

RESEARCH UPDATE

SCIENCE FOR HIGH-INTEGRITY CARBON MARKETS

Introducing SHIFT-CM and the Role of
Digital Monitoring in Natural Climate Solutions

Photo provided by YCNCC Faculty Paulo Brando

1. INTRODUCTION

Carbon markets offer mechanisms to help rapidly scale investment in natural climate solutions (NCS). By channeling finance into projects that reduce or remove greenhouse gas emissions, they create incentives for climate-smart practices across land use sectors, such as forest protection, ecosystem restoration, sustainable agriculture, and improved land management.

However, in recent years, carbon markets have come under scrutiny due to concerns about the quality and credibility of issued carbon credits. Persistent uncertainty around how to measure, monitor, report, and verify the outcomes of these projects has led to widespread skepticism among buyers, developers, regulators, and the public. To drive real impact, the credits issued must reflect real, additional, and measurable climate benefits.

Science for High Integrity Frameworks to Transform Carbon Markets (SHIFT-CM) is a new research initiative designed to address these evidence gaps that undermine trust in NCS carbon credits. Through a coordinated network of scientists and practitioners led by researchers at the Yale Applied Science Synthesis Program, the Yale Center for Natural Carbon Capture, and The Nature Conservancy, SHIFT-CM is advancing the science behind the data, methods, and guidance needed to bring greater scientific rigor to carbon accounting.

This brief introduces SHIFT-CM and highlights the central role of digital measurement, monitoring, reporting, and verification (dMMRV) in enabling more transparent, scalable, and cost-effective approaches to carbon crediting. The dMMRV working group, led by Yale researchers, is developing tools and frameworks to ensure that digital innovations advance not only technical accuracy but also equity and environmental integrity.

PURPOSE OF THE BRIEF

- Introduce SHIFT-CM as a new research network to align the best available science with carbon credit quality standards, addressing key market challenges.
- Explain the significance of dMMRV in accelerating continuous improvement in credit measurement.

WHY IT MATTERS

- Carbon markets face a crisis of confidence.
- Scientific guidance is urgently needed to ensure NCS credits are measurable, additional, and equitable.

2. WHAT IS SHIFT-CM?

MISSION:

- A network of researchers working on questions that close priority evidence gaps in carbon crediting methods for NCS.

HOW IT WORKS:

- Launched at Yale in December 2024 with 40+ experts.

- Focused on five key research areas, coordinated through a ‘hub-and-spoke’ model (Figure 1), identified through a structured gap assessment process:

1. Additionality and dynamic baselines

Defining robust, data-driven methods for setting project baselines

2. Digital measurement, monitoring, reporting, and verification

Exploring the role of digital tools in carbon credit monitoring and reporting and generating good practice guidance

3. Durability risk and management

Evaluating long-term carbon storage across various solutions

4. Leakage quantification

Understanding leakage patterns based on geography, project type, and mitigation strategy

5. Reversal risk compensation (buffer pools and beyond)

Developing alternatives to traditional and widely implemented mechanisms for managing carbon credit reversals such as buffer pools

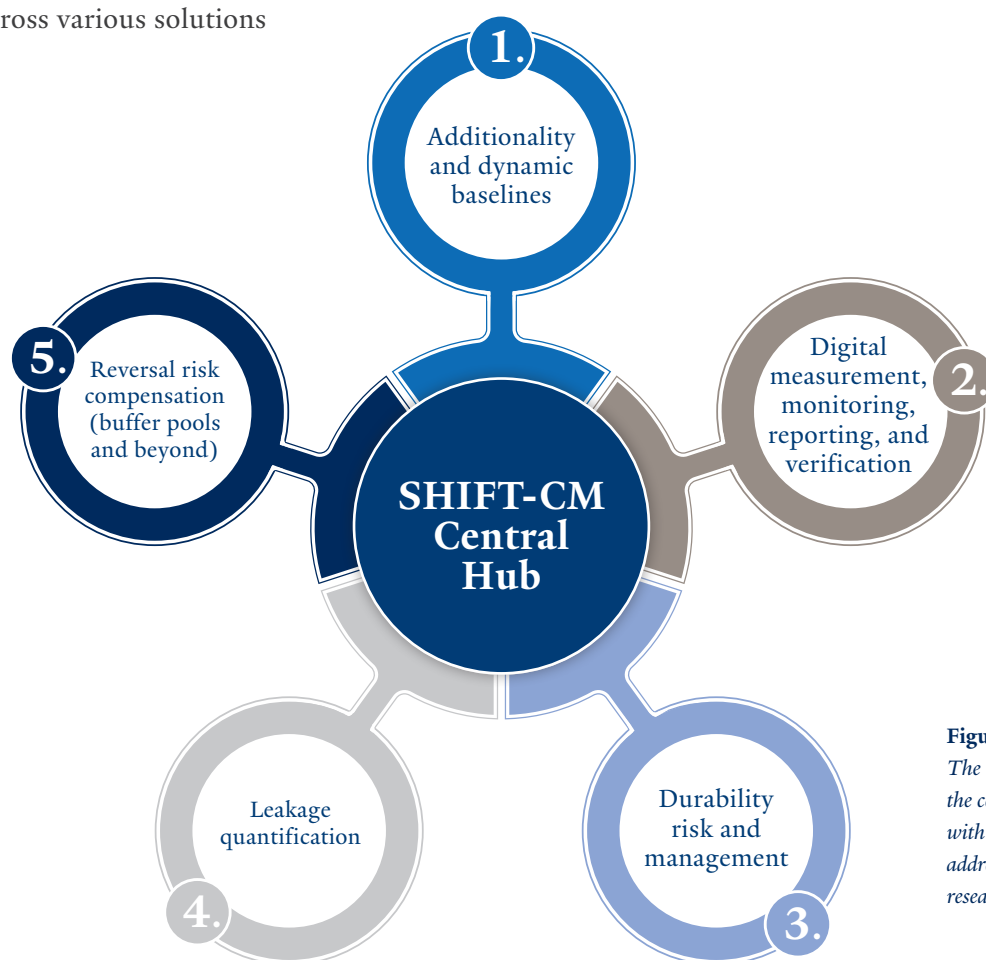


Figure 1:
The SHIFT-CM Hub is the central unifying network with groups of researchers addressing five priority research topics as the spokes.

