

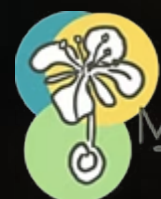
THE BARDAWIL & SINAI INITIATIVE

Blueprint for Biosphere Regeneration

The Weather Makers Foundation – Version August 2025



NoVo
Foundation



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“Our changing climate also comes with huge potential security impacts as the increasing droughts and floods affect the food- and water security of complete regions in the world. This has a disrupting effect on societies, especially in fragile regions, resulting in internal friction, migration flows and new breeding grounds for extremism. New concepts are needed to turn that tide.

The Bardawil & Sinai Initiative offers a groundbreaking comprehensive initiative for ecosystem restoration by restoring the water cycle in the region. A regreened Sinai can help restore the relationship between society and nature and counter the disruptive security effects of our changing climate.”

**Tom Middendorp
Chairman of the International Military
Council on Climate and Security**



CONTENTS

This document presents the Bardawil & Sinai Initiative which aims to restore the water cycle of the Northern Sinai Peninsula. The document is meant to invite organisations and individuals to be inspired and contribute into landscape scale regeneration. We must protect, restore, and manage ecosystems sustainably to ensure long-term resilience for human livelihood.

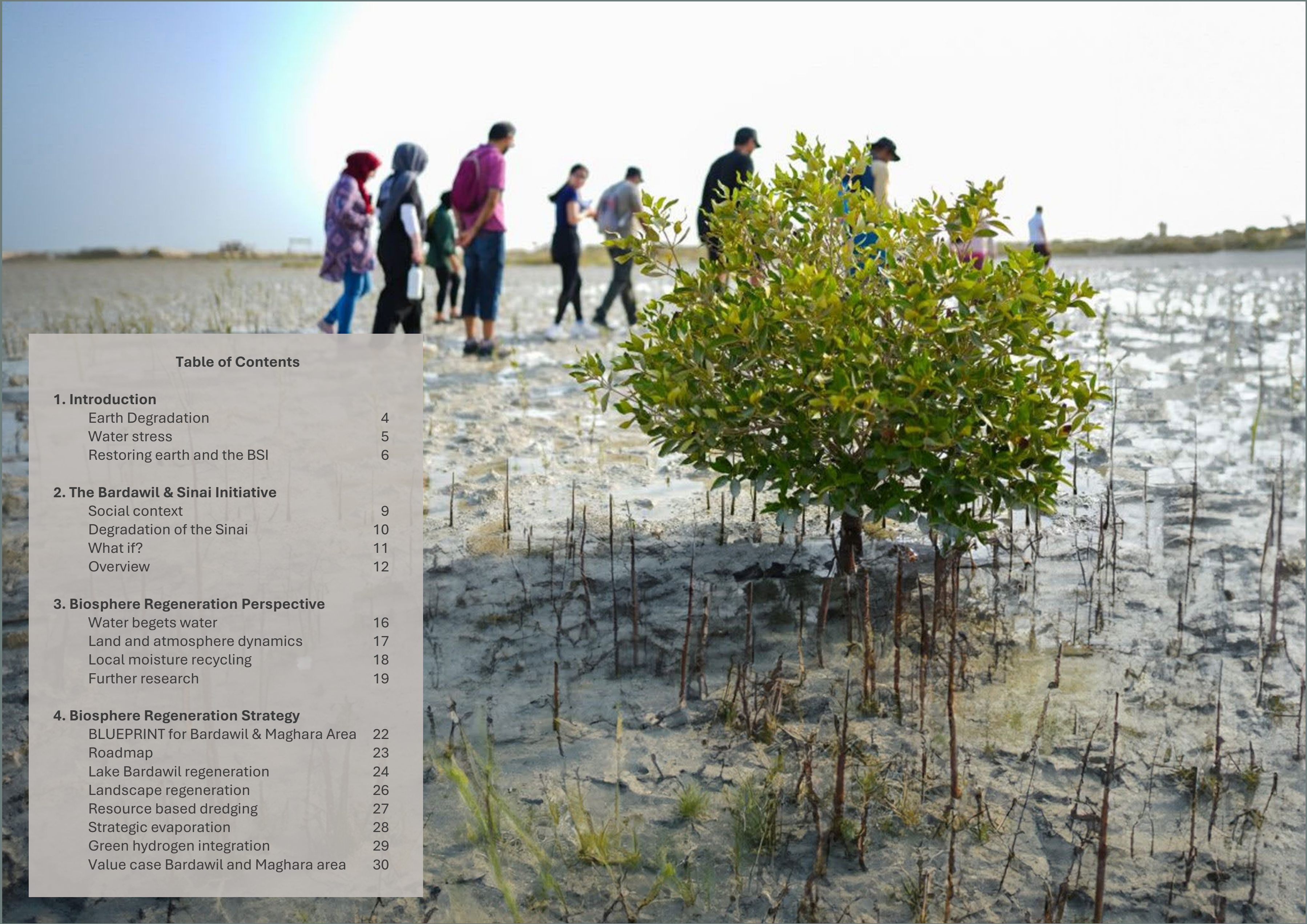
Reading guide

After a general introduction, the initiative is introduced. Hereafter a water cycle regeneration perspective is presented and a regeneration strategy which could become a blueprint for landscape-scale regeneration worldwide.

The BSI is work in progress and will be further developed over time. Supporting documents and updates are and will be made available on The Weather Makers foundation’s website.

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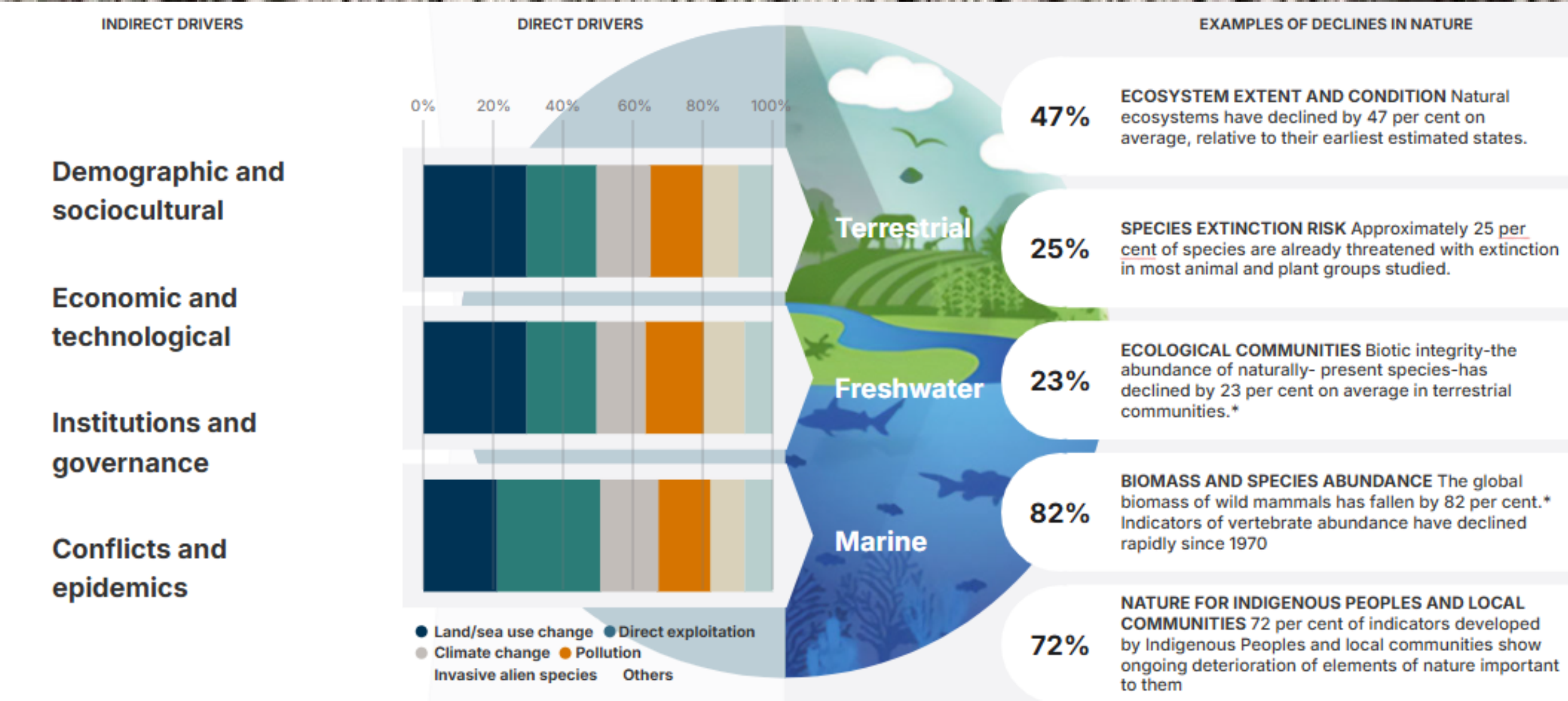


EARTH DEGRADATION

Climate change is no longer a distant threat; it is present day crisis. With global average temperatures already 1.1°C above pre-industrial levels, climate change is already causing widespread disruption pushing temperatures to extremes, accelerating the melting of glaciers and ice sheets, driving unprecedented ocean warming, and intensifying droughts, floods, wildfires, and storms.

These impacts are already disrupting communities worldwide, frequently eroding hard-earned development progress. Every additional fraction of a degree will only amplify these threats, especially for the more than 3 billion people living in highly vulnerable regions¹.

Human activity has extensively altered nature worldwide. About 75% of land, 66% of oceans, and over 85% of wetlands are significantly impacted. Forest loss continues, especially in tropical regions, despite gains in some temperate and boreal areas. Native species abundance has dropped by at least 20% since 1900, affecting ecosystem functions. Invasive species, habitat loss, and pollution are contributing to widespread biodiversity decline across land, freshwater, and marine ecosystems².



¹IPCC. 2022. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working. Cambridge: Cambridge University Press.

²IPBES. 2019. Global Assessment Report on Biodiversity and Ecosystem Services. Bonn: IPBES Secretariat. <https://ipbes.net/global-assessment>.

³Woodley, Stephan, Jarvis, Jonathan, and Andrew. 2011. “Ensuring area-based conservation meets the twin challenges of biodiversity loss and climate change.” Parks Stewardsip Forum.

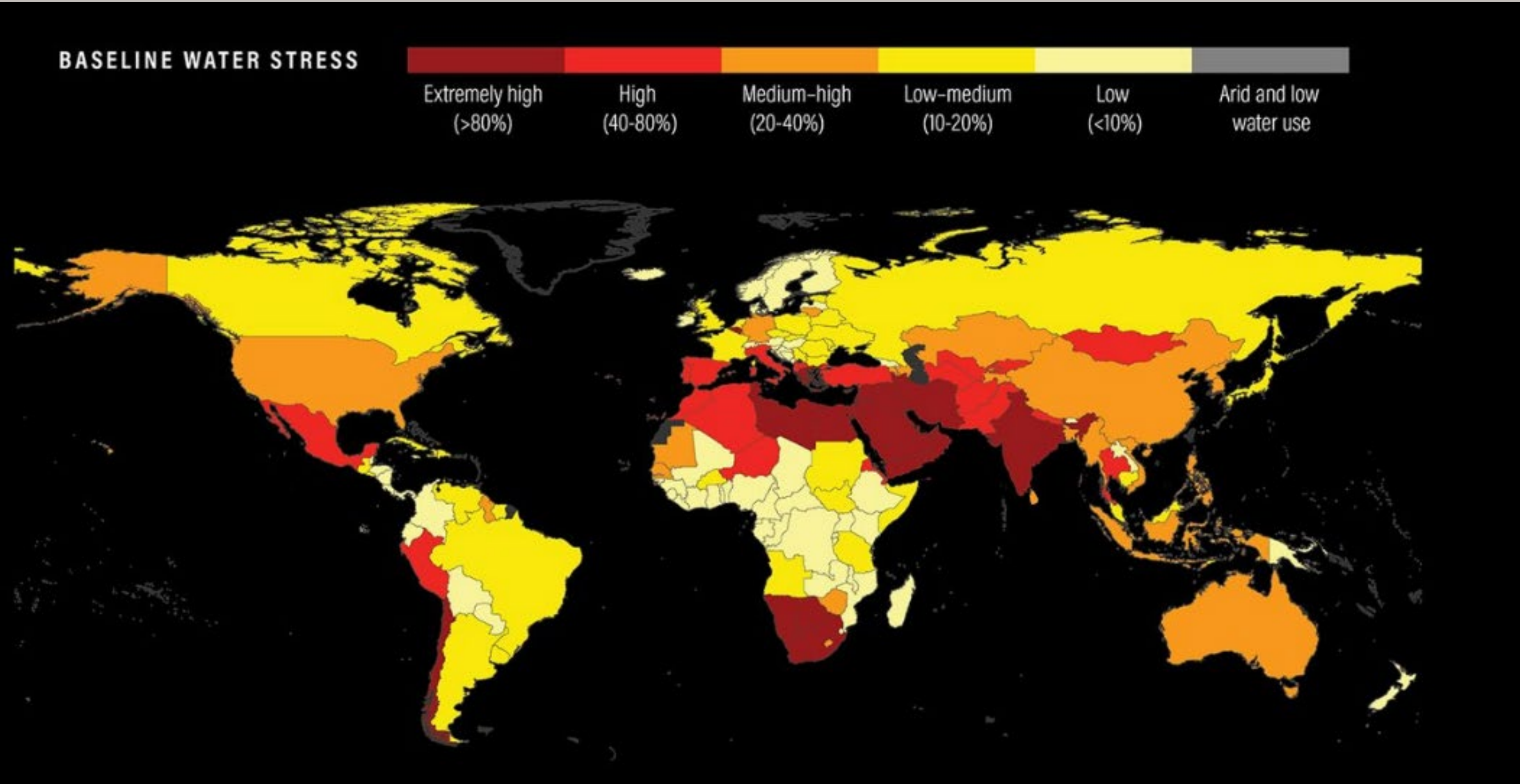
The primary drivers of biodiversity loss and ecological decline are land and sea use change along with direct exploitation, leading to habitat loss and extinction³.

WATER STRESS

One of the most urgent challenges is managing increasingly scarce freshwater resources. Currently, 40% of the global population lives in water-stressed areas, and demand is projected to rise by 55% by 2050¹.

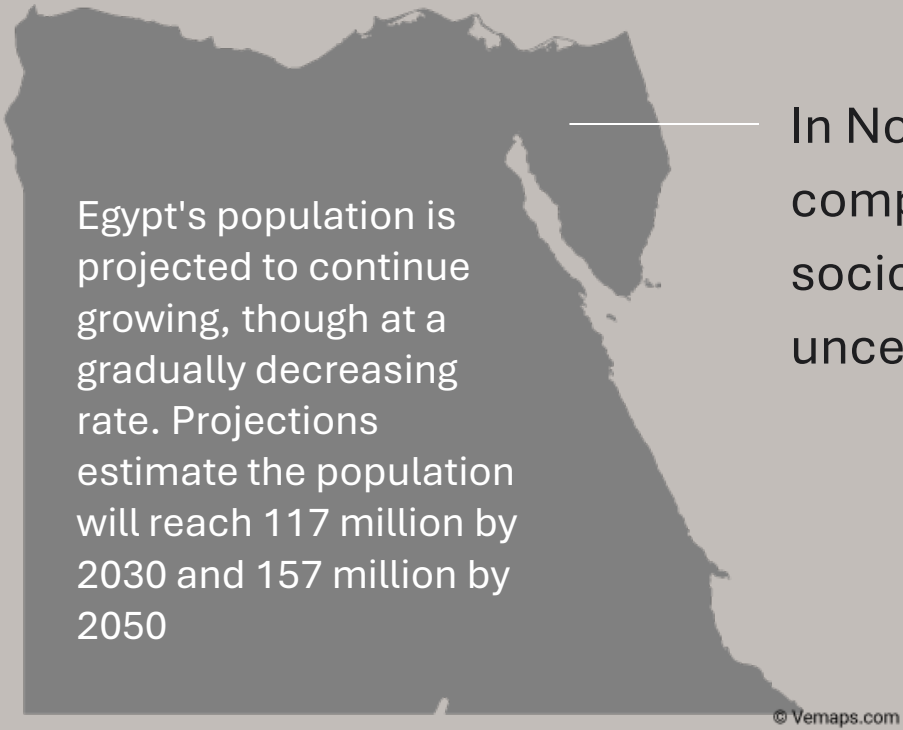
High water stress put lives, jobs, food, and energy security at risk. Water is essential for agriculture, health, power, equity, and climate goals. Without improved water management: growing populations, economic pressures, and climate change will intensify the crisis.

Water scarcity and its political, economic, and social impacts are felt far more acutely in the Mediterranean region. The area faces nearly every factor associated with global water crises, including limited and fluctuating freshwater resources, a rapidly expanding population, and shifting levels of economic development. The Mediterranean has been identified as one of the most responsive regions to global climate change, with observed warming expected to continue at a greater rate than the global average².



Countries and their corresponding baseline water stress levels. The Mediterranean and Middle East are facing extremely high to high water stress, which is projected to worsen. Source: wri.org/aqueduct

Egypt illustrates how these risks can converge. It faces chronic water scarcity, rapid population growth, and high vulnerability to climate change³. The country’s limited water resources pose a serious challenge to national development, particularly as agriculture consumes the most water



In North Sinai, these pressures are compounded by political and socioeconomic fragility, creating deep uncertainty for the region’s future⁴.

¹OECD. 2012. OECD Environmental Outlook to 2050. Paris: OECD Publishing. doi:<https://doi.org/10.1787/9789264122246-en>.
²Lionello, P., and L Scarascia. 2018. “The relation between climate change in the Mediterranean region and global warming.” Reg. Environ. Change. doi:<https://doi.org/10.1007/s10113-018-1290-1>.
³Mostafa, S. M., Wahed, O., El-Nashar, W. Y., El-Marsafawy, S. M., Zeleňáková, M., & Abd-Elhamid, H. F. (2021). Potential climate change impacts on water resources in egypt. Water (Switzerland), 13(12).
⁴Daligaux, C. 2023. “North Sinai Development: Exploring potential hotspots of tension from a hydrosocial perspective.”. MSc Thesis at Vrije University

RESTORING EARTH'S BALANCE

The climate crisis is often addressed in fragmented ways, focusing separately on greenhouse gases, biodiversity loss, unsustainable practices, and environmental degradation. This leads to isolated solutions rather than integrated strategies.

While cutting CO₂ emissions is essential, carbon-focused strategies alone are not enough. Climate stability also relies on biologically driven water and energy cycles, which are now disrupted, but that can be restored with human action.

With the global population expected to grow to 10 billion by 2050¹, the pressure on natural resources will only intensify. To meet future needs, we must protect, restore, and manage ecosystems sustainably to ensure long-term resilience for human livelihood.

Addressing climate change, biodiversity loss, and water scarcity as interconnected challenges allows us to develop cross-sectoral strategies with lasting impact. Central to this shift is the restoration of the hydrological cycle, a natural climate regulator often overlooked in current carbon-centric approaches. By prioritizing water cycle restoration, we can tackle both the causes and consequences of climate instability, enhance ecosystem resilience, and ensure long-term access to freshwater.

Ecological regeneration offers a powerful, science-based solution to both climate change and water scarcity by addressing the root causes of environmental degradation. Restoring natural ecosystems helps rebuild the land's capacity to absorb and store water, stabilize soils, and regulate local climates through processes like evapotranspiration and cloud formation.

Healthy ecosystems act as carbon sinks, drawing CO₂ from the atmosphere, while simultaneously improving rainfall patterns and groundwater recharge. Unlike fragmented technological fixes, ecological restoration works with nature's own systems, delivering multiple co-benefits: climate regulation, biodiversity recovery, food and water security, and resilience to extreme weather. By restoring the natural cycles that sustain life, regreening offers a holistic and scalable path forward, one that supports both people and the planet. It also revitalizes the hydrological links between land and atmosphere, helping to rebalance disrupted weather systems. As a nature-based solution, regreening aligns ecological integrity with human development, offering a regenerative approach to planetary health².



¹United Nations, <https://www.un.org/en/desa/world-population-projected-reach-98-billion-2050-and-112-billion-2100>

²IRP. 2019. Land Restoration for Achieving the Sustainable Development Goals: An International Panel Think Piece. Nairobi: United Nations Environment Programme.

THE BARDAWIL & SINAI INITIATIVE

RESTORING ECOLOGY, WATER, STABILITY AND A RESILIENT FUTURE

In 2017, The Weather Makers set out with a radical premise: that restoring ecosystems could be a path to a peaceful, climate-resilient future. Our belief has only grown stronger.

The Bardawil & Sinai Initiative (BSI) began with a deceptively simple goal, regenerate a lagoon. But Lake Bardawil, a shallow, over-silted lagoon on Egypt’s northern coast, is more than a body of water. It’s a collapsed coastal engine, once teeming with life and livelihoods, now drained of both by ecological decline and human pressure. Restoring it is the first step in a system-wide transformation of the Sinai Peninsula. An integrated strategy to revive the biosphere, reactivate the water cycle, and rebuild regional stability.

The initiative was officially launched at COP27 in Sharm El-Sheikh with the support of the Egyptian government. Interest followed, but just as momentum gathered, the ground shifted. Regional instability flared. Security risks in North Sinai made progress impossible. Egypt’s economic headwinds tightened. Investment flows stalled.

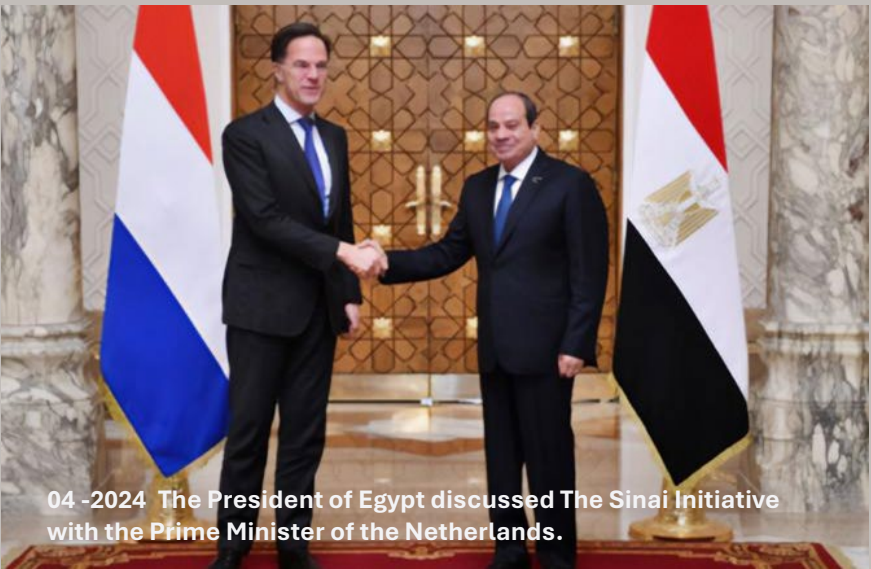
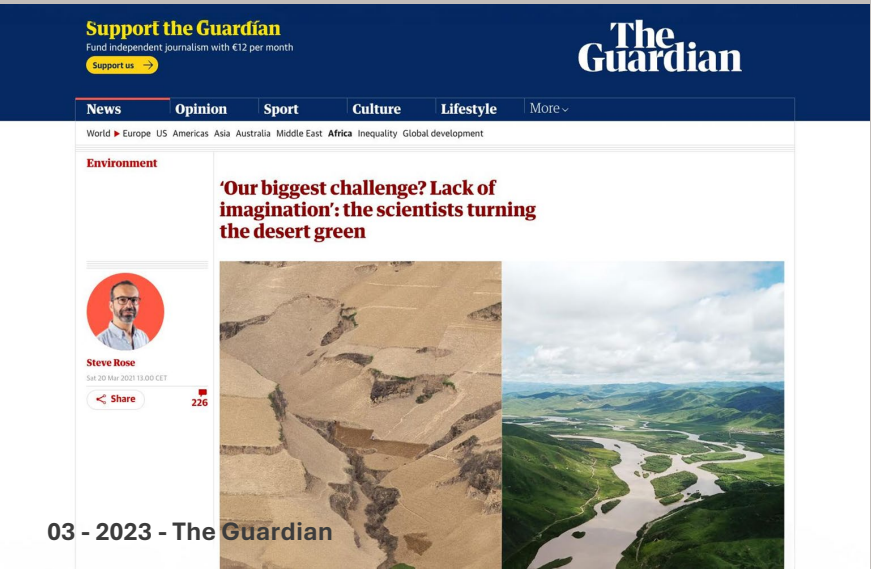
Still, we never paused our conviction. The link between ecological degradation and geopolitical instability is no longer speculative it’s visible.

And we believe landscape transformation can address root causes of water stress and food insecurity. To continue the mission under these complex conditions, we established The Weather Makers Foundation (TWMF) a nonprofit platform to unite science, policy, engineering, and community into one coordinated effort.

