The potential of marine ecosystems and processes for carbon sequestration in Belgium and beyond

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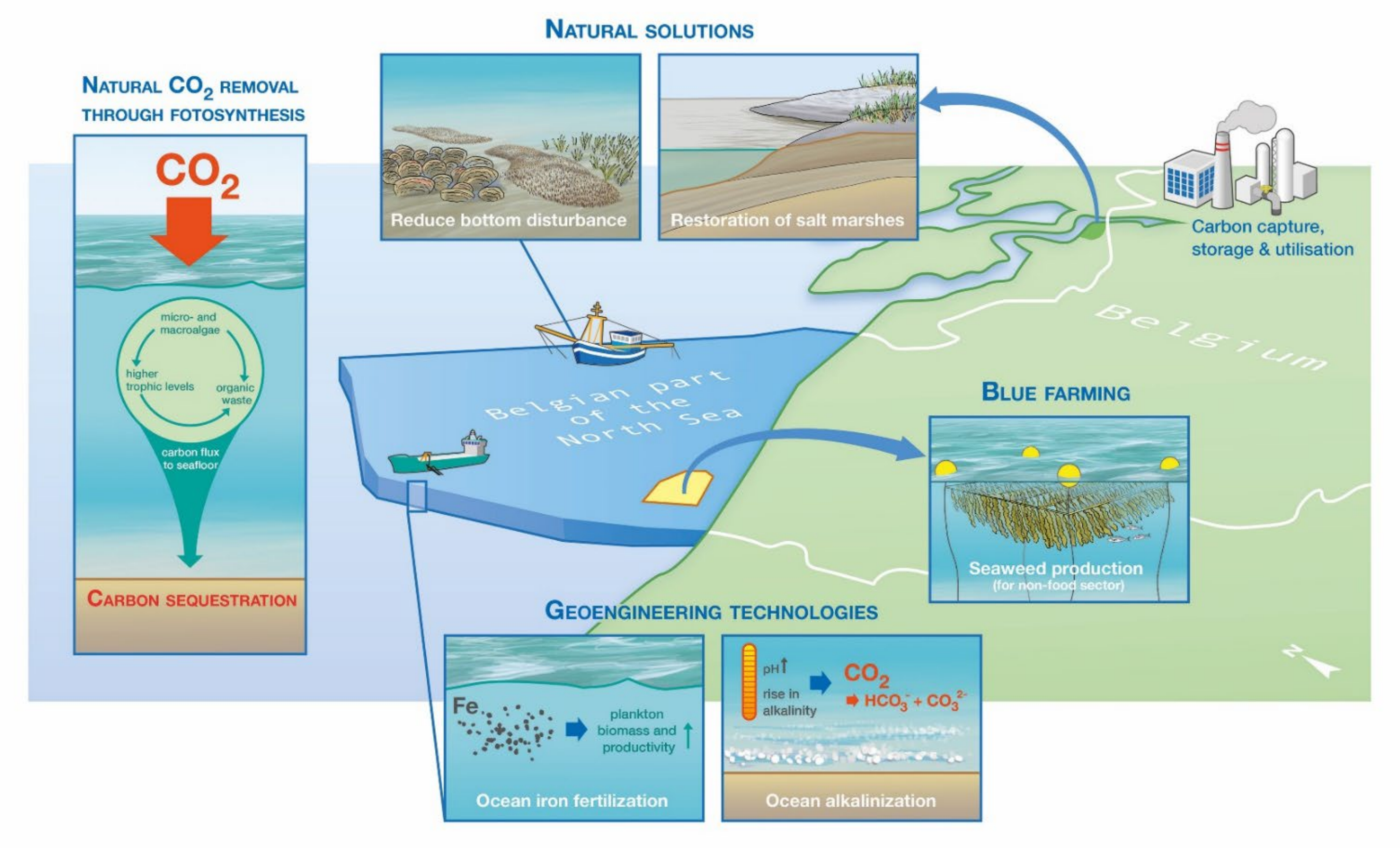
"There's no point in sequestering atmospheric CO_2 if we don't stop emitting it."

"To limit temperature rise to 1.5° C, carbon sequestration actions are required on top of an emission stop"

To meet the Paris Agreement's goal of limiting temperature rise to 1.5°C, greenhouse gas emissions must reach net-zero by 2050. This will require reducing existing emissions in all sectors in combination with the deliberate removal of atmospheric greenhouse gasses through human actions. With this brief we highlight the opportunities using oceans, seas and estuaries in reducing the causes and consequences of climate change, globally and locally. In addition, associated risks are presented as well.



