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ARTICLES

# Right to Food and Geoengineering

**Teea Kortetmäki[1,2] · Markku Oksanen[3]**

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**Abstract**
Climate change poses grave risks to food security, and mitigation and adaptation actions have so far been insufficient to lessen the risk of climate-induced violations of the right to food. Could safeguarding the right to food, then, justify some forms of geoengineering? This article examines geoengineering through the analytical lens of the right to food. We look at the components of food security and consider how the acceptability of geoengineering relates to the right to food via its impacts on these components. Our examination shows that results vary greatly between different forms of geoengineering: while some forms of geoengineering fail to respect the right to food, certain other forms may even become obligatory to protect the right to food. It appears that there is no support for aerosol-based solar radiation management, whereas some carbon dioxide removal methods can help protect or promote the right to food. The ethical challenges related to carbon dioxide removal methods are, we note, similar to those that will also be faced in the course of climate change mitigation.

**Keywords** Climate engineering · Food security · Food justice · Climate emergency · Global warming · Human rights

## Introduction

It is likely that climate change is hampering fulfilment of the right to food (RTF). It adversely affects food security (Mbow et al., 2019) by influencing food availability (via crop failures and declines), access to food (via price impacts), food utilization

✉ Teea Kortetmäki
teea.kortetmaki@jyu.fi

Markku Oksanen
moksanen@uef.fi

1 Department of Social Sciences and Philosophy, University of Jyvaskyla, PO Box 35, 40014 Jyvaskyla, Finland

2 School of Resource Wisdom, University of Jyvaskyla, PO Box 35, 40014 Jyvaskyla, Finland

3 Department of Social Sciences, University of Eastern Finland, PO Box 1627, 70211 Kuopio, Finland

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(via safety risks and decreased nutritional quality), and supply stability over time (via yield fluctuations and other climate change induced humanitarian crises). Therefore, protecting the RTF necessitates climate change mitigation and adaptation.[1] The insufficiency of progress in terms both of mitigation, to avoid dangerous climate change, and adaptation to the harmful consequences of climate change (IPCC, 2018, 2022), has increased interest in technological alternatives and additions to current mitigation and adaptation measures. These additional or alternative methods, generally known as geoengineering, work either by reducing the amount of carbon dioxide in the atmosphere or reducing the solar radiation on the Earth's surface.

It has been suggested that geoengineering boosts crop yields under climatic pressures, linking geoengineering with food security (Fan et al., 2021; Kravitz, 2021). In addition to this possible argument for geoengineering for food security, the main arguments proposed to justify geoengineering under some circumstances have remained quite similar to those set out in the landmark report by the Royal Society in 2009 (see Gardiner, 2011 for a critical commentary). One is the buying time argument (e.g. Preston, 2016, 12–13): the current generation has failed to curb carbon emissions and more time is needed in order to achieve a substantial low-carbon transformation. Thus, it makes sense to deploy geoengineering to leave more time for the development and scaling up of mitigation and adaptation measures. The last resort argument is another approach: if emission reductions fail, geoengineering is still less bad than catastrophic climate change (Crutzen, 2006). These stances have generated numerous critical responses on grounds of ethics (e.g. Gardiner, 2011; Preston, 2013, 2016). Nevertheless, several authors concur with Preston in acknowledging 'that *some* form of climate engineering will make *some* contribution to climate justice in the future under certain highly constrained circumstances' (Preston, 2016, xxi, italics original). The repetition of 'some' in this remark leaves many doors open yet also refers to the need for very specific circumstances to justify the use of geoengineering. Thus, the ethics of geoengineering should be contrafactual, comparing alternative likely realities rather than ideal situations (Preston, 2016; Svoboda, 2017). Since various techniques are labelled 'geoengineering', examinations should also be clear about which techniques they discuss.

This article examines geoengineering through the analytical lens of the RTF. What, if any, are the forms of geoengineering that the RTF could justify, and under what circumstances? In choosing a rights-based approach as an analytical lens, we follow the path that favours concrete and specific approaches to addressing geoengineering (Gardiner, 2011) and we provide a novel example of the application of a human rights-based approach to geoengineering ethics. While the RTF is only one of many human rights, we regard our food-specific viewpoint as being particularly important for several reasons. First, recent academic work links geoengineering to food production and food security, making the issue very topical. Second, it has been suggested that food's importance to humanity even justifies war (see e.g. Peperkamp

[1] However, climate mitigation does not automatically promote food security (Kortetmäki 2019). In particular, actions that generate land use conflicts, decrease agricultural resilience or raise food prices can risk food security.

