Blue Carbon in Our Backyard

Hotel 1620 | *September 10, 2019*

Coastal Wetland Blue Carbon: State of the Science, Policy and What Comes Next

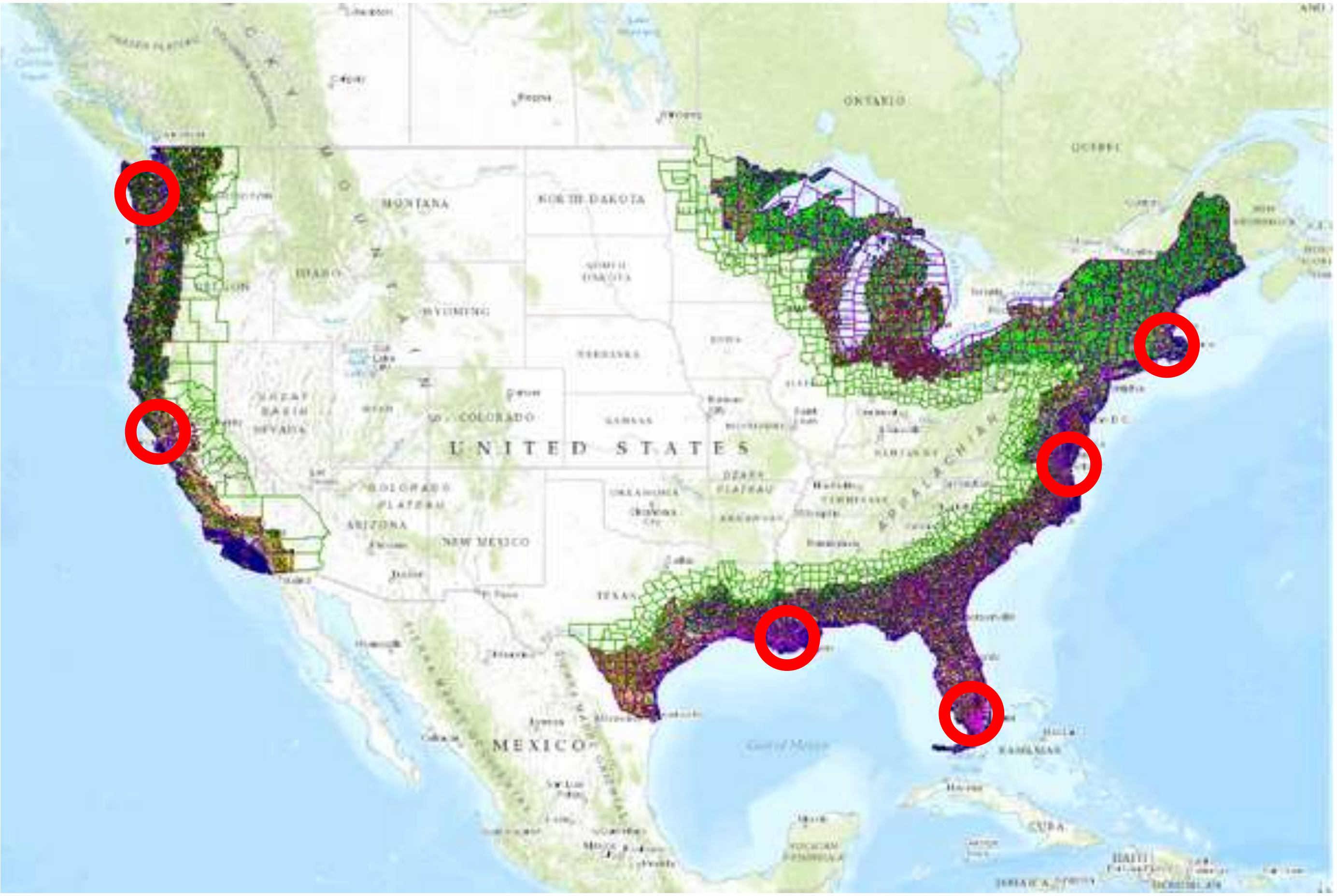
Dr. Ariana Sutton-Grier

University of Maryland

We have come a long way!

- State of Science
- Policy and Management connections
- Big picture thoughts on where the field needs to go…

Science: NASA Coastal Wetland Carbon Grant



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NASA grant of $1.7 M, PI at DOI/USGS

NASA Carbon Monitoring System Grant

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LETTER

Uncertainty in United States coastal wetland greenhouse gas inventorying

James R Holmquist[1,14], Lisamarie Windham-Myers[2], Blanca Bernal[1,3], Kristin B Byrd[4], Steve Crooks[5], Meagan Eagle Gonneea[6], Nate Herold[7], Sara H Knox[8], Kevin D Kroeger[6], John McCombs[9], J Patrick Megonigal[1], Meng Lu[1,13], James T Morris[10], Ariana E Sutton-Grier[11], Tiffany G Troxler[12] and Donald E Weller[1]

1 Smithsonian Environmental Research Center, 647 Contees Wharf Rd, Edgewater, MD 21037, United States of America
2 Water Mission Area, US Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, United States of America
3 Winrock International, 2121 Crystal Drive, Arlington, VA 22202, United States of America
4 Western Geographic Science Center, US Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, United States of America
5 Silvestrum Climate Associates, 150 Seminary Drive, Mill Valley, CA 94941, United States of America
6 Woods Hole Coastal & Marine Science Center, US Geological Survey, 384 Woods Hole Rd., Woods Hole, MA 02543, United States of America

Biggest Sources of Uncertainty: Palustrine Methane Emissions and Depth Lost to Erosion

