SEQANA

The Technical Buyer's Guide to Digital Soil Maps (DSMs):

How to evaluate their performance for your use case

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Introduction

There is a lot of buzz around Digital Soil Maps (DSMs), often communicated with slick visuals and dense technical language, which makes it difficult to discern meaningful differences in the performance of DSMs for your specific use case in order to set your project up for long term success. With this Buyers Guide, we aim to cut through the jargon and provide you with clear guidance on how to select a DSM provider that will scale with your project and meet your needs.

A DSM, in this context, is a spatially explicit map containing SOC (stock) predictions coming from a statistical model. The statistical model creates SOC (stock) predictions that form a DSM which is calibrated and validated based on physical soil samples combined with environmental data like climate, topography and land use. In carbon projects, this means project developers can quantify carbon stocks at scale with reduced sampling costs and lower uncertainties, making it faster and cheaper to track SOC stock changes over time. DSMs scale well across large project areas, and solve many of the logistical challenges for validating and initializing Biogeochemical Models (BGCMs); however, in order to make high integrity claims, it is important to properly vet the options.

A quick note on scope

While this guide uses specific requirements of Verra's VM0042 and VT0014 as its primary framework, the underlying principles are based in science and are hence critical for projects across all major methodologies, including Scope 3 interventions under the GHG Protocol's Land Sector and Removals Standard (LSRS). Today, MRV rigor exists on a spectrum. At the higher end of compliance sits VM0042 and VT0014, requiring strict probability sampling within the project area for rigorous validation and uncertainty assessment. At the lower end, some providers rely merely on regional soil samples for calibration and quote generic uncertainty ranges without validation.

Even if your project does not intend to follow VM0042 and VT0014, using them as a benchmark helps you understand the risks of low-integrity approaches and evaluate exactly where on the integrity spectrum your project needs to sit to satisfy your buyers, auditors and internal requirements. At Seqana, we have experience navigating this entire spectrum across all major methodologies, from VM0042 and VT0014 to LSRS and beyond. We co-authored VM0042. And we co-authored the soil modeling guidance for Gold Standard.

In the following five sections, we will walk you through the essential pillars of evaluating a DSM provider:

1. aligning the DSM with your specific quantification strategy,
2. deciphering what performance metrics truly mean for your bottom line,
3. designing an economically optimized sampling plan,
4. handling the complexities of dynamic baselines, and
5. ensuring your provider has deep regulatory expertise.

1. Does your chosen DSM's approach align with your project plan?

Because DSMs are used for different purposes depending on the quantification approach (QA) under VM0042, it has implications for things like required sample size and whether or not baseline control sites are needed.

The two different quantification approaches are QA1: Measure and Model, where biogeochemical models (BGCMs) are used, and QA2: Measure and Remeasure. The table below describes some key differences relevant for your DSM strategy.

	QA1: Measure and Model	QA2: Measure and Remeasure
How is SOC change quantified?	SOC stock change is quantified through predictions from a biogeochemical model (BGCM).	SOC stock change is calculated directly from the difference between two DSMs over the same area at two different points in time.
Primary role of the DSM	Provide SOC stock inputs to initialize the BGCM (point-level or field-level) and true-up the BGCM. **Point-level:** DSM outputs are SOC estimates for randomly selected points in the project area used to run the BGCM. **Field-level:** DSM outputs are SOC estimates for all fields in the project area used to run the BGCM.	Directly quantify SOC stock change by calculating the delta of two DSMs on the same area at two points in time.
Dynamic baselines?	Assessed through the BGCM on the project area by modelling the counterfactual baseline.	Assessed through a DSM on baseline control sites outside the project area (see Section 4 below).

What to look for from a DSM provider

A DSM provider must clearly demonstrate expertise in applying DSMs in your chosen quantification approach (QA1 or QA2). Choosing providers that are proficient in both quantification approaches gives you greater flexibility to have the widest array of options in terms of project implementation, which can be extremely beneficial.

Providers must specifically clarify the differences in implementation for each use-case, stating precisely what the DSM is optimizing for. Critically, the provider must connect the required model precision and associated sampling design directly to the resulting project economics. This involves modeling the trade-off between sampling costs and reduced uncertainty deductions to ensure the combination of sampling design and DSM is economically optimized for your quantification approach from the project outset.

Questions to ask:

- [ ] Which quantification approach does your DSM support, and have you implemented it following VM0042/VT0014 requirements before?
- [ ] How does the DSMs precision translate into the project's uncertainty deductions and ultimately the project's overall economics for my quantification approach?
- [ ] Can you detail the different DSM workflows between QA1 (BGCM initialization and true-up) and QA2 (direct change quantification)?
- [ ] For QA2: How does your approach handle the dynamic baseline requirement (see section 4 for details)?

2. Do the model performance metrics you're evaluating tell you the whole story?

Each methodology defines terms slightly differently, and may use terminology commonly found in statistics in unexpected ways. In this section we'll discuss some of the concepts that are often conflated and describe their definition in the context of VM0042 and VT0014 as well as their implications for your project to help navigate the often entangled concepts that are critical to the success of your project.

