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Comment on Geoengineering with seagrasses: is credit due where credit is given?

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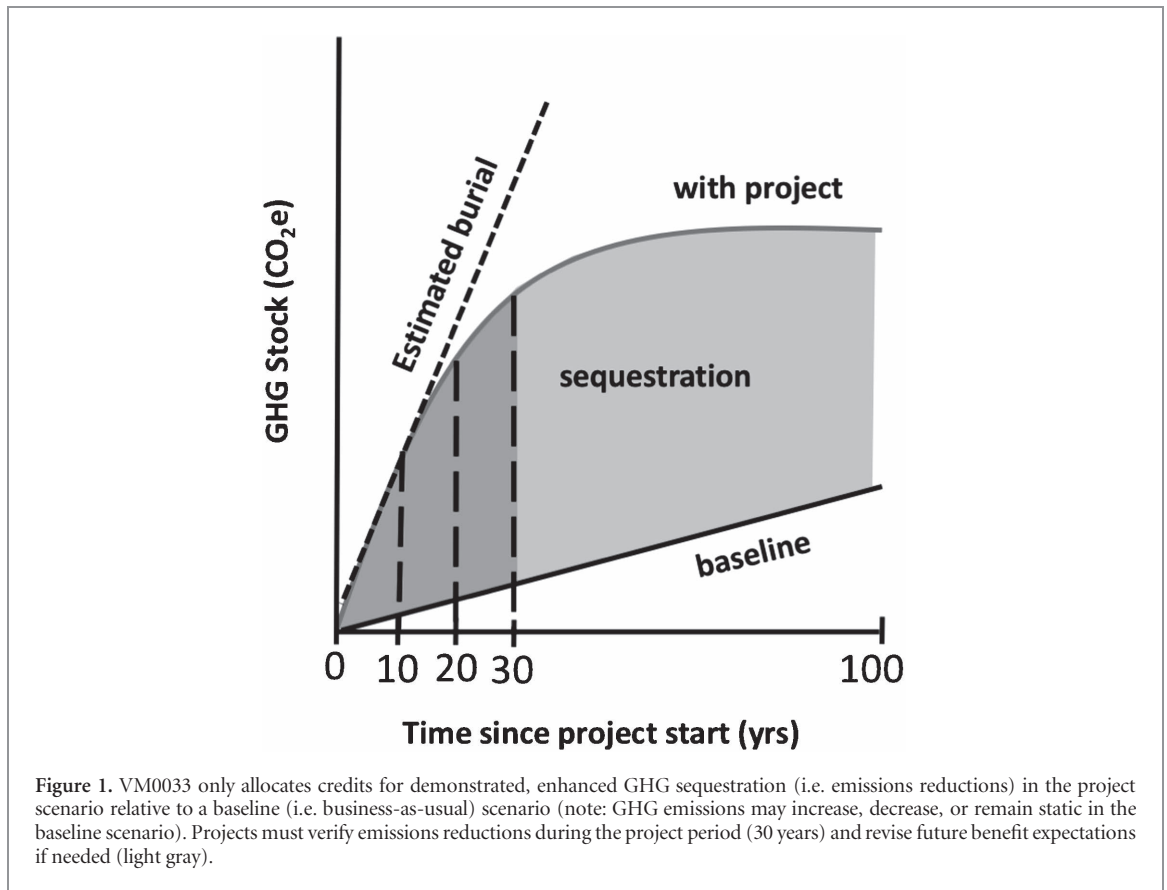
Abstract

