

Grounding Policy in Science: Developing a Policy Framework for Enhanced Rock Weathering in India

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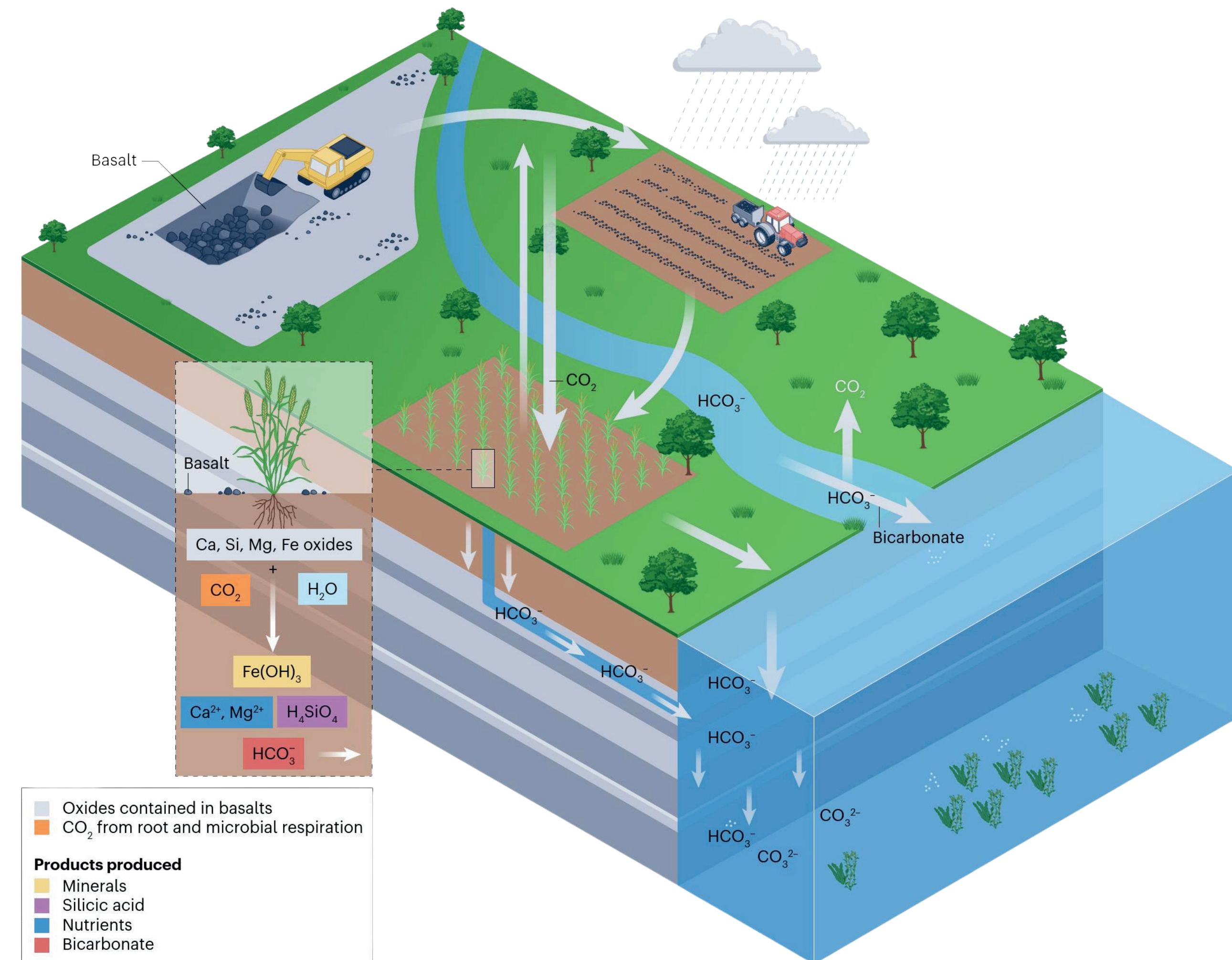
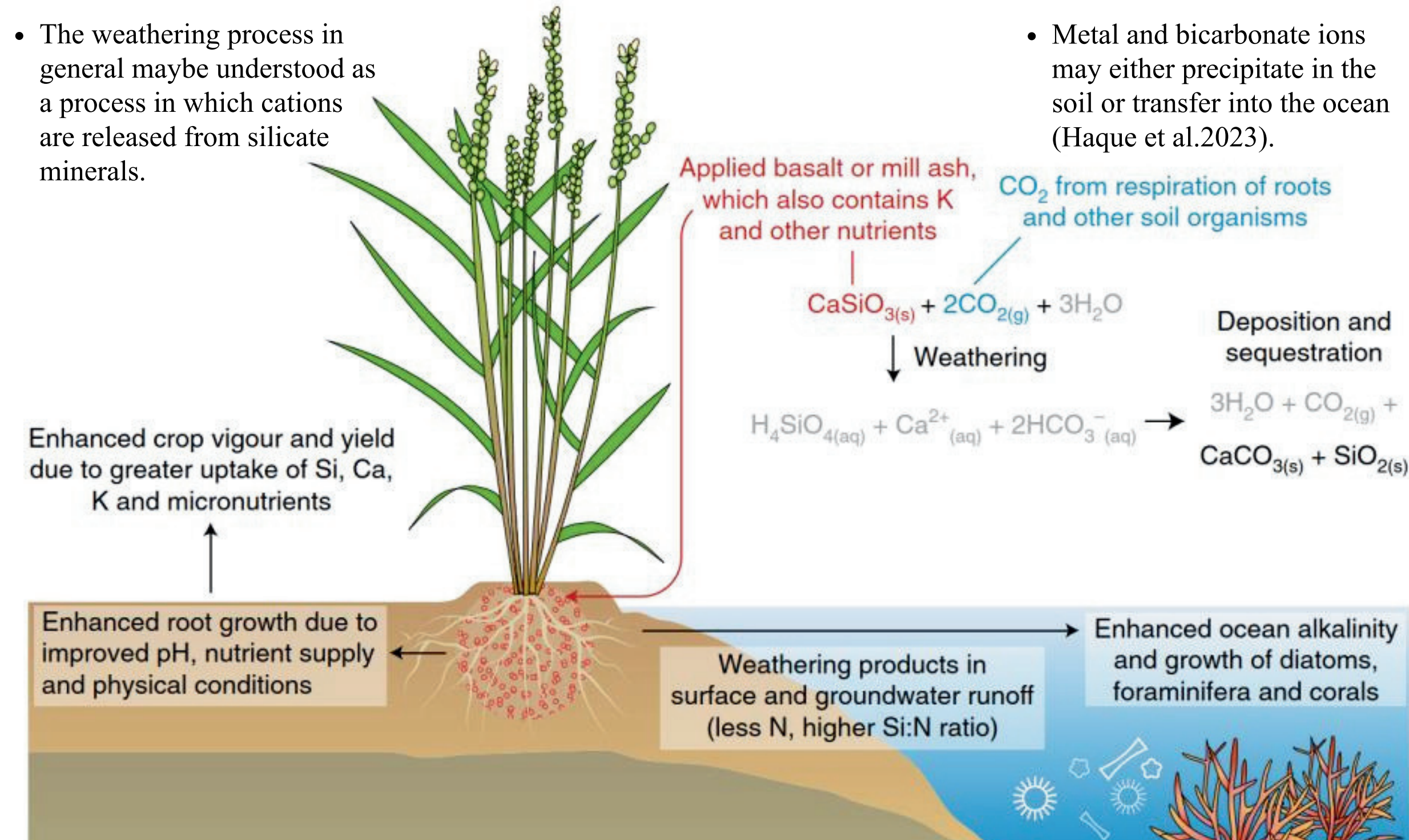
INTRODUCTION

