Response to Gallagher (2022)—the Australian Tidal Restoration for Blue Carbon method 2022—conservative, robust, and practical

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Running Head

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Abstract

The Blue Carbon Accounting Model (BlueCAM) is a tool for tidal restoration projects established under the *Tidal Restoration for Blue Carbon method* (2022) of the Australian voluntary carbon market. The commentary of Gallagher (2022) discussed that BlueCAM did not subtract allochthonous carbon, which is carbon in wetland soils from external sources, either terrestrial or marine sources, from estimated net abatement. This approach was used because all organic carbon preserved in a restored wetland soil, irrespective of its source, is deposited because the wetland was restored, and thus all carbon preserved above the baseline is "additional". As restoration projects develop, further characterisation of different soil carbon fractions as suggested by Gallagher (2022) may improve BlueCAM. BlueCAM is transparent, conservative, and importantly is feasible for implementation, as well as being consistent with the Intergovernmental Panel for Climate Change guidelines for National Greenhouse Gas Inventories and the Australian legislative offsets integrity standards.

Implications for Practice

- The Blue Carbon Accounting Model (BlueCAM) is a tool for carbon accounting for tidal restoration. It is a simplified model at a regional scale that is devised to support implementation of tidal restoration projects in Australia.
- BlueCAM does not subtract allochthonous carbon from estimated net abatement because all carbon trapped in restored coastal wetlands is considered "additional" (a consequence of the restoration project), that simplifies carbon accounting.
- BlueCAM accounts for baseline carbon sequestration in freshwater wetlands and for greenhouse gas emissions from other baseline land uses using approaches consistent with the Australian Greenhouse Gas Inventory.

- BlueCAM is more likely to underestimate than overestimate abatement, meeting the requirements of the Australian offset integrity standards.

Introduction

The *Tidal Restoration for Blue Carbon method* (2022) and its accompanying modelling tool, the Blue Carbon Accounting Model (BlueCAM), is an Australian method for calculating climate change mitigation benefits (called abatement) arising from restoration of coastal wetlands for the Australian voluntary carbon market (Lovelock et al. 2022). It builds upon an extensive and growing body of Australian and international research confirming coastal wetlands are a carbon sink (e.g. Serrano et al. 2019, Rosentreter et al. 2023) and that their conservation and restoration is important for climate mitigation as well as for the range of co-benefit they provide, including enhancements in biodiversity, fisheries, water quality and climate change adaptation (Barbier et al. 2011), yet offers flexibility for incorporation of new or site-specific information that will improve the precision of estimates of carbon abatement over time. The method reflects the unique evolution, sea level history, climatic settings, and biodiversity of Australian coastal wetlands that differ significantly from those in the northern Hemisphere. The contributors to method development had expertise from a range of disciplines, as well as from across the geographic diversity of Australian coastal wetlands. Gallagher (2022) provided commentary on the *Tidal Restoration for Blue Carbon method* 2022 and BlueCAM, described in Lovelock et al. (2022). Here we provide clarification of points made by Gallagher (2022).

Responses

One of the key goals in method development for carbon markets is that methods must be practical as well as scientifically robust, a requirement that is described as a part of the co-design process for Australian method development (https://www.cleanenergyregulator.gov.au/ERF/method-development/developing-methods). Thus, the *Tidal Restoration for Blue Carbon method* strikes a balance between scientific rigour and uptake/participation in the method by investors, landholders, and project developers, by providing a modelled approach to estimating abatement that is conservative by design (i.e. likely to underestimate, rather than overestimate, carbon abatement outcomes). While some of the points raised by Gallagher (2022) are scientifically interesting (see below), they did not consider the broader context of method development (e.g. that abatement methods are consistent with national and Intergovernmental Panel on Climate Change (IPCC) greenhouse gas inventory reporting standards, as well as the Australian legislative offsets integrity standards), or the practical implementation of a method. Some points raised by Gallagher (2022) arise from incorrect interpretation of BlueCAM.

