Advanced Review

What is carbon? Conceptualising carbon and capabilities in the context of community sequestration projects in the global South

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Carbon has been described as a 'surreal commodity.' While carbon trading, storage, sequestration, and emissions have become a part of the contemporary climate lexicon, how carbon is understood, valued, and interpreted by actors responsible for implementing carbon sequestration projects is still unclear. In this review paper, we are concerned with how carbon has come to take on a range of meanings. In particular, we appraise what is known about the situated meanings that people involved in delivering, and participating in, carbon sequestration projects in the global South assign to this complex element. There has been some reflection on the new meanings conferred on carbon via the neoliberal processes of marketisation and on how these processes interact with historical and contemporary narratives of environmental change. But less is known about how these meanings are (re)produced and (re)interpreted locally. We review how carbon has been defined both as a chemical element and as a tradable, marketable commodity. We discuss the implications these global meanings might have for situated understandings, particularly linked to climate change narratives, among communities in the global South. We consider how the concept of carbon capabilities, alongside theoretical notions of networks, assemblages, and local knowledges of the environment and nature, might be useful in beginning to understand how communities engage with abstract notions of carbon. We discuss the implications of specific values attributed to carbon, and therefore to different ecologies, for wider conceptualizations of how nature is valued, and climate is understood. We review in particular how this may impact on community interactions with carbon sequestration projects. Knowing more about how people understand, value, and *know* carbon allows policies to be better informed and practices more effectively targeted at engaging local populations meaningfully in carbon-related projects.

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INTRODUCTION

Climate change has become one of the dominant environment and development issues of the late 20th and early 21st centuries.[1,2] As carbon dioxide (CO_2) emissions are one of the major contributors to anthropogenic-induced climate change, nongeological carbon sequestration alongside limiting CO_2

emissions has become a major goal of international action to tackle global environmental change. Land use change, including deforestation, plays a particularly significant role in many countries' emissions portfolios, accounting for 11% of global annual emissions,[3] with historic land use change contributing an estimated 30% of current anthropogenic carbon in the atmosphere.[4] As such, emissions, land use, and carbon sequestration are both historically and contemporarily entangled.

Much of the climate lexicon around carbon is about the chemical compound CO_2. However, in attempts to minimize CO_2 emissions, terms such as carbon trading, storage, sequestration, and emissions have also become a part of a contemporary climate discourse. They are used on a day-to-day basis by the international climate change industry, which includes entities such as international organizations, national level governments, research institutions, NGOs, and private sector-based companies. All are involved in a global market worth 38.4 billion US dollars in 2013.[5] Thus, carbon, in whatever form, has taken on the mantra of a new natural resource in the 21st century that can be conserved,[4] stored,[6,7] and traded.[8,9]

In spite of the apparent ease with which terms such as 'carbon trading,' 'carbon storage' and 'carbon emissions' are used, carbon has also been described as an entity that is invisible, intangible and surreal.[1] In particular, how carbon is understood, valued and interpreted by actors involved in the implementation of carbon sequestration projects in developing countries is still unclear as little research has been done to consider the situated meanings of carbon in everyday life.[10] Jindal et al.[6], p. 124, comment that, 'farmers' understanding of the nature of carbon sequestration, carbon trading and their contractual obligations need to be better understood.' Indeed, studies of carbon sequestration projects in Africa and elsewhere identify a clear need to explore how communities and individuals within them understand carbon.[8,11,12]

In this paper, we aim to address these shortcomings. We explore the extent to which researchers from a range of disciplines have interrogated the meanings of carbon within communities that engage in carbon sequestration projects, and discuss the current position of community carbon research. The paper begins by providing a brief overview of carbon sequestration projects to date. It describes how these projects have been associated with two main problems: a series of ethical issues concerning the morality of buying up carbon credits as a license to pollute; and, a wide range of practical, implementation-related problems associated with land tenure, poverty reduction, and sustainability. Based on this overview, we suggest that a more fundamental issue might exist concerning a lack of understanding in the international climate change community of how local communities perceive carbon *per se*, and what these perceptions might mean for the success or otherwise of community-based carbon sequestration projects more generally. With this insight in mind, we then go on to explore four different potential meanings and values attached to carbon: (1) carbon as an element or compound; (2) carbon as (in)visible; (3) carbon as a commodity; and (4) carbon as a 'thing' situated within a specific socioeconomic, political, and historical context. Finding limited literature on this last aspect to date, the final sections of this article consider how carbon is valued and identifies Whitmarsh et al.'s[10] idea of 'carbon capabilities' to explore what additional theories and concepts might be required to inform our appreciation of local understandings of carbon. We draw on literatures concerning knowledges, abstractions, networks, and assemblages. The article concludes that attention to broader notions of abstraction and knowledge assemblages paves the way for greater insight into meanings of carbon within communities that engage in carbon sequestration projects.

