The On-farm fertilisation plan algorithm subroutines

Subroutine Pedotransfer

This subrutine develops some specific soil parameters using the pedotransfer functions and pedotransfer rules. The soil parameters will be used in modelling the nitrates cycle in soil.
The parameterisation procedure was used and the soil water retention curves were fitted by the well known van Genuchten's equation:

$$\theta_e(h) = \theta_r \cdot \frac{\theta_s - \theta_r}{(1+(\alpha \cdot h)^n)^{1-\frac{1}{n}}} \qquad h < 0$$

where:
θ_e (h) – effective soil water content as a function of pressure head

$$\theta_e\,(h) = \frac{\theta - \theta_s}{\theta_s - \theta_r}$$

θ_s – saturated soil water content – parameter (m^3/m^3)
θ_r – residual soil water content – parameter (m^3/m^3)
θ – actual soil water content (m^3/m^3)
α, n – empirical parameters

The computer code RETC (van Genuchten et al. 1991) was employed in order to optimise θr , θs , α, n parameters.

INPUT DATA
For a georeferenced soil profile

org_mat – Soil organic matter content (%)
BD – Bulk density (g/cm^3)
Clay – clay content (%)
Silt – silt (%)
topsoil = 1

```
if (org_mat < 5)
   dens = 2.64
else
   dens = 2.4
```

where dens – Soil dry bulk density (g/cm^3)

$$\alpha 1 = -14.96 + 0.03135 \cdot Clay + 0.0351 \cdot Silt + 0.646 \cdot \text{org_mat} + 15.29 \cdot BD - 0.192 \cdot topsoil - 4.671 \cdot BD^2 - 0.000781 \cdot Clay^2 - 0.00687 \cdot \text{org_mat}^2 + 0.0449 \cdot \text{org_mat}^{-1} + 0.0663 \cdot Log(Silt) + 0.1482 \cdot Log(\text{org_mat}) - 0.04546 \cdot BD \cdot Silt - 0.4852 \cdot BD \cdot \text{org_mat} + 0.00673 \cdot topsoil \cdot Clay$$

$$\alpha = e^{\alpha 1}$$

$$n = -25.23 - 0.02195 \cdot Clay + 0.0074 \cdot Silt - 0.194 \cdot \text{org_mat} + 45.5 \cdot BD - 7.24 \cdot BD^2 + 0.0003658 \cdot Clay^2 + 0.002885 \cdot \text{org_mat}^2 - 12.81 \cdot \frac{1}{BD} - 0.1524 \cdot \frac{1}{Silt} - 0.01958 \cdot \frac{1}{\text{org_mat}} - 0.2876 \cdot Log(Silt) - 0.0709 \cdot Log(\text{org_mat}) - 44.6 \cdot Log(BD) - 0.02264 \cdot BD \cdot Clay + 0.0896 \cdot BD \cdot \text{org_mat} + 0.00718 \cdot topsoil \cdot Clay$$

$$nvg = 1 + e^n$$

$$\theta_s = \frac{1 - \frac{BD}{dens}}{BD}$$

$$m = 1 - \frac{1}{nvg}$$

$$mvg = m$$

$$\psi_{infl} = \frac{\left(\frac{1}{m}\right)^{\frac{1}{nvg}}}{\alpha}$$

$$\theta_{infl} = \theta_s \cdot \left(1 + \frac{1}{m}\right)^{-m} \quad \text{w/w}$$

$$S = nvg \cdot \theta_s \cdot \left(\frac{2 \cdot nvg - 1}{nvg - 1}\right)^{\frac{1}{nvg-2}}$$

$$K_{infl} = \frac{10^{\left(-1.52+0.91 \cdot \left(\log\left(\frac{S}{\Psi_{infl}}\right)^2\right)\right)}}{\log(10)}$$

$$K_{infl} = K_{infl} \cdot 100 \cdot 86400 \ \text{(cm/zi)}$$

$$l_K1 = 0.0202 + 0.0006193 \cdot Clay^2 - 0.001136 \cdot org_mat^2 - 0.2316 \cdot log(org_mat) - 0.03544 \cdot BD \cdot Clay + 0.00283 \cdot BD \cdot Silt + 0.0488 \cdot BD \cdot org_mat$$

