Geosciences Support the Sustainable Management of Land and Aquatic Environments

Global environmental challenges such as climate change and biodiversity loss require actions and new ways of thinking across multiple sectors. Geoscientific research on carbon storages and sinks, geo-biodiversity, and sustainable land, inland water and sea use provides solutions towards more sustainable land use practices, healthy ecosystems and a resilient living environment.

Sustainable management of land and aquatic environments relies on deep understanding of our geoenvironment

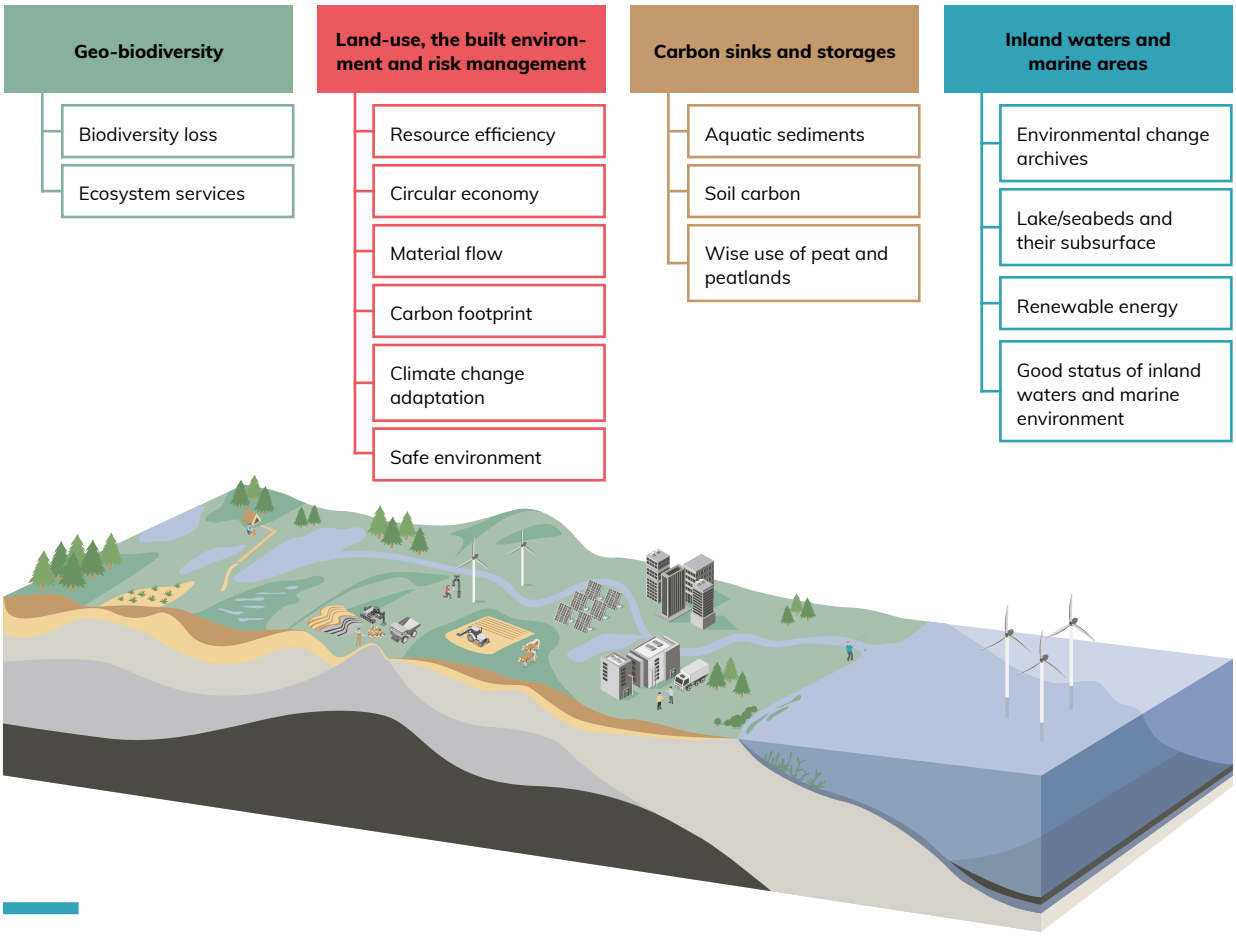
Geosciences are vital for the digital and green transition, helping to address climate change, biodiversity loss and resource scarcity. Geosciences provide critical insights into our geoenvironment and associated ecosystem services, essential for achieving carbon neutrality and environmental sustainability. Cross-disciplinary research into links between geo- and biodiversity is a key topic, yet it currently remains largely underexplored. Additionally, geosciences offer data, innovations and solutions that promote sustainable development, climate-proof land use and environmental resilience. GTK's geoenvironment research activities support the sustainable management of land and aquatic environments by focusing on:

- Carbon sinks and storages
- Geo-biodiversity
- Inland waters and marine areas
- Land use, the built environment and risk management

Human activities are drastically altering the Earth, pushing the planet beyond its safe limits and threatening global well-being through climate change, biodiversity loss, pollution and resource scarcity. Mitigating these impacts requires renewable energy and resource-efficient practices that simultaneously support regenerative land-use practices and nature restoration. Achieving carbon neutrality and environmental sustainability demands a multi-sector approach, whereby geosciences offer essential data, solutions and insights for sustainable development.

GTK research presented in this Policy Brief contributes to these United Nations Sustainable Development Goals

The geoenvironment research with GTK's key activitles



Mission possible – geoenvironmental knowledge addresses our greatest challenges

Carbon sinks and storages - our vital natural systems for climate and biodiversity resilience

Understanding natural processes that form carbon storages and sinks in soils, peatlands and aquatic environments helps to identify, support and measure nature-based carbon sequestration. This knowledge is vital for assessing the impacts of land-use changes and human activities on carbon sinks and developing climate change mitigation solutions. For example, lake and marine sediments are known as significant organic carbon sinks that can be supported with carbon-wise catchment-level management practices. In addition, careful planning of peatland after-use can preserve soil carbon storage and enhance sequestration, with afforestation and restoration especially favouring Sphagnum moss dominated mire vegetation. Careful evaluation of environmental impacts on climate change, water bodies and biodiversity enables the choosing of climate-wise as well as socially and economically feasible solutions for the after-use of peat extraction sites.

Climate-wise after-use of former peat extraction areas

Careful planning of the after-use of former peat extraction areas is essential because, at best, a site can preserve soil carbon storage and enhance carbon sequestration. The moisture conditions are crucial, as they determine the possibilities for after-use, together with the thickness of the remaining peat layer. Afforestation and the restoration of mire vegetation dominated by Sphagnum moss have been identified as the best forms of after-use for the climate.

Geo-biodiversity – interplay between geology and biology supports achieving sustainability goals

The abiotic environment significantly influences biodiversity, with geodiversity playing a key role in ecosystem functions and human well-being. Biogeochemical processes support ecosystem services such as water purification, nutrient cycling, food production, flood control and soil remediation, to mention a few. Geodiversity creates a foundation for a wide range of habitats and affects the life and abundance of living organisms. To put it simply, geodiversity can be defined as the diversity of the non-living natural environment. It encompasses the diversity of bedrock, soil, topography, hydrology and all related processes.

Geo-biodiversity also has a profound impact on various environments and the organisms that they support. The varying geo-biodiversity of the Baltic Sea from the open sea to archipelagos, the diversity of biotopes in the vicinity of rich fens, as well as distinctive geological formations with valuable groundwater resources are all representative examples of geo-biodiversity in marine environments and its essential role in nature and society.

Inland waters and marine areas - natural archives for environmental change and the foundation for life and various uses

GTK produces a wide spectrum of geodata on sediment dynamics and biogeochemical processes, as well as the composition and structure of lake- and seabeds and their subsurface in inland waters and marine areas. This research along the land-sea continuum continuum is pivotal for the sustainable management of freshwater and marine environments, enabling better understanding of human-caused and natural changes occurring in the catchment area and their impact on the coastal zone and marine ecosystems.

Land use, the built environment and risk management – responsible planning enhances the sustainable use of geological resources and proper management of geology-induced risks

Land-use planning shapes our living environment, and geosciences contribute to sustainable development by offering cost-effective solutions for infrastructure, resource use and circular economy practices. A holistic approach in using natural and circular aggregates in construction ensures resource efficiency and infrastructure durability. Sustainable land use aims to avoid the over-exploitation and degradation of land resources by managing them efficiently and by minimizing the negative environmental impacts of human interaction. In addition, sustainable land management is crucial for addressing climate change and biodiversity loss. The management of geology-induced risks such as acid sulfate soils and elevated geochemical concentrations in bedrock, soil and water, as well as geotechnical instabilities appropriately and in time ensures a safe living environment for society.