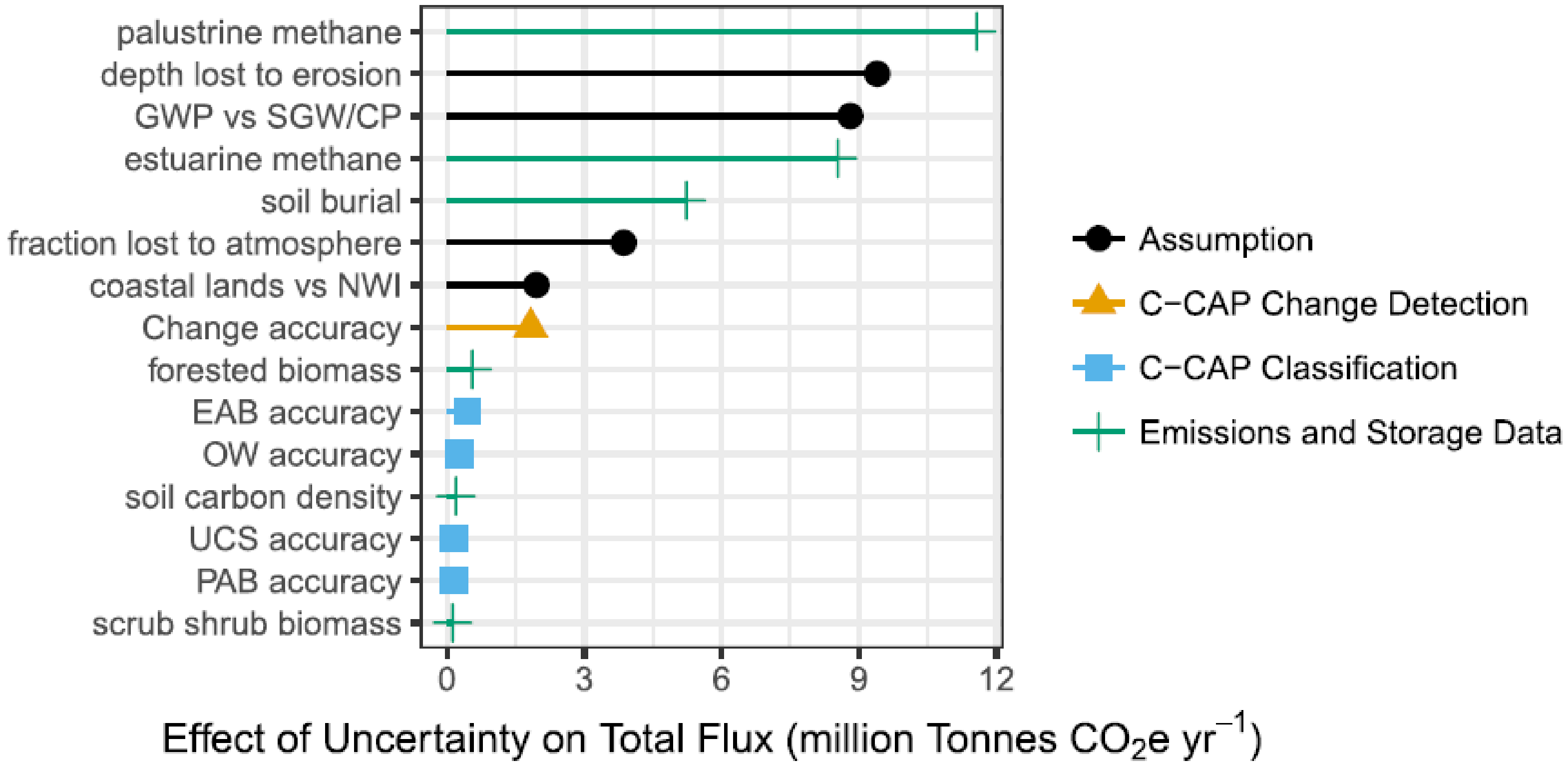


Figure 7. These fifteen inputs introduced the most uncertainty into the Coastal Wetland National Greenhouse Gas Inventory (NGGI) according to a one-at-a-time sensitivity analysis. GWP: global warming potential, SGWP: sustained GWP, SGCP: sustained global cooling potential, NWI: National Wetlands Inventory, EAB: estuarine aquatic bed, OW: open water, UCS: unconsolidated shore, PAB: palustrine aquatic bed.

Abdul-Aziz et al. (2018): Waquoit Bay

AGU100 ADVANCING EARTH AND SPACE SCIENCE

JGR

Journal of Geophysical Research: Biogeosciences

RESEARCH ARTICLE

10.1029/2018JG004556

Environmental Controls, Emergent Scaling, and Predictions of Greenhouse Gas (GHG) Fluxes in Coastal Salt Marshes

Omar I. Abdul-Aziz[1], **Khandker S. Ishtiaq**[1], **Jianwu Tang**[2], **Serena Moseman-Valtierra**[3], **Kevin D. Kroeger**[4], **Meagan Eagle Gonneea**[4], **Jordan Mora**[5], **and Kate Morkeski**[6]

[1]Ecological and Water Resources Engineering Laboratory (EWREL), Department of Civil and Environmental Engineering, West Virginia University, Morgantown, WV, USA, [2]The Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA, USA, [3]Department of Biological Sciences, University of Rhode Island, Kingston, RI, USA, [4]Woods Hole Coastal and Marine Science Center, U.S. Geological Survey, Woods Hole, MA, USA, [5]Waquoit Bay National Estuarine Research Reserve, Waquoit, MA, USA, [6]Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, MA, USA

Key Points:
- Coastal salt marshes in Cape Cod, Massachusetts, USA, exhibited high net CO_2 uptake and low CH_4 emission
- Soil temperature was the strongest driver of the GHG fluxes, which had weak linkages with well water level, soil moisture, and porewater pH
- Emergent power law-based scaling models successfully predicted the GHG fluxes from light (PAR), soil temperature, and porewater salinity

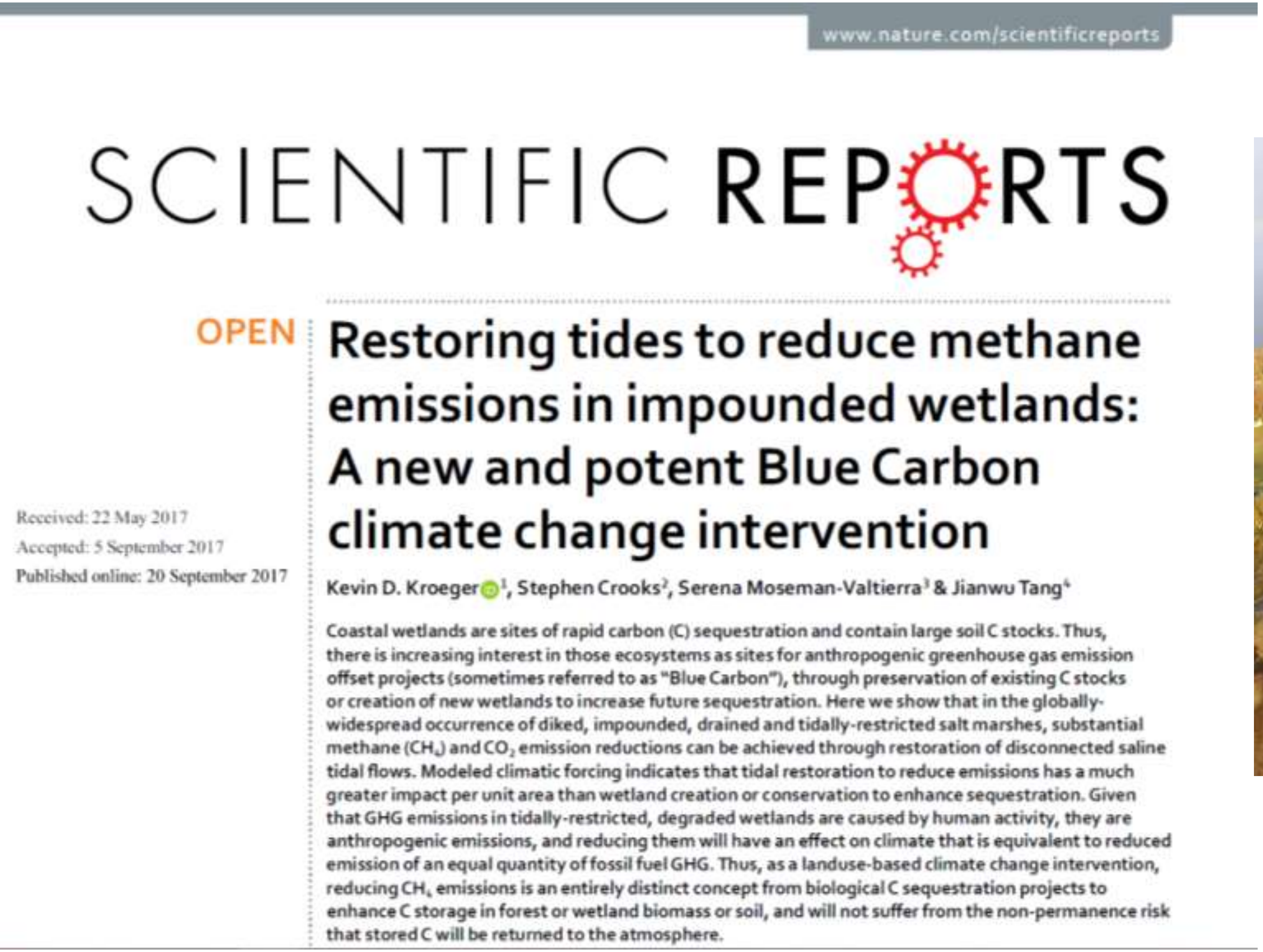
Supporting Information:
- Supporting Information S1