SHIFT-CM operates as a collaborative research initiative designed to ensure carbon market methodologies for NCS are grounded in the best available science. Each research area is led by a dedicated working group of experts who co-develop research priorities, synthesize and generate new evidence, and produce actionable outputs, such as peer-reviewed publications, methodological recommendations, and prototype tools. Findings from SHIFT-CM will feed directly into ongoing standard-setting efforts by engaging with leading registries, project developers, and technical bodies.

3. THE ROLE OF DIGITAL MMRV IN CARBON MARKET INTEGRITY

Credible and robust measurement, monitoring, reporting, and verification (MMRV) systems are essential to ensure that carbon credits represent at least one tonne of carbon dioxide removed or avoided from emission to the atmosphere. Traditional MMRV approaches have focused on site visits and field sampling, which are often costly, infrequent, and difficult to replicate and scale to relevant levels of management. Field-based approaches may be inaccurate and lack transparency, relying on field operators consistently measuring sites according to protocol, and project areas may only be sampled every few years. On the other hand, digital MMRV (dMMRV) refers to the use of remote sensing, geospatial analysis, cloud computing, and other digital tools to measure and monitor carbon outcomes across landscapes in near real-time. dMMRV could significantly increase the integrity of carbon crediting by reducing reliance on self-reported data. For example, high-resolution satellite imagery and LiDAR can independently track landscape-scale forest cover and biomass changes, ensuring that credits are issued only when real and verifiable carbon storage occurs. When paired with independent valuation data, dMMRV approaches could help prevent overestimation of climate benefits and enhance capacity to rate nature-based carbon crediting projects, giving buyers greater confidence that each credit corresponds to genuine climate benefits.

While dMMRV offers a powerful new potential for measurement, its value depends on how it is implemented. Scientific rigor, transparent methods and data streams, inclusive governance, and locally relevant indicators must be embedded in how digital systems are designed and deployed. SHIFT-CM's dMMRV working group aims to fill gaps in our knowledge on the technical and social aspects of expanding dMMRV. Specifically, the working group is developing good practice guidance for dMMRV based on existing literature and the collective experience of the group. By connecting researchers, technology developers, and practitioners, the group is defining best practices and building shared standards grounded in evidence. A critical focus of the group is developing equitable dMMRV solutions that incorporate, rather than overwrite, local knowledge systems and build trust in new digital protocols and standards.

If dMMRV systems are deployed in equitable, transparent, and collectively devised ways and leverage consistent global data and open-source methodologies, dMMRV has the potential to offer the following benefits:

- Increase transparency, making data accessible at near real-time to project developers, buyers, regulators, and communities.
- Reduce costs and transaction burdens, especially for smallholder or community-led projects.
- Increase participation and access of smallholders in carbon markets.
- Enable scalability, by monitoring outcomes across diverse geographies at lower cost and higher frequency and measuring the entirety of the project areas.
- Strengthen accountability, by providing independent, verifiable evidence of real-world impact that is more easily replicable by third parties.
- Reduce error in data collection for carbon MMRV and improve efficiency through automation of collection, analysis, and sharing.

KEY QUESTIONS OF THE dMMRV WORKING GROUP

To improve collective understanding of the deployment of dMMRV and how to implement its use responsibly and effectively, the working group is exploring the following key questions:

- What opportunities and constraints exist for incorporating dMMRV into carbon projects?
- How can digital tools support transparency, equity, and continuous improvement?
- What standards or protocols are needed for data quality, verification, and community involvement?
- What protocols and methods can help ensure accuracy, as compared to ground-collected data, and how can we measure and account for uncertainty in dMMRV?

4. WHY SHIFT-CM IS TIMELY AND UNIQUE

SHIFT-CM is unique in that it is intentionally and directly linked to market bodies. The team is connected in activities and in consultation with groups such as Integrity Council for the Voluntary Carbon Market (ICVCM), Verra, and Architecture for REDD+ Transactions (ART).

SHIFT-CM is grounded in and focused on scientific rigor and interdisciplinary collaboration, prioritizing scientific evidence, not ideology or marketing.

SHIFT-CM is explicitly equity-focused from the beginning. Human rights due diligence is not an afterthought; it's foundational in each of the SHIFT-CM working groups.

5. WHAT'S NEXT FOR SHIFT-CM

The first five working groups were launched in 2025, with new working groups on supply-side and demand-side issues potentially emerging later. SHIFT-CM is actively engaged in fundraising to support expanded activities, specifically to support targeted research that strengthens carbon credit quality. The working groups aim to actively collaborate with practitioners to, for example, pilot approaches emerging from SHIFT-CM research. The SHIFT-CM network is continuing to expand and develop new ideas to actively speak to ongoing carbon market debates.