- Human-induced emissions of CO₂ and other greenhouse gases over ~150 years have raised global average temperatures by ~1.2°C (WMO, 2020).
- IPCC recommends limiting warming to 1.5–2°C to avoid catastrophic climate impacts.
- IPCC's 5th Assessment Report shows 104 out of 116 climate scenarios require carbon dioxide removal (CDR) to meet temperature targets.
- Enhanced Rock Weathering (ERW) is a novel CDR technique with high potential and agricultural co-benefits.

OBJECTIVE

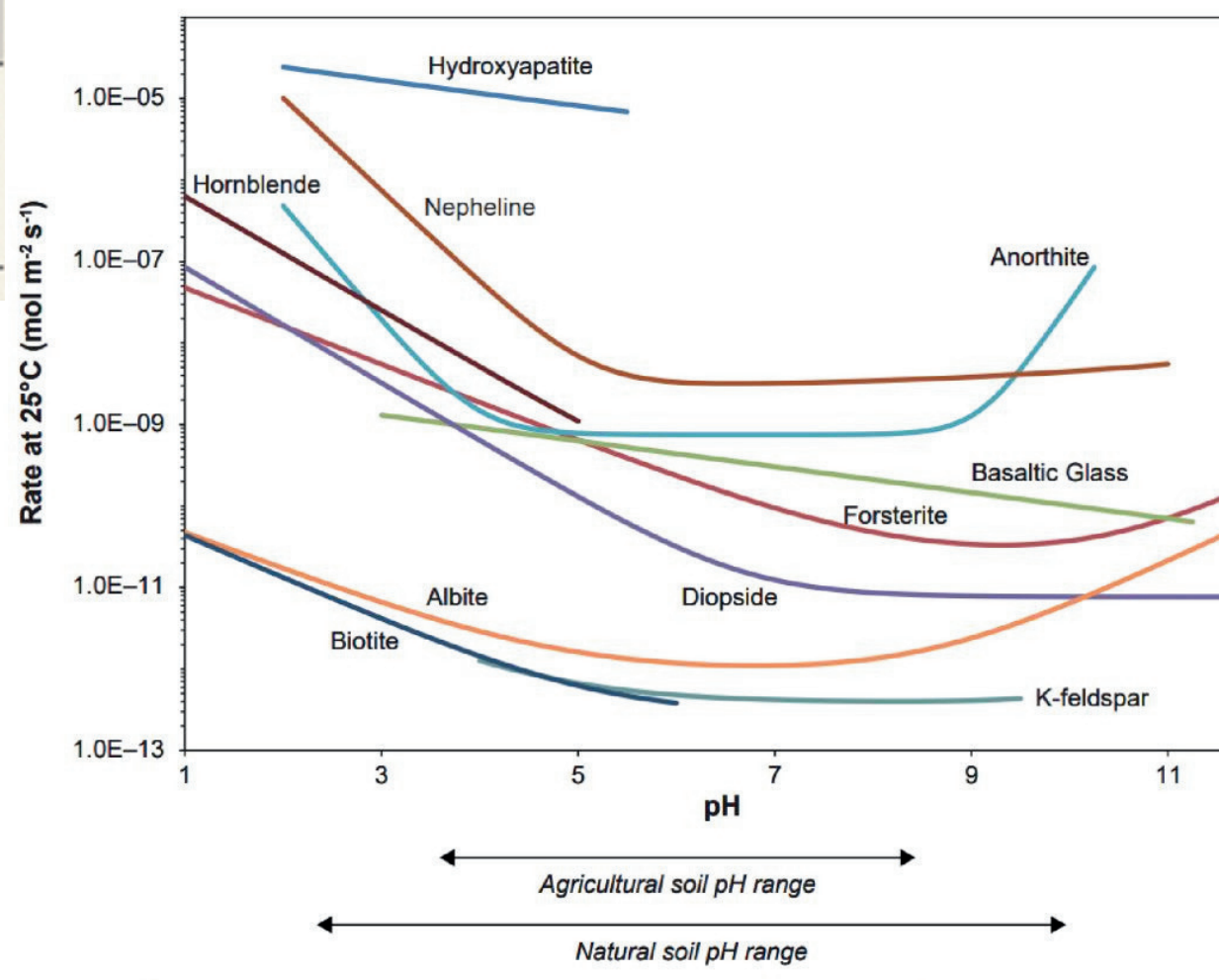
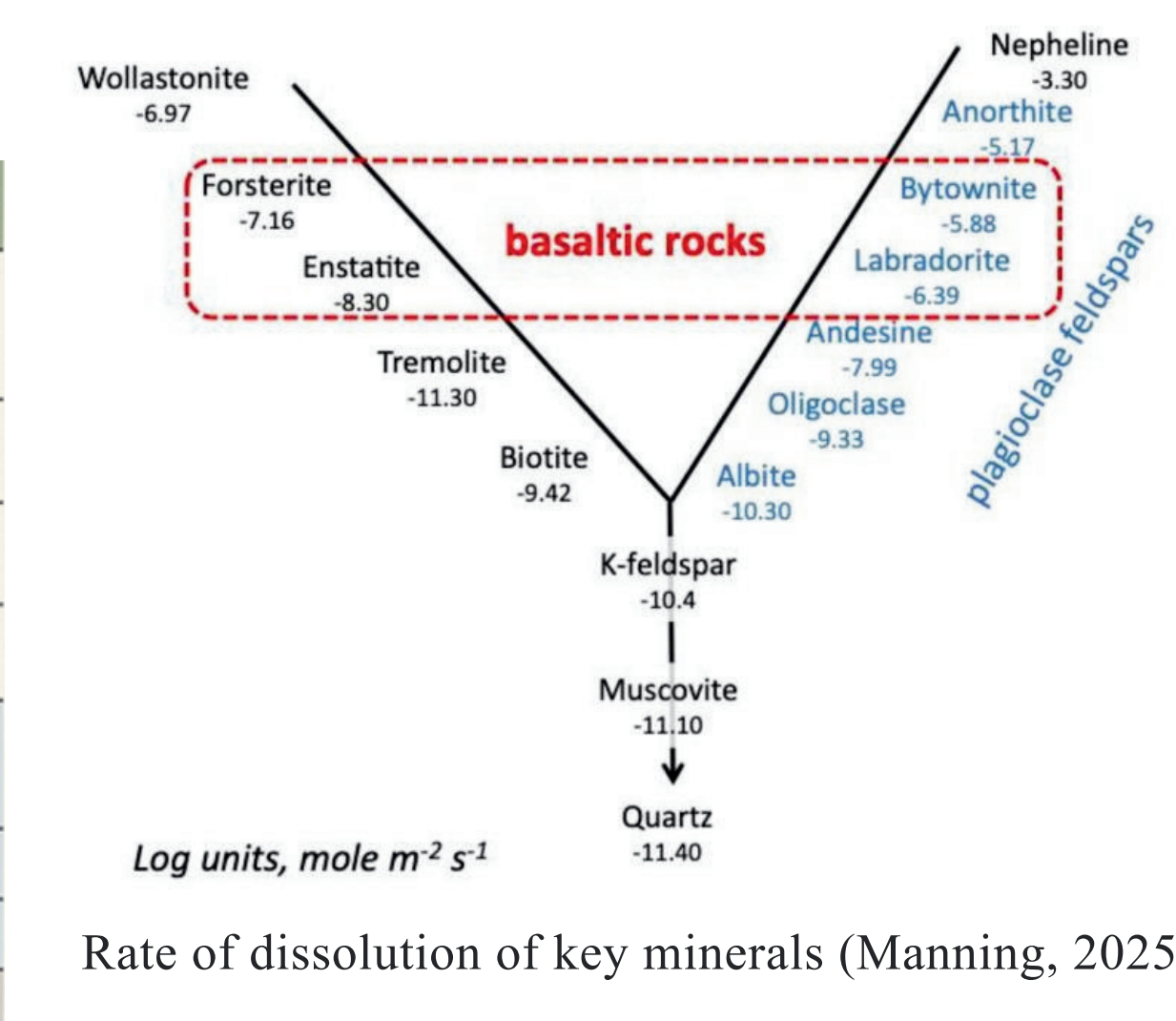
- Understand the prospects and limitations of geological methods such as ERW.
- Formulate ERW policy support with guidelines, incentives, and integration, and create a framework to assess its environmental, economic, and social impacts in India.
- Propose a Scalable Good Practices Framework for the practical and regionally adaptable implementation of ERW.

