Methodology Proposal for Soil Organic Carbon Estimation

v.0038

-Methodology Review-

Internal R1 Review Round

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[08/23/2022]

CONTENT referenced by reviewer's comment *e.g. Section number + paste exact text*	REVIEWER'S COMMENT *Please paste the comment from the reviewer*	AUTHOR'S RESPONSE *Please describe how the comment was addressed and include new content in quotations*	Reviewer's Conclusion [PASSED/ REJECTED *WITH COMMENTS*]
1.1 - Scope: "This methodology protocol uses soil sampling and remotely sensed multispectral imagery, coupled with machine learning, to estimate SOC stocks in a project area and areas beyond those which have been sampled."	Please add some eligibility criteria for land use/ management" Can you specify the types of land cover and land use that will be allowed? It would be helpful to know that from the beginning to set the context.Or, is all of that going in the credit class?	*Changed to: 1.1. SCOPE* *This methodology protocol proposes the use of remotely sensed multispectral imagery and* *soil sample results to train an Artificial Neural Network (ANN) to estimate Soil Organic* *Carbon (SOC) stocks within a project area. The main soil ecological health indicator, assessed in this methodology, will be carbon sequestration consisting of:* *1. SOC stocks.* *2. CO2 equivalents (CO2e).*	*I still feel there´s at least a mention to the main agricultural practices or systems missing here.* *Also, wouldn´t the scope be to track the "changes in stocks through time", instead of just to estimate stocks? Wouldn't this be SOC stocks measured as CO2 equivalent?*
1.1 - Scope: "Additional Co-benefits are:"	these are indicators that could be used for some co-benefit like soil health, I wouldn't say these are co-benefits per se.	deleted	*PASSED*
2.1.1 Masking "any man-made objects"	What about other non-qualifying cover types such as water and possibly other	Changed to "Any areas outside the defined spatial boundaries will be masked."	*PASSED*

	cover types such as forested land?		
2.2 Temporal Boundaries 1. "The minimum number of soil sampling rounds for a 10-year crediting period will be five."	This seems like a high minimum due to the likely prediction uncertainty vs expected sequestration rate. I agree with Ned, it´s a big ask , every 2 years at most.	Deleted	*PASSED*
2.2 Temporal Boundaries 6. The maximum time between soil sampling rounds will be three years. This proposal will initially be based on annual sampling rounds.	This does not equate with #1 well unless you are having multiple rounds in a year which seems unreasonable	Deleted	*PASSED*
2.2 Temporal Boundaries "This proposal will initially be based on annual sampling rounds."	It's not clear to me what "this proposal" is and why it's different from the constraints mentioned above.	Not yet addressed	Some clarity is needed. This is a methodology not a proposal. If you require annual sampling you can state that.
3.1 "approaches"	Which approaches?	Added "previous" before approaches	*PASSED*
3.1 "spectral index approach"	It would be helpful to explicitly	Not addresses	*PASSED*

	mention the types of land cover used in the studies (cultivates, pasture, bare soil vs. vegetated).		
3.1 "and forest type rather than"	these might work to get regional differences in SOC , rather than more local and interanual variability	Noted	*PASSED*
3.1 "In this methodology Sentinel-2 multispectral data will be used as the proxy (inputs) and soil sample samples will be used to provide ground truth SOC (targets) data."	Maybe move this to the beginning of this section.	Made a new section 3.2 and put this under that section	*PASSED*
3.3.1 "soil samples"	Is there a minimum number of soil samples? ANNs typically require a lot of training data especially when predicting SOC.	Not addressed	*PASSED*
3..3.1 "spatially correlated" & "sub-sample areas are smaller than the global variability"	correlated to what? spectral data? I haven't read the paper yet but area and variability use different units so not sure how they are being compared.	Changed to "CGS makes the assumption that the variability is spatially correlated and the sub-sample areas are smaller than the global variability (de Gruijter et al., 2016). Knowledge of the variability, gained during baseline, CGS sampling, will help optimize the number of samples in future sampling rounds."	*PASSED*

3.3.2 "SUBSEQUENT"	This section needs more detailed information	Deleted	*PASSED*
3.3.2 1. "scale"	I'm not sure what "scale" means in this context. Maybe use another term or describe what is meant.	Deleted	*PASSED*
3.3.2 2. "Knowledge of the variability in the Yr0 baseline SOC may enable stratified sampling. To enable the use of stratified sampling the variability will need to be shown to be consistent or predictable year on year."	"so does this mean that there might be changes in the location of the samples through the project lifetime?"	Deleted	*PASSED*
3.3.2 3. "Reducing the number of soil samples will be dependent on there being no significant change of ANN prediction accuracy."	What about increasing samples if change in accuracy or uncertainty is high?	Deleted	*PASSED*
3.3.2 5. "Networks"	I would use "models" or 'network models' especially if you are taking an ensemble approach.	Deleted	*PASSED*
3.3.2 5. "tested"	This is a little difficult to follow. It	Deleted	*PASSED*

| | seems as if you will evaluate models built using training data from the baseline sample using subsequent samples as a test data set. It would help if you articulate the model training, validation and test steps more clearly. Maybe a figure would help?