Correspondence to:
O. I. Abdul-Aziz,
oiabdulaziz@mail.wvu.edu;
omariaaziz@gmail.com

Citation:

Abstract Coastal salt marshes play an important role in mitigating global warming by removing atmospheric carbon at a high rate. We investigated the environmental controls and emergent scaling of major greenhouse gas (GHG) fluxes such as carbon dioxide (CO_2) and methane (CH_4) in coastal salt marshes by conducting data analytics and empirical modeling. The underlying hypothesis is that the salt marsh GHG fluxes follow emergent scaling relationships with their environmental drivers, leading to parsimonious predictive models. CO_2 and CH_4 fluxes, photosynthetically active radiation (PAR), air and soil temperatures, well water level, soil moisture, and porewater pH and salinity were measured during May–October 2013 from four marshes in Waquoit Bay and adjacent estuaries, MA, USA. The salt marshes exhibited high CO_2 uptake and low CH_4 emission, which did not significantly vary with the nitrogen loading gradient ($5–126\ kg \cdot ha^{-1} \cdot year^{-1}$) among the salt marshes. Soil temperature was the strongest driver of both fluxes.

Kroeger et al. (2017)



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SCIENTIFIC REPORTS

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Restoring tides to reduce methane emissions in impounded wetlands: A new and potent Blue Carbon climate change intervention

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Published online: 20 September 2017

Kevin D. Kroeger[1], Stephen Crooks[2], Serena Moseman-Valtierra[3] & Jianwu Tang[4]

Coastal wetlands are sites of rapid carbon (C) sequestration and contain large soil C stocks. Thus, there is increasing interest in those ecosystems as sites for anthropogenic greenhouse gas emission offset projects (sometimes referred to as "Blue Carbon"), through preservation of existing C stocks or creation of new wetlands to increase future sequestration. Here we show that in the globally-widespread occurrence of diked, impounded, drained and tidally-restricted salt marshes, substantial methane (CH_4) and CO_2 emission reductions can be achieved through restoration of disconnected saline tidal flows. Modeled climatic forcing indicates that tidal restoration to reduce emissions has a much greater impact per unit area than wetland creation or conservation to enhance sequestration. Given that GHG emissions in tidally-restricted, degraded wetlands are caused by human activity, they are anthropogenic emissions, and reducing them will have an effect on climate that is equivalent to reduced emission of an equal quantity of fossil fuel GHG. Thus, as a landuse-based climate change intervention, reducing CH_4 emissions is an entirely distinct concept from biological C sequestration projects to enhance C storage in forest or wetland biomass or soil, and will not suffer from the non-permanence risk that stored C will be returned to the atmosphere.

Main Findings:

- US coastal wetlands are a sink for greenhouse gases
- Loss of wetlands is a growing source; loss mostly in the Gulf
- A lot less restoration is occurring than loss
- Accomplished this with globally available Landsat data and the Wetlands Supplement → other countries can do this, too

nature climate change

ARTICLES

https://doi.org/10.1038/s41558-018-0345-0

Coastal wetland management as a contribution to the US National Greenhouse Gas Inventory

Stephen Crooks[1*], Ariana E. Sutton-Grier[2,3,8], Tiffany G. Troxler[4], Nathaniel Herold[5], Blanca Bernal[6,9], Lisa Schile-Beers[1] and Tom Wirth[7]

The IPCC 2013 Wetlands Supplement provided new guidance for countries on inclusion of wetlands in their National GHG Inventories. The United States has responded by including managed coastal wetlands for the first time in its 2017 GHG Inventory report along with an updated time series in the most recent 2018 submission and plans to update the time series on an annual basis as part of its yearly submission to the United Nations Framework Convention on Climate Change (UNFCCC). The United States followed IPCC Good Practice Guidance when reporting sources and sinks associated with managed coastal wetlands. Here we show that intact vegetated coastal wetlands are a net sink for GHGs. Despite robust regulation that has protected substantial stocks of carbon, the United States continues to lose coastal wetlands to development and the largest loss of wetlands to open water occurs around the Mississippi Delta due mostly to upstream changes in hydrology and sediment delivery, and oil and gas extraction. These processes create GHG emissions. By applying comprehensive Inventory reporting, scientists in the United States have identified opportunities for reducing GHG emissions through restoration of coastal wetlands that also provide many important societal co-benefits.

The IPCC's 2013 Wetlands Supplement provided additional guidance for countries to include wetlands in their national GHG inventories. The United States has responded to this opportunity by including managed coastal wetlands in its 2017 GHG Inventory report and subsequently including wetland data in the 2018 Inventory. The plan is to update the time series on an annual basis as part of the yearly submission of the United States to the UNFCCC. Here we show that it is possible to use publicly available data to incorporate coastal wetlands into national

in which countries can report GHG emissions and sinks; all other Inventory sectors only report sources of GHGs.

