United Nations Decade on Biodiversity

LITERATURE REVIEW ON THE POTENTIAL IMPACTS OF CLIMATE RELATED GEO-ENGINEERING ON BIODIVERSITY

1. The following document has been prepared in order to facilitate consideration of the potential impacts of climate-related geo-engineering on biodiversity. The document has been prepared based on a review of literature on different approaches to climate-related geo-engineering and its impact on biodiversity, ecosystems and relevant physical processes.

2. Section I presents a general overview of climate-related geo-engineering as it relates to the work of the Convention on Biological Diversity. Section II provides an overview of some of the tools available to assess the potential impacts of climate-related geo-engineering on biodiversity. Section III highlights some of the known and expected positive and negative impacts of climate-related geo-engineering as well as introducing examples of unknown impacts. Finally, Section IV presents some of the factors that should be considered when evaluating benefits and risks to biodiversity from climate-related geo-engineering.

3. The review is not intended to be comprehensive, but rather is intended to cover the breadth of issues that the group may wish to consider.

I. Introduction to Climate-related Geo-engineering as it Relates to the Convention on Biological Diversity

4. Decision X/33 of the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) adopted an interim definition of geo-engineering which includes any technologies that deliberately reduce solar insolation or increase carbon sequestration from the atmosphere on a large scale that may affect biodiversity (excluding carbon capture and storage from fossil fuels when it captures carbon dioxide before it is released into the atmosphere).

5. Within this definition, a broad range of activities are currently being considered by the scientific community, governments and the private sector. Generally, geo-engineering activities can be divided into those that change the radiative balance of the Earth's surface or the atmosphere - Solar Radiation Management, and those that change the amount of Carbon Dioxide in the atmosphere - Carbon Dioxide Removal.

6. It should be noted that a wide range of climate-related geo-engineering approaches have been included in this assessment without prejudice to past and on-going discussions by Parties to the Convention on Biological Diversity on the definition of geo-engineering as it relates to biodiversity.

II. Tools to Assess Potential Impacts of Climate-related Geo-engineering on Biodiversity

Observations

7. As Decision X/33 of the COP to the CBD calls for Parties to undertake only small scale scientific research studies conducted in a controlled setting, in accordance with Article 3 of the Convention, and only if they are justified by the need to gather specific scientific data and are

subject to a thorough prior assessment of the potential impacts on the environment, large scale observational data are not readily available for many types of geo-engineering. However, some geo-engineering approaches are able to draw observational data from natural processes such as volcanic eruptions.

8. The Pinatubo eruption, for example, injected particles into the atmosphere which changed the radiative balance allowing for opportunistic research into the possible impacts of solar radiation management on a variety of systems including, *inter alia*, ecosystem productivity, outputs from solar power generation, etc. However, such observations have weaknesses in that eruptions occur only occasionally with a short term impact on the radiative balance[1].

9. Furthermore, observational results from experiments in climate-related geo-engineering can be used to assess both the effectiveness of approaches as well as potential impacts and risks. The LOHAFEX large scale ocean fertilization experiment, for example, demonstrated minor impacts on carbon sequestration while observations of increased zooplankton predators were recorded[2]. Likewise, the SEEDS experiment in the North Pacific gave indications of increased harmful algal blooms as a result of ocean fertilization[3].

Modelling

10. Global and regional models of the potential effects of geo-engineering allow for an assessment of both the expected effectiveness of such approaches as well as the potential secondary and tertiary impacts of geo-engineering. Examples of some such models applied to a variety of geo-engineering approaches are presented in table 1 below.

Table 1: Modelling Climate-related Geo-engineering

Geo-engineering Approach	**Expected Impact on Climate Change**	**Expected Impact on Biodiversity / Ecosystem**	**Source**
Marine cloud seeding	Reduces expected warming as a result of a doubling of CO_2 by as much as 50%	Reduction in precipitation in some areas along the equator Increase in precipitation in the South Pacific convergence zone Reduction in sea ice loss for very large scale seeding	Rasch *et al*, 2009
Marine cloud seeding	Reduces land surface temperatures more than ocean surface temperatures	Increase in runoff over land	Bala *et al*, 2010
Injection of aerosols into the atmosphere	Decrease in global mean temperatures	Greater impact on hydrological cycles when compared to other approaches	Ban-Weiss and Caldeira, 2010
Changing leaf albedo	Seasonal offsetting of 1/5 of warming in North America and mid-latitude	Delay in Arctic sea ice retreat Increased soil moisture in	Ridgwell *et al*, 2009