CARBON SEQUESTRATION PROJECTS

Carbon sequestration means capturing CO_2 from the atmosphere or capturing anthropogenic (human) CO_2 from large-scale stationary sources like power plants before it is released to the atmosphere. Once captured, the CO_2 gas (or the carbon portion of the CO_2) is put into long-term storage. CO_2 sequestration has the potential to significantly reduce the level of carbon that occurs in the atmosphere as CO_2 and to reduce the release of CO_2 to the atmosphere. There are two major types of CO_2 sequestration: geologic and terrestrial. Geologic sequestration is the method of storage that is generally considered for carbon capture and storage (CCS) projects at an industrial scale. Terrestrial (or biologic) sequestration means using plants to capture CO_2 from the atmosphere and then storing it as carbon in the stems and roots of the plants as well as in the soil. In photosynthesis, plants take in CO_2 and give off the oxygen (O_2) to the atmosphere as a waste gas. The plants retain and use the carbon to live and grow. When the plant dies, part of the carbon from the plant is preserved (stored) in the soil. Terrestrial carbon

sequestration is a set of land management practices that maximizes the amount of carbon that remains stored in the soil and plant material for the long term and is the form of sequestration most often found at community level. No-till farming, wetland management, rangeland management, and reforestation are examples of terrestrial sequestration practices that are already in use by communities. Most community-based carbon sequestration projects make payments to communities for changing or maintaining their land use practices as 'carbon friendly.' However, it is important to remember that terrestrial sequestration does not store CO_2 as a gas but stores the carbon portion of the CO_2. If the soil is disturbed and the soil carbon comes in contact with oxygen in the air, the exposed soil carbon can combine with O_2 to form CO_2 gas and re-enter the atmosphere, reducing the amount of carbon in storage.

Carbon sequestration projects, when carried out at the local community scale, can represent a triple win-win situation achieving climate change mitigation, biodiversity preservation, and local socioeconomic development, particularly in rural communities in the global South.[4,6,13,14] Communities can benefit from direct cash incomes from projects, and payments can represent a significant increase in cash income for households.[6,15] Spillover effects can also be significant, from stimulating demand for infrastructure, through individuals spending extra cash income locally, to community trust funds which may receive a share of payments and which may be re-invested locally.[7] Klooster and Masera[4] further indicate that the global benefits of carbon mitigation could provide significant leverage for investment in rural communities in the global South, particularly in forest management capacities.

Communities may also benefit from access to nontimber forest products (NTFPs) generated through forestry activities,[6] e.g., access to fruits, minor timber, firewood, and other products through activities such as beekeeping, which may be supported within communities as a part of the broader sustainability of carbon projects.[14] Projects may also benefit the quality and quantity of locally valuable ecosystem services such as water supplies and soils, as well as improvements to rangelands.[6] Others argue that community-based carbon projects may provide financial incentives to better manage natural resources, and to improve agricultural production and food security, particularly in rangelands and pasturelands.[16] In relation to forest management, research has illustrated that community-based management (in some cases, for the purpose of carbon sequestration), can be more effective both in terms of environmental conservation and community development benefits than state governance.[17,18]

However, research has also pointed to the questionable sustainable development benefits of carbon sequestration projects, as well as limited benefits to local communities. While carbon and carbon reductions have become a new arena for capital investment and speculation, some critics question its value to the poor in the global South.[1,13,18] Not all projects aim to provide benefits to communities. Some are purely private investments, particularly large projects aimed at forest planting.[6] While large-scale plantations and protected areas are typically more economically viable, and offer considerable carbon sequestration potential, they pose risks for local people including exclusion from resources and losing access to land,[11,14] as well as potentially decreasing biodiversity.[19] Klooster and Masera[4] suggest that those projects with the greatest potential for carbon mitigation are those which protect natural forests, or 'avoided deforestation,' such as those funded by the Reducing Emissions from Deforestation and Forest Degradation (REDD) program. Indeed, REDD, and REDD+, payments are often significantly higher than existing Payment for Ecosystem Services (PES) projects.[20] However, like plantations, some avoided deforestation projects may offer little benefit to communities, particularly if they are excluded from access to forest resources and land. Indeed, Sandbrook et al.[18] suggest that REDD creates a paradox: increasing the value of forest resources (and other forms of environmental resources) through global carbon markets without securing local land rights will create political incentives toward centralized governance. Centralized governance of natural resources has been associated with biodiversity and forest loss, such that REDD may ultimately lead to greater ecological damage and lower benefits for the poor. While others contest this logic,[21] there are nonetheless serious questions associated with governance of carbon projects and the trade-offs between local community development, conservation, and biodiversity, carbon sequestration, and the likely economic success of projects.[11–13,22,23]

Where projects are aimed at communities, poorer households may face difficulties in investing in new land practices for carbon sequestration. Transaction costs for registering as a Clean Development Mechanism (CDM) project can be very high, and community development-orientated projects will typically have the highest project costs and are therefore less likely to attract large investors.[6] Broadly, research to date has found conflicting evidence as to the net benefits of community-based projects to local

people in the global South, with some evidence that the poorest are least likely to be able to access the benefits,[14] and that, in some circumstances, participation in carbon projects may exacerbate inequalities within and between communities.[7,12] However, other reports suggest that it is poorer households who are more likely to participate in schemes, even though the impact on household livelihoods may still be small and are unlikely to lift them out of poverty.[7] Where projects have been built more decisively around poverty alleviation and social goals, as is the case in Mexico, the conservation and environmental benefits may receive less priority.[24] In addition, sequestration projects can lock poor communities into an unpredictable global market, which means that pay-outs to them can be unpredictable.[8,25] For example, estimates for the total value of the global carbon market dropped from 96 billion in 2011 to US$38.4 billion in 2013,[5] although World Bank figures reported an even greater value in 2012 of US $176 billion,[26] while the Bank now estimates the value to be US$34 billion in 2015.[27] The discrepancy between the measurements highlights the complexity of estimating the size of these markets. There is also considerable spatial variability in global carbon markets, demonstrated by the significant variation in carbon prices between carbon tax schemes, from as little as US$1 per tCO_2 (tonne of CO_2) in Mexico to US$168 in Sweden.[28] The result is that the carbon market crisis is inextricably linked to the uneven development impacts of carbon-related projects.[29]

