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Carbon as a commodity, retention as a service

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ABSTRACT

United Nations Climate Change convention protocols addressed the issue of anthropogenically reducing CO_2 emissions but failed to view carbon as a commodity that can be measured when sequestered in terrestrial biometric sinks. Forestry science tools quantify tree capture of atmospheric carbon volume annually, and in what tree parts it resides. Trees photosynthesize carbon by converting atmospheric carbon dioxide to sequester carbon atoms in trees. Carbon can be commodified and traded in competitive markets via conservation easement agreements legally binding willing buyers and sellers to consented terms. Based on biometric data projections, carbon is measured in discrete forestland areas as tons per year to express a balance between its emissions and its inferred sequestered volume. Timber harvest decisions viewed through the lens of its quantified carbon volume can serve as a powerful mechanism in offsetting carbon emissions while lengthening financially optimal timber harvest rotation decisions. A commodity trading framework is articulated to link willing carbon sequestration agents (forestland owners) with willing carbon sequestration buyers in an equitable trading platform with legal terms applied through temporally defined conditions. The framework to determine carbon sequestration allowances and carbon storage payments is discussed in terms of agreements which market participants enter. In a brief synopsis, we offer our view on aligning carbon emitters with forestland sequestration operatives articulating meaningful financial and social benefits for those involved.

INTRODUCTION

Carbon (C) is a naturally occurring earth isotope with approximately 98.9% found as Carbon 12 (^{12}C) (Brand et al. 2014). Carbon is transformed through biogeochemical terrestrial source reactions and physical processes to be measured as atmospheric carbon dioxide (CO_2). Oxidation-reduction reactions, such as photosynthesis, cause organic substances to be depleted in the atmosphere (Aguilera and Whigham 2018; Brand et al. 2014). As carbon biophysically enters a plant, it becomes ^{12}C.

Global climate warming changes have occurred since Earth started to climb out of the current ice age between 17,500 and 11,500 years ago (Bradley 2015). Fossil fuel burning for industrial purposes is a source of CO_2 that has increased atmospheric carbon concentration. High CO_2 levels in combination with rising global temperatures, brings these topics into the realm of great social concern. Greenhouse gas (GHG) atmospheric concentrations trap heat in earth's atmosphere (Whyte 2018), exacerbating these combined effects of global warming.

Four earthly carbon pools are described as the atmosphere, terrestrial biosphere (soils, plants, and animals), fossil fuels, and oceans (Shoemaker et al. 2021). Anthropogenic activities have converted subterranean carbon pools to atmospheric collections of CO_2. Anthropogenically modified concentrations of ^{12}C dominate through these events. The proportion of ^{12}C is prevalent because these carbon atoms have mostly passed through photosynthesis as they are pushed through animal bioconversion, decomposition, and as burned fossil fuels.

Global climate change is a naturally occurring process (Alkhayuon et al. 2021). During the past 1,100 million years Earth has experienced warming and cooling phases (Stein 1985). It has cycled from a global sauna at 25º Centigrade, down to an ice-igloo at 10º Centigrade (Scotese 2002), with about five cold troughs counteracted by four warm peaks during the last 500 million years. The current ice age turned into a warming trend between 17,500 and 11,500 years ago, marking the planet's beginning of the fifth warming trend in this half-billion-year series. This is the global exit from cold climates, extensive terrestrial glaciers, and sea levels significantly lower than those seen today (Bennett and Glasser 1996). As the planet continues to warm in this cycle, ocean sea levels are expected to continue rising, and the planet's average temperature will continue to climb.

Humans, in our modern form, have only been on this planet for the past 200,000 years (Arora 2019), and anthropogenic emissions of greenhouse gasses, specifically CO_2 into the atmosphere, have been increasing since about 1800 (Bradley 2015). The current geologic epoch, the Anthropocene, as officially named to have started in 1950 (Waters et al. 2016), shows atmospheric CO_2 levels accumulating at an increasing rate (Lindsey 2021; The Geological Society 2014).

INTERNATIONAL PROTOCOLS

The Kyoto Protocol was adopted on 11 December 1997, with a complex ratification process enabling its execution on 16 February 2005 (United Nations 2005). This treaty focused on capping greenhouse gas and specifically carbon emissions to the atmosphere by adopting countries. Rules and guidelines for carbon emission trading are under Article 17, where the term Cap & Trade dominated market interactions. Within this framework, greenhouse gas emitting industries would be given allowances permitting them to emit expressed amounts of greenhouse gas each year to be offset by emission reductions by other participants. This treaty focused specifically on reducing the amount of greenhouse gas emissions, not on how the atmospheric carbon sink could be reduced (Poulopoulos and Inglezakis 2016).

