Viresco Solutions
End-to-end sustainability

Monitoring, Reporting, and Verification (MRV) to Monetize Greenhouse Gas Emission Reduction and Carbon Sequestration

Brian McConkey

Viresco Solutions

What is MRV?

- **Monitoring, Reporting, and Verification** of Greenhouse Gas (GHG) emissions and removals
  - MRV is essential for projects that to change on-farm activities to achieve reduced GHG emissions or GHG removals (carbon (C) sequestration)
  - Monitoring is about continuous documentation of land (or herd) management
  - Reporting is describing the activities and their GHG impact
  - Verification is assuring that methodologies were correctly followed with possible checking of correctness

Connecting Supply and Demand

Supply

1. Emission reductions through adoption of appropriate technology
2. Carbon sequestration through adoption of appropriate land management that increases woody biomass or SOC

Demand

1. Corporate demand to report their GHG emissions impact and to meet their GHG targets
2. National government demand to report the national GHG emissions impact and to meet their GHG targets
3. Civil society and government investments in nature management, restoration and protection (e.g. Indigenous Protected and Conserved Areas, land conservancies)

MRV is the keystone that connects supply and demand

Supply

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Intervention Projects

Project developers organize the supply and appropriately account for the project GHG impacts

MRV

Accounting Integrity

Certifiers, Standards, Registries, and/or Regulators for:

- GHG Offsets
- Scope 3 emissions and removals
- Nature healthiness

Demand

1. **Corporate demand to report their GHG emissions impact and to meet their GHG targets**
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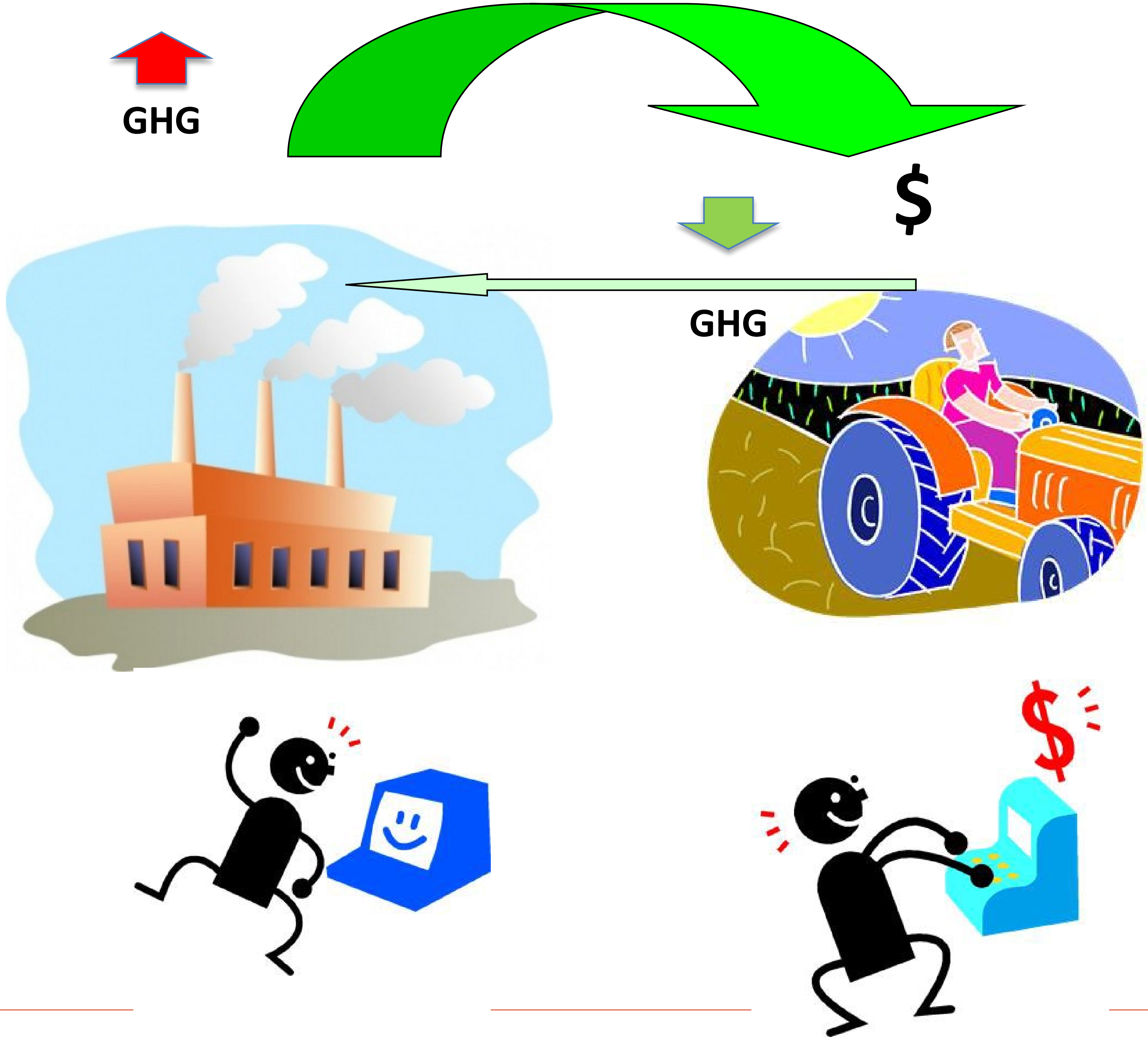
Must be a positive value proposition across the whole chain

