ARTICLE IN PRESS

Land Use Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

A practice-centered analysis of environmental accounting standards: integrating agriculture into carbon governance

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ARTICLE INFO

Keywords:
Carbon accounting
Environmental governance
Markets
Agriculture
Standards

ABSTRACT

Standards for carbon accounting are a core element of environmental governance. We study the production of standards as situated and practical action, which is shaped by opportunities, resource constraints, and existing infrastructure. Careful observations of this work reveals what people do and how they organize their actions relevant to the particular questions, conventions, and resources at hand. We apply this practice-centered, ethnomethodological approach to study the creation of an accounting protocol for nitrous oxide emissions from corn production, an effort within the broader project of enlisting agriculture in carbon markets. We find that efforts to create a far-reaching, rigorous, and efficient standard were frustrated by lack of data, contestation of knowledge claims, and the challenges of collapsing real-world heterogeneity into a model and a set of tidy decision rules. In this sense, carbon accounting standards should be understood as provisional, and potentially unstable, compromises.

1. Introduction

Carbon markets are heralded as the primary vehicleto address mitigation of greenhouse gasses (GHG). Through a detailed analysis of efforts to construct a standardized accounting protocol to enable carbon offsets from agriculture in the USA, we highlight the creative, practical work of actors engaged in creating equivalencies to enable carbon trading. We situate grounded problem-solving by actors within a structural context characterized by historically constructed political economic relations and infrastructure (e.g., conventions, standards, hardware). Critical scholarship has identified structural imperatives, political interests, and corporate strategies that yield carbon standards (Cooper, 2015; Lohmann, 2009; Lovell and Liverman, 2010). Yet, the 'brave new world of carbon trading' (Spash, 2010) that these standards were meant to kick start has splintered into a story of repeated crisis and setbacks. Recognizing the complex and contradictory nature of carbon markets, this paper advances a practice-centered study of an ambitious accounting endeavor to standardize the accounting of agricultural carbon emissions. In studying practice as expressions of local situated action and higher order structures, we advance an integrated, multi-scaled analysis of carbon governance.

Our analysis emphasizes interplay between creativity (i.e., openness) and friction (i.e., stickiness, path dependency) in carbon accounting and in broader processes of institutional change. While we focus on practical problem solving, our empirical work identifies solutions that are provisional and contingent. The agricultural carbon accounting protocol we study was successfully promulgated, but it has never been used. It is too early to draw conclusions as to whether this standard or some other standard will make carbon trading a mainstream practice in agriculture. For our purposes in this paper, the analysis highlights the importance of localized processes in making knowledge claims that structure potentially far reaching representations of nature and values.

Critical social scientists – i.e., researchers who aim to make visible the knowledge claims embedded in discourses, justifications, and actions - have advanced analysis of calculative practices and standards that support a managerialist (Lippert, 2015; Vesty et al., 2015) and transactional (Bumpus, 2011; Sullivan, 2010) approach to carbon governance. Asdal (2008) argues it is through calculations of accounting that nature comes to be enacted as a political, and manageable subject. Important contributions include efforts to highlight knowledge controversies in standard making (Bowen and Wittneben, 2011), equity implications of carbon standards (Bumpus and Liverman, 2011), and contradictions that constrain the capacity of carbon trading to address global climate change (Lohmann, 2009). The emphasis in this important and growing body of work is on theorizing the complex socio-technical relations – e.g. divisions of labor, distributions of rights and responsibilities, conventions, and grammars of legitimacy that govern

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https://doi.org/10.1016/j.landusepol.2018.08.003
Received 23 October 2017; Received in revised form 3 July 2018; Accepted 1 August 2018

construction and use of models - of representation of carbon emissions and offset credits. The establishment of commensurability of carbon in technical domains (MacKenzie, 2009) and in policy imaginations (Ascui and Lovell, 2011; Cooper, 2015; Lansing, 2011) is a primary focus of attention because these equivalencies animate a technocratic style of governance premised on particular beliefs regarding humans' capacity to know and to control nature (Lohmann, 2009; Scott, 1999). Further, standards create cultural norms, new subjectivities, and technical means to restructure the meaning of carbon (Liu, 2017; Ormond and Goodman, 2015) and to perform management across scales in ways that reinforce existing social relations of capital accumulation (María, 2011; Robertson, 2012).

Governance of calculating, standardizing, accounting, and verifying carbon is distributed in complex networks. Beyond the people, professions, and organizations, assemblages composed of formal rules, norms, incentives, accountability mechanisms, measuring devices, models, texts and various molecules are both the objects and the mechanisms of governance (Lövbrand and Stripple, 2011). Research on data-scapes (Lippert, 2015), professional accounting networks (Lovell and MacKenzie, 2011), assemblages (Freidberg, 2014), and regimes of calculation (Lövbrand and Stripple, 2011; Ormond and Goodman, 2015) highlight the work that quantification of carbon performs in enlisting nature into modern administrative and commercial routines. Through quantification, carbon can be communicated and management can be pursued across organizational, epistemic, and spatiotemporal boundaries.

Research focused on how the work of carbon accounting is advanced in specific settings is distinct from, and complementary to, theorizing why carbon emissions are calculated and whose interests are reflected in such projects. Careful observations of the coordination of accounting work – an ethnomethodological approach – can reveal what people do and how they organize their actions relevant to the particular questions, problems, and resources at hand (Garfinkel, 1991; Suchman, 2007). We study how a set of heterogeneous actors make sense of their context and develop agreements that advance negotiated objectives. By attending to the coordination challenges in developing accounting systems, it is possible to study accounting as a situated and practical activity, which is shaped by opportunities and resource constraints. These acts are embedded not only in political economic relations, but also in particular organizational settings, professional cultures, and physical spaces. Recognizing the centrality of fundamental questions of which kinds of (i.e., whose) knowledge is ignored, accentuated, or simplified in the course of carbon accounting, we focus on how actors make choices and justify their decisions when charged with the task of specifying models that collapse the messiness of the real world into tidy mathematical relationships and accompanying procedural guidelines. Drawing attention to the situated accomplishment of accounting as and when it occurs (Crabtree et al., 2009), we apply insights from Science and Technology Studies (STS) to advance a "practice-centered" approach to analysis. We view this grounded, empirical approach as complementary to the established tradition of political economic analysis. Specifically, we seek to advance analysis of interplay between situated practice, sociotechnical infrastructure, and political economic context.