& Tinnevelt, 2021): by analogy, if any reasons could justify geoengineering, food related ones would be among the top candidates. We remind the reader, however, that food is not the only salient issue when discussing human rights and geoengineering: other climate change induced human rights violations (see e.g. Caney, 2010) may prompt arguments for and against geoengineering for reasons other than those discussed here (see e.g. Svoboda et al., 2019).

The RTF entails a claim made by rights-holders (ordinary people) to public officials and other relevant agencies for food security. It imposes on public agencies the obligation to create and maintain the political, economic, technological, and ecological conditions under which people have access at all times to sufficient amounts of appropriate, safe and nutritious food. The secured access to safe and nutritious food is a matter of life and death and, thus, the RTF is a fundamental human right. Human actions that create or perpetuate (otherwise avoidable) hunger, food shortages or lack of access to adequate food are human rights violations. Inertia and lack of responsiveness, when action is required, also infringe human rights. The established pillars of food security concretize the RTF by categorizing its relevant aspects—food availability, access to food, food utilization (safety and nourishment) and supply stability—into a set of related rights and responsibilities and the specific holders of those rights and responsibilities. Food is a marketable commodity in the global marketplace, but whenever there are systemic food security failures, the food security pillars should inform domestic policymakers and the global community's response to them. In this respect, these pillars express the humanitarian ethos.

This paper is structured as follows. We begin by introducing geoengineering techniques and the RTF as an analytical lens and then utilize it to evaluate various geoengineering techniques in relation to various issues essential to food security: availability, supply stability, access and utilization. We show that solar radiation management (SRM) cannot be justified from the RTF perspective but that certain parties may even have an obligation to research or conduct carbon dioxide removal (CDR) to help protect the RTF. We also observe that RTF-related arguments against agricultural forms of geoengineering are equally relevant for climate change mitigation. Accordingly, they do not serve as arguments specifically against geoengineering, but rather as arguments for the importance of improved land use governance and social security for securing the RTF. This also contributes to broader discussions on the linkages between climate change action and the RTF.

## Geoengineering Techniques and Possible Effects

Geoengineering is an umbrella term for (often highly) technological means of managing the atmosphere or solar radiation to prevent or reduce the harms caused by climate change (see e.g. Preston, 2016; Sovacool, 2021). Geoengineering techniques are commonly divided into two main categories: SRM and CDR.

SRM aims at reducing incoming solar radiation energy and its impacts on the Earth. SRM methods include atmospheric radiation management with sunshades, aerosol injections and enhanced cloud albedo (McCormack et al., 2016).[2] Stratospheric aerosol injections have received the most attention of the possible solutions and in the context of ethics because such global-scale SRM is extremely risky but has also been proposed as being highly effective, relatively cheap and rapid in effects (see e.g. Keith et al., 2017). Heavy criticism of the risks and problems associated with SRM (including irreversibility, large-scale impacts on precipitation and moral hazard and corruption leading to dismissal of the root problems of the climate crisis) have generated numerous contributions within the ethics context (see Preston, 2013 for a comprehensive summary).

Regarding the 'pro-SRM' arguments, it is suggested that SRM can safeguard or promote food security by halting temperature increase related harms to food production (Fan et al., 2021; Kravitz, 2021). This is not necessarily a last resort type of endorsement for SRM: rather, it suggests that geoengineering could alleviate climatic harms to food security and therefore offer one reason for its justification. One argument for at least doing *research* into SRM is the suggestion of'a prima facie moral obligation to research SRM in the interest of developing countries, because SRM appears to be the most effective and practicable option available to alleviate a range of near-term climate damages that are certain to hurt the global South most of all' (Horton & Keith, 2016, 89; for criticism, see Hourdequin 2016). Damage to food production is among the gravest near-term impacts of climate change (Mbow et al., 2019).

CDR aims at reducing the atmospheric carbon dioxide levels and thereby tackles the cause of climate change directly.[3] CDR methods fall in two categories (McCormack et al., 2016): terrestrial carbon sequestration (e.g. bioenergy with carbon capture and storage, biochar and carbon-capturing machines) and marine carbon sequestration (e.g. ocean fertilization). CDR techniques lie on the same continuum with carbon sink enhancement for climate change mitigation: the scale of application determines the labelling so that geoengineering refers to practices with large-scale impacts that uptake the already emitted $CO_2$ (see e.g. Honegger et al., 2021). The IPCC (2022) considers CDR to be necessary in practice in order to avoid dangerous climate change. The obligation to achieve climate change mitigation can also be interpreted to involve obligations to conduct CDR (Honegger et al., 2021). CDR is doubly relevant for food-related reasoning since most of the CDR methods developed to date constitute agricultural geoengineering (geoengineering via agricultural practices) and directly influence farming activities too (Kortetmäki & Oksanen, 2016).