Gallagher (2022) focussed on the following five points:

(1) does not subtract allochthonous carbon

Allochthonous carbon refers to carbon that is deposited in the wetland from external sources (either from the terrestrial or marine environment) where it may be preserved in the wetland soil carbon pool. The *Tidal Restoration for Blue Carbon method* does not distinguish between allochthonous and autochthonous carbon. Unlike the VM0033 VERRA method (Needleman et al. 2018), the approach used in the *Tidal Restoration for Blue Carbon method* implies that the organic carbon preserved in a restored wetland soil, irrespective of its source, is deposited by virtue of the wetland being restored (and trapping sediment and organic matter), and thus all carbon preserved above the baseline is "additional". That is, based on the assumption that without the project it would be mineralised to CO_2 and emitted to the atmosphere. This approach is consistent with Australia's current carbon accounting framework, which assumes that all organic carbon lost from soil pools of terrestrial systems is emitted to the atmosphere as CO_2 (Kelleway et al. 2020).

While this approach was based on the principles of additionality, we also found there are limited data at a national scale to parameterise autochthonous vs. allochthonous contributions to coastal wetland soil carbon pools, which may vary on small spatial scales (e.g. across the intertidal zone), and that the use of isotopic and other methods to distinguish autochthonous vs. allochthonous sources of carbon in sediments have high levels of uncertainty (e.g. Saintilan et al. 2013, Needleman et al. 2018, Geraldi et al. 2019). As tidal wetland restoration projects are implemented nationally, future assessments of autochthonous vs. allochthonous carbon in restored coastal wetlands as well as research on fluxes of carbon among coastal wetlands, rivers and coastal oceans will enhance our understanding of variation in the extent of lateral transport of carbon in the coastal zone, which could contribute to future revisions of IPCC Guidance and the BlueCAM model.

(2) does not subtract slowly decomposing carbon fractions (referred to in Gallagher 2022 as “recalcitrant” or “black” carbon)

Slowly decomposing fractions of soil carbon (for example charcoal) can be subtracted from carbon abatement in carbon projects because they are unlikely to be mineralised to CO_2 (effectively inert carbon) irrespective of where the carbon is deposited in the landscape. Currently there are insufficient data to apply regional or national level estimates of the proportion of ‘recalcitrant’ carbon in soils of restored coastal wetlands. Recent studies highlight the difficulty in assessing this soil carbon component (Plante et al. 2023). As Gallagher (2022) suggests, there are few studies in Australia and recalcitrant carbon may be a small fraction of the soil carbon pool in many coastal wetlands. Thus, because of the high uncertainty and limited data at regional and national scales, it was not included in BlueCAM.

Instead, highly conservative soil sequestration values, which are low compared to those used in other international blue carbon accounting frameworks (i.e. lower than IPCC Tier 1 values, IPCC 2013, Kennedy et al. 2014) were used for each ecosystem and region in Australia. Further assessments of the recalcitrant carbon fractions in restored coastal wetlands sediments could permit this fraction to be included in revisions of the method in the future.

(3) whether baseline ecosystems are autotrophic carbon sinks

BlueCAM includes net abatement in baseline scenarios. In BlueCAM, freshwater wetlands in the baseline may sequester soil carbon. However, in many cases the baseline scenario comprises emissions from agricultural land uses that are aligned with their treatment in the National GHG Inventory or IPCC Guidelines. For example, the Australian GHG Inventory includes CH_4 emissions from constructed waterbodies on agricultural land, including bunded pastures, and CO_2 emissions from wetland soils that are converted to cropland and grassland. Baseline CH_4 and N_2O emissions are likely underestimated in BlueCAM as they are lower than global mean values in IPCC guidance (Lovelock et al. 2022), giving rise to conservative estimates of abatement for tidal restoration projects.