The Paris Climate Conference is officially known as the 21st Conference of the Parties (COP 21). The Paris Agreement was adopted by 196 Parties at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016 (United Nations 2016). The Paris Agreement again set greenhouse gas emission limitations for participating countries. The goal has been to reduce commercial GHG emissions, not to reduce atmospheric CO_2 concentrations, or to recognize terrestrial carbon sequestration benefits.

Removal of carbon from atmospheric sinks, even temporarily, serves to lessen the negative effects of GHG-enhanced climate change. Nevertheless, the intercontinental convention protocols described here seek only to lessen industrial carbon emissions.

Measurable impacts

Carbon sequestered by forests must be treated as a measurable commodity in carbon markets where willing buyers interact with willing sellers (Mei 2023). In this way, carbon exchanges can be meaningfully actualized in balancing out carbon emission totals expressed in tons per year, against plant-sequestered carbon totals of the same measure and at the same time (Hofstad 2016). Quantifying carbon sequestration appears as the only pragmatic solution to accomplishing a meaningful Carbon Negative status (SCS 2021; AES Corporation 2021; Microsoft 2020).

Currently, this is an arena where investments and capital needs for climate change challenges are not being adequately met.

DISCUSSION

Cleaning atmospheric carbon sinks

While international efforts focus on reducing carbon emissions from anthropogenic sources, little attention is given to the need of measuring how much carbon is annually sequestered in forests. Trees only incorporate carbon for growth through photosynthesis, and all that carbon is captured from the atmosphere (Smith and Smith 2012).

Critical in our approach to the issue discussed is Forest Growth and Yield software (FVS 2018; Arney 2012). First scripted in 1980 (Wykoff et al. 1982; Belcher 1982) these tools described tree diameter and height leading to annual estimates of gross timber volume (Miner et al. 1988). These approaches have since been extended to calculate tree volumes as commercial commodities expressed as timber sorts and grades (Schlosser 2020; Arney 2016). Forest biometric solutions have expanded to describe wildlife habitat, riparian zones, and carbon sequestration potential (Mildrexler et al. 2020).

Conceptually, people state that “a lot of carbon is sequestered in large trees”, but those heuristic statements fail to express it as tons of carbon held within the trees’ four segments defined as roots, stems, foliage, and bark (Crookston et al. 2010). Atmospheric CO_2 is incorporated into trees and held there for an indeterminant time (Schlosser et al. 2003). Plants and animals eventually die and decay with some carbon converted back to CO_2 and some retained in soil. In some instances, plants and animals are burned, and some of this carbon is again converted to a gas to reside temporarily in the atmospheric carbon sink.

The U.S. Environmental Protection Agency (US EPA) considers the burning of "forest biomass", that is wood, as a carbon-neutral process (US EPA 2018). Analytical considerations recognize how this cycling of ^{12}C from atmospheric sink to a terrestrial sink, then through incineration to return carbon to the atmospheric sink is a net carbon neutral path.

When timber is harvested, some tree parts are left on-site, where scheduled burning is often mandated for wildfire risk abatement (WDNR 2006; Oregon Secretary of State 1978). Tree log boles, converted to logs, are transported to lumber mills where pulp, boards, and veneer are recovered. These wood materials enter the competitive marketplace to be made into homes, furniture, paper, and more. It is estimated that the half-life of carbon held in structural lumber used in new home construction is 100 years (Skog and Nicholson 1998). Lumber mills converting logs to wood commodities significantly contribute to carbon sequestration needs (Schlosser et al. 2002).

The Forest Resource Analysis System Software (FRASS) (Forest Econometrics 2023) is a computer-based platform which we developed to use forest biometric indices with economic influences to determine financially optimal timber harvest decisions on each timber stand of each parcel (D&D Larix 2010). The process considers forest biometric growth and yield prognoses through multiple rotations with temporally matched competitive market prices (Schlosser 2020). An extensive array of temporally projected tree growth records for each timber stand is created. When sort and grade records are matched with accurate competitive market prices as interpreted through forest landowner financial discount rates, asset capitalization solutions are revealed (Schlosser 2023).