In their recent review, 'Geoengineering with seagrasses: is credit due where credit is given?', Johannessen and Macdonald (2016) invoke the prospect of carbon offset-credit over-allocation by the Verified Carbon Standard as a pretense for their concerns about published seagrass carbon burial rate and global stock estimates. Johannessen and Macdonald (2016) suggest that projects seeking offset-credits under the Verified Carbon Standard methodology *VM0033: Methodology for Tidal Wetland and Seagrass Restoration* will overestimate long-term (100 yr) sediment organic carbon (SOC) storage because issues affecting carbon burial rates bias storage estimates. These issues warrant serious consideration by the seagrass research community; however, VM0033 does not refer to seagrass SOC 'burial rates' or 'storage.' Projects seeking credits under VM0033 must document greenhouse gas emission reductions over time, relative to a baseline scenario, in order to receive credits. Projects must also monitor changes in carbon pools, including SOC, to confirm that observed benefits are maintained over time. However, VM0033 allows projects to conservatively underestimate project benefits by citing default values for specific accounting parameters, including CO₂ emissions reductions. We therefore acknowledge that carbon crediting methodologies such as VM0033 are sensitive to the quality of the seagrass literature, particularly when permitted default factors are based in part on seagrass burial rates. Literature-derived values should be evaluated based on the concerns raised by Johannessen and Macdonald (2016), but these issues should not lead to credit over-allocation in practice, provided VM0033 is rigorously followed. These issues may, however, affect the feasibility of particular seagrass offset projects.

1. Introduction

In their review of the seagrass carbon literature, Johannessen and Macdonald (2016) (hereafter, J&M) discuss methodological issues that may bias published seagrass carbon burial rates upward and imply that inattention to these issues in 'six published international protocols' will result in over-allocation of carbon offset-credits to seagrass projects by the Verified Carbon Standard (VCS). J&M outline six problems that potentially affect measurements of sediment organic carbon (SOC)

storage, most of them related directly or indirectly to calculating seagrass SOC burial fluxes. According to J&M, seagrass studies frequently 1. confuse sediment carbon inventories with fluxes, 2. extrapolate carbon measurements taken in *Posidonia* spp. meadows to generate global estimates, 3. neglect bioturbation, 4. neglect remineralization, 5. neglect export due to 'energy of the environment,' and 6. count allochthonous SOC as a seagrass GHG benefit. These issues are fairly common in the broader seagrass literature; however, the VCS only awards offset-credits



(i.e. Verified Carbon Units) for observed, enhanced GHG sequestration—not anticipated carbon ‘storage’ estimated from burial rates. Of the six protocols discussed by J&M, only the VCS-approved VM0033: *Methodology for Tidal Wetland and Seagrass Restoration* (Emmer *et al* 2015a) can presently be used to generate seagrass offset-credits (note, however, that one of the other ‘protocols,’ Emmer *et al* 2015b, is the VM0033 users’ manual).

Given J&M’s concerns about the quality of the seagrass carbon literature and apparent confusion about offset-crediting, we feel that it is important to identify the areas where their specific concerns are relevant for crediting purposes and to clarify offset-crediting concepts for the broader seagrass research community. We agree that the issues raised by J&M warrant serious consideration by seagrass researchers, especially sediment organic carbon (SOC) remineralization over short (i.e. ≤ 100 yr) timescales. We also agree that the problems J&M discuss may affect the proper application of seagrass offset-credits through VM0033 provisions that allow restoration projects to cite literature-derived values for specific GHG accounting parameters. The VCS allows projects to conservatively underestimate the net GHG benefit using default values in cases where direct measurements cannot be obtained. However, we also note that offset-credits are only issued by the VCS for net GHG emissions reductions achieved by the project, relative to a baseline (i.e. business-as-usual) scenario without the project. Projects may anticipate future GHG benefits by calculating SOC

accumulation from burial fluxes or another extrapolation technique, but VCS credits are only awarded *ex post* (VM0033 section 9), after an independent, third-party validator confirms that projected emissions reductions have taken place (figure 1).

2. Defining the seagrass offset-credit benefit

The GHG accounting process required by VCS to determine the creditable GHG benefit differs in important respects from methods used by recent studies to calculate seagrass ‘blue carbon’ benefits (e.g. Mcleod *et al* 2011, Fourqurean *et al* 2012, Greiner *et al* 2013). First, the VCS-approved, net GHG benefit must account for GHG emissions in the baseline and project scenarios, including potential CO_2 and CH_4 increases in the project scenario that reduce the overall benefit. Emission of GHGs during the construction of the project are also subtracted. Second, VCS requires that offset projects periodically monitor changes in particular GHG pools that affect net CO_2e emissions, including SOC, over a 30-year project period (VM0033 sections 8.1.1 and 8.2.1). Most seagrass literature studies are based on short-duration field surveys, lack decadal-scale measurement data, and, therefore, resort to estimating long-term (i.e. ≥ 100 yr) SOC stock changes using burial rates. Third, VM0033 and other reputable methodologies are designed to underestimate the net GHG benefit unless applicant projects take thorough, rigorous, direct measurements that