One of our focusses is on defining what we call the BSI Blueprint for the Sinai. Step one: a System-Based Regeneration Strategy. Together with out partners we’re designing reference methodologies for ecological engineering, hydraulic sediment transport, regenerative aquaculture, green hydrogen, and strategic evaporation.

The BSI blueprint will allow us to assess financial costs and regenerative returns: biodiversity restored, jobs, new rainfall, and resilience unlocked. With peer-reviewed insights on natural and social capital, we’ll present the case - open source- to partners, funders, and policymakers.

Our ambition remains the same: to regenerate life at scale. Sinai is where we begin, but not where we end. With each restored lagoon, each seeded tree, we model what a peaceful, climate-resilient future can look like. One rooted in water, in soil, and in collaboration.



THE BARDAWIL & SINAI INITIATIVE

*Landscape
transformation
at scale*



SOCIAL CONTEXT

The North Sinai region, marked by prolonged conflicts over time, has become a focal point for extremism, state-led counterinsurgency, and development efforts. The primary actors in this conflict include jihadist groups, Bedouin tribes, Egyptian and Israeli security forces, and international observers. Development, particularly through infrastructure and economic initiatives, is seen by the Egyptian government as a tool to undermine extremism. Lake Bardawil plays a crucial role in regional development, being a hub for fishing, agriculture, conservation, and salt mining, overseen by a complex network of governmental and non-governmental institutions.

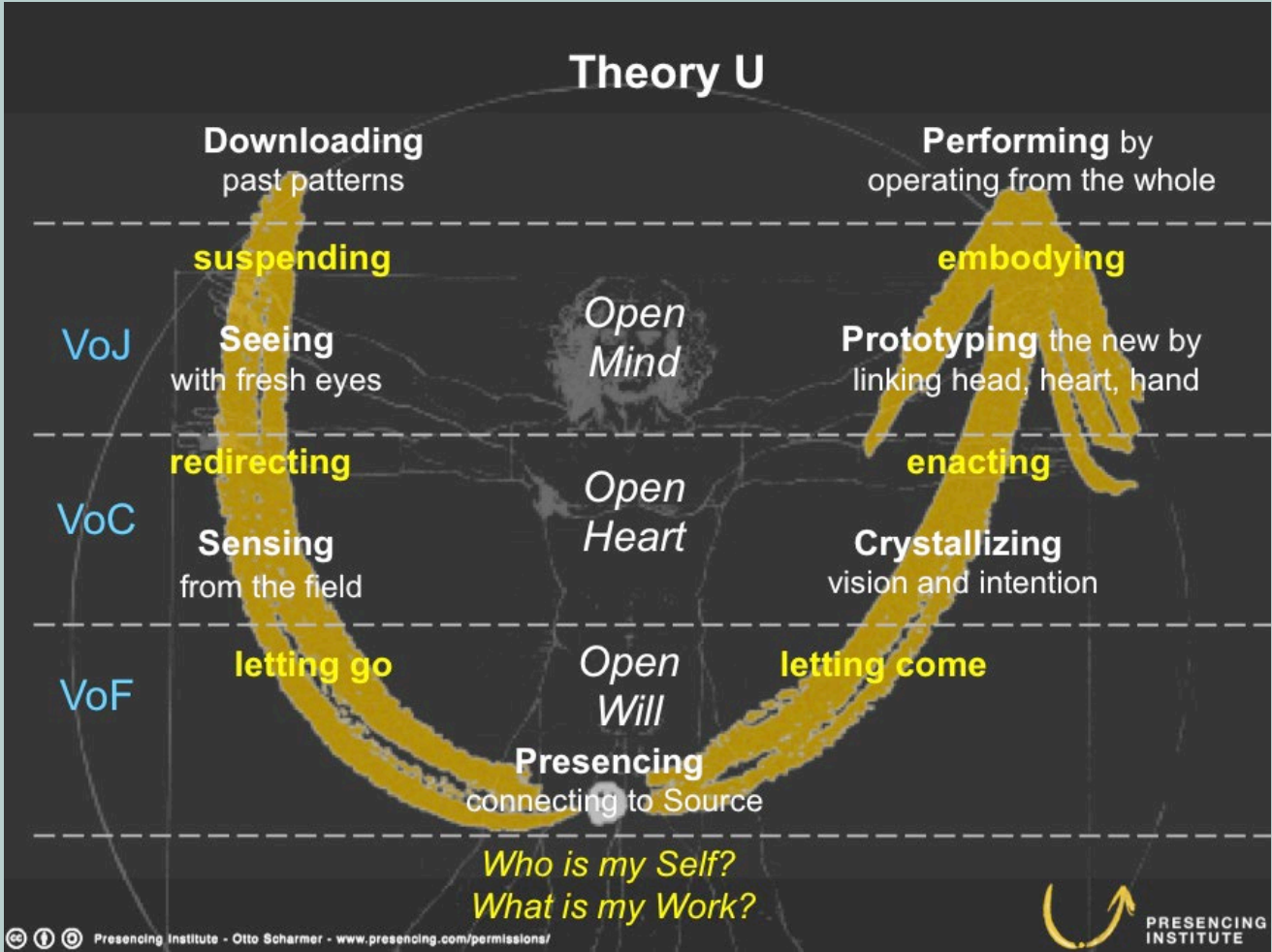
The Bedouin population have significant indigenous and local knowledges in resource management by their traditional legal systems, and the historical marginalization they have faced. Despite previous state policies that undermined their customary land rights and ways of life, Bedouins are increasingly being engaged in development projects.

Gender dynamics within Bedouin society remain conservative, though some shifts have been noted due to modernization and localized advocacy. The integration of Bedouin communities and their knowledge systems into state and NGO-led initiatives is identified as vital for ensuring sustainable development, social inclusion, and conflict mitigation in the region¹.

¹Rey, Andrea (2020) “Socio-environmental Systems Lake Bardawil and North Sinai”, MSc thesis Wageningen University & Research



We firmly believe that land restoration can only be successful through co-creation and bottom-up approaches that places local communities at the centre of all efforts. True regeneration is not just ecological; it must also be social and economic. This means actively involving Indigenous Peoples and Local Communities (IPLC), particularly those with deep ties to the land such as the Bedouin tribes of Northern Sinai, in the design, implementation, and stewardship of restoration initiatives. Their traditional knowledge, cultural practices, and lived experiences are not only valuable; they are essential. Furthermore, all benefits derived from restoration, whether environmental, economic, or social, must be designed to flow directly back into these communities, improving their livelihoods, strengthening their resilience, and empowering future generations. Only through this inclusive and equitable model can restoration efforts be sustainable, just, and truly transformative.



DEGRADATION OF THE SINAI

A multi-causal phenomena

Climate change is the result of complex interactions among natural variability, orbital dynamics, anthropogenic forces, and feedback mechanisms between land and atmosphere. While Milankovitch cycles have historically governed long-term climate shifts, particularly during the Pleistocene, human influence on landscapes and ecosystems, dating back to prehistory, has played a far more significant role than previously acknowledged. The concept of the Paleo-Anthropocene challenges the notion of a purely “natural” climate, highlighting early human impacts through land use, fire, and niche construction¹.

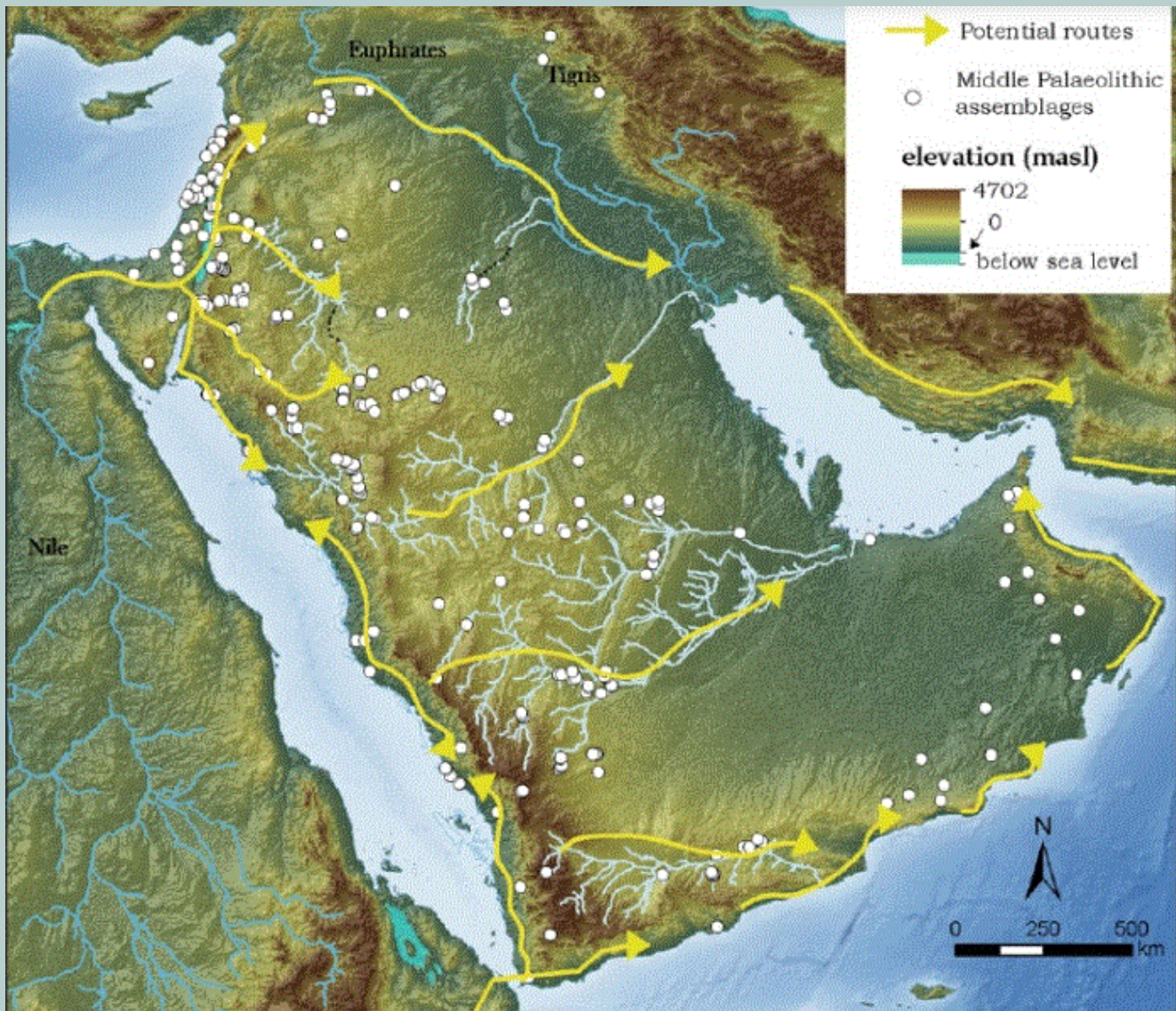
In northern Africa and the Middle East paleoclimatic records reveal that transitions from humid to arid conditions, such as the end of the African Humid Period, were neither uniform nor entirely explained by orbital forcing. The discrepancy between modelled and observed aridification rates shows that local vegetation loss and land degradation, possibly human-induced, accelerated regime shifts².

¹Boivin, N. L., Zeder, M. A., Fuller, D. Q., Crowther, A., Larson, G., Erlandson, J. M., Denham, T., & Petraglia, M. D. (2016). Ecological consequences of human niche construction: Examining long-term anthropogenic shaping of global species distributions. *Proceedings of the National Academy of Sciences*

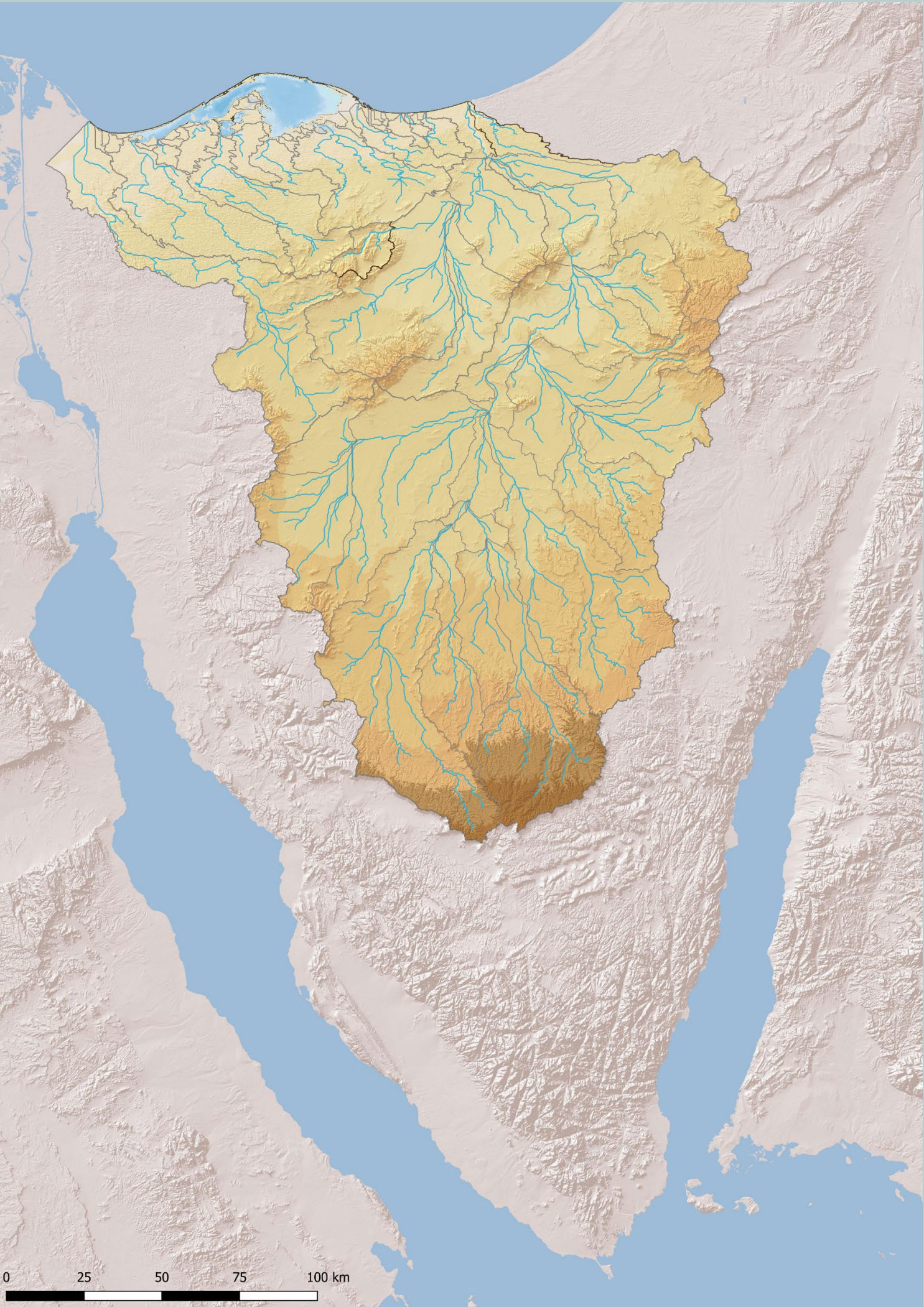
²Pausata, F. S. R., Gaetani, M., Messori, G., Berg, A., Maia de Souza, D., Sage, R. F., & deMenocal, P. B. (2020). The Greening of the Sahara: Past Changes and Future Implications. *One Earth*, 2(3), 235–250

³Wright, D. K. (2017). Humans as agents in the termination of the African humid period. *Frontiers in Earth Science*, 5

Archaeological and ecological data further support the idea that Homo sapiens have long been a keystone species, shaping ecosystems through migration, agriculture, and pastoralism. These interactions altered soil moisture, precipitation, evaporation, and biodiversity at multiple scales³. Modern climate and ecological restoration efforts must therefore be informed by long-term historical and geomorphological context to responsibly navigate the uncertainties of future interventions. Recognizing humanity’s longstanding role in Earth system dynamics opens new possibilities for deliberate, regenerative stewardship of the planet.



Potential routes of human expansion through Arabia during the Pleistocene (yellow arrows) and Middle Paleolithic archaeological sites (Michael D. Petraglia, Paul S. Breeze and Huw S. Groucutt, 2019)

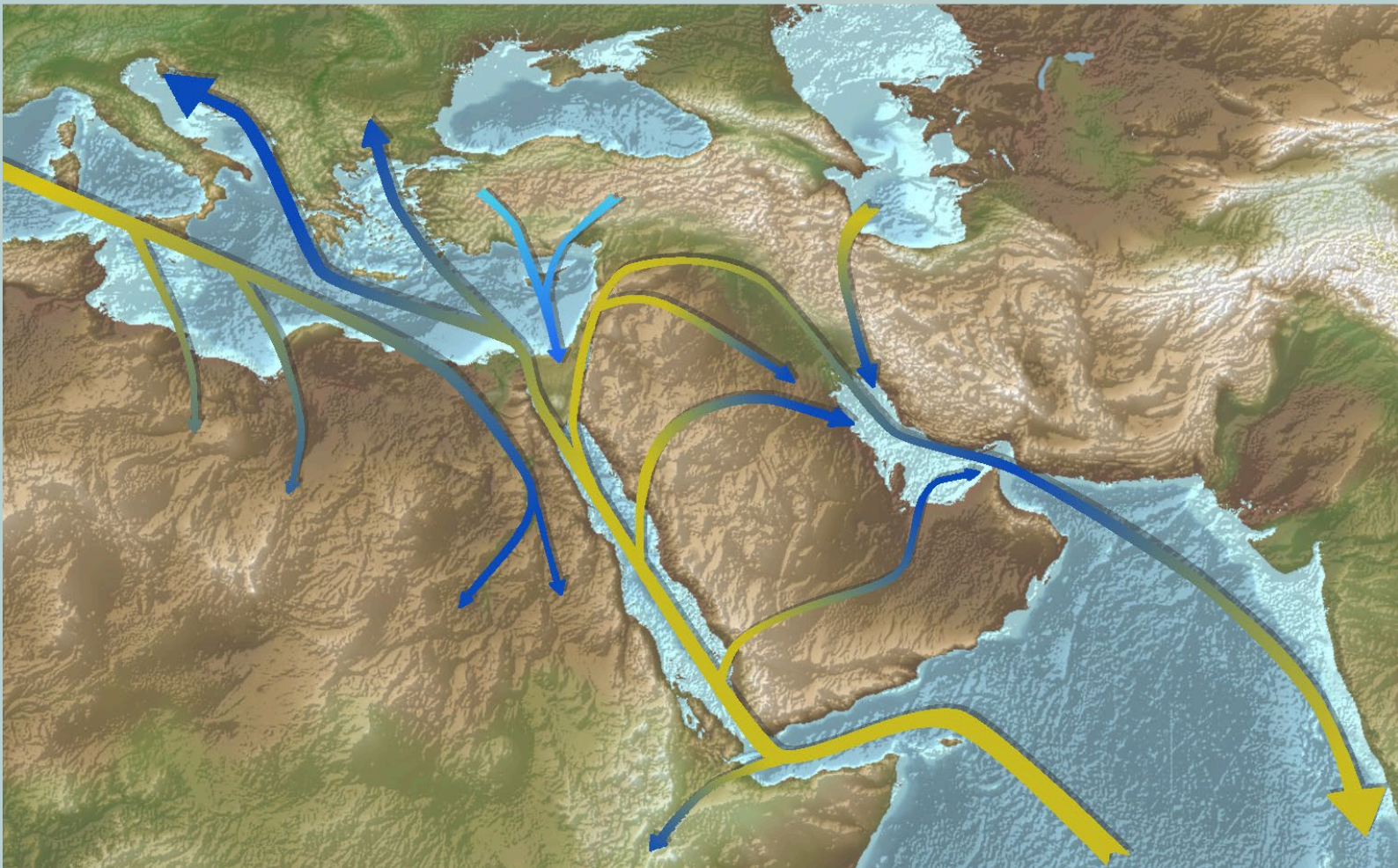
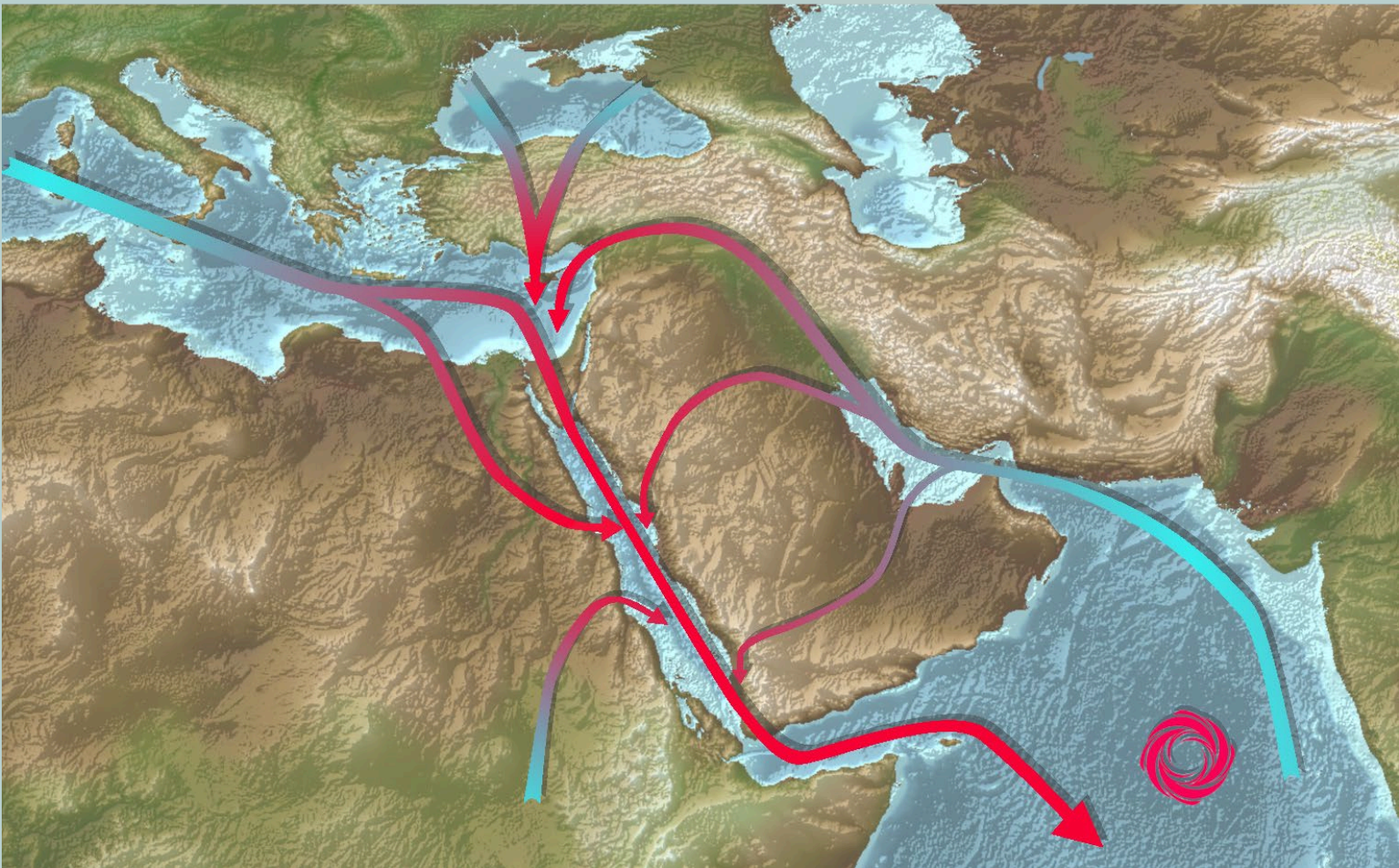
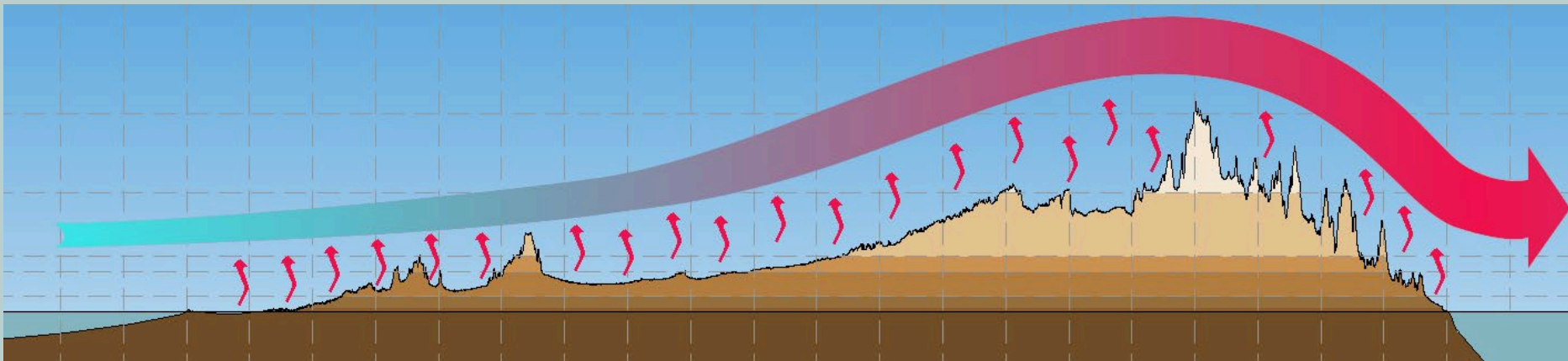
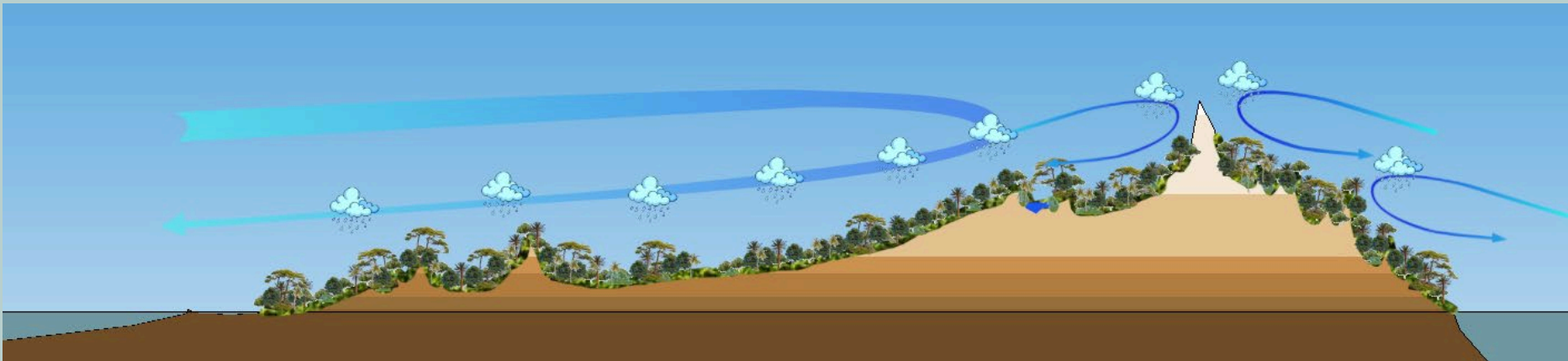


