Comparison of Daisy and Daycent N_2O-processes

As far as I could unravel

Merete E. Styczen, Agrohydrology,
PLEN, UCPH

KØBENHAVNS UNIVERSITET

Background

- This all started with a review:

CSIRO PUBLISHING

REVIEW

https://doi.org/10.1071/SR22009

SOIL RESEARCH 2023

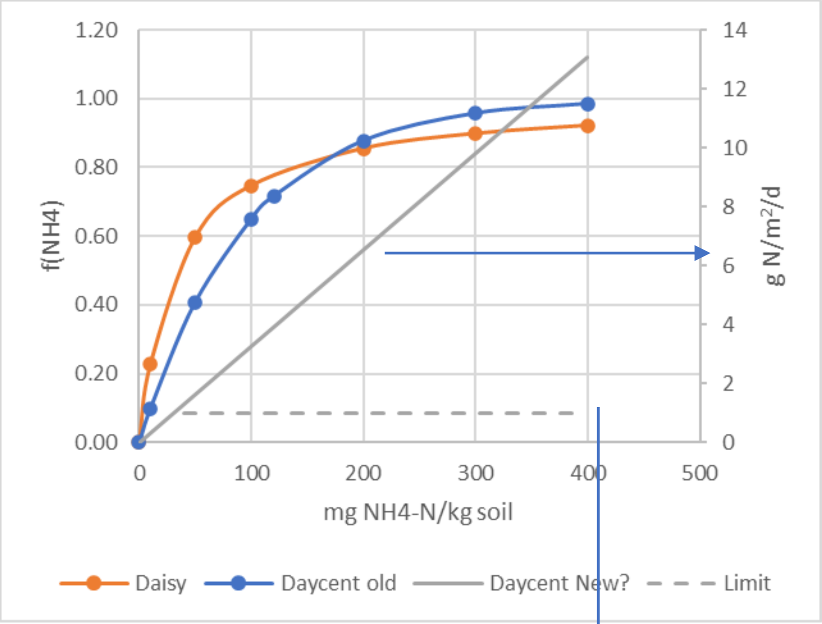
Modelling nitrous oxide emissions: comparing algorithms in six widely used agro-ecological models

Hongtao Xing[A,B], Chris. J. Smith[A,*], Enli Wang[A], Ben Macdonald[A] and David Wårlind[A,C]

- The article shows quite large differences between models and process-interpretation ☹.

- Many people wants something implemented in Daisy – but what?

Nitrification



Dependency on NH4+.

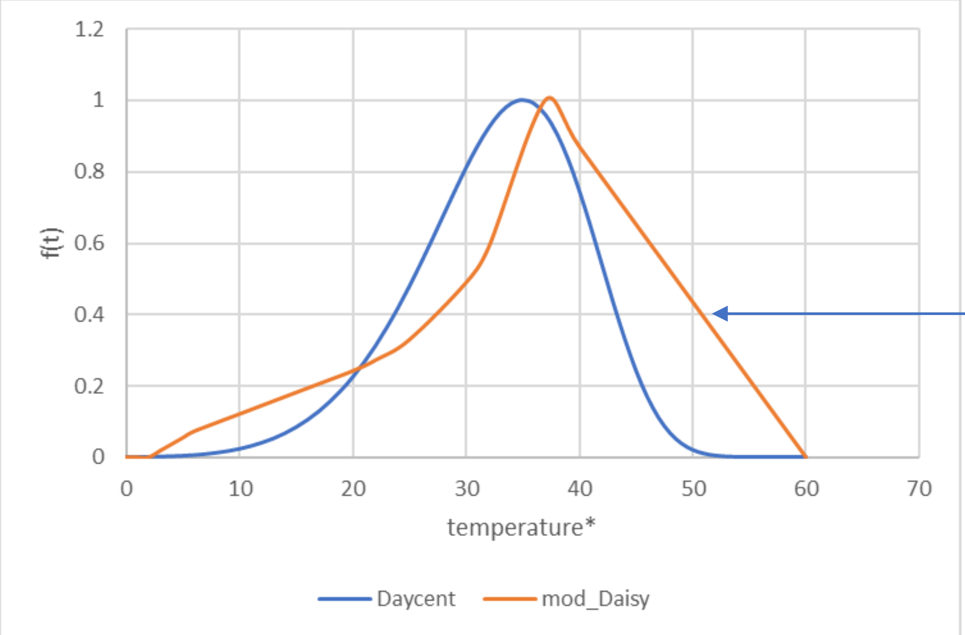
Daisy ($\xi_n = \frac{V_n(T,h)N_{am}}{K_n + N_{am}}$) and Old Daycent, curved.

