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Abstract

Meeting global emissions targets is highly likely to require the removal of previously emitted greenhouse gasses from the atmosphere, and increasing attention is being paid to novel innovations for carbon dioxide removal (CDR). Small Island Developing States (SIDS) are particularly at risk from climate change impacts and are therefore important to consider for CDR efforts, both in terms of CDR potential and risks. Grassroots, inclusive frameworks are valuable to advancing our understanding of the social implications of CDR, including valid concerns around efficacy and scalability, and should constitute crucial foundations in establishing the public support to develop, trial and transition novel proposals. This position paper, a collaboration between Vesta and researchers located in the Dominican Republic and the United Kingdom, presents a simple model for integrating local ownership, inclusion, and participatory governance of CDR through a case study of the establishment of a coastal enhanced weathering project in the Dominican Republic. This paper argues that the inclusion of actors from the Global South into CDR innovation will strengthen both ethical and governance considerations. Critical discourse around whether researching CDR in a SIDS context raises novel, locally embedded, and pertinent questions about the relationship between CDR and climate change adaptation. Conducting social science research to gauge understandings of climate change and public perceptions, while opening pathways for participation in project development, provides insight into and potentially addresses these emergent inquiries. Participatory, deliberative, and localized governance approaches may influence public perception in communities subject to climate change vulnerability, and evidence of its implementation would help to inform strategies to develop more ethical CDR solutions aligned with climate justice principles.

Keywords: Climate Justice; Coastal Enhanced Weathering; Environmental Justice; Negative Emissions Technologies; Ocean Alkalinity Enhancement; Ocean-Based Techniques; Responsible Innovation

The emergence of climate justice discourse

Small Island Developing States (SIDS) are particularly at risk from climate change effects such as sea level rise, hurricanes, and changing rainfall patterns (Nurse et al., 2014). These climate characteristics, combined with their socioeconomic circumstances, make SIDS among the most vulnerable countries in the world to climate change (Scandurra et al., 2018), and they will likely continue to experience a lack of environmental security because of their position at the forefront of climate change effects caused primarily by industrialized countries. Importantly, SIDS have not only represented the most vulnerable in the climate crisis – they have also been instrumental in calling for stronger action on a global scale and were among the first to call for putting climate change on the agenda of the UN Security Council (Mead, 2021).

One of the clearest injustices of the climate crisis is that those who contribute the least to the greenhouse gas problem often suffer the most severe impacts. Concomitantly, the development of research and implementation of solutions do not affect all citizens in the same way, as embedded inequities from climate change risk are reinforced by climate change mitigation and remediation (Healey et al., 2021). As such, notions of justice must play a strong role in any action to reduce the causes or impacts of climate change, including in the development of new technologies and interventions (Batres et al., 2021). The climate justice movement grew out of environmental justice action concerned with inequitable exposure to environmental risks (particularly pollution); the pursuit of 'just sustainability' involves managing the distribution of benefits and harms, not only between countries but also between different communities and generations (Healey et al., 2021). Against the backdrop of growing calls toward justice in adaptation to climate change (Adger et al., 2006; Popke et al., 2016), substantial research is focusing on decoloniality and advancing ethical and inclusive approaches to scientific endeavor (Mutua & Swadener, 2004; Trisos et al., 2021). The Intergovernmental Panel on Climate Change (IPCC) concludes that *"Inclusive governance that prioritizes equity and justice in adaptation planning and implementation leads to more effective and sustainable adaptation outcomes."*

According to Adams et al., (2009), the climate justice agenda should increase attention in four key areas: development disparities, vulnerable groups, governance, and resources. The climate crisis is a crisis of justice as much as it is a crisis related to the geophysical environment, and as such, calls for a reframing of climate, and broader environmental justice debates (Sultana, 2021). As a form of environmental justice, climate justice has three components: equitably distributed environmental risk, recognition for people's diverse needs and experiences and participation in the political processes that create and manage environmental policy (Schlosberg, 2007). Thus, the theory and practice of environmental justice includes not only distributive conceptions of justice, but also notions of justice based on recognition, capabilities, and participation (Schlosberg, 2007).

In this paper we briefly outline the key relevant discourses surrounding climate justice related to removing anthropogenically emitted CO_2 from the atmosphere, collectively known as Carbon Dioxide Removal (CDR), addressing the paucity of studies about social and ethical considerations. Presenting an example case from one of the SIDS in the Caribbean, the Dominican Republic, we argue for the value of a localized governance approach to CDR development, which explicitly addresses the key underlying principles of climate justice

and the related adaptation measures required to conciliate the social and ethical concerns surrounding CDR.

