Losing out in Land-based Greenhouse Gas Removal: A critical justice perspective on biochar

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Abstract

Biochar is an emergent technology that is currently being investigated for its greenhouse gas removal potential at scale. This provides an ideal opportunity to investigate the potential injustices that may arise with biochar production and deployment so that these can be addressed. We draw from original data collected in 2022—consisting of 37 semi-structured interviews with mostly UK-based stakeholders who have an interest or potential interest in biochar—supplemented with a document analysis. The paper uses the 'multioptic vision' model of who, what, *and* how *to explore the potential injustices of biochar production and deployment. A relatively small number of potential distributive injustices, with slightly more multispecies injustices, were identified. Procedural, recognition, and cosmopolitan injustices may be associated with biochar production and deployment, but these were not identified by our stakeholders or by the organisations in the document analysis.*

Keywords: biochar; greenhouse gas removal; GGR; distributional justice; multispecies justice; climate justice; climate change; carbon removal

Introduction

Alongside the reduction in the use of fossil fuels, greenhouse gas removal (GGR), sometimes known as carbon dioxide removal (CDR), has become an increasingly prominent dimension of policy discussions around climate change mitigation, including in the context of net-zero targets. GGR encompasses a wide range of technologies, including 'engineered' approaches such as direct air capture (DAC) and carbon capture and storage (CCS), the latter associated with energy production (e.g. as 'BECCS', bioenergy and CCS) and other industrial manufacturing processes. Also promising to remove carbon dioxide from the atmosphere are land-based GGR approaches. Somewhat distinct from their engineered counterparts, they rely on relatively large areas of rural and other semi-natural land (including transport verges) for activities such as growing trees or biofuel crops, restoring peatlands, producing feedstocks for biochar, and deploying biochar (**Jaschke & Biermann, 2022**).

However, some land-based GGR methods have engineered dimensions, making a clear-cut distinction between them difficult to uphold. For example, biochar can be produced through industrial pyrolysis methods, and rocks for rock-weathering GGR are typically derived from commercial scale quarrying. Proponents of land-based GGR argue that it has the potential to contribute to climate mitigation efforts, albeit to varying degrees. This raises the question, Can this be a *just* contribution? We are prompted to pose such a question by an increasing body of scholarship that applies a justice lens to the evaluation of climate technologies, particularly in the context of the energy sector, in which interest has focused on green energy technologies and the concept of the just transition (e.g. **McCauley & Heffron, 2018; Sovacool et al., 2017, 2021)**. However, justice perspectives are notably under-utilised within critical assessments of land-based GGR technologies (Forster et al., 2020).[i]

For example, there is a notable absence of justice considerations in media discourses **(Buck, 2013; Mclaren et al., 2016)**. Analysing the media discourses of climate engineering, which includes land-based GGR technologies, Holly Buck notes that 'the justice issue is seldom considered; even when it was present, it was rarely the dominant frame' (**2013: 176**). The reporting of biochar in UK print media illustrates this point well (**Morris et al., 2024**). As such, this paper seeks to contribute to this body of work by applying justice concepts to carbon removal as a distinct form of climate mitigation and by testing the mettle of these concepts in a land-based context, where the relationship between the human and 'more-than-human'[ii] is strongly to the fore, therefore suggesting utilisation of the novel concept of multispecies justice.

We undertake our task through the case of biochar, a relatively less familiar land-based GGR approach. Biochar is currently being investigated through a £30 million GGR 'demonstrator' programme funded by UK Research and Innovation (UKRI), a significant public investment that reveals the ongoing, experimental nature of land-based GGR approaches while simultaneously seeking to demonstrate their potential for 'scaling up'. Whilst the justice considerations of land-based GGR technologies such as biochar are often sidelined **(Buck, 2013; Morris et al., 2024)**, there is value in attempting to reveal these.

As McLaren argues, examining justice issues can 'helpfully illuminate key questions regarding the research, funding, and governance of potentially appropriate techniques for climate engineering as part of a portfolio of climate responses' (**2016: 154**). As biochar is an emerging technology, this is an ideal opportunity to investigate potential injustices that may arise from its production and deployment, so they can be addressed early. As a land-based GGR technology, biochar has a direct impact on other living and non-living entities throughout its lifecycle, especially soil, when it is deployed to the surface of rural or agricultural land. This study is among the first to consider potential multispecies injustices associated with land-based GGR technologies.

The article proceeds by firstly discussing our theoretical approach, outlining the literatures on key justice dimensions, particularly as these have been developed within the context of climate, climate change, and climate mitigation and the more-than-human. We then provide additional context on biochar as a land-based GGR technology. The multi-method approach to the production of empirical material is described before we present evidence of distributional and multispecies injustices, the two most prominent framings around biochar evident within our data. The paper concludes that addressing these injustices will be an important part of future research and policy development.