BASIC SCIENCE



FACTORS AFFECTING ERW

Conditions...	... impeding ERW	... favoring ERW
Mineralogy	Slower-reacting minerals (e.g., K-feldspar and Na-plagioclase)	Fast-reacting minerals (e.g., olivine, Ca-plagioclase)
Amorphous phases (glass)	Low content	High content
Elemental composition	Low base cation content (Ca, Mg, K* and Na')	High base cation and high Fe and Al contents
Grainsize	Coarse (>100 μm)	Mainly fine (<50-60 μm)
Soil pH	Circumneutral or slightly alkaline	Acidic soil conditions
Temperature	Low temperatures	Year-round warm temperature
Moisture regime	Arid to semi-arid	Humid to sub-humid
Texture	Heavy-clay or sandy soils	Intermediate (loamy soils)
Structure	Compacted, disconnected	Optimal porosity and connectivity
Water-holding capacity	Very poor (decreasing mineral exposure to water) or excessive (causing soil saturation)	Moderate between retention and regular flushing



CURRENT PROTOCOL FOR ERW

1. SITE SELECTION

Most suitable sites are acidic and degraded (e.g., polluted and eroded) arable and forest lands for revegetation and restoration

5. SOIL QUALITY AND FOOD SAFETY STUDIES

Soil and food contamination with metals and radionuclides by ERW should be studied in a long-term experiments

2. SILICATE ROCK SELECTION

Most suitable rocks are building materials due to lower content of metals and/or radionuclides, and for slags, to reduce metal contamination risk, ferrous slag is better than non-ferrous slag