Climate justice and coastal carbon dioxide removal

As one means of addressing climate change, increasing attention is being paid to proposals for CDR, also known as Negative Emissions Technologies (NETs). The IPCC states unequivocally that '*The deployment of CDR to counterbalance hard-to-abate residual emissions is unavoidable if net zero CO_2 or GHG emissions are to be achieved*.' (2022: 47). Indeed, debates are shifting away from *whether* CDR is required, to questions around how, where, why, and by whom (Bellamy & Geden, 2019) – questions which are similarly crucial to environmental justice movements (Batres et al., 2021). A recent commentary by Morrow et al. (2020:152) highlights that '*Not all carbon removal is created equal in terms of social, economic, and environmental impacts, and nuanced positions are needed to distinguish better technologies, practices, projects, and policies from worse ones*.' Our aim is to build upon known justice-based approaches and consider how this inherent inequality of impacts may be mitigated when exploring novel proposals for coastal CDR.

A diverse portfolio of CDR techniques may help to hedge against climate risk, for instance in the case of techniques proving unexpectedly unviable or unscalable (Cox et al., 2021). As part of this portfolio, proposals involving the ocean have been gathering increasing attention, and growing networks of actors and investment are increasingly promoting the so-called 'blue economy' (Boettcher et al., 2021). Ocean-based CDR is seen as attractive due to its potential to avoid the land availability issues associated with terrestrial CDR, as well as offering potentially long sequestration timescales due to the slow turnover of ocean waters (National Academies of Sciences, Engineering, and Medicine, 2022). Some proposed techniques also have the potential to slow or reverse anthropogenic ocean acidification (GESAMP, 2019). SIDS may play an important role in deployment of coastal CDR, because of their high ratio of coastal to inland areas, as well as the potential for synergies with adaptation imperatives such as coastal protection or alkalinization (Rosa & Lohmann, 2015). The understanding of the social and ethical implications of coastal CDR is at an extremely early stage, despite the fact that 'public acceptability' or social appraisal, appears as a standard feature in lists of potential constraints and limitations on the upscaling of CDR (Bertram & Merk, 2020; Bellamy, 2022).

Public perception of carbon removal is highly influenced by framing, necessitating responsible communication strategies for effective implementation. Important frames include the analogies and metaphors used to communicate the technologies, the nature-technology divide in valuing CDR, overestimations of potential emissions-reduction, and communication gaps regarding the social aspects of CDR (Bellamy and Raimi, 2023). The literature identifies several social and ethical considerations which need to be considered for upscaling CDR. Key issues include the risk that CDR merely treats the symptoms of rising emissions rather than addressing the cause, thus failing to deliver broader social and environmental sustainability (Cox et al., 2018). CDR also may divert attention away from emissions reductions via 'mitigation deterrence' (Markusson et al., 2018). Such concerns may be particularly relevant to SIDS for which delays in global climate change mitigation could have particularly catastrophic consequences. Work on public

attitudes towards CDR in the Global North finds that these issues are a major concern for lay publics, in addition to concerns about 'messing with nature' and the potential unintended consequences of intervening in complex, open ecosystems such as the ocean (Corner et al., 2013; Cox et al., 2021).

Least-cost modeling approaches often conclude that the Global South will play host to an outsized share of CDR, due to relative land availability and costs of land, energy, and labour (Fyson et al., 2020; Low & Honegger, 2020). Yet to date, the vast majority of social science research on CDR has been limited to the Global North (Sugiyama et al., 2020; Winickoff et al., 2015). One exception is a study on communities with high climate change vulnerability in Alaska, Sub-Saharan Africa, and South Pacific, which found a greater willingness to *reluctantly* consider climate engineering as a response (Carr & Yung, 2018). Importantly though, a key condition was that climate interventions should be responsive to local needs rather than the benefit of distant elites. We do not yet know whether these sentiments will be consistent in other communities vulnerable to climate change such as the Caribbean, and more research is needed which pays attention to differences in cross-cultural and geographical contexts for public perceptions of CDR.

Environmental and climate justice are emerging as increasingly central issues to CDR efforts (Batres et al., 2021; Pozo et al., 2020; Schlosberg & Collins, 2014), but there is a distinct lack of empirical research into the types of social and ethical dynamics which deployment of CDR in developing countries might entail (Cox et al., 2021). This partly stems from a lack of capacity, particularly in terms of available research funding (Delina, 2021). However, it may also stem from the way in which CDR has been predominantly framed as a top-down, global technique, aligned with its history as 'geoengineering' (Honegger et al., 2021; Lezaun, 2021). It has been divorced from older debates and lessons about the risks of effort sharing of carbon sinks (Carton et al., 2020). Indeed, work on marine CDR as a climate technique sits almost entirely separately from understandings of more locally situated techniques such as blue carbon and ecosystem restoration (Bertram & Merk, 2020; Lezaun, 2021). For example, research on mangroves illustrates the complex interactions between people's dependence on an ecosystem and their attitudes toward interventions in these ecosystems (Srivastava & Mehta, 2017). Various challenges remain in the politics of scaling up CDR techniques and decarbonization in rural and coastal communities, and Buck (2018) identifies three summary principles for the governance of CDR which are relevant to our case study: 1) entrenched interests can play a role in shaping how particular CDR techniques compete; (2) environmental justice concerns around CDR should be viewed as more than 'not-in-my-backyard-ism'; and (3) incentives must be tailored to local contexts.

