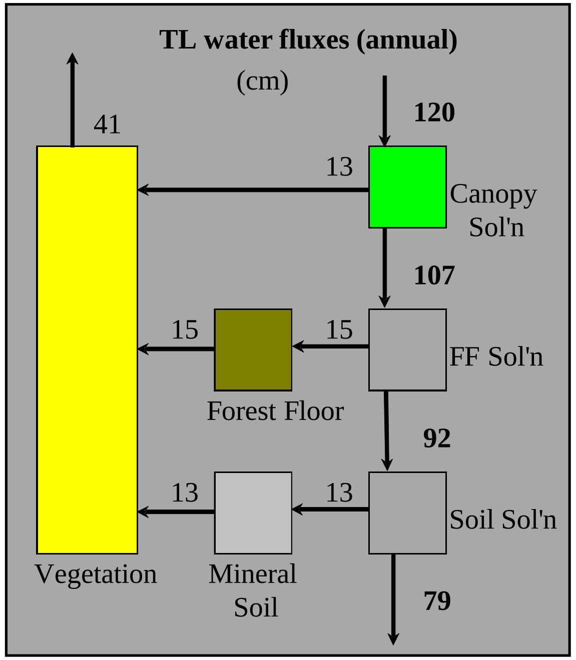
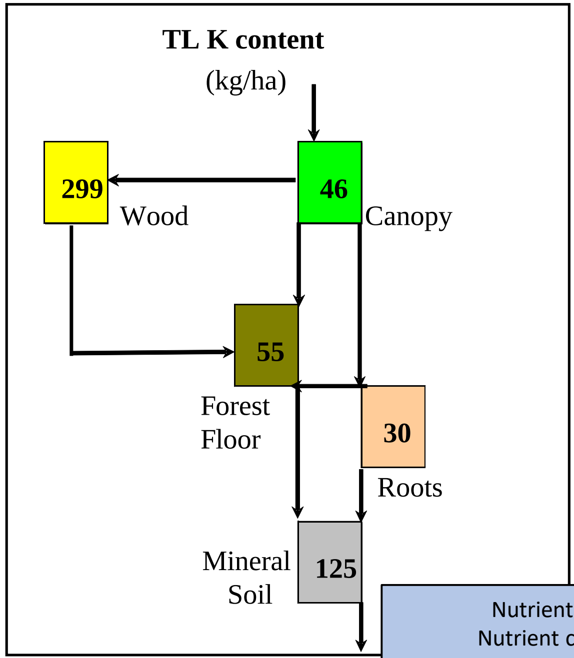
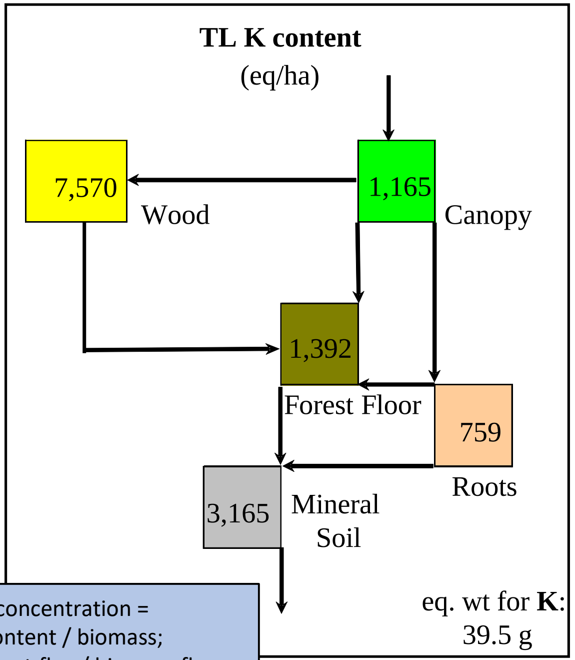
For3456/3457, Lecture 9. Forested watershed biomass and nutrient dynamics. Part 1: steady state quantification example for a tolerant hardwood site