Offsets

- GHG reductions and/or removals that is used by an entity to reduce their reported GHG emissions
  - Offset credit is the difference between GHG reductions and/or removals with an intervention to activities (i.e., "project") compared to what would have occurred without the intervention
- Relationship between supplier and buyer is transactional
  - No requirement for any sort of relationship beyond purchase
- Voluntary and compliance (regulated) markets
  - Compliance require lower emission impact from buyer by binding regulation
  - Voluntary where no legal obligation
- MRV assures that offset credit is real, quantified, verified and unique GHG emissions reductions or removals
  - Real = Permanent and additional to what would have happened
  - Quantified = accepted means of quantification
  - Verification = requirements to assure the correctness of the offset
  - Unique= no double counting or leakage (inducing new GHG emissions outside the project boundaries)


GHG
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GHG

Scope 1, 2, and 3 Emissions and Removals

Scope 2

Purchased energy

Scope 1

<u>Business Operations</u>

Processing

Own storage and transportation

Administration

Business travel

Scope 3

<u>Upstream</u>

Production and transportation of purchased inputs

Financing, insurance

Machinery, Buildings

Scope 3

<u>Downstream</u>

Transportation

Processing, storage

Retail

Use of products

Scope 3 emission reductions

- Claims are "credits" for scope 3 emissions
  - e.g., McCain Foods has set 2030 commitments to halve its absolute Scope 1 and 2 CO2 emissions, exit coal use, use 100 per cent renewable electricity and make a ***30 per cent reduction in Scope 3 CO2 emissions intensity***.
  - So McCain Foods needs to be able to make a claim about the reduction it directly affected
- Emission reduction from changes to upstream or downstream activities that occurred without the corporate action will affect the corporate GHG inventory
  - Change scope 3 emissions but no claims for that company
  - SOC change cannot be included in corporate GHG inventory unless meet the standards under which the inventory is developed
- MRV for scope 3 is about the claims
  - Sometimes claims called insets (vs. offsets) but that term is losing popularity
- High quality scope 3 emission can be transacted (transferred)along the value chain
- Beyond value chain interventions allowed to offset limited residual emissions when all reasonable efforts to eliminate Scope 1 and 2 emissions and reduce Scope 3 emissions are exhausted

MRV is essential

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Corporate GHG Targets Are the Main Driver

- Science based targets are to get to net zero by 2050 in alignment with the 2015 Paris Agreement
- Over 4000 companies have set GHG targets under the Science Based Targets initiative (SBTi)
  - >1/2 of the 4000 largest companies in the world
  - Corporate market value of companies with SBTi targets in December 2023: **US$134 *Trillion***
- 1/3 of the global economy
- Waning interest in voluntary offsets because of restrictions on acceptance
  - Increasing interest in Scope 3 emission reductions and removals
  - Rules for land-based being tested, should be available by 2025

MRV is collation and processing of documentation

- Documentation of the past practices
- Ongoing documentation of the intervention practices
  - Everything necessary to estimate the GHG emissions and removals
- Documentation of legal agreements between land or herd manager and the project developer
- Electronic collection, collation, and coherence between applications essential to reduce costs and increase reliability
- Land and herd managers have two things of values for sale
  - The product and its documentation about how it was produced

