200.,.05 //esnwdf

```



As a group we will review the contents of PLPGRASS.PRM, focusing upon those values highlighted with a line.

```
2 //iphenoddtm
0,0,20,1,70,2,130,3,185, //phenod
365. //phresetdd
0 //phresettm
-999. //phresetwt
0.,0. //dayln(1),
8. //phintemp
.3 //phinwatr
0.035,0.500,0.055,0.642 //gdigst
0.31,0.4,0.4 //ddigst,
0.008 //upmx
4.8 //upnkm
-999 //end mark
```

**Exercise:** Look at the PLPGRASS.PRM and the PLWOODS.PRM files in the “parms” directory.

**Method:** Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown. Note that everything to the right of “//” on a line is ignored by Savanna.

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## Vegetation Population Modeling in Savanna

Plant populations are affected by values set in several of the parameter files. However, each functional group has a POP\*.PRM file associated with it, which controls specific responses affecting population.

Whereas the PL\*.PRM files were similar for herbaceous and woody plants, the POP\*.PRM files are very different. Below is the POP\*.PRM file for palatable grasses:

### Poppgrss.prm

```
0.18 //seedrep - Seed-based reproduction
1.,.5,4.,.4 //hbmerinc - Rate of increase per ye
2.5,.072,3.,.052 //hbmerdec - Rate of decrease per ye
0.12 //hbgerm - Max rate of seed germin
0.,.1,0.25,1.0 //ewgrmb - Effect of Available Wat
100.,1.,250.,0. //ehrbet - Effect of Herbaceous Ro
0.,0.,1.,.10 //plkillhb - Fraction of plants/meri
```

The file describes the rate of reproduction by seed, germination rates, rates of change in meristem counts, the effect of water availability and crowding upon establishment, and death rates from grazing. The woody plant POP\*.PRM has similar components, but has several values describing the size and shape of the shrub or tree, as well.

### Popwoods.prm

```
7 //nspt - Index of the species(
0 //ievrgrn - Evergreen Tree Specie
0.,0.,.1,.1,.15,.2 //germrt - Maximum Germination R
0.,0.,.0,.0,.0,.0 //germlow - Establishment rate a
16.,1.,25.,1. //etgrmt - Effect of Temperature
0.1,0.0,0.8,1. //ewgrmt - Effect of Monthly PPT
1.7,1.,7.,0. //ewdlaigrm - Effect of woody total
150.,1.,300.,0. //ehrbet - Effect of Grass/Herb
0.15,0.002,0.001,0.001,0.001,0.0013 //drintr - Nominal Tree Death
0.,0.0001,0.3,0. //drwatw - Mortality rate vs. av
-30.,0.,-1.,0. //drtmpsd - Death rate of seedlin
0.,0.,1.,.15 //plkillhb - Fraction of plants ki
1.37 8.68 11.47 13.70 15.36 16.44 //cantop - Tree Canopy Top Heigh
0.00 2.60 3.44 4.11 4.61 4.93 //canbot - Tree Canopy Bottom He
1.78 7.90 10.44 12.47 13.97 14.96 //cdiam - Crown Diameters for
350. //rtbiodens - g/m2 of fine roots in
6*-99. //rdiam - If > 0, specifying a r
```



```
10.0 100.0 150.0 200.0 25.00 300.0 //sdiam - mm stem diam
0.3 0.25 0.2 0.17 0.17 0.17 //dincrmx - Max mm/month stem
0.068 60.499 200.086 467.505 902.965 1546.164 //sbsize - Mean
0.015 13.533 44.756 104.574 201.979 345.853 //rbsize - Root
0.020 1.963 4.418 7.854 12.272 17.671 //bleaf - Leaf
0.068 34.571 80.034 143.848 225.741 325.508 //fbsize - Fine
0.016 1.636 3.682 6.545 10.227 14.726 //frsize - Fine
.1,.2,.3,.4,.5,.6 //brnchlai - Projected m2 area/m2
2000.,2000.,2000.,2000.,2000.,2000. //spbrwt - Specific branch
.15 //contagn - 0-1 index of contagio
.65 //prsapwd - Fraction of coarse wo
1 //nform - Crown form, 1=cylinde
-999 //end of file mark
```

**Exercise:** Look at the POPPGRSS.PRM and the POPWOODS.PRM files in the “parms” directory.

**Method:** Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown. Note that everything to the right of “//” on a line is ignored by Savanna.

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## Initializing Woody Cover within Savanna

Savanna has been informed about the initial cover in the shrub and tree facets using the \*FAC.DAT files, but the initial distribution of age classes for each woody plant type remains to be set. These values occur in the TRHTFIL.PRM file.

### Trhtfil.prm sample