There are already emerging geographies of carbon sequestration investments and projects, both globally and within Africa. Carbon investments are unequally distributed, with relatively few CDM-financed projects based in Africa compared to Latin America and Asia,[6,14] despite the biophysical and spatial potential for carbon offsetting projects in Africa being high.[16,30] Within Africa, carbon sequestration projects are unevenly skewed toward East Africa.[6] Such geographical inequalities exacerbate the existing inequalities of climate change, to which Africa has contributed to the least, and yet is likely to experience the most severe impacts.[30]

A further concern particularly relevant to the sub-Saharan Africa context is that of land tenure and property rights. Without clear defendable rights to land, and the ecologies that inhabit them (forests, pastures, wetlands), suppliers may have difficulty making commitments to supply carbon offsets.[11] Even when communities act as local service providers (rather than individual smallholders) they may still not have secure rights to their land.[6,30,31] This situation is exacerbated in rangelands where local people may use common-property lands and resources, where land may have multiple uses, and where people and cattle move frequently.[16] Countries of sub-Saharan Africa often have multiple tenure systems, and customary, informal and local rights may conflict with official statutory national land ownership.[30,32] Unruh[30] illustrates that in some African contexts, tree planting can signify land claims, while customary laws may prevent certain groups, such as women, migrants, and tenants, from planting trees. National and international data can often disguise the overlap between state and communal/individual tenure. For example, 86% of the world's forests are owned by governments, with the remainder under private or communal ownership.[18] However, these formal forest statistics under-report communal forest tenure, and overlapping tenure claims. The formality and complexity of carbon trade agreements may favor those with clearly defined rights to resources and the capacity to enforce these rights.[16] Carbon sequestration projects and rights to the benefits of carbon offsets will inevitably be entangled with local tenure arrangements, and have the potential to exacerbate local and national conflicts over tenure rights.[16,20,30]

There are concerns about the sustainability of carbon sequestration projects.[13] The carbon sequestration potential of any project is threatened by the impermanence of the resource. For example, a forest can be burned or cut at any stage, releasing most of the sequestered carbon into the atmosphere. As many projects have long life spans to sequester the predicted amount of carbon (up to 100 years), the potential for vegetation change due to human activity over this period can be high.[6,7,14] As communities and individuals in sub-Saharan Africa may need to respond dynamically to environmental change through their use of local natural resources, there may be an incompatibility between this and the need for secure, predictable land-use patterns associated with carbon sequestration and storage.[30] Indeed, land use in many African contexts is already characterized as multifunctional, fragmented, and dynamic in nature, with complex histories of adaptation to environmental and market changes.[16,33,34] Furthermore, contracts of such length bind future generations to decisions and rules with which they may not agree,[7] assuming that such rules are enforceable for the lifetime of the project. Annual payments to communities and individuals for carbon sequestration can further complicate matters. For example, a project in Mozambique paid individuals annually over the first 7 years, in part to assist with establishment costs, yet farmers are contractually obliged to

provide carbon sequestration on the plot for 100 years.[7] In this case, time as well as carbon is abstract, as farmers are asked to make decisions and commitments far into the future and beyond their lifetimes.

Based on this review, it is clear that, while the potential benefits of carbon sequestration projects to the global South are very large, significant moral and practical barriers to their realization remain. One problem faced by the international community in overcoming these barriers is that there is relatively little understanding of how communities in developing countries perceive and understand what carbon is *per se* during the implementation of such projects. The next section, therefore, reviews the different ways in which the term carbon is used, from scientific element to invisible commodity, and examines how situated meanings have become attributed to this 'surreal' entity in attempts to make it more tangible.

WHAT IS CARBON?

Carbon exists as both a physical substance and also a discourse. Physically, carbon (C) is a chemical element that occurs in many different forms, including the compound CO_2. Carbon and its compounds are embedded within a complex carbon cycle, circulating through fast and slow chemical reactions that science is still working hard to fully comprehend. As a discourse, carbon exists in scientific notation, and also as part of an individual and collective imaginary where it is abstracted and defined as a tangible, marketable, tradable commodity, as well as a significant 'thing' linked to climate change. In the sub-sections that follow, each one of these meanings is examined in turn.