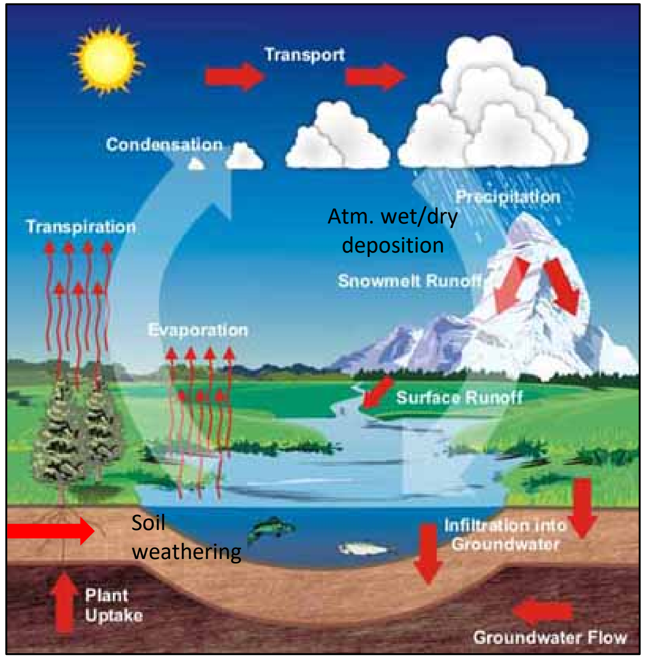
As it rains and snows, watersheds not only receive water, but also receive nutrients and other materials through atmospheric deposition. The quantities so received are important to overall watershed viability in general, and forest growth sustainability in particular. Through modelling, we are able to estimate quantities and fluxes of materials so received, retained and lost in a realistic manner. The information on the right for K cycling in a tolerant hardwood stand near Turkey Lakes, Ontario was obtained through diligent field sampling, done as part of an International Forest Study (IFS). This study collected data about forest biomass and nutrient contents and fluxes for 17 mature forest sites across North America, including one site in Norway. Other nutrients involved N, S, Ca, Mg, P. For your STELLA biomass and nutrient cycling modelling exercise, choose one IFS site and one nutrient.

