Carbon Credits and Credibility: A Collaborative Endeavor

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Introduction

Voluntary carbon markets (VCM) hold the promise of offsetting hard-to-decarbonize emissions for corporate climate and net zero strategies (Gentile 2022). However, concerns about greenwashing and the quality of voluntary carbon credits (VCC) have increased as these markets have grown (Holger 2023). This increased scrutiny of credit-stated impacts has generated both interest and work on identifying scalable validation solutions to get VCM on a legitimate path towards supporting net zero strategies (Coffield et al. 2022; Loftus et al. 2015).

At this moment in VCM, there are significant technological and financial barriers inhibiting precise estimates for a carbon sequestration project's impact (Gawel et al. 2023). This is particularly true for nature-based climate solutions (NBS), which achieve carbon sequestration through biological means, such as reforestation. Uncertainty related to measurements and assessment is a significant challenge, and this must be addressed with new rigorous scientific and economic approaches. This is an urgent task given the speed at which corporations must decarbonize to mitigate the worst impacts of climate change. VCC can play an important role in these efforts through offsetting hard-to-decarbonize-emissions.

This white paper is the result of a collaborative effort at the MIT Climate and Sustainability Consortium (MCSC) with BBVA and IBM Research focused on the challenges for robust and scalable measurement for VCM and for NBS in particular. From project inception to project retirement, robust systems for evaluating credits must incentivize developers towards activities that are most effectively and reliably sequestering carbon. The goal of this paper is to move beyond often discussed challenges in voluntary carbon markets, and show a potential pathway towards scientifically robust and scalable carbon sequestration assessments that could provide trustworthy market legitimacy. To do this, we constructed a case study using satellite data and AI to estimate the sequestered carbon of two carbon offset projects bought in 2023. This collaboration highlights the value of working across different market actors: technology providers (IBM), market participants (BBVA) and academics (MIT) to tackle climate change action bottlenecks.

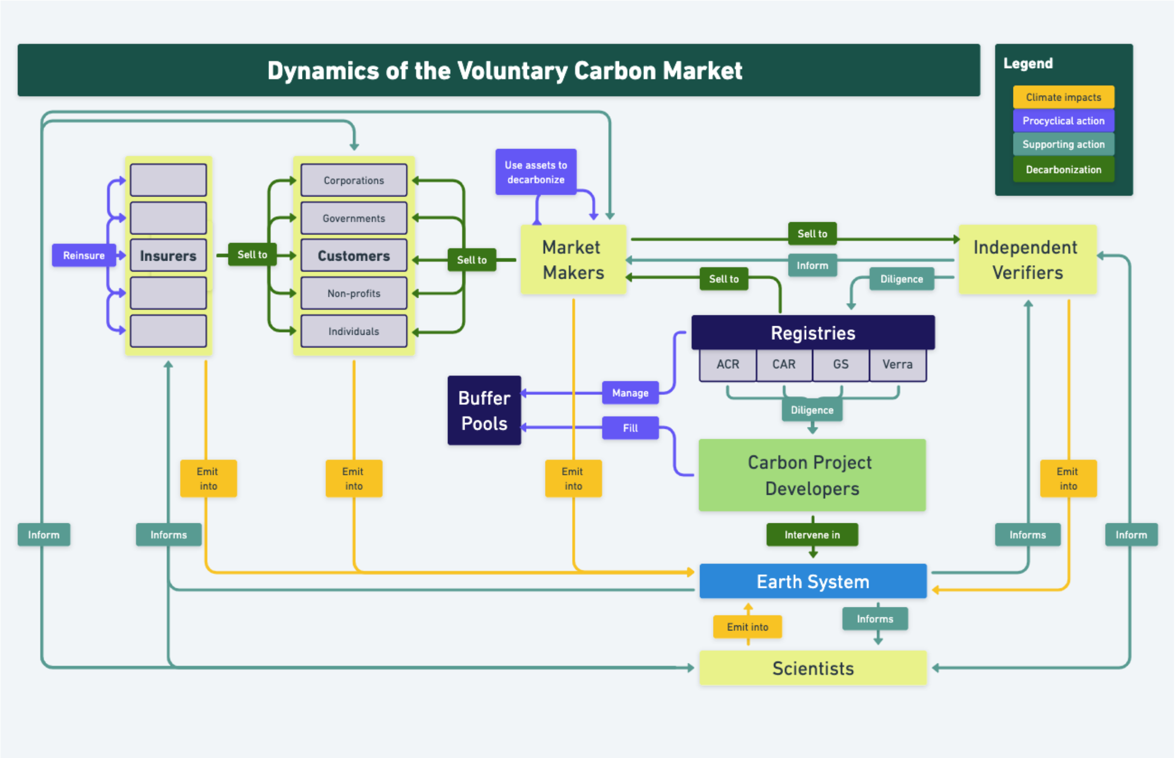

Figure 1: An overview of key players and their interactions within VCM. Arrows indicate actions, which are colored according to their broader impacts.

Carbon Markets at a Critical Moment

The increasing prevalence of corporate and public climate commitments is expected to increase carbon credit prices as corporations seek to offset difficult-to-abate greenhouse gas emissions with a limited supply of high-quality carbon credits. Stakeholders including investors and customers are voicing support for corporate climate commitments, which is driving voluntary net-zero pledges (Benveniste 2021; Frey et al. 2023). While the majority of the demand for carbon credits comes from voluntary commitments, the growing prevalence and establishment of compliance markets is expected to increase the price of credits (World Bank 2023). For example, the Singaporean government recently signed a memorandum of understanding with Verra and Gold Standard VCM registries that would allow for high quality credits to be used to cover 5% of domestic activity emissions reduction requirements in the country (Yin and Ghosh 2023; Raymond 2016).

Increased demand from potential compliance and VCM links could also support carbon credit projects, and could motivate carbon project developers to adapt their management practices to achieve higher market value according to buyers' preferences. As can be seen in Figure 2, in the last few years carbon market buyers have shown a greater interest in removal-based rather than avoidance-based credits, because removals have reduced reputational risks associated with purchasing offsets that are later found to have no detectable climate impact (Chyka 2023).