Carbon as Element and Compound

An element is a substance made from the same type of atom, while a compound is made up of different elements in definite proportions. Carbon in an elemental form is cycled through our planet in a range of different organic and inorganic compounds, and passes between these different forms in complex chemical processes. While these movements are subject to much scientific enquiry, their significance to society through policy and economy is becoming ever clearer.[35–38] Carbon has its own language that circulates between sciences, markets, the public and governments, and colloquial short-hands are common. For example, when talking about carbon trading, and units of carbon, these terms refer to volume of equivalents of CO_2; when implementing carbon sequestration projects, these terms are referring, generally, to sequestration of carbon in a range of different carbon compounds. Therefore while carbon and CO_2 have definitive meanings when used in scientific language, referring to carbon in its form as an element (C) or chemical compound (CO_2), everyday usage of the term carbon carries a plurality of meanings with associated values, variably referring to carbon as a tradable commodity, as a unit of (often monetary[39]) value and as a value applied to certain forms of vegetation or other biological organisms. These values do not pre-exist in carbon in its elemental or compound form, they are accrued to it by human individuals, communities and societies.[40–42]

Carbon as Visible/Invisible, Tangible/Intangible

Some forms of carbon can be observed, but much is only visible by proxy. A dense forest of trees contains a considerable tonnage of carbon; if cut and burnt that carbon is released as CO_2, and is no longer before the viewer in a physical, tangible sense. However, this visibility can be deceptive. Peatlands and soils can contain a considerable amount of carbon,[43–45] yet it is held beneath the surface and thus is perhaps less visible to the human observer. Whitmarsh et al.[10] suggest that climate change has low salience as a risk issue in part because it cannot be directly experienced. Unlike individual weather events, climate is not directly observable for the individual, and resultant environmental change is 'perceptibly a distant issue, and can only be indirectly judged'[46], p. 1020. In a similar way, carbon as a chemical element/compound, as a presence in the atmosphere (CO_2), as dissolved in the oceans (H_2CO_3) and as an effect on global climate change is, in some ways, invisible, intangible, abstract and perceptibly distant. Yet its presence in ecologies can also make it highly visible and tangible.

While climate policies at the international and national level have given carbon and CO_2 significant value in attempts to curb carbon emissions and increase levels of carbon storage and sequestration,[12,39,41,47] how these values are transcribed onto the material realities of individuals in their daily lives is as yet poorly understood.[10] What evidence does exist (largely from the global North) suggests that, because individuals find it conceptually difficult to translate values attributed to carbon by the international community into the material reality of their daily lives,[48,49] then the risks associated with environmental change seem equally distant and intangible. Individuals cannot easily see carbon in its stored form or in the atmosphere as CO_2, nor can

they sensually experience the effects of the changing balance of carbon in the earth's atmosphere. Coupled with, and inseparable from, this, it is socially inconvenient for individuals to alter their existing lifestyles in order to account for something which, in their daily lives, has little material effect. It is these issues which have led to arguments for carbon to be 're-materialized' in the lives of individuals, such that they can envisage the necessity for lifestyle change,[50] despite its 'uncooperative' status.[40]

Yet to suggest that carbon is entirely invisible to individuals and societies is perhaps disingenuous to the new imaginaries around carbon which have particularly evolved in the global North. Even though carbon is abstract from people's lives, the consequences of carbon processes have real and tangible outcomes for people. Increasingly some nongovernmental organizations, charities, businesses and corporations have worked toward reducing carbon emissions, e.g., through reducing air miles on consumer goods, or by offsetting their carbon emissions to become 'carbon neutral' as an organization.[51,52] These might be seen as attempts to re-materialize carbon, particularly as many are geared around consumer products and consumer choice which have a material presence and a system of values which seeks to tap into individual concern for carbon emissions.[53] Yet with these materializations come additional abstractions which tap into greater intangibilities existing beyond the day-to-day worlds of many individuals, as they rely a great deal on carbon also being a tradable commodity with abstracted values of equivalence.[54,55] While ideals of 'carbon neutral' appeal to new imaginaries of tackling global climate change in the global North, how these value judgements are translated into quantitative limits and then accounted for, e.g., in the legal system, may not be particularly tangible or visible to individuals.[56,57]

Carbon as a Commodity

Carbon as a marketable commodity is consistent with broader neoliberal and market environmentalism ideologies,[1] which emerged after the Washington consensus in the early 1980s and which also came to dominate much of international development policy.[24] The use of market mechanisms, in the form of carbon trading, has emerged as a key narrative in the international response to climate change,[1,24] formalized in the United Nations Convention on Climate Change (UNFCCC), and the 1997 Kyoto Protocol. Carbon trading was first proposed to the second Conference of the Parties (COP) of the UNFCCC in 1996, and was later enshrined in the CDM of the Kyoto protocol of 1997.[8,54,58,59] Although some carbon sequestration projects are financed through the CDM, a significant and growing number are voluntary emissions reduction projects, relying on investment from private companies, donor organizations (including the World Bank, and UN organizations), and national governments.[6,14,60]

By applying the logic of the market to environmental services, the North is able to support emissions reduction in the global South in return for credits toward Kyoto obligations. This process is cost effective for those in the global North because cutting emissions or enhancing carbon storage can be done in the global South much more cheaply.[6] Carbon offsets are typically valued as a price value per ton of CO_2 (tCO_2) sequestered. For example, a tCO_2 may sell for anywhere between US$4.50[7] to US$10.[24] Communities or individuals may receive this payment based on a geographical area. In the Nhambita Community Carbon Project in Mozambique, local households received cash payments of US$242.60 per ha over 7 years for carbon sequestered on their farms.[6] What is significant about this commodification of carbon is that carbon itself, and therefore anything which contains it, is given an abstract value which is equivalent across any context.[54,57] In some rural contexts of the global South, this abstraction can give forests, pastures, and agricultural land an absolute equivalent monetary value, while across the globe all manner of ecosystems and biological organisms can be equally valued in terms of their carbon storage capabilities.[9,37] As we argue below, this new degree of abstraction and equivalence is of considerable significance, yet how it is interpreted and potentially re-materialized in localities is poorly understood.