Increasingly, social scientists are arguing for the inclusion of a diverse range of actors in the development and deployment of novel CDR techniques, starting at an early stage and continuing throughout the innovation and upscaling process. Such so-called 'responsible innovation' should seek to anticipate potential risks and impacts, be reflexive regarding the purposes of research, be inclusive in its processes and outcomes and respond to public concerns (Stilgoe et al., 2013). Such an approach also entails opening up the innovation process to include non-experts, both in terms of directly affected local communities and broader publics. Work on the ethics of social impact assessment emphasizes the importance of procedural fairness and adequate reflexivity, as well as consideration of the distribution of impacts and benefits and the adaptability and resilience of communities to change (Parsons & Luke, 2021). One of the key goals of

this paper is to present a framework whereby approaches to responsible CDR might be put into practice in a particular context, using a case study of a coastal enhanced weathering project in the Dominican Republic.

Dominican Republic – climate change action in a Small Island Developing State

Since the first Global Conference on Sustainable Development of SIDS adopted the Barbados Programme of Action (United Nations, 1994), Small Island Developing States (SIDS) now comprise 52 small countries and territories in the tropics and low-latitude sub-tropics. While there is much diversity in SIDS' physical and human geographies, the United Nations (2005) describes how all display some level of similarity in terms of sustainable development. SIDS are particularly susceptible to the detrimental effects of climate change, such as sea level rise, hurricanes, and altered rainfall patterns (Nurse et al. 2014). These climate characteristics, combined with the socioeconomic circumstances of SIDS, make them among the most vulnerable nations in the world to climate change (Scandurra et al., 2018). Unfortunately, due to their geographical locations, SIDS will likely continue to experience environmental insecurity as they are at the forefront of climate change effects caused primarily by industrialized countries. Even though SIDS typically contribute less than 1% of total emissions, they are disproportionately affected by climate change (Kelman & West, 2009). The Wider Caribbean Region, comprising 23 SIDS, with around 50% of the population living within 1.5 kilometers from the coast, was hit by a record-breaking 30 tropical storms in 2021 including six major hurricanes.

Despite being the most vulnerable in the climate crisis, SIDS have played an essential role in raising awareness about climate change. They have been crucial in urging global leaders to take action to address climate change and were among the first to call for placing climate change on the agenda of the UN Security Council (Mead, 2021). SIDS have been influential in advocating for a stronger response to climate change on a global scale, highlighting the urgent need for action to protect the environment and those most vulnerable to its consequences.

The Latin America and the Caribbean regions suffer from a marked asymmetry between contribution to global GHG emissions and climate vulnerability (Bárcena et al., 2020). DR is a developing country in the Caribbean, classified as upper-middle income. It is ranked as one of the 10 most vulnerable and exposed areas in the world in relation to climate change effects, particularly extreme temperatures, changes in precipitation patterns, ocean acidification, projected sea level rise, and increases in tropical storm activity (USAid, 2013). As of 2020, the DR has an estimated population of 10.8 million, with approximately 83% in urban areas and cities (CIA, 2022). With one of the fastest-growing economies in the Latin America and the Caribbean region, and as an active player in the international climate regime, the government of the DR ratified the Paris Agreement in September 2017, and committed, within its Nationally Determined Contribution (NDC), to reducing its greenhouse gas emissions by 25% by 2030 compared to 2010 levels (Gobierno de la República Dominicana, 2020). The NDC also stipulates a commitment to a participatory and inclusive process, although specific details and mechanisms are not defined (WWF, 2020). Aligning with the NDC, the DR has been working on a Gender and Climate Change Action Plan to increase climate change resilience and address issues of gender inequity. The aim is to empower local representatives through

knowledge and capacity building, to integrate sustainable, gender-responsive actions into policy frameworks and foster climate change resilience. Aligning with the country's involvement in the Initiative for Climate Action Transparency to strengthen understanding and inclusivity in climate action, the Climate Action Enhancement Package works with over 50 other national governments in the Global South providing training of public servants on climate policies, climate assessment and climate reporting and by supporting their dialogue with national governments. Such initiatives respond to global calls for greater transparency, citizen participation and localized, collaborative governance on climate action, an emergent approach which is described below.

Ocean alkalinity enhancement research in the Dominican Republic

This paper presents learnings from mixed methods research into social responses to OAE research conducted in the DR by Vesta. Vesta's OAE approach aims to enhance the weathering (i.e., dissolution) of the silicate mineral olivine by spreading olivine grains in coastal zones. Silicate minerals like olivine have been slowly weathering on the Earth's surface for billions of years, gradually sequestering CO_2 as part of the global carbon cycle (Hartmann et al., 2013). The principle behind 'enhanced' weathering is to accelerate the dissolution of silicate minerals above natural background rates by grinding them into small grain sizes to increase the surface area to volume ratio and spreading them in coastal areas with high wave energy. This process may increase the rate of atmospheric CO_2 sequestration through the generation of alkalinity, with the additional benefit of potentially counteracting ocean acidification (Meysman & Montserrat, 2017; Schuiling & Krijgsman, 2006). Although ultimately Vesta did not place any olivine in the coastal environment in the DR (i.e., no field pilot was done), explained in more detail in the following section, the organization is still engaged in scientific collaborations in the DR related to ecotoxicology, ecology, biogeochemistry, olivine dissolution, geomorphology, and social sciences.