$$l_K = \frac{1 - e^{l_K1}}{1 + e^{l_K1}}$$

$$\Psi = \Psi_{infl}$$

$$R_\Psi_{infl} = \frac{((1 + (\alpha \cdot \Psi)^{nvg})^m - (\alpha \cdot \Psi)^{nvg-1})^2}{(1 + (\alpha \cdot \Psi)^{nvg})^{2 \cdot m}}$$

$$\Psi = 1$$

$$R_\Psi = \frac{\left((1 + (\alpha \cdot \Psi)^{nvg})^m - (\alpha \cdot \Psi)^{(nvg-1)}\right)^2}{(1 + (\alpha \cdot \Psi)^{nvg})^{2 \cdot m}}$$

$$K_{sat} = K_{infl} \cdot \frac{\frac{R_\Psi}{R_\Psi_{\text{infl}}}}{\log(10)}$$

$$\theta_{work_optim} = \theta_s * (1 + \frac{1}{mvg})^{-mvg}$$

$$\Psi_{work_optim} = \frac{1}{\alpha} \cdot \left(\left(\frac{\theta_{work_optim}}{\theta_s} \right)^{\frac{-1}{mvg}} - 1 \right)^{\frac{1}{nvg}}$$

$$\theta_{work_wet} = \theta_{work_optim} + 0.4 \cdot (\theta_s - \theta_{work_optim})$$

$$\Psi_{work_wet} = \frac{1}{\alpha} \cdot \left(\left(\frac{\theta_{work_wet}}{\theta_s} \right)^{\frac{-1}{mvg}} - 1 \right)^{\frac{1}{nvg}}$$

$$\Psi_{work_dry} = 10^{\frac{\log(\Psi_{work_optim})}{\log(10)} + 1.2 \cdot \frac{\log(nvg)}{\log(10)}}$$

$$\theta_{work_dry} = \theta_s \cdot \left(\frac{1}{1 + (\alpha \cdot \Psi_{work_dry})^{nvg}} \right)^{1 - \frac{1}{nvg}}$$

$$\theta_{field_cap} = \frac{\theta_{work_dry} + \theta_{work_wet}}{2}$$

$$\Psi_{field_cap} = \frac{1}{\alpha} \cdot \left(\left(\frac{\theta_{field_cap}}{\theta_s} \right)^{\frac{-1}{mvg}} - 1 \right)^{\frac{1}{nvg}}$$

$$\theta_{wilting} = \theta_s \cdot \left(\frac{1}{1 + (\alpha \cdot 10^{4.2})^{nvg}} \right)^{1 - \frac{1}{nvg}}$$

$$\theta_{acc} = (\theta_{\text{infl}} - \theta_{wilting}) \cdot BD$$

$$\theta_{drain} = (\theta_s - \theta_{\text{infl}}) \cdot BD$$

θ_s – saturated soil water content – parameter (m^3/m^3)
θ_r– residual soil water content – parameter (m^3/m^3)
θ – actual soil water content (m^3/m^3)

Therefore, the outputs of this subroutine are as follows:

Parameter symbol	Parameter name used in next subroutines	M.U.	Item name
α	alpha	1/cm	empirical parameter, related to the inverse of the air entry suction
nvg	nvg	nvg>1	empirical parameter, a measure of the

			pore-size distribution,
θs	theta_s	g/g	saturated soil water content
ψ_{infl}	Psiinfl	cm	Suction pressure at inflection point
θ_{infl}	thetainfl	g/g	Soil water content at inflection point
S	S		S factor
K_{infl}	Kinfl	cm/day	Hydraulic conductivity at the inflection point
K_{sat}	Ksat	cm/day	Saturated hydraulic conductivity
Ψ_{work_wet}	pfwork_wet	cm	Suction pressure at higher water content of workability
θ_{work_wet}	w_work_wet	g/g	Soil water content at higher level of workability range
Ψ_{work_optim}	pfwork	cm	Suction pressure at optimum water content for workability
θ_{work_optim}	w_work	g/g	Soil water content at optimum level of workability range
Ψ_{work_dry}	pfwork_dry	cm	Suction pressure at lower water content for workability
θ_{work_dry}	w_work_dry	g/g	Soil water content at lower level of workability range
Ψ_{field_cap}	pfcc1	cm	Suction pressure at field capacity
θ_{field_cap}	icc	g/g	Soil water content at field capacity
$\theta_{wilting}$	CO	g/g	Soil water content at wilting
θ_{acc}	Wacc	cm^3/cm^3	Available water content
θ_{drain}	Wdrain	cm^3/cm^3	Drainable water content

In order to simplify the next equations, the usual notation is chenged according the table,

Subroutine Thornthwaite_Calc

This subroutine aims to calculate PET and AET values using Thornthwaite method for an average year, computed using a large number of years.