The growth of the VCM, and higher carbon prices can help incentivise decarbonization (World Bank 2023; Tripathy, Sroka, and Junor 2023). Some companies may also place strategic investments on the future value of carbon credits, maintaining a surplus supply so as to reduce their cost liability to future emissions. The maintenance of a surplus supply can then incentivize companies to invest internally in decarbonization efforts and reduce their expected future emissions, so as to permit liquidation of their credit portfolio. This can increase demand, raising the price of credits within the broader marketplace and increasing the cost of inaction. However, holding onto credits can also lessen their value due to vintage considerations.

Robust carbon marketplaces and emissions regulations can incentivize decarbonization that organizations like the Science Based Targets Initiative (SBTi) highlight as a priority for large corporations. Released in April 2023, SBTi corporate net-zero standard (version 1.1) recommends that corporations use carbon offsets to neutralize residual supply chain and other company operations emissions after deep decarbonization (Moreno 2023).

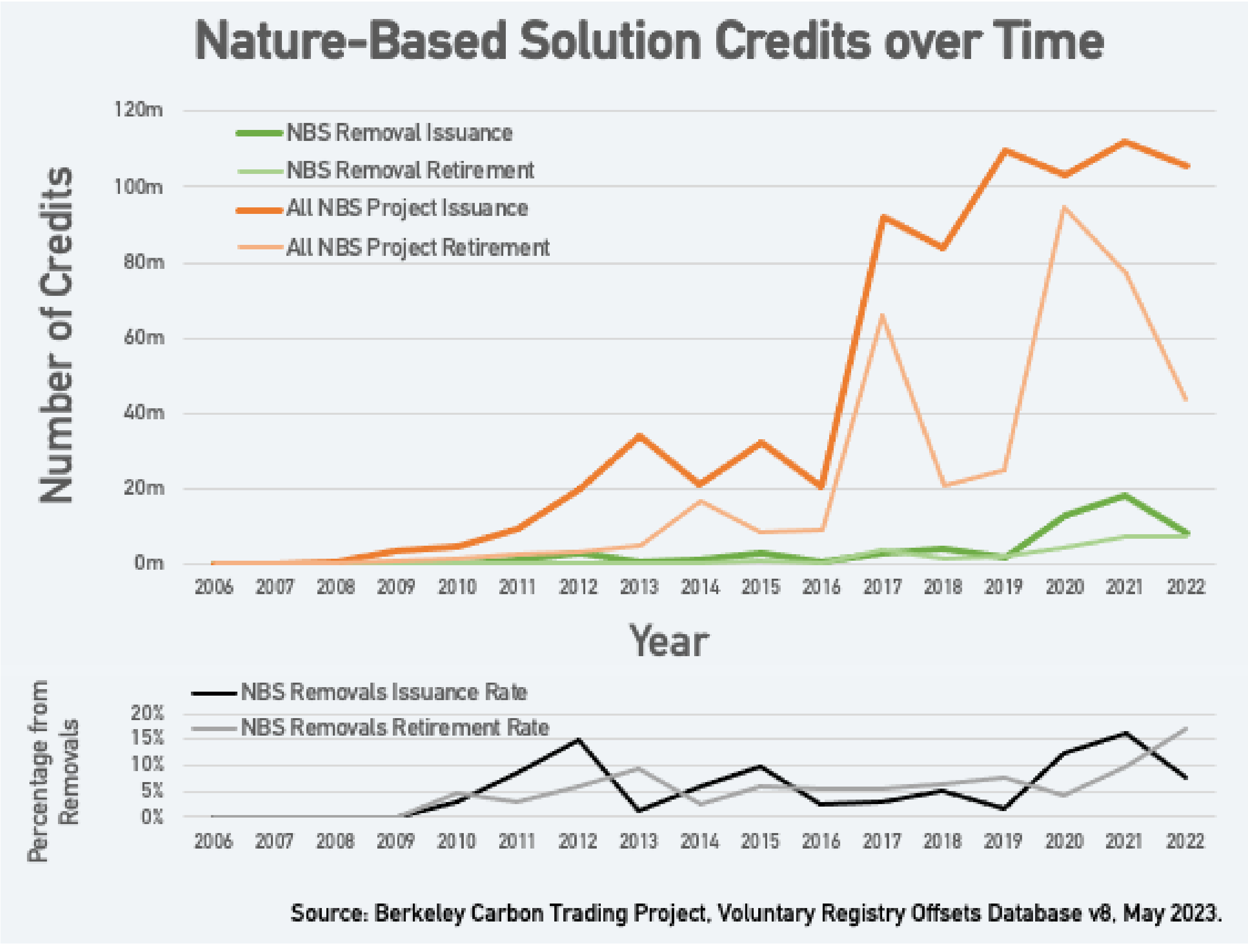

Figure 2: An overview of the growth of the NBS carbon credit marketplace over time. Credit issuances and project retirements are shown side-by-side. For comparison, the development of the NBS removals sector (which includes mostly reforestation and afforestation projects) is shown alongside the total supply of NBS-related credits from a mixture of removals and reductions (So, Haya, and Elias 2023).

Market Challenges: Standardization at Scale

Despite a range of credible certifiers widely recognized in the market, an increasing number of studies question the validity of existing methodologies (Elgin, Marsh, and de Haldevang 2023;

Gill-Wiehl, Kammen, and Haya 2023; Greenfield 2023; White 2023). Analyses of carbon credits and offsets using a mix of satellite and field plot surveys have found glaring inconsistencies between actual and reported carbon sequestration from carbon credit markets (Coffield et al. 2022). These reports negatively affect consumer and corporate confidence in the carbon market, reduce investment in carbon sequestration measures, slow adoption of sustainability projects, and destabilize needed investment in the carbon abatement and sequestration measures they provide. This controversy significantly affects an already opaque market and reinforces the need for proper regulation, common standardization and transparency (Taskforce on Scaling Voluntary Carbon Markets 2021).