First, we'll start with the foundations, the difference between precision and accuracy, and dive into what this means in the context of choosing the right DSM provider. Accuracy tells you whether the model is systematically wrong (i.e: biased) and DSMs have to pass a bias test for validation under VT0014. Passing this test is, however, only a minimum bar, which is why how a provider prevents and corrects bias in the modelling approach matters (see below). Precision tells you how much random scatter exists around the model's predictions (i.e: Variance / Uncertainty). Precision/variance is what drives uncertainty deductions once unbiasedness is established. A model can be highly accurate (insignificant bias) but imprecise (high variance). It can be precise (low variance) but inaccurate (significant bias).

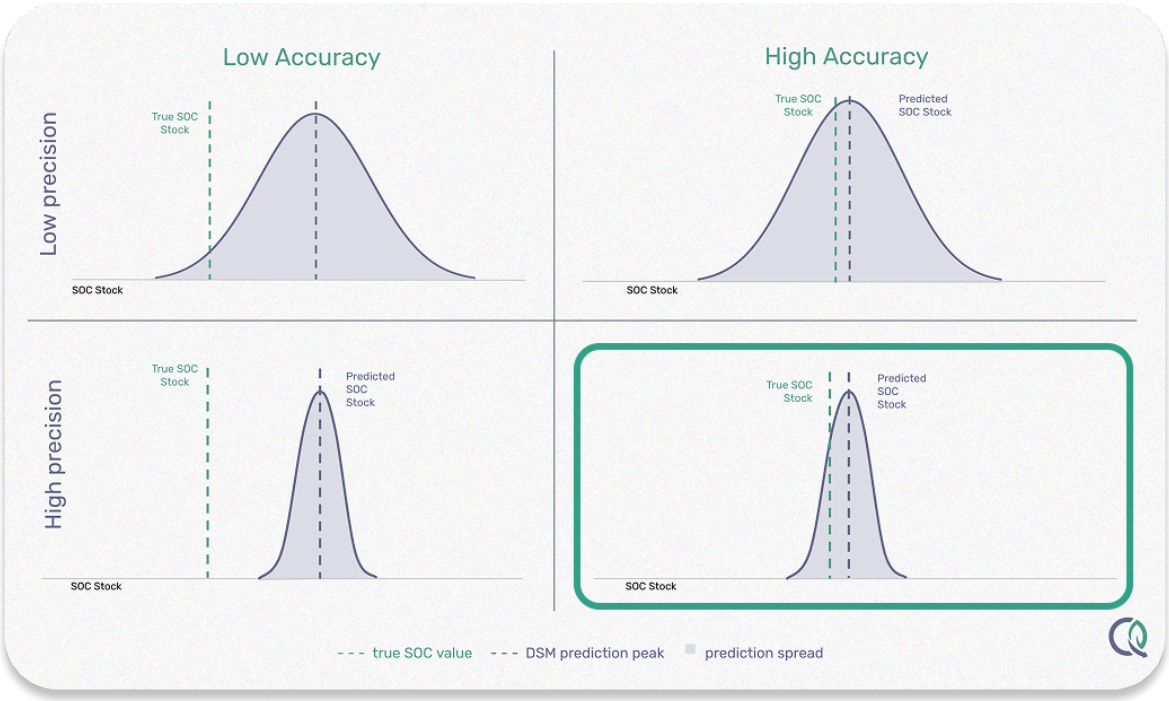
There are different definitions, but most commonly, accuracy and precision are viewed as two distinct and independent properties:

- **Accuracy (systematic error / bias)**

  The model is consistently wrong in one direction. This is an accuracy problem translating into systematically over-, or under-predicted SOC. To have a good understanding of whether or not a model is biased, the signed bias (Mean Bias Error) should be reported in addition to the Mean Absolute Error and the Root Mean Square Error relative to the ground truth probability sample.

- **Precision (random error / variance)**

  The model's SOC predictions scatter around the true value without a consistent direction. This is a precision problem translating into high variance and ultimately high uncertainty (deductions).



The visual shows that accuracy and precision are two separate properties of a DSM, and a model can fail on either one independently. Accuracy refers to whether a model is biased: a model with low accuracy will systematically predict SOC in the wrong direction, which is why validation requirements include a bias test. Precision refers to how wide the spread of predictions is around the peak, and it is this spread rather than accuracy that drives uncertainty deductions and ultimately affects how many credits a project can issue. The ideal scenario, highlighted in the green frame, is a DSM that is both accurate (insignificant bias) and precise (narrow spread), meaning the prediction peak sits close to the true SOC value and uncertainty deductions are kept low.