convince validators that the actual project benefit is higher than the conservative, estimated benefit. Projects are not required to monitor GHG benefits after the end of the project period, but they must quantify the risk that gains will be lost in this future time period (VCS 2012). VCS places a proportional number of credits into a risk ‘buffer pool,’ which can be released to projects over time, provided reversals do not materialize (VM0033 section 8.5.3).

J&M are correct that seagrass meadows are transient systems, and future SOC losses can happen due to events such as erosion and dieback. Their specific concerns provide important insights into how non-permanence risk analysis should be performed (VCS 2012). Long-term seagrass monitoring studies are clearly needed to better understand the factors that influence risk on decadal timescales. If a project cannot demonstrate that future benefit reversal risk is low, the project will likely be unfeasible, because high uncertainty will lead to a large credit withholding.

Although seagrass restoration projects may attempt to quantify CO₂ emissions in the project and baseline scenarios without direct sampling of specific carbon pools (e.g. using eddy flux), in practice, most seagrass projects will need to monitor SOC changes over decadal timescales to verify GHG emission reductions relative to the baseline scenario. We agree that a project will overestimate the net GHG benefit if they equate the project benefit with SOC burial and fail to account for remineralization (J&M problem #4) or export (J&M problem #5) of that stock over time. Some recent studies specifically equate seagrass SOC ‘burial’ and ‘sequestration’ rates (e.g. Mcleod *et al* 2011), but actual sequestration will be lower than expected burial over time, because of SOC remineralization within the bed (figure 1). We, therefore, advise validators and the VCS to be mindful of the issues described by J&M, especially with respect to long-term projections. Sediment cores collected at intervals over the project period—either for stock change assessment or repeated burial flux calculations—should confirm this lower sequestration over time. We also agree with J&M that projects, validators, and the VCS should consider factors that bias sedimentation rates if they calculate burial fluxes (J&M problem #3). However, we note that projects do not need to estimate SOC ‘burial rates’ in order to receive offset-credits, provided projects can account for bed accretion and erosion within the meadow. Taking repeated sediment cores over time (the stock change method) circumvents both bioturbation effects on sedimentation rates (J&M problem #3) and mineralization effects on SOC (J&M problem #4).