When the 2006 IPCC Guidelines were developed, many wetlands were not included because the science was considered to be insufficient to produce globally applicable default values on GHG emissions and removals due to human activities. The 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands[4] (Wetlands Supplement) helped to fill this gap. Countries currently have an opportunity (not a require-

Needelman et al. (2018)

Estuaries and Coasts
https://doi.org/10.1007/s12237-018-0429-0

MANAGEMENT APPLICATIONS

The Science and Policy of the Verified Carbon Standard Methodology for Tidal Wetland and Seagrass Restoration

Brian A. Needelman [1] · Igino M. Emmer [2] · Stephen Emmett-Mattox [3] · Stephen Crooks [4] · J. Patrick Megonigal [5] · Doug Myers [6] · Matthew P. J. Oreska [7] · Karen McGlathery [7]

Received: 4 August 2017 / Revised: 15 May 2018 / Accepted: 3 June 2018

Abstract
The restoration of tidal wetland and seagrass systems has the potential for significant greenhouse gas benefits, but project-level accounting procedures have not been available at an international scale. In this paper, we describe the Verified Carbon Standard Methodology for Tidal Wetland and Seagrass Restoration, which provides greenhouse gas accounting procedures for marsh, mangrove, tidal forested wetland, and seagrasses systems across a diversity of geomorphic conditions and restoration techniques. We discuss and critique the essential science and policy elements of the methodology and underlying knowledge gaps. We developed a method for estimating mineral-protected (recalcitrant) allochthonous carbon in tidal wetland systems using field-collected soils data and literature-derived default values of the recalcitrant carbon that accompanies mineral deposition. We provided default values for methane emissions from polyhaline soils but did not provide default values for freshwater, oligohaline, and mesohaline soils due to high variability of emissions in these systems. Additional topics covered are soil carbon sequestration default values, soil carbon fate following erosion, avoided losses in organic and mineral soils, nitrous oxide emissions, soil profile sampling methods, sample size, prescribed fire, additionality, and leakage. Knowledge gaps that limit the application of the methodology include the estimation of CH_4 emissions from fresh and brackish tidal wetlands, lack of validation of our approach for the estimation of recalcitrant allochthonous carbon, understanding of carbon oxidation rates following drainage of mineral tidal wetland soils, estimation of the effects of prescribed fire on soil carbon stocks, and the analysis of additionality for projects outside of the USA.

Macreadie et al. (2017)

Can we manage coastal ecosystems to sequester more blue carbon?

Peter I Macreadie[1*], Daniel A Nielsen[2], Jeffrey J Kelleway[3,4], Trisha B Atwood[5], Justin R Seymour[3], Katherina Petrou[2], Rod M Connolly[6], Alexandra CG Thomson[3], Stacey M Trevathan-Tackett[1,3], and Peter J Ralph[3]

To promote the sequestration of blue carbon, resource managers rely on best-management practices that have historically included protecting and restoring vegetated coastal habitats (seagrasses, tidal marshes, and mangroves), but are now beginning to incorporate catchment-level approaches. Drawing upon knowledge from a broad range of environmental variables that influence blue carbon sequestration, including warming, carbon dioxide levels, water depth, nutrients, runoff, bioturbation, physical disturbances, and tidal exchange, we discuss three potential management strategies that hold promise for optimizing coastal blue carbon sequestration: (1) reducing anthropogenic nutrient inputs, (2) reinstating top-down control of bioturbator populations, and (3) restoring hydrology. By means of case studies, we explore how these three strategies can minimize blue carbon losses and maximize gains. A key research priority is to more accurately quantify the impacts of these strategies on atmospheric greenhouse-gas emissions in different settings at landscape scales.

Front Ecol Environ 2017; 15(4): 206–213, doi:10.1002/fee.1484

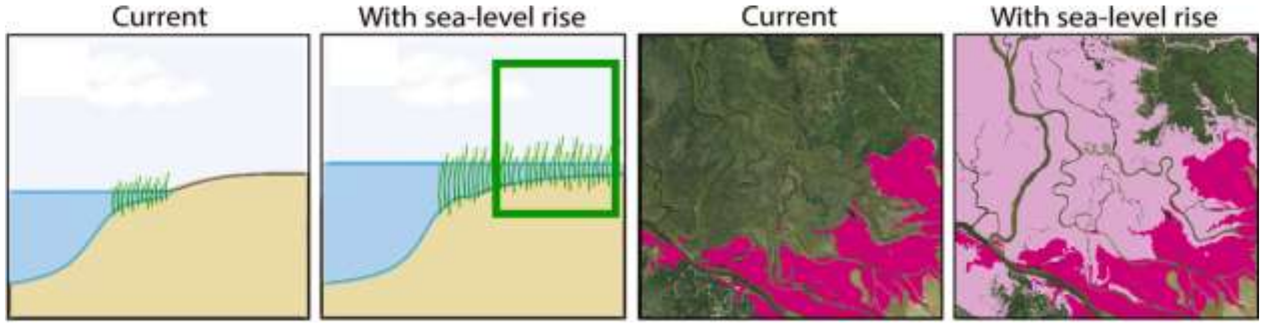
As the world begins its transition to a low-carbon economy, removing atmospheric carbon dioxide (CO_2) through biosequestration will be necessary to keep global warming under 2°C. Among the most efficient systems that provide biosequestration services are vegetated coastal habitats (VCHs), which include seagrasses, tidal marshes, and mangroves (Figure 1) and are known as "blue carbon" ecosystems (McLeod *et al.* 2011). VCHs occupy only 0.2% of the ocean surface, yet contribute 50% of the total amount of carbon buried in marine sediments (Duarte *et al.* 2013). They have the ability to accumulate carbon without reaching saturation, and can store it in sediments over millennial timescales (McLeod *et al.* 2011). As with important terrestrial carbon sinks (eg Amazonian forests, permafrost regions), ecosystem degradation can shift blue carbon ecosystems from carbon sinks to carbon sources (Pendleton *et al.* 2012).

Approximately one-half of the Earth's blue carbon

In a nutshell:

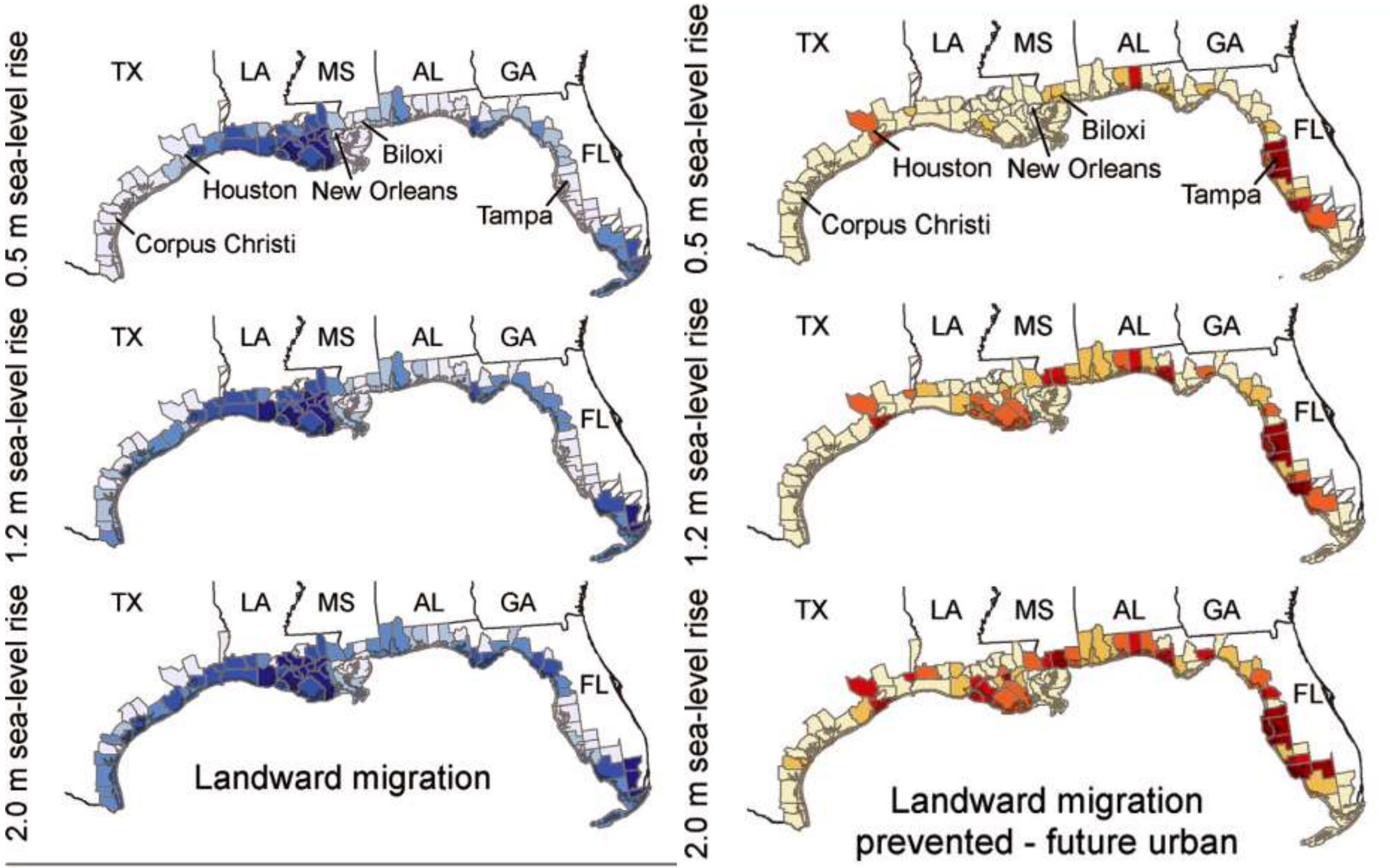
- Vegetated coastal habitats (seagrasses, tidal marshes, and mangroves) are important global sinks of organic "blue

Research on Future Blue Carbon



Enright et al. 2016. *Frontiers in Ecology and the Environment*

Future Blue Carbon Depends on Actions Now



Enright et al. 2016. *Frontiers in Ecology and the Environment*

NSF-Funded Coastal Carbon Research Coordination Network

Our goal is to accelerate the pace of discovery in coastal carbon science by serving a community of researchers and practitioners with data, tools and synthesis opportunities.

Coastal Carbon
Research Coordination Network

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Policy and Management Progress

Included coastal wetlands in voluntary carbon markets

- Verified Carbon Standard method to get carbon credits for coastal wetland restoration anywhere in the world (November 2015)
- VCS methodology for carbon credits for protection of coastal wetlands in review now

Blue Carbon: U.S. National Policy

Priority Agenda

Enhancing the Climate Resilience of America's Natural Resources

COUNCIL ON CLIMATE PREPAREDNESS AND RESILIENCE

Key Themes and Commitments Moving Forward:

This *Agenda* identifies four priority strategies to make the Nation's natural resources more resilient to a changing climate. For each strategy, the *Agenda* documents significant progress and provides a roadmap for action moving forward. Highlights of the key actions agencies will undertake in the near term to implement each of the four strategies are described below and in Table 1.

1. **Foster climate-resilient lands and waters** – Protect important landscapes and develop the science, planning, tools, and practices to sustain and enhance the resilience of the Nation's natural resources.

Key actions include the development of a Resilience Index[1] to measure the progress of restoration and conservation actions and other new or expanded resilience tools to support climate-smart natural resource management. Agencies will identify and prioritize landscape-scale conservation opportunities for building resilience; fight the introduction and spread of invasive species; and partner internationally to promote resilience within the Arctic. Throughout, agencies will evaluate resilience efforts to inform future actions.

2. **Manage and enhance U.S. carbon sinks** – Conserve and restore soils, forests, grasslands, wetlands, and coastal areas that store carbon. Maintain and increase the capacity of these areas to provide vital ecosystem services alongside carbon storage such as clean air and water, wildlife habitat, food, fiber, and recreation.

Key actions include the development of improved inventory, assessment, projection and monitoring systems for important carbon sinks and the development of estimates of baseline carbon stocks and trends to inform resource management. A number of actions will secure the continued health of the Nation's natural resources that provide carbon biosequestration, including forests, agricultural lands, and inland and coastal wetlands.

3. **Enhance community preparedness and resilience by utilizing and sustaining natural resources** – Harness the benefits of nature to protect communities from harm and build innovative 21st century infrastructure that integrates natural systems into community development.

Federal agencies will take action to encourage investment in natural infrastructure to improve resilience and enhance natural defenses through new federal guidance on ecosystem services assessment, an actionable research agenda, rigorous program evaluation, and expanded decision support tools and services. Federal agencies will increase assistance to states, tribes and localities interested in pursuing green stormwater management solutions and will expand partnerships that reduce wildfire risk and protect critical drinking water supplies, promote irrigation efficiency and water efficiency,

U.S. Coastal Wetland Carbon Work Group

- White House Priority Agenda Action
- NOAA, RAE, and EPA-led
- Use Wetlands Supplement guidelines;
  - Minimum Tier 1 assessment of coastal wetlands
  - Identify research gaps and needs
  - Based findings on NOAA Coastal Change Analysis Program (C-CAP) data, relevant scientific literature, and expert input

Coastal Wetlands in US Greenhouse Gas Inventory for the first time Spring 2017

The 2019 IPCC Refinements continues to suggest countries use the Wetlands Supplement and 2006 Guidance together

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Greenhouse Gas Emissions

- Greenhouse Gas Emissions
  - Overview of Greenhouse Gases
  - Sources of Greenhouse Gas Emissions
  - Global Emissions
  - National Emissions
  - Facility-Level Emissions
  - Carbon Footprint Calculator
  - GHG Equivalencies Calculator

Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015

View the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015* (published 2017), developed by the U.S. Government to meet U.S. commitments under the United Nations Framework Convention on Climate Change (UNFCCC).