The Many Faces of Justice in the Climate Crisis

Questions of justice are key to addressing environmental problems, including the climate crisis. Several theories of justice can be used to reveal the potential injustices which may arise from climate technologies such as land-based GGRs. These are distributional justice, procedural justice, recognition justice, intergenerational justice, and cosmopolitan justice. Multispecies justice can also be considered as an additional analytical dimension.

Distributional justice focuses on the fairness of outcomes and how social goods and ills are allocated across society **(Jafino et al., 2021; Newell et**

al., 2021; von Platz, 2020). *Procedural justice* relates to the fairness and legitimacy of the process or procedures that lead to an outcome, as well as to those who make decisions and those who can participate in these processes (**Jafino et al., 2021; von Platz, 2020**). *Recognition justice* acknowledges the injustices relating to Indigenous and other marginalised groups facing social, political, and cultural discrimination **(Fraser, 2008; Fraser & Honneth, 2003**). *Intergenerational justice* recognises the rising engagement of the youth movement within climate justice in which the current generation of polluters and decision makers are held to account for failing to act on climate change (**Newell et al., 2021**). *Cosmopolitan justice* focuses on individual wellbeing as opposed to communities or nations and considers all humans, bound and protected by moral principles, as having equal moral worth regardless of gender, ethnicity, or class (**Brock, 2009; Sovacool et al., 2019**). Finally, *multispecies justice* 'aims to identify a politics for composing a common world that considers the needs and livelihoods of a diversity of human and nonhuman life' (**Jones, 2019: 485**). Multispecies justice decentres humans and instead focuses on *living* and *non-living* entities and their processes, interconnections, and interactions (**Price, 2023; Tschakert et al., 2021**). This approach to justice is said to be more inclusive and more effective in revealing the complexities of the climate crisis.

Whilst multispecies justice may be a novel approach, particularly when considering land-based GGR technologies, similar theories are being considered for further advancing energy justice research. Given the impacts of modern energy systems on the living and non-living, Sovacool et al. (**2017**) have called for energy studies to seriously engage with animal-centred, biocentric, and ecocentric theories of justice. As they argue:

> *[R]ealising the enormity of the impacts of modern energy systems upon the nonhuman world, the limited success of past efforts to mitigate and reverse this harmful trajectory, and the increasingly widespread efforts to extend and redesign modern energy systems, it is ever more urgent that energy studies engage seriously with issues of justice to nonhuman nature* (**2017: 681**).

With the allied field of energy systems taking justice seriously for both humans and more-than-humans, scholars should be considering a similar approach for land-based GGR technologies.

These various dimensions of justice all have a role to play in revealing (un)just practices around climate change and land-based GGR technologies. Drawing on them simultaneously provides 'multioptic vision', which is 'a way of seeing that takes disparate justice claims seriously without privileging any one presumptively' (**Kim, 2015: 19**). Kim (**2015: 19**) argues that multioptic vision 'entails seeing from within various perspectives, moving from one vantage point to another, inhabiting them in turn, holding them in the mind's eye at once' (**2015: 19**). This form of vision enables multiple viewpoints to be considered simultaneously and encourages investigation of the *who, what,* and *how* of potential injustices arising from the production and deployment of biochar. A multispecies-justice dimension extends the *who, what,* and *how* to other *living* and *non-living* entities. The *who* can include animals, plants, soil, water, land, etc., and there are numerous scholars arguing that these entities are able to suffer injustices (see **Chao et al., 2022)**. Biochar has a direct impact on other living and non-living entities throughout its lifecycle and provides an ideal opportunity to be disruptive and radical in terms of justice concerns. At this juncture, it is worth considering in more detail what biochar is.

Biochar: A land-based GGR technology

Biochar is produced through pyrolysis, a process in which biomass is heated in limited oxygen. Under these conditions, the material does not fully combust but instead transforms into a stable, carbon-rich solid. Carbon from the original biomass source (such as virgin wood, agricultural or forestry residues, food, animal and human wastes, or fibres) is stored in biochar in a stable form and can remain in situ from decades to millennia (**International Biochar Initiative, 2023; Otte & Vik, 2017; Pourhashem et al., 2019; Rittl et al., 2015**).