3. ASSESSMENT OF CO₂ REMOVAL

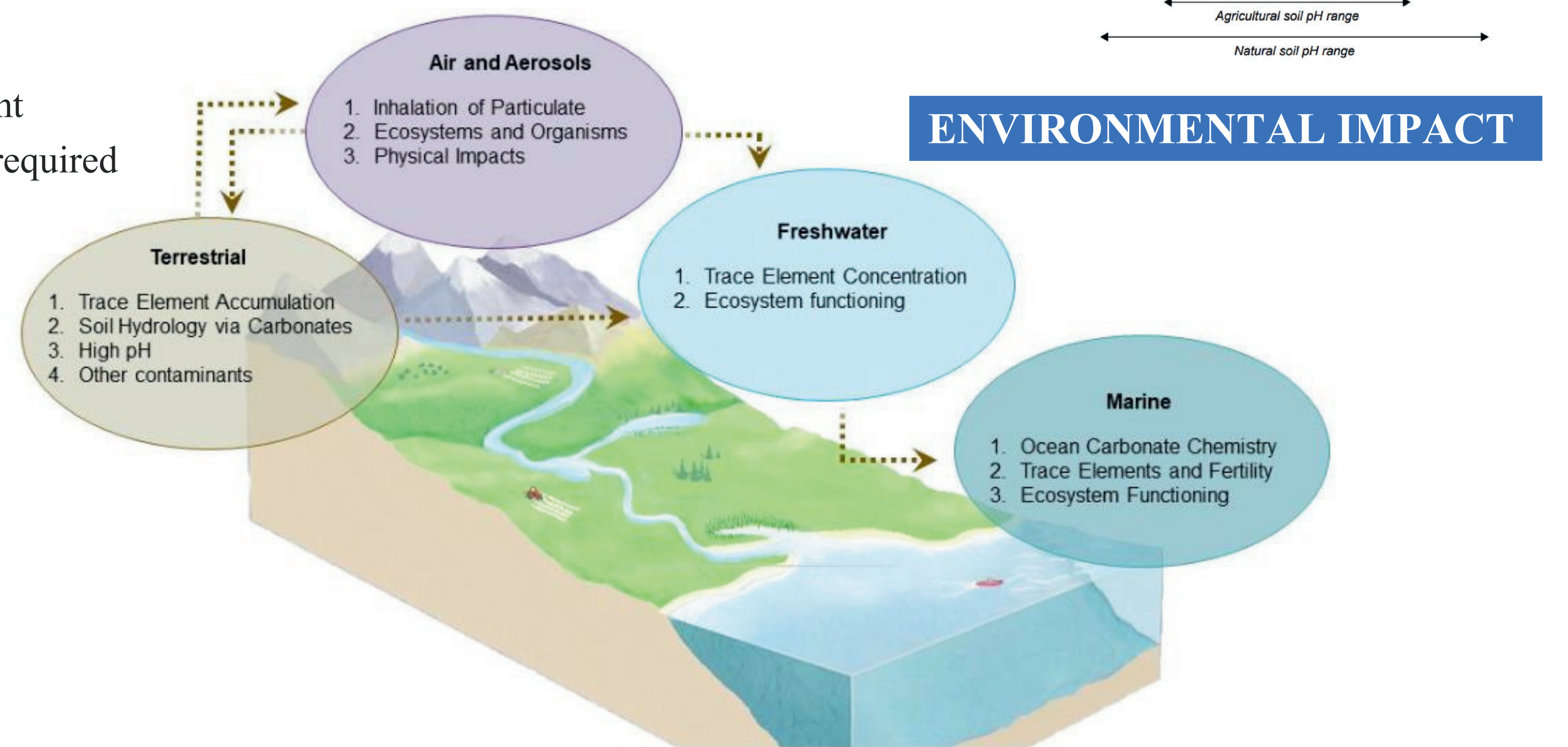
Site-specific responses of greenhouse gas emission and carbonate formation to ERW needs to be preliminarily assessed before the massive application

4. CROP YIELD ASSESSMENT

Extensive evidences on increased crop yield by application of divergent silicate rocks for various crops are required

Strategy for Pragmatic use of ERW

ENVIRONMENTAL IMPACT



CHALLENGES FOR ERW



Rock composition (toxic trace metal content, presence of asbestos)

Infrastructure and machinery for optimal grain size

Import/export infrastructure

Farming equipment (high load spreaders, dust suppression equipment)