The development of the research project in the DR by Vesta provides a unique opportunity to explore the social and ethical issues surrounding CEW in SIDS, including interrogating whether and how research can support local adaptation and development through inclusive methods of implementation (Lezaun, 2021; Morrow et al., 2020). For any actual olivine field deployment, CEW requires ongoing monitoring as olivine minerals continue to dissolve over time, which, in turn, necessitates a robust program with local, regional, and national communities to ensure ecological safety and efficacy of the research and any eventual scale-up. The history of climate interventions in the Global South clearly identifies issues with capacity-building, including a serious need to learn from the mistakes of the past by implementing genuine co-production processes with local communities and stakeholders. Such processes are especially important when there are still knowledge gaps (including literacy hurdles), risks, and cost/benefit calculations to be made. In addition, documenting and providing a platform for the public to share their opinions on this novel CDR technique may assist in developing political mandates and action on much-needed CDR regulations. It may also help researchers and practitioners to understand the extent to which social and ethical concerns around CDR identified in the Global North, such as mitigation deterrence, are salient in the context of SIDS such as the DR.

The experiments are being carried out by Vesta, a Public Benefit Corporation[1] based in San Francisco and also nationally registered in the Dominican Republic which first started researching coastal enhanced weathering as a nonprofit in 2019. The organization is engaged in collaborations with local experts, maritime stakeholders, communities and researchers at domestic and international universities, conducting studies on ecotoxicology, ecology, biogeochemistry, olivine dissolution, geomorphology, and social sciences.

The Dominican Republic was primarily selected for the following reasons: 1) It offered ideal environmental conditions for olivine dissolution due to year-round, warm seawater temperatures; 2) The sedimentological conditions were optimal for carbon removal with beaches consisting of silicate-dominant sand comprised of relatively small grain sizes 3) Olivine is a natural component of numerous regional rock formations, such as the peridotites and gabbros of the Puerto Plata Basement Complex (Huerta et al., 2012) and thus not a foreign mineral to regional ecosystems; 4) The potential site uniquely consisted of two nearly identical bays experiencing the same oceanographic conditions. Hence, they could support a small-scale, natural experiment with one bay receiving olivine while the other being left alone as a control site for comparison. 5) The sheltered conditions of the bay were also favorable for measuring changes in sediment transport and seawater chemistry at a field pilot scale due to calmer sampling conditions and high residence times in the bay; 6) Finally, there was a significant societal and economic demand for Negative Emission Technologies (NETs), driven by a global commitment to reducing greenhouse gas emissions by 27%. Taken together, these factors combined including the available natural resources make DR a highly suitable site to research and develop approaches for olivine placement. These factors also make the DR suitable to ultimately consider scaling up olivine placements at locations other than the pilot site that was being considered.

Benefits at the national level were considered due to the suitable, available resources in the DR for scaled olivine placements. However, to seriously consider a given site, Vesta also engaged with various stakeholders to understand their goals and motivations to consider working with Vesta in their location. Hence, Vesta worked with these stakeholders to understand how each group might benefit from a potential pilot project. As a result of this engagement, Vesta first began its work in the Dominican Republic with a permit to characterize baseline conditions of the bays (ecology, sedimentology, hydrology) that examined suitability for a pilot study prior to any olivine placement. Independent of the work described in the permit, Vesta also invested in developing engagement programs and hired local community experts to continue to learn from the community about how this project could align with their regional goals. The aim was to develop programs that could continue to benefit the community based on their input. Vesta learned that there was strong interest from the local and regional communities to increase tourism to these seldom frequented bays and an olivine deployment was seen as something that could attract more attention to the area. After the baseline characterization of the bays, Vesta determined that the geomorphological conditions of the sites were such that they were not conducive to olivine dissolution and in turn, not representative of sites for future olivine deployments. Thus, Vesta focused their efforts on conducting laboratory-based research but terminated the field work. Despite this shift in the scientific program, Vesta

[1] A Public Benefit Corporation is a for-profit corporate entity which pursues positive impacts to society, workers, the community, and the environment, as part of its legally defined goals.

continued its work to develop community benefit programs that aligned with the tourism goals resulting in sewing workshops for the community to craft items for sale at their souvenir stand. Additionally, Vesta worked with local educators to develop climate change curriculum for local schools along with the hiring of students to help execute laboratory projects with Vesta staff.

Vesta operated with a permit from the Ministry of Environment to conduct oceanographic baseline data collection at the project site. For the baseline phase of the project, there were no government requirements to carry out community engagement programs. During the baseline study phase of the project, Vesta began to draft the subsequent permit application for a future olivine deployment, and while Vesta did not ultimately proceed with the application due to the reasons stated above, there was a mandatory public comment period. While Vesta engaged with the ministry of Environment throughout the baseline study, they gave praise to our efforts to independently consult with the community and further develop community benefit programs even though Vesta decided to refrain from Phase II implementation.