Bias / Accuracy

Ensuring that models are unbiased[1] (by correcting for bias as part of the modelling approach) and that any remaining bias is reported is key for compliance and high integrity for soil carbon credits. A DSM can appear precise, showing tight prediction intervals and low uncertainty deductions, while still being systematically wrong (i.e: biased). VT0014 only allows models that pass a bias test (a two-tailed t-test on

[1] We recognize that a completely "unbiased" model does not exist. For simplicity, we use the term in this guide to refer to models that have been bias-corrected and for which the VT0014 bias test finds no statistically significant bias.

the mean prediction error at a 5% significance level) to be used for carbon accounting. It does not, however, explicitly require a bias correction step as part of model calibration, so whether and how bias is corrected is left to the provider and should be scrutinized.

Some providers have quoted accuracy figures of 99% or similar for their DSMs. This kind of claim is easy to misread as evidence that the model is guaranteed to produce low uncertainty deductions. It will not necessarily: depending on the exact definition of accuracy, it may just mean that the model can principally be validated and applied within VT0014 projects. Once a DSM is validated, what really differs among DSM providers is model precision, not model accuracy (provided bias has been properly corrected, which is itself worth checking). This difference is a real economic one, as uncertainty deductions depend on model precision, not model accuracy.

Bias correction and the bias test gap in VT0014

VT0014 requires that a bias test is passed but does not specify a power requirement for that test. Statistical power is the ability of a test to detect a real effect when one exists. In this context it means: The likelihood of detecting a bias if one exists. With too small a validation sample size, the power of the bias test is low, and even a substantially biased DSM can produce a non-significant result and pass VT0014 validation. Not because the model is unbiased, but because the test did not have enough data to detect the bias. In practice, this means a provider can technically pass VT0014's bias test with a DSM that has an economically relevant bias. Importantly, the test only flags a bias if it exists at the magnitude the test is set up to detect. It does not reflect how likely it is that a bias of that magnitude exists in the first place. That likelihood depends on how the model was built, which is why bias correction in the modelling approach matters more than the test itself.

The gap is therefore only critical if no bias correction is done. When bias correction is a deliberate part of model calibration, and its effect is demonstrated on independent validation data from within the project area, a large remaining bias is very unlikely and the limited power of the bias test becomes a much smaller concern. Without bias correction, the chance of a meaningful bias is higher and the bias test may not catch it. Because bias correction is not explicitly required by VT0014, it cannot be assumed that a provider does it properly: every provider should be scrutinized on whether they apply bias correction and how they do it.

Depending on the quantification approach and the accounting method selected for your project (cumulative accounting or periodic accounting), even small biases in the DSM may have real and irreversible economic consequences. Biased DSMs could lead to three possible outcomes:

1. Undercrediting, which negatively impacts project developers.
2. Overcrediting, which compromises the integrity of the system.
3. Neutralization, where the bias cancels itself out if it is identical across both snapshot DSMs.

A credible provider protects your project's long-term economics and integrity first by correcting for bias in their modelling approach and second by reporting the bias magnitude their validation sample size can detect as an additional check. To properly manage your undercrediting risk, they will be able to answer two key questions:

- "What magnitude of bias (MDD) would be commercially meaningful for this project, with the selected quantification approach and accounting method?"
- "What magnitude of bias can the validation sample size detect, and is that adequate for this project?"

VT0014, v1 mandates a 5% significance level for bias testing but sets no minimums for power or MDD. To give project developers a clear picture of risks and opportunities, credible DSM providers transparently disclose both statistical power and the MDD as part of the bias test. Just as importantly, they transparently describe how they correct for bias in their modelling approach.

Questions to ask:

☐ Does your modelling approach include a bias correction step as part of model calibration? If not, why not?

☐ How exactly do you correct for bias (method and data used), and how do you demonstrate on independent validation data that the correction works across the range of SOC values and across strata?

☐ For QA2: Is bias corrected consistently for each DSM time point, so that differing biases between snapshots do not distort the estimated SOC stock change?

- ☐ How was your validation sample size determined?
- ☐ What bias magnitude would you be able to detect under a defined power, significance and validation data sample size? Is that bias threshold adequate for my project?
- ☐ Do you report Mean Bias Error, not just Root Mean Squared Error or Mean Absolute Error?
- ☐ What is your plan if bias is detected across the project area?
- ☐ How do you make sure that undercrediting is avoided for the specific choice of quantification approach and accounting method?

Uncertainty / Precision

"Uncertainty" is another overloaded term that is used in many different contexts in soil carbon but likely has different definitions depending on the context. Two providers can quote the same-looking uncertainty metric and mean very different things. Uncertainty may refer to sampling uncertainty of a mean estimate, the predictive uncertainty from a model, measurement/lab uncertainty, or a combination of these in various forms. It can be expressed as a standard deviation or a variance, and in absolute or relative terms. In some cases, it may even be conflated with accuracy/bias.

On top of that, sometimes reported uncertainty figures are mistaken for the project's uncertainty deductions. These are not automatically the same, and uncertainty deductions are what actually affect project revenue. In this section we will look into the topic of uncertainty more closely and how it impacts broader uncertainty deductions.