This process defines the financially optimal timber harvest rotation timing for each timber rotation, on each timber stand and accumulated through perpetuity. This solution serves only the timber production goal, ignoring financial benefits of carbon sequestration co-production ends.

Carbon as a commodity

Tree carbon sequestration occurs in parallel with timber volume growth. Both metrics converted to financial terms can benefit forestland owners. At this time of global climate change focus, it is reasonable to assume that tree carbon sequestration needs to be elevated to the rank of a valuable measurable commodity which begs to influence timber harvest decisions. To start with, forestland owners need to be financially incentivized to sequester carbon in their growing trees and treat sequestered carbon retention as a service. Carbon emitters need a reliable mechanism to purchase offset credits against their current and potential atmospheric emissions.

Mass spectrometry

Mass spectrometry is a process where tree tissues are measured for carbon accumulations, expressed by the oven-dry weight content of tree tissues (Thomas and Martin 2012). These carbon content measurements show variation by biome, species, and tissue type. Integration of these data can be collected for each region where carbon sequestration is quantified and integrated into biometric tree growth data.

Carbon content measurements derived from mass spectrometry analyses create data arrays for regional areas, not just for local forests. Databases have been created describing carbon content specific for tree species (Thomas and Martin 2012; Rasche et al. 2010; Craig 1957). These collections can be maintained for broad application to forestland properties especially as they are integrated into forest biometric analyses.

When combined through time, these measures of carbon sequestered in trees morph into quantified data presentations of annual and 5-year time segments (quinquennia) extending into hundreds of future growth years. This is the measure of how much ^{12}C is taken out of the atmospheric sink to be held in this terrestrial biosphere forest bank.

Forest biometric solutions (FVS 2018) create records of carbon accumulations in each segment discussed. Marketability of carbon in these segments receives attention. Carbon in tree stems, bark, and roots is considered desirable for long-term carbon storage. Carbon in the branches is quarantined for a relatively short time before it becomes a detritus component. Carbon in branches, twigs, and needles (leaves) is sluffed away to be converted into forest duff and recycled to surface detritus. Emissions into the atmosphere are not immediate, carbon in this form only returns to gaseous stages through soil microbial decomposition and respiration, or fire (Smith and Smith 2012).

Carbon sequestration financial incentives

Carbon offset market exchanges

The National Carbon Offset Coalition (NCOC) (Sampson 2005) operated through the Chicago Climate Exchange (CCX), serving operations in the USA and Brazil to sequester carbon in terrestrial plants and soils. CCX ceased trading carbon credits at the end of 2010 due to inactivity in the U.S. carbon markets (Szabo 2010). The European Climate Exchange (ECX) managed the product development and marketing for ECX Carbon Financial Instruments until it was closed in 2010. ECX financial products are now fully owned by Intercontinental Exchange (ICE) selling carbon credit futures to provide the most liquid, pan-European platform for carbon emissions trading (Fernández 2010).

These exchange programs all articulate trading of emission allowances, not carbon sequestration efforts. Carbon sequestration is not currently eligible for Certified Emissions Reductions (CERs) from Clean Development Mechanism (CDM) projects or Emission Reduction Units (ERUs) from Joint Implementation (JI) project credits under both the Kyoto Protocol and Paris COP21 UN agreements (United Nations 2005; 2016).

Conservation easements

Since public carbon market exchanges globally are currently closed, conservation easement agreements could be an efficient and economically viable way to sequester carbon in terrestrial forest land legally binding willing buyers and sellers to commodify sequestrated carbon, and financially incentivize carbon emitters to pay forestland owners for carbon credits offsetting their emissions. Global climate change conventions, as discussed here, are concerned only with limiting carbon emissions into the atmosphere with the intended goal of reducing their effects on global climate change. These parallel goals (reduce emissions, and remove carbon from the atmospheric sink) offer a broad range of positive benefits.

This interaction can be overseen through existing mechanisms of Land Trusts empowered to direct uses of land to protect identified conservation values (North American Land Trust 2021). Conservation Easements have globally served for decades as a trusted mechanism for forestland owners to interact via these voluntary legal agreements between willing landowners and a land trusts or government agencies (Korngold 2011).