In terms of a prospective model of social-scientific research on community input and project execution, Vesta approaches every form of feedback for different aspects of the project with a risk assessment framework on a case-by-case basis, which takes into consideration both community and broader stakeholder input. Throughout the baseline study, Vesta and their local partners continuously held information sessions and town halls to receive feedback and determine if any adjustments may be needed about the project. Due to our ongoing engagement, the community did not express concerns or desires to change the project plans, and in fact were excited about how the project was proceeding. However, if for example, local, regional, and national permitting authorities issued permits, and thus official support, to move forward with the project but the community still had some concerns, Vesta would work with the community to understand each concern and develop actionable paths to try and resolve them. In this hypothetical scenario, these community concerns may in some cases delay the project until resolutions are reached and could involve various types of actions like adjusting sampling frequencies, types of monitoring, or other forms of engagement. However, if there is overwhelming community resistance to a project, even after extensive engagement efforts and project redesign to address concerns, Vesta would not move forward with the project.

Vesta employs assessments with local community and scientific experts to determine the benefits relative to the risks for each project. For some types of more serious risks, like the endangerment of certain protected species as a product of the project, Vesta, local experts, and the community may determine that the project cannot move past the baseline scoping phase. However, if local scientific experts and the majority of community members deem the potential benefits of the project to outweigh the known risks, then Vesta can determine to move forward with caution while also continuing to engage the minority of community members who still have concerns. Like with many communities adjacent to environmental interventions, there typically exists a spectrum of perspectives filled with supportive, neutral, or unsupportive individuals. For any project Vesta moves forward with, Vesta aims to ensure they have the support of local experts/authorities/organizations in addition to ensuring that most individuals in the community are supportive and/or neutral to the project after extensive education and engagement.

Methods

Ansell and Gash (2008) suggest that a collaborative process entails the interaction of several key factors: face-to-face dialogue, trust-building, commitment to process, shared understanding, and intermediate outcomes. They posit that successful collaboration requires a shared understanding among participating actors regarding the purpose and scope of the collaborative process. This entails a mutual agreement on the goals and definition of the problem at hand, as well as the relevant knowledge and expertise necessary to address it. The authors further contend that achieving small victories, such as through the use of strategic plans or joint fact-finding, can engender a positive feedback loop of trust-building and commitment, ultimately strengthening the collaborative process as a whole. Vesta developed a social science research and community engagement framework building upon these principles, which is outlined below.

Working closely with members of Guzman Abajo and surrounding communities in the DR, Vesta's social science research rests upon two central pillars: 1) investigating awareness about climate change and CEW with olivine through social science research and 2) developing a comprehensive community outreach program together with the community. When conducting scientific research in a coastal SIDS community, the overriding imperative should be to avoid entrenching inequities and to challenge outmoded and unethical research paradigms (Healey et al., 2021; Mutua & Swadener, 2004). A cycle of inclusion, openness and receptivity should be maintained. Developed through a reflexive process building on codes of research conduct and adoption of standards for community engagement, Vesta encouraged critical engagement with local communities following the collaborative governance and justice principles outlined in this paper. Social research and engagement at Vesta in the DR were led by a local female leadership team made up of a community engagement manager, a community engagement coordinator and a senior regional manager.

The research was initially planned to take place before and after Vesta's olivine placement in the area, thus adopting a quasi-experimental approach comparing pre- and post- datasets. However, due to local site conditions identified during Vesta's pre-placement monitoring period, it was determined that the site was likely not conducive for efficient olivine dissolution and in turn, carbon removal. As such, the field trial was canceled before any olivine was placed, although Vesta continued to conduct ecological and biogeochemical laboratory studies in the region. The decision to discontinue the localized field research led to a modification of the social science research to a cross-sectional design, which involved collecting data from specific representative community groups affected by or influential to the CEW research in the area. Ethical approval for this project was supported by the University of Exeter's ethics committee, in accordance with the Economic and Social Research Council guidelines. Consent forms which outlined the ethics, safety, rights, and safeguards of agreeing to the research were signed by all participants in Spanish. The approach included the following key components:

Socio-demographic and attitudinal baseline surveys

Baseline surveys were prepared prior to commencement of scientific research in the pilot area. The first survey phase used semi-structured interview questionnaires with participants drawn from a non-probability sample of the local population identified through a chain referral method (Bryman, 2021). This involved

selecting individuals as key informants referred to by local representatives and based upon criteria discussed with the community leaders (gatekeepers) representing the key target groups within the local community. Participants (N=42) were qualitatively interviewed whilst interviewers filled out paper and electronic questionnaires to assess the socio-demographic and situational profiles of the local communities, and the current knowledge, attitudes, and behaviours toward the project and toward climate change. Survey questionnaires were analysed using descriptive statistics to indicate knowledge and attitudes toward climate change and Vesta. The common messages and narratives were captured through transcribed audio recordings and in daily field notes accompanying the open-ended questions of the interviews, which were used to complement stripe coding using NVivo software (V12) to identify trends and patterns from the dialogue.