The scientific evidence on geoengineering impacts is mixed but there are uncertainties and evident risks related to its deployment. SRM, in particular, has been rejected on the basis of the argument that there are numerous less risky ways to reduce future harm caused by climate change (see e.g. Gardiner, 2010). However, it is now known that even if ambitious mitigation measures emerge very soon, climate

[2] Large-scale radiation management on the Earth's surface has very local impacts and is accordingly excluded from consideration here.

[3] Thus, CDR is also sometimes mentioned in the context of mitigation of *climate change* (Honegger et al., 2021). Yet, this is not identical to GHG *emission* mitigation (reducing future emissions).

change will continue. Thus, the risks presented by new technologies, including geoengineering, are to be weighed against climate change related risks that are either likely because of the ineffectiveness of mitigation efforts or unavoidable even if effective mitigation takes place.

## The Right to Food as an Analytical Lens

Human rights are a standard point of reference within debates on what makes acts that cause global warming *morally* wrong. The RTF is among basic human rights and can also be framed in terms of the right to subsistence as a broader set of basic rights (see Shue 1988) the enjoyment of which global warming affects. Basic human rights can be considered as the 'moral thresholds' that take priority over most other values: trade-offs that would leave disadvantaged groups below the threshold of rights fulfilment are not an acceptable cost for the achievement of some aggregate benefit (Caney, 2010, 72–73; see also Woods, 2016). The human rights viewpoint entails 'the authority, accessibility, and intelligibility of a widely endorsed moral, political, and legal framework' (Woods, 2016, 344). In other words, rights invoke duties of climate change mitigation, adaptation and compensation (for rights violations) (see e.g. Caney, 2010, 86–87). These are the building blocks of climate policy.

Thus, a human rights-based approach is a valuable perspective even though conflicts unavoidably arise between the protection and fulfilment of various human rights. In the SRM context, Svoboda et al. (2019) have argued that human rights cannot provide meaningful guidance if they are treated as inviolable constraints on action; rather, the approach must focus either on minimizing human rights infringements or prioritizing some human rights over others. If such prioritization were to occur, we would argue that the RTF has top priority, since food is vital to humans, and many other rights (economic, social and cultural rights) lose much of their meaning if human lives are dominated by the struggle to obtain enough food to stay alive and healthy (Shue 1988). However, conflicts can also occur within the RTF framework. For example, it may be asked whether human rights aim to protect one's RTF that comprises a diet the procurement of which causes climate damage (for instance, diets high in red meat) if such a diet is considered culturally appropriate. If any kind of consumption of red meat (per person) is a human right, then this application of the RTF can jeopardize the continuous enjoyment of the RTF because of its high carbon footprint. To ensure that the RTF makes sense, its contents must be fine-tuned and a wider, systemic perspective should be adopted, as discussed below.

The UN Human Rights Council offers a nuanced, influential account of the RTF: it means 'the right to have regular, permanent and unrestricted access, either directly or by means of financial purchase, to quantitatively and qualitatively adequate and sufficient food corresponding to the cultural traditions of the people to which the consumer belongs, and which ensure a physical and mental, individual and collective, fulfilling and dignified life free of fear' (Ziegler, 2008/UN General Assembly A/HRC/7/5, 9). The RTF represents an entitlement-oriented individualistic approach to food security, with emphasis on access to food as a fundamental entitlement (Sen, 1982). The European history of political thought combines the concept of a right with that of a duty. Thus, the right to life has often been accompanied with a duty of self-preservation or 'a right of necessity'. These wordings share the idea of allowing the deprived to act in otherwise illicit ways, possibly including theft, to meet the basic right to subsistence, i.e. food (Mancilla, 2016). In the current context, one might ask whether there is a case for developing and deploying geoengineering to help the needy fulfil the duty of self-preservation (see Smith, 2021 on geoengineering as self-defence, civil disobedience and revolutionary action).

