Organic carbon

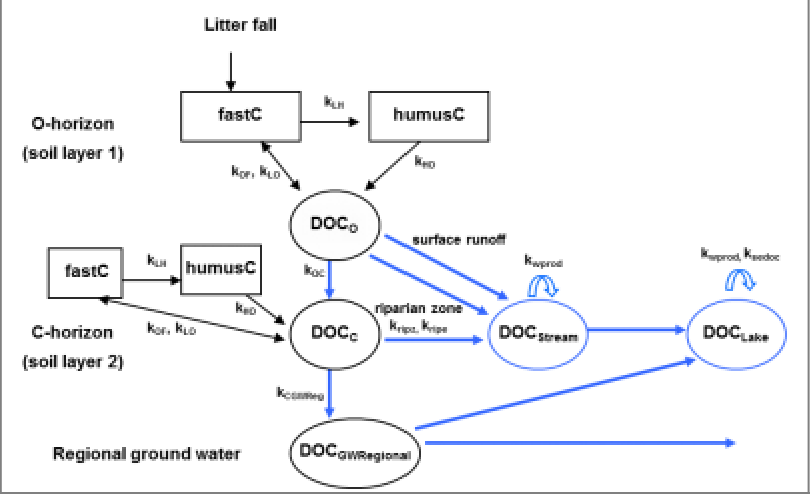

Figure 1: Schematic figure of the TOC-model.

Source of organic material

Litter fall in the form of plant residues add organic material to HYPE. It increases the levels of *fastC* in top two layers in soil. The organic carbon addition by litter fall is defined based on crop. Input, *resc* (*kg/ha/yr*), gives a daily supplement to the pool during the number of days determined by parameter *litterdays*.

Links to relevant procedures in the code

Modules (file)	Procedures
npc_soil_processes (npc_soil_proc.f90)	soil_carbon_processes

Soil processes

Soil pool initial values

The initial size of organic carbon pools in the soil is dependent on land use and determined by the user. The parameters (*humusc1, humusc2, humusc3, fastc1, fastc2, fastc3*) give OC content of the three soil layers. The unit for these parameter values is *mg/m3*. With this information, the pools the size in the different layers are calculated. The model transforms pools into the unit *kg/km2* by taking into account the thickness in the layers.

Common functions

Many soil processes depend on temperature and soil moisture. They use the same common functions as nitrogen and phosphorus. Organic carbon soil transformations (production of humusC from fastC, turnover of fastC and turnover of humusC) use the soil moisture function with parameters given by the user instead of the coefficients described for nutrients. The coefficient θ_{low} is replaced by the land-use dependent parameter *ocsoilslp*, and the coefficient *satact* is replaced by land-use dependent parameter *ocsoilsat*.

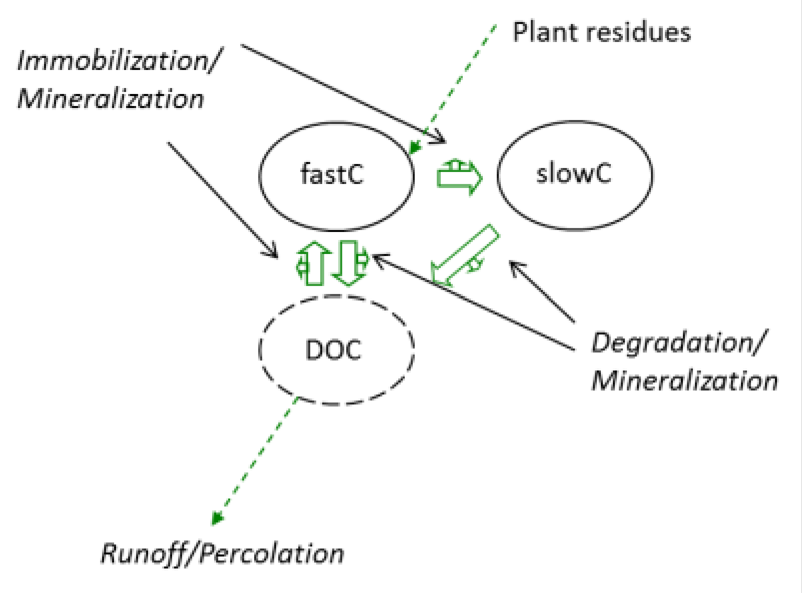

Figure 2: Organic carbon processes in soil.

Production of humusC from fastC

Some of the litter fall is converted into humus. For HYPE this means that fastC (the pool where litter fall was added) is transformed to humusC in the uppermost soil layer. In Figure 2 the pool of humusC is denoted slowC because of its slower transformation rates.