The development of carbon markets can be accelerated and supported through **standardization** of project documentation and more **scalable** monitoring, reporting, and verification (MRV) techniques**.** Inconsistencies in market data and project details reduce carbon credit liquidity and reinforce consumer skepticism. Voluntary carbon markets require assurance that carbon credits are contributing to carbon sequestration. Since rigorous in-situ verification is both cost and labor intensive, carbon registries including American Carbon Registry, Climate Action Reserve, Gold Standard, and Verra need to establish project disclosure criteria that are achievable in resource-constrained regions. Unfortunately, the minimum level of detail required for project certification is often not sufficiently compelling or credible for carbon credit purchasers. As a consequence, buyers and some specialized brokers of carbon credits need to engage in extra due diligence to ensure that a project meets the brokers' internal quality standards. Buyers that are unable to allocate resources towards collecting additional information are therefore more likely to purchase problematic credits that confer the aforementioned reputational risks.

The negative impacts of inconsistent data, a lack of transparency, missing documentation, and the resulting VCM skepticism is already evident in market pricing signals. As a 2023 Bloomberg New Energy Report states, "Corporations purchased and retired just 155 million carbon offsets in 2022, down from 161 million the previous year. The biggest driver was growing criticism of carbon offsets by investors and the media, tempering enthusiasm from buyers" (Chyka 2023). This drop in demand for carbon offsets by corporations is a result of market uncertainty around the quality and legitimacy of carbon credit projects as well as changing offset demands from certain industries such as cryptocurrencies.

Characteristics of Robust Carbon Projects

The challenges described so far impact liquidity and create additional work for market participants to conduct extra due diligence on carbon credits (Vereckey 2022). These market participants have developed a range of strategies. BBVA is an international bank that is active in carbon markets. As both a buyer and a market broker, BBVA identifies the following as the key features of carbon projects that guide their internal due diligence around VCM:

Additionality means that carbon sequestration would not have occurred independently of the project developers' actions. This attribute is important for investors since they want to make sure their investment is directly responsible for the stated impact on the environment. In order to ensure additionality, the developer shall provide evidence that the project would not be viable without funding from the sale of carbon credits and goes beyond the business-as-usual scenario.

Leakage refers to emissions that a carbon credit project creates elsewhere. These displaced emissions are important to incorporate into both the valuation of the carbon credit and the carbon accounting that the credits are applied towards.

Permanence refers to the time that sequestered CO_2 will remain removed from the atmosphere. Nature-based solutions have a hidden cost of replacement when CO_2 is re-released. Thus, every project should be covered by an insurance mechanism to compensate for potential failures. For example, most registries currently maintain a buffer pool of carbon credits from all projects, serving as a safety net to cover unexpected carbon reversals (Verra 2023).

Vintage refers to the certification or recertification date of the carbon credit. Credits with vintages of less than five years have greater traceability, and are therefore more desirable for investors.

A project's ability to preserve or improve **biodiversity** is also an important attribute of high-quality carbon credits. Monoculture reforestation, even if it might present higher carbon capture metrics on paper, could potentially harm the local biodiversity, disrupt ecosystems, and even compromise the long-term viability of the project due to heightened vulnerability to natural risks. Resilience to natural risks becomes even more critical when taking into account additional impacts from climate change (rising temperatures, extreme weather events, etc.). Therefore, nature-based projects that plant a diversity of native species are preferred.

Evaluating and comparing **co-benefits** across candidate projects, taking into account the project developer's understanding of local context, is also an important attribute in assessing an NBS project. BBVA values the social and economic development of local communities, especially in Latin American countries where BBVA is very prominent. Because NBS has the potential to combat climate change while also improving the resilience of local communities to climate extremes, they can provide social license to operate in and support at-risk regions.

These attributes are usually discussed in the project descriptions of main registries companies, but a **lack of standardization** inhibits market participants from quickly identifying targets for purchase, limiting market liquidity. There are many different verifiers that project developers can use to certify their project's credits, each with their own eligibility criteria and calculation methodologies. This heterogeneity increases the burden of the previously discussed extra due diligence consumers conduct, and disincentivizes engagement with the market.

With respect to MRV mechanisms, robust analysis of remote sensing data are promising avenues for **scalably determining how projects are performing** across these key dimensions.

"Applying technological solutions that tap into standardized data could aid in addressing the scaling challenge of VCCs. AI-powered technologies hold the promise of making the VCM more verifiable and thus enabling various players in the ecosystem to share information, increasing support for carbon markets as the tool that will help preserve biodiversity and support local communities."

— Marina Rakhlin
IBM Research

These technologies not only help estimate the captured carbon but also enable continuous monitoring of changes in forests over time, ensuring the integrity of these projects. A cost effective and consistent monitoring mechanism is key to ensure the long-term success of these nature-based solutions, given the risk of reversal.