This report was published in 2017. For a list of all archived reports, view the U.S. Greenhouse Gas Inventory Report Archive.

For the most recent report, view EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.

Download the Report Tables

- 2017 Main Report Tables (ZIP) (1 pg, 326 K)
- 2017 Annex Tables (ZIP) (1 pg, 324 K)

ENVIRONMENTAL STUDIES

Natural climate solutions for the United States

Joseph E. Fargione[1]*, Steven Bassett[2], Timothy Boucher[3], Scott D. Bridgham[4], Richard T. Conant[5], Susan C. Cook-Patton[3,6], Peter W. Ellis[3], Alessandra Falcucci[7], James W. Fourqurean[8], Trisha Gopalakrishna[3], Huan Gu[9], Benjamin Henderson[10], Matthew D. Hurteau[11], Kevin D. Kroeger[12], Timm Kroeger[3], Tyler J. Lark[13], Sara M. Leavitt[3], Guy Lomax[14], Robert I. McDonald[3], J. Patrick Megonigal[6], Daniela A. Miteva[15], Curtis J. Richardson[16], Jonathan Sanderman[17], David Shoch[18], Seth A. Spawn[13], Joseph W. Veldman[19], Christopher A. Williams[9], Peter B. Woodbury[20], Chris Zganjar[3], Marci Baranski[21], Patricia Elias[3], Richard A. Houghton[17], Emily Landis[3], Emily McGlynn[22], William H. Schlesinger[23], Juha V. Siikamaki[24], Ariana E. Sutton-Grier[25,26], Bronson W. Griscom[3]

Limiting climate warming to <2°C requires increased mitigation efforts, including land stewardship, whose potential in the United States is poorly understood. We quantified the potential of natural climate solutions (NCS)—21 conservation, restoration, and improved land management interventions on natural and agricultural lands—to increase carbon storage and avoid greenhouse gas emissions in the United States. We found a maximum potential of 1.2 (0.9 to 1.6) Pg CO_2e year^{-1}, the equivalent of 21% of current net annual emissions of the United States. At current carbon market prices (USD 10 per Mg CO_2e), 299 Tg CO_2e year^{-1} could be achieved. NCS would also provide air and water filtration, flood control, soil health, wildlife habitat, and climate resilience benefits.

INTRODUCTION

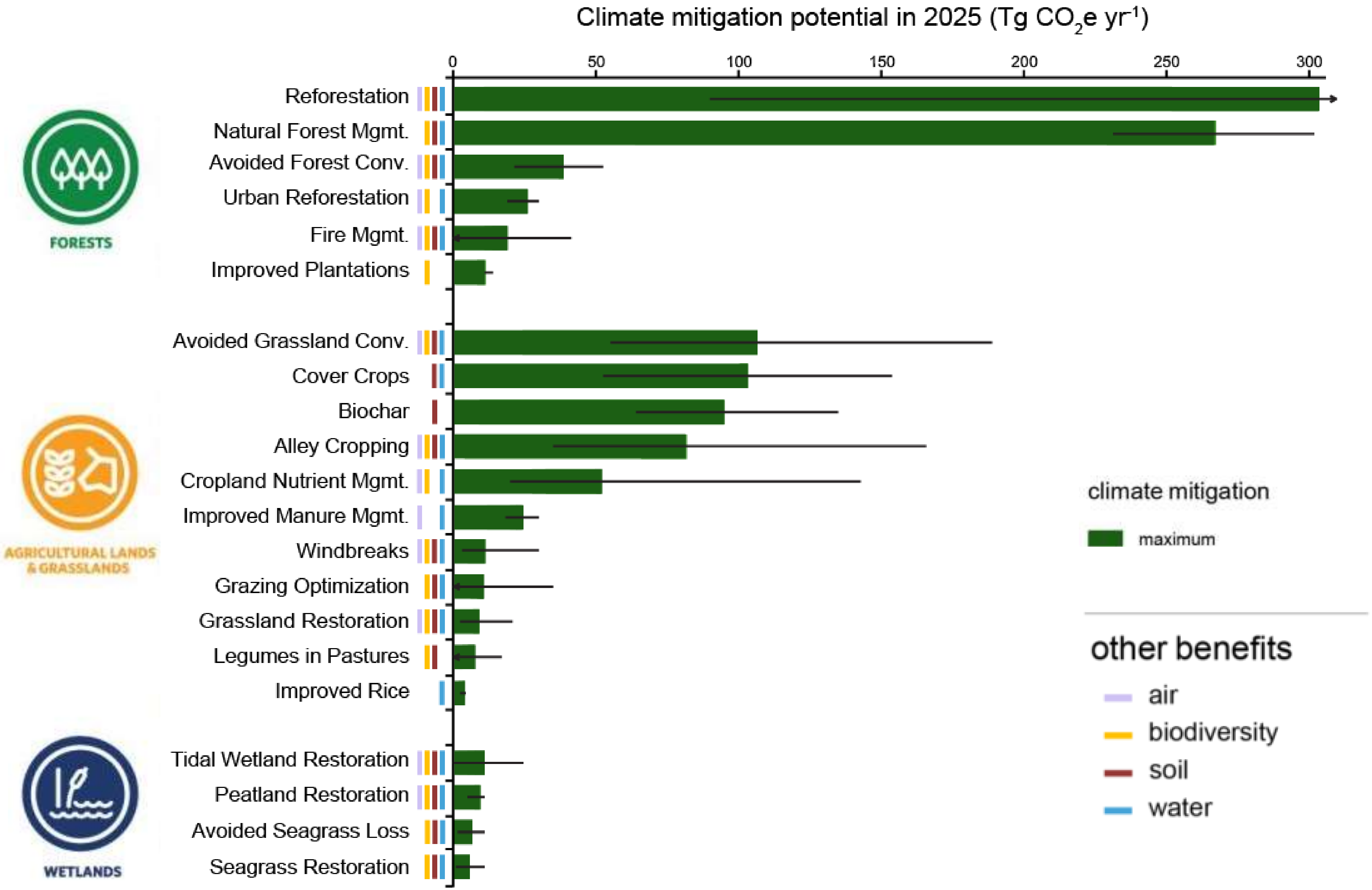
Limiting global warming below the 2°C threshold set by the Paris Climate Agreement is contingent upon both reducing emissions and removing greenhouse gases (GHGs) from the atmosphere (*1*, *2*). Natural climate solutions (NCS), a portfolio of discrete land stewardship options (*3*), are the most mature approaches available for carbon conservation and uptake compared to nascent carbon capture technologies (*4*) and could complement increases in zero-carbon energy production and energy efficiency to achieve needed climate change mitigation. Within the United States, the maximum and economically viable mitigation potentials from NCS are unclear.

