Integrated Farm and Land Management Method

Taxonomy of key concepts

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Taxonomy of concepts related to carbon farming and carbon stock estimation

The purpose of this document is to organise concepts related to carbon farming and carbon stock estimation. In particular, it aims to unify terms or definitions that may have similar meanings in different technical domains. Therefore the taxonomy contains a superset of definitions than are contained in the Integrated Farm & Land Management Draft Methodology and other relevant carbon farming and nature repair terms.

Concepts related to project eligibility

Carbon estimation areas (CEA)

- Designated zones within a carbon farming project where carbon stocks are quantified and monitored.
- CEAs must consist of eligible land and are central to the project's carbon accounting processes.
- These areas are selected based on their potential to sequester carbon effectively through specific management activities.

Land Management Strategy

- Describes the current state of the ecosystem and the natural and human processes impacting on carbon storage in the ecosystem, including a list of barriers preventing the ecosystem moving to a higher carbon state and planned land management interventions to address these barriers.

Gap analysis

- A comparison of current woody biomass against a relevant ecosystem benchmark, to identify the potential for carbon stocks to increase.

Ecosystem Benchmarks:

- Attributes of an ecosystem that is intact or more ecologically advanced state than comparable ecosystem which is less intact or less ecologically advanced.
- The maximum sustainable carbon stock is one potential benchmark, as are mature size structure, recruitment rate and mortality rate.

Maximum Sustainable Carbon Stock:

- The biophysical limit of land-based carbon sinks is a key ecosystem benchmark. This limit can be conservative and can be exceeded.

Reference Site:

- A real community of organisms and their associated environment.
- Comparable references sites should share biophysical conditions, species composition and climatic histories, but may differ in management histories or current context.

Conceptual Ecosystem Models:

- Notional communities of organisms and their environments.
- Conceptual models should include similar biophysical conditions and broad species compositions

Control Site:

- Sites paired in terms of ecological and biophysical characteristics and, unlike reference sites, share common land management histories.
- Control sites may be used to estimate the counterfactual ecosystem carbon stocks if no change in management occurs (i.e. valid control sites must continue business as usual). In practice, due to natural landscape variation, it can be difficult to find a well-matched control site that adequately reflects the status quo during the crediting period of carbon farming projects.

Concepts related to carbon stock estimation

Spatial Carbon Maps:

- Geographically referenced collections of modelled carbon stock estimates validated with independent measurements. These maps may be spatially referenced or spatially explicit.
- **Spatially referenced carbon stock estimates** describe a CEA in terms of summary statistics, such as the mean and variance. Total carbon stocks are estimated by multiplying the mean by the area.
- **Spatially explicit carbon stock estimates** describe the distribution of carbon within a CEA, usually at a resolution substantially smaller than the CEA. Total carbon stocks are estimated by integrating over the CEA (i.e. summing the carbon stocks of mapping units contained within the CEA)

Measurement:

- Data collected for calibration and validation of modelled estimates. Measurements for woody biomass are typically allometric size dimensions, and for soil carbon, soil cores.
- Measurements are often non-destructive and provide the basis for statistical inference in spatial carbon maps.
- Measurements are sometimes referred to as reference data.

Modelled Estimate:

- Extrapolations of carbon stocks using indirect auxiliary variables and/or predictive models since total woody biomass or soil carbon stocks cannot be measured directly over large areas.
- There are two key types of models:

    - **Process-based models** - also known as mechanistic models, which simulate carbon stocks through time based on ecological processes, typically requiring initialization and running from a starting point.
    - **Empirical models** - statistical or machine learning models that use current data to predict carbon stocks without simulating processes or requiring historical information.
- Either model type can be used to generate spatial carbon maps for a given point in time.
- Modelled estimates that do not use auxiliary variables may sometimes be described as ‘measured’ estimates, or a ‘measured only’ approach, however this is a misnomer. Calculating the mean or variance of a CEA from measurements is instead a simple empirical model.

Calibration:

- The process of developing a predictive model for carbon estimation that describes the relationship between auxiliary variables and measured carbon stocks.

Auxiliary Variable:

- Extra variables that may be used to inform carbon stock estimates, such as remotely sensed spectral information or topographic data.

Size variable

- Dimensions of woody vegetation that are useful for describing size. For example, tree size can be described by trunk diameter or height.
- Woody vegetation may be described in aggregate by size variables. For example, a stand of trees can be described by basal area, canopy area, or canopy volume.
- Size variables can be used to derive non-destructive measurements of carbon stocks.
- Many techniques for estimating size variables including tape measures, stepped diameter gauges, rangefinders and lidar.

Allometry:

- Equations quantifying the relationship between size variables and biomass or carbon stocks.
- Allometric transformation from size to carbon stocks can require multiple steps. For example, basal area can be used to estimate the aboveground biomass of a stand of trees. Total biomass can be calculated using a root:shoot ratio and converted to carbon stocks using average wood density and carbon content factors.
- Allometric equations are themselves a model that must be calibrated before being used to collect carbon stock measurements for calibration or validation of modelled estimates used for carbon stock maps.

Concepts related to carbon map validation

Validation:

- Evaluating the predictive skill of modelled estimates using independent measurement data that was not used for model calibration.

Accuracy:

- The closeness of a measurement or estimate to the true value. It reflects how close the measured or estimated value is to reality.

Precision:

- The degree of reproducibility or repeatability of a measurement or estimate. High precision indicates that repeated measurements or estimates are consistently close to each other, but not necessarily close to the true value.

Bias:

- A systematic error that consistently causes measurements or estimates to deviate from the true value in a particular direction. Bias can lead to consistently overestimating or conservatively underestimating the true value.

Statistical Inference:

- The process of drawing conclusions about a population based on a sample of data from that population.

Design-based Inference:

- A statistical approach that relies on sampling design to make inferences about a population. In this approach, the validity of the inference depends on the sampling design rather than on assumptions about the population's distribution.

Model-based Inference:

- A statistical approach that uses a model to describe the relationship between variables and make inferences about a population. The validity of the inference depends on the correctness of the model rather than on the sampling design.

Probability based Sampling Design:

- A method of selecting samples from a population where every unit in the population has a known, non-zero probability of being selected. This approach allows for statistical inference about the population based on the sample.

Uncertainty:

- Spatial carbon stock maps include errors in measurements and misfits in models combining measurement data with auxiliary variables.

Error Propagation:

- Accounting for all relevant error sources contributing to an estimated quantity, aiming for greater accuracy and precision or quantified uncertainty.

Sampling Error:

- Errors resulting from insufficient sampling of a population, affecting measurements and estimates.

Probability of Exceedance:

- A statistical approach for adjusting carbon stock change estimates to account for sampling noise. The approach allows for crediting even when there is some uncertainty but adjusts the creditable carbon stock change downward to account for that uncertainty.
- This method produces a conservative estimate of the carbon stock change. It accounts for uncertainty by crediting less than the average measured change.
- More precisely, the magnitude of carbon stock change relative to sampling error is assessed using a one-tailed Student’s t-test with the critical value for a one-tailed Student’s t-test is typically set to >60%.
- When the magnitude of change is large relative to the uncertainty of the carbon stock estimate, the t-statistic will be smaller.
- The creditable change represents a lower bound of the true change at the 60% confidence level.