Input data:

1. climatic data
2. soil data

1. Climatic data for each month i, each year j

Rain(i, year) – Monthly precipitation amount for month i, year year (i <= 12, year <= nr_years) (cm/month)

Temp(i, year) – Monthly average temperature for month i, year year (i <= 12, year <= nr_years) (°C)

2. Soil data

Lroot – root depth (cm)

BD(g/cm^3)

The output data from Pedotransfer subrutine

alpha

nvg

theta_s

pfcc1

pffc = 0.434295 · Log(pfcc1)

CO

Wacc

Wdrain

The following average multiannual monthly parameters are computed for each month: Temp_m(i) and Rain_m(i)

For i = 1 to 12

$$Temp_m(i) = \frac{1}{nr_years} \cdot \sum_{year=1}^{nr_years} Temp(i, year)$$

$$Rain_m(i) = \frac{1}{nr_years} \cdot \sum_{year=1}^{nr_years} Rain(i, year)$$

The next step: the annual heat index Ithn_m(i)

For i = 1 to 12

if $(Temp_m(i) > 0)$

$$Ithn_m\,(i) = \left(\frac{Temp_m(i)}{5}\right)^{1.514}$$

else

$$Ithn_m\,(i) = 0$$

Using these data, athn – the function of the annual heat index (athn) and multiannual monthly average values of Potential Evapotranspiration (ETP_m) for each month is computed

For i = 1 to 12

$$athn = 0.000000675 \cdot \sum_{i=1}^{12}(Ithn_m(i))^3 - 0.0000771 \cdot \sum_{i=1}^{12}(Ithn_m(i))^2 + 0.0179 \cdot * \sum_{i=1}^{12} Ithn_m(i) + 0.492$$

For i = 1 to 12

if $(Temp_m(i) > 0)$

$$ETP_m(i) = 0.533 \cdot \left(\frac{10 \cdot Temp_m(i)}{\sum_{i=1}^{12} Ithn_m(i)}\right)^{athn} \cdot 31$$

else

$$ETP_m(i) = 0$$

For i = 1 to 12

$$PPE_m(i) = Rain_m(i) - ETP_m(i)$$

$$mvg = 1 - \frac{1}{nvg}$$

$$availab = Wacc \cdot Lroot$$

$$drain = Wdrain \cdot Lroot$$

The water storage is initialised

$$storage(0) = availab$$

For each month,

For i = 1 to 12

if $(PPE_m(i) > 0)$

$$storage(i) = storage(i - 1) + PPE_m(i)$$

Else if $(storage(i) > drain + availab)$

$$storage(i) = drain + availab$$

Else if $(storage(i) < drain + availab)$

$$storage(i) = availab \cdot e^{\frac{PPE_m(i)}{availab} + Log\left(\frac{storage(i-1)}{availab}\right)}$$

'++++++++++ Soil water matric potential ++++++++++

For each month,

For i = 1 to 12

if $(storage(i) >= availab)$

$$ipf(i) = pffc$$

else

$$w = \frac{storage(i)}{Lroot} + CO \cdot BD$$

$$w = \frac{\text{w}}{\text{BD}}$$

if $(w > 0)$

if $(w <$ theta_s$)$

$$psi = \frac{\left(\frac{w - CO}{\text{theta_s} - CO}\right)^{\left(\frac{-1}{mvg}-1\right)^{\frac{1}{nvg}}}}{alpha}$$

$$ipf(i) = \frac{\log(psi)}{\log(10)}$$

else

$$ipf(i) = \frac{pffc}{2}$$

else

ipf(i) $= 4.2$

For each month,

For i = 1 to 12

x $= 2.7$

if (x $< pfcc$)