There are several uses for biochar, although significant emphasis is placed on deployment in agricultural settings (**Schmidt & Shackley, 2016**). In agriculture, biochar's main asset for its proponents is its ability to store carbon, although its co-benefits include increased soil fertility, increasing the water holding capacity of soil, and as a soil conditioner **(Otte & Vik, 2017; Pourhashem et al., 2019; Rittl et al., 2015**).[iii] Also in an agricultural setting, biochar has been investigated as an animal feed to establish if it has the potential to improve livestock health and milk quality and to reduce ammonia emissions from livestock (**Innovative Farmers, 2020**). Biochar can be used as a peat substitute in the horticultural industry (**Carbon Gold, 2023**), and can be applied to quarries, embankments, and mines for land remediation, soil restoration, and carbon storage (**TerrAffix, 2022**).

Other uses include the application of biochar to aggregates in cement and concrete production, in road construction materials, and in the production of textiles, ceramics, and paper **(Buck, 2019; Schmidt & Shackley, 2016**). There is also the potential for carbon removal through bioenergy with biochar capture and storage (**Buck, 2019**). Due to this versatility, biochar is beginning to attract attention from scientists, policy makers, industry, and entrepreneurs, especially as a land-based GGR technology. The estimated potential of greenhouse gas removal from biochar in the UK is 6 to 41 megatonnes of carbon dioxide ($MtCO_2$) per year, although globally it is projected to be between 1.9 and 4.8 gigatonnes of carbon dioxide ($GtCO_2$) per year (**Royal Society and Royal Academy of Engineering, 2018**).

Having provided additional context on biochar as a land-based GGR technology and discussed our theoretical approach outlining the literatures on key justice dimensions, we now turn our attention to our contribution. The aim of this paper is to add to the emerging body of work on justice perspectives around land-based GGR technologies. Given the existing research on the benefits of biochar, the paper uses the multioptic vision of *who, what,* and *how* to explore the often-overlooked potential injustices of biochar production and deployment in the UK.

Three questions guide the inquiry:

1) *Who* might suffer from the potential injustices associated with biochar production and deployment?

2) *What* are these potential injustices that may arise from biochar production and deployment?

3) *How* are these potential injustices arising?

The discussion now turns to how data were generated to provide answers to these questions.

Methodology

The work reported here arises from a UK-based, interdisciplinary research project on the application of biochar to agricultural land. This article presents one aspect of the social science research. Our overall objective was to explore stakeholder understandings of biochar.

We were interested in organisations and individuals with a specific interest in biochar who have made past statements and claims about biochar which were either positive, negative, or neutral. We considered these individuals and organisations as stakeholders in biochar. This diverse group consists of biochar industry representatives; biochar producers (commercial, farmer-led, and community based); a biochar pyrolysis machine manufacturer; environmental advocacy groups; research and development organisations within the agricultural sector; farming industry representatives; carbon trading companies; government departments and local authorities; and forestry organisations.

By engaging with a wide range of stakeholders, we tried to ensure that a diversity of understandings and opinions around biochar production and deployment were considered.

Data collection and selection

We identified stakeholders through a variety of approaches, listed below:

1) A social science literature review of biochar

2) An online (Google) search on the terms 'biochar and UK agriculture', and 'biochar and UK'. These search terms were used to ensure we initially identified only UK stakeholders due to the wider project's focus on carbon storage in a UK-only context. The searches were conducted on 29 September 2021

3) Reports related to 'net zero' or climate change that included biochar as a GGR approach

4) Twitter/X announcements of the publication of reports related to net zero or climate change that included biochar as a GGR approach

5) Suggestions made by other stakeholders (individuals and organisations), a method known as 'snowballing'

6) Stakeholders (individuals and organisations) who directly contacted us following national and local media coverage of the interdisciplinary demonstrator project.

In total, 94 individuals and organisations with an interest or potential interest in biochar were identified. Of these, 37 stakeholders agreed to participate in a semi-structured interview (see Table 1). Most stakeholders we interviewed were UK-based, although seven international stakeholders agreed to take part. We included these participants because of the role they could potentially play in the UK biochar landscape. Interviews lasted up to one and a half hours and were conducted online via MS Teams.

The interviews were conducted to obtain a comprehensive understanding of the claims and arguments related to biochar. Specifically, to gain insights from stakeholders regarding their expertise on biochar, its potential applications, the perceived benefits and risks, the opportunities and challenges associated with biochar feedstocks, and perspectives on the incentivisation and regulation of biochar.

