A User-friendly Model for Predicting Greenhouse Gas Fluxes and Carbon Storage in Tidal Wetlands

fact SHEET

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Bringing Wetlands to Market
Nitrogen & Coastal Blue Carbon

Why Is a Model Needed?

Tidal wetlands play a critical role in soil-atmospheric exchanges of the greenhouse gases (GHGs) of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). A delicate balance in climate, land uses, hydrology and other ecological drivers determine the role of wetlands as the net source or sink of GHGs, eventually determining whether wetlands mitigate or contribute to global warming. An accurate assessment of whether a tidal wetland is acting as a source or sink of carbon requires intensive field sampling with very expensive gas analyzers. Modeling GHG fluxes and carbon(C) storage in tidal wetlands can be very helpful to end users as it reduces the need to conduct this type of intensive field work at every location. A robust and tested user-friendly model is, therefore, needed to:

- Predict wetland GHG fluxes and C sequestration under various climate change and sea level rise scenarios, thereby, facilitating an appropriate management of C stocks in tidal wetlands and their incorporation into carbon markets.
- Reduce the cost of wetland C and GHG flux monitoring by estimating the fluxes and potential C storage from a small set of climatic and environmental drivers (e.g., light, temperature, water depth, salinity).
- Aid the development of appropriate GHG offset protocols for setting monitoring and verification guidelines for tidal wetland restoration and maintenance projects.

Beneficiaries and Users:

Coastal managers, land managers, restoration practitioners, Federal, state, and local agencies, conservation organizations, policymakers, and educators.

About the BWM Wetland C and GHG Model

The BWM wetland C and GHG model is a non-linear empirical model developed by fitting data from four different wetlands of Waquoit Bay, MA, representing biogeochemical and ecological variation. A multivariate data-analytic framework was utilized to select the dominant process variables as model inputs. The model uses soil temperature (ST), soil salinity (SS), water depth relative to marsh elevation (WD), and light (PAR) as inputs to predict the corresponding CO_2 and CH_4 fluxes. The model estimates the potential carbon storage both in gramC/m^2 and metric tonC/hectare by up-scaling the instantaneous predicted fluxes to the growing season and accounting for the lateral C fluxes between the wetland and estuary.

The model is presented in a single, simple Excel spreadsheet as a user-friendly engineering tool for coastal carbon management without requiring much input data. The BWM model is a novel and first available empirical (or data-based mechanistic) tool for estimating and predicting GHG fluxes and C storage from tidal wetlands using a minimal amount of observational data.

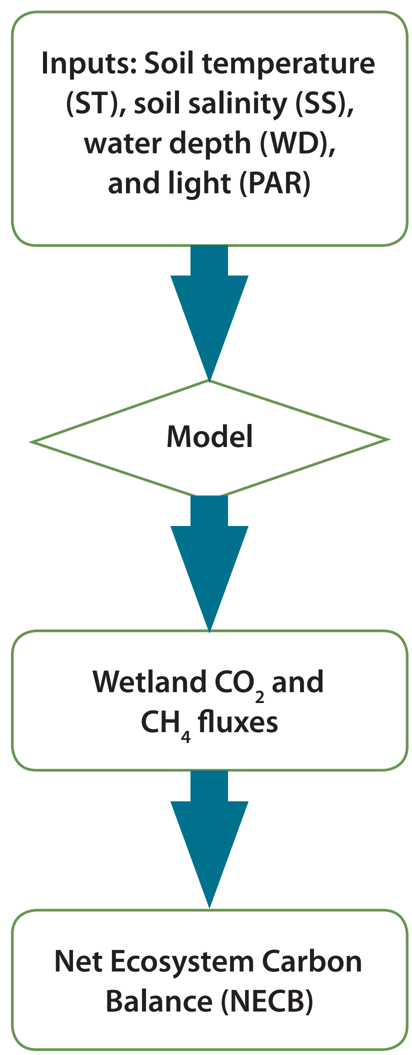

FIGURE 1: MODEL SCHEMATIC

Using the Model

Assumptions and Boundary Conditions: The model makes the following assumptions:

- Coastal salt marshes are productive mainly during the extended growing season (e.g., May to October);
- Tidal wetlands CH_4 fluxes mainly represent CH_4 emissions to the atmosphere;
- The model is appropriate for the Cape Cod tidal salt marshes. However, it can be used for New England tidal wetlands given similar wetland regimes (e.g., PAR range of 0 to 2100 micromole/

m^2/s, soil temperature range of 0 to 35°C, salinity of 10 to 40 parts per thousand, and water depth of up to 0.50 m (or more) above and below the marsh surface);

- The net ecosystem carbon balance (NECB) represents the potential C storage in wetlands. NECB = CO_2 sequestration flux- CO_2 and CH_4 emission flux - lateral C flux.

Input Variables in a Nutshell: The model will require data for the following input variables and parameters:

- Photosynthetically active radiation (PAR, units: micromole/m^2/s)
- Soil temperature (ST, units: °C)
- Soil salinity (SS, units: parts per thousand)
- Water depth relative to the marsh elevation (WD, units: m)

Measurements Needed:

- To run the model, at least 2 sets of inputs measurements are required: (a) Average (over the growing period) daytime soil temperature (ST), soil salinity (SS), water depth relative to marsh elevation (WD), and PAR; and (b) average (over the growing period) nighttime ST, SS, and WD.
- It is recommended to use 6 sets of observations (with a minimum acceptable set of 2 observations); that represent entire growing season to predict GHG fluxes. The more input data used the more representative the model predictions will be.
- Daytime is defined as any time of the day between 10 AM to 6 PM when PAR is greater than 300 micromole/m^2/s. Anytime otherwise with PAR<300 will represent nighttime data.
- Although the 300 mircomole/m^2/s is given here as an example threshold of PAR to distinguish between daytime and nighttime conditions, flexibility is provided in the excel spreadsheet to select any threshold PAR value from 0 - 900 micromole/m^2/s.
- Water depth (WD) is measured relative to the soil surface (units: m). If WD is above the soil surface, the sign of WD is positive and negative otherwise.
- Positive sign of predicted GHG fluxes indicates sequestrations (atmosphere to soil) and negative sign indicates emissions.
- If users wish to quantify the CH_4 emission fluxes and the NECB based on IPCC recommended 20 year and 100 year CO_2 equivalent global warming potential (GWP), they can use either 86 or 34 from the dropdown box of "Enter CO_2 equivalent global warming potential for CH_4". However, users can select 1.0 from the dropdown box to estimate the actual CH_4 emission and NECB.
- Users can choose to input the desired number of days in excel spreadsheet for which they want to estimate the wetland GHG fluxes and NECB.

Model Outputs: The model will produce five different outputs:

- Predicted CO_2 and CH_4 fluxes from the wetland,
- Net vertical CO_2 and CH_4 fluxes over the user defined growing period (i.e., up-scaled values), and
- Net ecosystem carbon balance (NECB) over the user defined period in units of gC/m^2 and metric tonC/hectare.

INPUT SET	DESCRIPTION
1, 2	Daytime and nighttime average of the input variables at the beginning of the growing period (May-June)
3, 4	Daytime and nighttime averages at the peak of the growing period (July-August)
5, 6	Daytime and nighttime average at the end of the growing period (September-October)

FIGURE 2: RECOMMENDED OBSERVATION SETS

Applying the Model: An Example

The example below illustrates how the model would work using two different scenarios:

1) a typical New England salt marsh and

2) a climate change scenario.