$x = pfcc$

else if (ipf(i) $<= x$)

$ae(i) = ETP_m(i)$

else

$$ae(i) = ETP_m(i) \cdot \frac{4.2 - ipf(i)}{4.2 - x}$$

For i = 1 to 12

if $(ETP_m(i) > 0)$

$$swf(i) = \frac{ae(i)}{ETP_m(i)}$$

else

$$swf(i) = 1$$

OUTPUT DATA

ipf(i) – pF values for each month

ae(i) – Actual evapotranspiration for each month

swf(i) – deeper soil water flux

Subroutine Drainage

It calculates the water amount lost by draining for each month, for all year, as well as by winter and spring drainage using soil hydrological charateristics calculated in the first subroutine, and the values of deeper soil water flux, actual and potential evapotransipration.

Input data:

alpha
nvg
Psiinfl
Kinfl
ipf(i) (i <= 12)
Rain_m(i) (i <= 12)

$$m = 1 - \frac{1}{nvg}$$

$$psi = Psiinfl$$

$$RPsiinfl = \frac{\left((1 + (alpha \cdot psi)^{nvg})^m - (alpha \cdot psi)^{(nvg-1)}\right)^2}{(1 + (alpha * psi)^{nvg})^{2 \cdot m}}$$

$$Qprec = 0$$

For each month,

For i = 1 to 12

$$ipf1(i) = 10^{ipf(i)}$$

$$R_Psi = \frac{(1 + (alpha \cdot ipf1(i)^{nvg})^m - ((alpha \cdot ipf1(i))^{nvg-1})^2}{(1 + (alpha \cdot ipf1(i))^{nvg})^{2 \cdot m}}$$

$$K(i) = Kinfl \cdot \frac{R_Psi}{\frac{R_Psiinfl}{Log(10)}}$$

$$Qprec = Qprec + Rain_m(i)$$

$$q = 0$$

For each month,

For i = 1 to 12

$$q = q + K(i) \cdot 30$$

$$Drainage = \frac{q}{Qprec} \cdot 0.75 \cdot 100$$

For each month,

For i = 1 to 12

$$dren(i) = \frac{30 \cdot K(i)}{Rain_m(i)} \cdot 75$$

$$winter_dren = \frac{dren(12) + dren(1) + dren(2) + dren(3)}{4}$$

$$spring_dren = \frac{dren(4) + dren(5) + dren(6) + dren(7)}{4}$$

OUTPUTS

dren(i) – values of water flux drained for each month
winter_dren – amount of water flux drained for 4 months: 12, 1, 2 and 3
spring_dren – amount of water flux drained for 4 months: 4, 5, 6 and 7
Drainage – for the entire year

Subroutine Mineralization_of_VegetaleResidues

Calculates the nitrogen mineralised from fresh organic pool and the rate of N imobilisation, based on precedent crop

Input data:

1. climatic data
2. soil data
3. crop data

1. Climatic data for each month i

Rain_m(i) – Multiannual average for Monthly precipitation amount for month i (i <= 12) (cm/month)
Temp_m(i) – Multiannual average for Monthly temperature for month i (i <= 12) (°C)
Itfgn (i)
swf(i)

2. Soil data

RDmax – agrochemical active depth (cm)
BD(g/cm^3)
The output data from Pedotransfer subrutine
alpha
nvg
theta_s
pfcc1
pffc = 0.434295 · Log(pfcc1)
CO
Wacc
Wdrain

3. *Crop data*

actualYield – the expected yield (t/ha)
precedentYield – the precedent yield (t/ha)
i_crop_actual – identifier for the actual crop
i_crop_precedent – identifier for the previous crop

i_crop	Crop	Crop (Romanian)
1	Winter wheat	Griu de toamna
2	Barley	Orz si orzoiaca
3	Maize	Porumb pentru boabe
4	Sugar beet	Sfecla de zahar
5	Potatoes	Cartofi
6	Sunflower	Floarea Soarelui
7	Rapeseed	Rapita de toamna
8	Flax for oil	In pentru ulei
9	Beans	Fasole
10	Peas	Mazare
11	Soya	Soia nemodificata genetic
12	Flax for clothes	In pentru fibre
13	Alfalfa	Lucerna
14	Clover	Trifoi