Studying production of standards from the perspective of situated actions and practices requires looking at the (inter)actions of professionals engaged in formalization of routines that structure specification and quantification. While this work is disciplined by existing infrastructure and historically constructed political economic relations, these people are working on the frontier. They do not have access to directly relevant precedents. They must adapt and create new ways of doing, interacting and justifying. This "radical openness" (Bowker and Star, 2000; Storper, 2000) characterizes the work of producing economic routines, just as it does social life and environmental governance. Existing scripts, conventions, norms, and rules enable and enhance the efficiency of social interaction, but they are abstract. They are, arguably, necessary, but they are not sufficient. Applied to real world action contexts, people working in specific material and sociocultural settings– for example, those engaged in producing a new accounting protocol - must act creatively and pragmatically (Lederer, 2012). In situations in which people enter from diverse scientific disciplines and professional cultures, the challenges of confronting novelty multiply. In these situations, the actors must develop 'workarounds' – i.e., practical agreements to complex, messy problems - and they must do so without the benefit of conventions (i.e., established grammars) that harmonize expectations (Thévenot, 1984).

Improvisations and workarounds are important to all social interaction. How to assess and how to act must be determined in relation to existing rules and shifting interpetations of context. The question of interest in this paper is how workarounds are constructed in relation to opportunities and constraints for quantifying carbon emissions and advancing a transactional (i.e., market-based) approach to governance. Attention to the openness, contingency, and agency that characterize the production of new technical standards can help us understand how historical processes and power relations are both reproduced and reformed. To address this question it is necessary to examine how production of models and accounting protocols are organized and what this implies for standards and their application. A practice approach focuses attention on ways in which actors creatively adapt and extend existing coordination resources in line with contextual requirements and the opportunity at hand. By assessing interplay between the way the production of a carbon accounting protocol is organized (structured) and the creative problem solving that occurs (workarounds), we get a sharper critical understanding of carbon governance. The accounting procedures in place are neither natural or predetermined, nor are they *ad hoc* fictions. As myths, they lend coherence to social action at grand scales by combining powerful insights on the world with claims that require suspension of disbelief. Creation of standards such as accounting protocols does not guarantee they will become used and institutionalized. It is possible that the knowledge claims they embody make them impractical, and it is possible that the circumstances in which they are created make them impotent. Creating something new is always accompanied by a risk of failure.

2. Carbon accounting protocols

Accounting protocols mediate interaction of regulators, buyers, and sellers in carbon governance. Carbon credits or offsets, the currency of carbon markets, are calculated by inputting prescribed data into a set of equations that yield representations of emission reductions. These representations can be compared and aggregated, as the carbon fluxes or greenhouse gas equivalence of the fluxes are made context independent. Controls (e.g., information disclosures and eligibility requirements) specified in the protocol ostensibly ensure that these reductions are attributable to the awarding of credits rather than alternative explanations. This work is accomplished by establishing a baseline to support comparisons and assert differences in relation to a counterfactual. Through specifying what data are essential and how these data are transformed into representations of greenhouse gas reductions, accounting protocols collapse biophysical and socioeconomic diversity along multiple dimensions to offer a reality that is stable, calculable and, thus, governable (Hopwood and Miller, 1994; Miller, 1992; Porter, 1992). The assessments, comparisons, thresholds, and categories asserted and created by standardized protocols have social and ecological consequences (Busch, 2011; Joskow et al., 1998; Lampland and Star, 2009; Thévenot, 2009; Timmermans and Epstein, 2010). Standards yield legitimated, privileged representations of a state of being or trajectory of change. While these representations introduce stability and efficiency into socioeconomic processes, they obscure the values (Busch, 2000), conventions of practice (Thévenot, 1984), and narratives (Bowker and Star, 2000) that gave rise to these privileged accounts. The power of a standard is based specifically on its capacity to mute arguments regarding alternative specifications of the world (Thévenot, 2009).

We examine a recent project to develop a carbon accounting protocol to integrate agricultural GHG emissions into the carbon market. Agriculture accounts for 20–40% of GHG, globally. N_2O emissions represent 9% of total US GHG emissions (Davidson and Kanter, 2014; EPA, 2014), and 80% of total N_2O emissions can be traced to agricultural production (Millar et al., 2012). Unlike recent moderation of industrial GHG emissions, agricultural emissions increased 8.7% from 1990 to 2012 (EPA, 2014 p.6), and are projected to increase further. Beyond climate change, N_2O has been called the "dominant ozone-depleting substance emitted in the 21st century" (Ravishankara et al., 2009), and mitigating N_2O pollution from agriculture will contribute positively to mitigating water pollution.

Lack of nitrogen (N) is the foremost constraint on primary productivity in crop production (Vitousek et al., 1997). To service plant nitrogen needs, farmers apply manure or nitrogen fertilizers to fieldsites. Not all the N applied to the soil is absorbed by the crops, and much of it escapes the field. Microbes in the soil denitrify or convert some N into N_2O, NO and N_2, while some of the N is lost in surface runoff or ground water in the form of water soluble NOx. Thus, N2O emissions caused by N application occur both on and off farm. Overall, N2O emissions depend on a host of ecological and management variables such as rainfall, soil texture, crop type, cropping system, and fertilizer type and timing. Precise predictions of N2O emissions are limited due to incomplete knowledge of these multiple pathways, the number of relevant variables, and lack of data.

To mitigate N_2O emissions from fertilizer applications, scientists propose management approaches that rationalize nitrogen application (Hatfield and Follett, 2008). By adjusting how nitrogen is supplied to crops, and the timing and placement of applications, fertilizer use efficiency can be increased. More ambitious approaches to address nitrogen losses from agricultural fields emphasizes agroecological approaches to managing soils, nutrients, and crops as an integrated system (Gardner and Drinkwater, 2009).

Despite evidence that crop production is an important source of GHG emissions, efforts to bring farming into the carbon economy lag behind efforts applied to industrial emissions, built environment, and forest management (Galloway and Cowling, 2002). The argument in support of linking agricultural production to carbon markets emphasizes opportunities to bring private money into agrienvironmental management and incentivize farmers to change the way they fertilize their crops in order to reduce GHG emissions. For example, when electric power producers are required by law to reduce GHG emissions, and emission reductions by farmers are less costly than those available to electricity producers faced with retrofitting pollution control equipment on power plants, enabling transactions is seen as enhancing the efficiency of conservation. Within this approach to carbon governance, assessing, managing, and communicating emission reductions becomes an act of bookkeeping, which demands generally agreed accounting standards (Asdal, 2008).