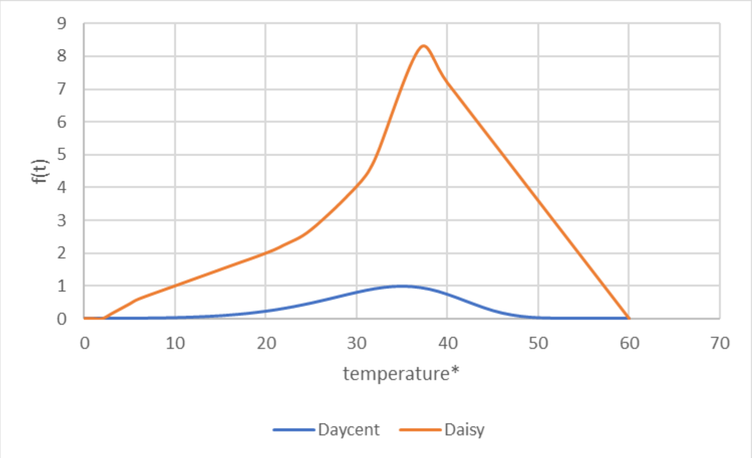
The Daycent relationship has changed in the recent code to a linear relationship.

Best guess:
absoluteMaxRate = min(MaxNitAmt, *ammonium * MaxRate)

Maxrate = 0.15 (day^{-1}?); *ammonium [g NH_4-N m^{-2}]
MaxNitAmt= site specific parameter; suggested value in code commentary: 1.0

Nitrification – temperature relationship





Daisy:

the temperature is the soil temperature in the layer in question. The Daisy temperature curve is normalised to max temp (37 °C) in top figure.

Daisy

$$f_n^T = \begin{cases} 0 & T \le 2 \\ 0.15 \cdot (T-2) & 2 < T \le 6 \\ 0.1T & 6 < T \le 20 \\ \exp(0.47 - 0.027T + 0.00193T^2) & 20 < T \le 37 \\ f_d^T(37) \cdot (1 - \dfrac{(T-37)}{(60-37)}) & 37 < T \le 60 \end{cases}$$

Daycent:

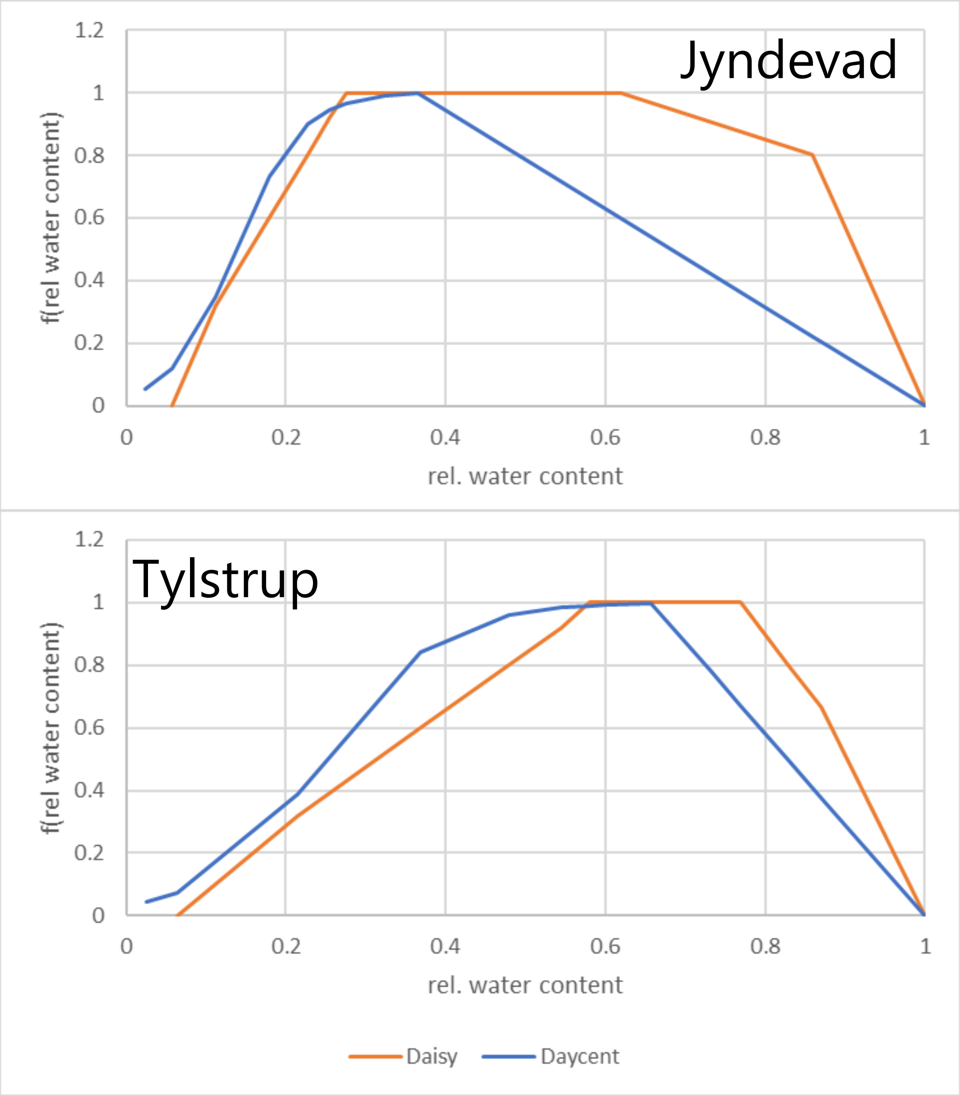
- maxT = long term average maximum monthly air temperature of the hottest month (°C).
- Soil temp = average of 2 top layers.

If maxT<35°C

T* = soil temp + (35-maxT) else

Toppoint of the temp-curve moves to maxT and T* = soil temp.

Nitrification – soil water



Daisy:

0 at pF 0 and 5; 1 between pF 1.5 and 2.5.

Daycent:

1/(1+30*exp(-9.0*avg_rel_wc) to FC, linear decline from FC to θsat.

Avg_rel_wc is relative to water content at FC

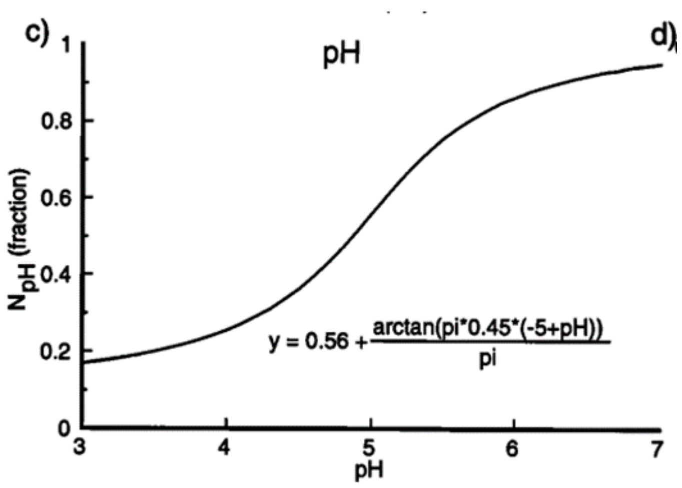
Jyndevad sand, 15 cm.