Here, we quantify the maximum potential for NCS in the United

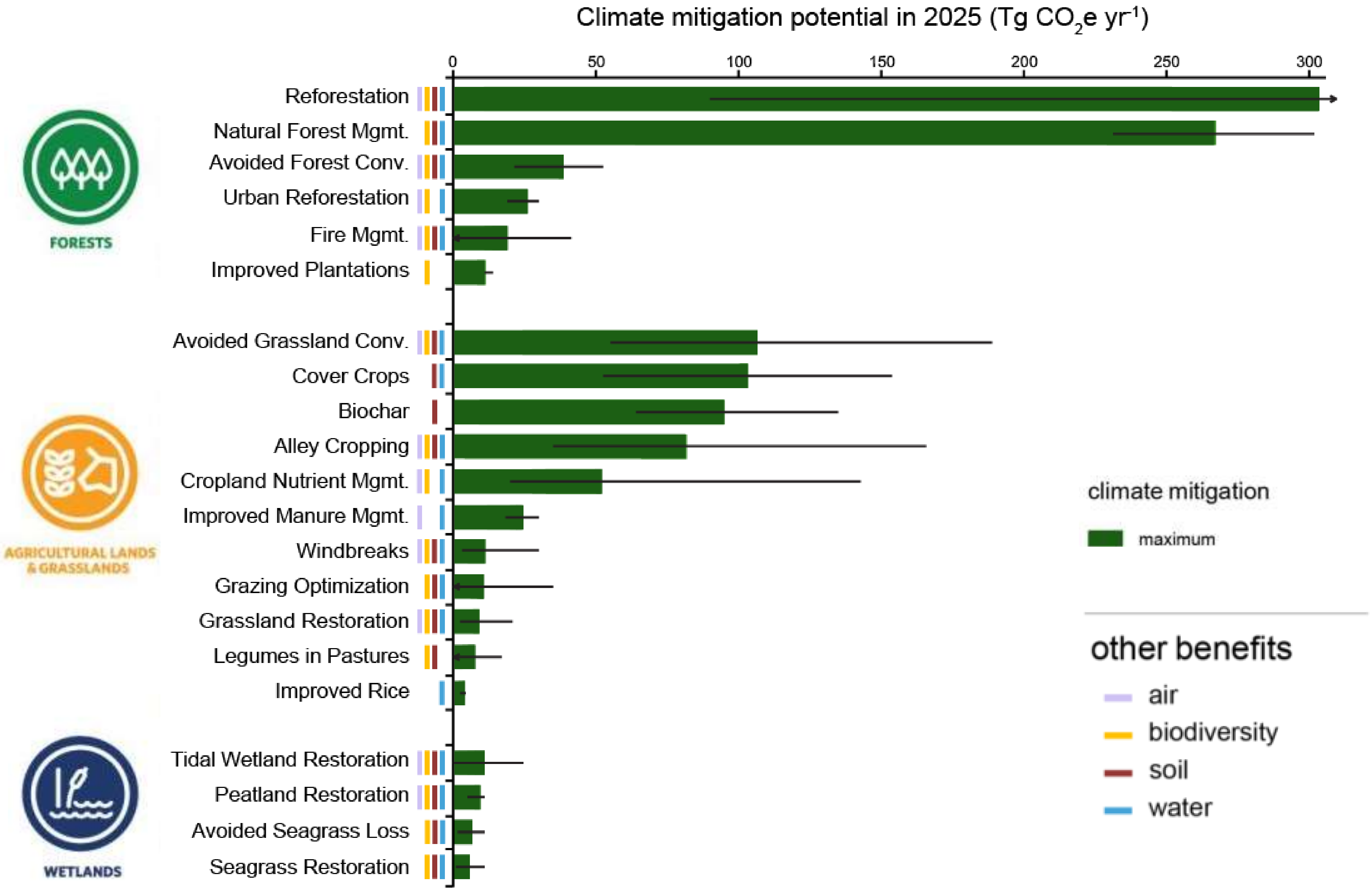
several price points. We consider 21 distinct NCS to provide a consistent and comprehensive exploration of the mitigation potential of conservation, restoration, and improved management in forests, grasslands, agricultural lands, and wetlands (Fig. 1), carefully defined to avoid double counting (details in the Supplementary Materials). We estimate the potential for NCS in the year 2025, which is the target year for the United States' Nationally Determined Contribution (NDC) under the Paris Agreement to reduce GHG emissions by 26 to 28% from 2005 levels. Our work refines a coarser-resolution global analysis (*3*) and updates and expands the range of options considered in previous analyses for the United States (*5*–*8*).

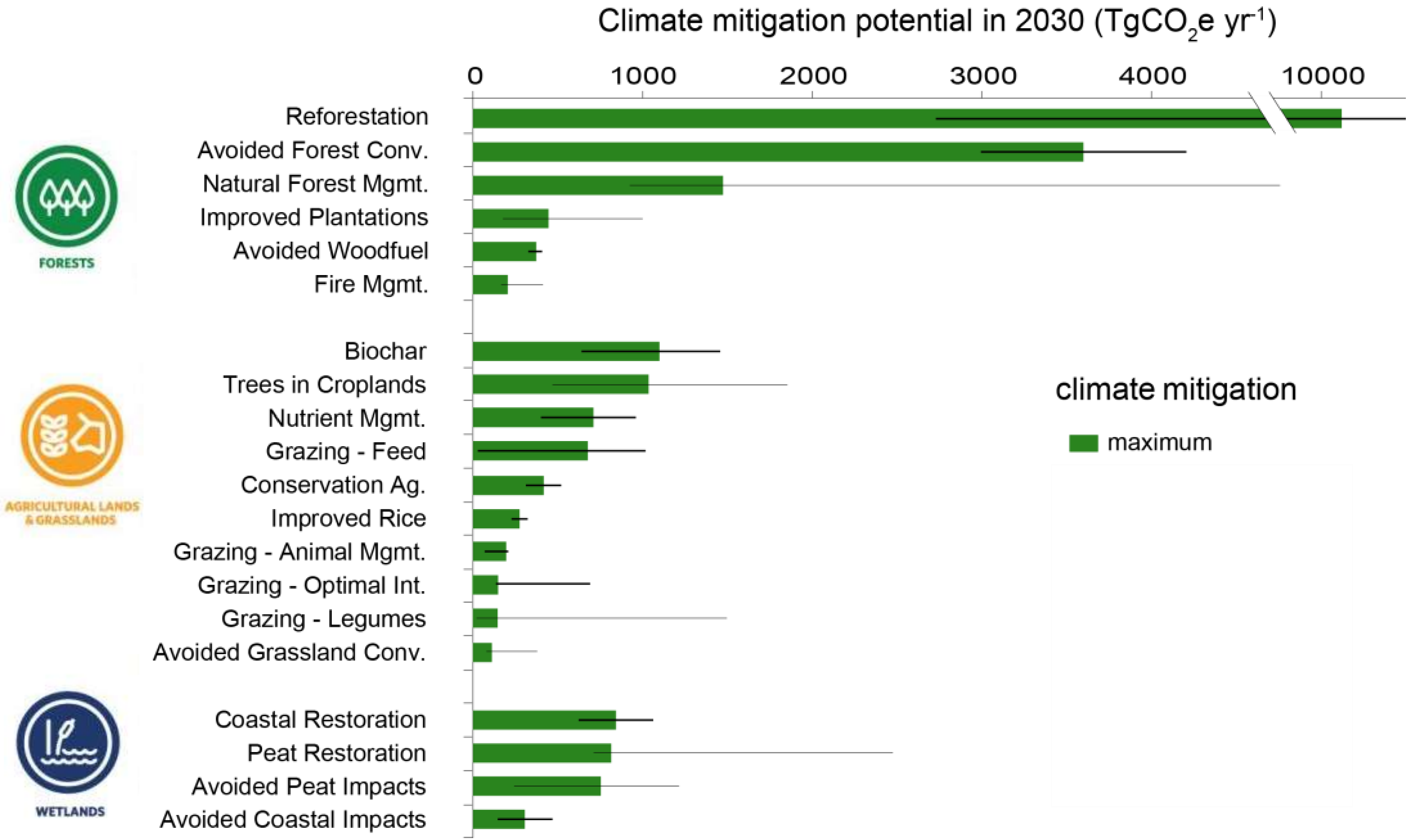
For each NCS opportunity (Fig. 1 and the Supplementary Materials),