VM0042 and VT0014 use the term "error" rather than "uncertainty" for the components that feed into total uncertainty deduction calculations. These terms refer to random error/variance, ***not*** systematic bias. When you see terminology like "Model Prediction Error" or "Model Input Error" in the methodology, these are sources of random error.

The calculation of uncertainty deductions for projects leveraging DSMs under VM0042

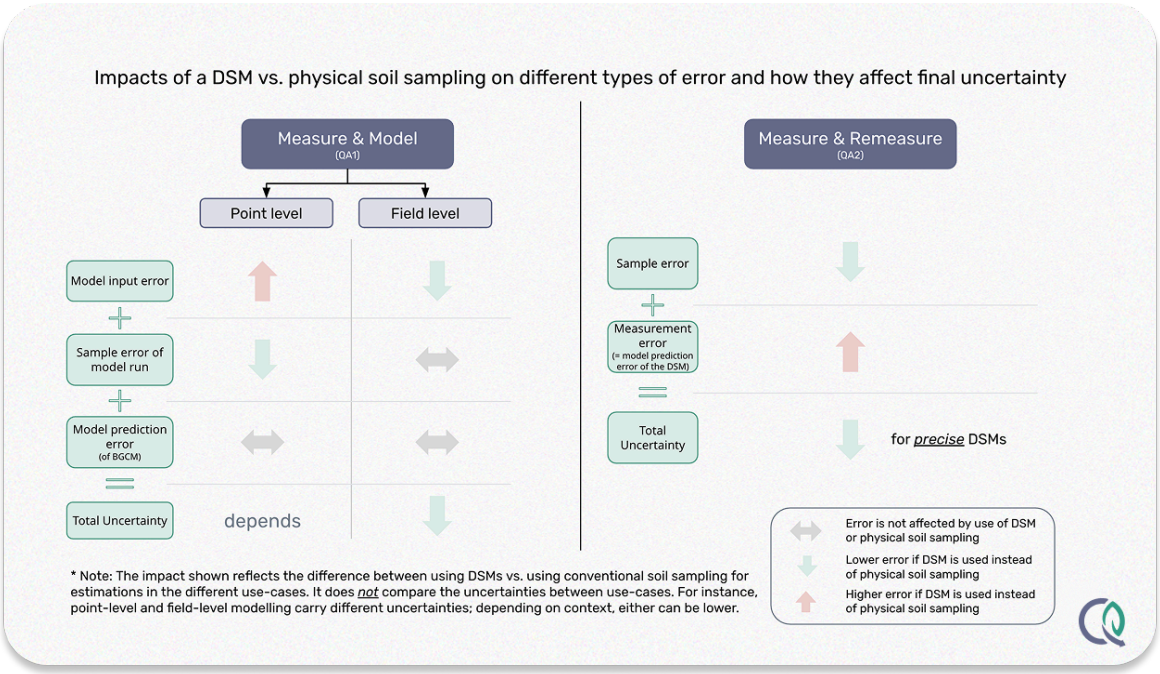
Uncertainty Deductions are calculated differently for each of the two quantification approaches. We take a look at how each of these are quantified in more detail below.

Types of error that make up uncertainty deductions under QA1:

Uncertainty Deductions for Measure and Model consider several types of error ensuring the defensibility of the final project claims:

- *Model prediction error (MPE)* reflects the inherent uncertainty in the outputs of biogeochemical models (BGCM) and tends to be the main source of uncertainty in QA1.
- *Model input error* encompasses uncertainties in the data used to initialize and run the BGCM.
- *Sample error of the model run* arises when the BGCM is applied to only a subset of the project area.

DSMs impact these errors in different ways depending on whether or not the BGCM is run on a field level or a point level.



When running a BGCM at the point level, the sampling error of the model will be lower when using a DSM compared to physical soil samples. This is because a DSM is a spatially explicit map, enabling the BGCM to run across significantly more points than physical samples would permit. There is, however, a tradeoff. The model input error will likely increase, as the error of a DSM prediction typically exceeds the direct measurement error of a physical soil sample. The final impact on uncertainty deductions will depend on how much the relative increase of one error is to the decrease in the other error.

When running a BGCM at the field level, model input error will likely decrease. Since other error types remain constant, BGCMs initialised with a DSM should result in lower overall uncertainty deductions compared to those initialised with physical soil samples. Furthermore, while VM0042 v3 now permits field-level modeling, the only default compliant methods for initializing a BGCM on a field level are using a DSM or sampling every field. Because sampling every field is rarely economically viable, DSMs are practically the only approach for field-level modeling that avoids the need to file a deviation request with a justification of how uncertainties are quantified.

Types of error that make up uncertainty deduction calculation under QA2:

Uncertainty deductions for Measure and Remeasure are calculated more simply. Uncertainty Deductions calculations consider:

- *Sampling error* results from measuring only a portion of the project area (i.e: random sampling).
- *Measurement error* of methods used to determine SOC stock (or other emission sources where applicable) at a sample unit.