Climate Action Reserve (CAR) – a carbon offset standards organization - initiated the Nitrogen Management Protocol Project (NMPP) in 2011 to develop standardized protocols for N_2O emissions from agricultural fields. This effort was linked to the creation of the California carbon market. The California Global Warming Solutions Act of 2006 (AB 32) aims to return emissions in the state to 1990 levels, and a carbon cap and trade program is a central element of this plan. As Bigger (2015) has shown, legislation in California led to the establishment of the cap-and-trade market, but this did not lead to market transactions. Bringing markets to life required enrolling technicians, accountants, and a broad range of professionals. These new "collectives" (Callon, 2009) are domains of social interaction where climate science, policy and management are debated, negotiated, and transformed. In studying these aspects of carbon governance we must address how these interactions are organized. Further, we must understand practical problems, workarounds, and the accounts that actors mobilize in support of bricolage.

By clarifying the way quantification projects are structured and how the actors overcome problems they confront in producing an accounting protocol, we advance a grounded analysis of CAR's effort to construct an accounting protocol. Importantly, while the NMPP was published in 2012 and CAR has expressed their intention to continue to strengthen the protocol, it has not yet been employed to support any carbon transactions. The standard has never been used. This case highlights points of friction in producing a new standard to govern carbon. We emphasize the practical strategies the actors pursued and adapted when confronting these challenges. By studying workarounds devised in response to problems faced by actors engaged in standard setting, we aim to advance understanding of the contingent and provisional nature of the carbon economy.

We focus on two specific moments in the construction of the Nitrogen Management Protocol Project. First, we document the way the actors addressed the question of how far data from cropping system experiments in Michigan – and expressions of equivalence between reductions in fertilizer applications and reductions in nitrous oxide emissions – can be extended to represent carbon fluxes elsewhere. Second, we document the specification of the baseline that makes it possible to express 'additionality' of nitrous oxide emissions reductions attributable to offset payments made under the protocol. Our approach in this paper is to leverage these moments as analytical opportunities to look inside the standard setting process.

3. Empirical case: Nitrogen Management Protocol Project

3.1. Climate Action Reserve

The Climate Action Reserve (CAR) is a non-profit entity enlisted by the State of California to develop standardized protocols for tracking offsets of carbon emissions. CAR's protocols are used in quantifying voluntary commitments as well as in the Californian regulatory compliance market operated by the state's Air Resource Board (ARB). Besides developing protocols, CAR also registers and verifies carbon offset projects.

Prior to the Nitrogen Management Protocol Project (NMPP), CAR developed protocols for carbon offsets generated by reforestation (and avoided deforestation or conversion), methane capture from improved management of mining, among others, but none for agriculture[1] . The goal of the NMPP was to develop a set of standardized processes that could be used by a farmer or aggregator to earn offset credits. These credits could then be purchased by offset buyers in the voluntary market or, if approved by the ARB, for use in the regulatory compliance market created by AB 32.

CAR is not the only organization developing agricultural carbon offset protocols. Among others, the American Carbon Registry (ACR) and the Verified Carbon Standard (VCS) have developed N_2O- based carbon offsets. Unlike CAR's ambition, N_2O offset protocols produced by ACR and VCS are less integrated, and project specific adjustments are required depending on variables such as crop, soil type, management history, and environmental conditions. For example, the VCS N_2O offset standard demands the use of different quantification formula for different areas. For example, corn-growing areas in the Mid-Western Region of the US use a different standard compared to other agricultural areas. CAR, on the other hand, prides itself in "doing all the hard work upfront" so that transaction specific costs of measuring are

[1] CAR launched two other agricultural protocols development projects in 2011 including a rice cultivation project and a cropland management project. The rice cultivation project was approved but the cropland management project was dropped.

minimized[2] . In CAR's vision, the same formulae and measurement procedures would apply across all eligible sites. Since expert judgment and model-calibration would not be required in administering specific transactions, transaction costs would be lower, more transactions would occur, and greater efficiencies in conservation would be realized.

CAR seeks to differentiate itself from other protocol developers through a commitment toward precision and accuracy in quantifying offsets.[3] CAR presentations, available on the website, claim the registered offsets are 'real, additional, verifiable, enforceable, and permanent'. The NMPP would apply across farmlands, ecological conditions, climatic conditions, and management practices without loss of technical validity under different conditions. CAR emphasizes transparency in constructing protocols. They upload the key documentations online, invite multiple stakeholders to comment, respond to individual comments, respond positively to requests for interviews, and host public meetings. The transparency is beneficial for researchers, and highlights the relational nature of standard making and the procedural foundations of legitimacy. CAR's protocol development process and commitments to openness are illustrated in Fig. 1. Our analysis is based on the available documents and interviews with CAR staff conducted in 2016. In the next section we discuss the NMPP and key deviations from CAR's normal operating procedures in the course of the NMPP.

3.2. Nitrogen Management Protocol Project (NMPP)

In 2011, CAR initiated a project to develop a nitrogen management protocol to address N_2O emissions from US farmlands. This proptocol is centered on a model that converts information about a farming operation into units of tradable carbon emissions reductions. The development of CAR's NMPP must be understood within the context of ongoing debates on N_2O quantification among ecological modelers. Despite a general consensus that nitrogen fertilizer applications leads to greater N_2O emissions (Syakila and Kroeze, 2011), the precise relationship depends on variables including weather, soil type, crop rotation, and nutrient management. There is no consensus on best strategies to model N_2O (Reay et al., 2012; Stevens and Laughlin, 1998; Walter et al., 2007). National scale models of emissions are associated with greater confidence levels and low costs (reduced data requirements), but they are very coarse. More granular models calibrated at the sub-state, regional, or farm level are problematic due to gaps in mechanistic understanding of biogeochemical processes and due to unavailability of data (Reay et al., 2012).

Following their standard procedure, CAR hired Terra Global Capital as the technical consultant to conduct background research and present recommendations on feasible approaches to quantification. Next, a multi-stakeholder workgroup (MWG) was convened to synthesize perspectives of industry, finance, offset developers, academics, government, lawyers, and agricultural advocacy associations.[4] The MWG was convened via web-conferences and service was unpaid.

