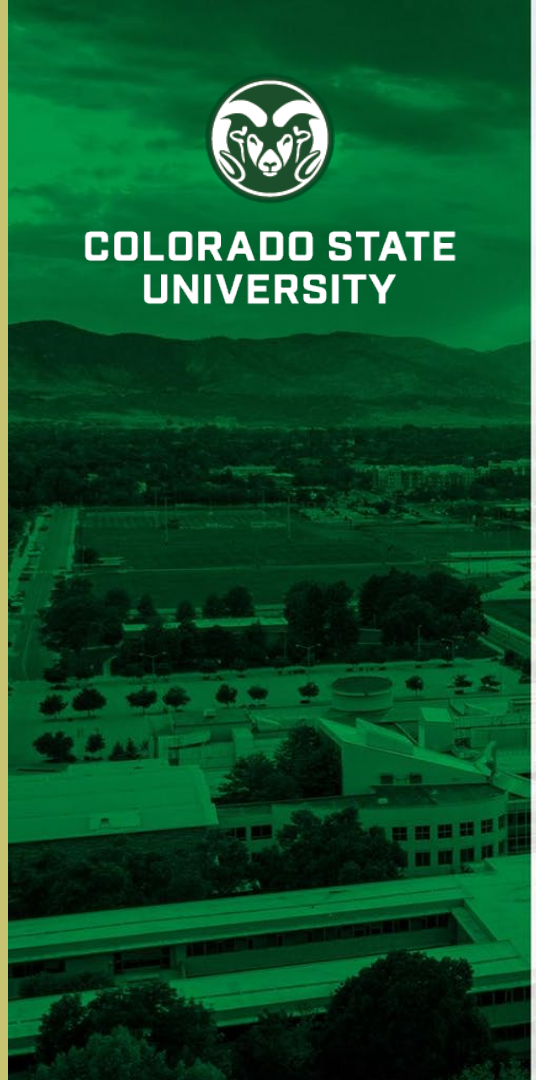


SWAT+ Carbon

Olaf David, Jeffrey Arnold, Natalja Čerkasova, Eric Coronel, Jack Carlson, Frank Geter, Xuesong Zhang

Colorado State University
USDA ARS
Texas A&M
Field-to-Market Association

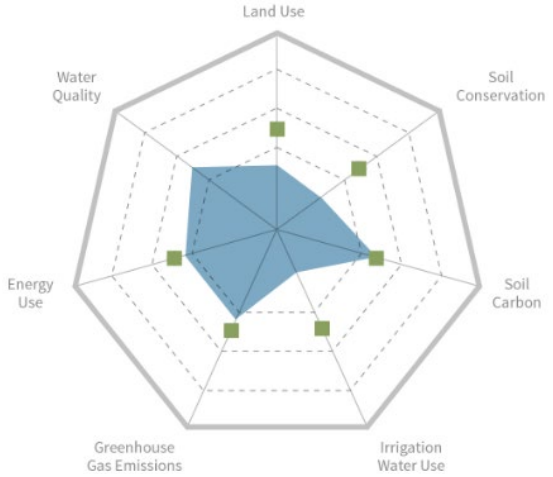
Motivation

“Field to Market” Association Sustainability Program

Support of modeling technology through USDA Fieldprint Platform

The Fieldprint Analysis estimates field level performance on the following sustainability indicators:

- Biodiversity
- Energy Use
- Greenhouse Gas Emissions
- Irrigated Water Use
- Land Use
- Soil Carbon
- Soil Conservation
- Water Quality