Sampling error will decrease with the use of DSMs. In most cases a spatially explicit DSM is produced, in which case the sampling error is effectively zero, because you are now quantifying every single pixel of the entire project area. What will likely increase, however, is the measurement error because it is now being measured with a DSM rather than only physical soil samples.[2] Nevertheless, for precise DSMs the overall uncertainty deductions will decrease for projects under QA2 when using a DSM compared to physical soil samples.

What to look for in a DSM provider

Your chosen DSM provider should explicitly define what any quoted uncertainty figure means and map it to a specific component in the VM0042/VT0014 framework, so that you know that you are comparing uncertainty metrics fairly. Bias should be clearly distinguished from Random Error.

The provider should map uncertainty components to your project's overall uncertainty deduction according to the requirements laid out in VM0042 and VT0014. The sample size recommendation should be based on passing VT0014 validation criteria and improving project economics by balancing

[2] Although a DSM is technically a "model-based estimate", Verra's VM0042 methodology treats it as a measurement technology, meaning that the model prediction error of the DSM (referred to in VT0014 as "prediction error (...) at time t" , VT0014 V1.0, eq. 1) is factored in as a measurement error in QA2.

uncertainty deductions and sampling costs for calibration. When projecting uncertainty deductions for Measure and Remeasure (QA2) using only single snapshot data, providers must make underlying assumptions about temporal autocorrelation. Because these assumptions heavily dictate the final uncertainty deductions your project will ultimately face, they must be transparently disclosed and scientifically justifiable for you to trust the provider's claims.

Questions to ask:

- ☐ What exactly do you mean by any “uncertainty” figure you quote, and how is it calculated?
- ☐ Does this figure relate to my project's uncertainty deduction under VM0042?
- ☐ What is the expected uncertainty deduction, or how will it be determined?
- ☐ For QA2 uncertainty deduction claims based solely on snapshot data: What are your assumptions regarding temporal autocorrelation, and what is the scientific justification behind them?

3. Does your sampling design align with your project goals?

The core purpose of sampling when using DSMs under VT0014 and VM0042 is fundamentally different from traditional soil measurement. It is *not* to quantify SOC change directly or use samples to initialise and true-up a BGCM, but to calibrate and validate the DSM in a way that reduces uncertainty deductions and optimizes your project's long-term economics.

Sampling decisions are consequential: Undersampling or allocating samples incorrectly can prevent validation entirely, let significant bias go unnoticed (especially where the modelling approach includes no proper bias correction), and lead to high uncertainty deductions that make the project financially unviable. A well-rounded sampling design for DSMs is in line with sampling design requirements (see VM0042 Section 8.2 in V3 draft and VT0014 Section 5.2) and is economically optimized, balancing sampling costs and uncertainty deductions.

How to determine the sample size for DSM projects

Determining the final sample size for a DSM project is a four-step process that balances regulatory compliance with project economics.

First, you must establish the minimum sample size required to conduct meaningful validation according to VT0014 validation criteria. While this ensures model applicability, VT0014 lacks a prescribed minimum power for the bias test, meaning significant bias could go undetected when very small validation sample sizes are taken, which matters most where the model is not properly bias-corrected.

Second, projects should consider the Economic Optimum Number of Samples (EONS) for DSM calibration. This is the ideal sample size that maximizes your net financial benefit by balancing the upfront costs of soil sampling against the long-term revenue gained from reducing uncertainty deductions through better calibrated models. The underlying concept of optimising for project economics is identical to the approach used in our EONS calculator for standard design-based and model-assisted estimates (i.e., those without a DSM). We highly recommend exploring different scenarios with that tool to get a feel for the core concept. However, when you introduce a DSM into the mix, the underlying mechanics change significantly. Determining EONS for a DSM requires bespoke simulations for your specific project and alignment on your specific use case. This need for highly

customized analysis makes a simple, one-size-fits-all online calculator impractical for DSMs. Instead, it demands a tailored EONS for DSMs analysis for your specific project. At Seqana, we run this analysis for our DSM clients to make the economic trade-off between sample size and uncertainty deductions tangible.

Next, the resulting sample size and allocation must be checked against the variogram fitting requirements[3] of VT0014. If the sample size does not meet the necessary spatial distribution for reliable variogram estimation, additional samples may need to be placed.

Finally, the resulting sample size needs to undergo a budget reality check. If the optimal sample size exceeds your current budget, you will need to make strategic trade-offs. You can either reduce sample size to meet your immediate budget constraints while accepting reduced long-term revenue due to higher uncertainty deductions, or you increase the sampling budget to allow for better long term economics. A reliable DSM provider acts as a strategic partner, helping you navigate the complexities of data-driven decision-making by clarifying and measuring the inherent tradeoffs involved in your project. This strategic partnership is what we specialise in at Seqana.