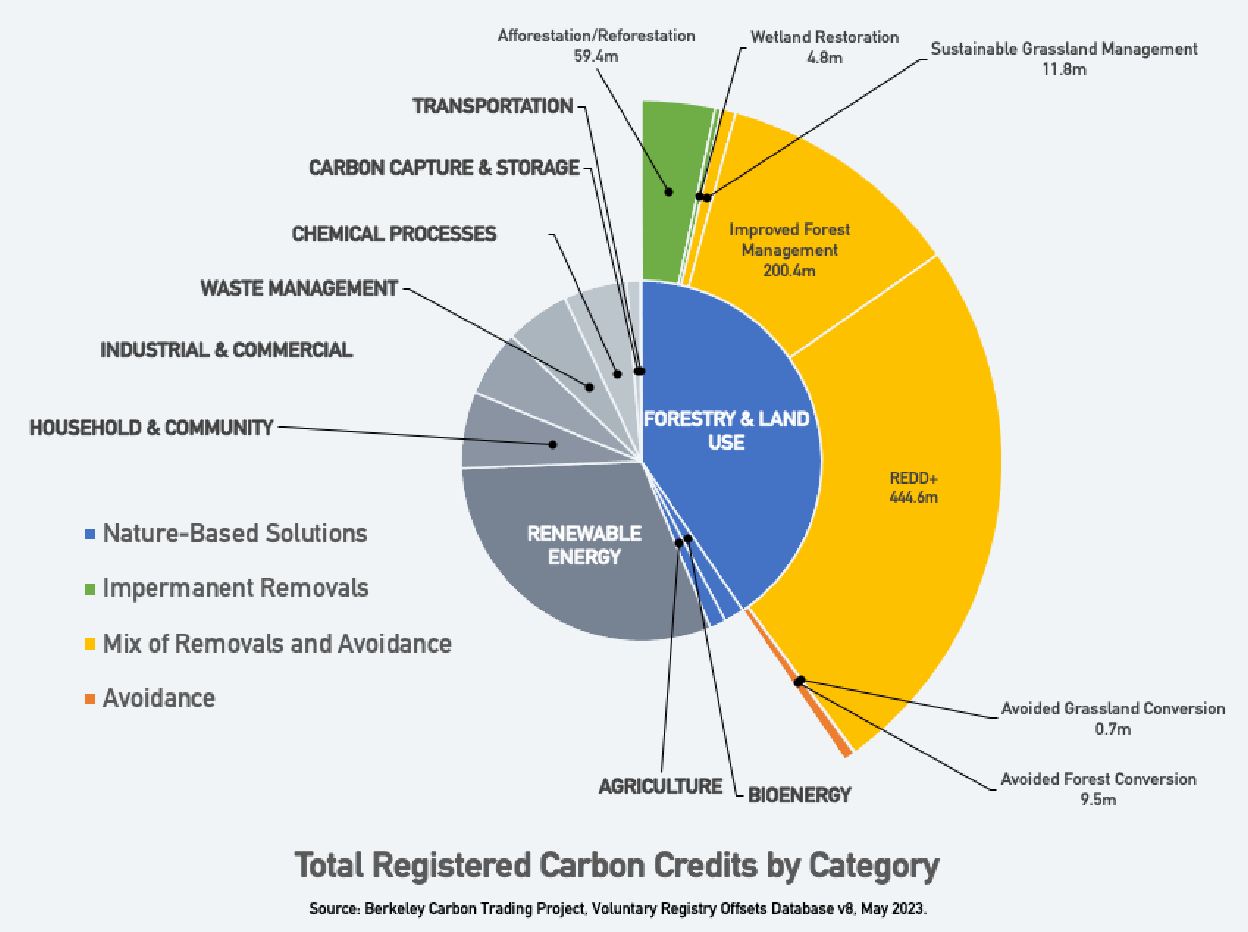

Figure 3: An overview of the voluntary carbon credit marketplace. The net supply of credits is shown for different intervention classes. Blue wedges indicate nature-based solutions credits. Within forestry and land use projects, we break credits down further by intervention, and color them by the degree to which they represent emissions removals rather than emissions reductions (So, Haya, and Elias 2023).

Solutions: Linking Different Forms of Measurement

A major challenge within carbon offsets from nature-based solutions lies in tracking the quantity of atmospheric carbon which is captured by soil or vegetation. The heterogeneity of soil and vegetation provides an immense variety of physical and chemical characteristics that make methods of direct carbon measurement difficult. Typically, carbon measurement requires collecting samples and burning them in a controlled laboratory environment. The difference in weight before and after sample combustion is related to the carbon content of the sample. However, this is a time-intensive, expensive, invasive, and destructive procedure to perform at scale for the purposes of monitoring the carbon content of natural ecosystems.

Alternative methods involve field measurements, where relationships between vegetation characteristics (wood density, carbon percentage by mass) and size or shape are studied in the scientific field known as allometry. The allometric approach, combined with field measurement of trees, is considered the most reliable approach by forestry services to quantify carbon storage in trees. Field measurement data are essential to calibrate and validate many carbon sequestration models.

"Measuring visual features such as shapes and sizes from a satellite- or drone-based platform is straightforward, thanks to the rapid growth of the private space sector and the increasing availability of small-scale drone hardware. However, remotely sensing ground-based chemical signatures from these same systems is extremely challenging. New and up-incoming measurement systems using special hyperspectral cameras, such as Planet's Tanager constellation and Orbital Sidekick's GHOSt microsatellites, may assist in reducing the uncertainty of Nature Based Carbon Sequestration models within the next two calendar years. With a team of scientists at MIT Lincoln Laboratory, the MCSC is investigating whether we can track carbon sequestration by natural systems more accurately by pushing these emergent technologies to their limits."

— **Evan Coleman**
MCSC Impact Fellow

Years of dedicated research to understand local vegetation, by institutions around the globe, has provided a diverse collection of local models of biomes in scientific literature. There are emerging efforts to extend local modeling to a global context, and a global initiative developed by the International Panel of Climate Change (IPCC) already provides guidelines for estimating carbon sequestered by nature-based climate solutions (Shukla et al. 2019). However, in their current form, models are simultaneously too generic to be globally realistic and too difficult to customize for individual projects, where accuracy in estimates is paramount. Today, no single measurement methodology or model quantifies naturally sequestered carbon across the globe in a reliable, low-cost manner. There is a growing need for improved Nature Based Carbon Sequestration models in combination with self-supervised and/or one-shot learning AI techniques. Researchers at IBM are approaching this challenge by leveraging massive geospatial data combined with Geospatial Foundational Models to quantify the global Nature Based Carbon Sequestration (da Silva et al. 2022; Nathaniel et al. 2022).[1]

“Building on decades of technological advances and frequent, continuous, and reliable measurements, today satellite data are an important ally for the transparency of MRV methods to be applied for carbon offset markets.”

— **Ademir Ferreira**
IBM Research

The number and diversity of deployed Earth observation satellites requires intelligent ways of combining and harmonizing datasets across space and time. But in formulating methods for carbon sequestration assessment via satellite data, a range of decisions related to data management must be made. Many of the data sources reside in different databases and have different data encoding formats, measurement units, and spatial-temporal coverage. Furthermore, the data is stored as raw values, and discoverability of common patterns and similarities is left to the users. IBM is working on a Geospatial Discovery Network research project, which aims at significantly improving the discoverability and useability of geospatial information, thereby accelerating the development of nature-based carbon sequestration and other climate impact related applications (Watson et al. 2023). Accounting for data acquisition intervals, tracking differences in data integrity, and performing data post-processing are automated in Geospatial Discovery Network along with geospatial functions, to discover patterns as well as trendlines in datasets spanning different geographies, data modalities, and models. Connecting various databases across continents can enable federated learning and discovery, where a large volume of data does not need to be moved but only relevant AI model features distilled from the data are transferred between databases. The Geospatial Discovery Network has built-in, readily available data curation functions like cloud removals and compensation for atmospheric scattering effects. The data curation and similarity in data allow automatic creation of reliable labels required for AI model training. All this data is ultimately used to train powerful Geospatial Foundational Models to have common architectures and improve the transparency of AI models used for downstream assessment tasks like Nature Based Carbon Sequestration estimates, environmental risk assessments, and quantification of biodiversity.