Model Inputs

Set 1: Daytime (PAR>300 umole/m^2/s)

Average Soil Temperature, ST = 20.43 °C
Soil Salinity, SS = 29.58 ppt
Light, PAR = 1454.29 micromole/m^2/s
Water Depth, WD = 0.07 m

Set 2: Nighttime (PAR>300 umole/m^2/s)

Average Soil Temperature, ST = 17.92 °C
Soil Salinity, SS = 30.67 ppt
Light, PAR = 32.52 micromole/m^2/s
Water Depth, WD = 0.067 m

Click the RUN button

OUTPUTS

(Assuming growing period from May to October and no lateral flux)

Net CO_2 sequestration = 514.54 gC/m^2
Net CH_4 emission = 0.16 gC/m^2
Net Ecosystem Carbon Balance = 514.38 gC/m^2 or 5.14 metric ton C/hectare

SCENARIO ANALYSIS

Scenario: 1% increase in daytime temperature (ST), 3% increase in nighttime ST, 0.05m increase in mean water (RD) due to sea level rise, and consequent 2% increase in salinity (SS).

Result: NECB will be 494.18 gC/m^2 or 4.94 metric ton C/hectare.

Interpretation: The assumed temperature and sea level will reduce 20.2 g/m^2 or 0.20 metric ton C/hectare from the baseline C storage for the wetland under consideration.

Future Research Goals

To enhance the capability of the model, future research will include further validation of the model with data from a broader range of marsh types and environmental conditions (e.g. higher salinities, nitrogen loads, and range of temperatures).

Download the Model:

http://www.waquoitbayreserve.org/research-monitoring/salt-marsh-carbon-project/

References

1. Abdul-Aziz, O.I. and Ishtiaq, K.S. (2014). "Robust modeling of greenhouse gas (GHG) fluxes from coastal wetland ecosystems." Presented at the American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, December 15-19.

2. Ishtiaq, K.S. and Abdul-Aziz, O.I. (2014). "Scaling for Robust Empirical Modeling and Predictions of Net Ecosystem Exchange (NEE) from Diverse Wetland Ecosystems". American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, December 15-20.

3. Abdul-Aziz, O.I. and Ishtiaq, K.S. (2014) (INVITED). "Empirical modeling and predictions of greenhouse gas fluxes from coastal wetlands: A data-analytics approach." Joint Aquatic Sciences Meeting 2014, Portland, Oregon, May 18-23.

4. Abdul-Aziz, O.I. and Ishtiaq, K.S. (2013). "Relative linkages of climatic and environmental drivers with net ecosystem exchanges of six diverse terrestrial ecosystems." American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, December 9-12.

5. Ishtiaq, K.S. and Abdul-Aziz, O.I. (2014). "Relative linkages of canopy-level CO_2 fluxes with the climatic and environmental variables for US deciduous forests." Environmental Management, DOI: 10.1007/s00267-014-0437-1.

Additional Information

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Learn More

User-Friendly Model for Predicting Greenhouse Gas Fluxes and Carbon Storage in Tidal Wetlands is part of a series of informational resources developed under the Bringing Wetlands to Market Project (BWM), which was led by the Waquoit Bay National Estuarine Research Reserve (WBNERR), The BWM Project examined the relationship between salt marshes, climate change, and nitrogen pollution and provided cutting edge science and tools to help coastal managers and policy makers leverage blue carbon to achieve broader wetlands management, restoration, and conservation goals through verified carbon markets and climate and conservation policy avenues. Learn more about the project and other available resources at: Bringing Wetlands to Market – Project Webpage: https://www.waquoitbayreserve.org/research-monitoring/salt-marsh-carbon-project/.

Bringing Wetlands to Market

Nitrogen & Coastal Blue Carbon

WAQUOIT BAY NATIONAL ESTUARINE RESEARCH RESERVE

National Estuarine Research Reserve System Science Collaborative

dcr Massachusetts

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Restore America's Estuaries

NERRA National Estuarine Research Reserve Association

USGS science for a changing world

FIU Florida International University

MBL Biological Discovery in Woods Hole
Founded in 1888 as the Marine Biological Laboratory

Manomet Center for Conservation Sciences

Waquoit Bay National Estuarine Research Reserve

The University of Rhode Island