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The Uncertainty Challenge: Making Soil Carbon Measurement Credible at Scale

Part 3: Implementation and Automation for Scalable Success

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1 Introduction

In this short series of articles, we've sought to demystify the process of monetising the value of soil organic carbon (SOC) through Verra's VMD0053[1] and VT0014[2] standards: firstly, by exploring how trust can be built in the overall methodology and then by taking a deeper dive into the quantification process itself, focusing on the mathematical rigour and handling of uncertainties that underpins the validity of reported carbon changes over time.

Rounding off the series, this third and final article examines the considerations and steps required to achieve cost-effective Verra-compliant reporting, not just at a production unit level but reliably across a portfolio. Automation and integration are key to achieving this and so those topics are discussed in more detail before the updates to the current standards are explored in terms of anticipated general direction and specific areas for improvement. The series wraps up by sharing thoughts on the current state of soil carbon monitoring, reporting and verification (MRV), its future and what that means for those wanting to monetise their sequestration, or just monitor their soil health, using methods and data they can trust.

KEY MESSAGES

- Implementing a Verra project requires expertise and is a significant commitment.
- The route to reducing project cost and administrative burden is automation.
- An integrated, automated cloud-based MRV service is needed to deliver cost-effective, compliant projects.
- Automating a scalable system for Verra VMD0053 and VT0014 is complex but essential.
- Updates are expected to both standards and any MRV systems should be designed to adapt accordingly.
- The future depends on automation and integration.

2 Implementing and Scaling a Verra Project – What's Required

Implementing a Verra-compliant SOC project is a substantial undertaking that extends well beyond selecting a carbon model or measuring soil stocks. It requires the coordinated delivery of project design, scientific quantification, landholder engagement, data management, monitoring, independent assurance and commercial operations. Scaling the project introduces a further challenge: maintaining methodological integrity and consistent reporting while expanding across properties, soil types, climatic regions and management systems.

As discussed in Part 1 of this series, successful implementation requires the integration of five capabilities: sound project design, defensible quantification, auditable data infrastructure, scalable operations and a credible route to market. Considering each in more detail:

1. Project design and methodology selection

The first task is to establish whether the proposed activities are eligible under the applicable Verra Verified Carbon Standard (VCS[3]) requirements. Then comes the definition of project boundary, establishment of land tenure and participation arrangements, development of the SOC baseline and identification of the MRV method.

2. Establishing the measurement and modelling infrastructure

A credible project requires a structured evidence base that combines field measurements under a compliant sampling strategy with laboratory data, environmental information and supporting data such as land management records, and a robust modelling infrastructure must be in place to support modelling activities. Selecting VMD0053 or VT0014 has significant implications for the entire project, with both requiring model details to be submitted and rigorous

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uncertainty handling to be applied, but VT0014 additionally requires a defensible spatial prediction and validation (as detailed in Part 2 of this series) suitable for independent review. The resulting system needs to maintain traceability from original observations through processing and modelling to reported carbon outcomes. Scientific credibility depends not on the volume of data collected, but on whether the data and methods adequately support the conclusions drawn.

3. Validation, registration and ongoing compliance

Following those key decisions, a project submits paperwork for approval and once registered, must implement its activities, monitor outcomes and prepare the prescribed monitoring documentation for either VMD0053 or VT0014 compliance. This includes liaising with the Independent Modelling Expert (IME).

4. Building a repeatable monitoring and reporting operation

The transition from a pilot to a commercial project requires monitoring and reporting to become a repeatable operational process. A mature system must support automated data ingestion, quality checks, modelling workflows, uncertainty propagation, spatial interpolation or aggregation, and report generation. Automation reduces manual effort and timelines, improves consistency and is essential for achieving cost-effective MRV, particularly at scale.

5. Scaling across properties and regions

However, scaling introduces challenges that are not necessarily visible during a small pilot. Soil characteristics, climate, vegetation, management practices and data availability can vary significantly between properties and regions. A model validated in one setting may require further assessment before it can be applied elsewhere. The modelling infrastructure must therefore accommodate the ability to accept new data, recalibrate and validate as well as cover greater areas and report from pixel (in the case of VT0014) to portfolio scale – this drives the need for an integrated, digital platform is needed at the operational level.

