Input data sets for EPA global simulations

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**Model description**

The DAYCENT ecosystem model has been used to estimate N2O emissions and soil C stocks in several studies (Del Grosso et al. 2002; 2005; 2009), and is also the basis for a Tier 3 method that is used to estimate soil N2O emissions in the US National Greenhouse Gas Inventory (EPA 2012). The DAYCENT process-based model (Parton et al. 1998; Del Grosso et al. 2001, 2011) simulates biogeochemical C and N fluxes between the atmosphere, vegetation, and soil; and representing the influence of environmental conditions including soil characteristics and weather patterns, specific crop and forage qualities that influence the C and N cycle, and management practices. The DAYCENT model utilizes the soil C modeling framework developed in Century model (Parton et al. 1987, 1988, 1994; Metherell et al. 1993), but has been refined to simulate dynamics at a daily time-step.

Key processes simulated by DAYCENT include plant production, organic matter formation and decomposition, soil water and temperature regimes by layer, in addition to nitrification and denitrification processes. The plant-growth submodel simulates C assimilation through photosynthesis; N uptake; dry matter production; partitioning of C within the crop or forage; senescence; and mortality. The soil-water balance submodel calculates water balance components and changes in soil water availability, which influences both plant growth and decomposition/nutrient cycling processes. Dynamics of soil organic C and N are simulated for the surface and subsurface litter pools and the top 20 cm of the soil profile; mineral N dynamics are simulated through the whole soil profile. The three SOM pools represent a gradient in decomposability, from active SOM (representing microbial biomass and associated metabolites) having a rapid turnover (months to years), to passive SOM (representing highly processed, humified, condensed decomposition products), which is highly recalcitrant, with mean residence times on the order of several hundred years. Soil temperature and moisture, tillage disturbance, aeration, and other factors influence the decomposition and loss of C from the soil organic matter pools. Soil mineral N dynamics are modeled based on N inputs from fertilizer inputs (synthetic and organic), residue N inputs, soil organic matter mineralization, symbiotic and asymbiotic N fixation. Mineral and organic N losses are simulated with leaching and runoff, and nitrogen can be volatilized and lost from the soil during a variety of processes including nitrification and denitrification. N2O emissions from denitrification are a function of soil NO3- concentration, water filled pore space (WFPS), heterotrophic (i.e., microbial) respiration, and texture. Nitrification is controlled by soil ammonium (NH4+) concentration, water filled pore space, temperature, and pH.

**Baseline data used for the analysis**

Table Inputs.