PC_rez – the percent of incorporated vegetal residues into the soil (%)
Incorporation_month – the month of incorporating the vegetal residues into the soil (<= 12)

' secondary yield

$$PrecedentYield_2 = coef(i_crop_precedent) \cdot precedentYield$$

$i_crop_precedent$	Crop	coef($i_crop_precedent$)
1	Winter wheat	1.3 / 2.3
2	Barley	1
3	Maize	1.6 / 2.6
4	Sugar beet	1
5	Potatoes	0.5 / 1.5
6	Sunflower	3 / 4
7	Rapeseed	3 / 4
8	Flax for oil	3 / 4
9	Beans	1.5 / 2.5
10	Peas	1.5 / 2.5
11	Soya	1.5 / 2.5
12	Flax for clothes	0
13	Alfalfa	0.2
14	Clover	0.2

' C:N from vegetal residues

$qwim = PrecedentYield_2 \cdot PC_rez \cdot coef2(i_precedent_crop)$
$C_N = C_N(i_crop_precedent)$ – from table

$coef2(i_precedent_crop)$– from table

$i_precedent_crop$	Crop	C_N	$coef2(i_precedent_crop)$
1	Winter wheat	110	10
2	Barley	110	10
3	Maize	70	8
4	Sugar beet	24	2
5	Potatoes	60	7
6	Sunflower	70	8
7	Rapeseed	130	10
8	Flax for oil	60	7
9	Beans	40	3
10	Peas	40	3
11	Soya	80	9
12	Flax for clothes	60	7
13	Alfalfa	28	3
14	Clover	28	3

$$FR_0 = PrecedentYield_2 \cdot 1000 \cdot PC_rez$$
$$FoN_0 = 0.58 \cdot \frac{FR_0}{C_N}$$

$$Nleg = precedentYield * coef_N2$$

i_crop_precedent	Coef_N2
1-8, 12	0
9	35
10	25
11	20
13	6
14	6

$$C_N1 = 20$$
$$FR_0rad = 0.1 \cdot PrecedentYield_2 \cdot 1000 \cdot PC_rez$$
$$FoN_0rad = 0.58 \cdot \frac{FR_0rad}{C_N1}$$

$$WNO3 = 3.5$$
$$WNO3 = WNO3 \cdot BD \cdot RDmax \cdot 0.1$$
$$FoN(Incorporation_month) = FoN_0 + Nleg + FoN_0rad$$
$$FR(Incorporation_month) = FR_0 + FR_0rad$$
$$CN_Residue = 0.58$$

For each month

For i = Incorporation_month + 1 to 12

-----MINERALIZATION

-------from the fresh organic pool (crop residue & microorganisms)

'SWAT Eq.:10.2.5

If $(FoN(i-1) + WNO3 > 0)$

$$cnr = CN_Residue \cdot \frac{FR(i-1)}{FoN(i-1) + WNO3}$$

Else

$cnr = 0$

If $(cnr < 0)$

$cnr = 0$

'SWAT Eq.: 10.2.8

$cnp = e^{\left(-0.693 \cdot \frac{cnr - 25}{25}\right)}$

If $(cnp > 1)$

$cnp = 1$

If $(cnp < 0)$

$cnp = 0$

--- carbohydrate-like material

If $(FR(i - 1) >= 0.8 \cdot FR_0)$

$rc = 0.8$

Rem cellulose Like material

If $((FR(i - 1) >= 0.1 \cdot FR_0)$ **AND** $(FR(i - 1) < (0.8 \cdot FR_0))$

$rc = 0.05$

Rem lignin

If $(FR(i - 1) < 0.1 \cdot FR_0)$

$rc = 0.0095$

Rem decay rate constant [EPIC 2.153] SWAT Eq.: 10.2.7

If $(swf(i) \cdot Itfgn(i) > 0)$

$dcr = cnp \cdot rc \cdot (swf(i) \cdot Itfgn(i))^{0.5}$

Else

$dcr = 0$

Rem N mineralization rate (kg/ha/day)

'SWAT Eq.10.2.9

$\mathrm{rmn(i)} = \mathrm{dcr} \cdot \mathrm{FoN(i-1)}$

If $(rmn(i) < 0)$

$rmn(i) = 0$

Rem.....IMMOBILIZATION

Rem N immobilization rate (kg/ha)

