DNDC Modeling and Reductions Calculator Tool for Rice Offsets

William A. Salas*, Peter A. Ingraham, Richard J. Emery, Pavel Dorovskoy, and Justin P. Fisk

Applied Geosolutions, LLC. (*corresponding author: wsalas@appliedgeosolutions.com)

- The California Air Resources Board *Compliance Offset Protocol for Rice Cultivation Projects* uses market-based incentives to reduce emissions from US rice production
- The Denitrification-Decomposition (DNDC) process-based biogeochemical model is used as part of the Protocol to simulate GHG reductions
- The Modeling and Reductions Calculator Tool allows novice users to enter and manage data to be used for Protocol-compliant DNDC reductions simulations
- The Tool is built using open-source tools with minimal licensing fees, reducing costs over time

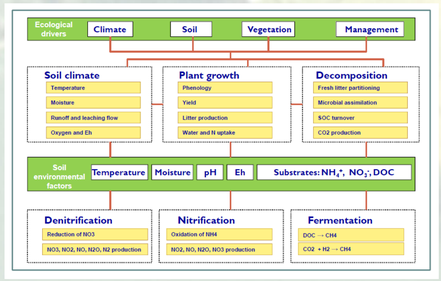
Background

Abstract

The California Air Resources Board (ARB) Compliance Offset Protocol for Rice Cultivation Projects requires high-level technical knowledge to implement and has large data input specifications. The DNDC Modeling and Reductions Calculator Tool website, designed and built by Applied Geosolutions, supports the Protocol and greatly simplifies the data acquisition and entry process. The Protocol relies on the use of process-based modeling of rice farms using the Denitrification-Decomposition model (DNDC), a biogeochemical model developed over 25 years at the University of New Hampshire. DNDC models agricultural soil processes and simulations greenhouse gas emissions like methane, nitrous oxide, and carbon dioxide, as well as crop yield. DNDC has intensive data requirements, but through the use of the Tool, users have access to a data management system customized for the Protocol, are not burdened by external data acquisition (soil and weather data are automatically acquired based on location), and do not need specific knowledge of DNDC. The Tool has an intuitive interface with a logical workflow that allows users to enter and store crop management data, creates inputs formatted for DNDC, and calibrates crop characteristics based on Protocol specifications, and calculates greenhouse gas (GHG) reductions based on model results. In addition, the Tool is built using entirely open-source tools with minimal licensing fees: the website framework was designed in Django, a model-view-controller (MVC) written in the Python programming language; web pages are HTML styled with CSS enhanced by Javascript components; the Tool's database is built with PostgreSQL with the PostGIS

US Rice GHG Offset Protocols

The State of California has committed to reducing GHG emissions to 1990 levels by 2020 to 80% 1990 by 2050. Its cap-and-trade program is one strategy that will help meet its reduction goals – mitigation of emissions from rice production (principally methane) will add to the cap-and-trade program and is defined as part of the *Compliance Offset Protocol for Rice Cultivation*. Producers or their representatives can generate carbon credits by changing rice management and reducing emissions under the oversight of the Protocol. Similar emissions mitigation protocols exist outside of the California regulatory environment through the American Carbon Registry (and their *Voluntary Emission Reductions in Rice Management Systems* methodology) as well as the Climate Action Reserve (and their *Rice Cultivation Project Protocol*).

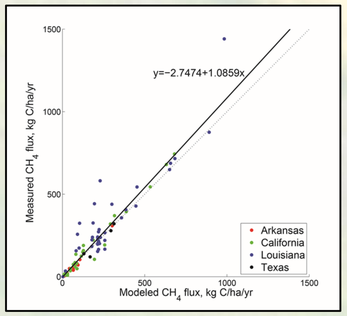


DNDC Model

The Denitrification-Decomposition (DNDC) model performs process-based simulations of nitrogen and carbon dynamics in agroecosystems. Based on environmental drivers (inputs like soil characteristics, temperature and precipitation data, crop characteristics, and crop management) the model predicts crop growth and yield, greenhouse gas emissions (such as carbon dioxide, methane, and nitrous oxide), and other environmental effects (like nitrogen leaching and runoff). DNDC is used widely around the world and has been tested against many field datasets in the US and abroad.