[1] https://newsroom.ibm.com/2023-08-03-IBM-and-NASA-Open-Source-Largest-Geospatial-AI-Foundation-Model-on-Hugging-Face.

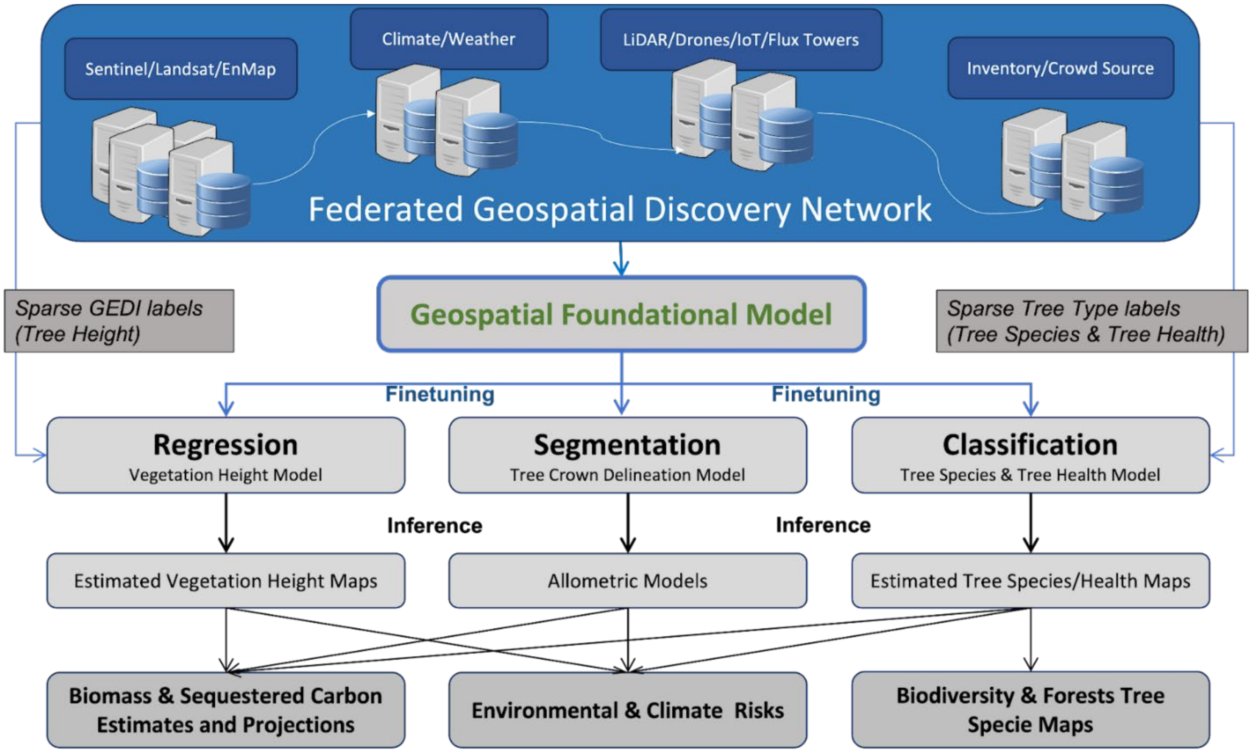

Figure 4: Details of IBM Research's AI based approach to estimate Nature Based Carbon Sequestration. Federated data management through Geospatial Discovery Network is integrated with Geospatial Foundational Models for multiple parallel downstream tasks to quantify carbon sequestration, assess climate risks and quantify biodiversity.

IBM's Geospatial Foundational Models can overcome scalability issues and aid nature-based carbon sequestration solutions in the following ways:

1. Use of a common Geospatial Foundational Model for training AI models and running multiple fine-tuning tasks in parallel. The self-supervised learning models trained on massive and heterogeneous data sources (satellite images, flux tower measurements, weather and climate data) enables rapid fine-tuning of carbon sequestration quantification, tree species identification and assessments of climate risks.
2. Verification and identification of optimum land management practices to verify the quantity of carbon sequestered, as highlighted in Registry reports, and quantify the potential for highest carbon sequestration given local practices and climate projections.
3. Assessment of the long-term risks, growth, and permanence for carbon sequestration in a scalable and verifiable approach, based on open-source data and transparent AI tools.

With the emergence of Geospatial Foundational Models, AI approaches can better generalize across many locations by learning latent representations that are unique and invariant across space and time. Using a self-supervised learning model reduces the need for multiple supervised AI model trainings, and minimizes the volume of labels required for training different models like regression, classification or segmentation. Label sparsity is prevalent in many of the Nature Based Carbon Sequestration applications, where tree species, tree health or biodiversity assessment are impeded by the lack of ground truth data. With Geospatial Foundational Models, the scalability of the model is built in as well as the explainability and the interpretability of results by intelligently combining allometric equations, tree species, tree age, tree health and ecoregion's tree growth factors. Space-based Light Detection and Ranging (LiDAR) instruments, such as Global Ecosystem Dynamics Investigation and Ice, Cloud, and Land Elevation Satellite, are emerging as critical tools to supply sparse but global coverage labels for nature-based carbon sequestration.

One key advantage of satellite observations is the ability to monitor early signs of deforestation, drought, wildfire, or pathogenic infestation. With weekly satellite observations, meaningful changes that occur compared to an established baseline can be detected and monitored. Another advantage of AI-driven satellite verifications is consistent assessment of carbon sequestration and risks across different continents and different time intervals.

Project Case Study

Based on geographical considerations and market purchases in 2022, for this pilot project, BBVA proposed an analysis of factors influencing the quality of two institutionally held carbon offset projects, located respectively in Colombia and Uruguay. These projects are useful examples of the particularities involved in afforestation and reforestation projects, and the need to find variables which can aid in transparent assessments of year-to-year carbon accumulation in trees.