Watersheds of the Sinai discharging into the Mediterranean Sea

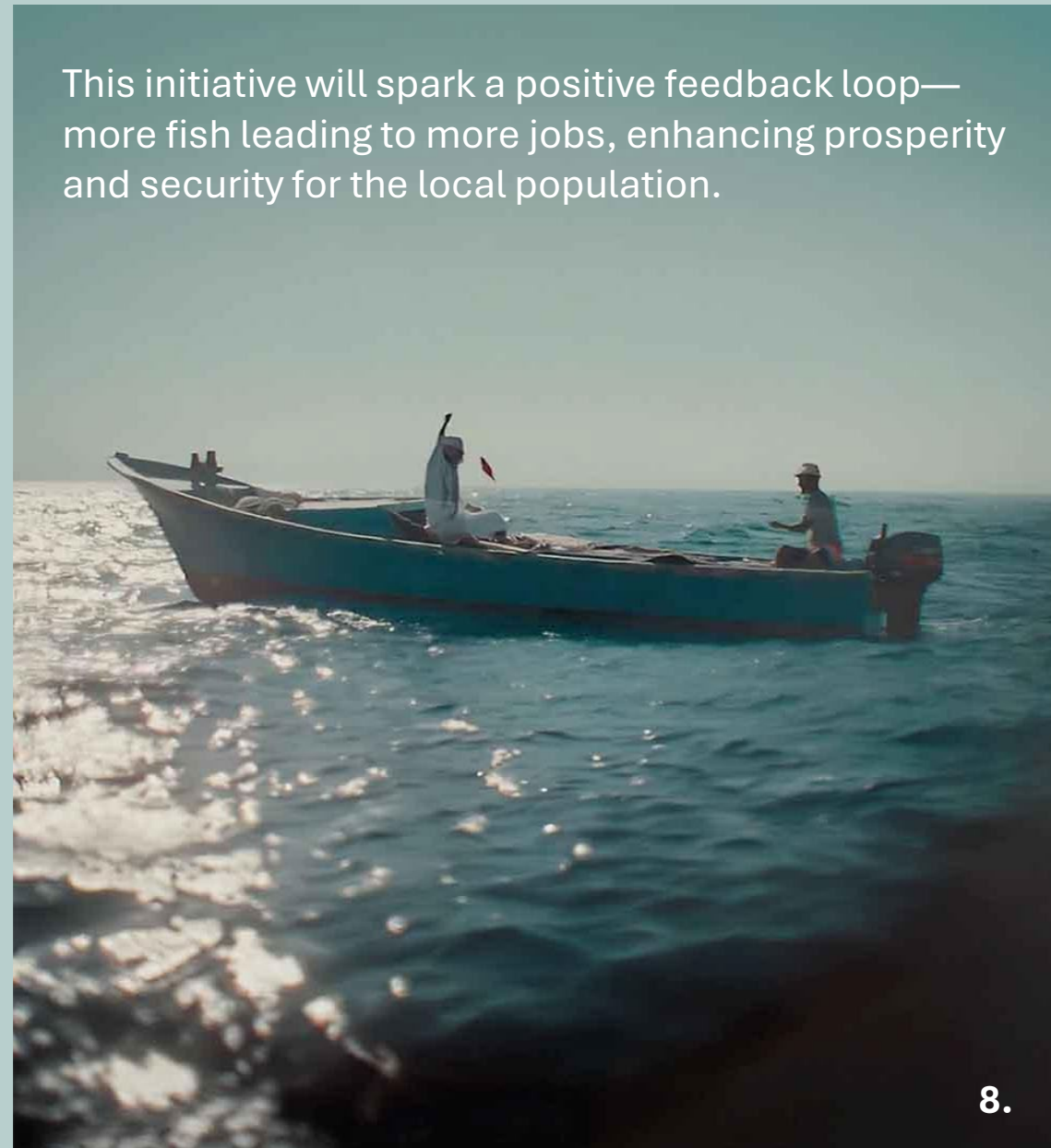
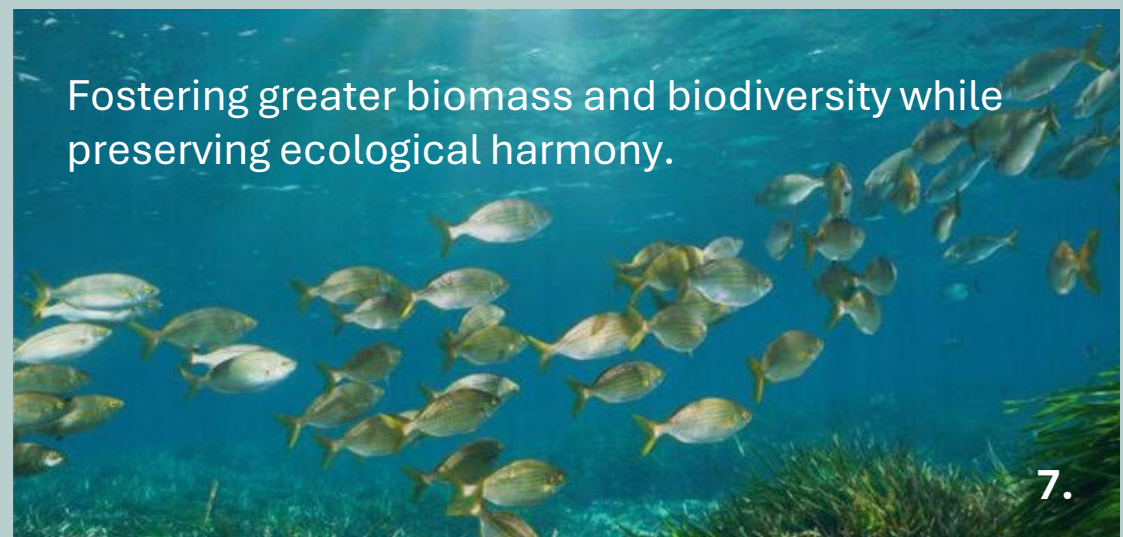
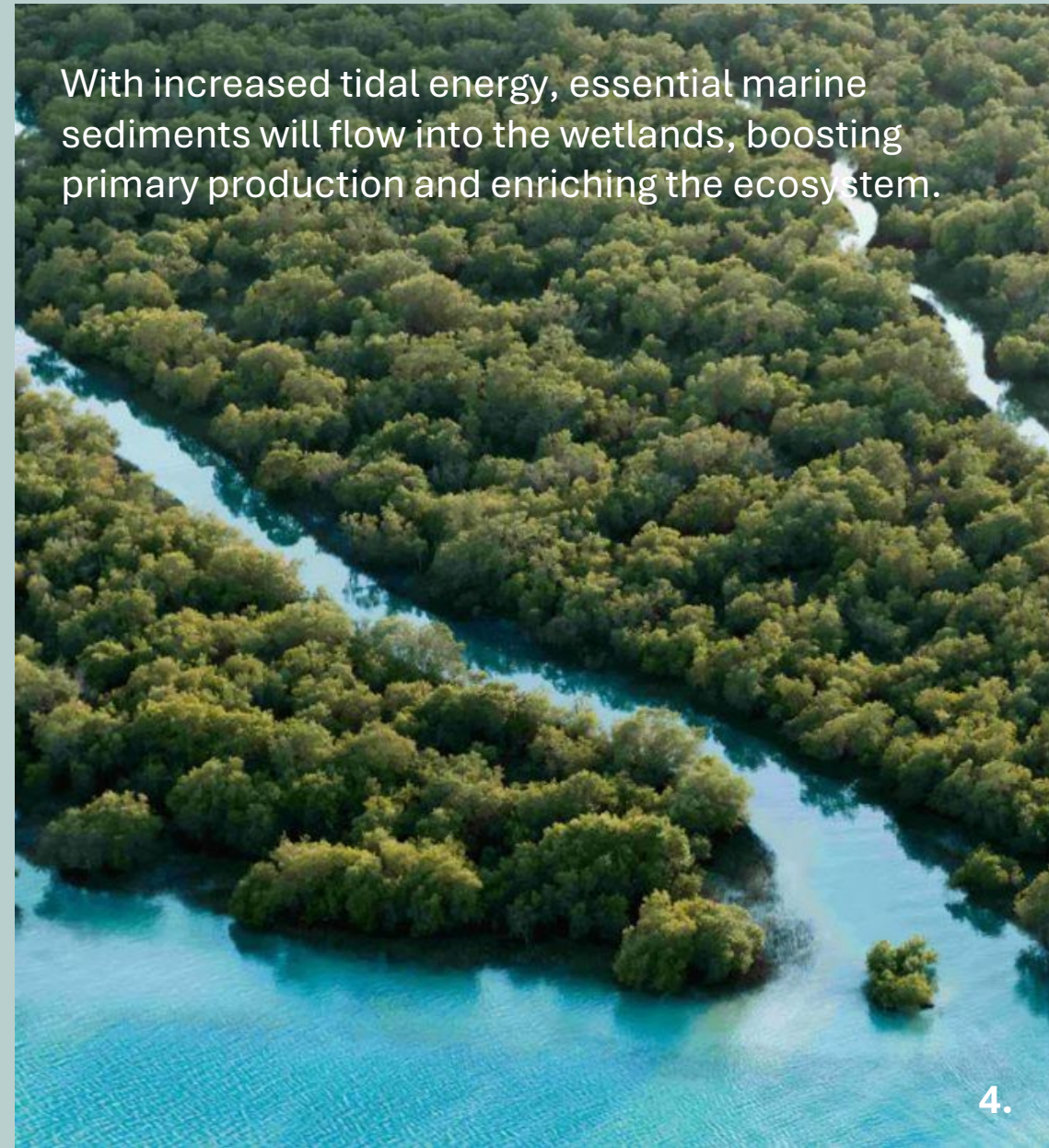
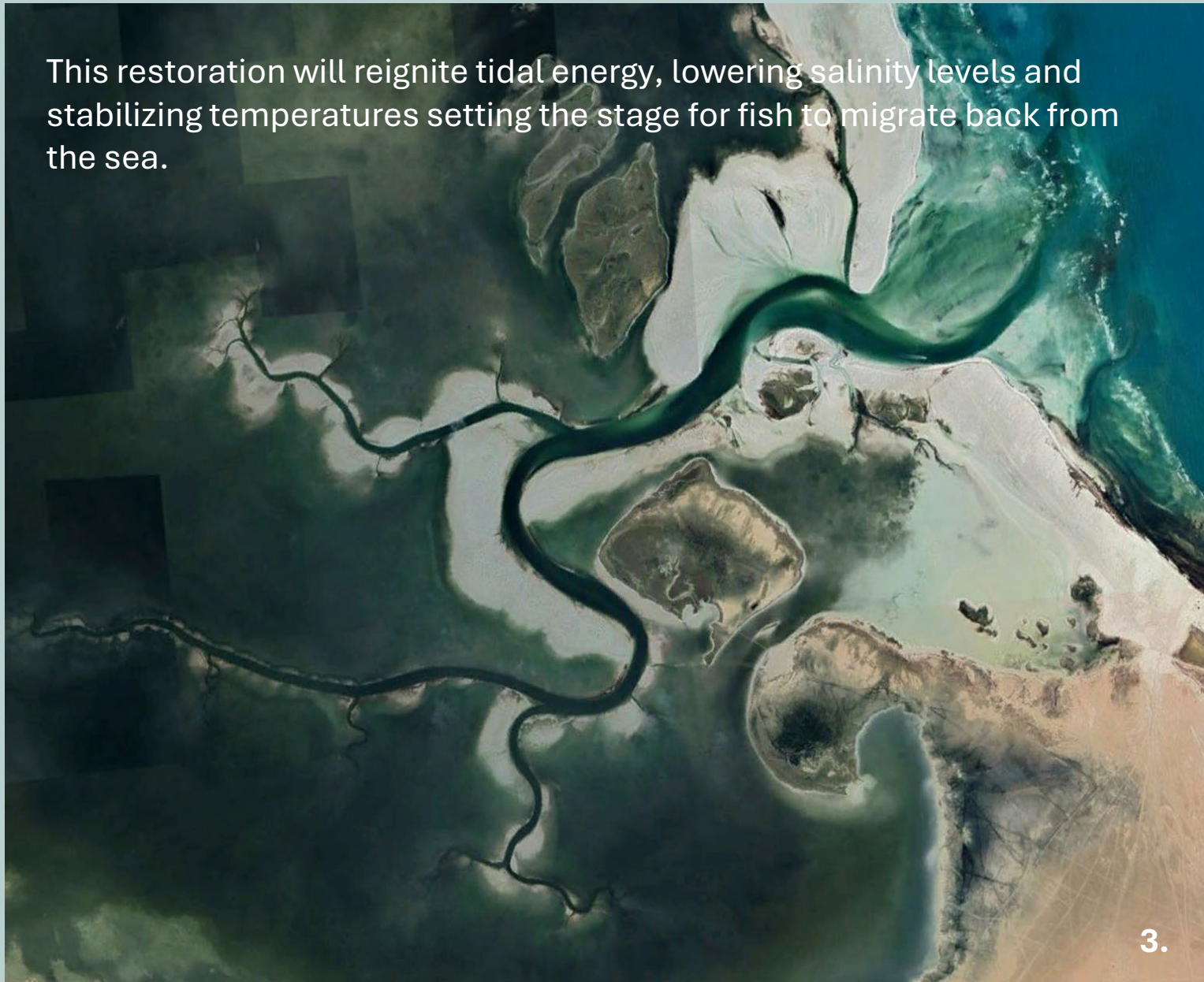
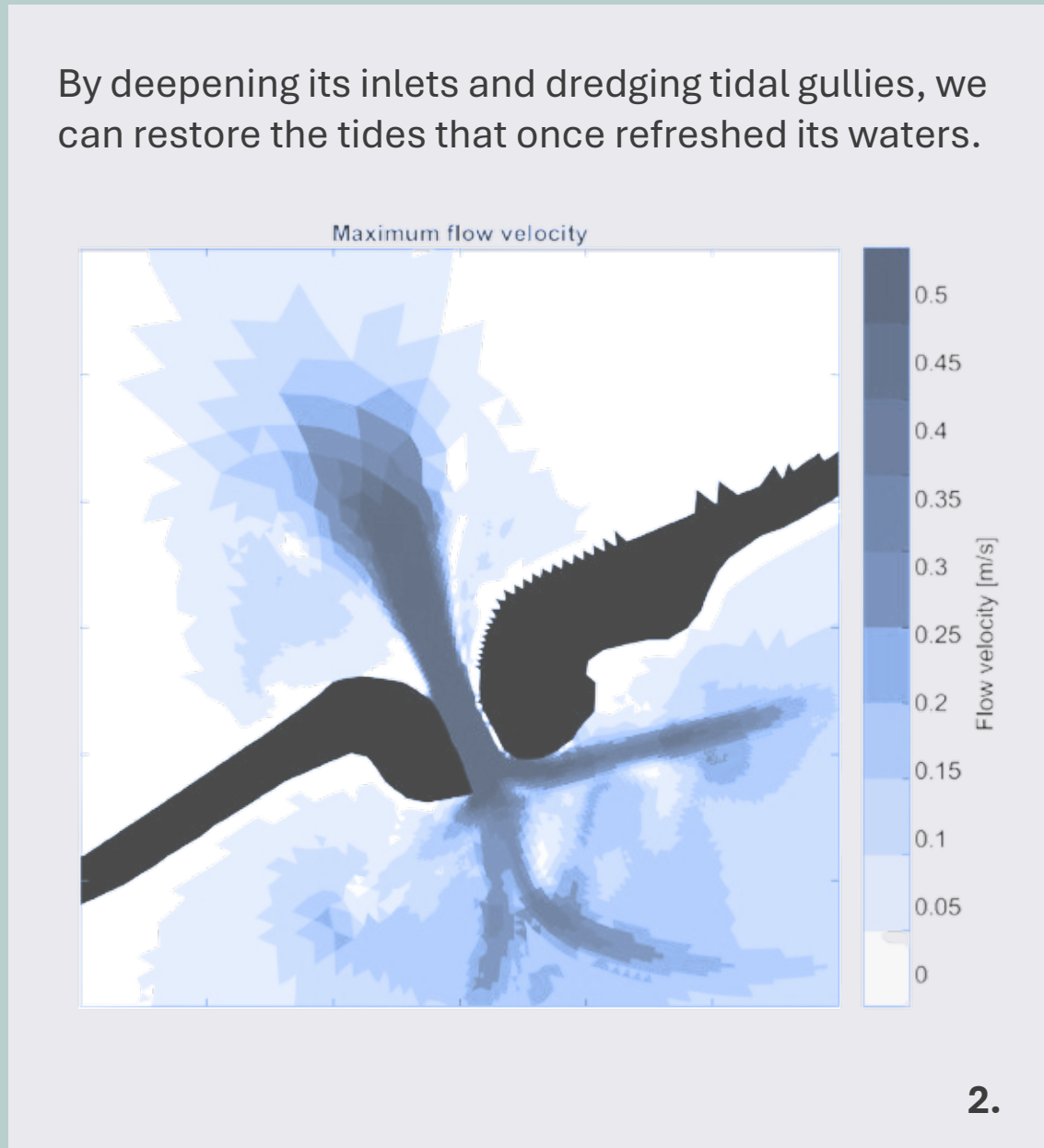
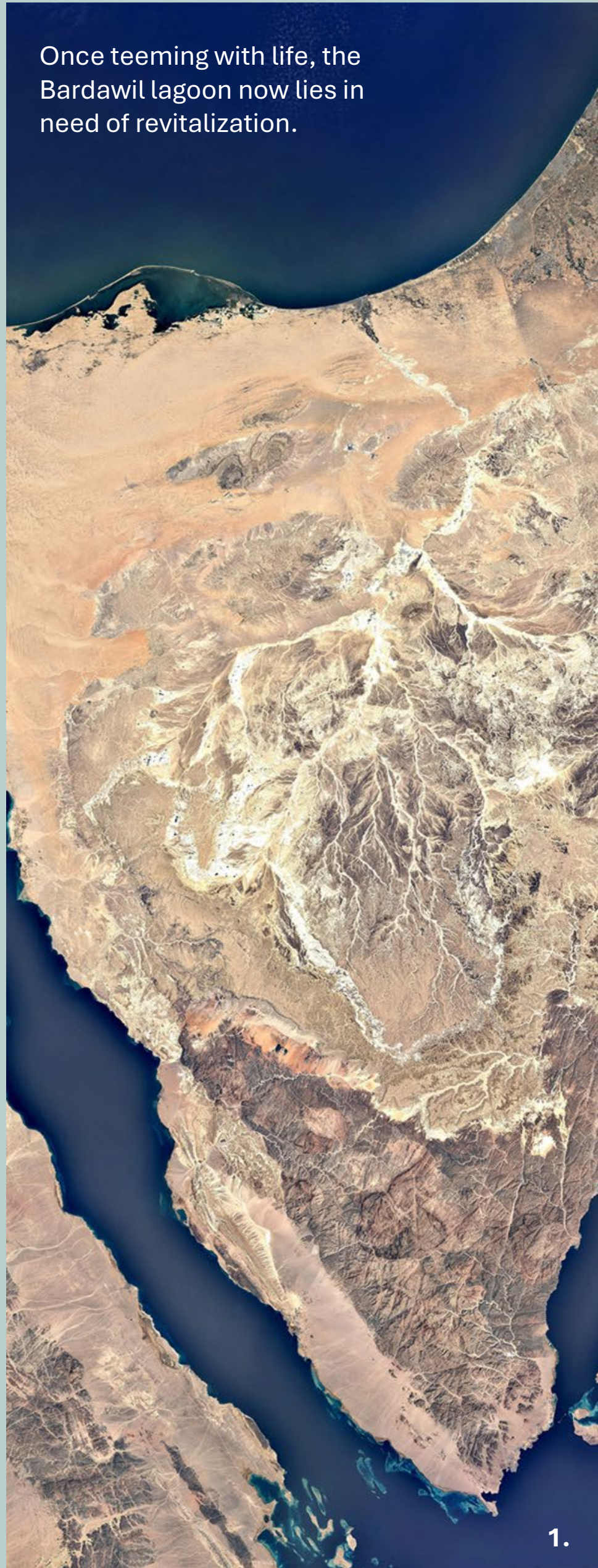
WHAT IF?