The Land Trust Alliance (Chiang et al. 2020) developed an interactive methodology with carbon sequestration agents to develop Carbon Offsets in Conservation Easements: Essentials for Land Trusts. The framework establishes timber-producing organization participation in carbon sequestration to receive annual payments for carbon sequestered by plants above the "business-as-usual" framework.

These payments become incentives to extend financially optimal timber harvest rotation lengths (Mei 2023). Although the heretofore mentioned Land Trust Alliance took significant leadership to establish their California carbon sequestration example, their detailed analytical process did not specify how they measured the sequestered carbon in forestland sites. They did not refer to the four parts of trees where carbon is stored (roots, boles, bark, and foliage). Without these measurements explicitly identified, the Land Trust Alliance carbon sequestration genesis remains an unknown.

To extend the logic of their immediate purpose, conservation easements can serve as the mediator for carbon commodity markets where willing buyers and willing sellers interact to serve the interests of the players involved. Tangible verifications and clear processes need to be explored. Each country should engage in their own legal process to determine an appropriate carbon sequestration framework.

Financial incentives to forestland owners

Critical participants in this North American process are indigenous peoples of the USA, Indian Tribes and Nations (Pevar 2002). Indian Reservations are lands previously held in US Federal Trust status but were reverted to tribal management control beginning in 2010 (Cobell Settlement 2010). Tribes are intrinsically linked to the need of climate change abatement (Whyte 2018). Indian Tribes across the North American continent have reduced carbon emissions (NICC 2017), but are still challenged to articulate volumes of tree-sequestered carbon on tribal forestlands.

Carbon sequestration revenues will potentially benefit Tribal, Non-Industrial Private Forestland (NIPF), Timber Investment and Management Organizations (TIMO), state, and federal agency landowners. Carbon emissions need to be described in support of its goal of "enhanced sequestration" with the boots-on-the-ground effectual carbon exchange programs based on quantifiable carbon measurements.

TIMO and NIPF forestland owners are obligated to maintain their forestlands within the system of local and state taxation needs. These lands are levied an annual property tax as owners seek revenue to maintain their lands and grow trees. Timber harvests have been viewed as the primary way for forestland owners to financially balance their forestland ledgers (Daniels 2005).

Carbon sequestration credits can serve as a landowner's incentive to hold growing tree status for longer time periods as compared to production solely for commercial timber production. Added revenue streams will extend financially optimal timber harvest timing. Timber harvest decisions can be integrated into each Conservation Easement agreement for each parcel encumbered. Timber harvests are not carbon emission events: the agreement's wording should clearly state this.

Deeds of Conservation Easement are binding on property owners (Passar 2021; McLaughlin 2007). The approach we offer articulates volume in tons of carbon sequestered on forestlands and then held in each tree classification type. This is integrated into the conservation easement framework (Weeks et al. 2018).

Sequestration markets

The FRASS computerized system incorporates forestland biometrics, geospatial analyses, and econometric evaluations to discover financially optimal timber harvest timing for landowners (Schlosser 2023). Property databases, accumulated by FRASS, contain thousands of time-specific biometric data cells to be aligned with ever-changing macroeconomic conditions. These data, blended with microeconomic reality of a forestland owner, are designed to create a roadmap leading to financially optimized management decisions.

Carbon sequestration should be treated as a viable commodity provided by forestland owners who can be motivated to diversify the portfolio of their financial and social benefits within a developing market of carbon exchanges. Historically underrepresented communities, such as Indian Tribes/Nations and NIPF forestland owners, can be initial beneficiaries of this approach. They become financially linked to a broader framework of activities to mitigate negative effects of global climate change.

Investigations can be targeted where capital needs for climate solutions have not been met. Forestland owners and managers have potential to enter carbon sequestration markets, but only if a standardized and transparent system is developed and explained.

By integrating a biometric approach through FRASS, based on actual accumulation of carbon sequestered in the growing trees, a reliable and measurable volume of carbon can be calculated for willing buyers to purchase. Market considerations must develop a two-phase value consideration to the sequestered carbon. The first market phase involves evaluation of sequestered carbon taken out of the atmosphere and locked in trees. The second phase considers the carbon intended to be held in the growing trees on the physical forestland site.

Carbon capture is a commodity

This first phase of atmospheric carbon capture is a feature of tree growth expressed as the volume of woody fiber. It is a highly variable growth feature, but the carbon in these woody fibers is relatively consistent by oven-dry weight. Mass spectrometry can verify the exact carbon amounts, but regional averages will most likely serve competitive markets. This is one phase of carbon market maturity which will develop in time.