1.2 Pg $CO_2e\ yr^{-1}$ ($100tC)



20% of US net emissions





Griscom et al. PNAS

More of these natural climate solutions national analyses underway

- China
- India
- Canada

Management: Blue Carbon Projects

Photo: Pamela D'Angelo

- 9,200 acres of eelgrass at the Virginia Coast Reserve (VCR) since 2009; trying to link to carbon markets to support more restoration
- Herring River tidal marsh restoration with greenhouse gas benefits

Next Steps

1) Keep doing policy-relevant science

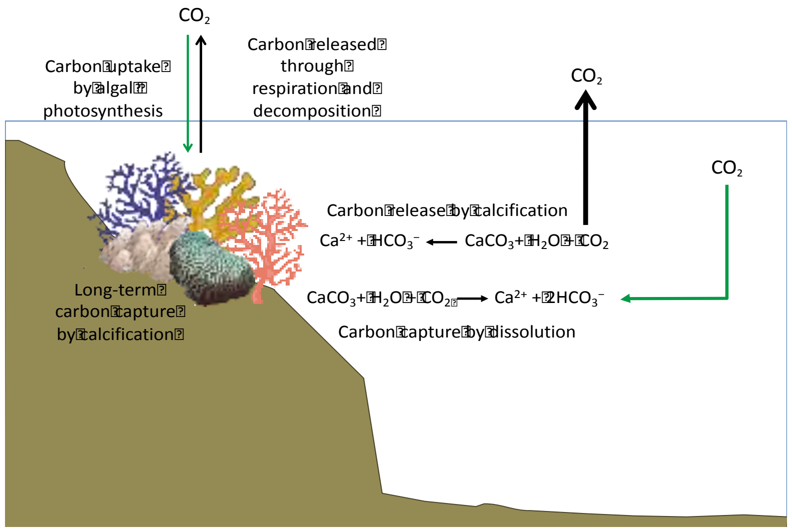
- Macroalgae??
- Methane!
- What happens to carbon in drowning wetlands or salt marsh invaded by mangroves?
- How to better track restoration projects and effectiveness of restoration?

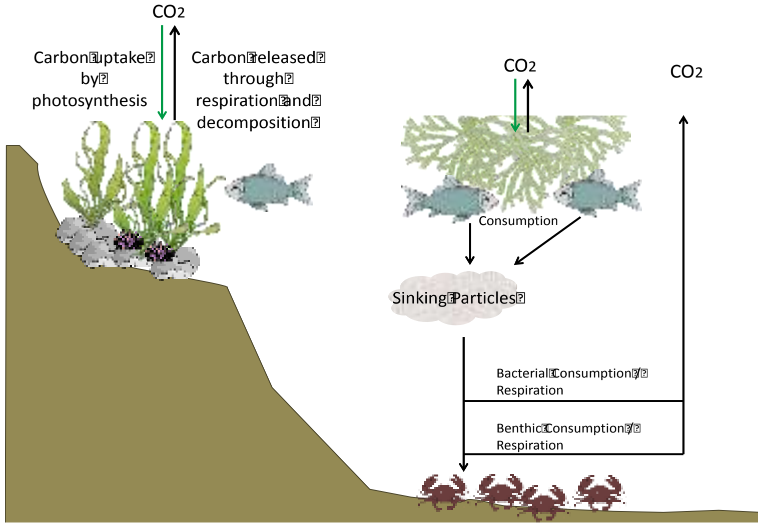
Clarifying the role of coastal and marine systems in climate mitigation

Jennifer Howard[1†*], Ariana Sutton-Grier[2,3†], Dorothée Herr[4], Joan Kleypas[5], Emily Landis[6], Elizabeth Mcleod[7], Emily Pidgeon[1], and Stefanie Simpson[8]

The international scientific community is increasingly recognizing the role of natural systems in climate-change mitigation. While forests have historically been the primary focus of such efforts, coastal wetlands – particularly seagrasses, tidal marshes, and mangroves – are now considered important and effective long-term carbon sinks. However, some members of the coastal and marine policy and management community have been interested in expanding climate mitigation strategies to include other components within coastal and marine systems, such as coral reefs, phytoplankton, kelp forests, and marine fauna. We analyze the scientific evidence regarding whether these marine ecosystems and ecosystem components are viable long-term carbon sinks and whether they can be managed for climate mitigation. Our findings could assist decision makers and conservation practitioners in identifying which components of coastal and marine ecosystems should be prioritized in current climate mitigation strategies and policies.

Front Ecol Environ 2017; 15(1): 42–50, doi:10.1002/fee.1451





Next Steps

- Continue to spread the word because many people still don’t know about the blue carbon benefit

09:12 PM, September 06, 2019 / LAST MODIFIED: 09:20 PM, September 06, 2019

Scientific hub to be established to protect ocean carbon ecosystems

Says Australian Foreign Minister Marise Payne

Next Steps

- Continue to think outside the box: What's possible? Innovate!
  - When and how can we connect blue carbon to people's lives and livelihoods to find more champions and more opportunities?
  - Where can we reduce sources or increase sinks with the least cost but with the most benefit?
  - How can we do coastal restoration at a larger scale without costs getting out of control?
  - Where are there additional partnerships we could develop to do more together?
  - How can we increase the price of carbon so more coastal wetland projects can become viable?

Wylie et al. 2016

Keep up the good work!

Coastal wetlands and communities everywhere are depending on us.

Thank you!

ariana.suttongrier@gmail.com
suttongrier.org

Section #2

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