Simple soil carbon model for use in the HighCrop decision model

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The change in soil carbon (ΔC) (Mg C ha^{-1} yr^{-1}) on an annual time scale is determined by the difference in net carbon additions (C_{net}) (Mg C ha^{-1} yr^{-1}) and the degradation of native soil carbon (C_{deg}) (Mg C ha^{-1} yr^{-1}).

$$\Delta C = C_{net} - C_{deg} \quad (1)$$

The amount of degradable soil C (C_{hum}) (Mg C ha^{-1}) is calculated from the amount of soil total nitrogen by assuming a C/N ratio of 11.

The degradation of soil C is calculated as a proportion of the native soil C using an annual degradation corresponding to 1.36 % estimated from long-term experiments at Askov research station in Denmark (Christensen, 1990):

$$C_{deg} = 0.0136\ C_{hum} \quad (2)$$

The net addition of carbon to the soil is calculated at the added amount (C_{add}) (Mg C ha^{-1} yr^{-1}) multiplied by a humification coefficient (h):

$$C_{net} = h\ C_{add} \quad (3)$$

The humification coefficient is set to h = 0.15 for plant residues, corresponding to a 15% retention of added carbon over a number of years (Christensen, 2005). For manure the humification is set to 0.30, and this is increased to 0.40 for digested manure (Thomsen et al., 2012). For biochar the humification is set to 1.00.

For most crops the added carbon is calculated as

$$C_{add} = C_{top} + C_{root} \quad (4)$$

where C_{top} is added carbon in aboveground crop residues (Mg C ha^{-1} yr^{-1}) and C_{root} is added carbon in belowground crop residues (Mg C ha^{-1} yr^{-1}).

Sampling of roots of cereals at flowering have shown slightly higher root biomass in winter cereals compared with spring cereals, but little or no effect of fertilization and management (Chirinda et al., 2012). Therefore fixed values of added carbon in roots are used for each crop based on estimates used for the C-TOOL model (Taghizadeh-Toosi et al., 2013) (Table 1).

The added C in the top depends on dry matter crop yield (Y) (Mg DM ha^{-1}) and whether the straw is removed. It is assumed that dry matter has a carbon content of 45%:

$$C_{top} = 0.45\ [\mathrm{Y}\ (1\text{-}HI)\ (1\text{-}f_{straw})] \quad (5)$$

where HI is the harvest index and f_{straw} is the proportion of above-ground residues (straw) that is removed when straw also is harvested. If straw is not harvested then f_{straw} is set to 0. The estimates of HI and $f$straw for the different crops are shown in Table 2.

Table 1. Carbon additions in roots (C_{root}).

Crop	C_{root} (Mg ha^{-1})
Winter cereal	1.6
Spring cereal	1.0
Winter rye	1.6
Spring oats	1.0
Pulse	1.1
Cereal-pulse intercrop	1.1
Lucerne	3.0
Grass-clover for cutting	4.0
Grass-clover for green manure	4.0
Grass-clover for grazing	4.0
Clover for seed	2.0
Sugar beet	0.6
Winter oilseed rape	1.6
Maize	1.5
Potato	0.6
Catch crop, poorly developed	0.7
Catch crop, medium developed	1.0
Catch crop, well developed	1.3

Table 2. Parameters for estimating carbon additions in tops of plants. *HI* is the harvest index and f_{straw} is the fraction of straw that is harvestable.

Crop	*HI*	f_{straw}
Winter cereal	0.45	0.45
Spring cereal	0.45	0.45
Winter rye	0.38	0.50
Spring oats	0.40	0.40
Pulse	0.42	0.40
Cereal-pulse intercrop (grain)	0.42	0.45
Lucerne for cutting	0.90	0.00
Grass-clover for cutting	0.95	0.00
Grass-clover for green manure	0.00	0.00
Grass-clover for grazing	0.80	0.00
Clover for seed	0.06	0.00
Sugar beet	0.70	0.50
Winter oilseed rape	0.37	0.50
Maize for silage	0.80	0.00
Potato	0.70	0.00
Catch crop, poorly developed	0.00	0.60
Catch crop, medium developed	0.00	0.70
Catch crop, well developed	0.00	0.80

For manure the amount of carbon added is calculated from the total N applied (N_{man}) (kg N ha^{-1}) in the manure using fixed C/N ratios (CN_{man}) for each manure type:

$$C_{add} = CN_{man} N_{man} / 1000 \quad (2)$$

The C/N ratios for the different manure types are shown in Table 3.

Table 3. C/N ratios of organic carbon to total N in various types of manure.

Manure	CN_{man}
Cattle slurry	8.5
Pig slurry	4.3
Digested manure	5.0*
Liquid manure (ajle)	2.0
Grass-clover silage	15.0
Deep litter, fresh	19.0
Deep litter, stored	13.5
Poultry manure, fresh	7.5
Poultry manure, stored	7.5
Compost	13.0

* Great variation between digested pig slurry (2.0) and digested cattle slurry/plant biomass (5-7.5)

References

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