A potential, even if unlikely outcome based on your experience is that more samples will be needed | | |
|---|---|---|---|
| 3.3.2 5. "without or very reduced soil sampling" | so does this mean you will also do future modeling and if there´s a match in the predictions and sample results from some consecutive years you might end up dropping sampling? if that´s the case how would this comply with the requirement to sample every 2 years at most until the end of the project crediting period? | Deleted | *PASSED* |
| 3.4 "Other high-resolution imagery" | Are there resolution constraints. "high-resolution" is not well defined | Changed to "spatial and spectral" | *PASSED* |
| 3.4 3. "Extracting samples" | What's the difference between | Deleted | *PASSED* |

	soil sampling and extracting? Maybe you mean sampling framework design?		
3.4.2 1. "sample dates for the project area and the sample dates for the area providing the ancillary data will"	This is a little confusing. Maybe you need to define what you mean by "ancillary". Above it sounds like your talking about ancillary thematic data and here and below it seems like you talking about representative data from outside the study area.	Changed to "The soil sample dates for the project area and the sample dates for the area providing the ancillary data will fall within one month of each other."	*PASSED*
3.4.2 2. "Recommended sampling depth in the Regen Network guide is 15cm, however, for more accurate measurement SOC, this proposal will use a core depth of 30cm."	I would simply say it´s 30cm which is the standard from most protocols.	Changed to "This proposal will use a core depth of 30 cm."	*PASSED*
3.4.6 4."12-band"	I think this is 11-band if you're not using band 10	Table 1 includes 8A which means the number of bands is 12	*PASSED*
3.4.6 5. "Images will be averaged"	I advise against this approach. Seasonality will have a huge impact over any 8-month period and averaging will not give you meaningful data. You would almost certainly be better of using a protocol to select the	Changed to "If multiple images are available the nearest, by date, cloud free image will be used"	*PASSED*

	"best" image in that date range. Defining "best" needs some thought and can be impacted by atmospheric conditions, seasonality and other factors.		
3.4.10 "accuracy and uncertainty"	I'm not certain but lit looks like you will use cross validation to calculate uncertainty and MAPE to calculate accuracy. This should be more clearly laid out. You could also provide some guidance related to the type of cross validation you plan to use.	Added in "SOIL SAMPLE ANALYSIS UNCERTAINTY The declared uncertainty of the laboratory soil sample analysis will be propagated though any calculations made from this data"	*PASSED*
3.4.10 "a test set used to test the network accuracy. Validation will use a subset of the ground truth soil sample data."	This needs some clarification. Often the training and validation data are selected form the same data set. Validation data is used to gauge model performance during training. Test data are completely independent and the model hasn't seen those data.	Changed to "Network Prediction uncertainty The network prediction accuracy will be quantified using the mean absolute percentage error (MAPE), where number of values (n), actual soil sample value (A_t), estimated network predicted value (F_t):"	*Should "accuracy" in second paragraph be "uncertainty" to align with header?*
3.4.10 "using the mean absolute percentage error (MAPE),"	Using the test data set?	Changed to "Network Prediction uncertainty The network prediction accuracy will be quantified using the mean absolute percentage error (MAPE), where number of values (n), actual soil sample	You need to specify where the soil sample values come from. That likely requires defining your train/test/validate data partitioning scheme.

		value (A_t), estimated network predicted value (F_t):" UPDATED EQUATION	
3.4.11 "The spatial resolution of the pixels will be adjusted, if required, to match units of tonnes per hectare before calculating the sum. The results will be compared with calculating the SOC stocks using the mean sampled SOC[t/ha], in those areas where sampling was carried out."	I would do this by calculating the tons per pixel area, before summing, instead of resizing the pixels... Not sure why you would do this since accuracy was calculated using the method described above.	Changed to "For areas where there are network SOC predictions the total SOC stocks [t] will be calculated by using the sum of the pixel values of the output image from the network"	*Maybe use "model" instead of "network" at end of paragraph*
4.4 "estimates"	I would change this to "model predictions" or something like that.	Changed to "Laboratory percent soil organic carbon measurements."	*PASSED*
6. "will stored for monitoring verification."	Is there a minimum length of time for data storage. Say 5 years after the project ends?	Changed to "All data used during the analysis will stored for 5 years after the completion of the project."	*PASSED*
7. "verified:"	Who will do the verification and how frequently?	Changed to "The following data will be made available to the verifier:"	*PASSED*

Additional Written Response from ecomteric.

- We strongly believe in an annual monitoring frequency but have not made that clear in the method text (we will adjust method text to reflect). It looks like you disagree with this so we will need to justify, can you elaborate on why you don't think it is a good idea?
  - Response - Regen - **The main issue is that changes in actual SOC will likely be small relative to SOC change error estimates. Most of what I have read suggest 5 - 10 years between sampling event. Carbon Plus is sampling more frequently so it's difficult to suggest a coarser time step then what we use but I strongly suggest we don't promote a finer time step. In the end it's up to Ecometric to decide what they want to use so my comment is more of a recommendation rather than a requirement.**
  - **Gisel: I believe annual should be the minimum, not the max. Not sure why they are asking for that high frequency?**
    Main reason is costs. Is true that sequestration takes time, but I would argue, the more points in time you have the more you capture interannual variability and cope with the sampling and analysis errors… but that increases the costs a lot if we are speaking about soil sampling… I think it goes back to the question of which systems are they willing to monitor with the method
- Although we haven't formally defined eligibility criteria, our onboarding process has ensured the adoption of regen-ag methods is either intended or has started, which I hope would meet most standard eligibility criteria by nature. Projects to date have included, horticulture, arable, temporary and permanent pasture and new woodland. We will now formally define this as part of the suggested credit class document.
- The UK buyer has set a 20% buffer pool with 10-year permanence period. Only SOC stock change net of uncertainty discounts (35%) and whole-farm emissions is considered as tradable surplus.

- Environmental co-benefits have not been considered as part of the first trade but they have been described on the project report eg complete avoidance of pesticide for >5years with beneficial insect strips planted in every field to increase insect predator biodiversity.
- I'll leave Hywel to comment directly on accuracy and uncertainty as he has just completed a detailed evaluation of total method uncertainty, including each laboratory test uncertainty.