Type	Number of Stakeholders
Farmer Focused	
Science / R & D	3
Representation / Advocacy	4
Provision of Goods and Services	2
Environmental	
Advocacy	2
Government (National and Local)	
National Government	4
Local Authorities	3
Biochar Producers	
Commercial	6
Farmer led	3
Community	1
Pyrolysis Machine Manufacturer	1
Forest Focused	
Tree and Woodland Management	2
Biochar Industry Representatives	
Representation / Advocacy	4
Carbon Trading	
Carbon Trading Companies	2
TOTAL	37

Table 1: *Types and the number of stakeholders who were interviewed.*

To complement our stakeholder interviews, we also conducted a document analysis. Individual websites were reviewed for any documents or reports related to biochar that had been released by an individual or organisation. The term 'biochar' was used in this search. Any document or report mentioning biochar in relation to the UK was included. Additionally, documents related to net zero that were produced by key agricultural stakeholders, such as the National Farmers Union (NFU), were included. This was to ensure we captured key arguments about other potential land-based approaches to greenhouse gas removal recommended to biochar stakeholders. A total of 36 items were identified (see Appendix 1 on this article's home page).

N.B. We *guaranteed all stakeholders interviewed their anonymity*. As such, the type of stakeholder (e.g., 'carbon trading company') and a generic respondent number (e.g., 'R13' for 'Respondent 13') are noted when interview data is presented.

Data analysis

As we began to analyse the data, it became clear from the interview data and document analysis that stakeholders were anticipating potential injustices associated with the production and deployment of biochar. Therefore, we pursued this initial finding through a thematic analysis that drew on the different dimensions of justice, as previously mentioned: distributional, procedural, recognition, cosmopolitan, and multispecies justice.

Although there are several different approaches to thematic analysis (**Clark et al., 2021; Ryan & Bernard, 2003**), we used the six-stage process developed by Braun and Clarke (**2006**) in this study. For each potential injustice we noted *what* injustice may be transpiring, *how* the injustice may be occurring, and *who* may be impacted by the injustice. In addition, we noted which stakeholders from the interviews and document analysis were identifying these potential injustices.

Potential Injustices Associated with Biochar Production and Deployment

Our analysis revealed a relatively small number of potential distributive injustices and slightly more multispecies injustices. Whilst procedural, recognition, and cosmopolitan injustices may be associated with biochar production and deployment, these were not identified by our stakeholders or by the organisations in the document analysis.

The potential injustices of biochar production and deployment are discussed in detail below, described in terms of the multioptic vision approach of *who, what* and *how.* We start with distributional injustices.

Distributional injustices

Agricultural residues

Agricultural residues include straw and corn stover and are mostly left on fields after crops are harvested. These agricultural residues currently have several uses including animal feed or bedding, incorporation into the soil for nutrient provision and soil conditioning, in-field protection of high value crops, and co-fired energy production **(Glithero et al., 2013; Groves et al., 2018; Wilson et al., 2014**). Whilst these residues may appear to be a 'waste' product and are sometimes deliberately identified as such, they do have several uses and a monetary value.

Who is willing and able to pay the most money for agricultural residues will determine who wins and loses access to these 'waste' products as a feedstock for biochar production. Potential economic tensions due to competition over agricultural residues may lead to different injustices occurring. Three different scenarios were identified.

In the first scenario, the *who* were arable farmers; the *how* was 'afford to pay for agricultural residues'; and the *what* was 'loss of nutrients to soil from the removal of straw for biochar production'. (As straw decomposes, nutrients return to the soil.) For arable farmers, straw from cereal crops is an important nutrient resource **(Glithero et al., 2013; Groves et al., 2018; Wilson et al., 2014**). A farmer-focused (in terms of representation and advocacy) stakeholder ('R13') we interviewed argued,

> *'Actually, farmers should be going, hang on a minute, if this [straw] stuff's taken away, it has nutrient value which I'm going to lose from my land, so I should be thinking, at the very least, of not removing it from the field until I'm getting more [money] than its nutrient value'* (**R13, interview, 2022**).

The second scenario arises from the use of straw for animals. The *who* of this potential distributive injustice were 'livestock farmers'; the *how* was 'affording agricultural residues', and the *what* was 'loss of animal feed and bedding'. In this scenario, a farmer-focused (in terms of provision of goods and services) stakeholder ('R28') described how 'waste products at the moment may be […] going into animal feed, so again, there's going to be an economic tension there because […] animals want feed' and straw could potentially become unaffordable for livestock farmers (**R28, interview, 2022)**.

In the third and final scenario, the potential *how* of the distributive injustice arises from 'competition for agricultural residues between differing GGR approaches', which results in the *who* of 'biochar producers' facing the *what* of 'losing out on purchasing biomass'. The Royal Society and Royal Academy of Engineering describes how biochar could be produced from waste biomass 'although again there is competition for use of this waste from various GGR methods' (**2018: 36**). During an interview, a carbon-trading stakeholder identified one GGR technology that biochar could potentially be in competition with for biomass: bioenergy with carbon capture and storage (BECCS). They explained, 'Depending on the feedstock that you would use that there was a kind of clear competition upstream […] with BECCS' (**R33, interview, 2022)**.