|  |  |  |
| --- | --- | --- |
| Data Type | Description | Source |
| Daily Weather | Daily weather for 1901 – 2010 at 0.5 degree resolution in latitude by longitude. This includes daily minimum temperature, daily maximum temperature, and daily precipitation. | The original data source was the MsTMIP project's 6 hour CRU + NCEP combined data. This was aggregated to daily, and all non-land cells were removed.  <http://nacp.ornl.gov/MsTMIP.shtml> |
| Soils | This data was the same as was used for previous the DayCent global simulations. The data is at 0.5 degree resolution in latitude by longitude and includes sand, silt, clay, bulk density, pH, number of soil layers. | FAO, 1996. The Digitized Soil Map of the World Including Derived Soil Properties, CDROM. Food and Agriculture Organization, Rome. |
| Agricultural cells to simulate | This mask was computed from the fraction of agricultural area. The fraction of agricultural area is provided at 5 minute resolution in latitude by longitude. This data was aggregated it to 0.5 degree resolution by latitude and longitude. We selected cells where fraction of agricultural area ≥ 0.05. | Agricultural Lands in the Year 2000.  Described in the publication, Ramankutty et al. (2008), "Farming the planet: 1. Geographic distribution of global agricultural lands in the year 2000", Global Biogeochemical Cycles, Vol. 22, GB1003, doi:10.1029/2007GB002952. |
| Year of plow out | Fraction of area in agriculture for years 1700-2007 at 0.5 degree resolution in latitude by longitude. We computed the first year when the fraction of agricultural area is 50% of the fraction of area in 2000 – this determined the year of plowout for the cell. | [*Global Cropland and Pasture Data from 1700-2007*](http://www.geog.mcgill.ca/landuse/pub/Data/Histlanduse/)  This is a beta release of an updated version of our original historical cropland data set that spanned the 1700-1992 period. The original data set was described in the publication by Ramankutty and Foley (1999) in Global Biogeochemical Cycles. This release updates the data to the 1700-2007 time period.  ([http://www.geog.mcgill.ca/landuse/pub/ Data/Histlanduse/](http://www.geog.mcgill.ca/landuse/pub/%20Data/Histlanduse/), Accessed June 29, 2012). |
| Crop Specific Planting and Harvest Dates | Planting date (day of year) and Harvest date (day of year) for each crop at 0.5 degree resolution in latitude by longitude: Barley (Winter), Barley (Spring), Maize (main season), Maize(second season), Millet  Sorghum (main season) , Sorghum second season), Soybeans, Wheat (Winter), Wheat (Spring) | Sacks, W.J., D. Deryng, J.A. Foley, and N. Ramankutty (2010). Crop planting dates: an analysis of global patterns. Global Ecology and Biogeography 19, 607-620. DOI: 10.1111/j.1466-8238.2010.00551.x. |
| Harvested Areas and Yields by crop type in year 2000. | Harvested Area (proportion of grid cell area) and Yield (tons/ha). The data is provided at 5 minute resolution in latitude by longitude. We aggrgated the data to a 0.5 degree resolution.   1. These measured yields were compared to simulated yields from the baseline simulation. 2. Harvested area will be used in the post-processing step for aggregating model results. | [Harvested Area and Yields of 175 crops (M3-Crops Data)](http://www.geog.mcgill.ca/landuse/pub/Data/175crops2000/)  Monfreda et al. (2008), "Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000", Global Biogeochemical Cycles, Vol.22, GB1022, doi:10.1029/2007GB002947. |

**DayCent schedule files**

Schedule files specify the chronological order of all events to be simulated by day and by year. Vegetation types, vegetation and soil disturbances, and cropland management practices are defined in schedule files. Schedule files indicate the current tree, grass, or crop type to grow, when growth begins and when the plant dies, and the weather file to read from. Additionally, the day of year that each planting, harvest, tillage, fertilization, and irrigation event occurs is specified along with more information about the event. For example, each fertilizer event specifies the amount of N applied to the soil, each harvest event specifies whether grain is harvested and the fraction of crop residue removed, each irrigation event specifies the amount of water applied to the soil, and each cultivation event specifies the intensity of soil disturbance. Simulations included two steps, a spinup run and a run implementing cropland management over time.

**Spinup runs**

The 0.5 degree gridcells included in the simulations were those where the fraction of area in agriculture in the year 2000 ≥ 0.05 (Ramankutty et al. 2008). First, we simulated native conditions for 3000 years to establish an equilibrium state for soil C pools, which is determined by the climate, soil characteristics and native plant characteristics. Native conditions were determined from the Potsdam model comparison data (Cramer and Field 1999) for native vegetation (Melillo et al. 1993). The last event in the spinup schedule file is a kill event that kills all vegetation. Binary files from the spinup runs were saved to initialize all subsequent agricultural simulations. Daily weather from 1901 – 2010 was repeated many times to drive the model during the spinup period. Each grid cell had one spinup schedule file and up to 128 (8 crop types x 8 cropland management scenarios x 2 water management options (rainfed and irrigated)) schedule files describing cropland management from the year of plowout to 2035.