Field cap. is set to pF2. If 1.8, the curve top-point will move towards 0.43-0.44.

Tylstrup, 10 cm.

Field cap. is set to pF2.

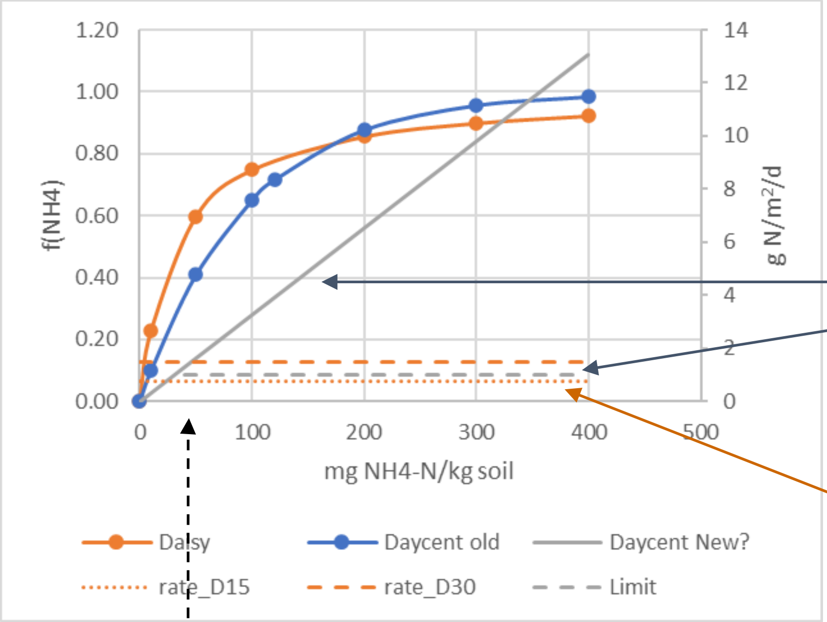
Nitrification- pH, overall level, and N_2O



pH-relationship for Daycent

Daisy does not have a pH-relationship.

Absolute rates of nitrification??



Daisy: Kmax *f(NH4) ***f(T)** *f(pF)

Daycent: 0.1 gN/ha/day+
Kmax *f(NH4) ***f(T)** *f(θ) *f(pH)

Kmax (Daycent) = 0.15 g N/m^2/day (?)
Kmax(Daisy) = 2.08E-7 g N/cm3/h.
For 15 cm of soil: 0.749 g N/m^2/day

100 kg NH4-N/ha = 10 g/m^2 ~ 50 mg N/kg soil

N_2O = 2% of nitrification (Daisy – and Daycent?)

Denitrification

Daycent

$R_d = \min(F_d(NO_3), F_d(CO_2)) \cdot F_d(WFPS)$

Originally, the equations were simple:

$F_d(NO_3)$ [µg N/g soil] = $1.15 \cdot C_{NO3}^{0.57}$ [µg N/g soil]

$F_d(CO_2)$ [µg N/g soil] = $0.1 \cdot CO_2^{1.3}$ [µg C/g soil]

$F_d(WFPS)$: longer story, see below

No temperature function

BUT there are changes.

Daisy

$R_d = \min(F_d(NO_3), F_d(CO_2) \cdot F_d(WFPS) \cdot F_d(T))$

$F_d(NO_3)$ = 0.02833 [h^{-1}] * conc. of NO_3^- -N in soil [g cm^{-3}]