The first and second scenarios could indicate a lack of awareness of the importance of agricultural residues to the farming community. In scenario three, potential competition between 'wastes' are identified. Not being specific enough about the types of wastes used for biochar production, in particular agricultural residues, may create increased competition and therefore economic injustice for some types of farmer. A lack of clarity around the existing uses of agricultural residues may result in those less versed in agriculture to be unaware of their importance to the agricultural community.

Biochar and affordability

Given that biochar is promoted as a land-based GGR technology with a significant emphasis on deployment in agricultural settings, those who are being asked to use it are either most likely to be excluded due to cost or are expected to carry the burden of its deployment. Interest in deploying biochar to agricultural land is largely driven by scientists and scientific organisations, biochar entrepreneurs, carbon trading companies, and some policy actors, who frame it as a promising climate mitigation tool. In the interviews conducted, there was an acknowledgement that the *what* of biochar being unaffordable for the *who* of many farmers was due to the *how* of biochar's (current) excessive cost. A farmer-focused (in terms of representation and advocacy) stakeholder observed that 'the problem is the price of biochar is high at the moment, and farmers don't have a lot of disposable income' (**R30, interview, 2022)**. Typically, biochar costs between £400 and £1,000 per tonne wholesale (**Biochar Demonstrator, n.d.**). Additionally, the documentary analysis indicated that industry and scientific organisations also perceived cost as one of the limiting factors in the application of biochar. This high cost was noted by the agri-tech organisation CIEL (**2021**), and The IPCC noted 'constraints on biochar adoption include: the high cost' (**2019: 399**). Similarly, the British Society of Soil Science argued, '[F]or the UK, the efficacy and GHG [greenhouse gas] removal potential of biochar is limited by domestic biomass resource and prohibitively high costs' (**2021: 4**). Given that organisations such as these evaluate GGR technologies for their viability, the fact that cost has been identified as problematic should not be overlooked.

Biochar was not only viewed as costly to purchase; the equipment required to produce it was also considered prohibitively expensive. In this context, the *what* of pyrolysis machines being unaffordable to the *who* of many farmers was again linked to the *how* of excessive cost. Interviewees described a market in which the available machines were poorly matched to their needs: as one biochar producer (community) stakeholder explained, the options were 'all pretty much large-scale industrial units or really tiny batch retort processes' **(R8, interview, 2022)**. This mattered because the large units were far beyond the financial reach of most producers, while the very small units, although physically compact, did not offer the capacity required for meaningful or efficient biochar production. A farmer-led, small-scale biochar producer and stakeholder highlighted the financial barrier directly, stating, 'I've looked at getting help […] because the prices of the materials are just horrendous. It's probably about four thousand pounds for one of our units to buy the materials for' (**R25, interview, 2022)**.

Taken together, these issues show how cost and the limited suitability of available technologies restrict access to biochar production. When this is combined with the potential loss of agricultural residues that hold value beyond biochar, the high cost of purchasing biochar itself, and the expense of acquiring pyrolysis equipment, the result is a clear distributional injustice for agricultural communities. We now turn to potential multispecies injustices.

Multispecies injustices

Potential multispecies injustices were identified by stakeholders and in the document analysis; these may potentially occur to other-than-human living and non-living entities due to biochar production and deployment.

Soil and micro-biodiversity

The significance of soil to overall environmental health is now being recognised (**Krzywoszynska, 2019; Lyons, 2020; Puig de la Bellacasa, 2017**). As an acknowledgment of its importance, the Food and Agriculture Organisation of the United Nations (FAO) declared 2015 the 'International Year of Soils'. Soils are not purely natural phenomena; their structures are manipulated via human labour (**Scoones, 2015**). Often, soil has been mistreated. According to the FAO, globally, '33 percent of soil is moderately to highly degraded due to erosion, nutrient depletion, acidification, salinization, compaction and chemical pollution' (**2015: 4**).

The application of biochar to soil and the potential injustices that may arise to both soil and its inhabitants was acknowledged by interviewees.

Many respondents acknowledged that the *what* of 'suffering harm' by the *who* of 'rhizosphere inhabitants' (such as micro-organisms, earthworms, nematodes and microarthropods), may be due to the *how* of 'biochar not naturally occurring in soils'. Once biochar is added, it cannot be removed, and this irreversibility could have far-reaching consequences. A government stakeholder stated they were

> *…thinking about micro-biodiversity to begin with […] [I]f you put material into an environment that's not from that environment originally then what are you doing to the microbial diversity of that area? You're affecting it in some way* (**R6, interview, 2022**).