History

Explored various carbon models in Summer 2023

Teamed up with Jeff and Natalja in Fall 2023

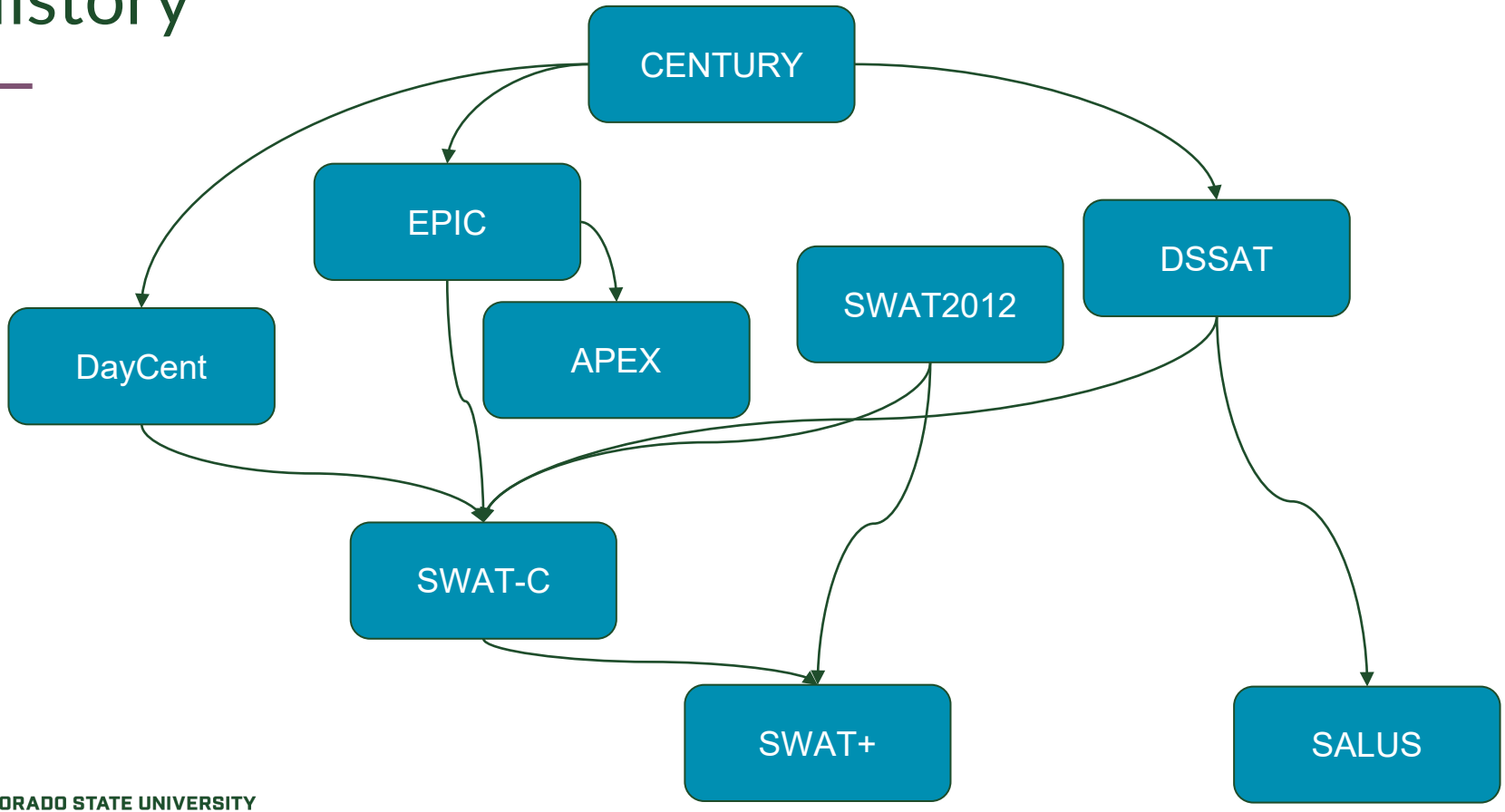
Code migration in Fall 2023

Regular FtM meetings since Fall 2023

GitHub migration of the new code

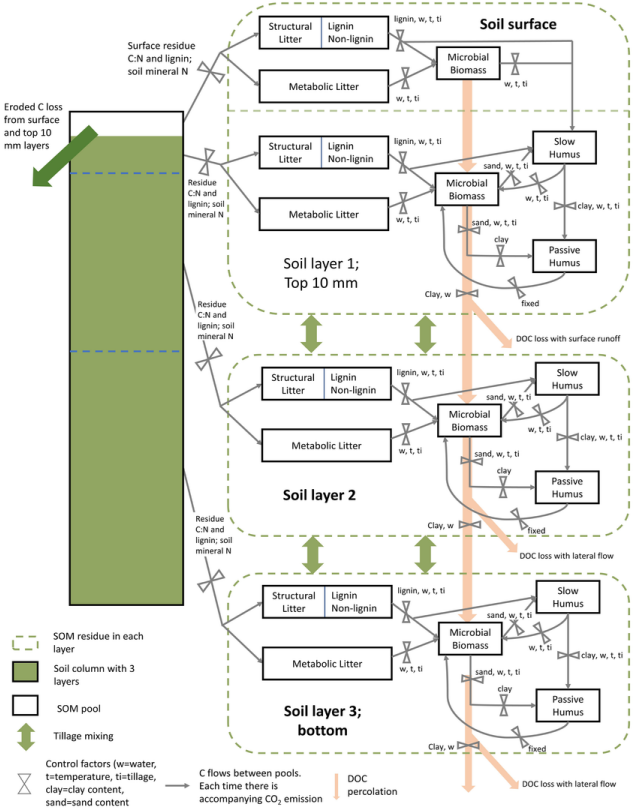
SWAT+ Service integration with the Cloud Services Integration Platform (CSIP) in Spring 2024

History



SWAT-C

- Xuesong Zhang USDA-ARS has developed and is supporting SWAT-C
- Plans to incorporate into SWAT+, Organic object(s) will make cleaner code
- Require modifications from SWAT
- Soil carbon budget and sequestration.
- Plant growth and management impacts
- Transport in channels and reservoirs

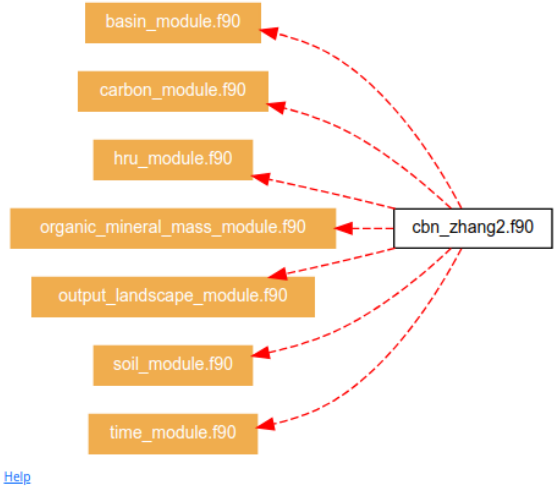


New Modules / Subroutines

carbon_module.f90, new types:

- carbon_terrestrial_inputs
- carbon_inputs
- organic_controls
- organic_ratio
- organic_transformations
- organic_flux
- carbon_soil_transformations
- carbon_soil_gain_losses
- carbon_residue_gain_losses
- carbon_plant_gain_losses

subroutine cbn_zhang2



Outputs

basin_carbon_all.txt

```
  1  demo                     SWAT+ Jun 03 2024        MODULAR Rev 2024.60.0.1 -1-gb633f79
  2         jday         yr            org_soilc        org_plc       org_resc
  3                                        kg/ha          kg/ha          kg/ha
  4          365        1975  basin    8772.735      0.0000000E+00   8429.526
  5          365        1975  basin    8772.735      0.0000000E+00   8429.526
...
```

hru_soilc_stat.txt

```
   1  demo                     SWAT+ Jun 03 2024        MODULAR Rev 2024.60.0.1 -1-gb633f79
      2         jday        mon         day          yr           unit              gis_id     name              tot_org_c           str_c           lib_c
   meta_c          man_c    humus_low_c   humus_pass_c       microb_c
      3                                                                                                          kg/ha           kg/ha           kg/ha
   kg/ha           kg/ha          kg/ha          kg/ha          kg/ha
      4          365          12          31        1975           1                     1 hru0001          4386.369      5.1080967E-10  5.5364041E-10
   0.0000000E+00  0.0000000E+00  1.0781458E-11  1.1151467E-14  1.6715649E-13
      5          365          12          31        1975           2                     1 hru0002          4386.367      1.0223121E-09  1.1074021E-09
   0.0000000E+00  0.0000000E+00  2.1454572E-11  2.2191299E-14  3.3259504E-13
   ...
```