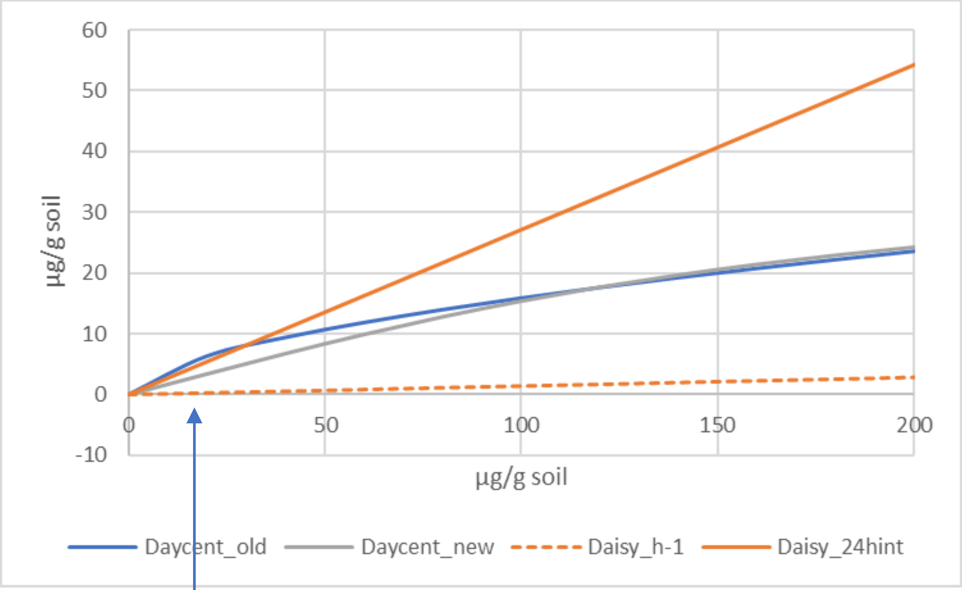
$F_d(CO_2)$ = α^* * g CO2-C/h (/cm^3) from the OM-module

α^* = 0.1 [(g NO3-N/h)/(g CO2-C/h)] (default)

$F_d(WFPS)$: see below

$F_d(T)$) : same as for nitrification

Denitrification, $F_d(NO_3)$



Daisy_24hint: integration of hourly rate over 24 h

I expect concentrations below 50 to be most common: (40 % water, 50 mg/l, topsoil with BD=1.45 ~ **14 NO_3-N µg/g soil**).

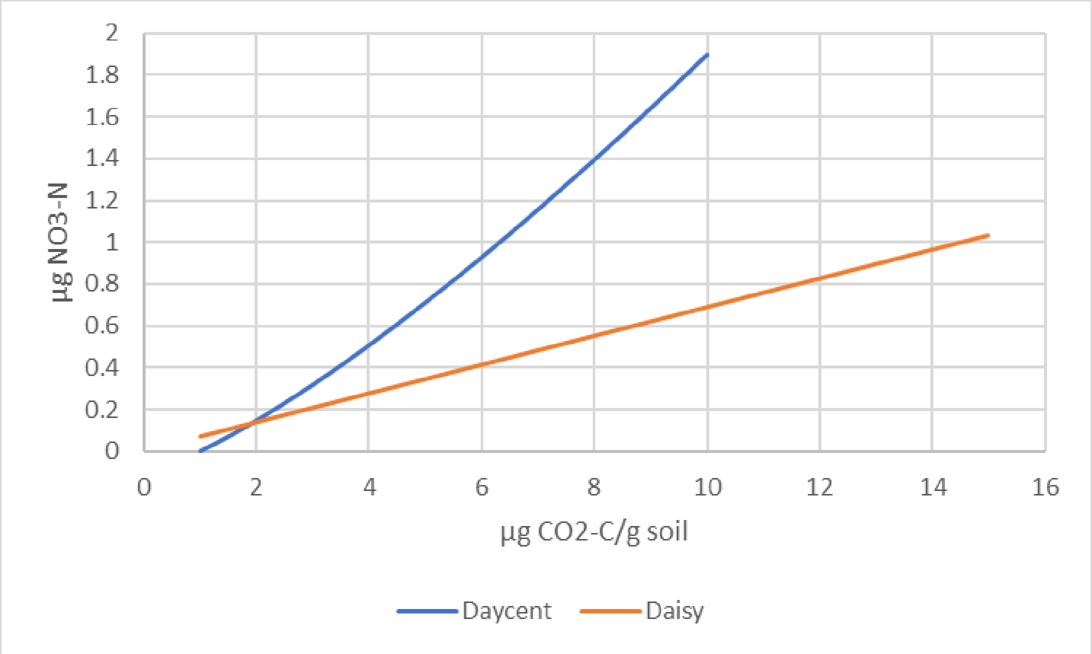
Old Daycent and Daisy_24hint quite similar in the relevant range.