Potential issues for biodiversity following biochar application to soil were also addressed by a farmer-focused (in terms of representation and advocacy) stakeholder, who explained,

> *[The] critical thing really is to demonstrate that this is not harmful in terms of the potential impact on the rhizosphere. You wouldn't want to be spreading biochar that killed earthworms to put it bluntly. But it's not just the earthworms, it will be all sorts of soil invertebrates, and other important soil microorganisms and so on* (**R13, interview, 2022**).

The second potential soil injustice related to the addition of biochar is the possibility of soil becoming contaminated. A farmer-focused (in terms of representation and advocacy) stakeholder stated how 'poorly made biochar could potentially be a source of contaminants' (**R13, interview, 2022**). Even the high temperatures used during the pyrolysis process will not destroy the toxic chemicals and heavy metals found in some feedstocks. Thus, if the *how* of 'low-quality feedstock containing toxic chemicals or heavy metals being turned into biochar' is applied to the *who* of 'soils' this may result in the *what* of 'contamination'. A (farmer-led) biochar producer pointed to the inconsistent quality of biochar production, explaining, 'There's going to be a lot of biochar about, and it's going to be [of] different qualities. There's a real danger that inappropriate stuff could be put into agricultural soils or spread on peoples' gardens' (**R15, interview, 2022**).

Some stakeholders view the soil itself, as having the capacity to suffer potential injustices. It is important to ensure these injustices do not arise, because if they do, there is the very real threat of the loss of a functioning soil ecosystem **(Ferguson and Northern Rivers Landed Histories Research Group, 2016; Krzywoszynska, 2019)**. In an agricultural setting, this ultimately impacts food crops.

Atmospheric injustices

Biochar is presented as a land-based GGR technology with the potential to address climate change, but there are possible injustices for the *who* of ‘the atmosphere’ that may arise from biochar production and deployment, which may further contribute to the *what* of ‘a warming climate’.

The atmosphere is considered one of the global commons, along with oceans and the seabed, Antarctica, and outer space (**Nakicenovic et al., 2016; Soroos, 1998; Standing, 2019**). Commons are shared resources where each actor has an equal interest and right of access. However, the atmosphere has been enclosed, encroached, commodified, and commercialised through fossil fuel–driven industrialisation (**Palmer & Jackson, 2023; Shiva, 2016; Standing, 2019**). As a result, gases in the atmosphere are increasing (particularly carbon dioxide) resulting in climate change.

Transportation of organic residues

The first potential atmosphere-related injustice concerns the transportation of organic materials—such as straw, waste wood, and green waste—to be turned into biochar. In this case, the *what* is the movement of bulky, low-value organic materials leading to increased carbon emissions; the *how* is the need to transport them over long distances for commercial biochar production; and the *who* is the atmosphere exposed to the additional carbon emissions generated by this transport. Although these materials are relatively light, they are high-volume, meaning that transporting even modest quantities requires multiple journeys or large vehicles. This increases fuel use and associated emissions, potentially undermining the climate benefits that biochar is intended to deliver. A farmer-focused (in terms of provision of goods and services) stakeholder responded:

> *[L]ogic and gut feeling says we need to be producing them [feedstocks] here [in the UK] because it’s going to be a low-value, light product. It’s not heavy. It’s going to be very high-volume. So, you’ve got transport issues. […] But I certainly think if we start carting it around the world, that’s defeating the whole idea of the gains [from biochar]* (**R28, interview, 2022**).

This perspective underscores how the logistical realities of transporting bulky organic materials can generate additional emissions, thereby diminishing the environmental gains associated with biochar. As such, the movement of organic materials for biochar production presents a potential atmosphere-related injustice within emerging biochar systems.

Biochar-production emissions

The second potential atmosphere-related injustice concerns the emissions released during the biochar-production process itself. Here, the *what* is the amount of carbon emitted during pyrolysis; the *how* is the energy-intensive nature of biochar production; and the *who* is the atmosphere, which absorbs these emissions and therefore determines whether biochar delivers a net climate benefit. A farmer-focused (in terms of provision of goods and services) stakeholder argued:

> *The production of biochar itself is technically quite difficult…. [P]robably […] the biggest issue is the overall emissions associated with production of biochar. [...] [I]t's one thing to talk about its benefits […] in terms of reducing emissions. But if its [carbon] footprint […] is as great as its benefits […] then clearly it has no benefit* (**R18, interview, 2022**).