The 1966 UN International Covenant on Economic, Social and Cultural Rights (ICESR) focuses on rights-related duties and attributes responsibility for realizing RTF to the State Parties (ICESCR, Art 11). As with human rights generally, the RTF is thus posited institutionally as generating moral obligations for states as the primary bearers of obligations corresponding to rights (Ziegler et al., 2011, 19). It is the duty of a state to establish coercive laws, policies, and social institutions so that human rights violations cannot take place without legal consequences and individuals' opportunity to fulfil their food-related needs can be met under existing societal circumstances. Ziegler et al., (2011, 8–9) recognize three types of obligations in relation to the RTF: (i) *The obligation to respect.* States and other actors (such as public agencies, firms, NGOs, individuals) must not arbitrarily deprive people of their RTF. (ii) *The obligation to protect.* States should establish judicial measures to prevent third parties from violating the RTF. Third parties may either be individuals or market actors whose actions may fail to respect rights and thus constitute an injury or a harm. These harms can also be inflicted indirectly via causing greenhouse gas emissions. (iii) *The obligation to fulfil.* States must engage in active measures to facilitate people's capacity to feed themselves (and their families) and thus meet the conditions of the RTF. In some cases, this may involve the obligation to fulfil the RTF directly by material provision to people who are incapable of realizing this right (due, for example, to severe poverty or disability). While states are the primary bearers of RTF-related responsibilities, duties to respect the RTF also bind non-state actors and citizens.

This conception of the RTF is burdensome: it obliges states not only to refrain from acting harmfully but also to foster the RTF. Thus, although all three obligations (to respect, protect and fulfil) may look binding, opinions as to how to act and as to how to accord priority to particular actions can lead to conflicts. A strong cosmopolitan and egalitarian view holds that there is a universal duty to participate in creating and maintaining a food system in which concern for the hungry or food-insecure people goes beyond state borders. There are also nationalist or statist views, including views that the positive duties stop at state borders (except perhaps in the event of a humanitarian crisis) and that duties to nationals of the same state as oneself take precedence over duties to those living in distant states (see Held & Maffettone 2016). Generally speaking, cosmopolitan and nationalist normative positions lead respectively to different assessments of geoengineering. A cosmopolitan perspective might involve emphasizing that geoengineering protocols must be consistent with global efforts to tackle the (global) food crisis, whereas a nationalist perspective might focus on efforts that promote national interests. Of course, the aims and means of these extreme positions may overlap to an extent, allowing for various middle positions.

Today the RTF is accomplished patchily. If a state cannot meet its obligation to ensure that its people can feed themselves and their families or get help from the state to do so, the question arises as to whether, when and how the global community should assist in realizing the RTF of these ill-fed people—in particular, when the situation invokes positive duties to promote (fulfil) the RTF.[4] Regarding climate change, the obligations invoked by the RTF imply that state-level actors must address climate change and its harmful impacts. Because climate change now poses one of the gravest threats to its future fulfilment, the RTF has increasingly become a global issue.

Some climate actions can hamper the ability to fulfil the RTF even if the intention was the opposite. The potential harms caused by climate policies may concern different food security pillars: food availability (caused, for example, by reduced availability of cropland), access to food (energy and food price impacts and farmers' livelihoods), utilization (storing and cooking facilities) and supply stability (resilience, the viability of farming) (Kortetmäki, 2022). Thus, the demand for climate action must be paired with the demand that climate action must not violate the RTF by impairing or severely risking food security.[5] Nevertheless, counterfactual reasoning based on the IPCC's special report (Mbow et al., 2019) suggests that most effective climate actions are, at least, *more effective* in protecting the RTF than inaction from the viewpoint of food security.

We now examine geoengineering through the lens of the RTF with respect to the various aspects of food security: food availability, food supply stability (included under the discussion on food availability), access to food and food utilization. Geoengineering can conflict with the desire to uphold the RTF if geoengineering activities violate or pose a risk to the RTF to a greater extent than likely alternative pathways (i.e. a failure to *respect* the RTF). The RTF can provide potential justification for geoengineering if geoengineering activities help *protect* the RTF by protecting people from the climatic harms to food security. Finally, in the best-case scenario the need to uphold the RTF can engender geoengineering obligations if undertaking geoengineering activities appear to be the only feasible means by which to ensure *fulfilment* of the RTF amidst the unavoidable impacts of climate change.