These projects were first selected from among those satisfying BBVA's quality criteria described above. This study was then structured and developed cooperatively, through conversations between financial experts at BBVA and scientists, both at the MCSC and at IBM Research. The strategy behind our analysis had four principles, which build on one another as follows:

1. **Clear gaps in scientific understanding:** Extracting CO_2 from the atmosphere using natural processes, such as nature-based solutions are the most effective and viable approaches that currently exist, but the associated risks of CO_2 permanence are challenging to quantify.
2. **Feasibility of measurement:** The mass of carbon stored within a given forest is a well-characterized quantity.
3. **Interpretation of additionality:** Among carbon credits available for purchase, reforestation and afforestation credits form the largest body of removals. While afforestation may come with unique verification challenges (they may deplete soil carbon stocks at a greater rate than reforestation (Berthrong, Jobbágy, and Jackson 2009), it is easier to interpret afforestation projects as being additional because trees are not present on that land prior to human intervention. For this reason, our collaboration chose to study afforestation over reforestation projects.
4. **Relevance and recent vintage:** The project documentation should be up-to-date and exemplify current market practices. In addition, the state-of-the-art space-based LiDAR

instrument (as Global Ecosystem Dynamics Investigation instrument) has only been deployed for Earth observations recently. As such, data availability motivated us to consider credit vintages from the past two years.

With these guiding criteria, BBVA identified within their portfolio the following two carbon offset projects for analysis:

- CUMARE: afforestation, Colombia (ID 2532), and
- GUANARE: afforestation, Uruguay (ID 959).

Scientists at IBM Research studied these projects to develop verification methodologies for carbon sequestered in vegetation and applied Geospatial Foundational Models to calculate carbon sequestration using remote sensed observations and compared remote sensing approach with the data reported in the CUMARE and GUANARE projects description.

One clear advantage of IBM's approach here is the identification of spatial locations where the carbon sequestration can be significantly increased under proper management practices; e.g growing forest adapted to the environment, applying variable management practices like fertilizer, or forest thinning for faster growth. Both images in Figure 5 demonstrate that some regions of the two projects have higher carbon storage than other areas that are less effective to store carbon. The existence of areas with reduced carbon density suggests regions where management practices (like replanting slow growing, already infested or dead trees) might investigate further or allocate additional resources in order to bolster the success of the forestry project. Such spatial relationships can aid in both estimating and realizing the maximum carbon storage potential within a project's boundaries, which is a service of interest both to carbon project managers and to carbon credit purchasers. This more sophisticated inference and optimization is not possible with current registry documentation, because such reports generally provide only a mean estimate of carbon sequestration over the entire region.

A frequent concern for integrating satellite-based methods of assessment into the preexisting infrastructure of carbon markets lies in establishing consensus around measurement comparisons. How can we combine on-the-ground and satellite-based assessment methods to increase certainty in carbon credit projects? Recent academic research has analyzed how to compare LiDAR, survey and other on-the-ground assessments to calculate carbon sequestration (Johnson et al. 2022; Urbazaev et al. 2018). There are models that project risk out for 100 years, but the granularity of detail (spatially and temporally) must match the needs of market participants to be useful (Anderegg et al. 2022). This is particularly true in markets such as the VCM where there is a lack of standardization.

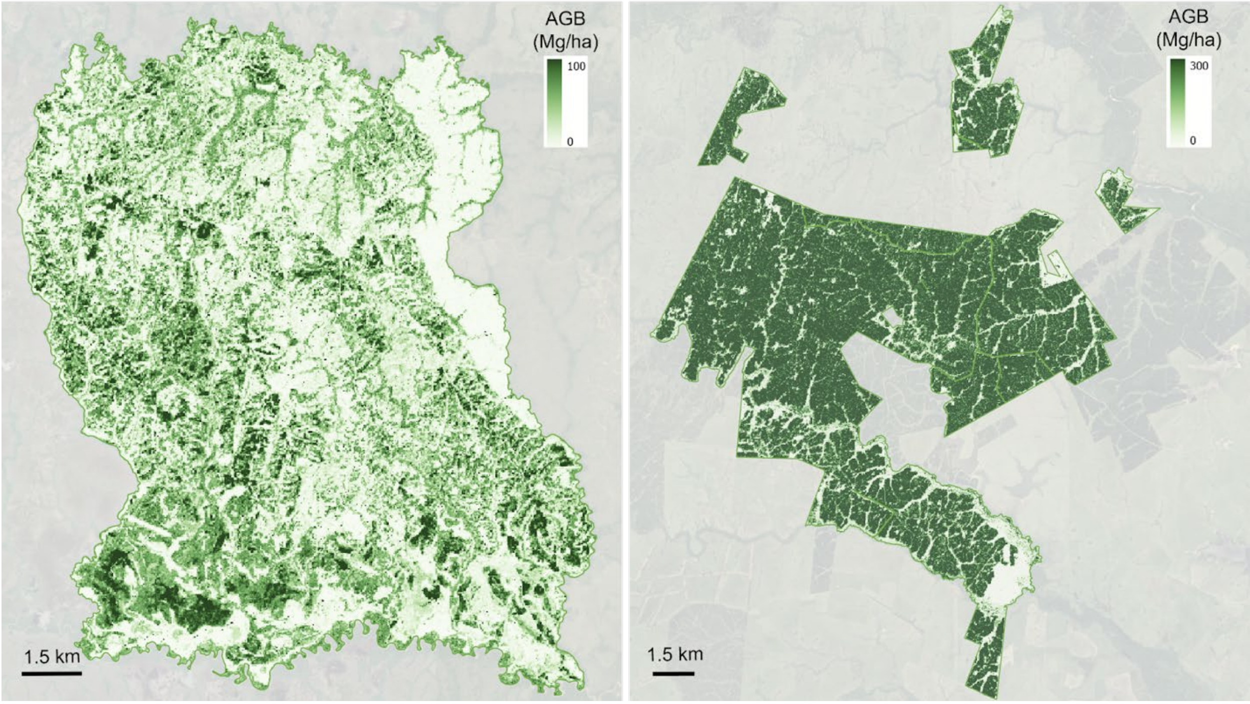

Figure 5: Carbon sequestration estimates for CUMARE and GUANARE afforestation projects respectively. Remote sensing observation detects significant spatial variation of carbon sequestration indicating regions that already sequestered large amounts of carbon and delineating regions that under proper management have high potential to increase the amount of carbon sequestered.