If $(FR(i - 1) > 0)$

$cnfr = \frac{FoN(i - 1)}{FR(i - 1)}$

$wim(i) = dcr \cdot FR(i - 1) \cdot (0.016 - cnfr)$

If $(wim(i) < 0)$

$wim(i,) = 0$

Else

$cnfr = 0$

$wim(i) = 0$

$idcr = dcr$

If $(wim(i) >= WNO3)$
  If $(FR(i-1) > 0)$
    $dcr = 0.95 \cdot \frac{WNO3}{FR(i-1) \cdot (0.016 - cnfr)}$
    $wim(i) = idcr \cdot FR(i-1) \cdot (0.016 - cnfr)$
    If $wim(i) < 0$
      $wim(i) = 0$
  Else
    $idcr = 0$
    $wim(i, year) = 0$

$FoN(i) = FoN(i-1) - rmn(i) \cdot 30 + wim(i) \cdot 30$
$FR(i) = FR(i-1) - idcr \cdot FR(i-1)$

Initialising
FoN(0) = FoN(12)
FR(0) = FR(12)
For each month
For i = 1 to Incorporation_month

Rem.....MINERALIZATION
Rem from the fresh organic pool (crop residue & microorganisms)
'SWAT Eq.:10.2.5

If $(FoN(i-1) + WNO3 > 0)$
  $cnr = CN_Residue \cdot \frac{FR(i-1)}{FoN(i-1) + WNO3}$
Else
  $cnr = 0$
If $(cnr < 0)$
  $cnr = 0$

'SWAT Eq.: 10.2.8

$cnp = e^{\left(-0.693 \cdot \frac{cnr - 25}{25}\right)}$
If $(cnp > 1)$
  $cnp = 1$
If $(cnp < 0)$
  $cnp = 0$

--- carbohydrate-like material
If $(FR(i-1) >= 0.8 \cdot FR_0)$
  $rc = 0.8$

Rem cellulose Like material
If $((FR(i-1) >= 0.1 \cdot FR_0)$ AND $(FR(i-1) < (0.8 \cdot FR_0))$

$rc = 0.05$

Rem lignin

If $(FR(i-1) < 0.1 \cdot FR_0)$

$rc = 0.0095$

Rem decay rate constant [EPIC 2.153] SWAT Eq.: 10.2.7

If $(swf(i) \cdot Itfgn(i) > 0)$

$dcr = cnp \cdot rc \cdot (swf(i) \cdot Itfgn(i))^{0.5}$

Else

$dcr = 0$

Rem N mineralization rate (kg/ha/day)

'SWAT Eq.10.2.9

$\boldsymbol{rmn(i) = dcr \cdot FoN(i-1)}$

If $(rmn(i) < 0)$

$rmn(i) = 0$

Rem.....IMMOBILIZATION

Rem N immobilization rate (kg/ha)

If $(FR(i-1) > 0)$

$cnfr = \dfrac{FoN(i-1)}{FR(i-1)}$

$wim(i) = dcr \cdot FR(i-1) \cdot (0.016 - cnfr)$

If $(wim(i) < 0)$

$wim(i) = 0$

Else

$cnfr = 0$

$wim(i) = 0$

$\boldsymbol{idcr = dcr}$

If $(wim(iyear) >= WNO3)$

If $(FR(i-1) > 0)$

$dcr = 0.95 \cdot \dfrac{WNO3}{FR(i-1) \cdot (0.016 - cnfr)}$

$wim(i) = idcr \cdot FR(i-1) \cdot (0.016 - cnfr)$

If $wim(i) < 0$

$wim(i) = 0$

Else

$idcr = 0$

$wim(i) = 0$

$wim(i) = 0.4 \cdot wim(i)$

$FoN(i) = FoN(i-1) - rmn(i) \cdot 30 + wim(i) \cdot 30$

$FR(i) = FR(i-1) - idcr \cdot FR(i-1)$

Closing cycle of months

If $(C_N >= 100)$

$qwim = 10$

$$rmn_t = \sum_{i=1}^{12} rmn\,(\mathrm{i})$$

$$wim_t = \sum_{i=1}^{12} wim(i)$$

OUTPUTS

rmn(i) - Nitrogen mineralised from fresh organic pool for each month

wim(i) - Nitrogen imobilisation rate for each month

Subroutine Mineralization_Manure

Calculate the nitrogen in active and stable organic pool and the N mineralised based on data about the livestock size and manure management