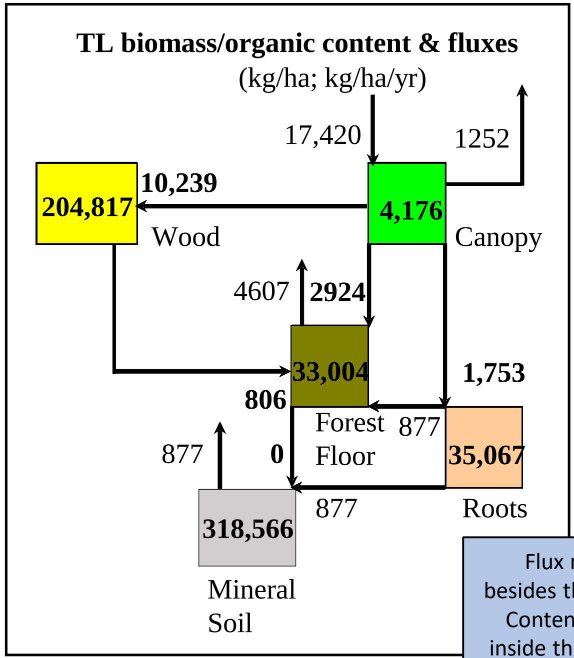




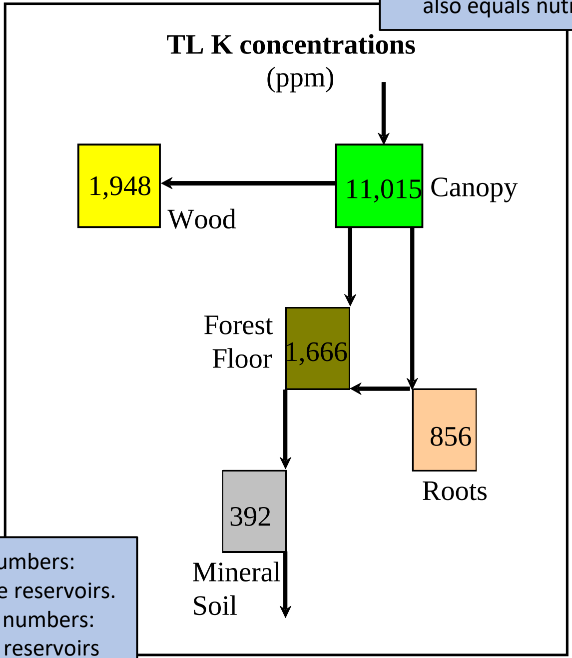


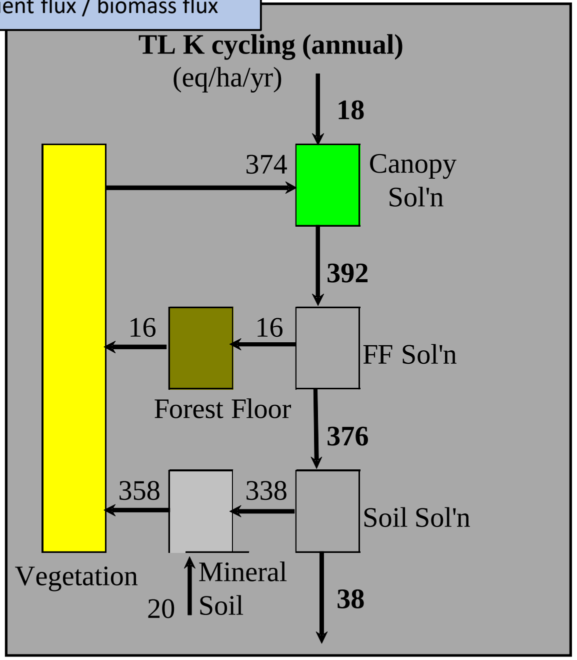
Nutrient concentration =
Nutrient content / biomass;
also equals nutrient flux / biomass flux





