Overview of C-Farm® simulation model

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C-Farm is a cropping systems model that simulates, in a daily time step, the soil carbon balance, water balance, crop growth and yield, and other processes. The main objective is to provide accurate simulations of soil carbon and nitrous oxide emissions when accumulated over 3 to 5 years. The inputs to the model are simple, readily accessible, or easy to define. The inputs to the model are: (1) a daily weather file that includes the location description (latitude, longitude, and elevation), (2) a soil description for the site, layer by layer, (3) a cropping sequence, (4) basic agronomic info about each crop (average planting, flowering, and maturity date), (5) a list of the tillage tools used (from a drop down menu of available tools) with the approximate date for each operation, (6) irrigation set up (automatic or fixed-date irrigation). Once the weather and soil files are available, it takes a few minutes to set up a simulation. The outputs are available in a daily or annual basis for several soil and crop variables, including crop yield, residues yield, root biomass per layer, soil carbon balance by layer, crop transpiration, soil evaporation, runoff, percolation, and other variable of interest. We are in the process of linking the carbon cycling with already developed nitrogen cycling algorithms to provide estimates of nitrous oxide emissions. The model input/output interface is user-friendly and accessible through Excel spreadsheets. A stand-alone version will substitute the current beta version in VBA.

The basic input information is relatively easy to acquire but it has to be accurate for the model to provide realistic estimates of carbon storage rates for a given site. In particular, the current soil carbon content needs to be provided as initial soil carbon is a key element affecting carbon storage rates.

Unique features of C-Farm

Three general features are unique in C-Farm:

1. **Soil carbon cycling**: the carbon cycling subroutine has been originally developed for this model. Soil carbon is composed of a single carbon pool whose turnover rate depends on the size of the pool. The higher the carbon pool, the higher the turnover rate. Unlike C-Farm, in multi-compartment models the soil carbon pool is subdivided in several pools (typically three) each having a different turnover rate. Thus, the overall turnover rate depends on the relative amount of each pool in the total soil carbon. A weakness of the multi-pool model is the difficulty in setting up the actual turnover rate of each pool, and the implicit assumption that as a carbon pool increases or decreases in size, the turnover rate remains stable, which is likely not true. The approach taken in C-Farm to regulate the soil carbon turnover rate is much simpler, and empirical evidence suggests it is sufficient to represent carbon turnover for different soils and climates. Similarly, the humification rate (the fraction of the decomposed carbon in plant residues or manure that remains in the soil as humus after an “effective” microbial attack) is controlled by the soil carbon
level in each layer. We consider that physical protection exerts a major control on humification rate (Withmore and Hassink, 1997; Six et al, 20XX). Therefore, clay content and soil carbon content control the humification rate of each layer. These are, of course, empirical approaches to represent complex processes.

(2) Tillage effect on carbon turnover: Tillage accelerates the turnover rate of soil carbon; however, no robust and scientific accepted procedure has been developed to represent this effect. In C-Farm, we developed a methodology to accelerate the turnover rate which is based on soil texture, the tool performing the operation (based on information developed by USDA National Resource Conservation Service for different tools), and the number of operations.

(3) Soil water balance: there are multiple robust models for soil water balance. Nonetheless, and to conform to the structure of C-Farm and its computational efficiency, new sub-routines were developed for soil water redistribution (for water above field capacity) and soil water evaporation. These approaches accurately reproduce water flow in the profile and the typical two-stage soil water evaporation rate for soils with different texture, without resorting to a numerical solution to the water flow in soils.

(4) Crop growth and radiation interception: crop growth is driven by radiation or transpiration. The transpiration-driven growth in C-Farm follows the approach outlined in Kemanian et al. (2005), which introduced a variant to the Tanner (1981) and Tanner and Sinclair (1983) approach. This modification improved the simulation of biomass production and therefore the estimation of carbon inputs. To the best of our knowledge this is the first time it is parameterized for several crops and used in a crop simulation model.

Below are screen shots of the C-Farm model Excel Interface, which is a beta version written in Visual Basic for Applications. A standalone version in Visual Basic substituted this beta version.
**Input Control Interface**

![Input Control Interface Image](image1)

**Management Control Interface**

![Management Control Interface Image](image2)
Sample of Output – Annual summary per soil layer

Sample of Output – Soil carbon evolution