Geodiversity lays the foundation for marine biodiversity

Marine biodiversity loss caused by climate change, habitat degradation, overexploitation, invasive species and pollution is a global concern. The increasing use of marine areas is also critical for the Baltic Sea. Understanding geo-biodiversity in different marine environments is crucial for the sustainable management of marine areas. GTK actively participates in the Finnish Inventory Programme for Underwater Marine Diversity (Velmu programme), which was established to fill the data gaps and needs that are essential for effective marine management, conservation and spatial planning.

Aquatic environment

Geological records of lakes and seas, particularly the muddy, organic-rich sediments that have accumulated nearly continuously on the bottom, provide unique information on past long-term environmental changes. These sediments are also archives for revealing (past and recent) human activities in the catchment area, including loading of harmful substances into the aquatic environment, i.e. pollution. Understanding past environmental changes is crucial for predicting and managing future changes in the aquatic environment.

Lake beds and the seafloor can be composed of substrates of different types and ages, from bedrock to modern mud, depending on various changing factors such as deepwater flow velocity, the climate, biological productivity and land uplift. The spatial distribution of different bottom substrate types is often very patchy, and the erosion, transportation and accumulation patterns of the sediments display considerable spatio-temporal variation. Therefore, conducting detailed lake or seabed surveys is essential when planning representative environmental sampling campaigns, restoration activities or any constructions in water-covered areas.

Research-based information on geochemistry to support decision making

Acid sulfate soils have been referred to as "the nastiest soils on Earth". These sulfide-containing soils may pose a significant risk to the environment when exposed to oxygen, which mainly occurs because of human activities such as soil drainage or soil excavation. As large parts of Finland's land area have acid sulfate soils or a similar acidification potential due to the presence of naturally occuring sulfur-rich black shales, risk management measures to avoid or minimize their environmental effects are essential. With up-to-date data and site-specific risk assesment, we can ensure that geochemical background concentrations and anomalies, acid sulfate soils and black shales can be properly considered by decision makers and other end users in land-use and water management planning, as well as in risk assessment and risk management.

Sustainable land use and responsible construction

The responsible management of natural aggregates ensures their availability for construction, the long-term durability of structures, realization of the circular economy and the reduction of emissions. Natural stone is highly durable, can replace concrete, and production side streams of natural aggregate quarries can be utilized for manifold construction purposes.

Bedrock fragmentation and associated groundwater, as well as the distribution and characteristics of fine-grained sediments may create challenging pre-conditions for construction. Recognizing these geological characteristics in an early phase results in time and cost savings, such as through a decreased need for stabilization or mass replacement, as well as enhancing the reduction of carbon emissions and supporting risk management.

Topical applications of geoenvironment research support coping with global challenges

Carbon sinks and storages

- **Aquatic sediments**. Through understanding of the impact of catchment-level land-use practices on the carbon sink potential of aquatic environments, GTK supports the development of carbon-wise management practices and restoration.
- **Soil carbon**. Focusing on carbon-rich areas, GTK supports the maximization of carbon stocks and tackles the risks that threaten them.
- **Wise use of peat and peatlands**. Carbon-wise site-specific plans for the next land use of former peat extraction and other peatland areas enable carbon-smart solutions and carbon market actions. GTK carries out multi-disciplinary research to find the most appropriate climate- and environment-wise after-use option, restoration method or new solutions for climate-wise growing media.

Geo-biodiversity

- **Biodiversity loss**. Geodiversity contributes to the diversity of habitats and thus the abundance of species, ecosystem services that soil and bedrock can offer, the diversity of aquatic environments, topography, geological heritage and climate change mitigation. It is essential to understand the relationships between geo- and biodiversity in various environments and assess the risks that may threaten this vital interaction.
- **Ecosystem services**. Geo- and biodiversity are both inherently associated with ecosystem services provided by nature, meaning the cost-free benefits that nature offers and produces for humans. Geoscientific expertise is required for the careful management of such services, including catchment-scale water quality and nutrient recycling, nature-based flood and coastal protection and aquifer recharge.