## Food Availability, Supply Stability and Geoengineering

### Cooling the Climate by SRM

Food-related arguments in favour of geoengineering usually presuppose that it alleviates heat stress and thereby promotes food availability (see e.g. Fan et al., 2021; Kravitz, 2021; Pongratz et al. 2012). Thus, geoengineering could help foster the RTF by protecting crops from the harmful impacts of climate change and strengthening

4 Another practical question is that of whether countries are willing to shoulder the costs of this task.

5 This general negative duty could be articulated in slightly different forms considering the nuances involved. It should be noted that we do not cover here the issue of food security in terms of access to *culturally appropriate* food.

people's ability to feed themselves. In respect of SRM we focus on aerosol injections since they have the greatest potential but present the biggest risks and have recently received significant research programme funding around the world. In the future, a similar but separate assessment is required regarding marine cloud brightening. However, this is currently such a new and unknown method that we lack sufficient information to carry out such an assessment. Cooling the climate using aerosol-based SRM could yield benefits in many hot regions. However, SRM also decreases sunlight, thus counteracting such benefits. Thus, the critical argument for geoengineering and SRM from the RTF food viewpoint has been expressed as follows: '[aerosol-based] SRM may not be able to substantially lessen the risks that climate change poses to global agricultural yields and food security' (Proctor et al., 2018, 482). It may therefore be that even if climate change reduces the availability of food, the use of SRM may not improve the situation. New research may prompt revision of these premises and potentially alter related ethical reasoning. However, even positive estimates on SRM's impacts on food availability indicate that SRM will fail to alleviate the ocean acidification that follows from increased $CO_2$ levels and impact on fish populations, endangering food security in densely populated coastal communities where fish constitutes a staple food. Thus, even the most positive assessments suggest that SRM will have a limited effect on food availability.[6]

Decreased precipitation both globally and in drought-prone regions by up to 10% (see e.g. Laakso et al., 2017; Da-Allada et al., 2020) constitutes another modelled impact of aerosol-based SRM. Thus, SRM may influence precipitation in perilously food insecure regions, which may be the most crucial RTF-related objection to its use. The weightiness of this objection depends on counterfactual comparisons: climate change is also predicted to decrease precipitation in drought-prone areas. It seems that embracing SRM for the sake of the RTF may cause damage to numerous other things of value by compromising participatory justice and making human beings more dependent on the utilization and upkeep of increasingly complex, large-scale and risky engineering techniques to maintain secure conditions for human life on Earth.

While mitigating climate change requires global action, preparing and responding to the *impacts* of climate change must be carried out at local level. This creates a spatial asymmetry between securing the RTF—which calls for local actions—and large-scale SRM as a response. If further studies indicate that SRM benefits food production after all, this spatial asymmetry may be relevant: SRM creates *additional* alterations to the global atmosphere to address locally manifesting problems caused by previous alterations. This is different from emission mitigation and CDR, which aim to *reduce* previously caused alterations to the atmosphere. SRM adds to global complexity and creates further unknown risks and dependency on upkeep of the new alteration systems. By contrast, some alternative measures that protect the RTF locally—adaptation and locally beneficial CDR methods, as discussed in the next sections—can be realized without creating additional alterations elsewhere. As

[6] Our empirical remarks in this article are not all-encompassing but highlight what we consider as the most relevant information for evaluating whether the RTF lens might justify or prohibit the various forms of geoengineering.

Sillmann et al., (2015, 291) remark: 'As SRM, for instance by stratospheric aerosol injection, has effects over a much larger scale, it is not an obvious response to such a regional emergency and, owing to spatially heterogeneous hydrological responses, may pose more of an additional threat than offer a remedy'.

Overall, the RTF does not provide support to justify aerosol-based SRM—convincing evidence that SRM would help protect or fulfil RTF is lacking but the case is not closed (Kravitz, 2021). Rather, RTF provides reasons to reject SRM, which poses significant risks of failing to respect the RTF by risking food availability. This argument essentially relies on the globally non-beneficial impacts of SRM on yields due to decreased sunlight. Precipitation-related impact concerns suggest that aerosol-based SRM could fail to respect the RTF by hampering the ability of people in certain regions to feed themselves. However, precipitation impacts may be similar to the likely unavoidable impacts of climate change (IPCC, 2018 Ch. 3). Thus, undesirable precipitation impacts alone do not constitute a reason to reject SRM. However, embracing the protection of the RTF via a method that is assessed as being liable to reduce *both* precipitation and sunlight, both of which critical to cropping, appears unwise.

## Non-agricultural CDR

The IPCC report on reducing global warming to 1.5 °C summarizes the current research on the estimated impacts and relative effectiveness of CDR techniques (IPCC, 2018, 344). We use the RTF lens to examine the IPCC's findings from a food ethics perspective. Our examination distinguishes non-agricultural and agricultural CDR because, through the RTF lens, agricultural CDR invokes more issues to be considered due to its direct connection with food production.