This concern is echoed in the wider scientific commentary. As the British Society of Soil Science notes:

> *It is possible that in some circumstances the natural SOC [soil organic carbon] store can be augmented to some extent through use of basalt minerals or biochar, which offer potential for longer term inorganic or organic C [carbon] storage—but the whole life cycle C [carbon] costs of such techniques need to be considered with care before genuine sequestration benefit can be claimed* (**2021: 6**).

Together, these perspectives highlight that if the emissions produced during pyrolysis approach or exceed the carbon stored in the resulting biochar, the climate benefits of the technology may be negated. This raises the possibility of an atmosphere-related injustice if biochar systems inadvertently contribute to, rather than mitigate, carbon emissions.

Decrease of surface reflexivity

The third potential atmosphere-related injustice concerns the effect of biochar on soil colour. In this case, the *what* is the darkening of soil surfaces after biochar is applied; the *how* is the reduction in surface albedo caused by the black colour of biochar; and the *who* is the atmosphere, which absorbs the additional heat retained by darker soils. When soil becomes darker, it reflects less sunlight and absorbs more heat, potentially counteracting some of the climate mitigation benefits attributed to biochar. The IPCC notes that the application 'of biochar to cultivated soils can darken the surface and reduce its mitigation potential via decreases in surface albedo' (**2019: 193**). (Albedo is the 'measure of the percentage of sunlight that a surface reflects away') (**NASA, n.d.**). Environmental non-governmental organisation (NGO) Biofuelwatch similarly argues that biochar 'darkens soils, reducing albedo, which could undermine proclaimed climate benefits' (**2020: 5**). An environmental advocacy stakeholder participating in our study also mentioned the potential impact on albedo, explaining:

> *[B]iochar is black carbon. […] One of the problems that's been identified is that if you put black stuff in the soil, the soil gets hotter because black absorbs heat. And that's something that hasn't been really explored well enough* (**R5, interview, 2022**).

If the additional heat absorbed by darkened soils offsets some of the carbon storage benefits attributed to biochar, the overall climate mitigation potential of the technology may be reduced. In such circumstances, the atmosphere bears the burden of this unintended warming effect, giving rise to a potential atmosphere-related injustice.

All three of these potential atmosphere injustices related to biochar contribute to climate change in one form or another. GGR technologies, including (but not limited to) biochar, have been identified as contributing to the phenomenon of 'mitigation deterrence'. Of McLaren's (**2020**) typology of mitigation deterrence, the potential injustices identified with biochar and the atmosphere tie in with the typology of 'rebounds'. With 'rebounds', the unintended consequences associated with GGR technologies may result in additional greenhouse gas emissions. In summary, biochar could have the potential to further damage the atmosphere.

Consequently, several multispecies justice concerns surrounding soil and the atmosphere were raised by study participants. It is worthwhile to remember that 'human agency is distributed through and made possible by the non-human world' (**Ferguson and Northern Rivers Landed Histories Research Group, 2016: 965**). Therefore, multispecies justice concerns need to be taken seriously.

Discussion

Proponents of GGR technologies often frame them as techno-fixes required to save the planet from impending climate catastrophe (**Celermajer et al., 2024; McLaren, 2016; Mclaren et al., 2016**). These innovations typically originate in universities, hi-tech laboratories of large organisations and technology start-ups based in the global north, or in the emerging economies of China, Brazil, or India (**Scoones et al., 2015**). Once a technological innovation is considered viable, the power to frame narratives surrounding it lies largely with technology experts, and consequently its social implications tend to be downplayed. In addition, without adequate governance frameworks for GGR technologies, scientific research and intellectual-property acquisition dominate innovation and deployment (**Oldham et al., 2014**), which means that justice considerations are often sidelined (**McLaren, 2016; Sovacool et al., 2017**).

The diverse cohort of stakeholders we interviewed and documents we analysed identified several actors (both human and more-than-human) that could potentially suffer injustices, which suggests that issues of justice around biochar production and deployment should be, and are being, considered. Many of these injustices were not only identified by environmental advocacy stakeholders but also by scientific organisations and biochar producers. The unsettled nature of the biochar landscape could provide the opportunity for some of these potential injustices to be addressed in advance of the wider use of biochar being pervasively deployed as a GGR approach. Biochar producers themselves are key to ensuring biochar production and deployment is as just as possible.