(4) the reduction in air–sea flux during periods of submersion

Recent review of GHG fluxes from coastal wetlands indicate that methane and N_2O fluxes are not necessarily reduced during submersion and often peak with wetting and drying cycles (Rosentreter et al. 2021). Methane and N_2O fluxes in BlueCAM were scaled to regional annual rates based on measured emission rates from individual studies, and BlueCAM uses conservative median values (lower than the mean values) of GHG fluxes from both baseline land-uses and restored coastal wetlands, reflecting the typical log-normal distribution of GHG flux data. BlueCAM operates at annual time steps and is based on monitoring of changes in aerial cover of ecosystems. It integrates abatement over annual variation in environmental conditions like fluctuations of tides (and submergence), salinity of porewater, wind and other factors that influence short term variation in GHG fluxes (Rosentreter et al. 2017). It includes CH_4 and N_2O emissions from restored coastal wetlands but does not include CO_2 emissions from restored coastal wetland soils (unless they have been excavated within the project area). The development and adoption of new GHG monitoring technologies (e.g. satellite remote sensing of CH_4, Jacob et al. 2022) and development of models incorporating on-ground observations of GHG fluxes and biophysical conditions, could lead to future models that estimate CH_4 and N_2O fluxes at high temporal and spatial scales from Australian wetlands. Evaluating emissions of CH_4 and N_2O is a rapidly developing field that may support future improvements in BlueCAM and other national models (e.g. Cusworth et al. 2022).

Gallagher (2022) misunderstood the application of global warming potentials within the *Tidal Restoration for Blue Carbon method* and BlueCAM. Consistent with all other Australian carbon abatement methods, CH_4 and N_2O emission are expressed as CO_2 equivalents that are adjusted for their global warming potential (see Equation 7 and 8 within the legislation, *Carbon Credits* (*Carbon Farming Initiative—Tidal Restoration of Blue Carbon Ecosystems) Methodology Determination 2022,* https://www.legislation.gov.au/Details/F2022L00046). Thus, BlueCAM accounts for CH_4 and N_2O emissions from coastal wetlands and incorporates these contributions to overall abatement.

(5) does not account for increases in animal biomass within components of net ecosystem production

Gallagher (2022) also suggested animal biomass, particularly consumption of organic matter by animals, which can be exported from the system (e.g. as fish biomass), should be included as a deduction from the BlueCAM model. Gallagher (2022) asserts that because animal biomass may increase over time in restoration projects, biomass of animals within a restored system should be included in BlueCAM. However, animal biomass is not considered a permanent carbon stock, in contrast to carbon within soils and woody biomass in coastal ecosystems that can persist for hundreds or thousands of years (Rogers et al. 2019) and is therefore not included within carbon methods or GHG inventories.

Conclusion – Conservative abatement at regional and national scales

At a regional and national scale, BlueCAM is conservative and unlikely to overestimate carbon abatement within restored coastal wetlands. The parameters within BlueCAM are low compared to IPCC global values provided in IPCC Guidelines for GHG accounting (Lovelock et al. 2022). While BlueCAM may under- or overestimate carbon abatement at any given site because of site-specific variation in environmental conditions, on a regional and national scale BlueCAM is likely to underestimate levels of abatement from restoration of coastal wetlands. Estimated carbon abatement evaluated in analyses of uncertainty fell within the 40th percentile of modelled carbon abatement (Lovelock et al. 2022). The BlueCAM model is intended to be evaluated and improved over time as tidal restoration projects proceed and additional data become available. Globally, carbon abatement methods for coastal wetland restoration can be improved through uptake of carbon methods (e.g. the *Tidal Restoration for Blue Carbon method* (2022) and other methods), through enhanced knowledge of net abatement for a wide range of restoration activities using multiple measurement techniques, including eddy covariance, and by the use of models that deliver abatement estimates at fine spatial and temporal scales, and that can be verified at low cost using remotely sensed approaches (Macreadie et al. 2022). Overall, BlueCAM complies with its objectives of being evidence-based, transparent, conservative, feasible for implementation, and consistent with national and international integrity standards.

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