Among the methods with significant potential[7] for CDR, only two do not directly involve agriculture. These are enhanced weathering and direct air carbon capture and storage. The impacts of these methods are generally analogous to the impacts of emission reductions, while combining them with emission reductions would make overall climate change mitigation efforts more effective than emission reductions alone (atmospheric $CO_2$ levels can be brought below the level that could be achieved by emission reductions alone). However, the need for scalability and cost-effectiveness pose big questions given that it may take decades to put the relevant methods in place and utilize them on the scale required (IPCC, 2018, 345–346). Because of this estimated delay in effective deployment, the RTF provides neither reasons to object nor to endorse EW and DACCS unless technical maturation makes them scalable and cost-effective (and safe from the RTF perspective): it remains unclear whether they could contribute to securing the RTF in a timely manner. If non-agricultural CDR could be a factor in buying time for agricultural adaptation and reduce yield losses, it would help protect the RTF (Kortetmäki & Oksanen, 2016, 129), although the immaturity of the available techniques undermines this potential. We suggest,

[7] These include soil carbon sequestration (SCS), enhanced weathering (EW), direct air carbon dioxide capture and storage (DACCS), bioenergy with carbon capture and storage (BECCS) and afforestation (AR).

however, that the RTF may create an obligation to continue researching and developing such techniques, since their carbon uptake potential is among the highest within CDR options (IPCC, 2018, Ch. 4) while risks to food security are low if methods are safe from sudden carbon leakages. One proviso to this suggestion concerns resource allocation: if effective non-agricultural CDR is expensive, as Kortetmäki & Oksanen, 2016 suggest (although technical advancements may rapidly change the situation), the relative costs and benefits of non-agricultural CDR need to be compared to what could be achieved at the same cost using alternative measures.

## Agricultural CDR

Agriculture-associated CDR techniques entail soil carbon sequestration (SCS), biochar, bioenergy carbon capture and storage (BECCS) and (re-)afforestation (AR). Of these, SCS and biochar (a form of SCS) alter soil properties; BECCS uses croplands to simultaneously produce bioenergy and carbon storage; and AR transforms cropland into forestland.[8] While these techniques are safer than SRM from a food security perspective (Kortetmäki & Oksanen, 2016), their other impacts need consideration. It should be acknowledged, however, that agricultural geoengineering overlaps with conventional emission reductions.

SCS techniques benefit soil quality without creating land use trade-offs or external risks. Because soil quality degradation hampers crop productivity generally as well as in many regions prone to food insecurity, SCS can support food availability, supply stability and thus food security (IPCC, 2018, 344–345). SCS thus implies respect for and even protection of the RTF. Since the most significant food-related benefits of SCS manifest locally, SCS could be utilized in regions where food insecurity relates to soil degradation. SCS may offer a relatively cost-effective (IPCC, 2018, 344) way to promote the overall availability of food and supply stability. Accordingly, supporting SCS activities could be suggested as an obligation of certain advantaged parties[9] to protect and promote RTF.

Biochar and BECCS are the most discussed forms of agricultural geoengineering. Biochar, enriching soil with carbon-rich material, improves soil properties and crop productivity in some circumstances (Wang & Wang, 2019) and thereby promotes food availability. However, due to its expense (IPCC, 2018 Ch. 4), large-scale biochar application is unlikely in the absence of significant technical advances and would not boost food availability in the low-income communities that are of greatest concern. Consequently, biochar in its justified form represents a local adaptation solution rather than a form of geoengineering.

Bioenergy carbon capture and storage (BECCS) combines biofuel production with $CO_2$ uptake. It requires high volumes of biomass and may, therefore compete

[8] AR can be conducted outside croplands but since agricultural land use is so significant, the potential of AR essentially relies on transforming croplands.

[9] It is beyond the scope of our examination to identify such advantaged parties but in essence we understand them as comprising countries that have significantly benefited from fossil fuel based economic growth over the previous decades. These parties have the obligation, in our view, to promote food availability and RTF using these measures in order to compensate the harm they have caused to food availability by contributing to climate change (see Caney 2010).

with food production land and potentially endanger food security (Schübel & Wallimann-Helmer, 2021). This argument concerns food availability (cropland availability), supply stability (bioenergy price fluctuation impacts on farmers' cropping decisions) and access to food (price impacts—see the next section). It is worth noting that since BECCS typically produces bioenergy in addition to achieving carbon sequestration, it is at least a better solution for addressing anthropogenic GHG emissions than biofuel cropping measures alone, albeit that the latter are frequently proposed as a key component of emission mitigation schemes. While it cannot be straightforwardly argued that using existing fields for the production of non-edible crops (such as using them for the purposes of BECCS) undermines or risks food security, especially regarding fields used for feed cropping (Kortetmäki, 2022, 34–36), the risk of displacing edible crops is a concern as regards both food availability and supply stability. Land clearing, to avoid land use competition between food cropping and BECCS, would in turn undermine the effectiveness of CDR and harm other species and ecosystems to the extent that these costs alone would likely rule this option out as unjustifiable, even from a morally anthropocentric viewpoint.[10]