MRV and SOC

- Increasing in soil organic carbon (SOC) removes the greenhouse gas (GHG), carbon dioxide, from the atmosphere
- Pledges to reach net-zero by 2050 made by many countries and companies
  - There will be some extremely difficult GHG emissions to control
    - N2O emissions from agricultural soils is one
  - Keen interest in SOC increases because the increases can "net out" those difficult emissions
    - This is allowed providing scope 1 and 2 emissions reduced as far as feasible
- Because forest C is relatively easy to quantify by measurement, expectation by stakeholders there will also be "measurement" of agricultural SOC
  - (Measurement of other GHG emissions from agriculture not expected)
  - Quantifying SOC is critical part of MRV

Soil Carbon

- Soil organic carbon (SOC) is carbon derived from organic materials: plant residues, animal residues, soil microbes
  - Recent to 1000s of years old
- Inherently extremely spatially variable because soil forming factors
- Soil Organic Matter (SOM) typically taken as 1.72 x SOC
  - Not exact across soils but an established method
- SOC is
  - Indicator of soil quality: soil structure, soil nutrient cycling, soil biological health

SOC is a mass

- SOC mass = SOC concentration X Soil Bulk Density (BD)
- BD goes up and down over time due to many effects including hoof action, tillage, machinery traffic, rainfall, frost action, cycles of wetting and drying, SOC changes
- **Uncertainty** of SOC mass results from
  - Inherent spatial and temporal variability in soil SOC concentration and soil BD
  - Measurement difficulties
  - Quantification method

What is the impact of uncertainty of SOC increases

- Compliance offsets
  - Will depend on each regulator
  - Effects of uncertainty usually included in the quantification protocol
- Voluntary offsets
  - More flexibility in quantification methods and varies greatly among registries
  - Most common to impose a discount to the amount of SOC change used for the credit based on the uncertainty of the estimated SOC stock change
- Scope 3 emission reductions
  - Treatment of uncertainty being developed
  - Typically look to adapt methods voluntary offsets with high integrity, such as the Verra registry

Trade-off between cost of quantification and uncertainty

- Low cost methods will usually have high uncertainty of ***SOC change***
- Well done high-cost methods **can** have "low" uncertainty of ***SOC change***
- Originally focus for offsets and insets was "proving" that SOC change occurred by having SOC change meeting specific uncertainty thresholds with a high (90 or 95%) confidence
  - If it does not meet thresholds, then punishing discounts including no credits
  - Only high-cost methods would enable so infeasible for commercial projects
- Now focus on only providing uncertain evidence that the SOC change occurred but always have a discount to the credits based on the uncertainty
  - Example, Climate Action Reserve Soil Enrichment Protocol discount is 52% of the uncertainty value expressed as a standard deviation

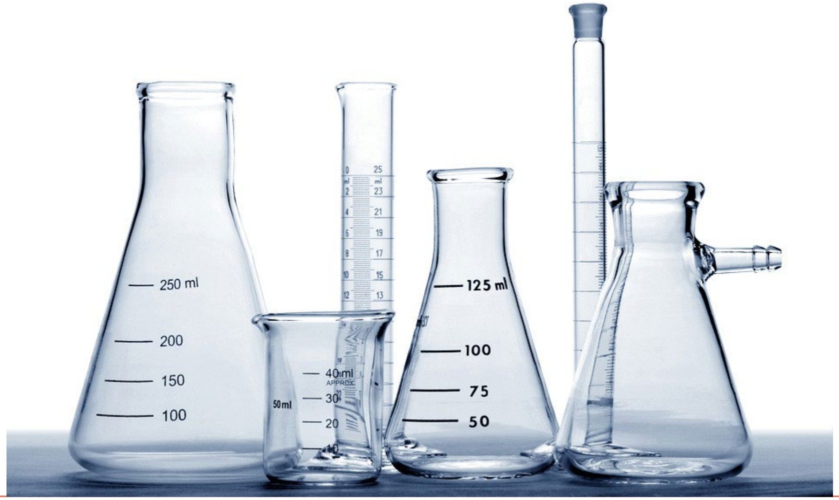
SOC measurement

Direct Measurement of SOC by Dry Combustion

- "Gold Standard"
- SOC concentration
  - Dry combustion (DC) with heat + oxygen of a thoroughly mixed subsample of soil (< 1 gram to few g of soil depending on analyzer) with the C in the evolved CO_2 measured by an elemental analyzer
  - Soil inorganic carbon (carbonates) has to be either removed first by acid pre-treatment or measured separately
- Bulk density is measured
  - Most common method is cores, large (≥1.5 cm diameter) core best
  - Another method is careful measurement of excavated soil mass and excavation volume
- The "gold standard" is a non-repeatable point measurement
- Change is SOC stock from difference between measurements at two times for points in the same vicinity