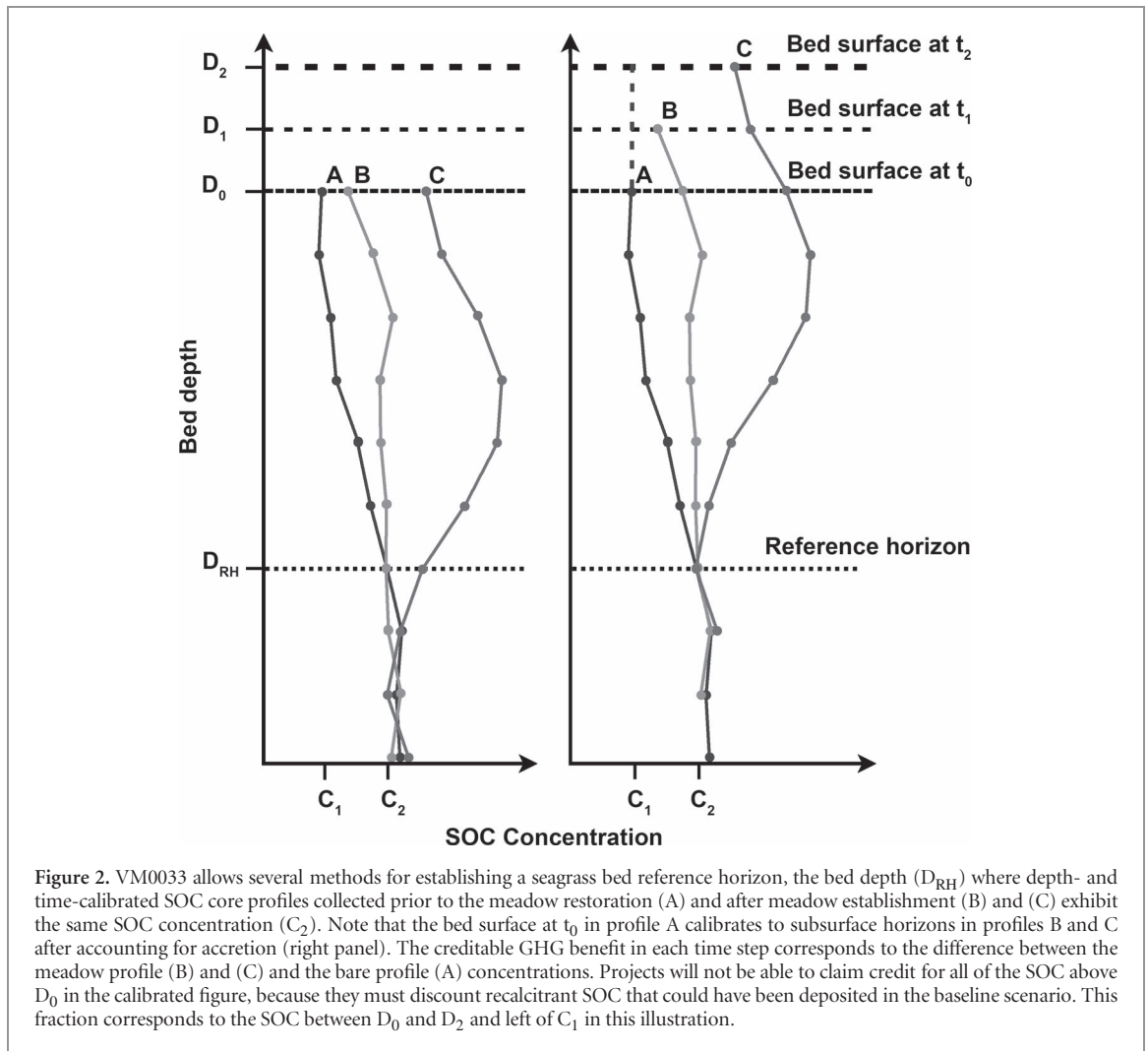
3. Feasibility of the stock change approach

J&M dismiss the stock change method as ‘difficult, if not impossible’ for assessing SOC changes in sediment cores, pointing out that hummocky bed surfaces,

horizontal sediment advection, slow accretion times, and near-surface mixing complicate efforts to establish a marker horizon in seagrass beds. These issues complicate stock-change accounting but do not render it scientifically invalid.

We acknowledge that projects cannot precisely compare changes in SOC concentrations along depth-calibrated profiles over time without a reference plane and that these and other dynamics within seagrass meadows complicate this process. VM0033 permits several options for identifying a reference plane in seagrass systems, some of which may not be feasible for a given project. In addition to installing a physical reference plane and other common techniques, projects may identify ‘a strongly contrasting soil layer’ or compare cores down to ‘a layer with soil organic carbon indistinguishable from the baseline SOC concentration’ (VM0033 section 9.3.7). These methods can potentially be used to quantify accretion at meadow sites without calculating sedimentation rates, which may be subject to variable sediment velocity (J&M problem #1) and sediment mixing due to bioturbation (J&M problem #3). For example, meadow restoration increases fine-sediment deposition (McGlathery *et al* 2012), which may result in a ‘contrasting soil layer’ attributable to bed accretion, provided the finer, accreted sediment abruptly transitions to coarser sediment in cores. Another method, the ‘indistinguishable’ SOC concentration approach, can be employed using the following steps (figure 2):