The NMPP lasted about one year (Table 1). In the first draft report, CAR identified a substantial list of agronomic practices including diversified crop rotations and cover cropping, as potentially eligible for mitigation credits. Lack of evidence regarding the performance of these practices and corresponding emissions reductions in site-specific contexts prompted a deviation from the typical CAR protocol development process. For the first time in CAR's history, a Science Advisory Committee (SAC) was convened to interpret the state of research on the list of agronomic practices and to advise CAR and the MWG on the merits of various quantification methodologies. The SAC was comprised of ten established scientists with expertise in agriculture and nitrous oxide emissions. SAC members were chosen from a preexisting initiative called the Technical Working Group on Agricultural Greenhouse Gases (T-AGG) organized in 2009 at Duke University. In the absence of clear evidence represented by peer-reviewed studies, CAR saw the SAC as nitrogen modeling experts who could point to additional sources of data and extrapolate from existing studies. Unlike MWG members, SAC members received a small honorarium. The SAC was presented with the following three prompts:

1 *What is the "scientific validity" of providing GHG mitigation credits for a variety of nitrogen management practices?*
2 *Which GHG sources, sinks, and reservoirs (SSRs) must be quantified to accurately and conservatively assess the net effect of a change in nitrogen management practice on GHG emissions?*
3 *What is a scientifically valid, economically practical, and ultimately verifiable approach to quantifying GHG reductions from nitrogen management offset projects?*

In their response to the first question, the SAC was asked to answer with a Yes, No, or a Maybe. Responses summarized in Table 2 illustrate efforts to extract authoritative, unambiguous guidance from technical debates that encompass multidisciplinary, multi-scalar questions each of which is subject to degrees of uncertainty along several axes. The NMPP, unlike a scientific study of nitrogen models, is far more practically focused and time-bound. The work of the SAC highlights the emphasis on arriving at workable and defensible conclusions based on the available information.

As summarized in Table 2, the final protocol that emerged from the NMPP recognizes only one conservation practice – reduction in annual synthetic nitrogen application. For other agronomic practices, including pollution prevention techniques and agroecological approaches, it was determined that the available evidence could not justify inclusion and/or no reliable means of quantification was available. This scientific synthesis effort highlights the original scope of ambitions to recognize and reward nitrous oxide mitigation techniques through the protocol. The results emphasize how creative projects are constrained by the availability of data, models, and evidence.

In addition to a significant narrowing of the set of agronomic practices recognized in the protocol, only farmers growing corn in the North Central Region (NCR) of the US are eligible to earn nitrous oxide emission reduction credits. Lastly, yield decreases disqualify farmers from receiving payments, as this constitutes "leakage" of benefits (i.e., reduced corn harvest under the protocol reduces supply and raises commodity prices, stimulating increased production, and increased nitrous oxide emissions, elsewhere). These caveats and the scaling back of ambitions for a far reaching, encompassing protocol point to the friction the actors confronted in making carbon governable. To understand how such decisions are made, we analyze two specific moments where creative problem-solving efforts were mobilized in response to challenges of credibly and practically representing emission reductions.

4. Constructing a carbon accounting protocol

4.1. Territorial dimensions of modeling

The NMPP pre-proposal draft aspired to develop a protocol using

[2] Webinar by Max DuBuisson, Business Development Associate – "Introduction to CAR" Feb 4 2010

[3] Presentation titled "Key Elements of the Protocol and Considerations for Project Submission as Early Action or Compliance" CAR 16th Apr 2013

[4] This included agricultural industry (Ag Refresh), financial cooperation (Scotia Capital), carbon offset developers (Blue Source), carbon trading companies (Preferred Carbon Group), industrial manufacturer (Camco), academic establishments (Stanford Law School, the University of California at Davis, Michigan State University), law firm (The Clark Group LLC, Environmental Defense Fund), non-academic scientists (Union of Concerned Scientists), environmental consulting firms (Environmental Services Inc.), state actors (USDA Natural Resource Conservation Service, US EPA), agricultural trade associations (Western Growers Association), environmental advocacy group (Natural Resources Defense Council), professional agricultural organization (Western United Dairymen), and an independent scientist.

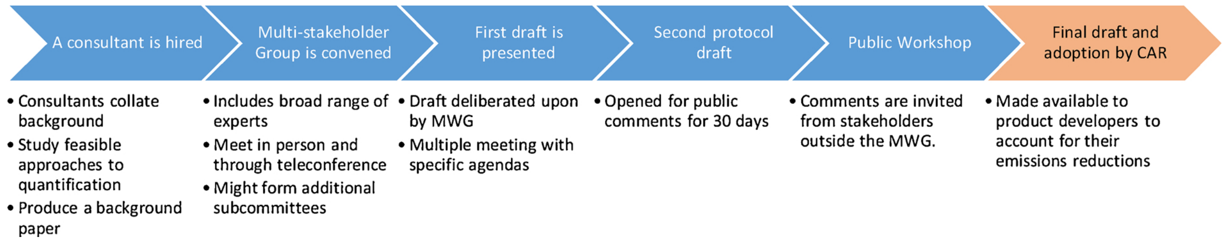

Fig. 1. CAR's General Protocol Development Procedure.

Table 1
Schedule of meeting dates and reporting deadlines for the NMPP.
Source: Adapted by authors based on CAR Protocol Development Timeline presented in Workgroup Meeting #1 on May 18, 2011, 10-12 AM PDT.

May 6, 2011	Methodology Synthesis Paper
May 18, 2011	MWG Meeting 1 (conference call)
June 27, 2011	MWG Meeting 2 (conference call)
July 18, 2011	Background Paper Completed (draft)
July 27, 2011	Draft protocol to workgroup
August 1, 2011	MWG Meeting 3 (Los Angeles)
September 7, 2011	Science Advisory Committee Meeting (Los Angeles)
October 25, 2011	MWG Meetings 4 (conference call)
November 11, 2011	MWG Meetings 5 (conference call), *continuation of mtg 4*
Oct– Dec 2011	Second Phase of Background Research
January 17, 2012	Science Advisory Committee (conference call)
January 25, 2012	MWG Meeting 6 (conference call)
March 2012	Draft Protocol for WG/SAC review
April 2012	Revised protocol & start of 30-day public comment period
April 2012	Public workshop
June 27 2012	Protocol adoption by Reserve Board

the Denitrification-Decomposition (DNDC) model to estimate N_2O emissions. While the precision implied by the DNDC model was attractive to CAR, they soon found that available datasets were insufficient to calibrate the model. The DNDC requires site-specific inputs including soil texture (% sand, silt, clay), bulk density, porosity, pH, organic C, mineral N, and weather measurements. As per the SAC's summary (Table 3), only one carbon standard development organization – the American Carbon Registry (ACR), uses a quantification protocol based on the DNDC model. The ACR protocol requires farm-level data collection including the incorporation of heat and water stress parameters and the running of a Monte Carlo simulation to assess uncertainty. Due to the site-specific data requirements and transaction costs, CAR dismissed the DNDC early in the NMPP process.