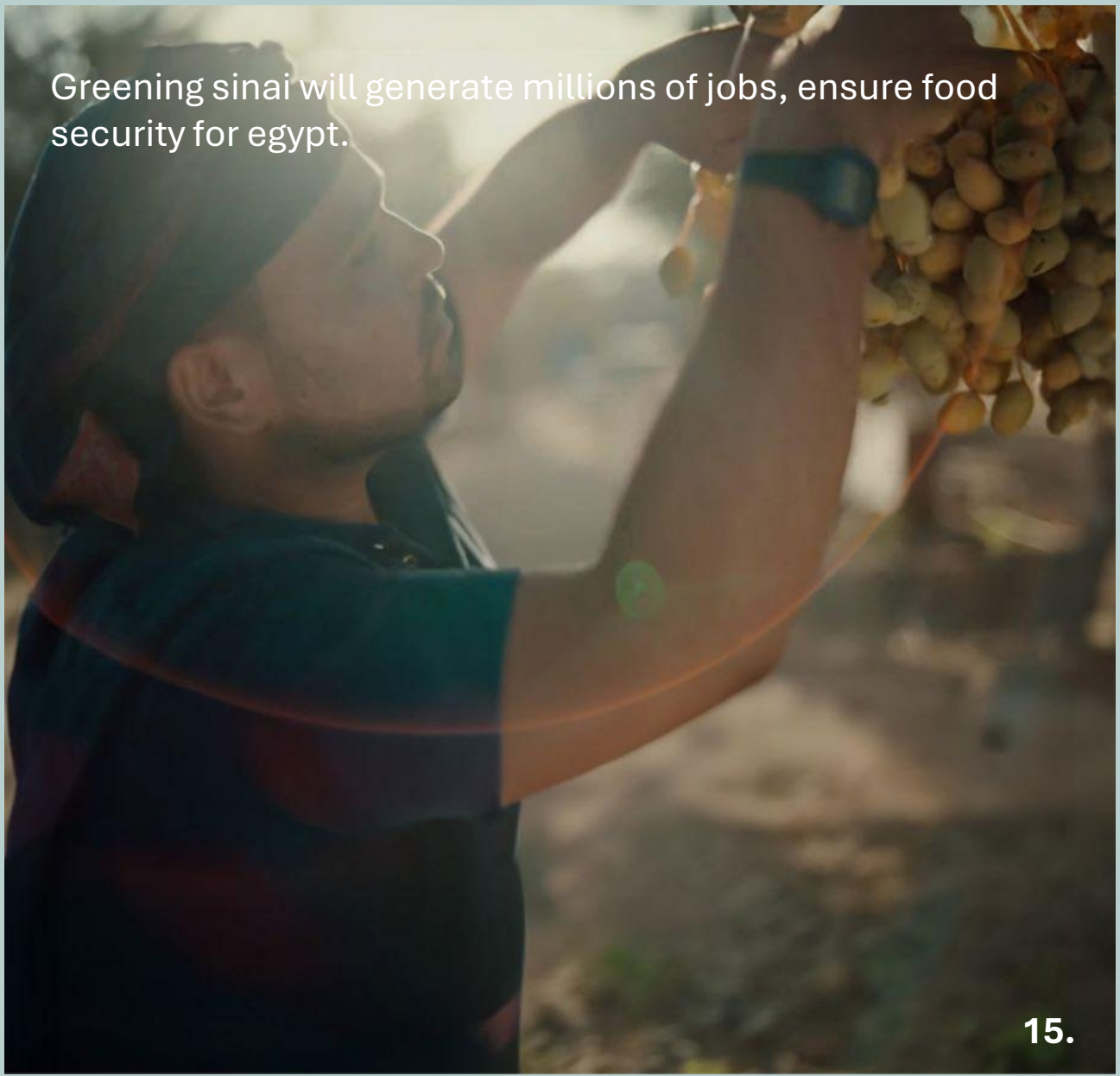
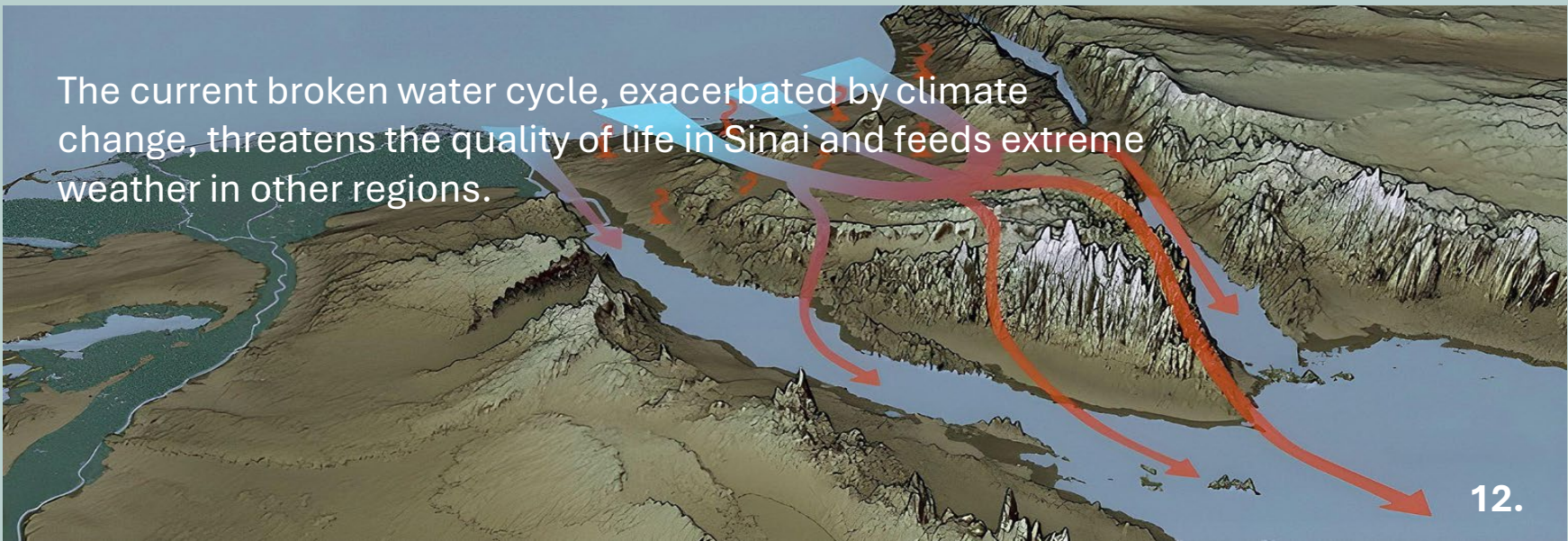
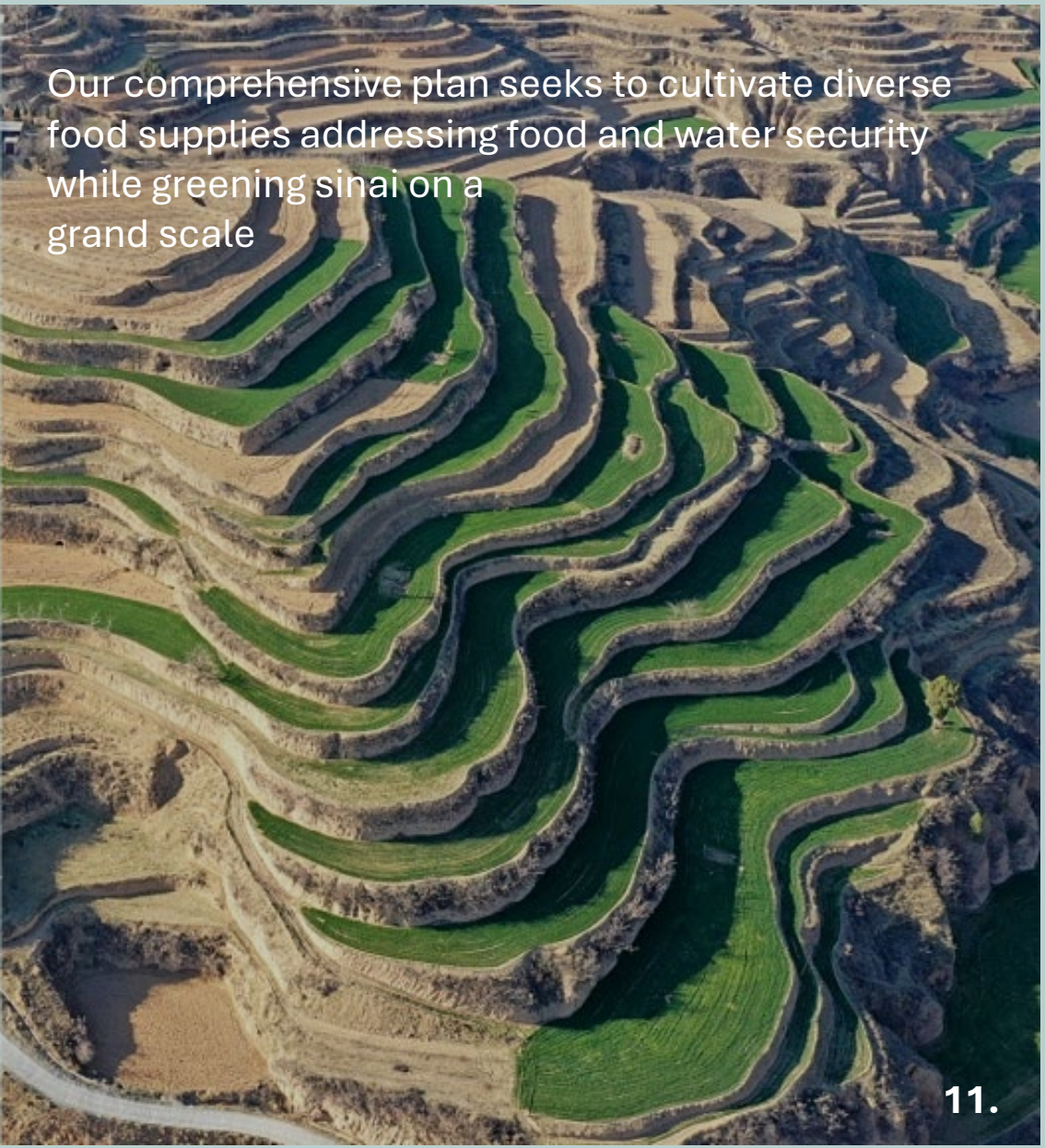
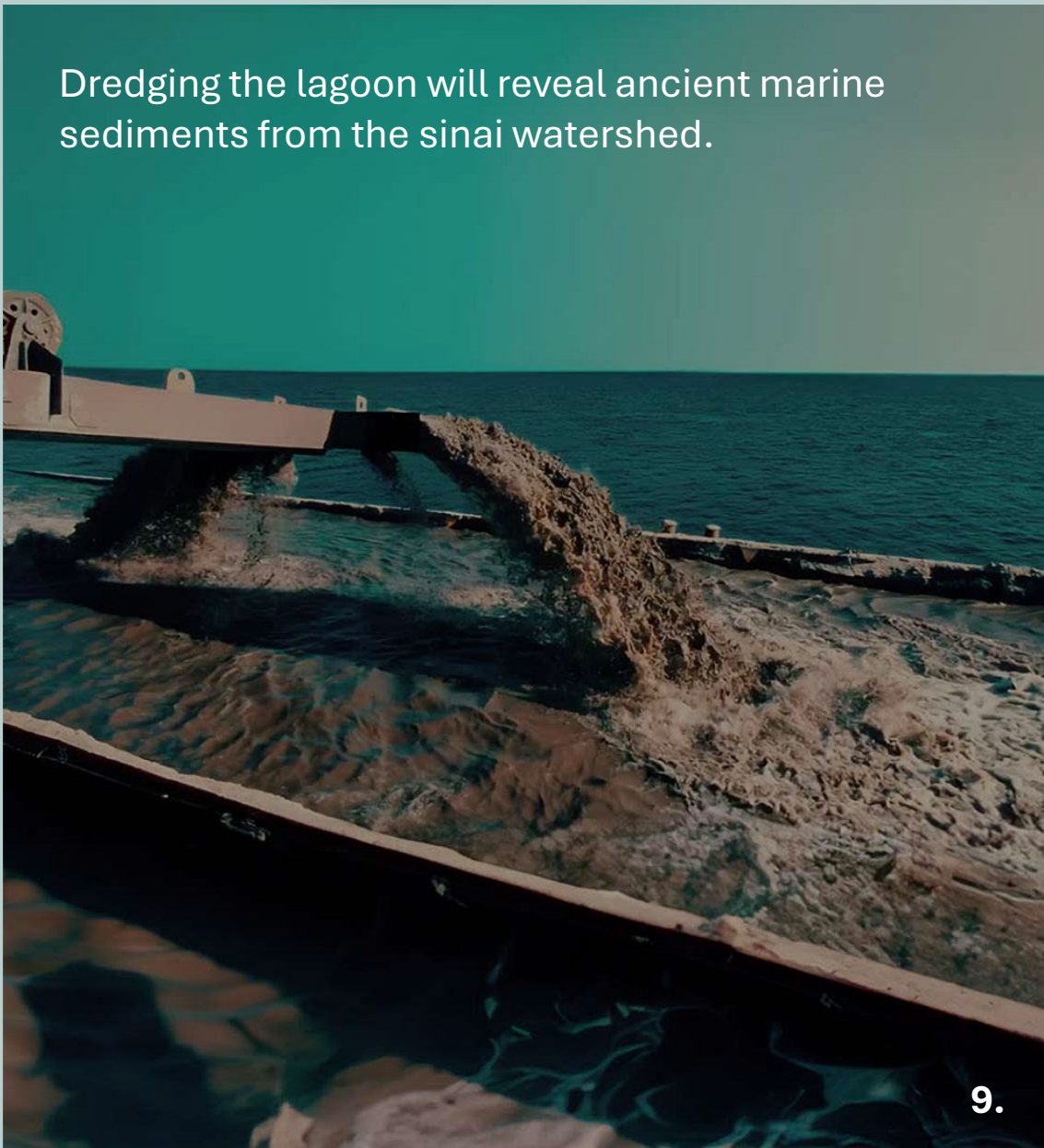
Like many other deserts on Earth, the Sahara (which in bio functionality includes the Sinai Peninsula) have witnessed much wetter conditions in the past. Research suggest that land cover change in the past might be more of a determining factor that has been previously understood¹. The pace of aridification in some portions of northern Africa appears to have been driven by humans in the regions for many millennia, due to pastoralism and de-vegetation². Moreover, an extensive North Sinai floristic and structure survey performed in 2005 and 2006 revealed that the flora of North Sinai has dramatically changed in the past 40-50 years, in which more than 60% of species recorded in previous surveys were no longer found³. If human actions were powerful enough to degrade the climate of such a vast region, they can also be powerful enough to help restore it to a healthier, more vegetated state.

Our hypothesis is that a regreened Sinai Peninsula could significantly alter weather patterns across the wider region. At present, the hot and dry conditions of the Sinai in summer, draw moisture winds from the Mediterranean to the Indian Ocean, where it fuels extreme weather events. A cooler, moister Sinai would reverse the direction of these winds, distributing the moist Mediterranean air more locally. As a result, this could significantly increase the precipitation to surrounding areas like Egypt, western Saudi Arabia, Jordan and beyond.



¹Pausata, F. S. R., Gaetani, M., Messori, G., Berg, A., Maia de Souza, D., Sage, R. F., de Menocal, P. B. 2020. “The Greening of the Sahara: Past Changes and Future Implications.” One Earth 2(3), 235-250.
²Wright, D. K. 2017. “Humans as agents in the termination of the African humid period.” Frontiers in Earth Science.
³Kamel, W. M., Zaghloul, M. S., Abd El-Wahab, R. H., & Moustafa, A.-R. A. 2008. “Current Status of the Flora of North Sinai: Losses and Gains.” Catrina: The International Journal of Environmental Sciences 3(1), 11–26.

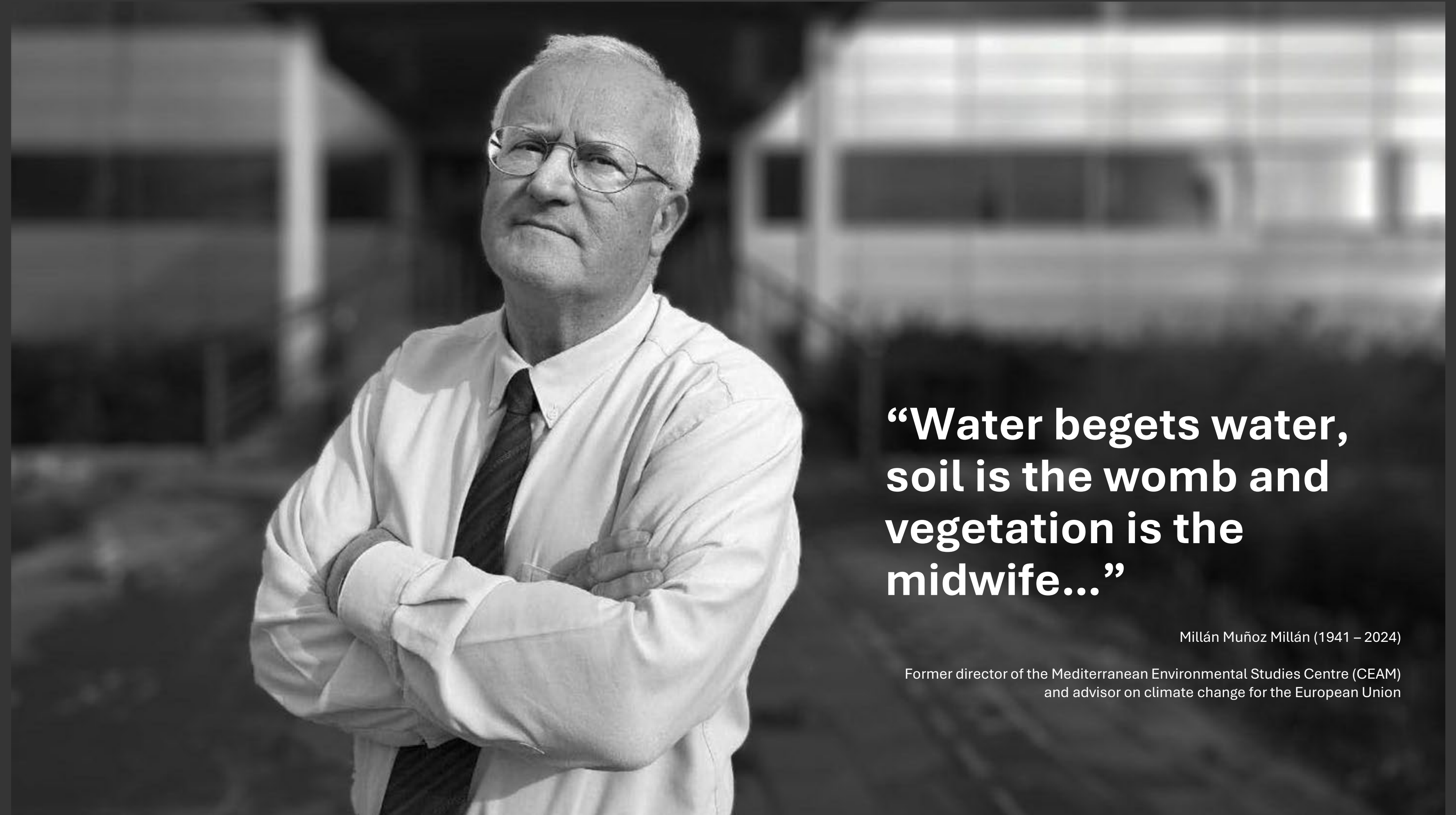




The living landscape as the engine of the water cycle

How much water a landscape can hold is proportional to how much life is in the landscape and soil to hold what arrives in periodic events by rain.

This water, once held, is transpired by vegetation back into the atmosphere to make clouds and rain and balances the water cycle.



**“Water begets water,
soil is the womb and
vegetation is the
midwife...”**

Millán Muñoz Millán (1941 – 2024)

Former director of the Mediterranean Environmental Studies Centre (CEAM)
and advisor on climate change for the European Union

BIOSPHERE REGENERATION PERSPECTIVE

**WATER CYCLE RESTORATION
BY FOSTERING LARGE-SCALE
ECOLOGICAL REGENERATION**

BIOSPHERE REGENERATION PERSPECTIVE

WATER BEGETS WATER

Millán Muñoz Millán (1941 – 2024) used to be director of the Mediterranean Environmental Studies Centre (CEAM) and advisor on climate change for the European Union. He helped us understand that the degrading of our landscapes can lead to a decrease in precipitation recycling and the small water cycle, and to the subsequent loss of rain. He played an important role as advisor to The Weather Makers and as an inspirator for ‘out of the box’ solutions within ecosystem restoration.

Millan graduated from University of Toronto in 1972 with a degree in atmospheric physics, then started working for the National Meteorology Center of Canada studying contaminant dispersion in the atmosphere. In 1991 he became the director of CEAM.

His findings indicated that deforestation, land degradation, and the expansion of impervious surfaces were primary contributors to rain reduction. Grasslands generate less evapotranspiration than forests, and paved areas produce even less than grasslands. As a result, the evapotranspiration needed to supplement ocean-derived moisture and bring atmospheric humidity to the saturation threshold had significantly declined. For precipitation to occur, the atmosphere requires moisture inputs from both the ocean and the land; however, the land-based contribution had been decreasing steadily for decades.



John D. Liu, Millán Millán and Ties van der Hoeven, Valencia 2019

WETSUS - Natural Water Production

Since 2019, Wetsus and The Weather Makers have worked together to deepen their understanding of water cycle restoration. Wetsus, the European centre of excellence for sustainable water technology, focuses on developing innovative solutions that contribute to a sustainable future. Within its broad research program, the “Natural Water Production” (NWP) theme specifically explores the science and technology needed to restore natural water cycles (wetsus.nl/research-themes/natural-water-production/).

Within the NWP theme, the fields of meteorology, hydrology, ecology, and mechanical engineering are brought together. The research is approached from a meteorological and hydrological perspective to understand the processes behind rainfall enhancement and the return of evaporated water as precipitation over land. From an ecological perspective, the focus is on designing strategies to restore a natural water cycle driven by vegetation-based evaporation. The mechanical engineering perspective supports the development of water technologies that enable water cycle restoration in arid regions.

The core focus of the NWP theme is developing technology to enhance atmospheric moisture and increase regional rainfall. By strategically using water technology to evaporate seawater in coastal areas, the resulting moisture can return as rainfall over land, helping to improve freshwater availability.

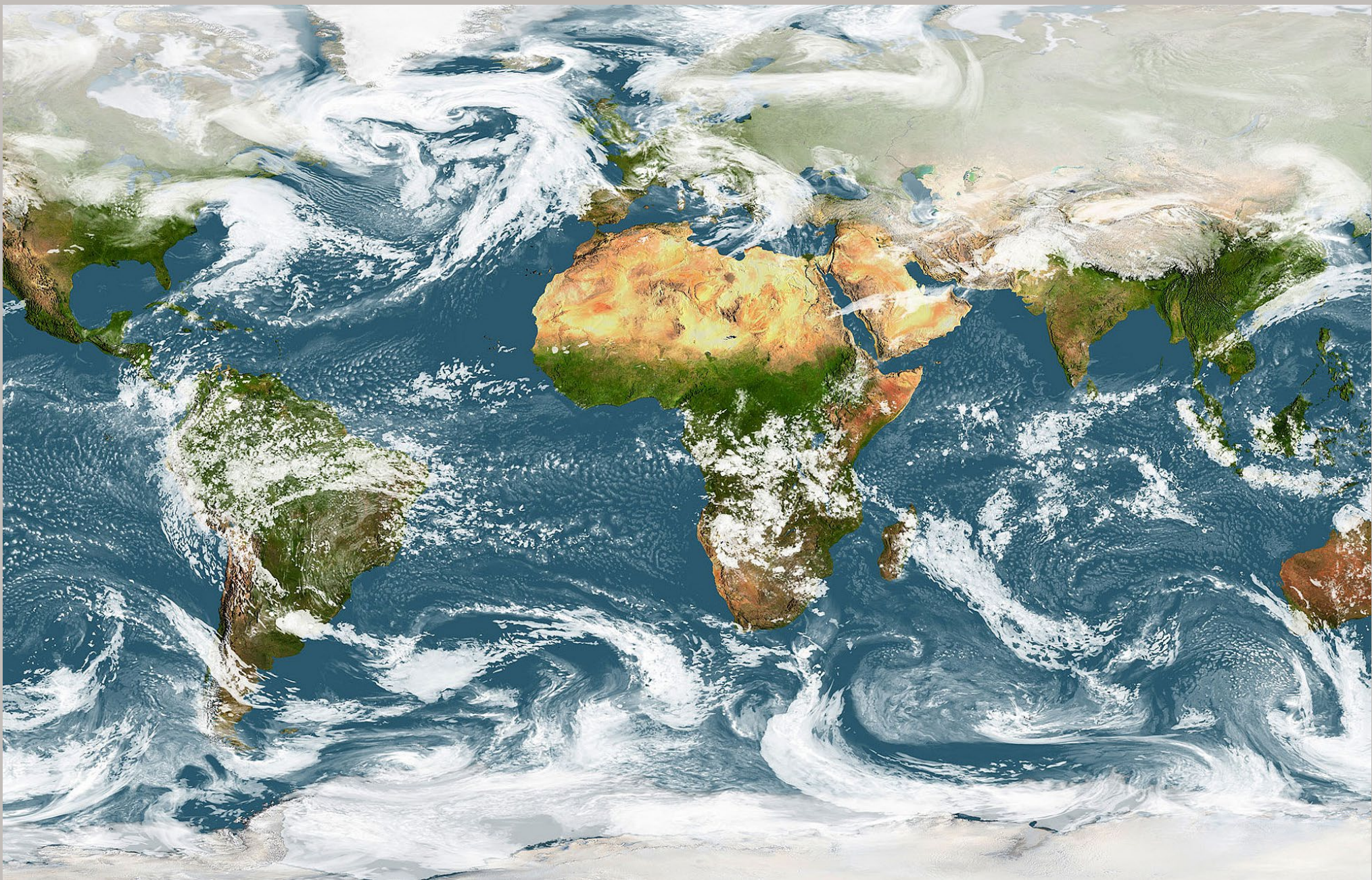


BIOSPHERE REGENERATION PERSPECTIVE

LAND AND ATMOSPHERIC DYNAMICS

Climate stability depends on biologically driven water and energy cycles, which must be restored alongside emissions reductions to truly rebalance the Earth system¹. The biosphere, which encompasses all life on Earth, plays a crucial role in regulating climate by influencing the carbon, water, and energy cycles². Powered by solar energy, the biosphere determines how much incoming radiation is reflected or absorbed, shaping Earth’s surface temperature and driving key processes like evapotranspiration³. This process, where water moves from the land to the atmosphere through plant transpiration and soil evaporation, uses more than half of incoming solar energy and is largely controlled by vegetation⁴. These water and energy exchanges occur at the atmospheric boundary layer, affecting local weather and global climate. Changes in land cover, such as deforestation or degradation, can alter surface properties like albedo and roughness, reducing evapotranspiration and shifting rainfall patterns⁵. These changes disrupt the natural feedback loops that stabilize the climate, often in ways that carbon metrics alone cannot fully capture. The loss of vegetative cover and its effects on energy fluxes have significantly contributed to climate change and extremes⁶. The impacts are highly location-specific, making it essential to design land restoration efforts based on local water cycles, ecosystem behaviour, and an understanding of regional climate interactions.