Overall, CDR may help secure the RTF by improving food availability and supply stability by reducing the crop risks that climate change otherwise poses. If the obligations to mitigate climate change also concern obligations regarding CDR (as Honegger et al., 2021 suggest), the RTF might also imply the obligation to conduct CDR from the perspective of food production. The related method-specific assessments need to be comparative from the cost-effectiveness viewpoint: the relative costs and benefits of the assessed activity should be compared with what could be achieved at the same cost using alternative (currently feasible) measures. Consideration of food availability and the RTF entails comparing CDR with other ways to reduce GHG emissions and support agricultural and food system resilience and adaptation to climate change in vulnerable communities.

## Access to Food and Geoengineering

Food and geoengineering discussions often focus on yield (food availability) impacts. The RTF perspective must go beyond food availability: unequal access to food, not food shortage, is often the primary reason for food insecurity and hunger (Sen, 1982). Access to food refers to assets and means that people have capacities or assets for acquiring food.[11] Food insecurity also relates to food system vulnerabilities and resilience to disruptions. Many food-insecure communities witness poverty

[10] The (un)justifiability of land clearing for BECCS does not depend on (non-)anthropocentrism because such extensive land clearing practices would contribute to biodiversity loss to the extent of threatening food security (IPBES 2019). A non-anthropocentric approach to justice and ethics would set stricter criteria for justifiable land use, but this issue is omitted here in order in favour of focusing on the RTF perspective.

[11] Assets are also influenced by, for example, the cost of housing, energy, heating and healthcare, which may take the lion's share of a household's overall income.

and other socio-economic problems that hamper access to food, farming and supply chain practices and the capacities of people and local institutions to respond to catastrophic disruptions (see e.g. Sen, 1982). We next discuss geoengineering from the access to food perspective.

Access to food is determined by socio-economic and cultural factors and related inequalities in resources and wealth. Thus, SRM influences access to food very little, except indirectly by influencing food availability as discussed in the previous section. The lack of impact on access to food is not a reason to reject geoengineering from the RTF perspective: such reasoning would reject most GHG emission reduction policies on the ground that they do not address the socio-economic factors influencing access to food. The lack of impact on access to food does, however, mean that SRM fails to address the primary reasons for the RTF being hampered. In respect of all potential circumstances in which it could be applied insufficient to entirely secure the RTF and provides at best a partial solution to doing so. Consequently, supporting the RTF does not in itself constitute a reason to embrace SRM *unless* it appears that, for some reason, SRM offers the only means of avoiding collapses in food availability.

CDR techniques, especially agricultural geoengineering, differ from SRM regarding their impacts on access to food. Techniques that create land use competition are likely to increase global food prices, which may endanger access and the RTF (see e.g. Stevanović et al., 2017; Honegger et al., 2021).[12] This may be a particularly relevant problem in relation to BECCS (Schübel & Wallimann-Helmer, 2021), which is one of the most effective CDR methods. On the other hand, the reasons for access to food problems are context-specific. Biofuel cropping (including BECCS)—alongside other measures that increase crop prices—can reduce rural poverty and thus promote food access in poor rural communities while creating challenges for urban communities (Thompson, 2012). CDR may help diversify farmers' income sources and reduce their vulnerability to the impacts of climate change by promoting adaptation measures in poor regions (see e.g. Olsson & Jerneck, 2010). The low risks[13] and reversibility of many agricultural CDR techniques could comprise a multitool for addressing the resilience and poverty of rural communities. Land-grabbing risks present an obstacle to the realization of such hypothetical benefits of BECCS. However, neither price impacts nor land-grabbing are problems unique to BECCS. They will be faced practically by all effective emission mitigation pathways because of the need to put a higher price on land and energy use, and because of the interest in biofuel and afforestation as forms of emission mitigation and compensation. Rather than an argument against BECCS, such issues provide an argument for improving land use governance for the benefit of the weakest parties. Duties to protect the RTF should, then, be cosmopolitan—regardless of whether geoengineering is done or

[12] Initial modelling-based estimates suggest that certain agricultural CDR practices may even double food prices. More research is needed before any conclusive statements can be made, however, and the political nature of food prices – as well as the likelihood that progressive climate policies will increase food prices – should be kept in mind.

[13] The issue of general safety should not be expected to apply to all CDR methods.

not—to ensure that climate responses do not harm disadvantaged communities but promote their access to food.