As an alternative to a DNDC-based quantification methodology, SAC suggested CAR use IPCC emission factors to estimate both direct emissions (i.e., N_2O from a given farm field) and indirect emissions (i.e., N_2O from off-site leaching, volatilization, and/or surface runoff from a given farm field). The IPCC recognized three tiers of N_2O models to quantify GHG. Tier 1 models use a single universal emissions factor and are useful in tracing national trends based on national GHG inventories, but Tier 1 models do not account for regional variation (Reay et al., 2012). The Tier 1 IPCC default factor for N2O emissions is 1%, which means 10 kg of N_2O is emitted for every metric ton of nitrogen fertilizer applied. Tier 2 estimates are based on simplified multivariate statistical models derived from data collected in specific field sites in the region and extrapolated for a larger geographical area. Tier 3 models are the most site-specific, as they rely on coefficients specific to particular locations. Whereas Tier 1 and Tier 2 emission factors are based exclusively on modeled relationships drawn from existing studies, Tier 3 estimates require a more nuanced, mechanistic understanding of nitrogen cycling (Climate Action Reserve, 2013, p. 117). The DNDC model is an example of a Tier 3 factor.

According to the SAC and CAR's technical contractors, the most reliable model available for N_2O emissions in the US was based on research funded by The Electric Power Research Institute (EPRI) at Michigan State University (MSU). The MSU-EPRI model was developed using data from a series of experiments conducted on five rain-fed fields in Michigan (Hoben et al., 2011). According to the authors, the model offered Tier 2 estimates for the North Central Region (NCR) – a region that encompasses Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. This MSU-EPRI estimation methodology was a key point of discussion within the MWG. Some of the developers of the MSU-EPRI model were represented in the SAC.

In discussions regarding the various options for quantification, CAR explicitly stressed their interest in a model that captured regional specificity and featured low transaction costs. This meant that they sought models that were calibrated for each state and did not require transaction specific data, such as local sampling of soil or grain. The use of a Tier 1 model – a national conversion factor - for quantifying emissions across all farmlands was deemed too crude, leaving CAR with the MSU-EPRI model Tier 2 model as the only feasible option. Because the MSU-EPRI model was based on experiments on rain-fed farms, and cycles of soil saturation and drying are important regulators of N_2O fluxes, irrigated farms were excluded from the protocol. Because the MSU-EPRI model was specific to only one N_2O mitigation strategy, reduced application of nitrogen fertilizer to corn, the protocol was restricted to this specific practice and this specific crop. Evidence and confidence to support establishment of more far-reaching equivalences did not emerge from the deliberations (see Table 2). The model included in the protocol combined Tier 2 estimates for direct emissions and Tier 1 estimates for indirect emissions (Climate Action Reserve, 2013).

Reliance on five field sites in Michigan to represent almost the entire Corn Belt did not sit comfortably with all MWG members. Some MWG members argued that the Michigan experiments were conducted on soils of loam texture and experienced only narrow climatic variation. The derived relationships, even though they were directionality consistent, were challenged as inaccurate when applied to fields outside of Michigan:

> *"In sum, the 12 state region represented in the draft protocol varies significantly from the five Michigan field sites. As a result, we do not believe the regression equation used to quantify N_2O emission reductions should be extrapolated that far from the conditions under which it was developed. Doing so misrepresents the potential N_2O emission reductions that can actually be achieved."*

(Gurwick, Niles, and Tonitto, Comments on Draft 1.0. p1)
CAR justified reliance on the model with heavy disclaimers:

> *"If calibration data are taken primarily from one area within a larger region (such as a Land Resource Region), an extensive validation data set, including data points from other areas within the region collected from a number of sources, might allow validation of the model for a much larger geographic area than the model was otherwise developed and calibrated for. It is worth noting that while the MSUEPRI methodology was adapted and included in the NMPP before independent data was available, this decision is not precedent-setting. The Reserve prefers a full structural uncertainty assessment using validation data that is representative for the geographic applicability region over the leave-one-out approach."*

Table 2
List of potential nitrogen management practices selected by CAR and the summary of SAC's responses to each practice based on confidence level for reducing Nitrous oxide emissions and the confidence in quantifying the emissions.
Source: Adapted by authors from the NMPP Workgroup Draft version 1.0 July 2011 and SAC summary report.

Approved practice	Description	SAC decision	SAC comment (condensed)
Reduce N application	Reducing the amount of N applied on the field without falling below the nitrogen uptake demand of the crops.	YES	The practice is well studied with the most consistent reductions. However, the SAC added a caveat that the relationship with between N_2O emissions is difficult to model in generic sense and instead advocated a system-specific relationship. They also advocated a focus on NUE rather than N rate reduction.
Optimize timing N fertilizer application	Change the timing of N fertilizer application to optimize the application for crop N demand, minimizing the N lost as emissions. Options include specific timing of application relative to planting date and crop emergence. Includes split application technology and management.	MAYBE	There are few studies and the results are inconsistent. Emissions reductions are influenced by water management strategies, placement of applications and delivery of applications. In some cases, emissions could increase. Potential for reduction is higher in irrigated systems. More studies needed for rainfed systems. There was more confidence in switching from Fall to Spring application but a lack of studies was noted.
Placement of fertilizer	Improve the placement of fertilizer by placing it closer to the active root uptake zone, maximizing the efficiency of N uptake by the plant. Includes injecting near seeds during sowing, injecting in sub-surface drip irrigation (fertigation), and precision agriculture (GPS-aided fertilizer application, optimized for the soils at each specific location)	MAYBE	Conflicting results and some studies have shown increased emissions High unpredictability in case of rainfed regions.
Include mixed cover crops in a rotation	Plant mixed cover crops to scavenge residual nitrogen and immobilize this nitrogen during the off-season and/or to use leguminous cover crops as a nitrogen source. To minimize increased emissions from using cover crops, the timing between cover crop incorporation and planting should be as minimal as possible.	MAYBE	Highly dependent on crop mixture. Studies show no or small reductions in emissions Members noted that cover crops consistently reduce nitrate leaching
Changing fertilizer composition	Change in the chemical composition of fertilizer (anhydrous ammonia to urea) or use of controlled-release nitrogen fertilizer; coatings provide slow release of mineral N.	YES (with limits)	Effects were considered consistent for certain fertilizer sources, but capacity to quantify benefits not reliable. Directional certainty observed regardless of region, but differences could exist across fertilizer type in some regions. Slow-release fertilizers feature lower emissions except in case of large precipitation events.
Use of organic amendments	Complete or partial replacement of inorganic N with organic amendments (such as, manure or compost).	NO	Studies show increase or no change in emissions with manure. SAC did not recommend this for any regions.
Use of nitrification and urease inhibitors	Use of nitrification and urease inhibitors to slow the biological transformation of nitrate and urea, respectively, leading to greater N use efficiencies	YES (with limits)	Only one study was cited as showing positive reductions and in specific regions (Akiyama et al., 2010). The SAC was confident about the combination of two inhibitors. SAC members expected high regional variability. The main concerns were data inconsistency in rainfed regions and soil types in the mid-south.
Adding deep rooting plants into rotations	Add in deep rooting plants (e.g. alfalfa) to crop rotation, which can scavenge residual nitrogen and redistribute nitrogen through the soil profile by root uptake.	No	Not enough data. High potential for leakage implications.