6. Commercial viability and monetisation

Ultimately, the project must deliver carbon credits of value that justify the project effort and investment. Remote sensing, digital soil mapping (DSM), process-based modelling and integrated data systems are fundamental to reducing the cost of doing so whilst improving monitoring efficiency and extending coverage across large areas. Their value lies in making robust carbon accounting more affordable without compromising the integrity of the results.

3 The Key Role of Automation

Automation is fundamental to making Verra-compliant SOC projects commercially scalable. While a pilot project may be managed through spreadsheets, manual data processing and specialist intervention, these approaches become increasingly costly, inconsistent and difficult to audit as the number of properties, sampling locations, monitoring periods and reporting obligations grows. The challenge is not simply to automate individual tasks, but to integrate the entire MRV process into a controlled, reproducible and auditable system.

For VMD0053 or VT0014, this requires a technical architecture capable of connecting physical measurements, remote sensing, environmental and management data, scientific models, uncertainty calculations and compliance reporting. Automation must offer seamless, end-to-end processing for both biogeochemical (BGCM) based modelling and DSM whilst providing a consistent operational framework for both and be designed for scale from the outset.

The solution is to create cloud infrastructure that has secure storage, strict access controls and security, reliable workflow orchestration and the capacity to process large geospatial datasets. Processing must be global and repeatable

across thousands of paddocks and multiple monitoring periods, with failures isolated and recoverable rather than requiring entire workflows to be restarted manually. Equally important is the infrastructure's ability to manage change. Methodology revisions, new datasets, updated model versions and corrected source observations must be introduced under controlled procedures. Historical results should remain reproducible under their original configurations, with all updates documented and justified.

4 Technical Considerations for Automated MRV

An automated, cloud-based solution for VMD0053 or VT0014 MRV requires a plethora of technical considerations and decisions to be made that must be informed by a deep understanding of not only the standards, but the nuances of carbon projects, geospatial data, data quality, cloud orchestration, optimisation, security and many other factors – not the least of which being cost.

Doing this topic justice would require a separate and longer article, but some fundamentals are shared here for those embarking on automation or seeking to review the credentials of a supplier offering such a capability. Essentially, six main factors require careful requirements capture before design, implementation and testing, verification and validation:

- **Automated data ingestion and quality control**

  The system must ingest data from multiple sources, including soil sampling campaigns, laboratory analyses, satellite imagery, climate datasets and weather data, soil maps, and topography. These inputs differ in format, spatial resolution, coordinate reference system, temporal coverage and quality. Automated pipelines must standardise formats and units, validate coordinates and dates, check for missing or anomalous values, offer the ability to fill in missing data with default values, identify duplicate records and flag inconsistencies for review. Each dataset should retain its provenance, acquisition date, processing history and quality status. This creates a consistent, traceable evidence base and reduces the manual effort involved in preparing data for each modelling or reporting cycle.

- **A common geospatial data architecture**

  All relevant information must be associated with the correct project, property, paddock, sampling location, depth and monitoring period. This requires a geospatial data model that can reconcile field observations with remotely sensed imagery, environmental variables, management boundaries and model outputs. The system must also handle different spatial resolutions.

- **Automated modelling (BGCM or DSM)**

  The system must execute the correct workflow for the selected modelling approach and Verra standard chosen. Different BGCMs and DSMs should be supported, and the process should allow easy configuration as well as logging and reporting of key intermediate steps for validation, such as the output of spatial interpolation of soil sample data. All workflows must be repeatable, version-controlled and capable of running across multiple properties and monitoring periods. Model parameters, input datasets, software versions and processing configurations must be recorded so that results can be reproduced and independently examined.

- **Automated uncertainty quantification and validation**

  The process must include all required uncertainty data, completing missing data from a default referenced database where values are unknown, implement the required calculations and retain the intermediate results needed to demonstrate how final estimates were derived. Monte-Carlo methods must be supported and

efficient, allowing the run volumes needed to meet Verra criteria cost-effectively. For VT0014, different variogram models should also be supported.