Community working groups

Local community members affected by and influential to the project must be listened to, understood, and involved in decision-making processes through regular and structured outreach and engagement activities (Jacobson et al., 2015). An initial stakeholder mapping exercise identified appropriate groups to engage and their respective relationship to the project. The deliberative and inclusive process involved grouping stakeholders in terms of specific dimensions related to the management and engagement with local resources (for example, influence, power, importance), through open discussion and collective, formal ranking exercises (Govan et al. 2008). The identified groups consisted of a women's collective, fisherman's group, beach guardians (stewards from Chiquita and Los Cocos beaches), local government representatives (Municipal District), educational and religious leaders, a handicraft group, a cattle rancher group and the neighborhood council.

After the initial baseline surveys were conducted, the second research phase involved conducting focus group sessions defined by key community stakeholder groups, involving community representatives identified in the first phase baseline research and facilitated by Vesta staff and community members. The deliberative focus group meetings involved discussions about the project's development, encouraged feedback on any insights or queries from the broader cross-sections of the communities and included topics about climate change, CDR and others as requested by the community. These meetings aimed to understand the communal processing of notions and social constructs to generate meaning (Morgan & Morgan, 1997), and are regarded as a powerful method to provide rich understandings of certain social issues and socially constructed discourses (Agar & MacDonald, 2008). In this case the themes were determined by the community representatives, emerging from responses to the baseline survey interviews, although there was also a research commitment to explore important notions of climate change, socio-cultural significance of the coastal habitat, and perceptions of (and engagement with) the project. Six focus group sessions were held in the Dominican Republic throughout 2021 and 2022.

Qualitative interviews

Also in the second phase, immediately following each focus group session, qualitative ethnographic interviews were held with a chain referral sample of representatives from each of the local targeted community groups (N=10). These helped to reveal a further layer of depth to explore the research objectives, revealing the stories and personal perspectives that underpin the responses provided within the

baseline questionnaires and the collective notions brought up in the focus group sessions. The interviews were almost exclusively participant-led and included only a few guiding questions. They continued until no new or significantly relevant data or patterns emerged, or the category became well developed and validated (Strauss & Corbin, 1998). Ten community members from the stakeholder groups were interviewed to understand in more detail their respective backgrounds, context, ideas, perspectives, motivations, life stories and perceptions of the environment and climate change concepts. The qualitative interviews also served as an opportunity to understand the realities of climate change impacts already experienced within the community and their mandatory adaptations to them in order to sustain their livelihoods.

Qualitative data from the information sessions, focus groups and qualitative interviews were collected using notetaking during the sessions. This included systematically written, typed, filmed, recorded and photographed material all taken with consent. This was analysed alongside daily field notes taken by Vesta's DR researchers. Qualitative data was analysed using NVivo (V12) to identify common themes. Daily notes were recorded and written down by hand, then written "up" and eventually "out" (Madden, 2010) and synchronized into NVivo, importing all notes directly into the system to be immediately available for exploration, with insight into relationships between the research themes and guiding concepts (Flick, 2009). Comparative analyses were performed through framework matrix coding queries, comparing coding at nodes for sub-groups, following Applied Thematic Analysis (ATA) processes, a type of inductive analysis of qualitative data (Guest et al., 2013). Notable benefits of ATA as a pragmatic approach are that it is well suited to medium to large data sets, the interpretation is supported by the data and it can be used to study topics other than the individual experience (Guest et al., 2011).

Participatory governance and community outreach

Collectively, these multiple methods provide comprehensive and rich insights into the research objectives and help to gain a clear understanding of the cultural, communal, and local drivers of specific attitudes and behaviors relevant to climate change adaptation, and the key social considerations critical to engage in CDR initiatives. The nature of the methodology further helps to identify key local stakeholders, capture and respond to feedback, and initiate the enabling conditions for involvement where appropriate. Vesta works closely with local governments, universities, NGOs, and communities encouraging inclusion and collaboration at each step of the project's development. A long-term programme of community outreach and participatory activities was established to support community development in the areas surrounding the CDR trial sites, informed by exploration of needs within the baseline surveys, focus groups and qualitative interviews. Adoption of a possible model whereby carbon credit sales may be shared with local communities to support sustainable development (Blaufelder et al., 2021) is also central to the Vesta vision. Community members are actively encouraged to be spokespeople for climate change and coastal CDR to raise awareness within their offline and online social networks. Vesta also facilitates virtual platforms for dialogues about the work within and outside the community, including continuous updates about the scientific and community engagement aspects of the project. Regular feedback on the progress of the project is provided to a local steering committee comprising key stakeholders, including the National Environmental Ministry, science academy, National Authority for Maritime Affairs, Geological Society, and local NGOs. The committee routinely provides input and scrutiny into the scientific and public engagement approaches and has helped to inform the overall scientific strategy of the project.