US Rice Validation for DNDC

To test DNDC's ability to simulate methane (CH_4) emissions from US rice fields, experimental field data and accompanying management data were extracted from 15 published, peer-reviewed field experiments and two unpublished datasets. This resulted in a database of 12 sites across the 1989 to 2012 timeframe for a total of 88 site-years over four states: Arkansas (13 site-years), California (31 site-years), Louisiana (40 site-years), and Texas (4 site years). Experimental treatments represented a wide range of management and included numerous fertilizer nitrogen forms and rates and methods of flood water and residue management. When modeled CH4 flux was regressed on field-measured flux the r2 value was 0.92 and the model exhibited low bias. Model structural uncertainty is relatively low and resulted in a 12.8% reduction over any given project area.



Tool Design

Website features

- User management and permissions
- Rice field delineation
- Weather data acquisition
- Soils data acquisition
- Definition of cultivation years
- Crop management and yield data entry
- Crop parameter calibration
- Generation of DNDC model inputs & site uncertainty via Monte Carlo method
- Post-processing DNDC simulation results
- Calculation of GHG reductions
- Reporting results

Ancillary databases

The tool automatically downloads and pre-processes required DNDC physical inputs:

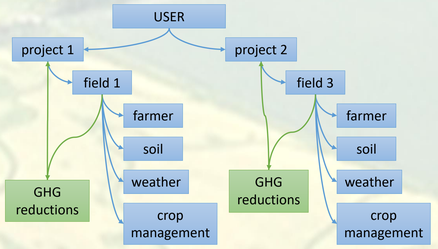
Soil (SSURGO / STATSGO)

Both SSURGO and STATSGO datasets have been subset by the rice growing regions and made part of the PostgreSQL and PostGIS database.

Weather (PRISM)

Similarly to the soil data, PRISM climate data has been subset by rice growing regions and converted into relational tables for querying.

Conceptual data structure



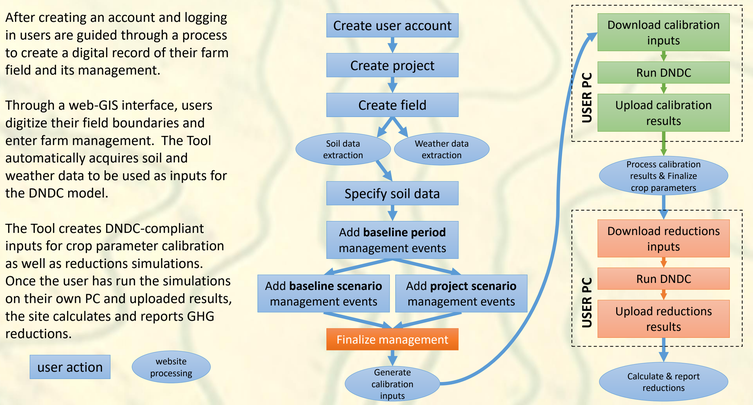
Users access all data under their purview
Users create/access data for one or more project
Projects are associated with exactly one user
Projects include one or more landowners
Landowners (effectively OPOs) are associated with exactly one user
Landowners must have one or more fields
Fields are associated with exactly one Landowner and exactly one project
Events are associated with exactly one field and exactly one cultivation year
Events include all aspects of crop management:
Planting
Harvesting (including crop cutting)
Tillage
Fertilization
Organic amendment
Irrigation
Flooding
Straw burning
Each event has a specific date

User workflow

After creating an account and logging in users are guided through a process to create a digital record of their farm field and its management.