- **Automated, compliant reporting**

  As well as generating a Model Validation Report for Verra compliance, the system should provide a complete audit trail so that each reported result is traceable to its source evidence and reproducible by the IME.

- **Secure, reliable and robust platform**

  The final non-negotiable is for the platform to be trusted to deliver, time and time again, at any scale, having maintained the security of client data and only given access to authorised users.

All leading cloud providers have solutions that enable such systems to be built, so the challenge is not the cloud components and potential cost base available, but how to assemble teams with breadth and depth of skills and experience across the science, modelling and validation as well as software and cloud computing.

5 Evolving Standards – Direction of Travel

The implementation challenge is made more complex by the evolution of the standards themselves.

In February 2026, Verra opened a major public consultation on revisions to VM0042 and VMD0053. The proposals addressed, among other matters, baseline approaches, cumulative accounting, repeated measurements and prediction-error true-up under a measure-and-model approach. The consultation ran until 31 March 2026. The evolution towards proposed v3.0 frameworks, alongside VT0014, is therefore a positive development. Verra is moving towards greater standardisation, explicit model validation, spatial prediction, repeated measurements and reconciliation between predictions and subsequent observations. In particular, improvements could be made by addressing:

- clearer rules for spatial generalisation;
- better approaches to temporal validation and the true-up procedure;
- appropriate validation sample sizes;
- handling of unknown uncertainties in input data;
- the clarity of applicable methods and metrics at some stages of the standards;
- the true-up procedure; and
- strengthening the IME capacity and process.

Organisations helping businesses register and deliver Verra projects will need to keep a close watch on emerging guidance and updated standards when they are published, and provide trusted advice to landowners interested in or already monitoring their SOC. The opportunity for Verra updates is therefore significant: to accelerate the adoption worldwide of a scientifically credible, mathematically rigorous and trusted MRV process for soil carbon.

6 Conclusion – The Future Depends on Automation and Integration

The opportunity presented by soil organic carbon is considerable, but its commercial potential cannot be realised through modelling or measurement alone.

VMD0053 and VT0014 provide different pathways for addressing the technical challenges of soil carbon quantification. Both demand a disciplined approach to evidence, model performance, uncertainty and validation but neither removes the need for sound project design, compliant reporting, independent assurance or a viable route to market.

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The organisations most likely to succeed will be those that treat soil carbon as an integrated measurement, reporting and commercial system. They will combine physical measurements with appropriate modelling, deploy digital infrastructure to make monitoring repeatable, maintain transparent and auditable records, and design projects around both methodological integrity and economic realities.

For extensive agricultural and pastoral systems, the ability to deliver reliable information over large areas at an affordable cost could be especially important. It may help make participation practical for landholders who would otherwise face prohibitive monitoring costs, while giving project developers a more scalable basis for managing carbon portfolios.

Ultimately, the goal is not simply to estimate more soil carbon, or to produce more detailed maps. It is to establish credible, verifiable and economically viable soil carbon projects that can scale without compromising integrity. That is the bridge between soil carbon science and investable natural capital: a system capable of demonstrating what has changed, how confidently it has been measured, whether it qualifies for crediting, and how that outcome can generate lasting value for landholders and the wider carbon market.

ABOUT D-CAT

D-CAT provides enterprise-grade observed ESG analytics, combining satellite Earth Observation with cloud-native processing, validated algorithms and AI to produce continuously updated environmental intelligence. Our platform integrates into existing ESG workflows, supporting carbon projects and providing automated SOC modelling and MRV reports for VMD0053 and VT0014 from pixel to farm, regional and national scales.

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References

1 **VMD0053, Model Calibration, Validation and Uncertainty Guidance for Biogeochemical Modeling for Agricultural Land Management Projects, v2.1**
https://verra.org/methodologies/vmd0053-model-calibration-validation-and-uncertainty-guidance-for-the-methodology-for-improved-agricultural-land-management-v2-1/

2 **VT0014, Estimating Organic Carbon Stocks Using Digital Soil Mapping, v1.0**
https://verra.org/methodologies/vt0014-estimating-organic-carbon-stocks-using-digital-soil-mapping-v1-0/

3 **Verra Verified Carbon Standard**
https://verra.org/programs/verified-carbon-standard/

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