**Baseline runs**

The baseline runs for each gridcell were extended from the grid cell’s spinup output. Baseline simulations included low-input (pre-modern technology, pre-1951) and modern agriculture (1951 – 2035). We created a separate baseline schedule file for each grid cell and each crop and each water management option (rainfed or irrigated). We simulated winter and spring barley, maize, millet, sorghum, soybean, and winter and spring wheat. All crops were represented as monocultures – there were no crop rotations. Crop-specific masks were used to determine where each crop was grown (Table Inputs). There was a separate crop-specific mask for rainfed and irrigated crops. Planting and harvest dates were obtained for winter and spring barley, maize, millet, sorghum, soybean, and winter and spring wheat (Sacks et al. 2010). Maize and sorghum had double-plantings in some areas. Conventional cultivation practices were simulated for developed countries (there was no conservation tillage), and less intensive cultivation practices were simulated for less developed countries (FAO data) (Table Cultivation). All crops had grain harvest. The fraction of residue that was removed varied by crop and region (FAO data) (Table Inputs, Table BaselineInputsByRegion).

Each baseline schedule file began the first year of cultivation (1725, 1775, 1825, 1875, 1925, or 1975) based on the timeblock when 50% of the current agricultural land base in a grid cell was initially cultivated according to Ramankutty and Foley (1999) (Table Plowout). From the initial cultivation year through 1950, low input agriculture was simulated. For years 1951 – 2010, modern agriculture was simulated with improving crop varieties, country-specific N fertilizer rates (FAO data); irrigation was simulated for cells where it is currently a common practice (FAO data), under the assumption that options for expanding irrigated agriculture are not likely over the next few decades. Fertilizer was applied in a single application the day before planting. There was no application of nitrification inhibitors and no use of split fertilizer applications or other improved nitrogen management practices. Schedule files for irrigated crops included four irrigation events, approximately 1 per month, starting on the planting date. Each irrigation event set soil moisture to 60% of field capacity. Daily weather from 1901 – 2010 was used to drive the model from the year of plowout through year 2010. Years 2011 – 2035 continued with the same crop management assumptions as for 1950 – 2010, with modern agriculture and improving crop varieties, but with N application rates equal to those in 2010. Daily weather from 1990 – 2010 was used to drive the model for this time period.

Model performance for the baseline simulation was evaluated by comparing simulated crop yields to observed crop yields (Monfreda et al. 2008). DayCent crop parameters were adjusted so that the range of simulated yields matched the range of observed yields and so simulated yield patterns across the globe matched those observed.

Table Plowout. Cult50 is the year when the fraction of agriculture has reached 50% its value in 2000.

|  |  |
| --- | --- |
| **Cult50** | **Cultivation begins** |
| 1700 – 1749 | 1725 |
| 1750 – 1799 | 1775 |
| 1800 – 1849 | 1825 |
| 1850 – 1899 | 1875 |
| 1900 – 1949 | 1925 |
| 1950 – 2000 | 1975 |

**DayCent run file column definitions (aycent\_epa\_global\_ag\_extended2\_devel.csv). This file was used by multiple programs (mksitesoil, the program that created all the crop schedule files, post-processing programs) so not all columns are relevant to actually running DayCent.**

global\_id – unique identifier for the cell.

Latitude – centroid of the grid cell (decimal degrees)

Longitude – centroid of the grid cell (decimal degrees)

veg\_extended- the native vegetation type (1..35). Native vegetation is needed for the spinup run. You will need to determine the native vegetation for the grid cells you are simulating. I gave you a map (cltveg.svf) that defines these for the 0.5 degree x 0.5 degree grid. Extended means we extended the original vegetation map to grid cells that previously had no vegetation type because they were on the coastlines.

soils\_extended - soil type we used. Not applicable to your runs since you have soil texture for each grid cell.

Code\_CindyPotsdam – country code that Cindy Keough used for previous global simulations we called “POTSDAM” from 10 years ago. These country codes are out of date.