However, if we are to take seriously the very real threat of system collapse caused by the climate crisis, justice cannot have an anthropocentric focus. Other living and non-living entities need to be considered if the climate crisis is to be tackled effectively. Land-based GGR technologies such as biochar are bringing the relationships between humans and more-than-humans to the fore, calling for a more diverse understanding of justice (**Newell et al., 2021**). Other living, and even non-living, entities deserve justice as well, despite the prevalent ideology of human exceptionalism (**Winter & Schlosberg, 2023**).

By using the multioptic vision of *who, what,* and *how* to explore the potential injustices of biochar production and deployment in the UK, multiple viewpoints around justice have been considered as a dimension of analysis. The use of multispecies justice in this study has enabled perspectives on more-than-human concerns to be considered that would otherwise be overlooked.

Procedural, recognition, and cosmopolitan injustices may be associated with biochar production and deployment, but these were not identified in large enough numbers by the stakeholders in our interviews or by the organisations in our document analysis to make an impact within our data. As biochar is an emerging GGR technology, its production and deployment are restricted to stakeholders with specialist expertise, which may have had an impact on the number and types of injustices identified. Given the significant emphasis on biochar deployment in agricultural settings, further collaborative research conducted with farmers and members of rural communities could help address the omission of possible injustices.

Finally, various scholars have argued that the current movement for climate justice is insufficient for addressing the climate crisis (**Celermajer et al., 2021; Chao, 2021; Tschakert, 2020; Tschakert et al., 2021**). To assist in transforming climate justice, Newell et al. (**2021**) propose three points of action:

1) Open up climate politics and policy to a broader range of actors and voices, especially those most affected by climate injustice.

2) Deepen climate justice by ensuring just responses to climate-related impacts on people and nature, and by addressing the structural drivers of vulnerability.

3) Transform governance by improving democratic access, strengthening representation of excluded voices, and opening up decision-making and access to justice in climate policy.

If climate justice is to be transformed in this manner, there needs to be an openness to the idea that the *who* which suffers injustices can be human or more-than-human. This is especially pertinent for land-based GGR technologies such as biochar, where the more-than-human is affected throughout the technology's entire lifecycle. As we have shown, by using multispecies justice as a dimension of analysis, it is possible to include the more-than-human in considerations of potential injustices around biochar production and deployment.

Conclusion

The aim of this paper is to contribute to the emerging body of work on justice perspectives around land-based GGR technologies. To achieve this aim, we applied justice concepts to carbon removal as a distinct form of climate mitigation and tested the mettle of these concepts in a land-based context, where the relationship between the human and more-than-human comes strongly to the fore, therefore requiring the use of the novel concept of multispecies justice.

Whilst proponents of land-based GGR technologies make the case for their potential contributions to climate mitigation efforts, it would be unwise to accept these technologies unequivocally. Using the approach of 'multioptic vision', we have explored the potential injustices of biochar production and deployment in the UK, revealing potential distributive and multispecies injustices in the process.

We have shown that key stakeholders in biochar are aware of (at least some of) these potential injustices. These potential injustices should be addressed whilst biochar production and deployment are still nascent to ensure that all concerned voices can contribute to it being a *just* land-based GGR technology. There is an opportunity to open up debate on biochar, considering a full range of perspectives from biochar stakeholders and thus providing an opportunity for procedural justice to be enacted.

Further research with other GGR technologies is needed to establish other potential more-than-human injustices. The urgent need to address the climate crisis requires all potential tools at our disposal, including GGR technologies such as biochar. However, these tools need to be considered under terms of *justice* for both humans and more-than-humans.

Finally, it is also important to note that this study did not involve direct interviews with farmers about their own experiences or perspectives on biochar. Instead, we interviewed representatives from the wider agricultural sector, who contributed insights based on their organisational and professional roles. While these stakeholders identified several potential distributional injustices for parts of the farming community, their views are not a substitute for the perspectives of farmers whose land may be used for biochar deployment. This remains an important area for further research.

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Endnotes

[i] We acknowledge the critique within emerging social science literature on climate change that focuses on the risks of 'mitigation deterrence', that is, delays in reducing greenhouse gas emissions arising from the deployment of any form of GGR technology. These include **Carton et al., 2023; Markusson et al., 2022; McLaren et al., 2023; Price et al., 2024a** .

[ii] The term *non-human* is still widely used in the social sciences and humanities, but many scholars are turning towards using *more-than-human* instead since it pushes against binaries such as nature and culture (**Price and Chao, 2023**). We define the more-than-human as 'a holistic approach to acknowledge the intrinsic value of, and network of interdependencies between, all living and non-living things across all time' (**Price et al., 2024b**).

[iii] Soil fertility is the ability of soil to sustain plant growth and optimise crop yield through nutrient supply. A soil conditioner improves soil structure and texture but does not usually increase soil fertility.