1. Project proponents collect sediment cores prior to meadow restoration (t_0) and periodically after meadow establishment ($t_{1,2,3,\dots}$) (note: cores from a comparable bare control site can be substituted for the t_0 observation).
2. The surface horizon of the bare core will equate to a subsurface horizon at meadow sites if there is meadow-mediated bed accretion (Bos *et al* 2007). The meadow SOC concentration profile may, therefore, appear to decrease to an equivalent background concentration at a deeper core depth than would be suggested by comparing the two SOC profiles side-by-side. Projects can depth-calibrate the bare and meadow profiles by aligning the point on both profiles where the SOC concentrations first become indistinguishable.
3. The net SOC increase attributable to the meadow above this reference plane is then determined by subtracting the bare concentration (t_0) from the meadow SOC concentration (t_1) at each time-equivalent point along the two profiles and summing the differences. Dividing the total net increase by the time that has transpired since t_0 yields an accumulation rate. Meadow SOC profile shapes may vary considerably depending on location (Oreska *et al* 2017a), which is why projects should collect multiple, spatially-distributed cores.



- Projects must conduct periodic monitoring, because the amount of SOC enhancement within the meadow may increase in a non-linear fashion and fluctuate after the meadow reaches maturity. Meadow cores collected in subsequent time periods ($t_{2,3,4,\dots}$) may show additional SOC from both surface accretion and belowground biomass accumulation (figure 2). If profiles exhibit considerable variability, VM0033 requires that projects take additional samples and constrain parameter uncertainty using confidence intervals (section 8.5.2).

This stock change approach will capture any SOC losses due to remineralization (J&M problem #4) or export (J&M problem #5), along with any SOC increase within the bed from belowground biomass. This latter SOC accumulation pathway further complicates the burial flux approach. The profiles in figure 2 are based on seagrass restoration studies that show SOC concentration changes within the bed following revegetation (e.g. Greiner *et al* 2013, Marbà *et al* 2015). The carbon concentration peak observed approximately 4 cm below the sediment-water interface in a restored seagrass bed by Greiner *et al* (2013) corresponds with the rhizosphere in that system.

This outlined method may not be appropriate in all cases. If a project attempts to use this method to establish the reference plane but a third-party validator concludes that it is subject to error, VCS will not certify the requested offset-credits. Projects can instead calculate bed SOC accumulation using an approved equation, for example J&M's 'direct method.' However, all projects must determine the bed depth to which the meadow enhances sediment SOC. Nowhere in VM0033 or in the associated manual (Emmer *et al* 2015b) are projects allowed to count all of the SOC within the top meter of a seagrass bed as a GHG benefit.

4. In some cases literature issues will affect carbon crediting methodologies

In cases where measuring a specific stock change proves prohibitive, carbon credit methodologies allow projects to estimate the change in both the project and baseline scenarios using default values and approved models. We agree that the issues raised by J&M may affect the use of literature-derived values; for this reason, the use of these values in VM0033 is severely restricted. Literature values and models must derive from the 'same or similar systems,' as defined by the

VCS (VM0033 section 8.1.4.1), and projects must be able to justify their use ‘as appropriate for project conditions’ to the validator and ultimately to the VCS (VM0033 sections 8.1.4, 8.2.4, 9.3.2, and 9.3.3). The concerns raised by J&M are, therefore, important, because proposed projects will use the scientific literature to support their calculations, and independent validators should be aware that some sources overestimate benefits.

The concerns of J&M about the quality of data in the seagrass literature may be particularly relevant in cases where projects cite a general default factor. For example, a project may use the latest IPCC (2014) Tier 1 seagrass restoration default value, currently $-0.43 \text{ t C ha}^{-1} \text{ yr}^{-1}$ (IPCC 2014: p. 4.29, table 4.12), to estimate emissions reductions in the project scenario. This figure need not be accurate, provided it conservatively underestimates the net GHG benefit. It is essential to understand that use of this default value must be justified as conservative for project conditions to the independent validator, and the project must still deduct an allochthonous carbon fraction from this number (see below). As J&M point out, values from *P. oceanica* studies are not conservative estimates for all seagrass systems, because this mat-forming species generates unusually high sediment SOC stocks (J&M problem #2). The IPCC (2014) value derives from two *P. oceanica* studies (Mateo and Romero 1997, Serrano *et al* 2012), but it appears conservative relative to the range of sediment carbon accumulation rates compiled by Mcleod *et al* (2011), $0.45\text{--}1.90 \text{ t C ha}^{-1} \text{ yr}^{-1}$. The IPCC (2014) number is also comparable to the sediment SOC accumulation rate observed in a *Zostera marina* restoration project, $0.37 \text{ t C ha}^{-1} \text{ yr}^{-1}$ (Greiner *et al* 2013), which excludes biomass sequestration. Despite these allowances, we expect that most projects will need to make direct, stock-change measurements, because the project system exhibits different ‘geomorphic, hydrologic, and biological properties’ and is, therefore, not ‘the same or similar’ to these other systems (VM0033 section 8.1.4.1).