New Daycent lower.

Daycent, new function

$F_d(NO_3)$= max(0.0; 1.556+76.91/π*arctan[π*0.00222(C_{NO3} – 9.23)]

Denitrification – Dependency on CO_2



Several jokers here:

- Orange line, CO_2-conc/g recalculated to cm^3 using BD=1.45 g/cm^3.
- Soil depth?

Daycent seems to calculate per day (high x-value), while Daisy calculates per hour (low x-value).

Yearly average ~ 4 µg CO2-C/g soil

Daycent uses a corrected CO_2-conc. A threshold is calculated: WFPS 0.8 or a bit lower). If below the threshold, no correction. If higher than threshold, it is increased (factor 1-maybe 1.1), higher with low diffusivity and close to saturation.

Denitrification- dependency on water content

Daycent

Parton et al. 2001,

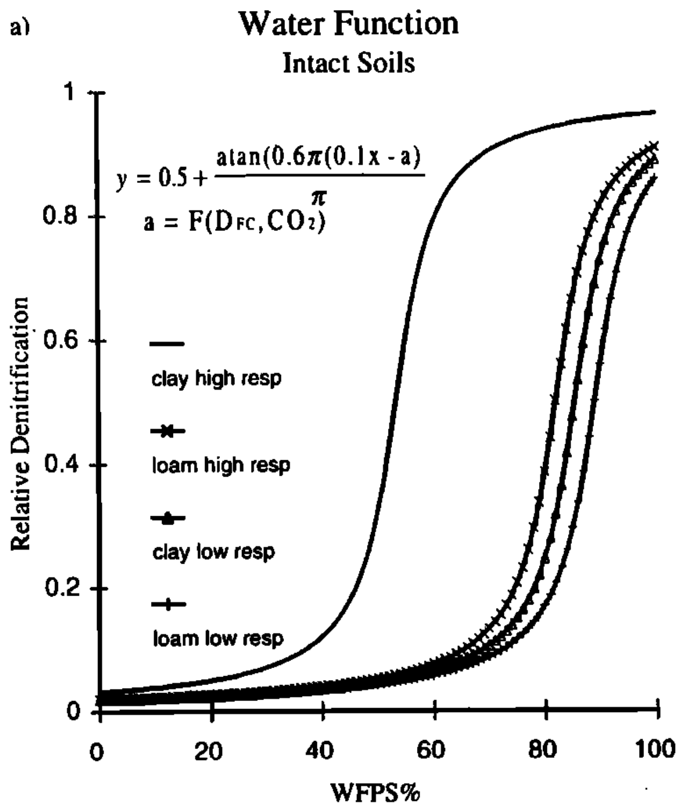
F_d(WFPS) = 0 for WFPS< 55 %, and

F_d(WFPS) = 0.5+atan(0.6π (0.1x – a))/ π for WFPS >= 55 %.

X = WFPS, a = f(soil gas diffusion and heterotrophic respiration.