Increasing awareness of the value of coastal resources that provide resilience to climate change can reduce vulnerabilities, in the same way that strengthening law enforcement can reduce unsustainable exploitation of resources (Rosa & Lohmann, 2015). Academic seminars and workshops with the Ministry of Environment are carried out alongside openings for student internships from a national Young Women in Science scholarship programme. Newsletters and participation in local media networks help to disseminate findings to both the broader scientific and lay public. To address the unique concerns of all representatives of the local communities, the working groups encourage members to review the information they are receiving, voice concerns, ask questions and make suggestions. Insights from the groups are communicated back to the management team in order to review recommendations and adapt approaches accordingly through a reflexive process. Responses are reviewed by the project team and responses are again relayed to the working groups at follow up- sessions, where appropriate inviting input from stakeholder representatives relevant to the query or concern raised.

The main objective of this approach is to ensure that every community member's opinion, concerns, or objections, are genuinely heard and addressed. Beyond simply attempting to avoid the mistakes of scientific research projects in the past, we also aim to develop new understandings of how a process of participatory governance might work in practice, with a commitment to reflexivity and an acceptance that mistakes will occur with ensuing adaptive measures. In doing so, supporting the goal for research in the area to inform local decision-making processes, the aim is to generate knowledge about participatory processes and CDR in the Dominican Republic, which may also be relevant to a wider range of contexts and interventions. The outcomes of the conducted research have been prepared for future publication. Consequently, they have not been presented in this paper to maintain a concentrated emphasis on the model and methodologies employed.

Toward localized governance and inclusion as standard practice in CDR development

In developing countries, achieving a meaningful role for CDR will need to be based on careful and sensitive programmes of stakeholder and public engagement (Healey et al., 2021). Responsible innovation can be seen as a way of embedding deliberation within the CDR development process. The framework proposed by Stilgoe et al. (2013) presents four dimensions of responsible innovation (anticipation, reflexivity, inclusion and responsiveness) stressing the importance of the input of diverse stakeholders and publics. Crucial to this process is second-order reflexivity (Schuurbiers, 2011), in which the value systems and theories that shape CDR governance are themselves scrutinized. Ultimately, defining and addressing issues which are specific to CDR approaches in each context will be critical to ensuring that it is done in a way that fairly distributes responsibilities and burdens, with communities at the core of decision-making (Batres et al., 2021). The US National Academy of Sciences argues that *"it is critical that research and development activities [on marine CDR] incorporate equity, diversity, and inclusion with a particular focus on coastal communities"* (2022: 59). While current discourses of CDR continue to be framed in planetary terms, attention should also be given to local and regional scales of assessment (Lezaun, 2021), and mechanisms must be designed that can mitigate the place-based conflicts that are bound to emerge in developing CDR at scale. Bellamy &

Geden (2019) call for governance of CDR from the ground up, with reference to individual methods as they emerge in specific contexts. Localizing coastal CDR is crucial in characterizing its governance challenges, as it is necessary for identifying and involving the collectives and environments that will be most directly affected by their implementation.

Wyllie et al., (2018) examined the various barriers to adoption of renewable energy, in Barbados, a small island nation in the Caribbean, which has been actively pursuing a transition to renewable energy sources. They highlight the challenge of the absence of definitive national energy policy formulated to boost solar energy uptake and propose a mitigation framework to bridge the gap of renewable energy deployment. Barbados' government has taken a localized governance approach by engaging local communities, businesses, and stakeholders in the development and implementation of renewable energy policies and projects. They established a feed-in tariff program that allowed homeowners and businesses to sell excess renewable energy back to the grid, encouraging decentralized energy production. Despite the localized governance approach, challenges arose due to limited financial resources and technological capacity. The government had to navigate funding constraints and attract private investments to support the transition. Additionally, managing the integration of renewable energy into the existing grid and addressing technical issues required coordination between various local and national entities. Benzaken et al., (2022) presented lessons from the Seychelles, an early adopter of the blue economy, using a mixed-methods approach to explore governance's role in integration. Seychelles' vision was to protect and sustainably use ocean resources, with early leadership and international engagement which raised awareness and established a national blue economy framework, securing innovative finance. Implementation faced governance challenges, including political momentum, stakeholder engagement, and institutional coordination. Bridging global expectations and local realities requires locally driven reforms considering scale, culture, and capacity. Similar to the case study we present here, the Seychelles' localized governance approach involves empowering local communities and stakeholders in marine conservation efforts. These examples illustrate how localized governance in SIDS can be instrumental in addressing environmental challenges (Scobie, 2018). By involving local communities, integrating traditional knowledge, and tailoring solutions to the specific needs of the region, SIDS can make progress in environmental conservation and sustainable development. However, challenges such as limited resources, coordination, and balancing competing interests remain, emphasizing the importance of adaptive and collaborative governance structures.

The development of this pilot study by Vesta provides a unique opportunity to explore the social and ethical issues surrounding coastal CDR in SIDS, including interrogating whether and how research can support local adaptation and development through inclusive methods of implementation (Lezaun, 2021; Morrow et al., 2020). Investment and support of these technologies could potentially support national efforts for climate change adaptation and resilience in the Dominican Republic and other SIDS (Kelman & West, 2009). Much of the adaptive benefit of CDR emerges from strengthening response capacity and addressing the drivers of vulnerability through developing new economic opportunities, knowledge networks and data sources (Buck et al., 2020a). The potential for CDR to increase adaptive capacity is not inherent in the technology itself and relies on effective and inclusive implementation, with sufficient uptake to scale impact. The exact mechanisms of actualizing and distributing the social, environmental, and economic benefits of climate

change adaptation remain unclear, and one should be cognizant that as well as increasing adaptive capacity, new vulnerabilities may also be introduced, depending on policy and project design (Buck et al., 2020a).