Carbon as Situated

Scientific studies of carbon sequestration and storage, which typically seek to value particular resources in specific ways, have generally paid little attention to what carbon might mean in a particular human context, either to an individual or a group of individuals (commonly: 'community') who reside in a specific geographical place. The situated meaning of carbon matters because it is in the local contexts of individual's lives in which decisions are made which impact upon the emission and storage of carbon. In the global North how individuals and various publics value carbon and understand it as linked to their daily and life-long lifestyle choices has considerable impact on, and control over, the emission of carbon into the atmosphere.[10,49] In the global South, how people understand carbon, its storage

and sequestration, and what this might mean for their own lives locally and those more globally, may have important implications for actual carbon storage and emissions.

These situated meanings of carbon may not necessarily marry neatly onto the abstracted, globalized knowledges of carbon as a marketable, tradable commodity, as an element or compound, and as a new system of values associated with lifestyle choices. What individual people understand of carbon sequestration, storage, emissions and values may be very different to the values which are placed on these things by the international community, and equally how individuals envisage the material existence of carbon may not coincide with internationally accepted conceptualizations. Research has illustrated that situated meanings of natural resources, e.g., those associated with meanings of water in specific geographic localities, may vary considerably from widely accepted understandings, and have considerable implications for how these resources are used and conserved locally.[61,62] Situated meanings of carbon therefore refer to the understandings, values and meanings of individuals and communities as situated in places, not (necessarily) the abstracted values commonly accepted by the international community, and as such these values may differ from place to place, and may depend on factors contingent to the context both in space and time.

VALUING CARBON

Understanding and valuing carbon is not just part of a broad trend to tackle climate change through neoliberal instruments, it must also be situated within even broader trends within academia, and policy and practice in environmental and natural resource management to assess the value of nature.[19] In contemporary policy and practices, including those associated with valuing carbon, this process is typically understood in terms of 'valuation' of services provided by nature.[61] Although there may be some consensus around the value of carbon and its association with climate change among the scientific community, Liverman[1] illustrates that scientific information can still be presented by international bodies such as the IPCC with clear value judgements, e.g., by overlooking the spatial geographies of climate change.[37] Governments of the global North and environmental campaign groups have also typically used the 'language of certainty'[49], p. 690, to downplay scientific uncertainty in climate change policy, and in environmental campaigns. These, often 'official' discourses, alongside those of competing climate discourses, such as those of sceptics[49] illustrate how understandings of climate change and carbon may be highly value-laden.[37] Indeed, placing values internationally on carbon implies value judgements.

By putting a value on carbon sequestered, different forms of land use and ecologies are then also assigned a market value based on their ability to sequester carbon.[54] Drylands sequester only 0.05-0.7 tons of carbon (tC)/ha/year compared to 0.43 tC/ha/year for Miombo woodlands and 5.9 tC/ha/year for Alnus woodlots.[6] Models of carbon storage, such as those used by the Edinburgh Centre for Carbon Management (CO2Fix-V3.1) to provide data on carbon storage in biomass, incorporate parameters including wood-carbon content, timber production, and expected lifetime of the project. Both these forms of measurement, while based on sound science, imply judgements on the value of different ecosystems, and new ways of calculating carbon stored in biomass and soils are continually emerging.[63] Tradable amounts of carbon per ha are often calculated as the sequestered amount of carbon due to project activity subtracted by a percentage buffer amount (against damage to plots), and a baseline of plots before sequestration activities.[14] The science behind how these values are derived is still developing and may incorporate considerable uncertainty[14] and can be contested[9] yet these values which are placed on the material worth of carbon by actors external to communities have significant implications for how local communities may perceive, understand and (re)interpret the importance of particular ecologies, and indeed may have implications for how they themselves come to value carbon. For example, Robertson[9] illustrates that there is tension in this process of creating social abstractions which bear monetary value between scientists, market-led organizations, and economists in the values placed on wetlands in the USA. However, little is known at present about how the values, knowledges, and understandings of the producers in the new carbon economy in the global South contribute to, and interpret, these tensions locally.

This commodification of carbon and its entanglement with development in the global South has considerable implications. Liverman[1], p. 293, argues that 'the commodification of carbon emission reductions within the international climate regime has immense theoretical and practical implications.' It has created a new but highly slippery commodity in the form of carbon credits generated from excess emission reductions and international investments in emissions reduction projects in the developing world,

and 'by choosing the market solution of trading carbon we have created a new and surreal commodity'[1], p. 279. Indeed, the market narrative has been used to create a new commodity of carbon that has rapidly become a new form of development investment, such that the value of carbon and local development investments have become deeply entangled.[8,25,40] Investments in the form of carbon sequestration projects represent a valuable financial inflow for countries of the global South, with some research suggesting that this investment can aid alleviation of rural poverty.[6] It is important to recognize however that the value associated with carbon is part of a broader geopolitical discourse associated with neoliberal governance.[24] Arguably, the market solutions which have placed an international value on carbon, and therefore on various forms of carbon sinks, have been proposed and implemented by powerful states and neoliberal actors to partly serve their own interests.[1,9,64,65]