Table 3
Nitrous oxide emissions models employed by standard setting organizations.
Source: Science Advisory Committee Summary Report

Protocol Options	Methodology
EPRI-MSU protocol	Tier 2 for Corn-systems in NCR, derived from empirical field measurements in Michigan Tier 1 (using IPCC factors) for everything else
Alberta Offsets protocol	Tier 2 factor calibrated for Canadian eco-regions, derived from Canada's national inventory
American Carbon Registry (ACR) protocol	Tier 3: Uses DNDC biogeochemical process model at a field level
COMET VR or COMET Farm tools	Tier 2/3: COMET uses a simplified version of the DAYCENT biogeochemical process model, with certain parameters constrained so it is not completely site specific

(Climate Action Reserve, 2013, p. 128)

To address concerns of weak validation, SAC members suggested a "leave-one-out" cross validation exercise similar to statistical bootstrapping. Statistically, this means excluding one field site in the MSU-EPRI model and developing the model with data from the remaining four sites. The predictions of the new model were then validated against the empirical observations from the excluded site. Using this "leave-one-out" strategy, the uncertainty of the model increased from 2 to 4 percent. The CAR team accepted the statistical manipulation, although reluctantly:

With no independent field data for the other states in the NCR, the Reserve cannot explicitly quantify the structural uncertainty of the quantification approach included in the NMPP at this time. Thus, for all states in the NCR (except Michigan), the Reserve increased the uncertainty deduction used in the MSU-EPRI methodology by 15 percent to account for this lack of independent field data to evaluate the quantification approach.

(Climate Action Reserve, 2013, p. 44)

In addition, CAR responded to concerns that the climatic conditions in the Michigan field sites were not necessarily representative of the entire NCR by further restricting eligible regions. Specifically, areas with statistically different rainfall were eliminated. The protocol's spatial applicability slowly shrunk to corn growing farmlands in the NCR where the annual level of precipitation, calculated based on 100 years of data, was between 600–1200 mm (Climate Action Reserve, 2013, p. 33).

CAR concluded the final protocol with an additional disclaimer that the NMPP was a 'work in progress' and 'modular' rather than a finalized standard. They added promises for further expansion and provided details on what kinds of data are needed to take next steps. CAR's effort to specify a quantification methodology exemplifies the tensions in extrapolating data across a large and diverse territory and the creativity required to negotiate and justify what constitutes adequate precision and confidence. The specification of the NMPP model to assert carbon fluxes was an outcome of field studies, models, and scientific synthesis, as well as strategic concerns and looming deadlines.

4.2. Constructing a baseline

CAR repeatedly emphasized the importance of high accountability standards for establishing additionality of offsets recognized by the NMPP. This effort pivots on demonstrating that offset payments make a positive contribution to reducing N_2O emissions. Specifically, the protocol requires evidence that the farmer would not have invested in conservation measures and the pollution reduction benefit would not have materialized in the absence of incentive payments. To assert additionality you must compare the prediction of the model to some baseline. Establishing the baseline requires determination of procedures for specifying events that did not happen (i.e., a counterfactual scenario).

In working to specify what constitutes an additional GHG emission reduction, CAR focused on two criteria– 1) absence of a legal obligation to reduce nitrogen application and 2) absence of an economic motivation to reduce nitrogen fertilizer application. If a farmer was not motivated by legal obligations or by potential cost savings, and they reduced their application of nitrogen, they would be eligible for payment under CAR's standard. More importantly, the buyer of the carbon offset can feel confident about the way they discharged their responsibilities and claims they make about environmental protection.

CAR's approach to ensuring additionallity can be summarized through reference to three filters (Fig. 2) – a) an historical assessment of nitrogen use efficiency in corn in each of the relevant states to assess potential for emission reductions in the absence of incentive payments, b) an eligibility criteria to filter out farmers who lag behind the population in rationalizing nitrogen management, c) comparison of proposed nitrogen application rates relative to the applicant's nitrogen management history.

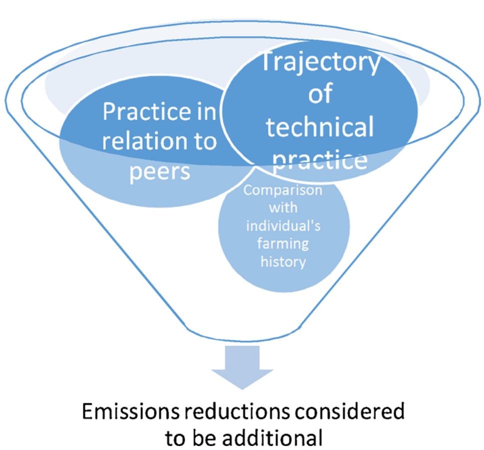

Fig. 2. Three filters to ensure additionality.

In order to make strong claims about GHG reductions stemming from reduced application of nitrogen, CAR perceived a need to mobilize evidence that such a change in farming practice would not occur in the absence of offset payments. The final NMPP presented tables summarizing historical trends in N application rates in corn for the US and for states in the NCR. They concluded from these tables that fertilizer application rates had stabilized over the last ten years, and on this basis no decreases should be expected. Where they did notice decreasing rates (e.g., the state of Missouri), they dismissed them as outliers. CAR used these data to argue that, in aggregate, farmers have exhausted opportunities to rationalize nitrogen use. A finding of 'No significant trend' toward decreased nitrogen application rates supported the claim that an economic incentive from the carbon market would generate emissions reductions beyond a "business-as-usual" scenario.

Because some farmers nitrogen use efficiency is higher than others, CAR identified a need to impose eligbility requirements to screen out farmers who could be expected to reduce their nitrogen application rates in the absence of incentive payments. To select only the 'better than average' farmers would ensure that the adopted practices would lead to 'truly additional' reductions. CAR debated developing a dynamic model that accounted for fertilizer prices, corn prices, and weather, but in the end they opted to apply a simple eligibility threshold determined for each state.