These market exchanges can be expressed as annual carbon sequestration amounts paid for by willing buyers to the cooperating forestland owners.

Carbon retention as a service

Once carbon has been sequestered, it will be retained in the host trees of each site. This is a service forestland owners can be compensated for as it offsets the carbon otherwise held in the atmosphere. In addition, if carbon is stored in this terrestrial form, it is reducing the negative effects of climate change.

Forestlands mature, age, and ultimately die. When the trees are lost to decay, insect, disease, wildfire, or timber harvest, the status of carbon retention on the site ends. These events will ultimately conclude the forestland owner's annual carbon retention service.

In this scenario, the landowner would not forfeit their services of sequestration and retention, they simply conclude their carbon capture and retention obligations. The incentive to promote wildfire control, or healthy forest successes would motivate forest landowner behavior. The longevity of carbon retention would sustain sequestration preservation and revenues through time.

Timber harvests are not completely a carbon emissions event. Timber entering lumber mills is converted to lumber transitioning to homes, furniture, and other commodities where carbon is retained for substantial times (Skog and Nicholson 1998). Carbon market maturity will evolve with societal recognition that plant-based sequestration delivers temporally defined carbon sinks. Profitable commodity and service markets will develop within these structures.

CLIMATE EQUITY

Our approach ensures development of underserved communities to align and deliver financial benefits from natural climate change solutions. These benefits are locked with existing protocols to link property title restrictions with carbon sequestration agreements.

Although forestland owners have the incentive to diversify management objectives, it is often timber harvesting which guides financial decisions. Other management opportunities, such as riparian management zones for fisheries, removes trees from active timber harvest opportunities. Those lands are administratively taken out of profit motivations from timber harvests. However, all forestlands are available to serve as carbon sequestration sinks, albeit oftentimes as part of the business-as-usual baseline. When monetized, the flow of carbon sequestration and retention revenue to landowners will serve to extend timber rotation profiles, while abating negative effects of increased GHG concentrations, specifically by sequestering carbon in terrestrial sinks.

Forestland owners of all types can serve the carbon sequestration goal only if there is a clear and reliable incentive to achieve these ends. It can start with the heretofore unarticulated side effect delivered with monetized carbon sequestration and retention payments. Conservation easements make annual carbon sequestration payments to incentive timber stand maintenance in its tree-growing status. As this revenue stream enters the forestland owner’s financial profile, timber harvest timing events will be delayed. Timber harvest timing is set individually by owners to achieve their timber harvest financial optimality based on their impatience factor and resulting financial discount rate (Schlosser 2023).

Extended timber harvest rotation lengths will accumulate additional wood volume on each site. The rate of carbon sequestered on each site will decrease annually, and this diminishing annual revenue rate will feed into each landowner’s financial optimality decision matrix.

CONCLUSIONS

In an attempt to slow down Global Climate Change it is critical to identify the unknowns in this carbon sequestration game in order to quantify the qualities involved. Carbon is defined as a substance, as a quality negatively affecting the balance required, but without its numerical expression it eludes any possibility of even setting up the rules in this game. Forestlands are universally recognized as a traditional carbon sink, but its identification as a volume or quantity we are dealing with, prevents us from considering any feasible way in our attempts to build a bridge from the abstract concept to the practical scenario of using carbon in a viable financial transaction exchange in competitive financial markets.

In this commentary, we recognize the international climate change conventions, which consider forestry growth as a business-as-usual prospect, not worthy of financial incentivization. The world of political favor and societal focus to build a green economy shines light on carbon removed from the atmosphere, here considered a carbon commodity sequestration event. The continuation of this terrestrial forest carbon sink comes as long-term carbon storage, here considered the carbon sequestration service.

Forest biometric analysis tools deliver a convincing and reliable metric of carbon volume captured from the atmosphere to be stored in trees. The longevity of stored carbon remains sequestered as long as financial incentives are extended to the forestland owner.

Financial markets can serve this arrangement through the means of a conservation easement, administered in each geopolitical region where forestlands are located. Development and maturity of competitive market forces will evolve and with them, so will administrative guidelines to ensure price stability. Forestland co-production of timber, carbon sequestration, and carbon storage services benefit societal goals while financially offsetting forestland expenses.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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