Carbon is not only situated in recent valuations as part of its place within a new market economy, and the calculations of land managers, but also it sits within ongoing and historical global narratives of climate change, driven by global international actors. Daniels and Endfield[66], p. 217, ask: 'What do climate change narratives mean for publics in specific places and what are their effects; how do they matter?' suggesting that it is important to consider the historical narratives of understandings of carbon[66] alongside the immediate 'project' within which communities may be engaged. Indeed, the rise of ecosystem services and climate change discourses in the global North have a history and narrative of their own,[1,9] emerging from Eurocentric thinking about nature and value, with roots in enlightenment science, industrial technologies, market economies, and Judeo-Christian philosophies. The hegemony of western conceptualizations of nature (and of development more broadly) have been accused of marginalizing local knowledges and values.[61,67–69] As carbon, both in terms of its scientific and market value, is defined so clearly by the international community, understanding local values under these conditions is necessary yet potentially more challenging than dealing with other aspects of the nonhuman world. Unlike water,[61] forests,[70,71] wetlands,[72] or soil fertility,[34,69] carbon, as a conceptual category, may have little resonance with 'other' environmental histories and value systems. Soil, for example, is likely to have a tangible history with local communities, yet it is highly unlikely that this is the case for carbon.

Based on this review of the different ways in which carbon is conceptualized, it is clear that there are potentially many different ways in which carbon might be understood and valued by communities involved in sequestration projects in the global South. The next section, therefore, draws on the idea of 'carbon capabilities' to explore what additional theories and concepts might be required to inform our appreciation of local understandings of carbon.

CARBON CAPABILITIES

Whitmarsh et al.[10], p. 57, use the term *carbon capabilities* to capture the 'contextual meaning associated with carbon,' along with the ability to make informed judgements and to take effective decisions regarding the use and management of carbon, both through individual behavior change and collective actions. Although Whitmarsh et al.'s[10] study is located in the United Kingdom, and thus largely refers to public understandings of carbon in order to stimulate behavior change to reduce emissions, the term carbon capabilities might be equally useful in bringing together conceptualizations of how communities value and understand carbon, with how they make decisions and judgements, and how these translate into individual behavior and practices which may also engage with systems and governance of carbon. It therefore offers a useful framework with which to understand how carbon is not only conceptualized by individuals, but also how it is encountered materially, and negotiated politically among wider networks which intersect with the local. Carbon capabilities address how individuals develop capabilities to act in these wider networks, and how these actions interplay with how carbon is known and valued.

Theories from psychology can offer some insight into how abstract qualities can become known to individuals as part of their set of carbon capabilities. Whitmarsh et al.[10] discuss how Social Representational Theory can be used to understand how individuals evaluate changes to their physical environment, through the processes of 'objectification' (translating abstract concepts into the concrete and tangible) and 'anchoring' (categorizing according to pre-existing cognitive frameworks, thus rendering familiar). Thinking about these processes may be useful in beginning to understand situated meanings of carbon, and how individuals and communities in the global South 'translate and apply knowledge about carbon and climate change to their daily lives'[10], p. 58. For example, the UK study by Whitmarsh et al.[10] suggests that objectification rarely occurs between individual actions and abstract ideas

associated with climate change, and often anchoring occurs between what individuals regard as 'similar' environmental issues (which may lead to misconceptions and conflations).

Understanding carbon capabilities has important practical implications for existing and future carbon sequestration projects. For example, Palmer and Silber[14] suggest that current understandings of farmers' risk preferences for different carbon schemes, and the factors that determine their adopting of carbon sequestration projects alongside other livelihood activities, are currently poorly understood. Equally, it is unclear if communities can engage with carbon sequestration without significant external funding,[12–14,23] again exposing the necessity for a situated understanding of community carbon capabilities. The carbon capabilities framework allows us to consider how values, knowledges and understandings link with both local and broader political actions. To develop its utility in the context of community-based carbon sequestration projects in the global south, we now explore how debates around knowledge abstraction, networks, and assemblages can extend the relevance of carbon capabilities as a useful concept.

Knowledges and Abstractions

Although much has been made of how communities may hybridize local knowledges with those of science,[73,74] the invisible and intangible nature of carbon and carbon sequestration may present a different form of dialect between knowledges. Research has illustrated that scientific knowledges ('facts') can be interpreted in diverse ways by different individuals,[10] suggesting that these processes of hybridization may also have local, uneven geographies. Additionally, research has shown that typologies and abstractions of the nonhuman world are not unique to neoliberal capitalism[9] nor science,[75,76] and it may therefore be important to consider how local forms of abstraction (and therefore, value) interact with new forms of abstraction based around carbon.