```
1 //Method switch 1-initialize by vegetation typ
15 //Number of vegetation types that follow, only
1 2 // - Forb/Grassland -
4 .41,.34,.14,.06,.04,.01 // PShrub
5 .41,.34,.14,.06,.04,.01 // UShrub
2 2 // - Sedge/Grassland -
4 .41,.34,.14,.06,.04,.01 // PShrub
5 .41,.34,.14,.06,.04,.01 // UShrub
3 2 // - Mixed grasses/Forb
4 .41,.34,.14,.06,.04,.01 // PShrub
5 .41,.34,.14,.06,.04,.01 // UShrub
4 4 // - Bamboo -
4 .41,.34,.14,.06,.04,.01 // PShrub
5 .41,.34,.14,.06,.04,.01 // UShrub
6 .55,.15,.10,.10,.05,.05 // Woods
7 .45,.15,.15,.10,.10,.05 // Forest
...
```

As shown, the TRHTFIL.PRM file is composed of groups of lines, with one group per vegetation type that has woody plants. Each line identifies the plant functional group it applies to, and then gives six values, representing the initial proportion of plants in each of the six age classes. In NCA-Savanna, some vegetation types have two lines, meaning that shrubs occur in that type (even if a very small amount). Some vegetation types have four lines, meaning both shrubs and trees occur in that type.





**Exercise:** Look at the file TRHTFIL.PRM in the “parms” directory.

**Method:** Use Windows Explorer to move to the \savanna\sites\ncs\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown. Savanna ignores anything on a line that is to the right of “//”, and the comments at the bottoms of files.

**Notes:** As mentioned at the top of TRHTFIL.PRM, rather than specifying proportions in each age class for each vegetation type, Savanna can use height maps. The grids in these maps (one for each woody plant type) contain mean height of the trees in that grid cell.

Note that these are initial conditions only. A simulation run of 30 to 45 years is made to stabilize the values.

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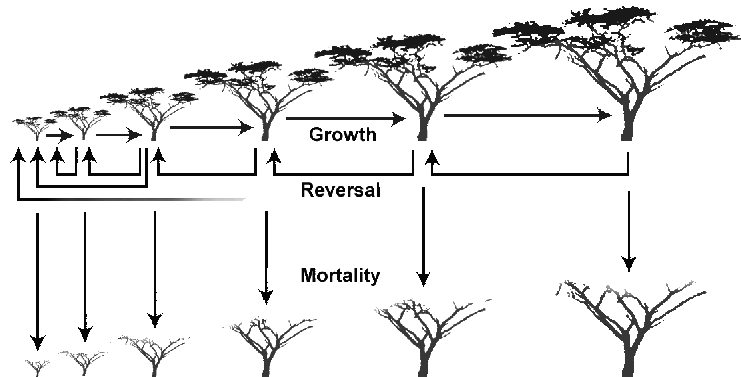
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## Woody Plant Growth

During a Savanna simulation, trees grow leaves, flowers, and seeds each week. Any left-over production is accumulated. At the end of each year, the excess production is allocated to stem and root biomass.

The amount of net primary production allocated to stems versus roots is determined by the size and shape of trees within *six size classes*. These size classes generally relate to seedlings, small trees or bushes, up to very large individuals.



Should a tree in a given size class exceed the upper size limit for that class, it is promoted to the next size class (unless it is in the largest size class). If biomass is removed from trees, either through herbivory or a disturbance like fire, the average size class of trees may move from a larger size class to a smaller size class. Finally, during each weekly time step, some portion of the trees in each size class may die.



**Exercise:** Look at the POPWOODS.PRM parameter file in the “parms” directory.

**Method:** Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown. The lines with six sets of values correspond to values describing the size and shape of plants in the six size classes.

**Notes:** Age classes may seem to be a more intuitive way of modeling growth in trees, but size classes work better. Both very old and relatively young plants could be the same size, if they are going on substrates with different nutrient levels. Also, when a disturbance occurs, such as a fire or herbivory, damaged trees can be assigned to a smaller size class, denoting a loss of biomass.

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## Decomposition and Nitrogen Mineralization in Savanna

Savanna uses a simple decomposition and nitrogen mineralization submodel. Models over longer time periods must simulate changes in active soil organic matter that vary over long time periods. In contrast, Savanna treats these organic matter pools as if in steady-state over the model period.

In Savanna, when leaves on plants die, they may stay on the plant for some period of time, then drop to the ground. The model partitions vegetation litter into two pools, one resistant to decomposition called the structural pool (that is, structural parts of plants that are difficult to breakdown), and one more easily decomposed called the metabolic pool. The ratio of lignin to nitrogen for a given plant part determines if it is structural or metabolic.

Decomposition and the mineralization of nitrogen are controlled primarily by values set in DECOMP.PRM:

### Decomp.prm

```
45.          //tmaxd    - Maximum temperature
35.          //toptd    - Optimum temperature
.2           //thsr     - Shape of temperatur
2.63        //tshl     - Shape fo temperatur
10.         //dec1     - Decomposition rate
30.         //dec2     - Decomposition rate
20.         //dec3     - Decomposition rate
2.,.2.      //decinvrt - Decomposition rate
.1          //microbnc - N:C of microbes - c
30.         //arain    - Annual precip (cm)
.02, .0012  //fligabv  - Parameters for regr
.26, -.0015 //fligblg  - Parameters for regr
.4          //fbrlig   - Fine branch lignin
.4          //cbrlig   - Coarse branch ligni
.4          //crtlig   - Coarse root lignin
150.       //rcestr(1) - Ratio of C to N of
.5          //fecesfr  - Fraction of N to fe
.25        //feclig   - Feces lignin conten
.2         //urinevol  - Fraction of urine v
.05        //vlossg   - Fraction of gross N
.21,0.00028 //pptnfxa(1) and (2) - Parameter
0.,.0.     //pptnfxs(1) and (2) - Parameter
0          //iplantfx  - 1-symbiotic N fixat
1         //inlossgn  - Switch to 1-model N
-999      //End marker (added)
```



Decomposition and mineralization in Savanna are affected, in part, by water availability within the first two soil layers, the soil temperature, and the lignin content of plant parts, as shown in DECOMP.PRM. Savanna also models the fate of nitrogen in high detail, partitioning nitrogen that: is volatilized, is fixed by plants, lost in drainage, and volatilized as part of animal wastes.

**Exercise:** Look at the DECOMP.PRM file in the “parms” directory.

**Method:** Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown.

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