Definition Box

CO_2 removal: This process occurs naturally when atmospheric CO_2 is taken up by terrestrial and marine vegetation and planktonic micro-algae through photosynthesis. and stored as carbon in biomass and soils.

Carbon sequestration: the long-term storage of carbon in soils, geologic formations, and the deep ocean. Carbon sequestration occurs both naturally and as a result of anthropogenic activities and typically refers to the storage of carbon that has the immediate potential to become carbon dioxide gas.

Negative emission technologies (NETs): technologies that remove greenhouse gases (GHGs) such as CO_2 from the atmosphere.

Carbon capture and storage (CCS): the industrial process of capturing and storing carbon dioxide (CO_2) before it is released into the atmosphere.

Carbon capture utilisation (CCU): The captured carbon is used for industrial applications.

Carbon Credits: Credits are created when a project is deemed to have eliminated 1 ton of greenhouse gas emissions. Planting a forest that would eliminate 1 ton of carbon emissions would be enough to create a credit. Credits do however decay over time.

Blue carbon: refers to the carbon stored in coastal and marine ecosystems.

Ocean alkalinization is an approach to remove CO_2 from the atmosphere by increasing the alkalinity of the coastal seas and the surface ocean to enhance the ocean's capability to act as a natural carbon sink. Adding alkalinity to the ocean removes CO_2 from the atmosphere through a series of reactions that convert dissolved CO_2 into stable bicarbonate and carbonate molecules, which in turn causes the ocean to absorb more CO_2 from the air to restore equilibrium.

Ocean iron fertilization is a form of geoengineering that involves adding iron (Fe) to the upper layers of the ocean to stimulate phytoplankton activity in an attempt to draw down atmospheric CO_2 levels.

Which role can Belgium play?

Natural solutions: Restoration an conservation of marine natural ecosystems

TIDAL MARSHES ARE NOT THAT EFFICIENT IN TERMS OF CARBON SEQUESTRATION, BUT THEY ARE WELL-STUDIED AND OFFER NUMEROUS CO-BENEFITS (ECOSYSTEM SERVICES, BIODIVERSITY) AT AFFORDABLE COSTS. THE SEABED OF SHALLOW SEAS (<200M) CAN HAVE A SIGNIFICANT CONTRIBUTION TO CARBON SEQUESTRATION WHEN IT REMAINS UNDISTURBED BY HUMAN ACTIVITIES. THE CONTRIBUTION OF COASTAL CARBON SEQUESTRATION IS ESTIMATED TO BE SIMILAR AS THE CONTRIBUTION OF THE AVIATION INDUSTRY TO GLOBAL CARBON EMISSIONS.

COASTAL INLAND HABITATS, especially tidal marshes, are extremely valuable habitats delivering a multitude of ecosystem services such as coastal protection, nursery areas for fish and carbon sequestration. However, due to embankments and changing hydrodynamic conditions, many of the MARSHES are lost and the remaining ones are threatened by sea level rise. During the last decades, restoration of tidal marshes became an essential element in estuarine management and restoration, mainly driven by environmental legislation at a regional and national level.
The role of these marshes for carbon sequestration depends on various factors, including suspended sediment concentrations and inundation frequency affecting sedimentation rates and the amount of organic matter present.

THE SEABED receives about 2 Gt carbon per year from organic matter settling down from the water column, and ~10% of this organic carbon is sequestered in sediments. This seabed carbon sequestration corresponds to a removal of up to 4% of our annual global carbon emissions, locking the carbon away from exchange with the atmosphere for centennial to millennial timescales. Especially SHELF SEAS (< 200M WATER DEPTH) are important sites for carbon sequestration, removing up to 1.5% of our current annual emissions. Yet, shelf sea sediments experience intense disturbance from various human activities that negatively affect carbon sequestration. One of these human activities occurring on the seabed is bottom trawling for fish and shellfish. Demersal fisheries are highly fuel-inefficient and produce most of the fishing industry's direct green-house gas emissions. A shift to less damaging fishing methods could provide major net benefits for increasing natural carbon storage in the seabed, whilst significantly reducing emissions of CO_2.

Geoengineering technologies

GEOENGINEERING SOLUTIONS (IRON FERTILIZATION, ALKALINIZATION) ARE NOT WELL STUDIED AND COME WITH A RISK. YET, THIS RISK SHOULD BE CHARACTERIZED WITH REGARDS TO THE CONSIDERABLE RISK OF TAKING NO ACTION. A REGULATORY FRAMEWORK TO PERFORM REALISTIC SCALE EXPERIMENTS TO ALLOW THIS BENCHMARKING IS THEREFORE NEEDED.