Afforestation can enhance terrestrial precipitation by increasing atmospheric humidity and reinforcing local moisture recycling, as seen on China’s Loess Plateau⁷. Vegetation-driven processes like evapotranspiration support cloud formation, although they may reduce water yield. The biotic pump theory proposes vegetation-driven atmospheric motion, yet the mechanisms of moisture transport remain debated. Small-scale processes—often missed by global climate models—are critical. Advancing afforestation as a climate strategy requires interdisciplinary research, improved observations, and integrated modelling to ensure positive regional water and climate outcomes⁸.



¹Kool, J., Rose, S., Wright, D.K., van der Hoeven, T., Hatim, M,Z. (2022). A strategic ‘living systems’ approach to climate stabilization.

²Gettelman, A., & Rood, R. B. (2016). Components of the Climate System (pp. 13–22). https://doi.org/10.1007/978-3-662-48959-8_2

³Moon, M., Li, D., Liao, W., Rigden, A. J., & Friedl, M. A. (2020). Modification of surface energy balance during springtime: The relative importance of biophysical and meteorological changes. *Agricultural and Forest Meteorology*, 284, 107905. <https://doi.org/10.1016/J.AGRFORMET.2020.107905>

⁴Trenberth, K. E., Fasullo, J. T., & Kiehl, J. (2009). Earth’s Global Energy Budget. *Bulletin of the American Meteorological Society*, 90(3), 311–324. <https://doi.org/10.1175/2008BAMS2634.1>

⁵Keys, P. W., Wang-Erlandsson, L., & Gordon, L. J. (2016). Revealing Invisible Water: Moisture Recycling as an Ecosystem Service. *PLOS ONE*, 11(3), e0151993. <https://doi.org/10.1371/journal.pone.0151993>

⁶Sy, S., & Quesada, B. (2020). Anthropogenic land cover change impact on climate extremes during the 21st century. *Environmental Research Letters*, 15(3), 034002. <https://doi.org/10.1088/1748-9326/AB702C>

⁷Zhang, B., Tian, L., Zhao, X., & Wu, P. (2021). Feedbacks between vegetation restoration and local precipitation over the Loess Plateau in China. *Science China Earth Sciences* 2021 64:6, 64(6), 920–931. <https://doi.org/10.1007/S11430-020-9751-8>

⁸Theeuwens, Jolanda JE, et al. (2025). "Forestation tends to create favourable conditions for convective precipitation in the Mediterranean Basin." *EGUsphere* 2025 (2025): 1-35.

BIOSPHERE REGENERATION PERSPECTIVE

LOCAL MOISTURE RECYCLING

Precipitation is the only sustainable source of freshwater, enhancing rainfall over land is essential. Although no universal strategy exists due to variations in landscape, climate, and geography, certain key factors, such as evaporation, can be leveraged to support rainfall¹. Contrary to past assumptions, vegetation does influence local and regional rainfall. Plants play a vital role in transporting moisture from oceans inland and maintaining rainfall through evapotranspiration. This process adds moisture to passing air masses, increasing the likelihood of condensation and precipitation^{2,3}. Understanding where rainwater originates, known as the "precipitation shed", helps inform water governance and land management. In many areas, land-based evaporation supplies much of the rain that falls inland. Loss of vegetation and degraded land surfaces reduce this evapotranspiration, threatening rainfall stability and water availability. Moisture recycling over land is a powerful feedback loop: water evaporates from land, contributes to cloud formation, and returns as precipitation. In some major river basins, the majority of rainfall comes from land-based evaporation. Studies show that restoring vegetation can reactivate this cycle, making rainfall a modifiable and recoverable resource through thoughtful land cover management.

An increase in vegetation enhances the interception on rainfall. This water can easily re-evaporate. The re-evaporation of intercepted precipitation positively correlates with local moisture recycling⁴. Re-evaporation of intercepted water, compared to transpiration, typically travels shorter distances through the atmosphere before it returns as precipitation to land⁵.

Vegetation strengthens the hydrological cycle. With an increase in vegetation, evaporation will increase. As a result, the water vapor content of the air increases which promotes rainfall, and therefore moisture recycling. For semi-arid regions, moisture recycling seems to be essential to prevent local drying.



¹Anthes, R. A. (1984). Enhancement of Convective Precipitation by Mesoscale Variations in Vegetative Covering in Semiarid Regions. *Journal of Climate and Applied Meteorology*, 23(4), 541–554. [https://doi.org/10.1175/1520-0450\(1984\)023<0541:EOCPBM>2.0.CO;2](https://doi.org/10.1175/1520-0450(1984)023<0541:EOCPBM>2.0.CO;2)

²Keys, P. W., Wang-Erlandsson, L., & Gordon, L. J. (2016). Revealing Invisible Water: Moisture Recycling as an Ecosystem Service. *PLOS ONE*, 11(3), e0151993. <https://doi.org/10.1371/journal.pone.0151993>

³Millán, M. M., Estrela, M. J., Sanz, M. J., Mantilla, E., Martín, M., Pastor, F., Salvador, R., Vallejo, R., Alonso, L., Gangoiti, G., Ilardia, J. L., Navazo, M., Albizuri, A., Artíñano, B., Ciccioli, P., Kallos, G., Carvalho, R. A., Andrés, D., Hoff, A., ... Versino, B. (2005). Climatic Feedbacks and Desertification: The Mediterranean Model. *Journal of Climate*, 18(5), 684–701. <https://doi.org/10.1175/JCLI-3283.1>

⁴Theeuwens, Jolanda J.E., et al. (2024). "Ecohydrological variables underlie local moisture recycling in Mediterranean-type climates." *Journal of Geophysical Research: Biogeosciences* 129.10 (2024): e2024JG008286

⁵Van der Ent, R. J., et al. (2014). "Contrasting roles of interception and transpiration in the hydrological cycle–Part 2: Moisture recycling." *Earth System Dynamics* 5.2 (2014): 471-489.

BIOSPHERE REGENERATION PERSPECTIVE

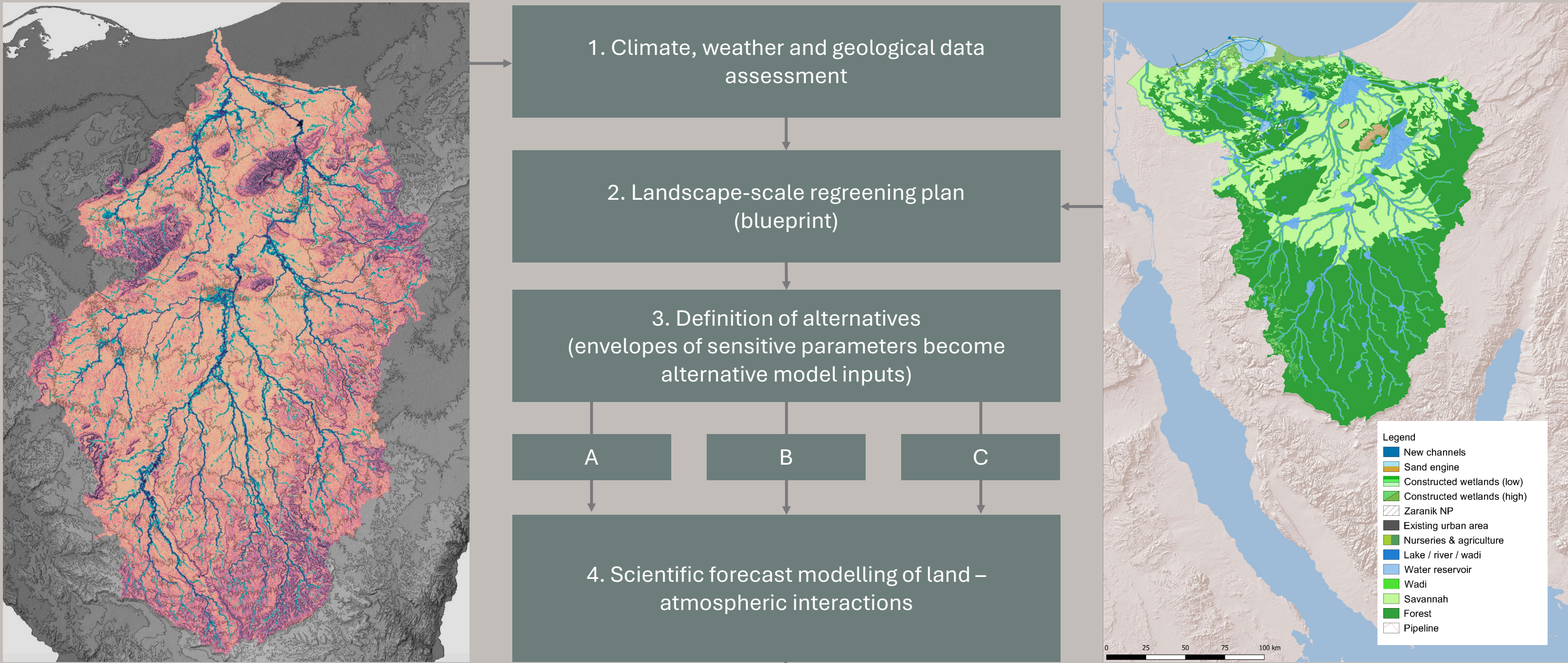
FURTHER RESEARCH - THE NATURAL WATER PRODUCTION THEME OF WETSUS

To better understand the hydrological effects of the evaporation technology and vegetation it is desirable to quantify their impact on precipitation, not only locally but also non-locally. The large eddy simulation model is the first step into quantifying the impact of the technologies and vegetation on precipitation. However, a more complex model needs to be used to better understand the impact of the evaporation technologies and vegetation on different atmospheric processes. Currently we focus on the processes within the ABL, however, other weather events that result in precipitation and take place on the meso-scale may also be affected by these technologies and vegetation. Such processes and phenomena can be studied using regional or global weather models.

BECOME A THEME MEMBER

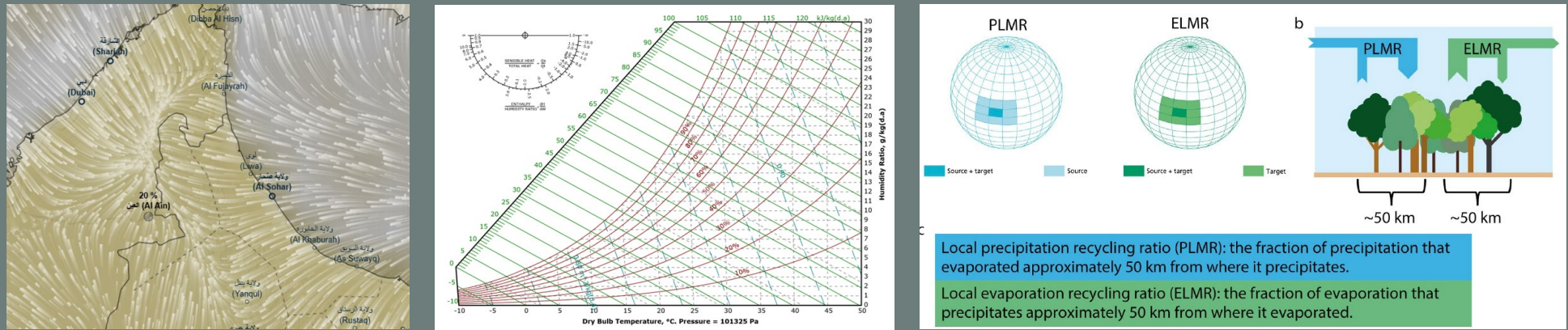
To become a member of the natural water production research theme and support a PhD project in this theme, a 4-year commitment is needed of 66 kEur/yr. All further costs of the project are covered by WETSUS, being 3x more. The funding scheme of WETSUS including the contribution of the company member would cover all costs for an entire PhD project.

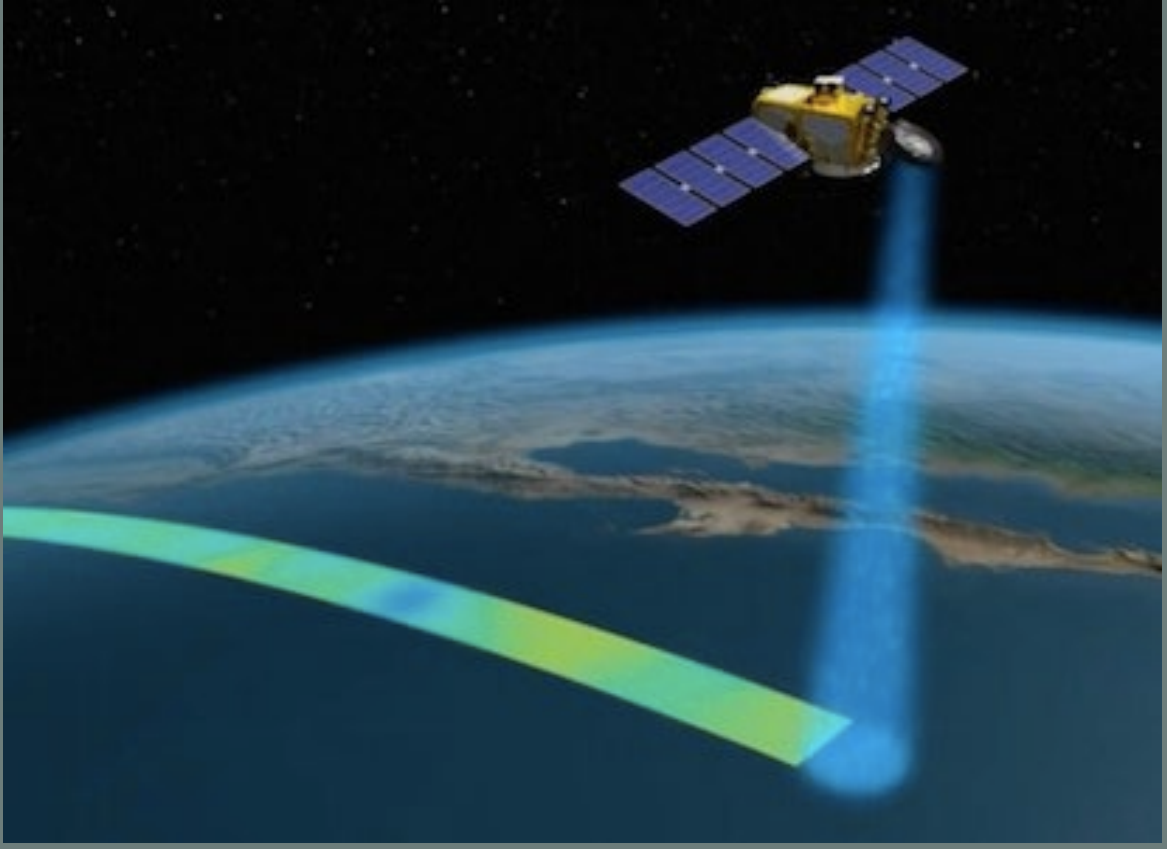
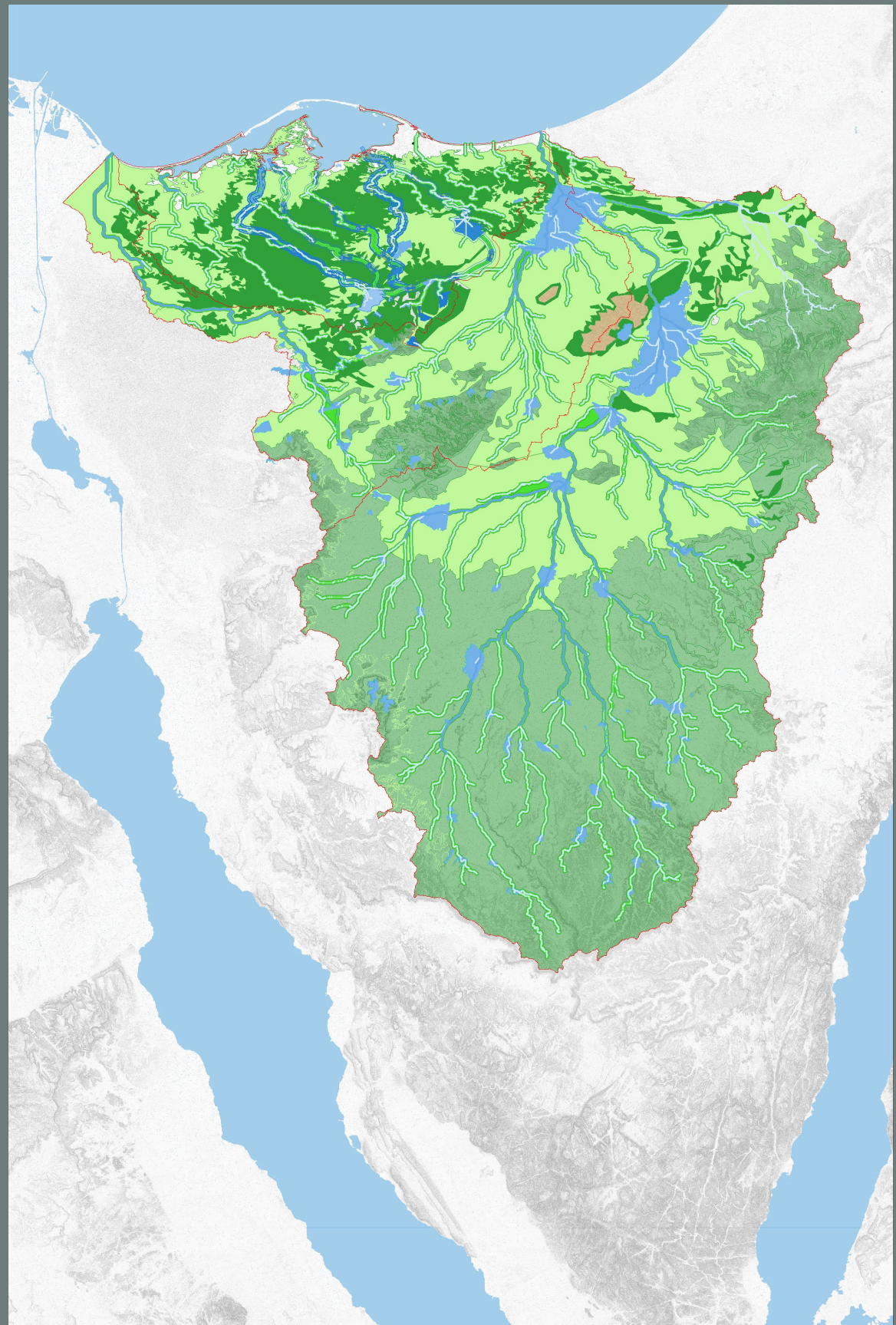
The company member will be part of the Natural Water Production theme, in which the projects regarding meteorology, solar evaporation and greening take place. Next to the donor one other company is funding the research. All parties have access to all results of all the projects.



Atmospheric models are used to describe the local land-atmospheric interactions to predict the performance in terms of rain and validate the design. Models suitable for judging water cycle restoration potential seem to be missing. In the past 4 years TWM and WETSUS have developed several models to bridge this gap:

- Moisture Tracking models;
- Atmospheric Boundary Layer based models;
- Turbulence models
- Case studies for validation by machine Learning





BIOSPHERE REGENERATION STRATEGY

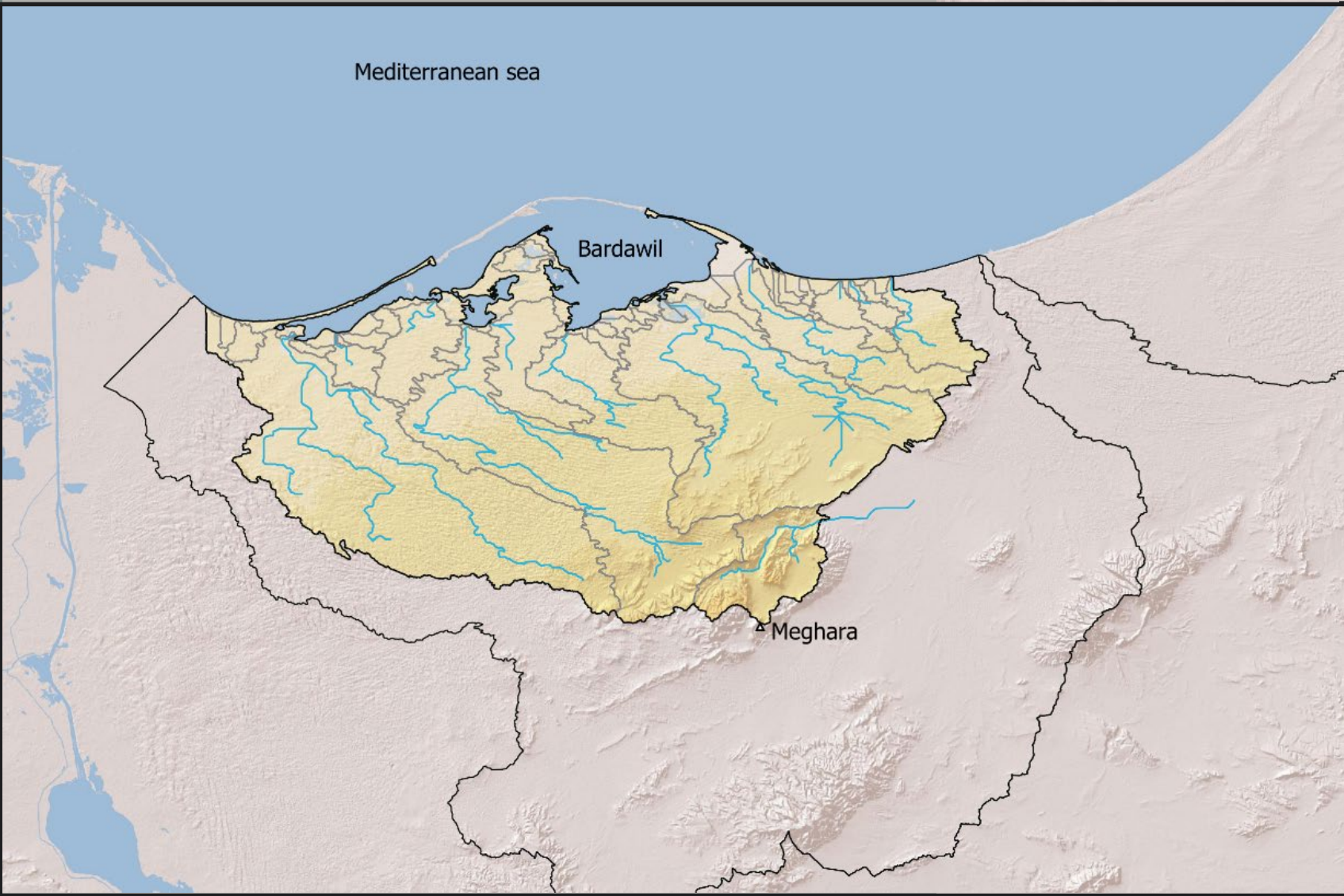
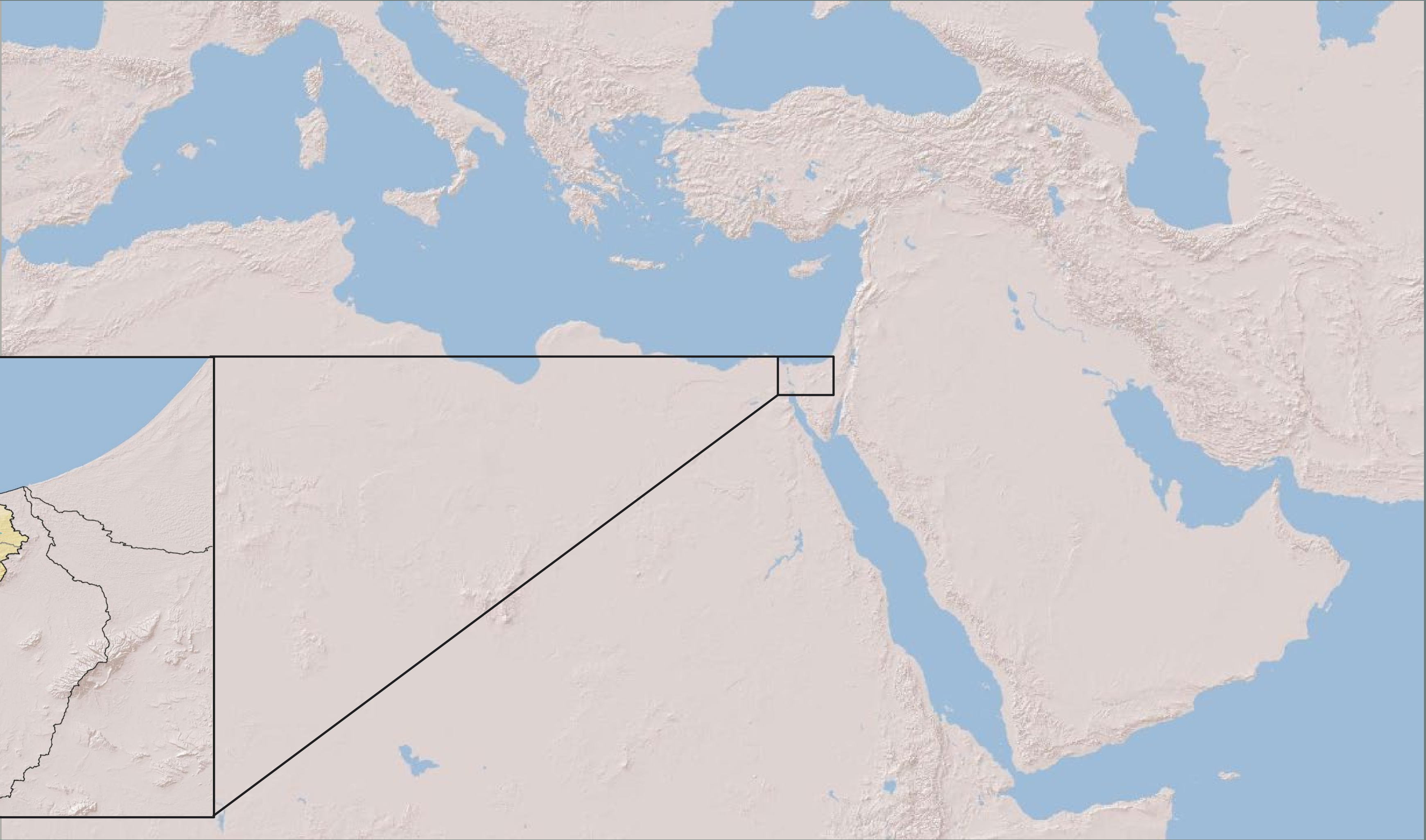
BLUEPRINT TRANSFORMATION OF THE BARDAWIL & MAGHARA AREA

BIOSPHERE REGENERATION STRATEGY

BLUEPRINT TRANSFORMATION OF BARDAWIL & MAGHARA AREA

The Bardawil – Maghara area has a size of 5,000 km² and consists of Lake Bardawil lagoon connected to the Mediterranean Sea, the Maghara mountains in the south and a relative flat dune landscape in between.