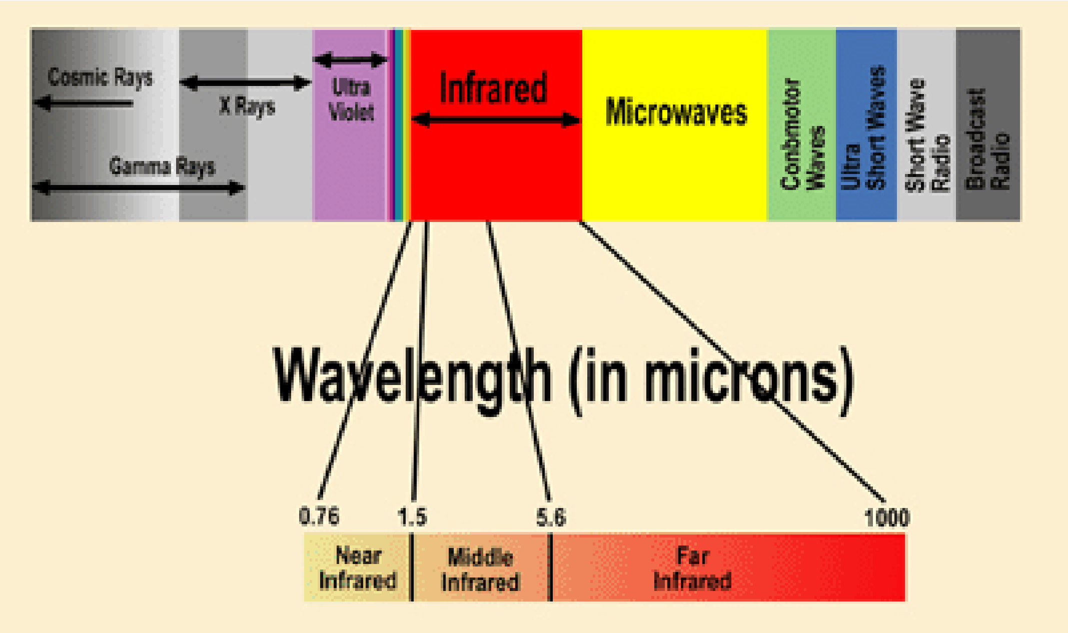
Wet Combustion (WC)

- Expensive lab technique for estimating SOC concentration for soil sample
- SOM oxidized with strong chemical oxidant (Walkley-Black is the most common method) and SOC concentration is estimated by amount of oxidant that remains
- Not considered as accurate as dry combustion since oxidation of SOM may not be complete
- Common in historical measurements (< 1990) and still acceptable in the science literature



Infrared Reflectance Spectroscopy

- Reflectance spectroscopy in specific bands in the 400-2500 nm bands (visible to near infrared, Vis-NIR) and 2500 to 25000 nm bands (mid infrared, MIR) are related to functional groups unique to SOM.
- Usually lab measurement now but field equipment is available to measure in the field



Infrared Reflectance Spectroscopy

- Training set of many diverse soil samples with known SOC concentrations from DC (or WC) are used to train the empirical model that relates those reflectances to the SOC concentration
  - Much interest in using national datasets (libraries) of spectroscopy measurement and SOC concentration to reduce costs to calibrate models
  - Training data sets that do not include soils from the local area of interest are rarely accurate
- Model prediction accuracy is quantified by validating the model using a testing set of soils that were not used for model development and are for the local area of interest
- Portable units for field testing available
  - Affected by condition of the soil from moisture, nature of the sample soil surface for which reflectances are measured, and visibility of intra-aggregate SOM
  - *For field use, the model to estimate SOC needs to trained for the conditions representative of field conditions*
  - Will not be accurate for field measurement if trained using spectroscopy for air-dried, ground laboratory soil samples (unless latter were derived for samples taken at same time and place as the field IR measurements).
- SOC can be estimated without removing or measuring soil inorganic carbon separately
- Will always require accurate bulk density to accurately convert estimated SOC concentration to a mass

All of the above are point estimates and they have to be scaled up to make an SOC estimate for a field or paddock