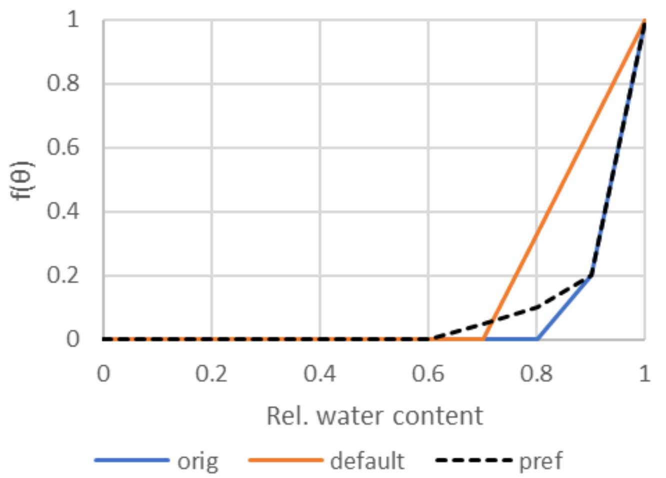
Implemented:

fDwfps = max(0.0, (0.45 + atan(0.6*PI*(10.0*layers->wfps[ilyr]-x_inflection)) / PI));



Daisy:

Dependency on relative water content, 3 examples



Denitrification- dependency on water content

Daycent – calculation of infliction point:

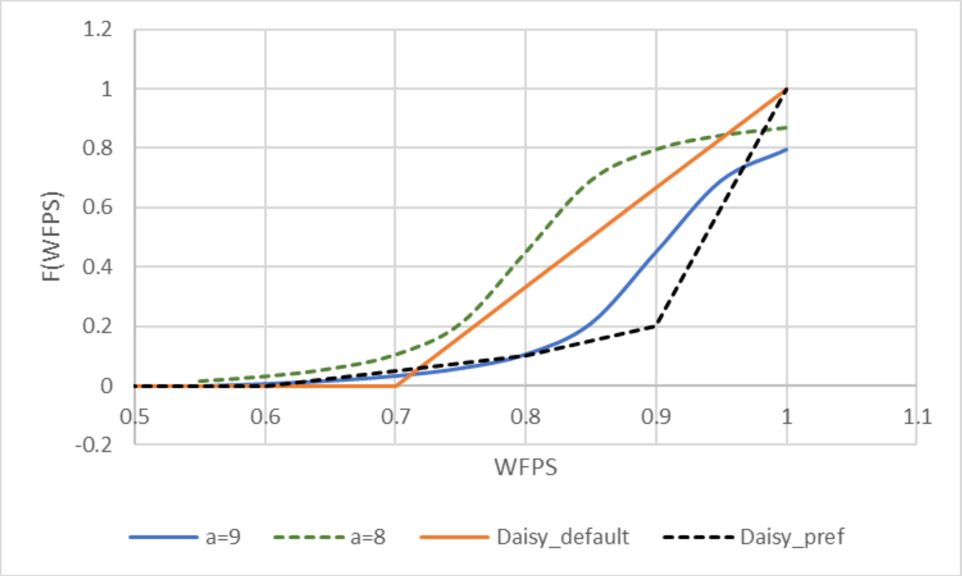
Del Grosso (2000)

x inflection = 0.90 – M*(CO_2) and M= min(0.113, D_{FC})(-3.05)+0.36, (D_{FC} not relative.)

In the "old" code:

x_inflection = (9.0 - (min(0.113, dD0_fc) * (-1.25) + 0.145) * (double)co2_correction[ilyr]) * (double)sitepar->wfpsdnitadj

Correction from earlier Site specific adjustment



Denitrification

Daycent

$R_d = \min(F_d(NO_3), F_d(CO_2)) \cdot F_d(WFPS)$

Daisy

$R_d = \min(F_d(NO_3), F_d(CO_2) \cdot F_d(WFPS) \cdot F_d(T))$

$F_d(NO_3)$: used to be quite similar, now Daycent is a bit lower in the relevant range

$F_d(CO_2)$: higher in Daycent

$F_d(WFPS)$: not that different

$F_d(T)$: May be a joker that increases denitrification in Daisy [can be user defined]. It slows down the process below 10 °C, increases to 2 at 20 °C and 2.72 at 25 °C.