The nature of these projects requires multi-year monitoring as olivine minerals continue to dissolve over time, which, in turn, necessitates a robust program with local, regional, and national communities to ensure ecological safety and efficacy of the research and any eventual scale-up. Including citizens within a process of participatory governance could potentially contribute toward the responsible innovation of coastal enhanced weathering. The history of climate interventions in the Global South clearly identifies issues with capacity-building, and a serious need to learn from the mistakes of the past by implementing genuine co-production processes with local communities and stakeholders. Such processes are especially important when there are still knowledge gaps, risks, and cost/benefit calculations to be made. In addition, documenting and providing a platform for the public to share their opinions on this novel CDR technique may assist in developing political mandates and action on much-needed CDR regulations. It may also help researchers and practitioners to understand the extent to which social and ethical concerns around CDR identified in the Global North, such as mitigation deterrence, are salient in the context of SIDS such as the Dominican Republic.

Traditionally, CDR has been seen as most closely connected with mitigation (Cox et al., 2018; Heyward, 2013). Importantly for areas vulnerable to climate change effects, research on CDR also tends to sit apart from conversations on climate change adaptation, which arguably have a longer and richer history of engaging with climate justice discourses (Berrang-Ford et al., 2021; Popke et al., 2016). A critical question for this research is therefore whether studying CDR in a SIDS context raises novel, locally embedded and pertinent questions about the relationship between CDR and climate change adaptation. For example, there may be synergistic opportunities to conduct coastal enhanced weathering in conjunction with beach nourishment efforts for adaptation to sea level rise; yet the relationship between CDR and adaptation could also generate new risks, including the risk that CDR efforts could divert funding and policy attention away from vital coastal adaptation and capacity-building programs. Again, this creates a unique learning opportunity, and several groups including Vesta are exploring partnerships with coastal nourishment projects; this will need to focus on areas where sand placement methods are well developed and have well established assessment frameworks. Future research may be able to explore the potential impact of CDR upscaling on the ability of SIDS like the Dominican Republic to adapt to climate change.

We have outlined a simple model for integrating local ownership, participation, and localized governance through a case study in the Dominican Republic. The insights from this study align with recommendations that the inclusion of actors from the Global South may strengthen both research and governance (Winickoff et al., 2015). Reflexive approaches as presented here require that scientists think critically about the boundary between their roles and wider, moral responsibilities and that they challenge prevailing conceptions about the moral division of labour within science and innovation (Stilgoe et al., 2013). Care should be taken with adopting community-based and localized governance approaches, acknowledging the need to avoid forcing participatory processes (Cooke et al., 2001) and to recognise that local knowledge may reveal inaccuracies in methodological or ethical approaches (Tibby et al., 2007). We argue that

encouraging a sense of agency, ownership and deliberation could help to foster inclusion-based principles and propagate localized governance opportunities.

Conclusion

The Caribbean is one of the most susceptible regions in the world to climate change, and the Dominican Republic is one of the top 10 most vulnerable countries to climate change effects, despite contributing only a relatively small amount to global greenhouse gas emissions. Notions of climate justice must play a strong role in any climate intervention, including novel proposals for Carbon Dioxide Removal. We have outlined a simple model for integrating local ownership, participation and localized governance, through a case study within a research project on enhanced coastal weathering, being conducted by Vesta in the Dominican Republic.

We argue that it is necessary to take into consideration the adaptation needs of groups vulnerable to marginalization in rural and coastal communities that are likely to be disproportionately affected by climate change. The inclusionary, selectively framed and locally salient principles outlined here speak to the foundations of climate justice, which we and others have presented as crucial principles for establishing the social trust and support to develop, trial and transition CDR technologies. In addition, supporting the goal for research in the area to inform local decision-making processes, this project may help to further the understanding of social and ethical risks and benefits associated with CDR; in particular, we will identify knowledge gaps relating to the interaction between CDR and climate adaptation, and around public attitudes toward CDR (especially ocean-based CDR) in the Global South. The project presents a unique learning opportunity to explore the translation of theories of responsible and just innovation into a real-world deployment context, with all its associated complexities and uncertainties. The goal is to encourage further research which investigates how participatory, democratic, localized governance and selective framing approaches may influence public attitudes toward CDR in more climate vulnerable communities, and to inform strategies to develop more inclusive and just CDR solutions.

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Localized governance of carbon dioxide removal in Small Island Developing States

Highlights

- Small Island Developing States are particularly at risk from climate change impacts
- Participatory frameworks are key for societal appraisal of carbon dioxide removal
- Localized governance may positively influence public perception acceptability
- Social research can provide insights into public understandings of climate change

Declaration of interests

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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