Input data:

N_UVM1 – (from Calculator UVM) – N amount from livestock for the farm area (kgN/ha)

Napp – number of manure applications

For each application j (j<= Napp)

Month(j) – month of manure application (j<= Napp)

MonthStorage(j) – number of months for manure storing to be applied in application j (j<= Napp)

org_mat

Clay

CaCO3

Itfgn(i) (i <= 12)

swf(i) (i <= 12)

$$N_UVM = \frac{N_UVM1}{365}$$

$$Norg = N_UVM$$

For i = 1 To 12

$$NappORG(i) = 0$$

For jj = 1 To Napp

$$NappORG(Month(jj)) = Norg \cdot MonthStorage(jj) \cdot 30$$

$$OC = \frac{org_mat}{1.7}$$

$$HON = \left(10^4 \cdot \frac{OC}{14}\right) \cdot BD \cdot 1.2 \cdot BR \cdot 0.1$$

$$fr_actN = 0.1 \cdot (0.1 + 0.4 \cdot e^{-0.0277 * 50})$$

$$Orgna(0) = fr_actN \cdot HON$$

$$Orgns(0) = HON - Orgna(0)$$

' STICS - cap VII pp 47

$fmin1 = 0.03$

$fmin2 = 9$

$fmin3 = 30$

$$k2pot = \frac{fmin1}{(fmin2 + Clay) \cdot (fmin3 + CaCO3)} \cdot 100$$

For K = 1 To 3

if (K > 1)

$Orgna(0) = Orgna(12)$

$Orgns(0) = Orgns(12)$

For i = 1 To 12

Rem Flow rate between active and stable pools kg/ha/day

'SWAT Eq.: 10.2.3

$$ron = 0.00001 \cdot \left(Orgna(i - 1) \cdot \left(\frac{1}{fr_actN} - 1\right) - Orgns(i - 1)\right)$$

if $(ron >= 0)$

$Orgna(i) = Orgna(i - 1) - ron \cdot 30$

$Orgns(i) = Orgns(i - 1) + ron \cdot 30$

else if $(ron < 0)$

$Orgna(i) = Orgna(i - 1) + Abs(ron) \cdot 30$

$Orgns(i) = Orgns(i - 1) - Abs(ron) \cdot 30$

if $(Orgna(i) < 0)$

$Orgna(i) = 0$

if (Orgns(i) < 0**)**

$Orgns(i) = 0$

Rem Mineralization rate for humus pool (kg/ha/day)

SWAT Eq.:10.2.4

if (swf(i) $*$ Itfgn(i) > 0**)**

$hmn = k2pot \cdot (swf(i) \cdot Itfgn(i))^{0.5} \cdot Orgna(i)$

else

$hmn = 0$

$Orgna(i) = Orgna(i) - hmn \cdot 30 + 0.2 \cdot rmn \cdot 30$

if (Orgna(i) < 0**)**

$Orgna(i) = 0$

$N_min(i) = hmn \cdot 30 + 0.8 \cdot rmn \cdot 30$

$Orgna(0) = Orgna(12)$

$Orgns(0) = Orgns(12)$

For i = 1 To 12

Rem Flow rate between active and stable pools kg/ha/day

'SWAT Eq.: 10.2.3

$ron = 0.00001 \cdot \left(Orgna(i-1) \cdot \left(\frac{1}{fr_{actN}} - 1\right) - Orgns(i-1)\right)$

if $(ron >= 0)$

$Orgna(i) = Orgna(i-1) - ron \cdot 30$

$Orgns(i) = Orgns(i-1) + ron \cdot 30$

else if $(ron < 0)$

$Orgna(i) = Orgna(i-1) + Abs(ron) \cdot 30$

$Orgns(i) = Orgns(i-1) - Abs(ron) \cdot 30$

if $(Orgna(i) < 0)$

$Orgna(i) = 0$

if ($Orgns(i) < 0$**)**

$Orgns(i) = 0$

$Orgna(i) = Orgna(i) + NappORG(i)$

Rem Mineralization rate for humus pool (kg/ha/day)