This second filter featured a regulatory screen and a performance standard test (PST). The legal test eliminated farmers required by law, court order, environmental mitigation agreement or other legal contracts to reduced N application. Nitrogen use reductions in these settings were deemed non-additional, as they are expected whether or not incentives were offered. The PST proved more challenging. How to determine that a farmer is applying excess fertilizer without data on their specific farming system, soil tests, history of cropping N fixing crops, and weather generated substantial debate. Since CAR was committed to a standardized approach, they invited the MWG to identify what might be the broad factors - economic, social, financial, and technical - that drive N application decisions. To support the deliberations, CAR assembled publically available data-sets, farm reports, and surveys such as reports by USDA National Agricultural Statistics Service (USDA-NASS) and Agricultural Resource Management Survey (ARMS). The main conclusion drawn from the review was that farmers are likely to do tomorrow what they did yesterday.

The PST incorporated into the NMPP is based on a farmer's historic mass balance ratio of N removed by crop (i.e., N in harvested corn) to the total N applied (Removed-To-Applied or RTA). A farmer's RTA is compared to the state RTA which is calculated using state-level averages of N application rates, yield, and levels of protein in harvested corn. CAR initially declared their intention to restrict eligibility to farmers above the 75% percentile of the RTA distribution.

CAR's plan to direct incentive payments to those farmers who are most judicious in their use of nitrogen was contested by many MWG members. MWG members asked why CAR was focused on those on the high end of the distribution rather than those on the bottom. A similar challenge was pointed out by the MSU-EPRI team in their formal comments:

> *"In effect, the performance standard that has been proposed is likely to result in very few farmers using the protocol, as it appears that only those farmers who already have made significant strides to increase their N-use efficiency would be eligible to participate and receive credits for N rate reductions. This would be a very unfortunate outcome.*
> *We believe that it is important to incentivize farmers who legally use excessive amounts of N fertilizer to reduce their N fertilizer usage both to reduce GHG emissions and reduce nitrate losses. To this end, we encourage CAR to revisit the design of the RTA, and most importantly to reconsider use of the RTA and in particular the 75% RTA performance threshold that is proposed to be adopted."* (Climate Action Reserve, 2013, p. 20)

MSU-EPRI's support for relaxing the eligibility threshold was disputed by CAR:

> *"We expect these N-use efficiency improvements to be most easily achieved on fields with historically low RTA values (i.e., those with the most room to improve). We also assume that fields with the lowest historic RTA values represent a group that would most likely adopt nitrogen use efficiency improvements regardless of a carbon market."*

(CAR, 2012, p. 19)

However, based on interest in seeing the protocol used widely and in incorporating the judgment of others engaged in the standard setting process, CAR later lowered the threshold from the 75th percentile to the 50th percentile. This outcome reflects how *a priori* commitments to maintaining a conservative stance in asserting additionality intersect with practical considerations emerging from deliberation in the production of standards.

Determining this threshold required balancing two core commitments – restricting eligibility to ensure additionality while also remaining open to a large segment of the population of farmers and farm fields (CAR, 2010). References to economic theory were important elements of the design of eligibility requirements, but the final decisions were shaped by competing practical concerns such as data availability, appeal to potential users, and deadlines. Lohman argues "Carbon quants have no choice but to present the counterfactual without-project scenario not as indeterminate and dependent on political choice but as measurable, singular, determinate and a matter for economic and technical prediction" (Lohman, 2009, p244). Faced with possible challenges to the legitimacy of the protocol, CAR adopted a conservative approach. While they accepted that the threshold could risk crediting some non-additional actions, they positioned their PST as more likely to exclude 'truly' additional projects.

The third filter for ensuring additionality involves assessing a farmer's proposed reduction in nitrogen use relative to their relevant historical practice. The protocol specifies the necessary documentation farmers must provide, and the model uses this historical data as a baseline to estimate the emissions reductions attributable to decreased application of nitrogen.

Our analysis of how additionality came to be specified highlights how technical and strategic considerations are intertwined. We emphasize how actors present and justify alternative specifications, and eventually negotiated a baseline that makes it possible to assert value generated by carbon offset payments. As a counterfactual, this baseline is an extrapolation, an abstraction. Yet, participants must construct it from available references, datasets, records, and logics. What qualifies as rigorous and defensible is contested and resolved, iteratively. Understanding what is considered adequate by particular actors in particular circumstances, how adequacy is performed, and the consequences of these performances demand attention from analysts and participants in carbon governance.

5. Discussion

Carbon accounting cannot be understood as a purely technical undertaking. Social scientists have written extensively on processes of obscuring the social and institutional work that underlies efforts to transform qualitative and disjointed datasets into quantified statements of differences (e.g., Espeland and Stevens, 2008; Barry, 2002; Hopwood and Miller, 1994). Extending this critical tradition, we aim to go beyond explanations of carbon governance as an outgrowth of political economic relations that serve private or class-based interests and fail to serve public or ecological needs. By developing and applying a practice-centered analysis, we advance a grounded, situated approach to studying carbon governance and standard setting. Scientific knowledge (e.g., experimental data, sensitivity analysis, expert opinion) and strategic interests (i.e., exercise and pursuit of power) shape outcomes, but we also need to recognize that actors respond to inevitable obstacles and objections by mobilizing resources available to them, and this lends an *ad hoc* component to outcomes.

The STS literature on carbon governance has emphasized assemblages and infrastructure (i.e., enrollment, as developed in the ANT tradition) and the material implications of accounting and numbers (i.e., performativity). Further, attention to governmentality has emerged as an important focus of efforts to understand the impulse fueling quantification and the wider project of imposition of discipline around carbon. We advance these lines of inquiry by highlighting that building infrastructure and creating practical knowledge is a messy, contested, and contingent process; one that can fail to extend the reach of contemporary carbon governance and visions of a transactional approach to sustainability. We study the situated work of knowledge making that underlies efforts to extend infrastructure and institutionalize new knowledge claims. Our paper emphasizes the interplay between creative, *ad hoc* aspects of governance and the path-dependent, cumulative nature of processes that characterize sociotechnical development.

By following a practice-centered approach, we argue that carbon accounting – and production of accounting techniques - is an interactive endeavor dependent on negotiations, and real-time problem solving by actors who identify and reference purposes, interpretations, and material constraints. We consider the practice-centered approach to be part of post-structuralist approaches as exemplified by STS studies of carbon accounting. This approach allows us to emphasize how specific actors shape the form and function of quantifications of carbon. As a complement to analyses of macrostructural drivers and constraints, we advance a more humble effort to analyze the work of setting carbon accounting standards on its own terms.