Environmental impact of increasing mining operations

Health hazards related to dust exposure

Transport energy requirements, costs, and carbon footprint

Spreading energy requirements, costs, and carbon footprint

Legal and social resistance to mining

Grinding energy requirements, costs, and carbon footprint

Transport and storage conditions

Social resistance against widespread geoen지니어ing

Mining energy requirements, costs, and carbon footprint

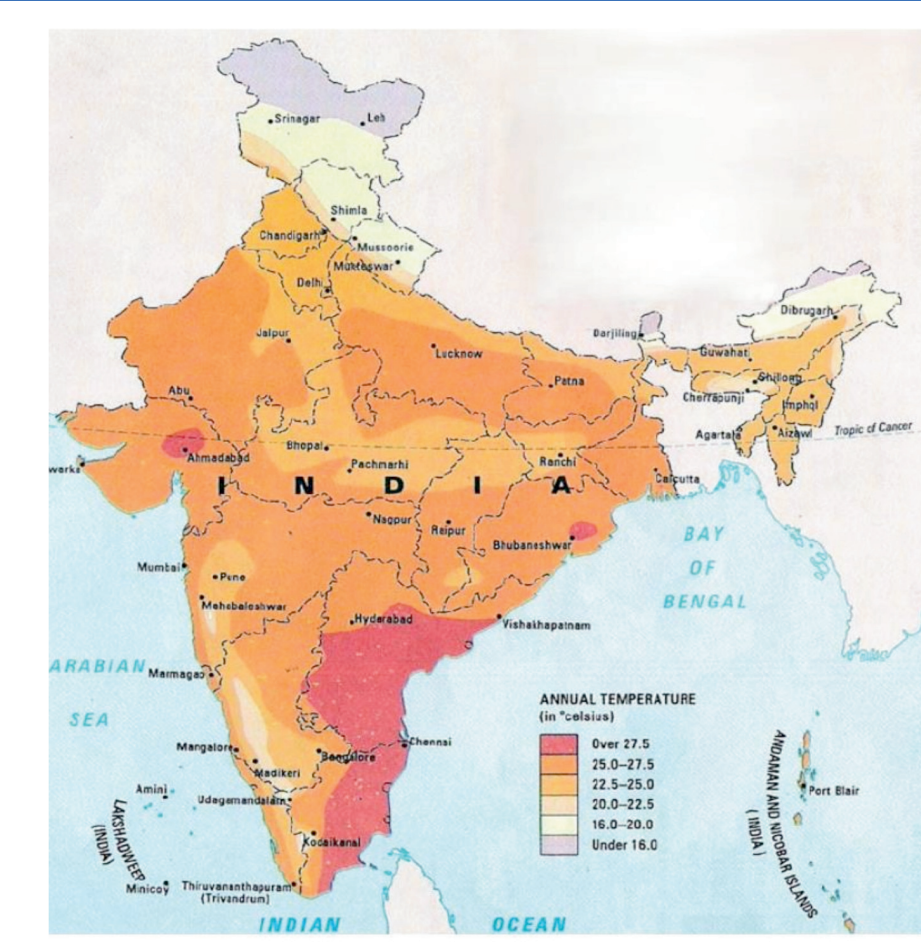
Packaging costs

Health hazard due to dust exposure and environmental regulation

POTENTIAL FOR INDIA



Map of Deccan Traps (Shome et al. 2013)



Average annual temperature across India, suitable for ERW (Sirohi et al. 2007)

POLICY RECOMMENDATIONS (SELECTED)

- Need to build a national consensus and protocol specific to identified sites.
- Nodal agency should be the Ministry of Mines, with the Geological Survey of India as the lead agency for the measurement, reporting and verification (MRV) of ERW feedstocks; leveraging the use of existing geochemical and lithological maps (1:25,000) to select suitable rock types for ERW.
- It should follow processes of environmental clearances from both national and state cells with EIA, along with local consultations.
- Involvement of the Central Ground Water Board to monitor groundwater, stream and river health; and Indian Council of Agricultural Research to monitor soil health and crop yields.
- Documents must be shared on every organisation undertaking ERW, with mandatory quarterly reports which include sourcing of rock, upstream and downstream impacts measured, steps taken towards mitigation measures.

SELECTED REFERENCES

- Beerling, D.J., Reinhard, C.T., James, R.H., Khan, A., Pidgeon, N. and Planavsky, N.J., 2025. Challenges and opportunities in scaling enhanced weathering for carbon dioxide removal. *Nature Reviews Earth & Environment*, pp.1-15.
- Beerling, D.J., Kantzas, E.P., Lomas, M.R., Wade, P., Eufrazio, R.M., Renforth, P., Sarkar, B., Andrews, M.G., James, R.H., Pearce, C.R. and Mercure, J.F., 2020. Potential for large-scale CO removal via enhanced rock weathering with croplands. *Nature*, 583(7815), pp.242-248.
- Dupla, X., Brantley, S.L., Paulo, C., Möller, B., Power, I.M. and Grand, S., 2025. Geochemical drivers of enhanced rock weathering in soils. *Geoengineering and Climate Change: Methods, Risks, and Governance*, pp.207-230.
- Haque, F., Khalid, R., Chiang, Y.W. and Santos, R.M., 2023. Constraining the capacity of global croplands to CO drawdown via mineral weathering. *ACS Earth and Space Chemistry*, 7(7), pp.1294-1305.