Whitmarsh et al.[10] suggest that it may be particularly difficult to understand and relate to the complex, uncertain, and global issues associated with climate change, and this may be further complicated by the abstract values placed on carbon. Gibbs[61] has illustrated in reference to water resources in Australia, that often water is given specific value, associated with specific places, times, and effects, rather than being conceptualized as an abstract or generic category. Equally, individuals may make messy, untidy connections between abstract, scientific notions and personal, grounded experiences and emotions which contribute to specific values.[61] Values themselves may further be characterized by variability, rather than being fixed,[61] in much the same way that local knowledges of other environmental phenomena have also been conceptualized as dynamic.[73,77] Yet such variability and dynamism may contradict static values assigned to natural resources by scientific ecology or economic markets.[23,58] In a rare example where local knowledges have been taken into account with regards to the impact of PES programs, Shaprio-Garza[24] finds in the context of Mexico that the epistemological place of 'nature' changed little for respondents, who understood PES as government subsidy rather than a market-like initiative in which they engaged as producers. She also, very briefly, touches on community understandings of carbon, revealing that local understandings could be partial and were linked to apprehension of carbon as a commodity to be 'taken away.' Survey research in the United Kingdom has found a diversity of meanings (and some misconceptions) associated with the term 'carbon,' 'climate change' and 'global warming.'[10,48] However, these meanings were commonly linked to cultural framings of environmental pollution, consummate with the concerns of carbon consumers in the global North.[78] These insights are useful, yet only give us some tentative insights into the potential carbon knowledges and value of communities in the global South.

Although Whitmarsh et al.[10] argue for use of the carbon capabilities framework to 're-materialize' carbon, it would be unwise to ignore the value which abstract forms of knowledge might have.[55] Indeed, abstraction from the material in order to understand and 'know' the nonhuman world is not solely the property of Western science.[61,75,76] Therefore, we should not assume that it is necessary to make carbon tangible, visible and concrete, as Whitmarsh et al.[10] suggest, as individuals may need and use abstract understandings and conceptualizations to make sense of this complex thing.[55] Additionally, Whitmarsh et al.[10] use the capabilities framework to suggest that capability can be 'low' or 'high,' implying measurement, or a trigger point at which capabilities are sufficient to both know and engage with carbon. However, the dynamic nature of knowledge suggests that this is perhaps an over-simplification of a complex process. How knowledges of carbon come to interact with existing knowledges of environmental management and of nature, or the nonhuman world, in communities may be revealing of how carbon capabilities are assembled over time and space. While it might be prudent to discuss building community carbon capabilities, the idea that they might

be at a certain 'level' sits uneasily alongside the insights of the assemblages literature that follows.

Networks, Bundles, and Assemblages

While the concept of carbon, and the narratives of climate change it is bound up in, may be relatively 'new' to some communities, others will have been engaged with previous projects, such as participatory forest management (PFM) in Tanzania[17] or community-based forestry in Mexico,[24,70] for some time, making carbon sequestration projects a part of an ongoing narrative associated with conservation of the nonhuman world. Tanzania possesses one of sub-Saharan Africa's most advanced and widespread PFM programs.[17,18] Equally, communities may have other historical narratives of NRM to which contemporary carbon projects may only be a relatively recent addition. Contextualizing community understandings of carbon will require an attention to these ongoing locally-situated narratives, with attention to how carbon has altered the landscape of local environmental knowledge and capabilities in particular localities.

To aid our conceptualization of carbon, it is therefore important to consider the networks through which assemblages of knowledge and materialities around carbon and carbon capabilities are formed locally,[79] as well as globally.[37] Studies which have focused on local environmental knowledges have illustrated that even relatively remote rural communities in the global South are exposed to a matrix of narratives through public media, schooling, and formal education, as well as NGOs and government educational campaigns.[80–82] As such, local knowledges of carbon may be assembled from these sources, rather than purely being an interaction between 'prior' local knowledges and external scientific understandings.[78,83] Access to forms of education, media and networks may influence how knowledges and capabilities of carbon within communities are assembled differently according to individuals' ages and genders. Shapiro-Garza[24] illustrates that, in the context of rural Mexico, social movements linked to carbon projects gained political leverage which helped to shape national understandings of carbon. Other studies have highlighted the role of the newspaper media in the global South in communicating messages about climate change, and the extent to which these too have been influenced by discourses from the global North.[84]

Understanding carbon from the perspective of capabilities and networks may also include situating carbon within a greater assemblage or 'bundle' of resources which make up any ecology. Robertson[9] identifies how economists may separate any given ecosystem into different bundles each with different values, including nitrogen-fixing, water quality, and carbon sequestration functions. Ecologists have highlighted that this not only simplifies ecologies which are inherently complex, but also ignores the interrelated and entangled nature of these functions.[9] Values associated with carbon as a resource may equally be inseparable, or at least deeply entangled with, other values, be these value systems associated with other resources, or indeed values beyond the economic, such as social, moral, and ethical values which accompany experiences of everyday life. Just as resources such as water and soil are interconnected and inseparable from the rest of the world,[61,69] it may be crucial to consider how individuals and communities make links between forms of value associated with carbon. This entanglement of carbon with other functions of ecologies, and the capabilities of communities to conceptualize such inter-related functions may also be of interest to future research agendas.