Our analysis indicates that carbon accounting is not advanced by isolating technicians and scientists from practical considerations and organizational presssures. While carbon accounting serves as a boundary object to connect science, markets, and regulators (Bowen and Wittneben, 2011), the boundary between accounting practices and carbon governance is a two-way highway. We observed how assumptions and abstract rules inform reasoning, actions and outcomes (see Pollner, 1974). We identify abstract designs as relevant to processes of standard setting, but always in reference to conditions at hand (Suchman, 2007). The twin focus on mundane actions and the ideals that are mobilized in giving accounts in decisionmaking processes blur distinctions between practice and theory. The ethnomethodological approach allows us to see the NMPP as an innovation premised on historically structured political economic relations and *ad hoc* negotiations around infrastructure. By making a careful account of construction of objectives and rules, the abstractions and justifications become visible. Here, we echo Stripple's (2010, p. 81) suggestion for studying carbon governance: "Contrary to much contemporary thinking, what matters is not whether hierarchies, markets or networks govern, but the kind of rationality that informs the governing." As we find in our study of the CAR NMPP project, the final specification of the protocol, and the consistent pattern of ratcheting back ambitions to link offset payments to detailed measures of benefit streams, highlights the challenges of realizing a data-rich, evidence-based standard. In studying the construction of this protocol, carbon accounting comes across as ordinary, inexact, and dependent on the resources and constraints at hand.

The intersection of conservative impulses and creative problem solving yielded solutions to practical problems of delineating the territory over which available models yielded credible results and the specification of how to represent additionality. Yet, the protocol has not been used to support carbon trading, and CAR continues to work to develop a revised protocol. This suggests that deliberations regarding standards of evidence may be reopened. Such a possibility highlights the provisional nature of the closure of such debates. It is possible that the availability of new data could change the judgments of the actors, and it is possible that differences in political economic and ecological context could produce different outcomes. Detailed analysis of the practical work of the people negotiating judgments in this situation is needed to understand outcomes.

The metaphor of imbrication helps us understand how informational infrastructures build upon each other. Imbrication is the practice of mixing and matching different sources of information and bringing them into dialogue with one another in a manner that is considered *adequate* (Bowker and Star, 2000). In this empirical case, CAR's core responsibility was to integrate different resources – e.g., NASS, ARMS, MSU-EPRI, state-level farm management datasets, farmers' records. But each of these datasets is structured according to logics and routines specific to their function and the contexts in which they are collected and housed. Layering different data sets, with their different formats and methodological assumptions highlighted tensions that had to be resolved in order to advance standard setting. Because CAR, the standard setter, is a consumer not a producer of models, the construction of the quantification tool is clearly patchwork.

Imbrication, useful in understanding how informational infrastructures build upon each other, also highlights how accountability in carbon governance is constrained by the unarchived, situated interactions or negotiations that shape standards. While standards are indeed engendering, transforming, and performing carbon realities, trying to work backwards to identify the political or technical variables that shape carbon standards confronts the problem that they emerged from practical and situated concerns. This is demonstrated in the 'radical openness' faced by the CAR team where they found that the explicit or even implicit rules to arbitrate the validity of datasets and statistical evidence had to be crafted in the process of developing the standard, thus making it impossible for them to reference some external credible information source. Deliberation and creative problem solving allowed the actors engaged with NMPP to overcome such informational problems, which, with further refinement, might become encrusted as new norms of carbon accounting, referenceable by others.

The *ad hoc* dimension of innovation processes and the proliferation of short-term project forms in environmental governance raises important questions about the nature of learning and the cumulativeness of knowledge production (Munck af Rosenschöld and Wolf, 2017). While there may cumulativeness (or less optimistically, path dependency) in production of carbon accounting standard making, it is also worth considering the possibility that new conventions established during these short-term project forms do not inform future efforts. Each episode could be isolated and there is no learning. However, because consultants serve to circulate knowledge, and professional groups are forums of exchange and cumulativeness, we should not take this for granted. Knowing more about ways in which knowledge produced in projects such as the NMPP is archived, circulated, applied, and perhaps forgotten is needed, given expectations that carbon accounting will be a central feature of carbon governance heavily regulated through market coordination. A practice-centered approach allows us to see how political economic relations play out on the ground and how creative efforts of local actors contributes to institutional change.

6. Conclusion

As of May 2018, four years after being published by CAR, the NMPP has not registered a single carbon offset project. The failure of the NMPP to attract users could be understood as an outgrowth of low carbon prices, but it can also be seen as an outcome of the negotiations that shaped the accounting protocol. The final nitrogen management protocol was narrowly specified to corn growers in parts of the midwest and for only one management practice – reduced application of nitrogen fertilizer. At the time of writing this paper, CAR is reconvening a new MWG to improve the NMPP with new quantification methodologies. While this study does not provide the empirical evidence to speak about the protocol's current success or failure - unresolved at the moment – tensions among commitments to wide-spread applicability, scientific rigor, and low transaction costs were fully visible in relations between CAR, SAC and the MWG in the efforts to specify a quantification methodology for estimating carbon fluxes and for defining a baseline (i.e., a counterfactual scenario) to ensure additionality.

Our analysis of the challenges of constructing a carbon accounting protocol, and the empirical fact that this expansive effort did not yield changes in farming practices and carbon fluxes, contributes to understanding of carbon governance and institutional change, more broadly. Rather than interpret lack of uptake of the protocol as a failure, we highlight how this result points to friction in processes of technical and institutional change. This friction invites creative efforts aimed at innovation, and at the same time it presents a conservative context characterized by a degree of inertia. Analysis of institutional change requires attention to both political economic dynamics and to the work of actors on the ground. Our treatment of the NMPP illustrates the potential to advance this kind of nested, multi-level analysis. We note that future research should advance more fine-grained, actor-centered analysis in order to realize the full potential of ethnomethodological commitments to this interdisciplinary analytical project.

Our account of the construction of the NMPP is not a tale of the rigors of science injecting discipline into a project fueled by commercial impulses to commodify nature. At the same time, we do not conclude that the process is characterized by empty performances of evidence and science. CAR made it clear that their mission was to develop a protocol that is applicable in the carbon market, and they did not define their objectives in relation to environmental protection. The approach or method for constructing the accounting standard involved commitments to "good science" and a performative dimension in which invocations of data, evidence, and models project a sense of objectivity that reproduces the positivist and managerial foundations of carbon governance. Some of the decision rules that emerged from the protocol development process are so coarse as to make CAR cringe, and they have committed publicly to improving the standard. The protocol is, in the end, a product of negotiation, deliberation, and compromise. Detailed, empirical assessment of this situated, practical work can inform our understanding of the governance of standard setting and the processes through which standards structure environmental governance.

Declaration of interest statement

The authors declare no conflict of interest

Funding

The research was supported by a project titled "Optimizing Legume Management to Reduce GHG Emissions and Increase Resilience" funded by USDA-NIFA (Grant Number: 10.310).

Acknowledgements

We appreciate Noel Gurwick's contributions to the research. Helpful comments from Samir Passi and Ranjit Singh are noted.

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