OCEAN IRON FERTILIZATION (OIF) is arguably one of the best studied ocean-based carbon dioxide removal (CDR) approaches. However, OIF is not featured in most CDR research agendas and initiatives, being perceived as inefficient and with potential large negative impact on ecosystems. Since the early 90s, when OIF in the Southern Ocean was first proposed as an ocean-based CDR approach, seven OIF experiments and two studies of natural iron fertilization (downstream of islands) were carried out in the Southern Ocean. While in all cases iron fertilization has resulted in significant increases in local plankton biomass and productivity, the impacts of iron fertilization on plankton assemblage composition, food webs, carbon export and carbon export efficiency at relevant larger scales are still poorly known and understood. OIF is only efficient in specific areas which are iron-depleted, which is not the case in coastal seas such as the North Sea or even the North Atlantic.

The principle behind OCEAN ALKALINIZATION is to speed up the natural CO_2 neutralization process by adding minerals to the ocean that release alkalinity upon chemical weathering. This idea of "enhanced weathering" involves: (1) selectively using minerals with high dissolution rates, such as freshly mined carbonate or silicate rock, but also waste products from mining or industrial byproducts (2) increasing the reactive surface area and dissolution rate by pulverizing the source rock into small particles, and (3) distributing the resulting mineral particles in locations with high weathering rates. In theory, ocean alkalinization could remove many billions of tons of CO_2 per year, yet the true CO_2 sequestration potential remains poorly constrained, as more research on ocean alkalinization remains to be done to assess the CO_2 sequestration efficacy, the cost and economic feasibility as well as the environmental impacts.

Bioenergy production or Blue farming

AQUACULTURE SOLUTIONS COULD PROVIDE BIOLOGICAL RESOURCES BUT DO NOT PROVIDE LONG TERM SEQUESTRATION SOLUTIONS (SEAWEED VERSUS, SHELLFISH).

SEAWEED PRODUCTION, both from wild stocks and from aquaculture, potentially represents an option for CO_2 removal from the atmosphere. The high growth attained by seaweed lies at the basis for them being considered as an effective solution to capture CO_2, but also the fact that seaweed cultivation does not compete for arable land and does not rely on fertilizers or pesticides makes a seaweed solution attractive. Yet, the potential of seaweed production to mitigate climate change by sequestering CO_2 has not yet been fully incorporated into the emergent concept of Blue Carbon. Several options are being considered at present, including large-scale offshore cultivation of large brown seaweed, but as such it is not contributing to carbon sequestration, unless seaweeds are buried or sunk below carbon sequestration depths.

There is no potential for carbon sequestration by using **SHELLS FROM AQUACULTURE** as building material. Shells form a waste-, or by-product of shellfish aquaculture, and consist almost completely of calcium carbonate and thus for 12% of pure carbon. However, there is a net CO_2 emission during natural calcification, and during the processing of the shell waste (e.g. by using them as building material), effectively making shell fish aquaculture a source of CO_2

Recommendations

While a regulatory framework exists for land-based carbon sequestration technologies (which enables a carbon credit market), it is lacking for marine technologies. A triple helix effort (research-policy-industry) is required to go forward.

The next step is to recognize current knowledge gaps on negative carbon emission in the oceans and to identify future research directions and applications to the enhancement of negative carbon emissions including:

- Launching long-term time series stations to observe carbon sequestration in representative coastal and offshore waters and sediments;
- Initiating integrated experimental studies to better understand carbon sequestration under paleo-, current and future oceanic conditions;
- Identifying an international collaborative project dedicated to ocean negative carbon emissions

Some knowledge gaps identified so far

1. What is the mechanism to assign additional CO_2 removal to a particular intervention?
Needs: Knowledge of variability in current carbon sequestration; modelling and in situ tools for evaluation and attribution, design controlled field and modelling experiments
2. How to quantify the effectiveness of CO_2 removal?
Needs: In situ tools for monitoring stability and longevity; long-term controlled field experiments
3. How can we quantify and prevent any detrimental environmental impacts?
Needs: detection, attribution of unexpected indirect effects; design controlled field and modelling experiments
4. How can we scale up marine NETS to 'make a difference' ?
Needs: Model experiments, engineering developments; spatial planning, governance, societal acceptance, research into policy

Outlook

- *NETs can never overcome continuing emissions*
- *NETs are needed to protect our habitable climate*
- *Blue Carbon potential has to be assessed for specific ecosystems and regions*
- *A legal framework is required for testing new technologies at relevant scales*
- *Accurate Blue Carbon accounting methods need to be developed*

This policy brief is based on the presentations and discussion that took place during the Marine Carbon sequestration symposium organized the 11th of May 2022 by EMBRC and ILVO at Bluebridge Ostend in Belgium. Contributors were:
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