In order to evaluate the diversity of tools and methodologies outlined in reforestation and afforestation reports from VCM registry databases, the integration of IBM's DeepSearch tools with Geospatial Discovery Network is used to parse and to extract geospatial information from available PDF documents from the registry database (Livathinos et al. 2021). The georeferenced data can enhance current knowledge for a specific location and automatically generate labeled data for Geospatial Discovery Network if that information is included in the pdf document. The goal is to automatically extract variables (like estimation methodologies, supporting data and graphs, and projected carbon sequestration for the next decades) from carbon project registries which can be used consistently to understand expected sequestration differences across projects.

When applying modern computing techniques to the collection of carbon registry data, not all reporting to these standards is created equal. The presence of handwritten information, dislocated numbers, and non-standard mathematical notation poses a significant challenge for the automatic validation of the asset's underlying quality.

Ultimately, for carbon marketplaces to responsibly scale to future expected demand, registries must standardize their methods of reporting. The transparency and predictability of project documentation are two necessary components of any external credit quality assessment performed by carbon market consumers. In the absence of that transparency, consumer complacency will incentivize obfuscation in reporting, which ultimately undermines the fairness and credibility of the entire verification marketplace.

Takeaways for Improving Carbon Markets

Voluntary carbon markets are at a crossroads (Tripathy, Sroka, and Junor 2023). On the one hand, they have grown dramatically over the last decade, and particularly in the last three years (Porsborg-Smith et al. 2023). On the other, they are under increasing and legitimate scrutiny, as journalistic reporting and scientific analyses of carbon offsets find actual impact from these projects debatable or wholly invalid (Coffield et al. 2022). Additionally, developments in compliance markets have the potential to impact VCMs.

The challenges that VCMs face need to be dealt with through coordination across a range of different institutions. The principal thesis guiding research within the MIT Climate & Sustainability Consortium is that private sector entities and scientific institutions can engage with one another to identify scientifically-rigorous, scalable, practical, impactful solutions to climate change. The learnings from these efforts can then inform policy in a more comprehensive way than either institution could achieve individually.

Through this collaboration, the MCSC, IBM and BBVA have sought to outline where we are at this current moment with carbon markets and where we need to go to ensure that offsets in these markets provide actual emissions reductions to support corporate net zero strategies. Our pilot project here has focused on identifying solutions that could standardize and scale MRV of carbon credits. Remote sensing observations coupled with AI have the potential to better inform brokers and buyers about the quality of a carbon credit project. Monitoring vegetation health and growth provides insight into a current project’s progress towards achieving its stated biodiversity goals. Remote-sensing observations can help inform buyers and brokers about the expected permanence of a candidate project. Long-term monitoring can provide more robust time histories of growth and provide a more accurate assessment of projects with older vintages.

Several key areas of carbon markets as addressed in this paper:

1. While there are documentation inconsistencies and limitations, the existing carbon credit project descriptions do enable the kinds of additional analysis we have demonstrated in this pilot study. Project design documents must always be readily available to preserve market legitimacy and support transparency. Initiatives such as the Berkeley Carbon Trading Project represent positive steps to consolidate all carbon market projects into a uniform list (So, Haya, and Elias 2023).
2. Units of measurement and forms of analyses for carbon credit projects should be fully disclosed and available.
3. Satellite data enables monitoring that can inform project developers about the progress and potential risks to their sites, as well as which management strategies could be effective.
4. Limitations on historical satellite data do not allow for detailed past assessments of nature-based carbon sequestration offsets and credits, which currently inhibits satellite verification for carbon credits with older vintages. However, our ability to validate those sequestration estimates will improve over time as we collect progressively larger satellite and ground-truth datasets.

Going forward, we expect that geospatial data will be increasingly embedded into carbon market infrastructure (Caldecott et al. 2022). Carbon markets brokers, registries and other market participants have been working on strategies to connect carbon credits with geospatial carbon sequestration evaluations.

Improving the legitimacy and impact of carbon markets will allow public and private entities to make valid decarbonization and net zero pathway choices as we collectively respond to climate change (Allen et al. 2020; Knox-Hayes 2016; Reichelstein 2022). The MCSC's efforts to organize collaborations such as this, represent efforts to speed up this process and get us to where we need to be to limit severe impacts from worst-case climate scenarios.

There are now a range of organizations attempting to correct the issues of governance in VCM highlighted in this paper. Beginning in 2020 at COP26 in Glasgow out of the Taskforce on Scaling Voluntary Carbon Markets, the UK government, UNDP, and the Children's Investment Fund launched the Voluntary Carbon Markets Integrity Initiative (VCMI).

Building on the VCMI, the Integrity Council for the Voluntary Carbon Market (ICVCM), an independent governing body for the VCM, recently released the Core Carbon Principles, an extensive framework with the aim of guaranteeing the highest quality of credits, integrity and transparency, and it is expected to help standardize quality indicators. The ICVCM is currently working on creating clear categories of carbon credits, framing credits into different categories including those in NBS, which has been the focus of this collaboration. VCM participants should closely follow ICVCM's future developments and adapt their quality criteria and offsetting strategies accordingly.

As mentioned, SBTi, launched in 2015, develops guidelines for corporate net-zero target setting. The 2021 corporate net zero standard defines the concept of "beyond value chain mitigation," which is the space where SBTi sees a clear role for VCM. SBTi is currently updating this category of their corporate net zero standard. Supporting this clarification work, VCMI recently released a Claims Code to help guide corporations on how to navigate buying carbon credits and understanding what associated claims they can make in relation to their net zero strategies.

Increased scrutiny and evaluation of VCM has supported integrative work between these standard setting initiatives, and presents a useful pathway to bring in satellite, LiDAR, and machine learning assessments into standard carbon offset practice. Beyond these voluntary initiatives, public sector UNFCCC and the EU carbon removals certification framework programs are helping to push this standardization around VCM MRV (Edmonds et al. 2021).