## Food Utilization and Geoengineering

Food utilization refers to the nutritional quality and safety of food. While there are few studies on geoengineering's impacts on food utilization, some focal issues can be inferred from the mechanisms that are known to link climatic factors and food utilization. Climate change risks food safety through heat, extreme weather events and humidity impacts that frequently expose foods to the risk of contamination and spoilage. Increased atmospheric $CO_2$ is predicted to degrade the nutritional values of many crops, although the early-stage nature of these studies should be borne in mind. Particular concerns exist regarding the nutrient values of rice and protein-providing crops, potentially negatively influencing the food utilization of more than 500 million people (early estimates) (Mbow et al., 2019, Ch. 5.2.4.).

Consequently, geoengineering may benefit food utilization by reducing the food safety risks related to warming and heat stress. However, food safety also depends to a great extent on infrastructure, in the form of storage, transport, and food preparation techniques, equipment and conditions. Thus the claim that geoengineering can crucially benefit food safety should be made with a degree of circumspection. When it comes to nutritional quality, SRM and CDR differ greatly from one another from a food utilization viewpoint: SRM cannot help alleviate the nutritional quality risks related to increased $CO_2$ levels, but CDR can do so. The potential risks posed by geoengineering to food utilization have not, to our knowledge, been examined either explicitly or indirectly. Since the main identified food security issues concern increased insolation and decreased (and less predictable) precipitation patterns, they seem irrelevant to food utilization. However, it would be premature to make a conclusive statement on this.

## Conclusion

The RTF perspective prompts various considerations in relation to geoengineering techniques. Aerosol-based SRM is a mistargeted weapon that fails to address any of the food security dimensions adequately, and is not justified by arguments related to respecting, safeguarding or fulfilling the RTF. Instead, our reasoning suggests, in line with Honegger et al. (2021), that CDR may even be an obligation for some parties as an aspect of securing the RTF by mitigating the harms caused by climate change to food availability, supply stability and rural access to food. The RTF does not provide reasons to object to non-agricultural forms of CDR that may improve food availability, supply stability, and food utilization, but more research is needed in order to gain insight into their specific impacts and costs. Prioritizing research for effective CDR could be proposed as an obligation of parties that conduct or invest in geoengineering research. Because climatic risks to food security manifest locally, the RTF may justify the use of agricultural

CDR techniques that support local food availability and supply stability, although many applications would be so small scale in impact (by being local) that they would not count as geoengineering. At best, CDR could help improve food quality (by decreasing atmospheric $CO_2$ levels) in ways that conventional climate change mitigation cannot accomplish, which would argue in favour of using CDR to secure RTF. On the other hand, large-scale agricultural CDR involves risks to access to food and food availability via land use impacts. However, since similar risks are likely to be created by climate change mitigation measures this does not constitute a weighty objection to the use of CDR. Respecting and safeguarding the RTF in the face of climate change instead creates an additional obligation to address the underlying factors, especially land use rights and governance and social security, to help ensure low-income groups' access to food.

The limitations of our scope should be noted. While the RTF relates to vital human needs, it is not the only criterion for assessing the (un)justifiability of geoengineering in overall terms. There may be certain other reasons for prohibiting the use of a method that the RTF would justify (consider, for example, a method that would benefit the RTF but violate other fundamental human rights by having, for instance, very unhealthy impacts on human beings). Moreover, stating that a particular geoengineering technique can be justified by reference to the RTF does not amount to a final statement about what should be done, how, and by whom. Further assessment of the impacts of different actions (and related trade-offs) is needed and should involve consideration of the various socio-cultural and economic factors from a food systems perspective.

Engaging in CDR discussion in food ethics is highly topical because IPCC (2022) considers CDR as practically necessary to avoid dangerous climate change. Our considerations are limited by the assumption that dangerous climate change can be avoided. The actualization of a climatic catastrophe would fundamentally change food and climate ethics, including with respect to geoengineering.

Our reasoning has also general implications for food justice research. Although food security is largely about access to food, the cosmopolitan implications of the current stage of climate change have not been much addressed in food justice literature even though there has been a great deal of discussion about the global dimensions of food system activities and their impacts. In a climate-constrained world and increased crop disruptions, the importance of diverse food procurement channels is crucial for food security everywhere: dependence on local food production is a highly vulnerable strategy. Thinking about the RTF in the future will involve integrating it with cosmopolitanism, which is prominent in climate ethics: it is time to reflect upon cosmopolitan obligations in respect of the RTF and global sharing of the climatic risks to food systems.

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## Declarations

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