We have developed a regeneration strategy for this area, suitable to expand to the whole Sinai Peninsula.

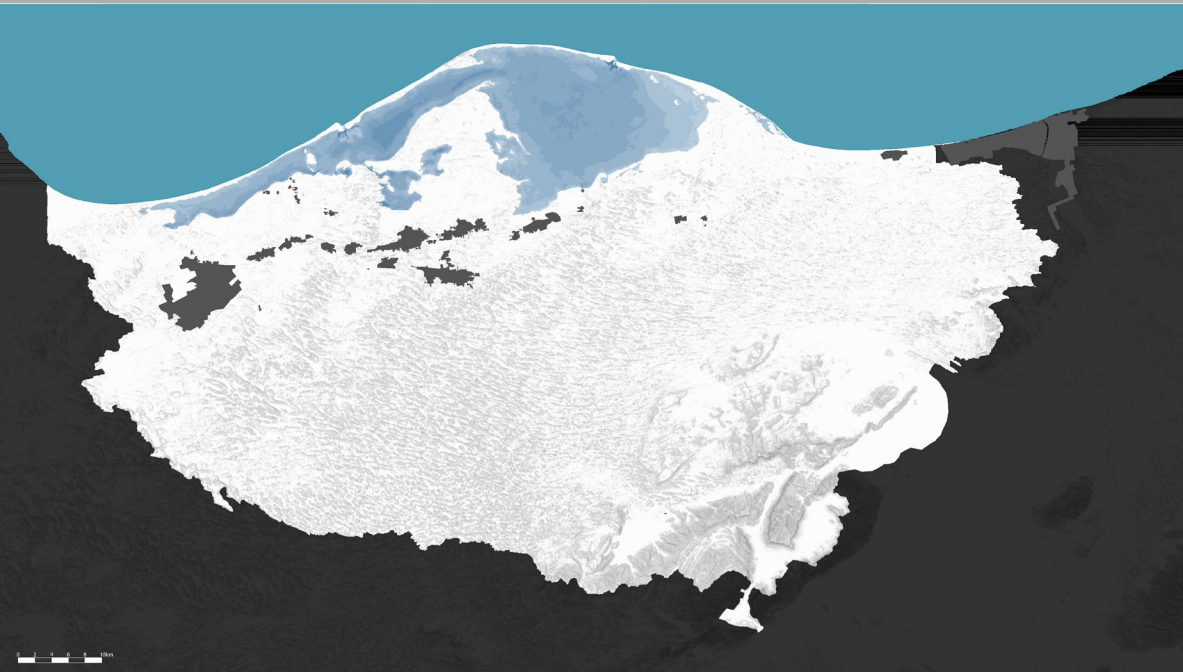


BIOSPHERE REGENERATION STRATEGY

PROPOSED ROADMAP FOR TRANSFORMATION OF BARDAWIL & MAGHARA AREA

VISION FOR MAGHARA

Large-scale biosphere regeneration requires a combination of diverse interventions and solutions that together form a coherent and integrated strategy. No single action is sufficient on its own, rather, a mix of approaches must work in harmony. These strategies complement one another, enhancing both ecological function and human well-being while addressing climate, biodiversity, and water challenges at the same time. Starting with context-specific, small-scale actions that are locally informed and community-driven, these interventions can be adapted, scaled, and connected across regions. This stepwise approach enables a holistic regeneration model that restores degraded ecosystems, supports resilient livelihoods, and contributes to environmental stability over time.



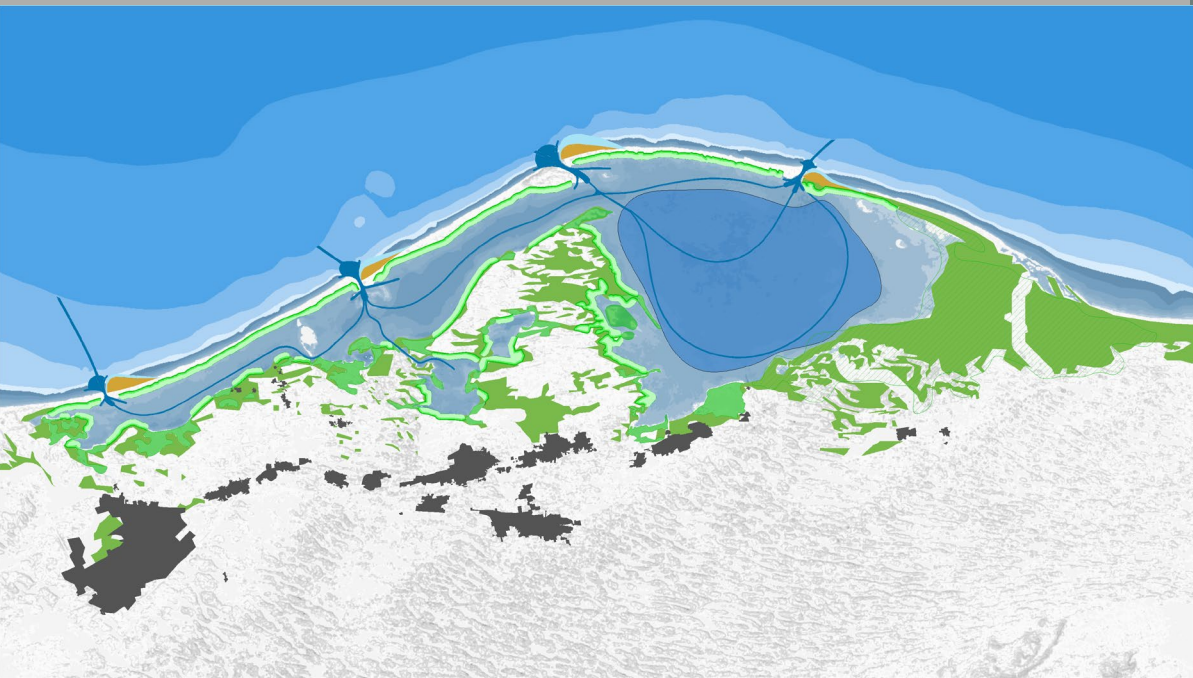
COASTAL REGENERATION

KEY INTERVENTIONS

- Dredging of inlets and gullies to improve water quality for the marine ecosystem
- Restoration and expansion of wetland habitats and coastal reinforcements
- Improve and expand sustainable fishing practices, capacity building and training
- Develop (international) fish supply chain and related industries

KEY BENEFITS

- Growth of sustainable fish catch industry
- Jobs in lagoon management, tourism and related industries
- Increase of biodiversity in water and on land
- Carbon sequestration



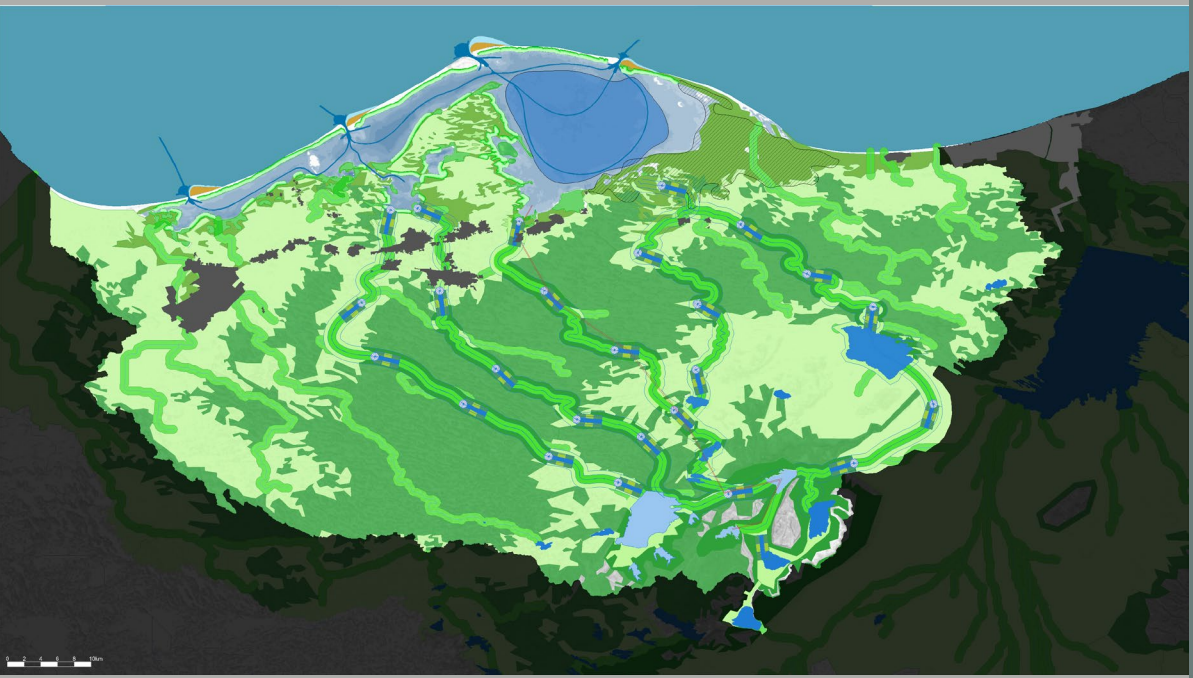
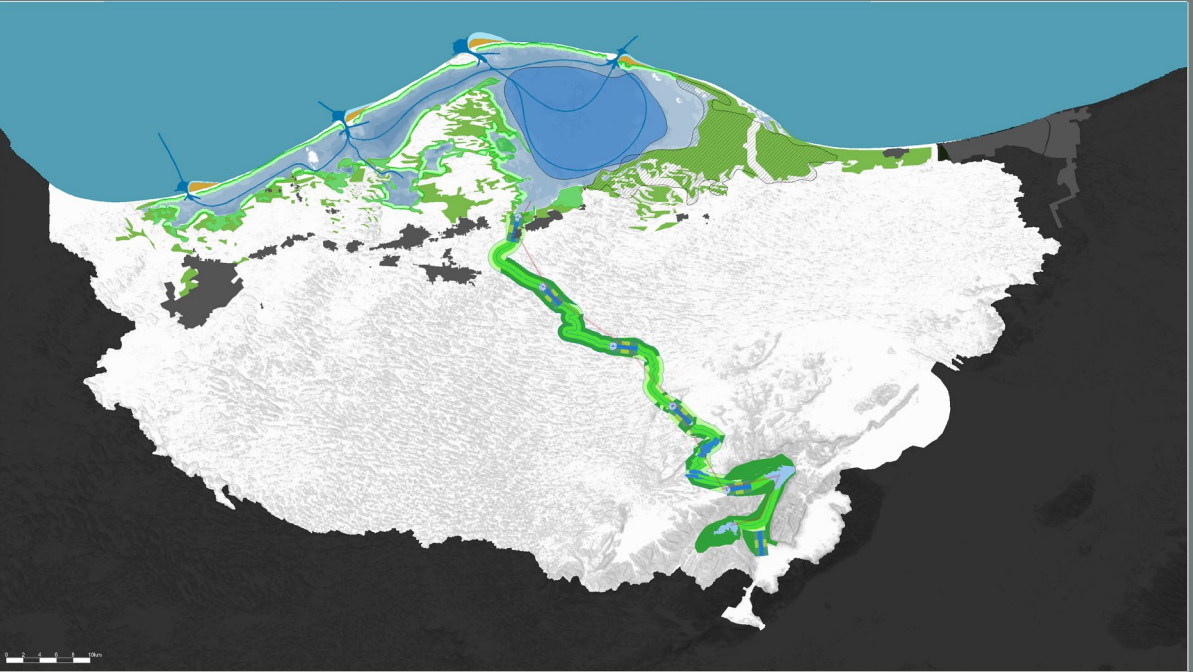
LANDSCAPE REGENERATION

KEY INTERVENTIONS

- Capacity building, masterplan co-creation, training, setup of institutional frameworks
- Agroforestry development, including grazing management
- Development of transport networks for fertile soils and water across the landscape
- Sediments revitalization facilities, including sustainable freshwater production and indoor farming facilities
- Introducing strategic evaporation technologies and water harvesting facilities
- Renewable energy landscape by developing pumped-storage-hydropower systems in combination with solar farms
- 100 MW green hydropower production plant

KEY BENEFITS

- Green jobs in management, agriculture and related industries
- Agricultural products
- Freshwater production
- Renewable energies for local economy
- Green hydrogen export
- Improved local climate conditions
- Biodiversity & Carbon sequestration



COASTAL REGENERATION

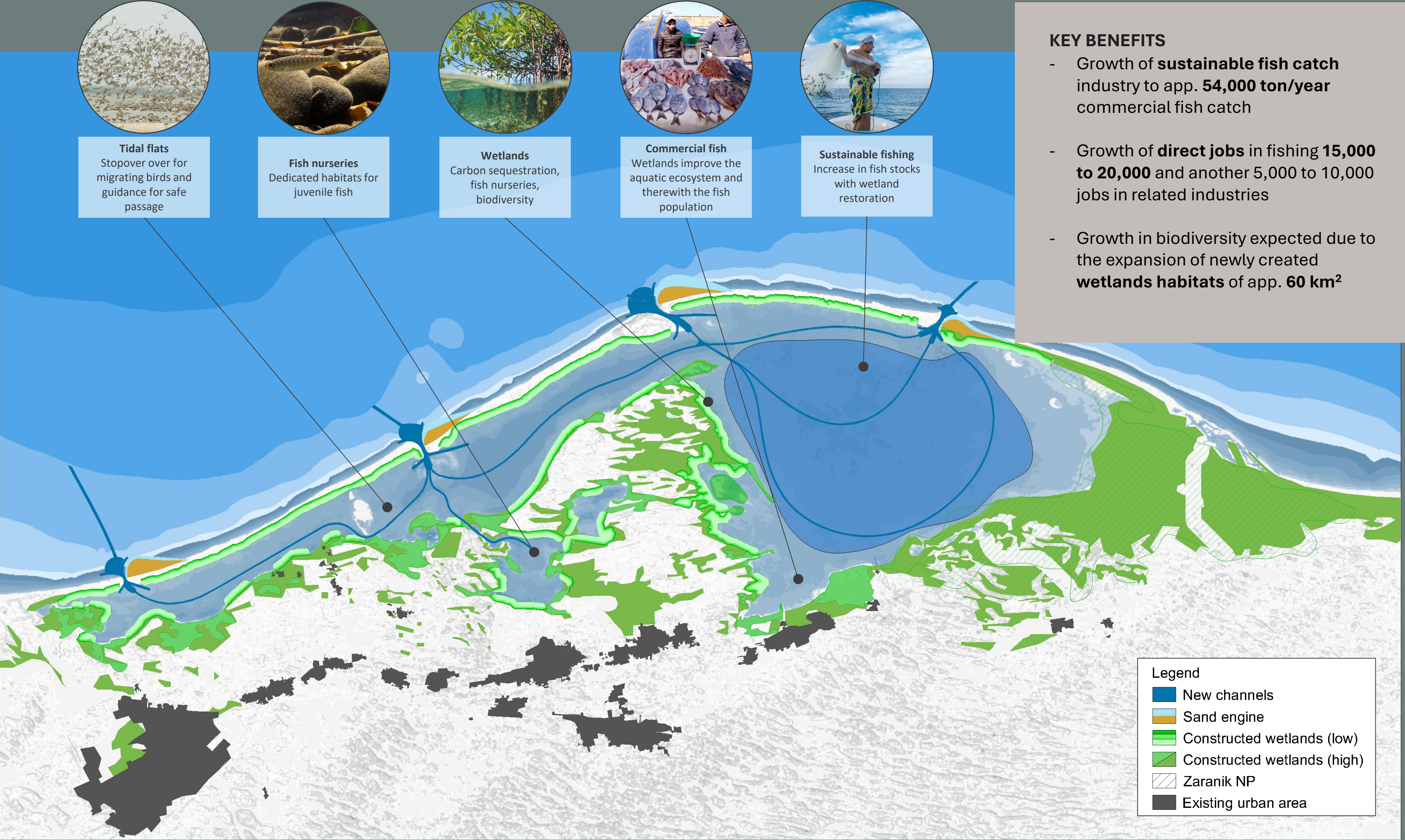
BARDAWIL LAKE DEVELOPMENT

Lake Bardawil is a shallow lagoon on Egypt's Sinai Peninsula and is vital for local communities' livelihoods but faces threats from sedimentation and human activities.

The lake's aquatic ecosystem can be restored to let fish populations and biodiversity flourish while supporting regional socio-economic development.

Interventions include deepening and widening of inlets, create new inlets, restoration of salt marsh wetlands and implementing sustainable fishing practices.

These interventions aim to increase tidal flow from the Mediterranean, improving water quality and nutrient availability, and facilitating fish migration.



COASTAL REGENERATION

BARDAWIL LAKE DEVELOPMENT – PHASE 1

Deepening and widening of existing inlets Boughaz 1 and 2, including the removal of breakwaters Dredging the inlets will improve the water exchange between the Mediterranean Sea and the lake and result in a better water quality (less salinity, lower water temperatures, etc) and attract more migrating fish, facilitated with deeper foreshore gullies to the open sea. Nutrient rich sediments will come into suspension and become available in the foreshore, thereby attracting more fish from the Mediterranean Sea for migration into the lake.

Dredging tidal lake gullies. The tidal gullies inside the lake will improve the connectivity and circulation patterns. The gullies interact with the inlets to further propagate the tide into the lake and provide increased water level variations and dynamics at the lake shores deeper into the lake.

The deeper gullies also provide habitat variation in the lake and will make way for the larger predator fish to migrate into the lake.

Construction of 1,000 ha wetland habitats. Several ecological zones will be constructed for various reasons, such as to improve the primary production in the lake, provide fish habitats and accommodate a large diversity of bird populations.

Sand spit reinforcements. The stability of the sand spit needs to be ensured to guarantee the safety of the system on the long term. Beach nourishments (also referred to as Sand Engines) constructed from the dredged material will be strategically placed and will naturally reinforce the adjacent coastline over the years by the action of waves, wind and current. These works should be combined with habitat development, such as dunes.

Improve and expand sustainable fishing practices, capacity building and training. To ensure sustainable use of Lake Bardawil’s resources, regenerative fishing and low-impact aquaculture practices are essential. The approach focuses on preserving the lake’s ecological integrity while supporting local livelihoods. Key elements include species selection based on environmental and market factors, integration with local fisheries, and close collaboration with stakeholders. A strategy combining fisheries management, aquaculture scoping, ecosystem modelling, and monitoring will guide efforts toward a resilient and regenerative fishery.