VM0033 also includes a VCS requirement that default factors undergo periodic re-assessment. If future work demonstrates that the current IPCC seagrass value is not conservative, the VCS will disallow its continued use (VM0033 section 8.1.4.1). We recommend that future amendments to the methodology include language instructing validators to specifically consider the concerns expressed by J&M, especially in cases where projects use sedimentation rates to estimate SOC accumulation.

5. Other offset provisions safeguard against credit over-allocation

The VCS and other rigorous standards enforce additional safeguards against credit over-allocation, because credit oversupply already depresses the average credit

price on the voluntary carbon market (Forest Trends 2016). Projects must meet the VCS ‘additionality’ requirement, which confirms that GHG benefits were a driver for the restoration effort (VM0033 section 7). Seagrass offset-credits will not be allocated for existing seagrass carbon pools, so concerns about seagrass global stock estimates are not relevant (J&M problem #2). Regarding export (J&M problem #5), projects only get credit for average, standing biomass, not leaf litter (VM0033 table 5.1). VM0033 also requires that seagrass projects remove inorganic carbon from sediment cores prior to carbon content analysis (VM0033 section 9.3.7).

Finally, we note that concerns about allochthonous carbon (J&M problem #6) are addressed in VM0033 in considerable detail. J&M are correct to note that allochthonous carbon deposited in a seagrass bed could be buried and stored absent the meadow (i.e. in the baseline scenario). For this reason, VM0033 requires that projects deduct recalcitrant allochthonous carbon from project benefits, unless the project proponents can show that this fraction would have been returned to the atmosphere absent the project (VM0033 section 8.2.4.2.2). Seagrass meadows enhance accumulation and preservation rates for deposited allochthonous organic matter (Duarte *et al* 2013), which may account for more than half of the SOC sequestered in some seagrass beds (Kennedy *et al* 2010, but see also Oreska *et al* 2017B). VM0033 conservatively requires that seagrass projects identify and deduct all of this recalcitrant allochthonous carbon from project benefits—even in cases where a project cites the IPCC (2014) default value for total SOC enhancement.

6. Conclusions

J&M provide a timely, thought-provoking review of seagrass carbon burial considerations; however, they incorrectly suggest that VM0033 (and Emmer *et al* 2015b) over-allocates carbon credits. We share J&M’s general concern about potential offset-credit misallocation, which devalues legitimate offset-credits. For this reason, VM0033 and other rigorous methodologies require that offset projects account for a variety of factors, including future gain reversals, stock remineralization, biomass export, and allochthonous carbon, among others, that may render seagrass projects inoperable in practice. We acknowledge GHG accounting complexities in seagrass systems, including SOC accumulation and remineralization processes operating on different timescales, and, therefore, suggest that the blue carbon literature differentiate between SOC net ‘sequestration’ and ‘burial’ when discussing seagrass offset-credits. Literature values can be used in specific cases, provided these values represent conservative parameter estimates and validators approve their use. Validators must carefully review all cited

literature values, emission factors, and models before approving project GHG calculations, given J&M's concerns. However, contrary to J&M's suggestion, VM0033 explicitly requires projects to either conservatively underestimate the GHG benefit or undertake sufficient monitoring to derive statistically accurate and scientifically defensible parameter estimates when calculating seagrass GHG stock changes.

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