Flux numbers:
besides the reservoirs.
Content numbers:
inside the reservoirs



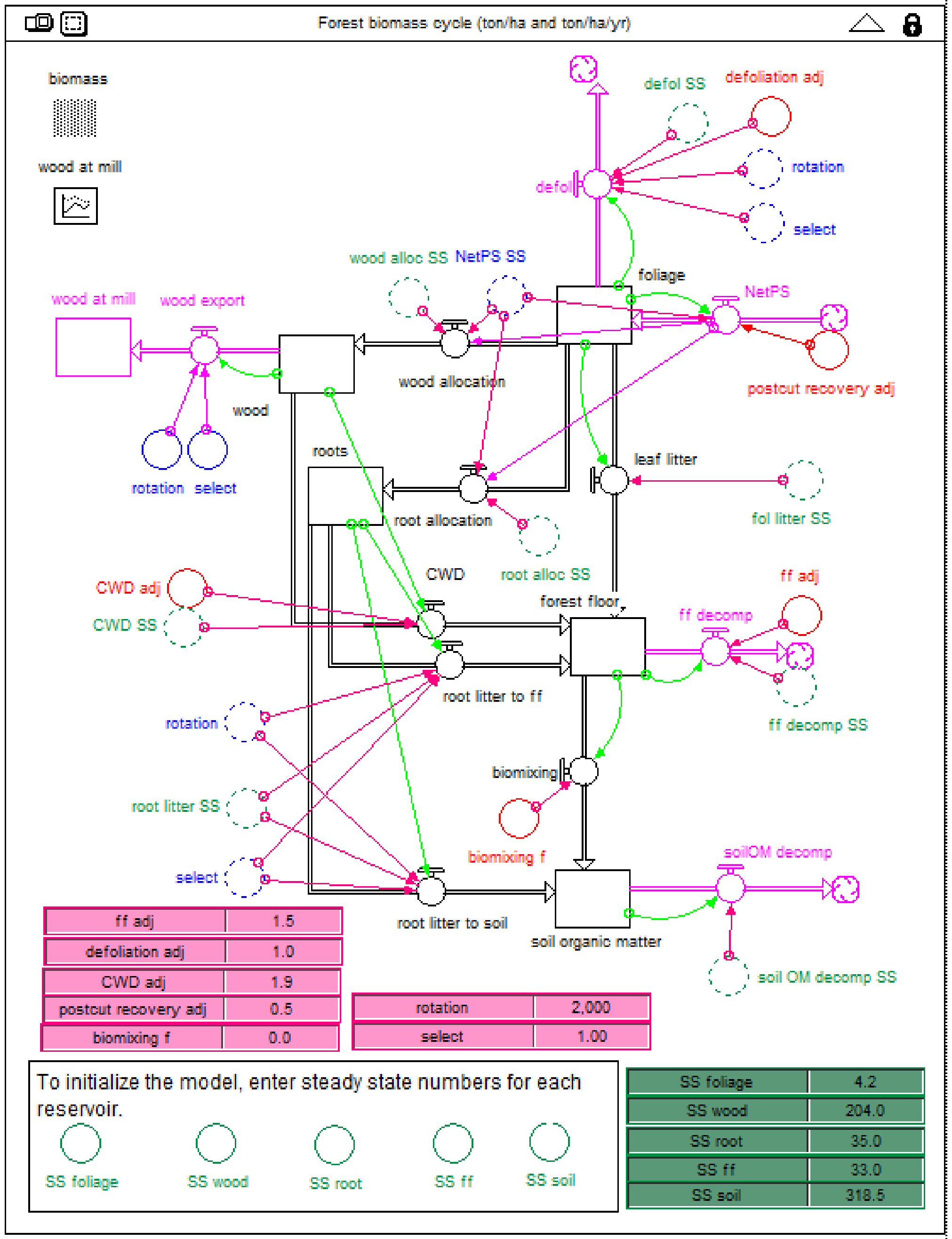


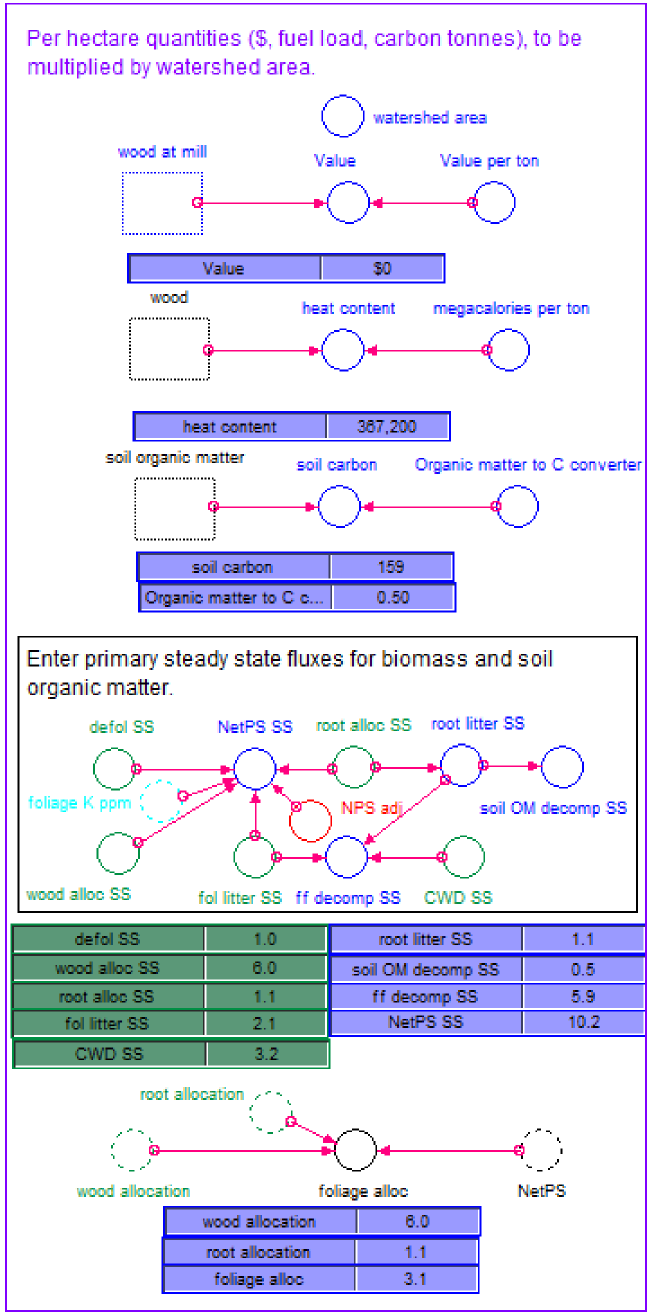
For3456/3457, Lecture 10: Forested watershed biomass dynamics.