How to stratify and allocate samples for DSM projects

While any stratification approach meeting VM0042 requirements is permissible for DSM usage, tailoring your stratification specifically for DSMs improves both sampling efficiency, DSM performance, and project practicalities. Generally, spatial prediction accuracy increases when samples are well-distributed and balanced across meaningful divisions of the quantification unit, such as model features, environmental domains, or geography (Viscarra et al., 2016; Diggle and Giorgi, 2019; Wadoux et al., 2019; Ma et al., 2020; Brus et al., 2023).

Regardless of the chosen stratification approach, a probability sample[4] is required for compliance under both, VT0014[5] and VM0042[6]. Validation data that does not meet this requirement will not support

[3] Variogram fitting is an integral part of DSM calibration.

[4] Probability sampling, also referred to as random sampling, is a method where every sampling unit in the quantification unit has a known strictly positive probability of being sampled at random (i.e. >0%). In the context of SOC MRV, this approach is critical to avoid bias and ensure that the results accurately reflect the variability of SOC across the entire project area.

[5] VT0014 Section 5.2.1 states: "Data used for model validation must be sampled exclusively from within the project area or baseline control site and should be drawn from a probability sample." While the methodology uses the word "should," the subsequent sentence clarifies that any deviation requires strict justification: "When a probability sample cannot be acquired, the project proponent must justify treating unsampled units as missing at random in the DSM-MVR."

[6] VM0042 requires stratified random sampling, which inherently results in a probability sample.

defensible claims to pass the validation tests, regardless of how large the dataset is or how good the model performance looks. While the probability sampling requirement guarantees high integrity, they often create operational bottlenecks for project developers, especially when project areas change (e.g. farms being added after sampling took place). Seqana has submitted a proposal to Verra for VM0042 V3 allowing such deviations when DSMs are used under certain safeguards. Until this is adopted, any deviation still requires a formal request.

When selecting a DSM provider, it is crucial to ensure that probability sampling is performed to be compliant with VM0042 and VT0014, or that a deviation can be justified. The stratification needs to be tightly integrated with the DSM and vice versa. Seqana offers comprehensive packages that combine Seqana's tailored sampling design with our advanced DSM, ensuring both components work seamlessly together to deliver superior results.

Which sampling specifications to use for DSM projects

While sample size and allocation are critical when optimizing sampling design for DSMs, they are not the only factors that matter. Several other technical sampling specifications significantly impact both DSM performance and overall project economics by directly driving sampling costs and DSM accuracy and precision. Key considerations include:

- Individual sampling vs. physical composite sampling vs. statistical aggregation
- Paired sampling vs. independent sampling
- Type of (lab) analysis methodology (e.g. dry combustion or proximal sensing)
- Depth intervals and SOC stock calculation using Equivalent Soil Mass (ESM)
- Coupled vs. decoupled measurement of SOC% and soil mass

A reliable DSM provider understands how these specifications balance cost and DSM performance. At Seqana, we take a holistic approach with our clients, defining the optimal sampling strategy tailored specifically to your DSM use case.

What to look for in a DSM provider

When evaluating a DSM provider, look for a strategic partner who understands that sampling design for a DSM requires a different approach than traditional sampling designs. An exceptional provider will not

hand you a generic, one-size-fits-all sample size, stratification and sampling specifications. Instead, look for a partner who delivers:

- **Economic simulations:** They should perform a customized Economic Optimum Number of Samples (EONS) analysis to clearly map how your upfront sampling costs trade off against long-term uncertainty deductions and creditable revenue.
- **Rigorous compliance:** Your provider must demonstrate that the sampling design yields a true probability sample to strictly meet VM0042 and VT0014 mandates. The sample size must be sufficient to conduct a meaningful validation and meet spatial distribution requirements for variogram fitting.
- **Holistic technical integration:** They should tightly integrate the stratification approach with the DSM approach and advise on nuanced technical specifications, from choosing between composite versus individual samples to selecting lab analysis methods, Equivalent Soil Mass (ESM) approach and depth intervals.
- **Practical solutions:** If your budget is constrained or farmer enrollment changes mid-project, they should guide you through strategic trade-offs or formal methodological deviation requests without compromising your timeline.

Ultimately, a credible DSM provider acts as your strategic MRV, going beyond just delivering a DSM. This is exactly the consultative, built-for-purpose approach we champion at Seqana.

Questions to ask:

- ☐ How do you plan to stratify, and why?
- ☐ Is the sampling design producing a probability sampling design for validation data?
- ☐ Does your approach include bias correction (see section 2), and does the validation sample size allow you to verify that it works?
- ☐ How was the sample size determined?

- [ ] How does this sample size affect our expected uncertainty deduction for our given use-case (QA1 or QA2), and what happens if we increase or decrease it?
- [ ] What is needed in terms of sampling when enrolling new farmers after the sampling campaign, in the same year and in subsequent years?
- [ ] What type of samples should be taken (individual cores, composites, or statistical aggregates), and how does that choice affect DSM validation and uncertainty deductions?
- [ ] Are VT0014 variogram fitting requirements met?
- [ ] Is this sampling design flexible and risk-averse?