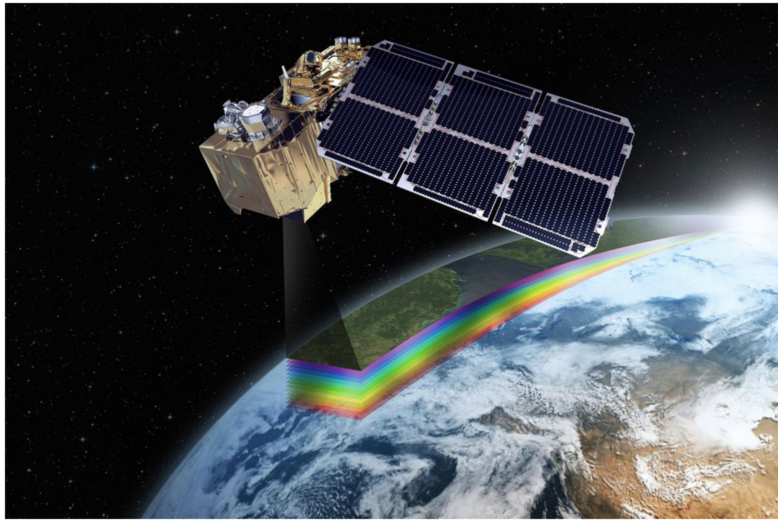
- Requires describing how SOC is expected to vary across the landscape
  - Essentially a representation, a model, of the SOC over the landscape
- Measurements placed strategically over the landscape so expected landscape variation in SOC is covered
- The SOC for the area is then estimated by multiplying the measured SOC by the area for which that SOC is representative
- Upscaling introduces uncertainty

Digital SOC Mapping techniques

- Based on relationship of land surface covariates to SOC
  - Typical covariates would be soil texture and soil type from legacy soil mapping programs, location on the local landform, vegetation and soil reflectance from remote sensing, soil moisture from remote sensing, etc.
  - Reflectance from observable soil surface in bands related to SOC (used in IR spectroscopy) provide valuable covariates
    - But soil often obscured by vegetation and/or litter so limited opportunities
- Builds an empirical model that estimates of SOC based on the measured SOC at points by DC and the covariates for that point
  - Typically built with Artificial Intelligence, such as machine learning
  - The model is then used to estimate SOC mass for all other points on area of interest using the covariate values for all those other points

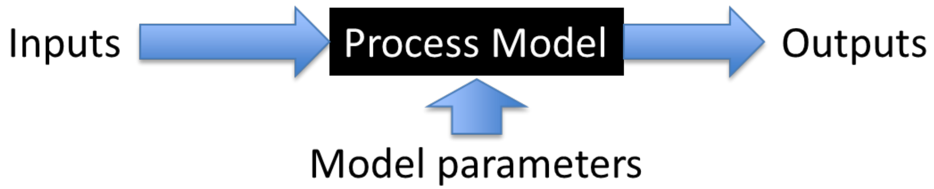
Digital Soil Mapping

- Density and quality of SOC training dataset is critical
  - SOC measurements typically limited, from the past, and usually done for a purpose other than soil mapping
- Method can be inexpensive (<$1/acre) when all covariates are from existing geospatial data and from satellite
- Estimate SOC for the time when the training set SOC measurements were made but using the current covariate values
- SOC change?
  - This has not been established that digital soil mapping can estimate SOC stock change in practice
  - Artificial Intelligence methods like machine learning require a lot of data and the lack of training data sets of SOC change is a fundamental problem
- *Upscaling is done as part of the method!*
  - One potential use to upscale point SOC estimates derived from other methods



Process Model

- Many do not trust the SOC change estimates from process models that represent the processes of SOC dynamics mathematically
  - Purpose designed to estimate SOC change
  - Models must be properly calibrated and the starting soil state properly initialized to work well
  - Models must be shown (validated) to make good estimates against real-world SOC change measurements across the range of conditions for which it will be applied



Model based Approach Advantages

- Potential to be standardized globally, attractive to multinationals
- Able to estimate expected future behaviour
- ***Able to model both with and without intervention conditions***
  - Ability to calibrate and validate using long-term field experiments with a practice change and a continuing "control" treatment is an accepted analog to the SOC difference between the with and without project situations
- Can use measured site data as input such as practices, initial SOC, soil texture, weather, yields, etc. so site specific
- Estimates are reproducible by someone else give the same inputs and parameters (measurements by soil sampling are irreproducible)
- Some models (DayCent, DNDC) do both SOC and N2O emissions