CountryName – we used this column for some post processing if results.

developed3 – the country’s development status. 1=developed, 0=developing. The “3” just means this is the 3rd the version we created. We used this to determine some of the cultivation practices for crop simulations. I suspect all of Europe would be considered developed.

farea2000 – the fraction of the grid cell that is under cultivation in year 2000.

cult50 - the year when the fraction of agriculture reached 50% its value in 2000.

The following indicate which crops to simulate for in the grid cell. These are rainfed crops, not irrigated.

maiz

wheas

wheaw

mill

sorg

barls

barlw

soyb

**This metadata for N fertilizer applications:**

[http://www.nrel.colostate.edu/wiki/conant/index.php/Nutrient\_management](https://mail.colostate.edu/owa/redir.aspx?C=47f512c989254404a26ad810795220d1&URL=http%3a%2f%2fwww.nrel.colostate.edu%2fwiki%2fconant%2findex.php%2fNutrient_management)

The information related to fertilizers could be found from different sources.

The **International Fertilizer Industry Association** (IFA) [[1]](http://www.fertilizer.org/ifa/ifadata/search) collects information on consumption, production, imports and exports of nitrogen, phosphate and potash (as general and specific product) by country from 1961 to 2008. In the website it can be found information on conversion factors (nutrients as percentage of product) of more than 20 products. In 2009 IFA produced an **Assessment of Fertilizer Use by Crop at the Global Level 2006/07 – 2007/08** [[2]](http://www.fertilizer.org/ifa/Home-Page/LIBRARY/Publication-database.html/Assessment-of-Fertilizer-Use-by-Crop-at-the-Global-Level-2006-07-2007-08.html2). In the report country information available at the IFA Secretariat covers 23 countries (considering the EU-27 as a single country). These countries, account together for 92% of world fertilizer consumption, making it possible to analyze fertilizer use by crop type at the global level. In the analysis, crops have been divided into eleven groups as follows: wheat, rice, maize, other coarse grains (barley, oats, rye, triticale, sorghum, millet, etc), soybean, oil palm, other oilseeds (rapeseed/canola, mustard, sunflower, groundnut, etc), cotton, sugar crops (sugar cane and sugar beet), fruits and vegetables and other crops (roots and tubers, pulses, nuts, rubber, coffee, tea, tobacco, ornamentals, turf, pastures, forestry, etc.).

FAOSTAT collects similar information for the entire world and the same time-frame of IFA [[3]](http://faostat.fao.org/site/575/default.aspx#ancor). The fertilizer statistics data is received from countries in fertilizer product format and is converted to nutrient format and summary totals calculated for production, imports, exports, non-fertilizer use and consumption for the straight fertilizers: nitrogen, phosphate and potash. Another FAO database is **FertiStat** [[4]](http://www.fao.org/ag/agl/fertistat/index_en.htm). This site has been conceived as a means to compile and store statistics on fertilizer use by crop (37 commodities in total) for selected key years (1985; 1995-2004) and 94 selected countries. The FAO Fertilizer Programme carried out trials and demonstrations on crops in farmer's fields from the 1970's through the 1990s. The purpose of these trials and demonstrations was to determine suitable fertilizer application rates for local crops that are commensurate with farmers' means. The demonstrations and trials differ in design and fertilizer treatment combination. The results of these trials and demonstrations provide information on crop responses to plant nutrients in 32 countries in Africa, Asia and Latin America. The information is collected in a nutrient response database called **FERTIBASE** [[5]](http://www.fao.org/ag/agl/agll/nrdb/index.jsp?lang=en). The aim of this database is to allow for the extraction of yield data per agro-ecological zone for the main food crops in a specific country. The extracted data enable the estimation of fertilizer input- and crop output ratios for projection of future fertilizer application to support increased crop yield targets.

In the World Resource Institute the EarthTrends database [[6]](http://earthtrends.wri.org/searchable_db/index.php?theme=8) contains information on fertilizer production, consumption (in nutrients) and fertilizer use intensity. The data refer to 2002-2007 and the source is FAOSTAT.