4. Does the DSM estimate the dynamic baseline (only applicable for QA2: Measure and Remeasure)?

If you are utilizing Quantification Approach 2 (QA2: Measure and Remeasure), your DSM must estimate SOC stock changes for both the project scenario *and* the baseline scenario, commonly referred to as the "dynamic baseline."

The uncertainty of this dynamic baseline estimate must also be factored into your overall uncertainty deductions. While there are various ways to model a dynamic baseline using a DSM, the only compliant method under VM0042 (without filing a formal deviation request) is to identify baseline control sites. The DSM is then used to estimate SOC stock changes on these baseline sites to calculate the net SOC stock change of your project.

When evaluating how a DSM provider handles dynamic baselines, look for a partner who can deliver the following:

- **Optimized baseline control site identification:** Finding sites that meet the similarity criteria defined in VM0042 (Table 6-3 in the V3 draft or Table 7 in V2.2) is typically a collaborative effort between the MRV provider and the project developer. An expert DSM provider goes a step further, applying advanced criteria to select control sites specifically optimized to lower your overall uncertainty deductions and risk for your project.
- **Comprehensive sampling design integration:** To be compliant, any DSM used must pass VT0014 validation. This means baseline control sites must be physically sampled and included in the probability sample used for DSM validation. A capable provider factors this into your initial sampling design from day one. In case you missed that chance, a good DSM provider can guide you towards potential solutions for a dynamic baseline without having to take new samples.
- **Strategic thought partnership:** Developing an effective dynamic baseline often requires navigating complex trade-offs between project economics, compliance risks, and justifying potential methodology deviations. Your provider should act as a consultative partner, helping you balance these elements and ensuring alignment with your Validation and Verification Body (VVB) and credit offtakers.

At Seqana we have experience with managing standard compliant dynamic baselines with DSMs. At the same time we acknowledge that identifying, managing, and sampling baseline control sites introduces additional costs, operational friction, and uncertainty for project developers. While this is currently the standard pathway for VM0042 compliance under QA2, Seqana is actively investing in research and development on solutions that eliminate the need to manage and sample physical baseline control sites and hope to bring this into VM0042 compliance in the future.

Questions to ask:

- ☐ How do you identify and select baseline control sites, and how do you ensure they align with the similarity criteria in VM0042 (Table 6-3 in the V3 draft or Table 7 in V2.2)?
- ☐ Are baseline control sites fully integrated into your sampling design to produce a probability sample for compliant DSM validation?
- ☐ If we need to request deviations from standard VM0042 and VT0014 requirements, how will you help us ensure that VVBs and offtakers accept those deviations?

5. Does the provider have expertise in VM0042 and VT0014 (or other relevant methodologies) compliance?

Both VM0042 and VT0014 contain rigorous, highly complex requirements that must be met to ensure compliance and mitigate long-term risks for your project. Navigating these methodologies requires more than just reading the text. It demands extensive practical experience, a deep understanding of the underlying soil science, statistics, and the ability to interpret nuanced methodological intent that is not always explicitly stated in the documentation.

Even if your project falls outside of VM0042 and VT0014, such as Scope 3 or LSRS projects where methodological requirements are often less rigidly defined, this deep expertise remains critical. In the broader market, Verra's methodologies are frequently used as the benchmark for high-integrity MRV. Navigating other frameworks often involves making deliberate, contextual deviations from VM0042 and VT0014 requirements to improve project economics or flexibility. However, doing so requires a profound understanding of soil science and statistics to accurately weigh the cost savings of a specific deviation against the compliance, auditing, and statistical risks it introduces for project developers and offtakers. An expert DSM provider knows exactly how to balance these trade-offs to keep your project both economically viable and scientifically defensible.

An exceptional DSM provider does not just build statistical models. They act as your regulatory compass. They should possess demonstrable, hands-on experience navigating the intricacies of both VM0042 and VT0014, alongside a proven track record of delivering end-to-end MRV services that successfully satisfy stringent audit requirements. As co-authors of VM0042 V3 and working group members for VT0014, Seqana brings unparalleled methodological expertise to our clients. We leverage this knowledge to act as your strategic consultant, guiding you through every regulatory nuance on the path to deploying fully compliant, high-integrity DSMs.

Questions to ask:

- ☐ How have you built your technical expertise in VM0042 and VT0014, and which specific methodology versions are you most experienced with?

- ☐ Have you successfully deployed and validated DSMs under VM0042 and VT0014 requirements in the past?
- ☐ How do you proactively identify, structure, and manage potential methodological deviations to ensure they are defensible to VVBs and credit offtakers?
- ☐ What specific documentation will you provide to guarantee a smooth and transparent review by the Independent Modeling Expert (IME) and Validation and Verification Body (VVB)?
- ☐ (For projects outside of VM0042 and VT0014, including Scope3 projects): How do you adapt VT0014 and VM0042 principles to ensure our DSM meets the requirements of my chosen methodology and balances economics and rigor?