'SWAT Eq.:10.2.4

if $(swf(i) \cdot Itfgn(i) > 0)$

hmn $=$ k2pot $\cdot$ (swf(i) $*$ Itfgn(i))$^{0.5}$ $\cdot$ Orgna(i)

else

$$\text{hmn} = 0$$

$$Orgna(\text{i}) = Orgna(\text{i}) - hmn \cdot 30 + 0.2 \cdot rmn \cdot 30$$

if $(Orgna(\text{i}) < 0)$

$$\text{Orgna(i)} = 0$$

$$N_min(\text{i}) = hmn \cdot 30 + 0.8 \cdot rmn \cdot 30$$

$$N_\text{min}\ _t = \sum_{i=1}^{12} N_min\,(\text{i})$$

OUTPUTS

Orgna(i) - Nitrogen in active organic pool for each month

Orgns(i) - Nitrogen in stable organic pool for each month

N_min(i) - Nitrogen mineralised fom active organic pool for each month

Subroutine N_Balance

Calculate the final balance of N in soil, the N amount needed by crop and the amount of mineral fertilizer

Input data

actualYield

i_crop_actual

precedentYield

i_crop_precedent

N - kg N / t yield for specific crops from external file "StartNflow_Crops"

INPUTs from Subroutine Mineralisation_Manure

N_min_t

N_min(i)

INPUTs from Subroutine Mineralization_of_VegetaleResidues

wim(i)

rmn(i)

rmn_t

wim_t

INPUTs from Subroutine Drainage

dren_m

dren(i)

Drainage

$N_actualYield = actualYield \cdot N$

$Nleg = N_actualYield \cdot coef_N3$

i_crop_actual	Coef_N3
1-8, 12	0
9	0.75
10	0.75
11	0.75
13	0.75
14	0.75

$Nlegprec = precedentYield \cdot coef_N4$

i_crop_precedent	Coef_N4
1-8, 12	0
9	35
10	25
11	20
13	6
14	6

$nyear = 1$

$Nlegprec = Nlegprec \cdot \left(\frac{0.8}{nyear} - 0.15\right)$

$nn = N_actualYield - Nleg - Nlegprec$

if $(nn < 0)$

$nn = 0$

$NmineralReziduriVeg = rmn_t$

$Nimobilizat = win_t$

$Nmineralorganicpool = N_min_t$

For i=1 to 12

$$Nresid(i) = \frac{dren(i)}{100} \cdot rmn(i)$$

$$Norg_h(i) = \frac{dren(i)}{100} \cdot N_min(i)$$

$$Nresid_t = \sum_{i=1}^{12} Nresid(i)$$

$$Norg_h_t = \sum_{i=1}^{12} Norg_h(i)$$

$$Nresidue = Nresid_t$$

$$Norg_hum = Norg_h_t$$

$$Nmin_dren = 0.5 \cdot (Nresidue + Norg_hum)$$

$$Min_fert = \left(nn - \left(1 - \frac{dren_m}{100}\right) \cdot (Nmineralorganicpool + NmineralReziduriVeg) + Nimobilizat\right) \cdot \left(1 + \frac{dren_m}{100}\right)$$

$$N_dren = Min_fert + NmineralReziduriVeg + Nmineralorganicpool - nn - Nimobilizat$$

For j= 1 to Napp

if $(month(j) \geq 1\ 0\ )$

$$Applic(j) = MonthStorage(j) \cdot \frac{winter_dren}{100} \cdot \frac{1}{2}$$

else

$$Applic(j) = MonthStorage(j) \cdot \frac{spring_dren}{100} \cdot \frac{1}{2}$$

$$Ndrained = \sum_{i=1}^{Napp} \text{Applic(i)}$$

$$Nneed_cor = Min_fert + Ndrained + Nmin_dren - N_dren$$

$$Ndrained_tot = Nmin_dren + Ndrained$$

OUTPUTs

nn – the N need of actual crop

Ndrained_tot – the amount of N lost by drainage

N_dren – the amount of drained Nitrogen

Min_fert – the mineral fertilizer amount

Nneed_cor - the final mineral fertilizer amount taking into acoount the manure application