Assemblage thinking also seeks to challenge Eurocentric and western conceptualization of things through considering the agency of nonhuman entities.[85] Assemblages have been conceptualized as 'composed of multiple networks across space and time in which humans and nonhumans are inextricably entangled'[86], p. 644, aligned more broadly with relational theories and flat ontologies rather than understanding socionatural systems as totalities or hierarchies.[87] Gibbs,[62] for example, focuses on the materiality of water to demonstrate that it has agency as part of an assemblage, agency which can act on other parts of that assemblage, including humans, providing an antidote to thinking of natural resources as separate, for humans to act on. Assemblage thinking may allow a conceptualization of carbon as part of an assemblage of both material and expressive (nonmaterial) elements, of which the values and meanings given to it by local people, their capabilities to manage and understand it (which might include how they materially experience it), are an important part. Yet while the materiality of other natural resources may be more apparent, carbon's invisible, intangible nature makes its materiality difficult to define. If materiality is 'associated with the concrete, the "bump-into-able"'[62], p. 470, but is equally a way of conceiving of the 'relations between the material and immaterial… the need to see the one in the other… to the point where the binary opposition has been dissolved'[88], p. 34, then how communities and

individuals come to conceptualize carbon, in both a material and abstract fashion, may allow for significant insight into what carbon is, and how it is perceived and conceptualized beyond scientific and market discourses. Equally, exploring the material and expressive agency that this 'new resource' has on communities and individuals may allow a deeper understanding of community carbon capabilities. As assemblage theories are also concerned with the ongoing composition of assemblages,[89] this might offer new conceptual possibilities for thinking about how knowledges in and across communities account for new abstractions alongside existing practices.

CONCLUSION

The existing research on the likely benefits and costs of carbon projects to communities and ecologies clearly puts into focus the need for a greater understanding of the situated meanings of carbon.[12] The capabilities framework[10] is useful in this regard, as conceptualising the capability of communities to engage with the values and mechanisms associated with carbon projects will allow them to better weigh up whether proactively engaging with projects will benefit the sustainability of their community and its natural resource use. Indeed, there is evidence from existing community-based carbon sequestration projects that some communities are rejecting project engagement,[90] yet how these decisions are reached, and their geographical and temporal contingency, needs much further exploration from research.[13] What the re-materialization and capabilities frameworks somewhat fail to engage with, however, are the complex networks and assemblages of local sociopolitical organization, multiple agencies of humans and nonhumans and existing constellations of knowledge networks which may impact on how individuals and communities value and engage with carbon successfully or otherwise.

The trade-off that many communities face between existing forest, pasture, or other land use and conservation for carbon sequestration is perhaps revealing of the agency of this new resource, but it is agency contingent on and in parallel with the agency of existing, often more tangible, nonhuman agents. Communities are also capable of placing their own intangible abstractions on nature built around more localized assemblages, as is apparent from local customary tenure rights, but how these intersect with new abstract notions of temporal value (e.g., the length of carbon storage contracts) needs further research at the community level. Significantly, this is not just a question of re-materialization, as existing community understandings may be abstracted and immaterial in nature, nor only a question of capabilities to engage with new structures and abstractions, as capability suggests that agency is only with the human part of the assemblage. 'Re-materialization' thus has the unfortunate tone of suggesting that individuals cannot fully engage with existing abstractions, or form their own abstractions, unless they are made materially obvious to them, when in fact their 'capabilities' may include the skills of abstraction from material reality, and the ability to understand the intangible. It is crucial for research to explore how social and geographical inequalities, existing human and nonhuman agentic assemblages, and forms of existing abstraction and knowledge are implicated in the situated meanings of carbon.

As carbon has been given value within the capitalist market system, carbon itself has become a new, abstract commodity, which can be used internationally to make abstract equivalences. For example, Robertson[9], p. 387, comments on the 'bizarre diversity of forms in this new economy,' forms which include wetlands, forests, rangelands, and ecosystems, emissions from factories, power plants, and motor vehicles, and all now have measurable abstract forms of equivalence, carbon, which can be exchanged. Importantly, these transactions of carbon 'are made possible by our belief in, and consent to, the adequacy of these abstractions'[9], p. 387, which, in the case of carbon, gives value to almost any physical process or material being. This valuing of nature is a momentous shift in the relationship between humans and nonhumans. Almost everything in the nonhuman world may now have a coherent and equivalent abstract value of carbon.[41] The marketisation of carbon as a commodity may make it 'visible' in particular ways. As Robertson[9], p. 389, notes 'the search for surplus value drives the work of measuring and codifying nature, which creates the conditions of *visibility* for nature as a socially necessary abstraction' (emphasis added).

While several authors locate how carbon is valued by other agents, including economists, international organizations, markets, and nation states,[9] as well as 'consumers' of carbon in the global North,[10,46,49,50,91] what is currently missing from these accounts are how local people both value, understand and conceptualize carbon as a resource. Shapiro-Garza[24], p. 13, has illustrated that the market-narrative associated with payment of ecosystems services (PES) projects was only partially understood by rural communities in Mexico 'precisely because it occurred in the realm of the

"extraordinary."' Yet it is unclear whether communities and individuals in the global South, the 'producers' of carbon sequestration, understand the market values, abstractions, and processes which have been constructed around carbon by international actors. Questions therefore need to be asked not only about how communities conceptualize the differences between carbon payments and support for other development programs, and how they conceptualize the contractual obligations which they are under when they take part in carbon sequestration projects, but how they understand carbon *per se*. How communities interpret this shift, or this new visibility to carbon, to which they come into contact through carbon sequestration projects, is an important question.

The carbon economy is now locked into international environmental law but also into the investment strategies of thousands of companies in the private sector,[1,8,92] while voluntary carbon reduction schemes are being implemented by an increasing number of third sector organizations, making significant impacts on local development trajectories in the global South.[57] An understanding of how local people, the producers of the carbon economy, come to know carbon, and their capabilities to deal with carbon and the economy in which it is now the central commodity, is currently lacking in the academic literature. Yet it is imperative for conceptualising the practical and theoretical geographies of this new commodity.

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