[1] Ban-Weiss and Caldeira, 2010

[2] www.awi.de

[3] Wells *et al*, 2009

	Eurasia under a doubling of CO_2	some regions, drying in other regions	
Reducing the solar flux (e.g. reflecting solar radiation before it reaches the atmosphere)	Assumes solar flux reduced by 1.8% leading to a decrease in mean average temperature by 2.42°C	Overall reduced precipitation although increased precipitation in some tropical regions	Bala *et al*, 2008

11. When considering modelling, however, it should be noted that most models conducted thus far do not integrate biological or ecological models but are rather based on climate modeling alone. This limits the current effectiveness of impact models in assessing the potential impacts of climate-related geo-engineering on biodiversity.

Controlled Experiments

12. Localized and confined field experiments can contribute to an improved understanding of the potential benefits and risks to biodiversity as a result of climate-related geo-engineering.

13. Some approaches to geo-engineering, such as biochar and afforestation, are better suited to such experiments than others. For example, Cornell University has conducted site assessments in Colombia to measure the impacts of biochar on crop yield, nutrient cycles, water availability and other factors[4].

III. Known and Predicted Potential Impacts of Climate-related Geo-engineering on Biodiversity

Potentially Positive Impacts

1. Decreasing threats to biodiversity from climate change

14. Geo-engineering, if successful in reducing the extent of global mean temperature rise, may have a positive impact on biodiversity through reducing the anticipated threats to biodiversity from climate change. For example, improved management of agricultural land has the potential to offset 5 to 15% of global fossil fuel emissions. Furthermore, it has been shown, for instance, that geoengineering techniques which enhance continental weathering over long timescales could help to mitigate ocean acidification by sequestering atmospheric CO2[5].

15. Given that the second Ad hoc Technical Expert Group on Biodiversity and Climate Change concluded that an estimated 10% of assessed species will face increased risks of extinction for every 1°C rise in global mean temperature, limiting temperature increase will be expected to limit extinction risks6. This is especially true when considering the avoidance of tipping points which are expected to lead to drastic and irreversible changes to ecosystem structure and functions7.

16. However, it is worth noting that solar radiation management will not address ocean acidification, meaning that this form of geo-engineering alone is unlikely to completely offset the

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[4] Major *et al*, 2010

[5] Uchikawa *et al*, 2008

[6] Secretariat of the Convention on Biological Diversity, 2009 (a)

[7] Secretariat of the Convention on Biological Diversity, 2010

projected increase in extinction risk. In order to better understand the positive impacts that geo-engineering could deliver, it will be necessary to disaggregate risks from temperature increase from other climate change risks to biodiversity.

17. Furthermore the effectiveness of carbon dioxide removal approaches need to be balanced against physical and biological processes expected to change as a result of climate change. Changes in such processes, such as increase microbial decomposition of soil organic matter, may result in a shift in a given carbon pool from carbon sink to carbon source. As such, discussions of thresholds and tipping points should be considered in the assessment of the benefits from climate-related geo-engineering.

2. Local manipulation of selected negative impacts of climate change

18. Localized approaches to geo-engineering, such as cloud seeding over the Arctic, may limit change in highly vulnerable ecosystems8. Such approaches can either reduce the impacts of change driven by direct solar radiation or reverse changes in precipitation where such an impact is the main driver of biodiversity loss, such as in wetlands in drylands.

19. It should be noted, however, that the local manipulation of the negative impacts of climate change is highly complex and not likely to be feasible given the current state of scientific knowledge. Furthermore, many such approaches may have negative impacts on biodiversity in other regions which should be weighed against potential benefits.

3. Increased ecosystem productivity

20. Some geo-engineering approaches such as reforestation and increased carbon sequestration in soils, may have positive impacts on plant diversity and ecosystem productivity. This is especially true in Nitrogen-limited environments and when actions restore degraded lands[9].

Potentially Negative Impacts

1. Increased pressure on land

21. Geo-engineering may result in accelerating land use change as a result of demands for afforestation, biochar production, changing surface albedo, etc. If not managed effectively, then such demand may increase pressure on biodiversity.

2. Poor management of genetically modified organisms

22. Approaches to geo-engineering, such as changing leaf albedo and large scale afforestation, may involve the introduction of genetically modified plant and tree species. If not handled safely, such organisms may have a negative impact on surrounding biodiversity.

3. Changes in ocean currents

23. Any geo-engineering approach that impacts the energy balance of the ocean through either changing the energy reaching the ocean surface or disrupting the thermal column in ocean waters

[8] Rasch *et al*, 2009

[9] Woodward *et al*, 2009

may change ocean currents and, as such, disrupt the breeding and feeding cycles of current dependent marine species.