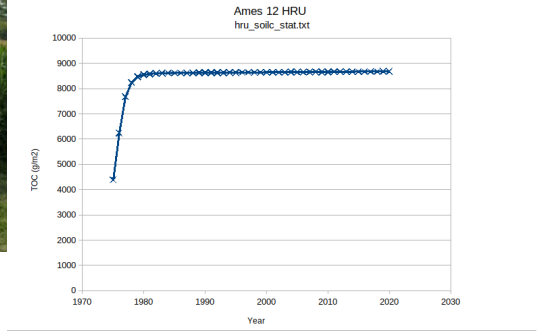
Planned Modeling Workflow Using SWAT+C

1. Leverage work with the National Agroecosystem Model (NAM) supporting USDA-CEAP building a very large database of pre-run SWAT+C model simulations
2. (Soft) Calibrate biomass, water balance, carbon and nitrogen flux related parameters by region, crop functional group, and soil strata; validate where sufficient hard data available (Clustering + Regionalization + Optimization, e.g. Particle Swarm Optimization)
3. For each field (steps 3-7): Initialize passive, slow, and active carbon pool fractions using pre-developed database values filtered by location and soil strata
4. Auto-create a 2007 to latest crop year management.sch file, applying NASS CDL for cropping sequence, operation date logic developed by SWAT+ team, and minimum FtM inputs
5. Incorporate minimum required FtM inputs:
    a. Amendment (N) amounts and kinds already collected by the Fieldprint Calculator for STEP
    b. Cover crop: cereal, annual grass, annual grass-legume, annual legume, or annual broadleaf
    c. Cropping intensity: crop(s) harvested in season year (verify CDL crops)
    d. Tillage class: intensive till (120+ STIR), conventional till (80-120 STIR), reduced till (60-80 STIR), reduced till (40-60 STIR), reduced till (20-40 STIR), no-till (0-20 STIR)
    e. Optional 0-30 cm SOC sample data
    f. Base period between 2007 and present; base period must have FtM-supplied inputs

Planned Modeling Workflow Using SWAT+C

6. Apply checks to determine fitness of inputs for simulation.
7. Run SWAT+ model from 2007 through pre-baseline, baseline, and practice change periods. Run model through pre-baseline and baseline periods, with baseline extended through practice change period. Provide option for 10-year projection. Provide option to select matching pre-run simulation results. Apply checks to rate quality of the results.
8. For soil carbon stock trend, subtract modeled base period SOC from modeled practice change period SOC. For netCO_2e removal trend, subtract blended baseline result from practice change result.
9. Workflow remains an adaptation of the USDA-endorsed COMET-Farm approach

Saunders County, Nebraska Corn Belt Test Case



Field Study Data: Mead/Ithaca sites, Ames test dataset

Soils: silty clay loam, silt loam moderately well drained, 3% organic matter, (29.6 mt/ac)

Ecological Site: Loamy Terrace, 4200 lbs/ac annual above ground biomass (big bluestem, switchgrass, indiangrass)

Average Annual Precipitation: 34 inches

2007-2023 Crops: consistently corn/soybean since 2007

Modeled soil carbon stock (early stage test, continuous corn): 35.4 mt/ac (8750 g/m2)

Model Validation Datasets Nearest KS Use Case

Potential Field Study Validation Data

Tribune, KS: 165 miles, LRR H, silt loam, limited irrigation corn/sorghum/wheat, start 2001, SOC measured 2010

Imperial, NE: 270 miles, LRR H, loam, dryland wheat/corn/fallow, 1970 start, SOC measured 2012

Dalhart, TX: 275 miles, LRR H, sandy loam, sporadic irrigated wheat/corn, 1999 start, SOC measured annually to 2006

Mead, NE: 290 miles, LRR M, silty clay loam, dryland corn/soybeans, start 1975/1982, SOC measured 1992, 1998, 2002

Otis, CO: 300 miles, LRR H, loam, dryland wheat/millet, start 1966, SOC measured 2012

Conclusions

SWAT+ & Carbon “Edge of Field” implementation as first step

SWAT+ open source availability and community support

Ongoing Service integration at scale, USDA data integration (CR_LMOD, Daymet, etc.)

Ongoing Fieldprint Calculator workflow integration