Choosing the right provider for your DSM project

Choosing a DSM provider is one of the most consequential decisions you will make for your soil carbon project. As we have explored in this guide, a high-performing DSM is about much more than slick visuals or isolated accuracy metrics. It requires a holistic approach that perfectly aligns with your chosen VM0042 quantification strategy, meticulously passes VT0014 validation tests, and optimizes your economic returns through strategic sampling.

When navigating these complex trade-offs, you do not just need a statistical model. You also need a strategic partner that helps you navigate regulatory and scientific questions. The ideal provider will transparently define their metrics, protect you from hidden biases that cause undercrediting through a documented bias correction approach, and run bespoke economic simulations to ensure you economically optimize the balance of sampling costs and uncertainty deductions.

At Seqana, we combine deep methodological expertise with advanced modeling capabilities to offer exactly this level of strategic partnership. Having co-authored the very methodologies shaping the market, we build bespoke DSMs that prioritize compliance, scientific integrity, and your project's long-term financial viability. We help you cut through the noise so you can make informed decisions, pass audits with confidence, and scale your impact.

Buyer’s Checklist for choosing a DSM provider:

1. Does your chosen DSM's approach align with your project plan?

- ☐ Which quantification approach does your DSM support, and have you implemented it following VM0042/VT0014 requirements before?
- ☐ How does the DSMs precision translate into the project's uncertainty deductions and ultimately the project's overall economics for my quantification approach?
- ☐ Can you detail the different DSM workflows between QA1 (BGCM initialization and true-up) and QA2 (direct change quantification)?
- ☐ For QA2: How does your approach handle the dynamic baseline requirement (see section 4 for details)?

2. Do the model performance metrics you're evaluating tell you the whole story?

- ☐ Does your modelling approach include a bias correction step as part of model calibration? If not, why not?
- ☐ How exactly do you correct for bias (method and data used), and how do you demonstrate on independent validation data that the correction works across the range of SOC values and across strata?
- ☐ For QA2: Is bias corrected consistently for each DSM time point, so that differing biases between snapshots do not distort the estimated SOC stock change?
- ☐ How was your validation sample size determined?
- ☐ What bias magnitude would you be able to detect under a defined power, significance and validation data sample size? Is that bias threshold adequate for my project?
- ☐ Do you report Mean Bias Error, not just Root Mean Squared Error or Mean Absolute Error?
- ☐ What is your plan if bias is detected across the project area?
- ☐ How do you make sure that undercrediting is avoided for the specific choice of quantification approach and accounting method?
- ☐ What exactly do you mean by any “uncertainty” figure you quote, and how is it calculated?
- ☐ Does this figure relate to my project's uncertainty deduction under VM0042?
- ☐ What is the expected uncertainty deduction, or how will it be determined?

3. Does your sampling design align with your project goals?

- ☐ How do you plan to stratify, and why?
- ☐ Is the sampling design producing a probability sampling design for validation data?
- ☐ Does your approach include bias correction (see section 2), and does the validation sample size allow you to verify that it works?
- ☐ How was the sample size determined?
- ☐ How does this sample size affect our expected uncertainty deduction for our given use-case (QA1 or QA2), and what happens if we increase or decrease it?
- ☐ What is needed in terms of sampling when enrolling new farmers after the sampling campaign, in the same year and in subsequent years?
- ☐ What type of samples should be taken (individual cores, composites, or statistical aggregates), and how does that choice affect DSM validation and uncertainty deductions?
- ☐ Are VT0014 variogram fitting requirements met?
- ☐ Is this sampling design flexible and risk-averse?

4. Does the DSM use a dynamic baseline (only applicable for QA2: Measure and Remeasure)?

- ☐ How do you identify and select baseline control sites, and how do you ensure they align with the similarity criteria in VM0042 (Table 6-3 in the V3 draft or Table 7 in V2.2)?
- ☐ Are baseline control sites fully integrated into your sampling design to produce a probability sample for compliant DSM validation?
- ☐ If we need to request deviations from standard VM0042 and VT0014 requirements, how will you help us ensure that VVBs and offtakers accept those deviations?

5. Does the provider have expertise in VM0042 and VT0014 (or other relevant methodologies) compliance?

- ☐ How have you built your technical expertise in VM0042 and VT0014, and which specific methodology versions are you most experienced with?
- ☐ Have you successfully deployed and validated DSMs under VM0042 and VT0014 requirements in the past?

- [ ] How do you proactively identify, structure, and manage potential methodological deviations to ensure they are defensible to VVBs and credit offtakers?
- [ ] What specific documentation will you provide to guarantee a smooth and transparent review by the Independent Modeling Expert (IME) and Validation and Verification Body (VVB)?
- [ ] (For projects outside of VM0042 and VT0014, including Scope3 projects): How do you adapt VT0014 and VM0042 principles to ensure our DSM meets the requirements of my chosen methodology and balances economics and rigor?

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Ready to evaluate the potential of a DSM on your project?

Reach out to our team →