More regulatory involvement is expected in the medium term as uncertainty regarding the legitimate balance between reduction and compensation for net zero claims, the use of credits, and greenwashing concerns is reevaluated.

Takeaways for MCSC Impact Pathways

Nature-based Solutions

"It is challenging to trust carbon marketplaces for many of the same reasons that it is difficult to verify the sequestration of atmospheric carbon by natural ecosystems. At the same time, reforestation and ecological restoration projects present the only nature-based climate solutions which corporate entities can deploy here and now to counteract emissions which cannot be abated. For all of the challenges in carbon markets as they stand, we cannot lose sight of the urgency with which we must act to mitigate climate change.

The bare expense of performing greenhouse gas sequestration — be that through a nature-based approach or through engineered capture — represents the theoretical minimum cost associated with the damage caused by greenhouse gas emissions, because it is the cost of reversal. When these minimum costs are rigorously characterized, measured, and reported, it becomes essentially unviable for large-scale emitters to fully externalize the negative impacts of their carbon footprints across the world. But in the absence of a fair assessment, the prevalence of reasonable doubt makes it nearly impossible to separate greenwashing from sincere efforts to decarbonize economically-critical industries.

What makes such assessments challenging is that 'fairness' is a matter of opinion. Scientists seem to characterize fairness as coming from precision, accuracy, and interpretability. Policymakers and corporate strategists seem to define a fair assessment as being sufficiently thorough that opposing stakeholders will agree it is representative of reality. Both points of view are crucial to ensuring that climate action occurs swiftly and with positive impact. Though AI and machine learning have their own limitations and are not a panacea, they are powerful tools to move past these roadblocks, because they can synthesize every bit of data we have at our disposal into task-specific models which extrapolate away from the body of known information, and can both motivate and inform action when decisions must be made on short timescales."

— **Evan Coleman**
MCSC Impact Fellow

Climate Finance

"The current state of voluntary carbon markets is parallel to that of other climate finance markets and mechanisms: rapid growth and a critical need for reevaluation. VCM has grown dramatically in response to corporate net zero statements and goal setting, yet concerns that existed at the beginning of these markets have yet to be adequately addressed. The reexamination of VCM over the last year highlights the weaknesses of current market infrastructure, but also illuminates the progress and steps in the right direction that carbon registries and other market participants have supported. Carbon markets are now at a key inflection point where we need to utilize criticism to support the integration of scientifically robust carbon sequestration assessments into carbon registries.

This project highlights the value of criticism to reform financial markets geared towards concrete and verifiable climate action. In response to reassessments of the effectiveness of different climate finance mechanisms, such as carbon markets, we should utilize criticism in a manner aligned to the scientific method. The addition of new forms of measurement to ensure carbon sequestration should build off of pre-existing market infrastructure in a way that enhances these systems instead of creating institutional paralysis given the urgency of climate action."

— **Aneil Tripathy**
MCSC Impact Fellow

Climate Risk and Resilience

"A scalable Nature Based Carbon Sequestration system could greatly benefit climate change resilience and adaptation planning efforts. Such a system would significantly improve our ability to assess regional resilience to physical risks that are expected to worsen with climate change. For example, wildfire models could benefit from more reliance on vegetation characteristics, or drought models that benefit from observations of a wide range of species are input to wildfire and drought. Healthier vegetation in wetlands and coastal regions can improve the resilience of those regions to disturbances like storms and sea level rise. Additionally, more precise estimates of Nature Based Carbon Sequestration helps establish better predictions of wildfire risk, and can be used to inform forest management policy."

— **Sydney Sroka**
MCSC Impact Fellow

Next Steps for Carbon Markets

Advocates for effective climate action and corporate decarbonization should utilize current skepticism of VCM as a tool to identify what is most critical to improve. To mitigate and effectively respond to climate change we need VCM to interoperate smoothly with other decarbonization efforts, and scale globally. Historical precedent has shown that critique can lead to more robust and functional financial markets through innovation (Riles 2011). Integrating scientifically-backed measures of quality into VCM can equip policymakers with the economic data necessary to price incentives, penalize bad actors, and implement other governance measures to accelerate decarbonization fairly and globally.

This collaboration identified barriers to scale in voluntary carbon markets as they exist today, and through a pilot project demonstrated some of the major challenges and limitations which the marketplace will need to grapple with in order to grow responsibly. The next step from this work is to jointly target the specific quality measures outlined in this report, and develop measurement tools and logical frameworks hand-in-hand which can stratify credit quality along clear and interpretable boundaries.

“Owning a CO2 credit means being responsible for that asset. If the credit removes more carbon than planned, the owner reaps the benefit. If the credit underperforms, the owner is responsible for the loss. Treating captured and avoided emissions as assets can help with many issues in voluntary carbon markets today.”

— Professor Roberto Rigobon
MIT Sloan School of Management

“Fundamentally, if we assess the number of companies that are pledging to Net Zero commitments worldwide and the material technological and financial barriers still existing to achieve these commitments, carbon markets will necessarily have to scale for carbon credits to help bridge the gap.

Putting a price on emissions is critical as it will help incentivize companies to address their carbon footprint in terms that are comparable and more marketable than tons of CO_2. A universal carbon cost will also help lower the technological cost curve for technological breakthroughs which play a key role in the decarbonization journey. Furthermore, efficient and transparent market prices would enable a swift prioritization of emission reduction efforts based on the lowest marginal reduction cost.

These efforts are fundamental to achieve market size expectations and a notable improvement in the functioning of carbon markets would constitute a strong complement to the greenhouse gas emissions reduction pathway.”

— Beatriz Roa Tejero
BBVA

“Additionality is challenging to measure because it is defined as a counterfactual. Verifying that a project was truly additional requires two copies of our universe — one where the project was implemented, and one where it was not. Sadly, we don’t have both of those worlds at our disposal. However, in this emerging market, large-scale early movers share an opportunity to specify the required diligence for projects, which could help to guarantee that a given intervention goes beyond business as usual from its inception.”

— **Evan Coleman**
MCSC Impact Fellow

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