Through a web-GIS interface, users digitize their field boundaries and enter farm management. The Tool automatically acquires soil and weather data to be used as inputs for the DNDC model.

The Tool creates DNDC-compliant inputs for crop parameter calibration as well as reductions simulations. Once the user has run the simulations on their own PC and uploaded results, the site calculates and reports GHG reductions.



Website framework

The website was built using Django, a model-view-controller (MVC) framework. Django's models are a relational data structure which make it easy to view and manipulate the underlying data input by the user. Database views perform all of the logic and calculations that the tool requires. The controller maps URLs to the appropriate website pages.

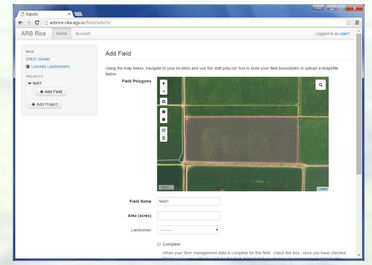
Code base

All of the back-end Django components are written in the Python programming language. The web pages themselves are HTML and styled with CSS. In addition, some pages contain Javascript components which provide reactive user interface improvements.

Database

The website uses a PostgreSQL database with the PostGIS extension. PostGIS adds spatial capabilities to the database and allows the website to store geospatial objects as well as perform spatial queries.

User Experience

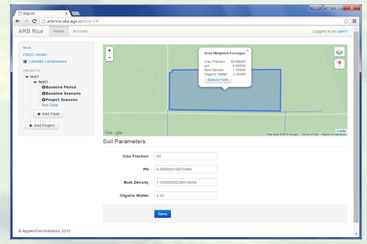


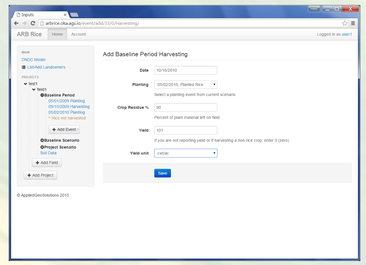
Fields

Fields are located and delineated via web-GIS or vector data upload. The website has a web-GIS interface that allows the user to digitize field boundaries over map and aerial photo data. Alternatively, the user can upload vector data (e.g. shapefile format) that represents the field's boundaries. In either case, the user can either accept auto-calculated area for that field or enter the actual area in the case where the actual area differs from the calculated area. Fields automatically determine their Rice Growing Region (CA, Mississippi River Delta/MRD, or Louisiana Gulf Coast/LGC) based on location.

Soil & Weather

Soil and weather data are automatically calculated for each field. The website has a service that calculates the intersection between field boundaries and NRCS SSURGO or STATSGO soil map units. The service calculates the relevant volume-weighted top-soil (10 cm) attributes for the map unit – relevant soil attributes include clay fraction (a proxy for soil texture), organic matter (used to calculate soil organic carbon), bulk density, and pH. The user can either accept auto-calculated soil attributes or can enter their own data based on field tests or other databases. Weather data are automatically acquired for each field. The website has a service that identifies the nearest PRISM pixel based on the field's centroid.



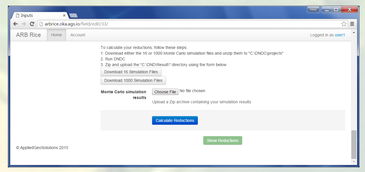


Crop Management

For each field, the user defines crop management. This simply involves adding a series of events as they occurred in the field. The screen to the left shows an example of specifying a rice crop, its harvest date, and yield.

DNDC Inputs

When a field and its management is completely defined, the Tool automatically creates DNDC-compliant inputs for crop parameter calibration and reductions simulations. DNDC simulations are run on the user's PC.



Reductions Calculations

The Tool accepts uploaded raw model output and calculates Protocol-compliant GHG reductions. Reductions are calculated on a field-by-field basis (below, left) and are summed at the project level (below, right)