N_2O-fraction of denitrification – only Daycent

N_2O-release from denitrification

According to **Del Grosso (2000)**, the ratio between N_2 and N_2O can be calculated (conc in ppm)

$Ratio(N_2/N_2O) = F_r(NO_3/CO_2) * F_r(WFPS)$

$F_r(NO_3/CO_2) = max(0.16 \cdot k_1, k_1 * exp((-0.8 \cdot C_{NO3})/CO_2))$; $k_1 = max(1.7, 38.4 – 350 * D_{FC})$

$F_r(WFPS) = max(0.1, 1.5 * WFPS - 0.32)$ (WFPS in fraction here, intact soil)

$N_2O\text{-loss} = R_d/(1 + Ratio(N_2/N_2O))$

In the code:

If $C_{NO3} > CO_2 * log(0.16)/(-0.8)$; $F_r(NO_3/CO_2) = 0.16 \cdot k_1$, else $k_1 * exp((-0.8 \cdot C_{NO3})/CO_2)$; $k_1 = max(1.5, 38.4 - 350 * D_{FC})$;

$Ratio(N_2/N_2O) = max(0.1, F_r(NO_3/CO_2) * F_r(WFPS)$ * **sitepar->N2N2Oadj**)

Special ratio for flooded areas (input ?)

Daycent also calculates NOx (according to del Grosso)

$$RNOx = 15.2 + (35.5 \cdot atan(0.68\,\pi(10 \cdot D/D_0 - 1.86)))/\pi,$$

I could not locate this code.

- RNOx = the ratio of NOx to N_20 fluxes and
- D/D_0 is the soil gas diffusivity.

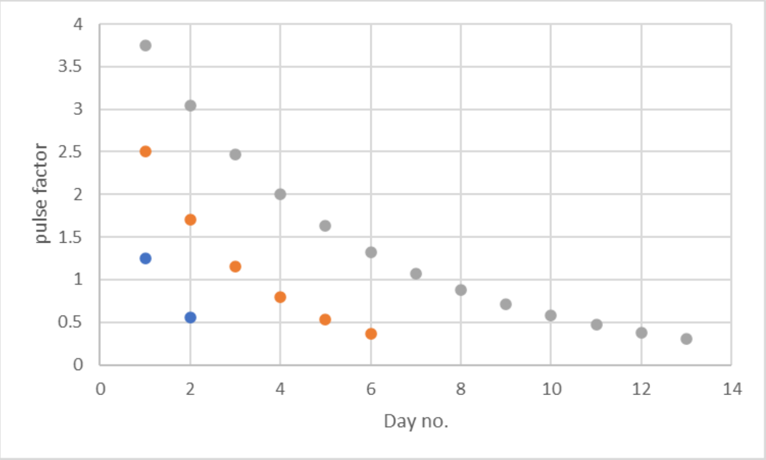
$$NOx = RNOx \cdot N_2O_{den} + RNOx \cdot N_2O_{nit} \cdot P$$

Daycent assumes a multiplier as f(precipitation, time)

Soil is dry if it received less than 1 cm of precipitation during the previous 2 weeks. The magnitude and duration of the pulse are functions of the amount of precipitation received and the number of days since the event:
If 0.1cm < precipitation< 0.5cm, then P = 11.19e-0.805·day, where 1 < day< 3;
if 0.5cm< precipitation<1. 5cm, then P = 14.68 e-0.384 · day, where 1 < day< 7;
if precipitation > 1.5cm, then P = 18.46-e-0.208 · day, where 1 < day< 14.

In the code changed to:

If 0.1cm < precipitation< 0.5cm, pl[indx] = 2.8 * exp(-0.805 * (ii+1)); 1 < day< 3
0.5cm < precipitation< 1.5cm, pm[indx] = 3.67 * exp(-0.384 * (ii+1)); where 1 < day< 7
precipitation > 1.5cm; ph[indx] = 4.615 * exp(-0.208 * (ii+1)); where 1 < day< 14.



For experimentalists

To make sense of your data, you need time series of:

- The water content
- The temperature
- Ammonium and nitrate concentrations
- CO_2 – or something about organic matter amounts and dynamics
- (pH)
- And hydraulic properties/diffusion relationships would be nice.

That was as far as I could get!

Questions?