SOC measurements for Verification

- The well-regarded offset protocol of the Verra registry, VM0042 Improved Agricultural Land Management, uses verification of SOC change for the project for verification
  - Called true-up for the model but the exact way the measured SOC will be used is not clear yet
  - Note, that that measurements of project area do not verify the credits as those are from the difference between the SOC change over time for the project and SOC change over time for the counterfactual without project situation
  - The true-up measurements are most expensive part of the using VM0042 so project developers do the minimum measurements to produce accurate estimates of SOC change for large projects
    - SOC change value for the whole project of limited value to improve calibration of the model since the SOC change will be highly uncertain at the spatial scales at which the model simulates
- VM0042 has an optional quantification approach that has control sites to represent the without project control
  - No verification of the measurements beyond
- Methodologies for Scope 3 emission reduction quantification are typically based on accepted offset protocol methodologies generally

Future

- A lot of what some call "measuring" SOC are really models that take various site-specific input values to estimate the SOC at scale
- **Process models of SOC dynamics** are different in that they represent the basic decomposition of SOM and stabilization of organic materials
  - Has advantage that that they are purpose designed to estimate ***SOC change***
- **All empirical and/or process models require calibration** with bona fide SOC measurements **and validation** with data not used in calibration to evaluate accuracy and uncertainty of predicted SOC

- Future is likely hybrid systems for SOC quantification: strategic direct SOC mass measurements by DC and measured BD, SOC investigation by IR spectroscopy to expand local coverage, digital mapping with earth-surface covariates for upscaling, and process models of SOC change that account for factors that affect SOC change such a plant carbon inputs, weather, and soil disturbance
  - Then the resulting credit has a discount from the estimated SOC change based on its uncertainty

N2O and CH4

- Too expensive to measure so stakeholder acceptance of using process models or empirical equations for offsets and Scope 3 emission reductions
- Process models need to be validated for project conditions
- Empirical equations need to be shown to be applicable for project conditions
  - Usually use the relevant equations suitable for National Inventory Reports
  - Not known yet when emissions reductions from management changes beyond simple inputs (soil N additions, normal feed types, and/or number, type, and size of animals)
- No verification other than checking inputs to models and equation against available documentation and the methodology followed correctly

Takeaways

- Monitoring, Reporting, and Verification (MRV) is the essential process that enables the potential supply of GHG emission reduction and C sequestration to the potential demand
- Essential to both offsets and Scope 3 GHG emission reductions and removals
- SOC under greatest scrutiny and verification pressure since GHG removals (C sequestration) allowed to compensate for limited obstinate residual GHG emissions that cannot be feasibly eliminated
- Quantification of SOC change will likely become a hybrid of multiple estimation technology
  - Some high quality (dry combustion with soil bulk density) will always be required

Thank you

Brian McConkey
Chief Scientist
Viresco Solutions

Laser-induced breakdown spectroscopy (LIBS)

- Laser-induced breakdown spectroscopy (LIBS) is a more recent method where a tiny portion (≈ 1 mg) of soil is vaporized by a laser into individual elements.
- Calibrated models can work across a wide range of soil, but the soil structure, chemical forms, and mineralogy can affect C released from the soil, Therefore, soil-specific calibration to SOC concentration gives the best accuracy.
  – The method can also discriminate between soil organic and inorganic carbon using multivariate analysis
- Portable LIBS analytical units for use in the field are available.
- Will require bulk density

New methods

- **Mobile Inelastic Neutron Scattering (MINS)**
  - Uses differing interaction of emitted fast neutrons with soil elements and the returning gamma rays using Pulse Fast Thermal Neutron Analysis to estimate the TC concentration.
  - MINS will measure a 2-m wide "ditch" to 25-40 cm deep
- In recent 2022 publication, development team says:
  - Can estimate total carbon to 10 cm
  - Requires BD from a separate measurement or estimate

- **Carbon Mapper**
  - Uses complex models of the interaction of electromagnetic radiation with different gases in atmosphere to estimate GHG concentrations in the different parts of the atmosphere
  - Then complex models of atmosphere movement to estimate fluxes (flows) of GHG to or from the surface
  - Currently only for large point sources of CO_2 or methane emissions
  - But promise to be have more capabilities as that is a research priority of governments to quantify GHG emissions and removals
    - May never be able to accurately estimate the emissions/removals for small parcel of agricultural land in a mosaic of land uses and land managements
  - Would not estimate SOC stocks and could be validated with SOC stock changes