Inland waters and marine areas

- **Environmental change archives**. Geological records of lakes and seas, particularly the sediments that have accumulated nearly continuously on the bottom, provide unique information on past long-term environmental changes, climate change and biodiversity loss.
- **Lake/seabeds and their subsurface**. The ecosystems and use of Finnish marine and coastal areas are changing at an unprecedented rate, including the unstable security situation in the Baltic Sea. For the sustainable management of lake/seabed resources, a multidisciplinary and coordinated approach to aquatic research is essential. The Finnish Marine Research Infrastructure FINMARI has improved marine research equipment and facilities and strengthened Finnish cross-disciplinary cooperation for the benefit of marine research for a decade already.

- **Renewable energy**. Several factors affect onshore and offshore wind power siting. The seafloor's characteristics play an important role in the planning of turbine locations and cable routing. Careful planning improves the profitability and acceptability of offshore wind farms and reduces their ecological impact.
- **Good status of inland waters and marine environment**. The ecological status of the Finnish inland waters is mostly good. However, human activities in the surrounding area, such as agricultural and forestry practices and construction, may deteriorate our waterbodies. It is crucial to direct and implement land-use and management practices in such a way that our watersheds and marine environment are not threatened. For instance, geological background assessments can inform the planning of preventive measures to mitigate the environmental impacts of activities in areas with acid sulfate soils.

Land use, the built environment and risk management

- **Resource efficiency**. Non-renewable geological resources are still required for infrastructure and construction, although the re-use of excavated Earth materials is a feasible option in many end-use cases. GTK's expertise enables optimizing of the most appropriate geological materials in terms of their geotechnical and geochemical quality to best fit the purpose in an early phase of planning processes. This enhances the resource-wise use of virgin materials and contributes to the sustainable use of non-renewable geological resources.
- **Circular economy**. The re-use of excavated materials (rock, soil and dredged sediments) in infrastructure and construction may require physical or chemical treatment to meet their end use requirements. To promote a sustainable and cost-efficient circular economy, GTK investigates how different industrial side-streams may be utilized for the neutralization, stabilization and solidification of excavated materials, as well as immobilizing potential harmful elements and substances. Opportunities to utilize waste rock from mining as aggregates are also considered in sustainable material management.
- **Material flow**. Up-to-date information on geological resources and their characteristics enables resource-wise use of materials in Finland and supports the land mass coordination of cities and municipalities.
- **Carbon footprint**. The aggregates to be excavated and extracted during construction can be identified and evaluated according to the quality requirements of the different uses. This enables the substituting of unexcavated natural aggregates and designing of processing and logistics chains to be low-emission and efficient.
- **Climate change adaptation**. The capacity of cities and municipalities to cope with climate change impacts is essential for a resilient society. Geological characteristics, together with human made structures, set boundaries for the feasibility of climate change adaptation measures designed in urban areas.
- **Safe environment**. Geological characteristics may result in elevated concentrations of potentially harmful elements in bedrock, soil and water or in acidification potential. Land-use changes may accelerate exposure to these. With up-to-date information on the occurrence of geochemical anomalies or potential acid-producing geological environments, these areas can be identified and considered, their potential risks can be evaluated and appropriate risk management measures can be planned and taken into action.

How can the sustainable management of land and aquatic environments be enhanced?

The following actions are recommended:

Carbon sinks and storages Enhance and strengthen natural processes that capture and store carbon in terrestrial and aquatic ecosystems and tackle the risks that threaten them.

Geo-biodiversity Focus on understanding how geodiversity underpins biodiversity to strengthen conservation and restoration efforts and strategies for land, inland water and sea use.

Inland waters and marine areas Use geoscientific data to guide sustainable management and to promote the good environmental status of inland waters and the Baltic Sea.

Land use, the built environment and risk management Enhance and support responsible infrastructure development, resource efficiency, circular economy initiatives, climate change adaptation, carbon footprint reduction and geological risk management for a safe and sustainable living environment. Promote healthy soils for people, food, nature and the climate.

Sources and additional information

GTK's research areas, policy briefs and research projects

Geoenvironment - information and research projects

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- **Renewable Sphagnum Moss Provides a Climate-wise Growing Media to Replace Peat**
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- **Europe-wide Effort to Improve Soil Health – Achieving New Objectives Demands Systematic Information about Soil**
- **Geodiversity Lays the Foundation for Biodiversity**
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