The other soil layers (*k*) also have a transition from fastC to humusC. The loss of fastC does not all end up in the humusC pool, but a proportion (parameter *minc*) is mineralized in the process. The transformation (*fasttohumus, mg/m2/d*) depends on soil moisture (*smfcn*) and temperature (*tmpfcn*), amount of Oc in the pool (*fastC*) and a vegetation dependent parameter *klh*.

$$fasttohumus\left(k\right)=klh\times tmpfcn\left(k\right)\times smfcn\left(k\right)\times fastC\left(k\right)$$

Turnover of fastC

Turnover of fastC is a sink for fastC and a source of dissolved OC in soil water in all soil layers (*k* = 1-3). The loss of fastC does not all go to the OC, but a proportion (parameter *minc*) is mineralized. Turnover (*transfC*, *mg/m2/d*) depends on a general parameter (*klo*), the temperature function (*tempfcn*), humidity function (*smfcn*) and the pool of fastC (*fastC*).

$$transfC\left(k\right)=klo\times tempfcn\left(k\right)\times smfcn\left(k\right)\times fastC\left(k\right)$$

In dry conditions a transfer in the opposite direction can also occur. The transformation of OC to fastC is a decrease of OC and a source of fastC in all soil layers (*k* = 1-3). The loss of OC is not all to fastC but a proportion (parameter *minc*) is mineralized. Turnover (*doctofast*, mg/m2/d) depends on a general parameter (*kof*) and the pool of OC (*OCpool*). The transfer is limited that the soil layer temperature must be less than 5 °C, the soil moisture (*sm*) must be less than field capacity and moisture function (*smfcn*) must be less than the parameter *koflim*.

$$doctofast(k) = kof \times OCpool(k)$$

Turnover of humusC

Turnover of humusC is a sink for humusC and a source of OC in all soil layers (k = 1.3). The turnover rate of humusC is lower than that of fastC, why it is also called slowC (e.g. in Figure 2). The loss of humusC does not all go to the DOC, but a proportion (parameter *minc*) is mineralized. Turnover (*transhC*, *mg/m2/d*) depends on a general parameter (*kho*), temperature function (*tempfcn*), humidity function (*smfcn*) and the pool of humusC (*humusC*).

$$transhC(k) = kho \times tempfcn(k) \times smfcn(k) \times humusC(k)$$

Percolation

Organic carbon is lost from the soil water as it flows down through the soil layers and where it is dissipated to become a regional groundwater flow. The decrease in concentration depends on soil moisture and temperature and a calibration parameter.

$$conc = conc \times \left(1 - par \times tmpfcn \times smfcn\right)$$

The soil moisture function and temperature function are the general functions described for soil processes. Percolation uses the nutrient coefficients for the soil moisture function, not the parameters that the OC transformations uses. The parameter, *par* in the equation, is *kcgwreg* for regional groundwater flow formation and *koc* for percolation between soil layers. Both are general parameters.

Links to relevant procedures in the code

Modules (file)	Procedures	Section
npc_soil_processes (npc_soil_proc.f90)	initiate_soil_npc	initial values
	soil_carbon_processes	production of humusC from fastC, turnover
	soil_carbon_pool_transformations	
	doc_percolation_reduction	percolation

Riparian zone

Runoff from soil may flows through a riparian zone before it reaches the local river. Surface runoff and drainage water from drainage pipes reaches the local river without passing through the riparian zone. In the riparian zone the levels of OC are affected, while flows remain unchanged. The change depends on soil temperature, class altitude (*elev* (in masl)), the water table (*gwat*) and its recent change, season and soil moisture (*sm*). The runoff concentration (*conc(i)*) of each soillayer (*k*) increases with the factor:

$$f(k) = 1 + ripz \times tmpfcn(k) \times \left(\frac{elev}{100}\right) \times f_{grw} \times f_{season} \times f_{sm}$$

$$conc\left(k\right)=f\times conc\left(k\right),\quad k=1..3$$

The temperature function (*tmpfcn*) is the usual of soil processes (see above). The following equations describe the other process functions:

$$f_{grw}=e^{ripe\times gwat}$$

$$f_{season}=\begin{cases} rips & autumn \\ 1 & otherwise \end{cases}$$

$$f_{sm}=\begin{cases} 0 & sm\leqslant wp \\ f_2\left(sm\right) & wp<sm<pw \\ satact & sm\geqslant pw \end{cases}$$

$$f_2\left(sm\right)=\begin{cases} \min\left(1,satact+\dfrac{\left(1-satact\right)\times pw-sm}{d\times\Theta_{upp}},\dfrac{sm-wp}{d\times\Theta_{low}}\right) & rising\,grw \\ \min\left(1,satact+\dfrac{\left(1-satact\right)\times pw-sm}{d\times\Theta_{upp}},\dfrac{satact\times sm-wp}{d\times\Theta_{low}}\right) & sinking\,grw \end{cases}$$

The activation of riparian zone processes is based on land use. It is primarily though to act on forest runoff. The land use dependent parameter *ripz* determines the overall level of increase in concentration in the riparian zone, and if set to zero no riparian zone processes are used. In addition two general parameters can influence the effect of the riparian processes; *ripe* which determines the groundwater level dependence, and *rips* which determines the seasonal influence. Season division is determined by ten-day and twenty-day averages of air temperature (T10, T20). Autumn is defined as the period when T10 is less than T20. The soil moisture function is different for an increasing (rising) and sinking ground water table (figure 2). It contains coefficients $\Theta_{upp}=0.12$, $\Theta_{low}=0.08$ and saturation (*satact* = 0.6). It depends on the soil moisture of all layers together (*sm*) and the water-holding capacity parameters; *wp* - wilting border and *pw* - total pore volume, in fractions of total soil layer thickness (*d*).