24. Additional potential negative impacts specific to solar radiation management and carbon dioxide removal are presented below.

Solar Radiation Management

1. Changes in precipitation

25. Solar radiation management has the potential to change precipitation patterns causing drying in some regions and increased wetness in others. The scale, extent and location of such impacts depend on the type of geo-engineering deployed and the location of the intervention10. For example, some modeling studies have shown a link between cloud albedo enhancement and atmospheric-oceanic systems such as the West African Monsoon and the El Nino Southern Oscillation[11]. Such perturbations are likely to impact significantly on terrestrial ecosystems.

2. Ozone depletion

26. Stratospheric geo-engineering may contribute to ozone depletion which is expected to reduce phytoplankton production in the Antarctic12.

Carbon Dioxide Removal

1. Changing ocean chemistry

27. Approaches such as ocean fertilization are expected to change the chemical composition of the oceans as a result of manipulation of nutrient balances and changing nutrient uptake as a result of phytoplankton blooms[13].

2. Reduction of oxygen availability in oceans

28. Ocean fertilization increases phytoplankton blooms and, as a result, is expected to decrease oxygen availability in sub-surface ocean waters, this in turn may result in fish kills[13].

Unknown Impacts

1. Changing leaf albedo

29. Bio-geoengineering to increase the leaf albedo of crops and canopies has been proposed as one way to change the Earth's radiative balance and affect cooling1. However, it is unknown the extent to which such an approach will impact on crop productivity, which is an important factor in assessing the impact that changing leaf albedo will have on land use change.

2. Changes in soil structure and composition

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[10] Ridgwell *et al*, 2009

[11] Latham *et al*, 2008

[12] Robock *et al*, 2009

[13] Secretariat of the Convention on Biological Diversity, 2009 (b)

30. Methods such as biochar and enhanced weathering have unknown long term impacts on soil structure and fertility which may, in turn, impact soil biodiversity. It is unknown whether this impact may be positive or negative14.

3. Changes in diffuse insolation

31. It is expected that the injection of aerosols into the atmosphere will increase the amount of clear sky diffuse sunlight reaching the Earth's surface, thereby changing rates of photosynthesis and associated ecosystem productivity[15]. This change is not, however, realized until reductions in incoming solar radiation exceed 1.8%[16]. What remains unclear is how increased rates of photosynthesis, and hence enhanced productivity, could affect biodiversity.

IV. Factors Affecting the Impacts of Climate-related Geo-engineering on Biodiversity

Scale

32. The potential impacts of climate-related geo-engineering will be affected by the scale of the intervention. This is the case when considering both the physical scale as well as the scale of change (e.g. scale of reduction of CO_2 in the atmosphere or the scale of the change to the Earth's radiative balance).

33. Consideration of the relationship between potential impacts and scale of the intervention may be particularly relevant when considering the assessment of research activities versus deployment and when considering the effectiveness of geo-engineering interventions.

34. For example, some approaches to geo-engineering, such as the deposition of floating reflectors in the ocean would require such a large geographic area in order to impact climate change that considering small scale interventions and associated impacts is not relevant17. On the other hand, reducing solar radiation by even a small amount will offset some temperature increases without a significant known negative impact on ecosystem productivity**Error! Bookmark not defined.**.

Control

35. The extent to which climate-related geo-engineering can be controlled will affect both the degree of impacts as well as the duration.

36. Controlling the physical extent of an intervention can, in some cases, limit the geographic area subjected to the impact, however, such control is not possible in many cases, such as ocean fertilization and the injection of aerosols which are spread on marine and atmospheric currents respectively.

37. Control can also be exerted over a given time scale. For example, marine cloud seeding requires constant intervention to be effective and, as such, the interventions and the resulting impacts can be stopped in a relatively short time frame.

Location

[14] The Royal Society, 2009

[15] Keith, 2010

[16] Govindasamy *et al*, 2002

[17] MacCracken, 2009

38. In many cases, the location of the intervention will affect the impacts with some regions and ecosystems being more vulnerable to the negative impacts or more responsive to the positive impacts than others.

39. For example, stratospheric geo-engineering in the Arctic will have a greater impact on mean temperatures compared to the same scale and scope in the tropics. However, the impact in the Arctic is of shorter duration. On the other hand, ocean fertilization of even a small scale (less than one kilometer square) is expected to have significant negative impacts on coral reefs and other sensitive habitats18.

[18] UNESCO/IOC, 2008

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