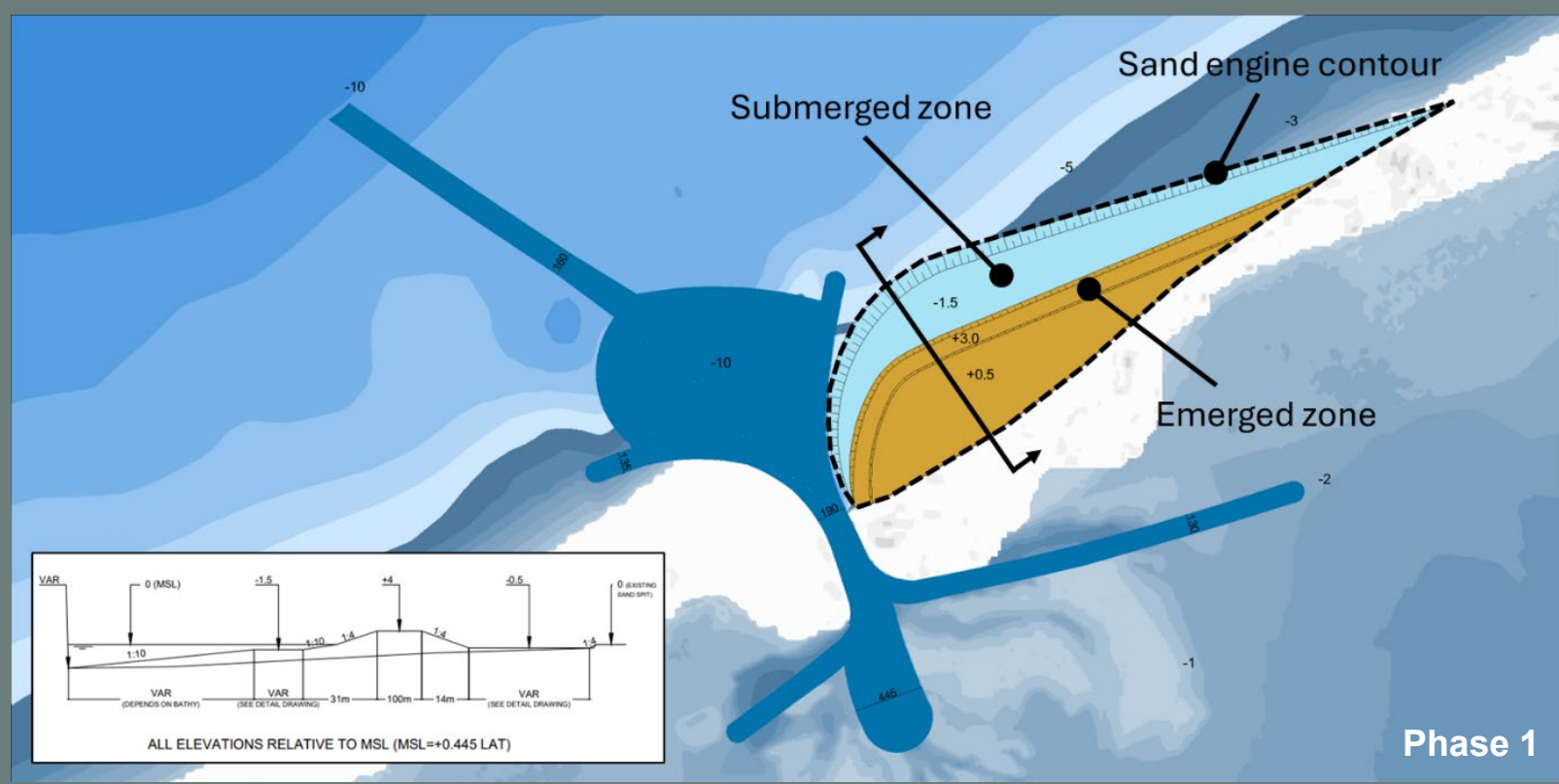
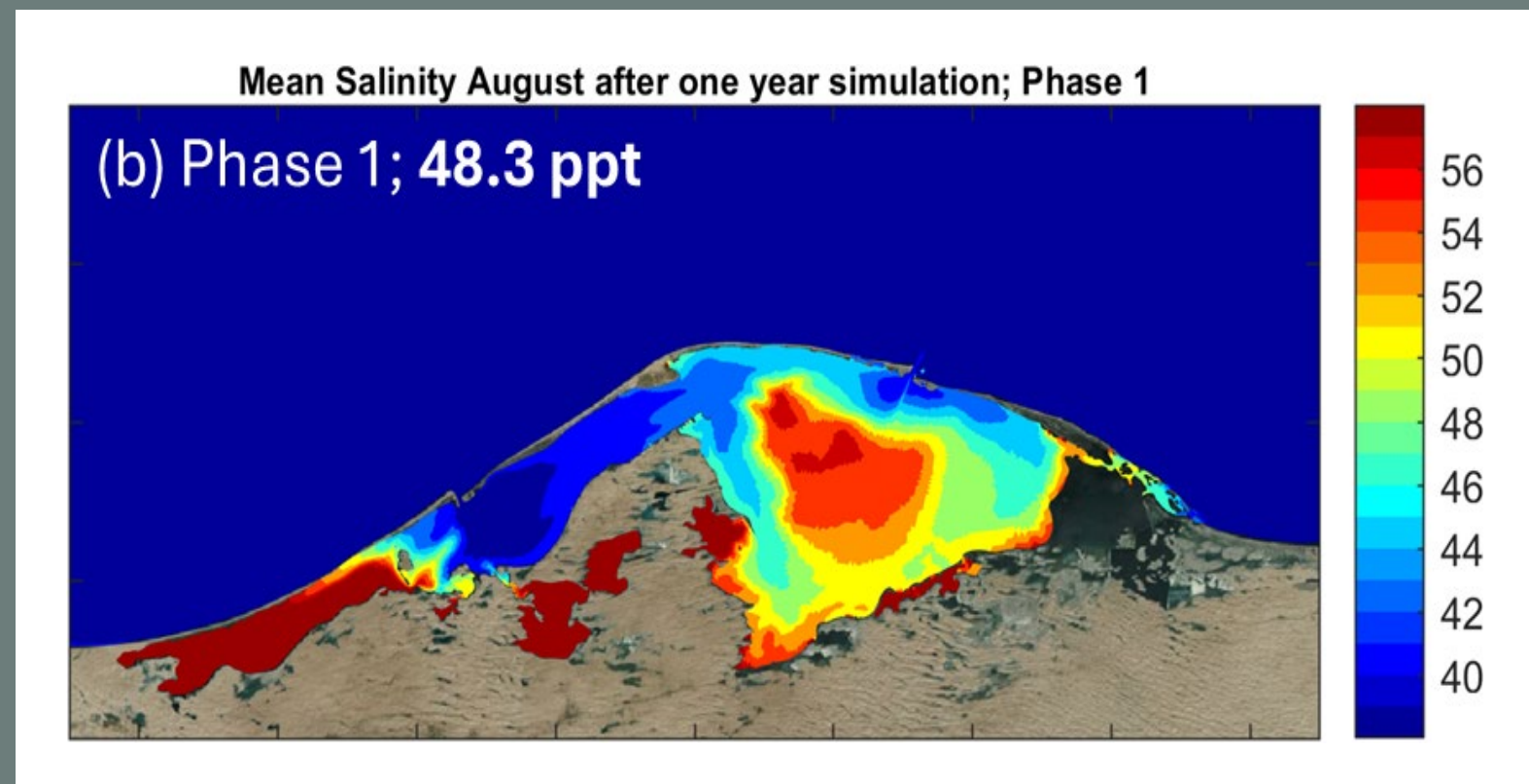
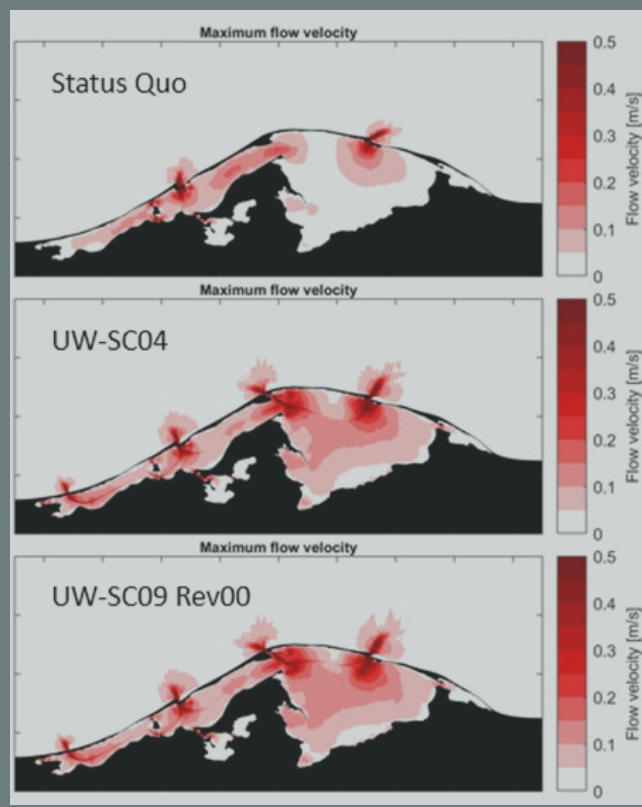
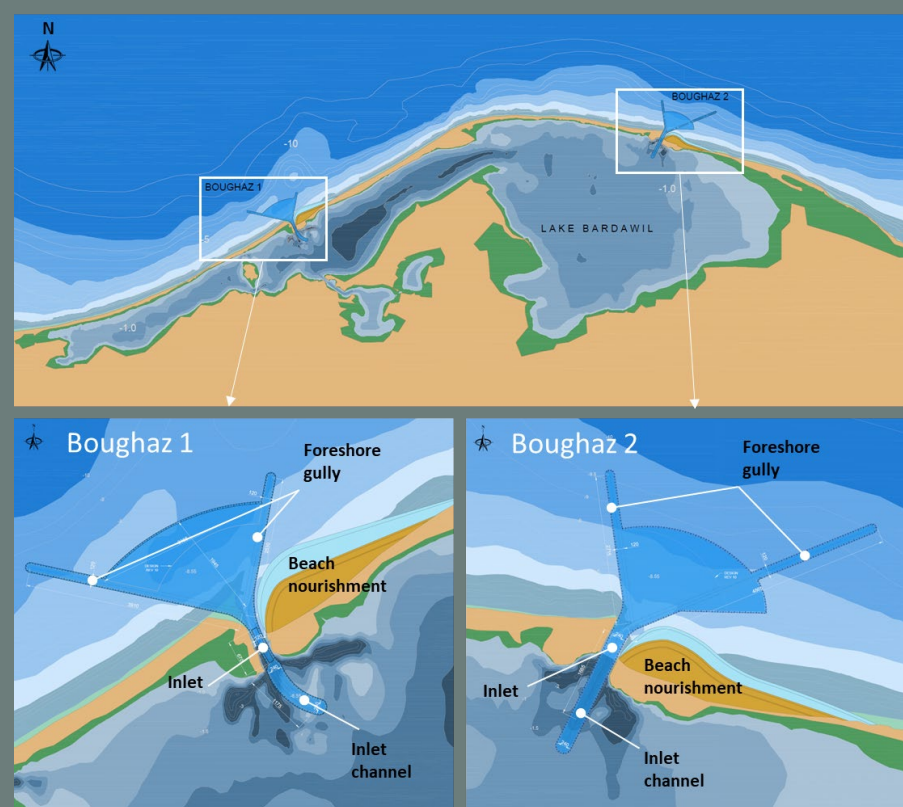
Develop (international) fish supply chain After the first phase has been established and the local food supply is secured; an international fish supply chain can be setup to further increase the economic benefits.

Dredging scope Phase 1

- Capital dredging volume is approximately 19 Mm³ and operational dredging is 0.5Mm³/year

Fish catch potential Phase 1

- In the P90 scenario, the annual incremental **fish catch** compared to the Baseline **can grow to nearly 11,000 ton/year**. Over time the number of direct **fishery jobs** can grow to a number between **3,000 and 15,000** and 1,000 – 5,000 secondary jobs (postharvest processing, transport, distribution). In addition to the jobs in the fish industry, the wetlands restoration and maintenance will create tens of job opportunities too.



LANDSCAPE REGENERATION

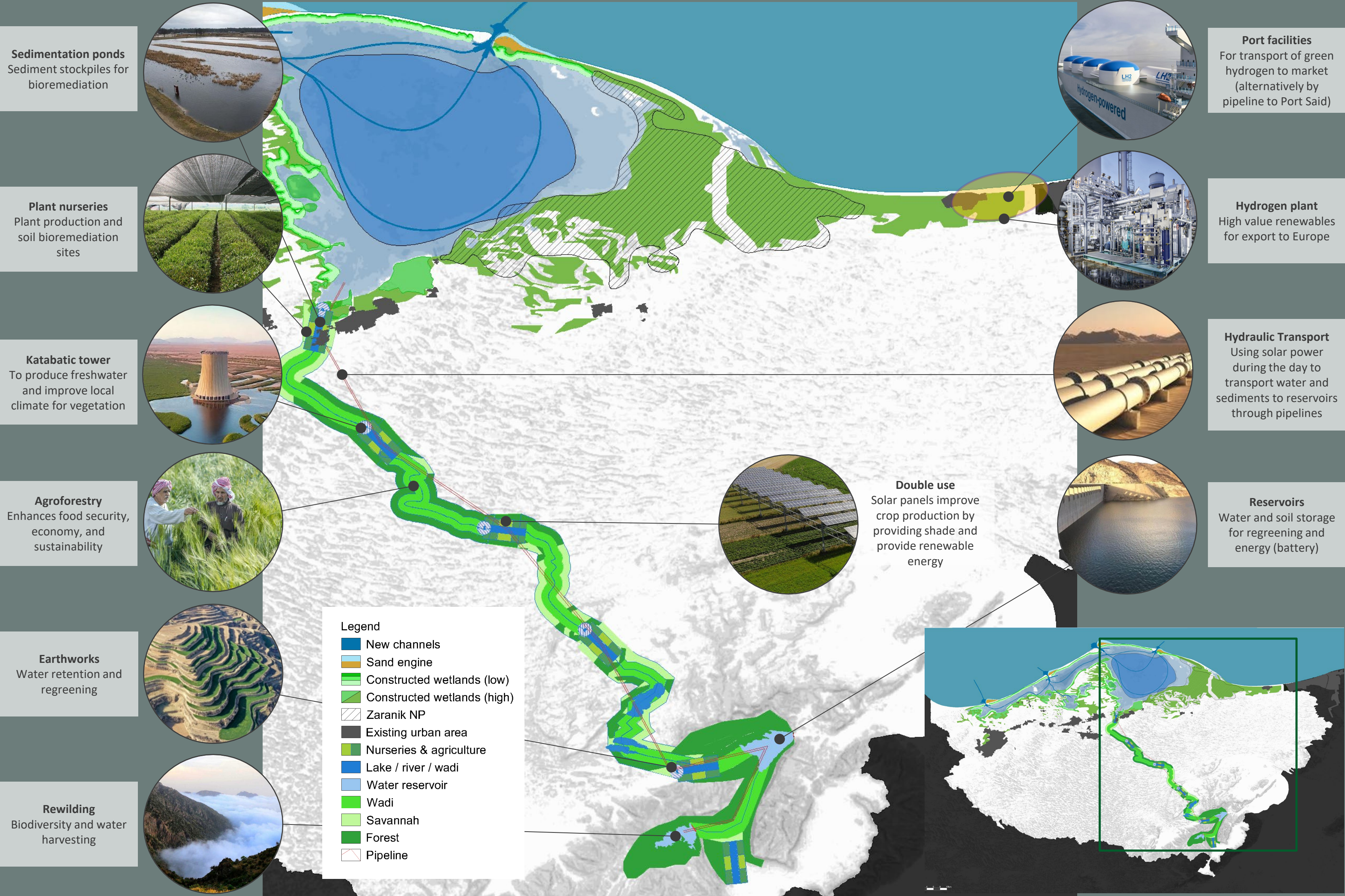
DEVELOPMENT BARDAWIL – MAGHARA AREA

The proposed strategy for regeneration of the Sinai is an integrated landscape-scale approach of resource based dredging and green hydrogen production.

We aim to use dredged sediments for building liveable soils. These sediments come available at the coastal regeneration efforts. Hydraulic transport is used to bring the sediments, rich of nutrients, at strategic locations in the watershed. Bioremediation is used to desalinate the sediments and prepare soils for agriculture and rewilding.

The required water network of pipes, pumps, lakes and reservoirs is also used within pumped-storage-hydro power system that functions as a battery for the area. Fed with solar power, this renewable energy landscape will drive the regeneration and is used to produce green hydrogen for export.

Katabatic Towers are constructed and produce cool moist air to create ideal climatic conditions to accelerate the bioremediation process, agroforestry production and rewilding.



LANDSCAPE REGENERATION

RESOURCE BASED DREDGING

Resource Based Dredging is a novel regeneration methodology that utilizes locally available coastal sediments and seawater for large-scale regeneration of arid landscapes. The technique addresses the problem of firstly, acquiring the vast quantity of required resources and secondly, the fundamental challenge of vegetation establishment in arid environments, because of water scarcity, nutrient deficiency, and poor soil quality.



Hydraulic Transport
Sediments can be transported with seawater over large distance at the dedicated regeneration location

Indoor farming
Indoor farming can accelerate the process as the ideal circumstances for plant growth can be achieved with efficient water use



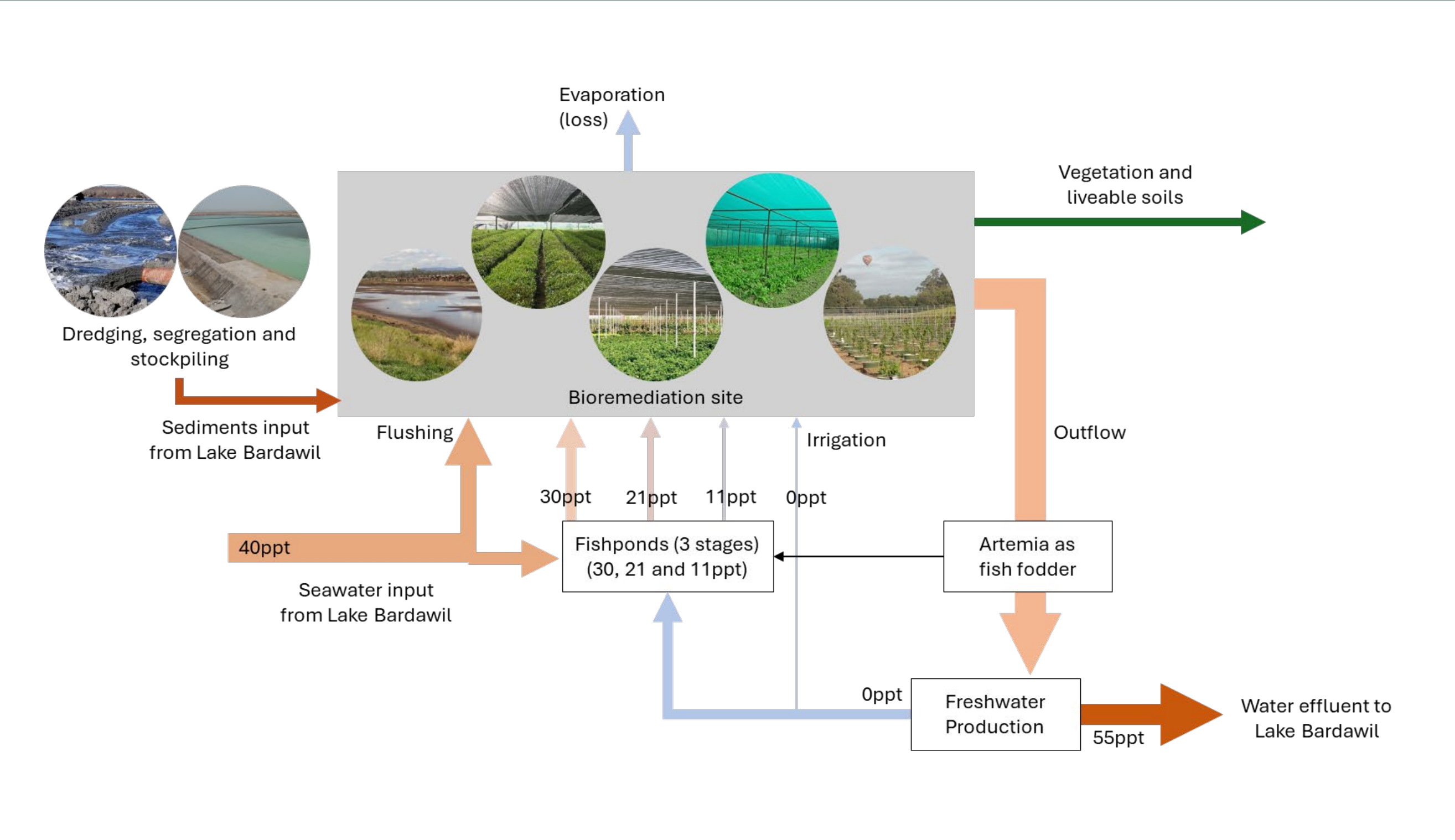
How it works
Coastal sediments at Lake Bardawil contain high concentrations of nutrients as resource for fertile soils but also contain salt and little to no active soil life.

After dredging and segregating the coastal sediments will be treated in a multi-stage bioremediation process where they undergo a desalinization process through leaching by flushing. This process is aided by sequential planting of diverse plant species, suited to salinity levels of the sediments, that aid the establishment of rich soil life.

The plants in the final stage will serve as the seedlings for the regeneration efforts.

An on aquaponics inspired system recovers nutrients from leaching effluent, creating natural fertilizers while managing water salinity.

The bioremediation process requires about 1-1.5 years to produce seedlings with high-quality soil amendments suitable for planting.



LANDSCAPE REGENERATION

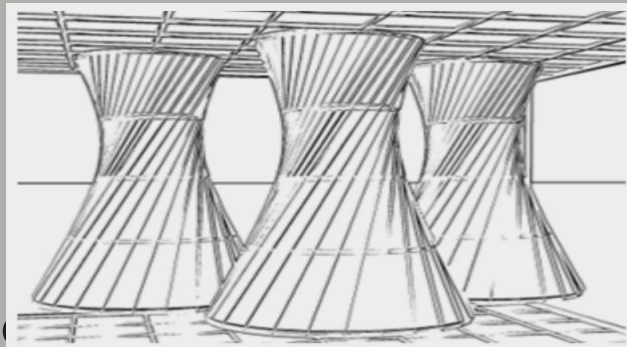
STRATEGIC EVAPORATION

How it works

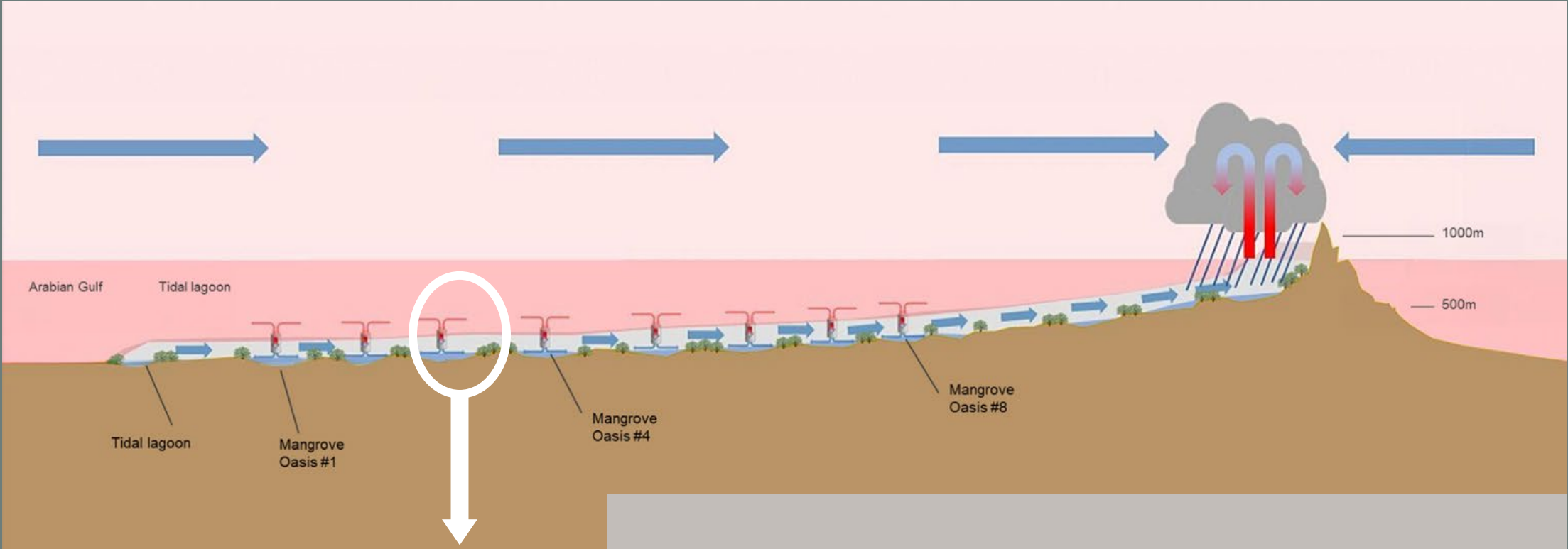
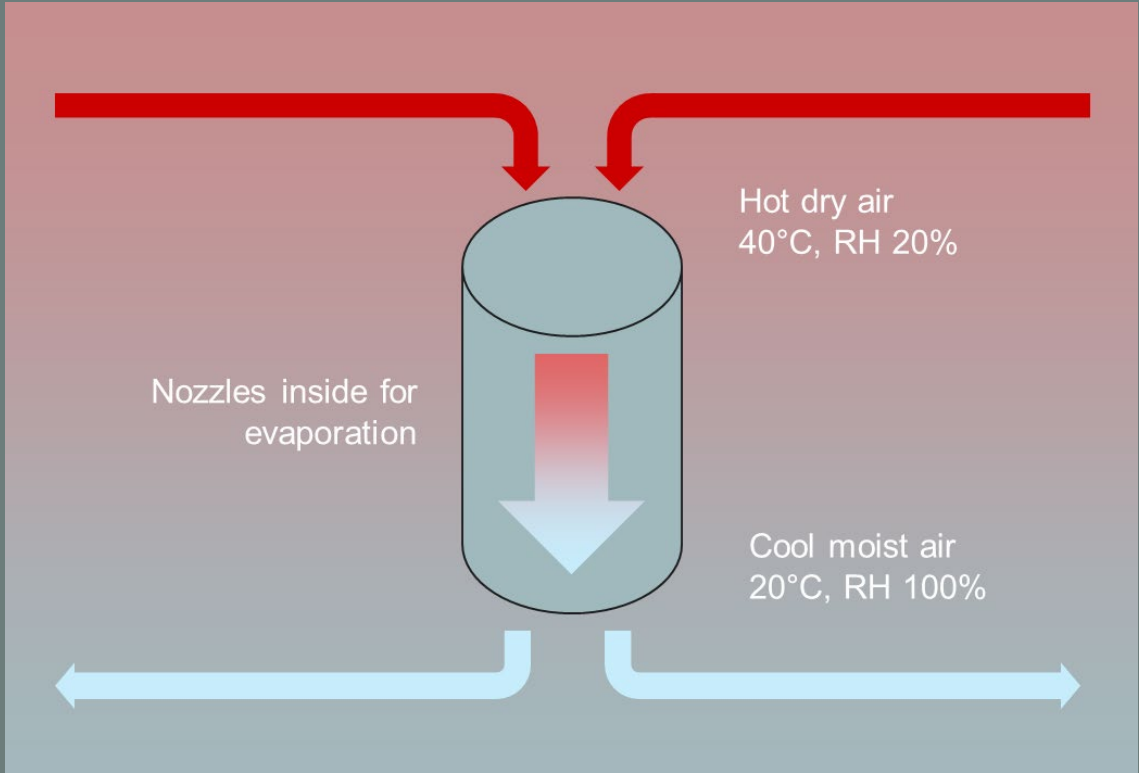
The Katabatic Tower is open vertical pipe structure. Seawater is sprayed at the top. The water evaporates while falling down through the vertical pipe. With continuous spraying hot dry air is sucked in at the top and cool moist air is pushed out at the bottom, generating a vertical air flow through the pipe, a so-called katabatic wind. The technology primarily works when hot dry air is available

Benefits

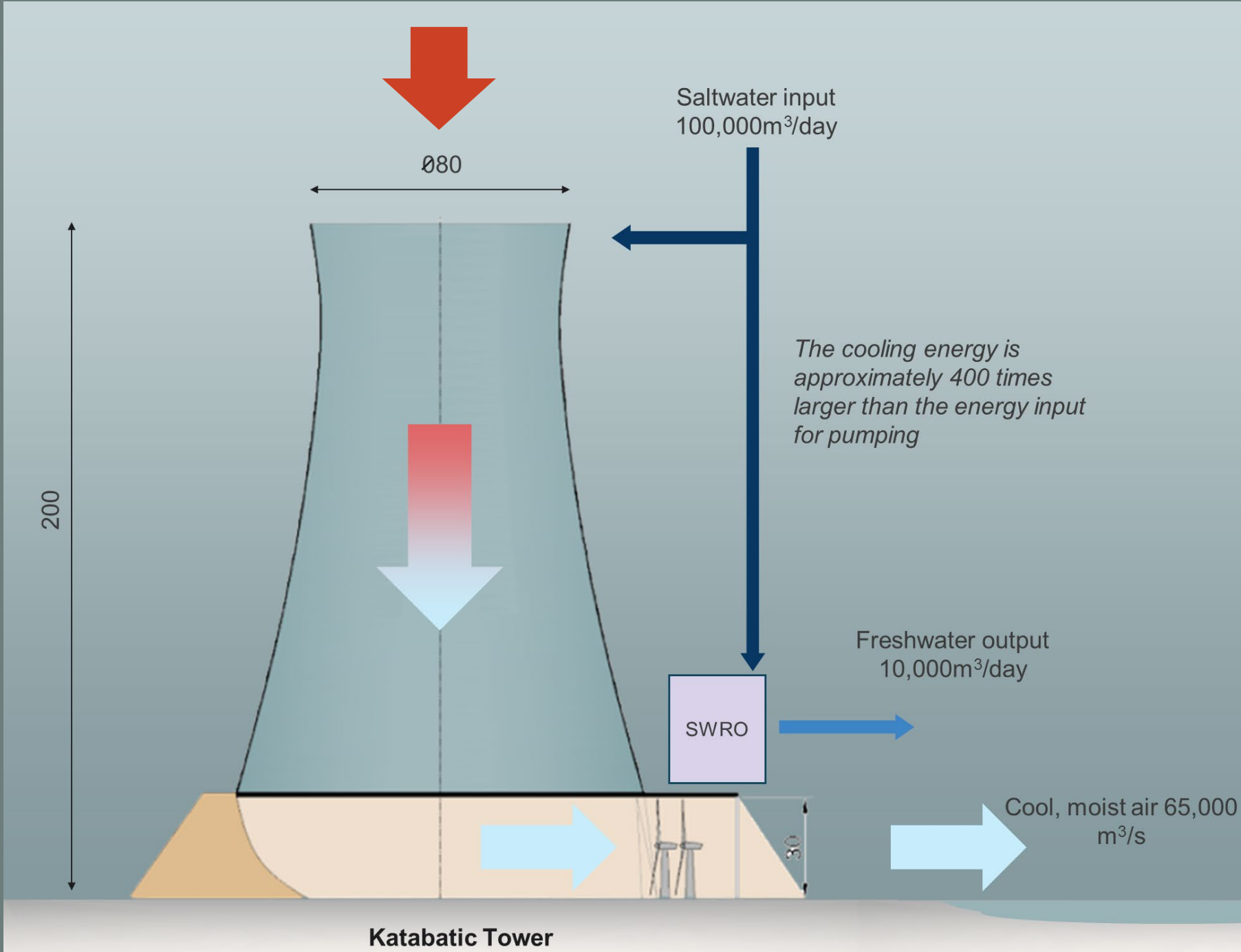
- With relatively low energy input, large volumes of air can be cooled and humidified;
- Cooling improves the conditions for vegetation growth. In case of right conditions and scale, rain events can be triggered;
- High wind speeds are generated.
- The technology uses existing techniques and construction methods;



Technology developed out in collaboration with Catabatics S.L.