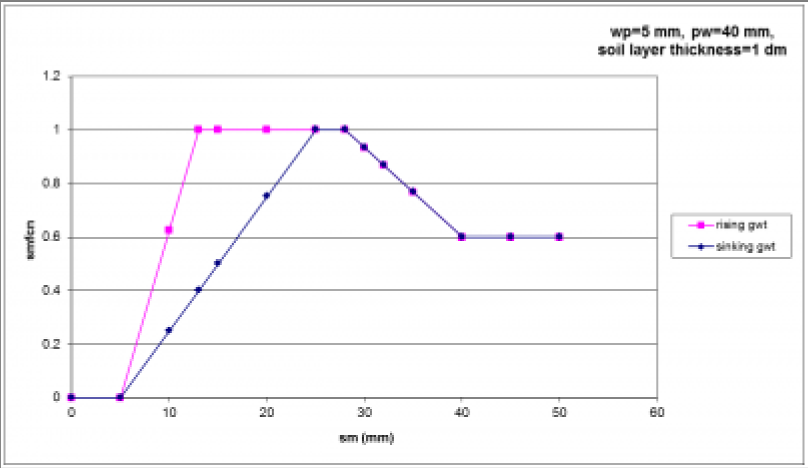

Figure 2: Example of riparian zone soil moisture function, and the dependence on changes in the groundwater levels.

Links to relevant procedures in the code

Modules (file)	Procedures
npc_soil_processes (npc_soil_proc.f90)	class_riparian_zone_processes
	riparian_moisture_factor

Rivers and lakes

Primary production and mineralization

Primary production is a source of organic carbon in rivers and lakes, while mineralization is a sink. Primary production and mineralization is calculated the same way as for nitrogen, but with its own calibration parameter (*wprodc*). The equations are repeated below. The production/mineralization depend on temperature and total phosphorus and lake area (*area*). The potential carbon transformation (*minprodCpot*, kg / day) is proportional to the potential nitrogen transformation (*minprodNpot*, see also NP section) with a transformation rate that depends on the carbon-nitrogen ratio (*NCratio* = 5.7). The calculated mineralization of organic carbon is limited to a maximum of 50% of the available OC pool. If phosphorus is not modelled a long-term average total phosphorus concentration as a lake region dependent parameter (*tpmean*) is used. If set, the long-term average concentration is reduced by the general parameter *limsedPP* before using it in the concentration function thus reducing the production/mineralisation of OC.

$$tmpfcn1 = \frac{watertemp}{20.}$$

$$tmpfcn2 = \frac{\left(T10 - T20\right)}{5.}$$

$$tmpfcn = tmpfcn1 \times tmpfcn2$$

$$TPfcn = \frac{\left(TPconc - limsedPP\right)}{\left(TPconc - limsedPP + halfsatTPwater\right)}$$

$$minprodNpot = wprodc \times TPfcn \times tmpfcn \times area$$

$$minprodCpot = minprodNpot \times NCratio$$

Sedimentation

Sedimentation in lakes is a sink for OC and works the same way as for organic nitrogen and particulate phosphorus. Sedimentation (*sedOC*, *kg/day*) is calculated as a function of OC concentration in lake water (*conc*)) and lake area (*area*). The settling velocity parameter *sedoc* is general or can be specified for each lake.

$$sedOC = sedoc \times conc \times area$$

Links to relevant procedures in the code

Modules (file)	Procedures	Sections
npc_surfacewater_processes (npc_sw_proc.f90)	oc_processes_in_river	primary production and mineralization
	oc_production_mineralisation	
	calculate_lake_tpmean	
	calculate_river_tpmean	
	oc_processes_in_lake	primary production and mineralization
		sedimentation
	oc_sedimentation	sedimentation

Links to file reference

Section	Symbol	Parameter/Data	File
Sources of organic material		*resc*	CropData.txt
		litterdays	par.txt
Soil processes		*humusc1, humusc2, humusc3, fastc1, fastc2, fastc3, koflim*	par.txt
	θ_{low}	*ocsoilslp* or 0.08	
	satact	*ocsoilsat* or 0.6	
	minc, klh, klo, kof, kho	*minc, klh, klo, kof, kho*	
	par	*kcgwreg* or *koc*	
Riparian zone	*elev*	calculated from *mean_elev* and *dhslc_nn*	GeoData.txt
	ripz, ripe, rips	*ripz, ripe, rips*	par.txt
	wp	calculated from *wcwp*, *wcwp1*, *wcwp2*, *wcwp3*	
	pw	calculated from *wcwp*, *wcwp1-wcwp3*, *wcfc*, *wcfc1-wcfc3*, *wcep*, *wcep1-wcep3*	
	d		GeoClass.txt

Section	Symbol	Parameter/Data	File
Rivers and lakes	*area*		GeoData.txt
	wprodc, *limsedpp*, *sedoc*	*wprodc*, *limsedpp*, *sedoc*	par.txt
		tpmean	
	halfsatTPwater	*hsatTP*	