The STELLA flowchart on the right quantities forest watershed biomass by way of five compartments: foliage, wood, coarse woody debris, roots, forest floor, and mineral soil. **The primary input** for biomass production per year is the net photosynthate production (netPS). **Primary outputs** refer to defoliation, wood harvesting, forest litter decomposition and soil organic matter (OM) decomposition. The biomass compartments are interconnected through wood and root allocation, leaf litter and coarse woody debris contributions to the forest floor (ff), root litter contributions to the mineral soil OM, and biomixing. At steady state, biomass or OM content of each reservoir do not change overtime. The numbers in the green boxes, pertinent to a particular IFS location, refer to the empirically determined steady-state numbers (SS) for: (1) each of the five reservoirs, and (2) netPS allocations to wood, root and leaf litter production, and defoliation. The remaining steady-state fluxes are automatically inferred from the steady-state condition.

The SS numbers supplied for the fluxes from the IFS forest sites may not completely represent steady state. It is therefore necessary to adjust some of the fluxes, as per the red boxes. Clicking on the "biomass" box will reveal whether or not all the reservoirs remain steady over time. If not, the numbers associated with the red boxes need to be adjusted.

The dynamic component of the STELLA model is realized when part or all of the forest accumulated wood is to be harvested. This can be set to occur at 20 years after time = 0. By setting the **rotation** length (time to re-harvesting) to 200 years or more and running the model reveals how fast the biomass reservoirs including soil OM recover from the harvesting operation. The rate of which this occurs can be adjusted through the **post-cut-recovery adjustor**. The **select** button can be used to modify the harvest intensity from clearcutting (1) to none (0). The rotation length can by set to any value, such as 40 or 50 years, which is now the time required for growing high-quality saw logs. From a general perspective, the model allows estimating watershed-wide values pertaining to wood harvested (wood at the mill), heat stored in wood, and carbon amount in each reservoir, including carbon associated with soil OM.





For3456/3457, Lecture 11: Forested watershed biomass dynamics.

Once the STELLA model for forest biomass is calibrated for the steady-state condition, one can then explore whether or not this model is **nutrient sustainable**. This can be done for any particular nutrient, as illustrated here for potassium (**K**). Again, referring to the IFS data, one obtains the kg/ha amounts for K in each of the 5 reservoirs. These are used to determine the K concentrations in each of the reservoirs (green buttons). Next, one obtains the K flux numbers for atmospheric deposition, and for the leaching losses from the forest floor and the mineral soil, in kg/ha/yr (above the green boxes on the immediate right bottom). **Primary inputs** into the K cycle refer to atmospheric deposition and soil weathering. **Primary outputs** refer to the leaching losses from the soil, the K exported by way of harvesting, and defoliation. Some of the insect species that feed on the foliage carry some of the nutrient away from the site through long-distance travel.

The next task is to ensure that the K cycle is not only at steady state for the first 20 years, but returns to the same steady-state values over the long run after cutting at time 20. This can be done by adjusting (calibrating) the **soil weathering** and **ff K leach** adjustors(red circles and buttons) so that forest floor K and mineral soil K remain at steady state, at least initially.

To provide the greater context re. forest biomass sustainability, the model introduces two additional adjustors:

(1) The **K uptake adjustor** (far right, bottom) can be change between 0 and 1 to determine how nutrient uptake is affected as the overall availability of soil K (available soil K reservoirs) decreases. Setting this adjustor to 0 means the nutrient uptake is not affected by decreasing available soil K. Setting it equal to 1 means that K uptake decreases in proportion with available soil K.

(2) With reduced K uptake, K content and concentrations in the foliage reservoir decrease. This generally produces to loss in photosynthetic productivity. The **NPS adjustor** (also far right, bottom) serves to explore this sensitivity. In detail, setting this adjustor to 0 implies no sensitivity, i.e. no change in netPS or biomass production. Setting this adjustor to 1 means that netPS decreases in proportion to the drop of foliage K ppm from its steady-state value. As a result, the biomass allocations to all of the five biomass and OM reservoirs decrease accordingly. The original steady state can therefore no longer be achieved.

The dynamics of this can be further explored by setting the adjustors to any value between 0 and 1, and changing the length of rotation and the proportion of the watershed to be harvested.