To induce rainfall, multiple towers shall be placed along the drainage line and connected with the same pipelines as part of the resource based dredging and green hydrogen infrastructure for water supply. The towers, together with the open water bodies, Lake Bardawil and vegetation, will evaporate sufficient water vapor into the atmosphere to induce rainfall.



Young Plants Indoor farming facilities 2,500 m²

Yearly input:
10 million seedlings
2.5 million m³ sediments

Yearly output:
10 million trees
5.0 million m³ fertile soils



Plant nurseries: regreening and bioremediation area

LANDSCAPE REGENERATION

GREEN HYDROGEN BY INTEGRATION

THE CONCEPT

A high-level investment business case is made for a 100 MW green hydrogen production facility powered by solar power only.

During the day a large solar PV plant produces the electricity which is directly used for green hydrogen production in the plant close to Al Arish. Simultaneously electricity is used to pump water into a large upper reservoir of hydro storage dam in Maghara mountain range. At night the water flows from the upper reservoir to a lower reservoir and generates power. This enables an autonomous and full continuous green hydrogen production in the Sinai.

This project requires an estimated 1.6 B\$ of investments and shall produce 14-16 kilotonnes of green hydrogen per year of approximately 15 \$ / kg, given a 10% project IRR.

BENEFITS

Multiple win-wins when the concept is combined with regeneration of the landscape with Resource-based Dredging:

Shared costs of:

- Water infrastructure: Pipeline, pumps and reservoir
- Port infrastructure and operations

Shared land use: several win-wins (e.g. double use solar panels and agriculture)

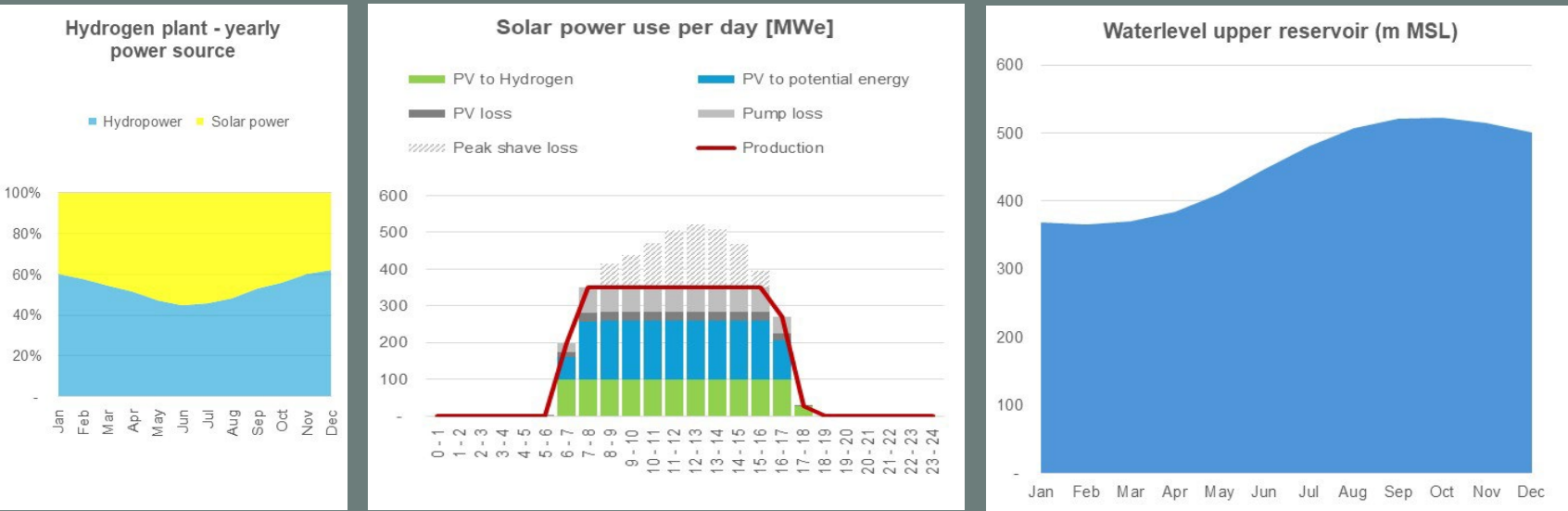
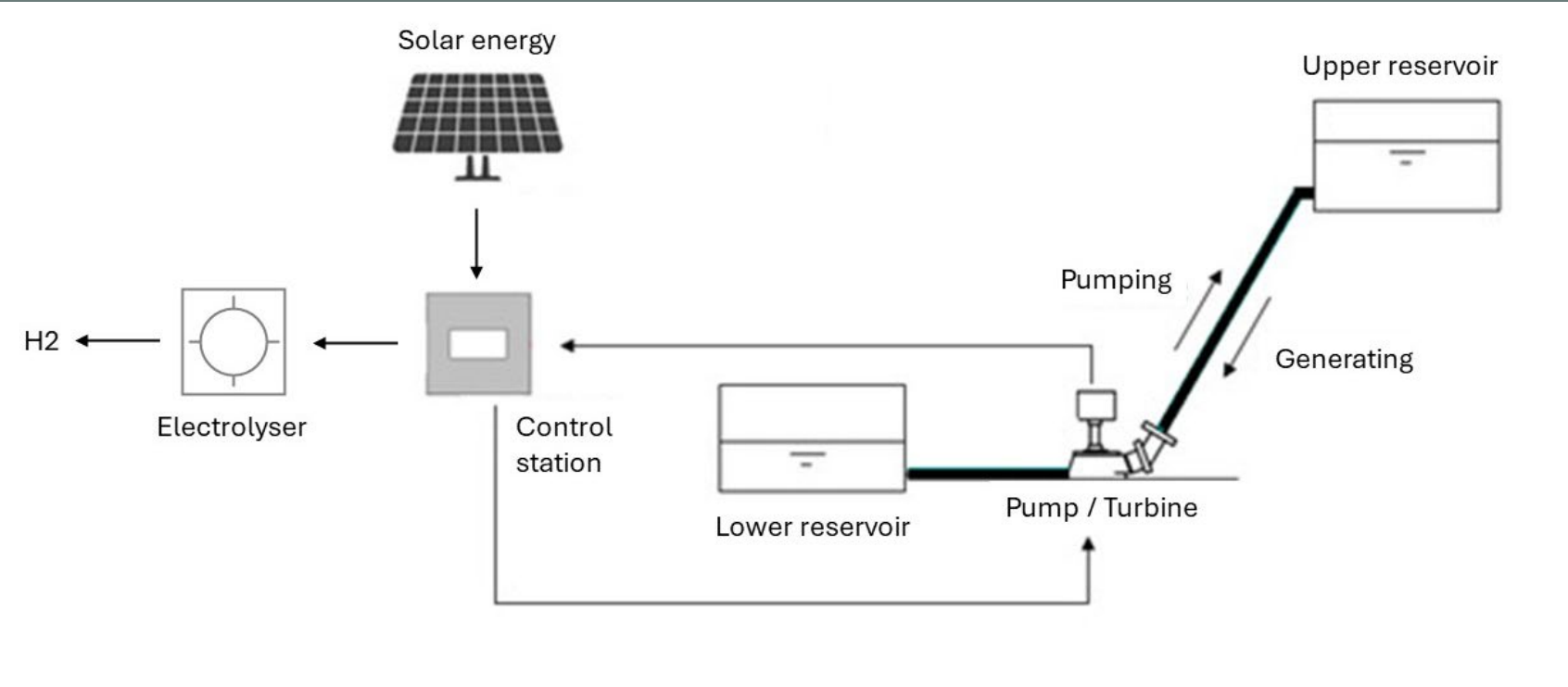
Shared landscape-scale challenges: regreening provides positive social and environmental impacts to the local communities

Sustainable Development Goals: holistic approach potentially improves all SDG's

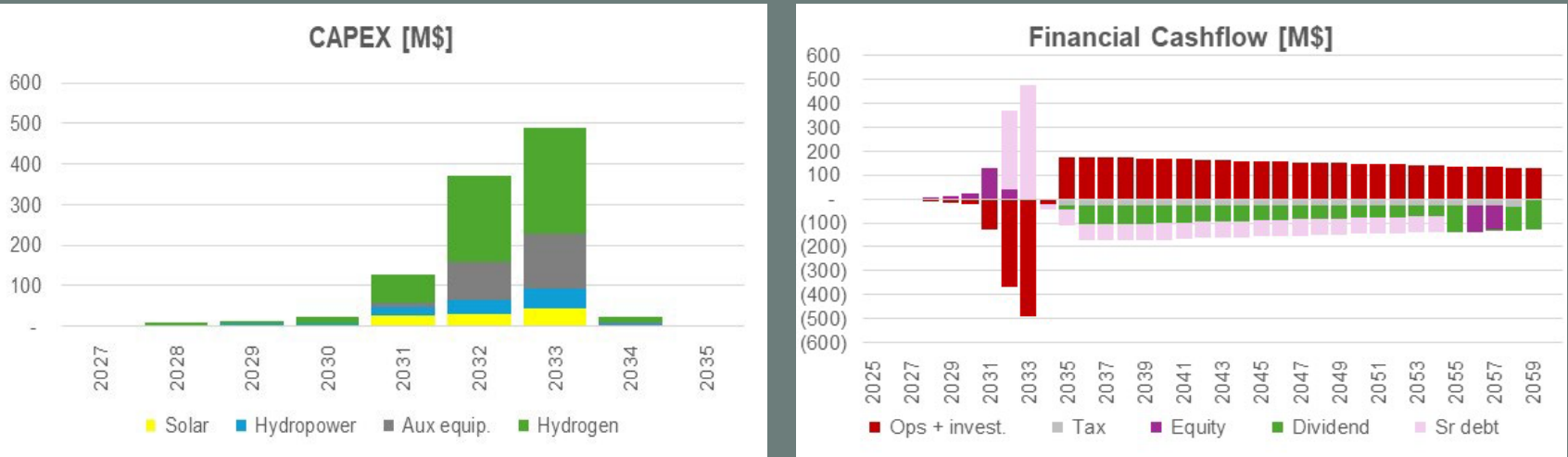
True Green Hydrogen: negative environmental impacts by Green Hydrogen are more than compensated with regreening

Main challenges

- Negative environmental impact of green hydrogen production
- Large project with high financing demand and long lifespan.
- Long construction time of hydro dams
- Uncertainties in the global green hydrogen market



Schematic overview of green hydrogen production by pumped-storage power supply



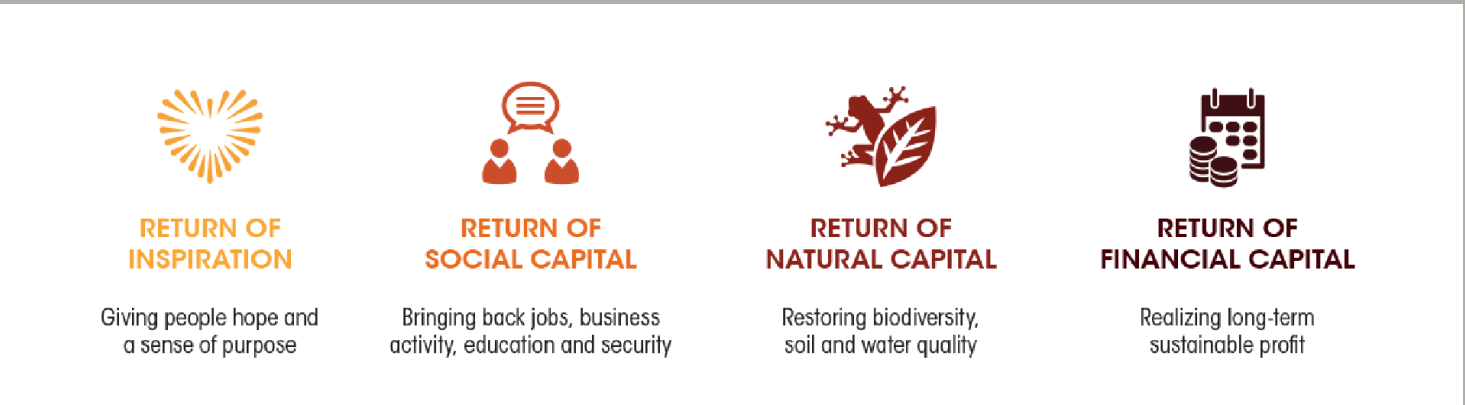
Preliminary cost-benefit analysis

BIOSPHERE REGENERATION STRATEGY

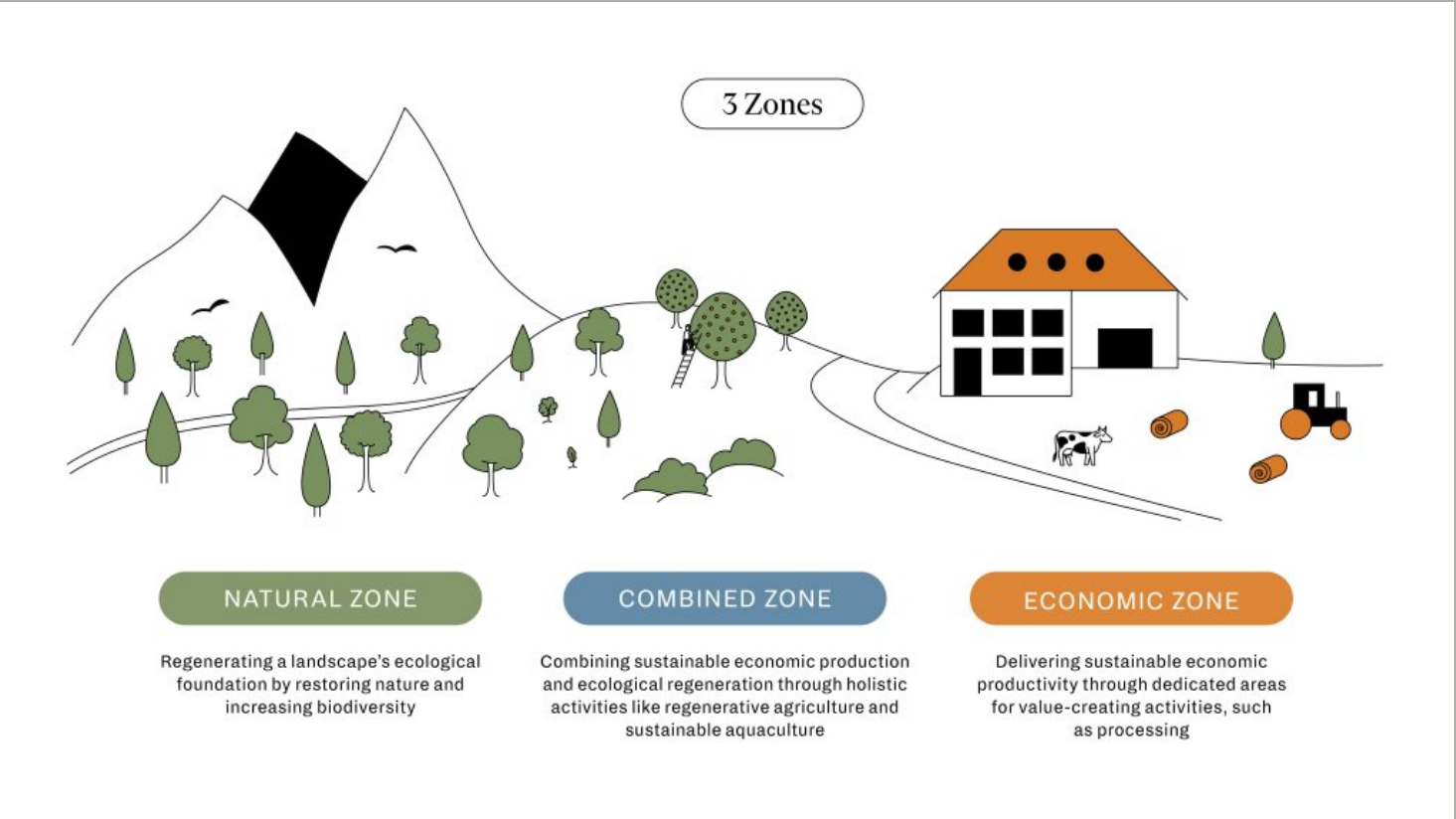
VALUE CASE BARDAWIL – MAGHARA AREA

The **4 Returns Framework** by *Commonland* is a practical, holistic approach to landscape restoration that aims to create a long-term, sustainable future by generating four key returns, over 20 years and within three defined zones.

4 Returns



3 Zones



20 Years

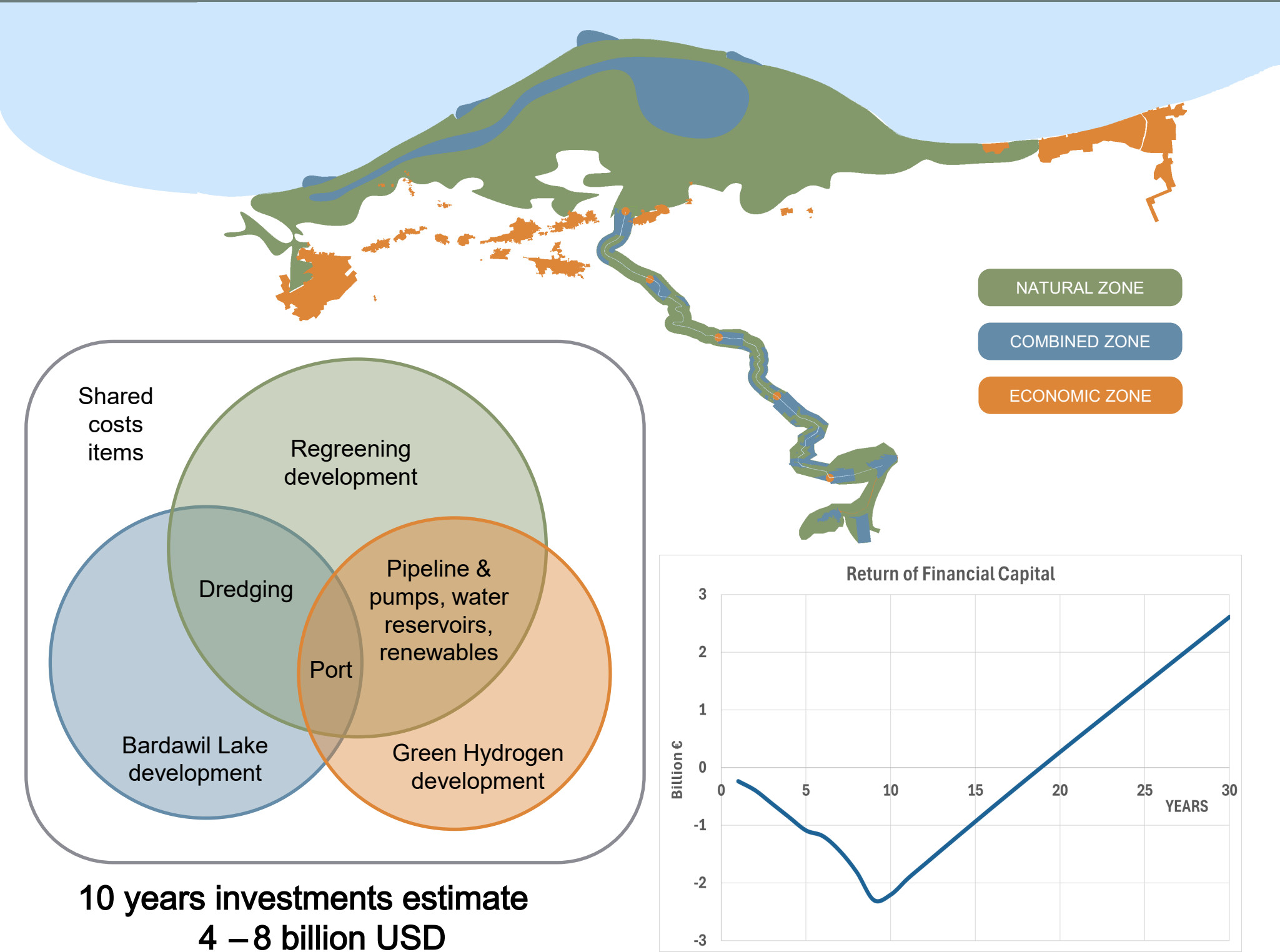
20

A long-term approach is important as it takes approximately 20 years – or one generation – to restore a landscape

KEY INTERVENTIONS

Lake Bardawil, wetlands and one drainage line

- Capacity building, masterplan co-creation, training and setup or enforce institutional frameworks
- Dredging of inlets and gullies to improve water quality for the marine ecosystem
- Restoration and expansion of wetland habitats and coastal reinforcements
- Improve and expand sustainable fishing practices
- Develop (international) fish supply chain and related industries
- Agroforestry development, including grazing management
- Construction of transport network for fertile sediments and water across the landscape
- Sediments revitalization facilities, including sustainable freshwater production and indoor farming facilities
- Renewable energy landscape by the development of pumped-storage-hydropower in combination with solar farms
- 100 MW green hydropower production plant for export



Return of Inspiration: connecting communities, governments, businesses and organisations towards a joint vision of healthy livelihoods for the long-term

Return of Social Capital: About 5,000 jobs in construction and over 35,000 permanent jobs in fisheries and agriculture

Return of Natural Capital: healthy, sustainable, biodiverse and productive ecosystems for the long-term

Return of Financial Capital: Positive business cases for the regenerative production of fish, agricultural products, water, energy and carbon credits

A portrait of John D. Liu, an older man with a grey beard and mustache, wearing a blue cap and a black puffer vest over a blue shirt. He is standing in a lush green forest, looking slightly to his right. The background is filled with dense foliage and trees.

“Now is the time to use our influence and knowledge to drive positive change. By restoring water cycles and the biosphere, we can enhance food security, biodiversity, and societal well-being.”

John D. Liu - Film maker and ecologist

The content presented in this document are work in progress and will be further developed over time. Updates and supporting documents are and will be made available on The Weather Makers Foundation’s website.

www.weathermakers.foundation.org



WEATHER MAKERS FOUNDATION

Restoring water cycles on a large scale takes teamwork. Contact us today to explore how we can join forces to rejuvenate our ecosystems.

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