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SAHEL GROUNDWATER

UNCOVERING THE SOCIO-ECONOMIC POTENTIAL OF GROUNDWATER-DEPENDENT ECOSYSTEMS IN THE SAHEL

CIWA LEARNING NOTES

Oasis farming in the Kanem region in western Chad. ©Anna Jefferys / IRIN

LEARNING NOTE TWO | APRIL 2023

INTRODUCTION

Fauna and flora provide goods and services such as food, medication, energy, and timber for construction, which are vital for human development. The absence of healthy ecosystems and natural environments can have profound and devastating consequences. The COVID-19 pandemic showed the world how the disruption of ecosystems can lead to zoonotic viral diseases that spill over to humans with staggering health, economic, and societal costs.

In the Sahel region, where water resources are mostly underground, groundwater-dependent ecosystems (GDEs) are important lifelines for communities, around which a multitude of social interactions and economic activities develop. **Healthy ecosystems are key for livelihoods and economies.** GDEs provide direct goods and services to humans including fish, livestock, plants, medicines, timber, and water storage and purification. Indirect benefits to human well-being derive from sustaining biodiversity, habitat, and landscapes for social, cultural, aesthetic, ethical, and economic reasons. GDEs are also fundamental to the survival of various protected species and figure prominently in sites covered by the RAMSAR Convention on Wetlands.

Human activity is an integral part of these socio-ecological systems. Despite their role in providing ecosystem services and supporting socio-economic development, **GDEs in the Sahel are poorly understood, and the groundwater requirements to meet their ecological functions are rarely considered in land-use policies and planning**.

> Groundwater-dependent ecosystems in the Sahel are still poorly understood.

DEFINING GROUNDWATER-DEPENDENT ECOSYSTEMS

GDEs are ecosystems that require access to groundwater on a permanent or intermittent basis to meet water requirements to maintain plant and animal life, ecological processes, and ecosystem services. Some ecosystems are supported entirely by groundwater while others also receive water from other sources. Groundwater is critical to certain species because it provides unique water chemistry or stable water temperature.

Natural groundwater discharge is the critical link between groundwater and the ecosystems it supports. Discharge is the movement of groundwater from the subsurface to the surface onto land or into streams, lakes, or springs. Without preserving the groundwater resources that GDEs require to cover the needs of all their components, the sustainability of these valuable ecosystems is threatened.

Groundwater supplies ecosystems in the following ways:

- Discharge upon land
- Discharge to the baseflow of a surface watercourse (e.g., perennial or seasonal rivers and streams)
- Discharge into a surface water body (e.g., wetlands, lakes, and ponds)
- Discharge into seawater through the seabed along the coast
- Evaporation from soil or evapotranspiration by uptake from plants

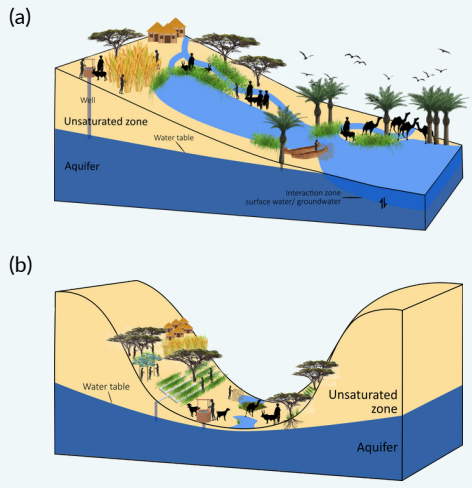
> GDEs are unique environmental assets of international ecological value, as well as assets of immense economic and social value to communities and pastoralism

Typologies of GDEs

The Sahel's GDEs have four main geographic typologies: inland surface waters, coastal and marine ecosystems, terrestrial oases and springs, and terrestrial vegetation.

1. Inland surface water ecosystems

These ecosystems are located around major Sahelian rivers, lakes, swamps, and wadis[1] and are ripe for agricultural activity. Groundwater is essential to supplement surface water irrigation, maintain surface water flow, and provide water access for domestic and livestock use.



Inland surface water ecosystems: riverine and lacustrine ecosystems (a) and wetland ecosystems (b)

1.1. Riverine and lacustrine ecosystems

Strong surface-groundwater interactions provide a rich and diverse habitat for flora and fauna, such as papyrus, spirulina, reeds, spiny trees and shrubs, fish, birds, livestock (e.g., camels, cattle, sheep, goats, donkeys and poultry) and wild animals (e.g., elephants, sitatunga and hippopotamuses). Groundwater discharge provides nutrients and temperature regulation that support agriculture, fishing, and fish farming. Small-scale farming of date palms, maize, sorghum, and cowpea and fodder production develop on the banks of rivers and lakes. These ecosystems provide pastures and a permanent source of water for transhumant livestock during dry seasons. The flourishing economic activity in these environments also favors the development of arts and crafts.

Niger Inner Delta in Mali. ©Christiane Spinnewyn

1.2. Wetland ecosystems

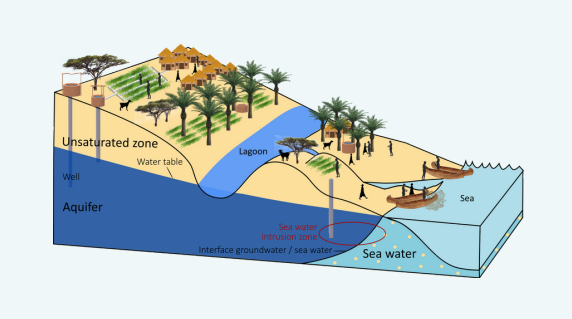
Wetlands are often found in dry valleys or large alluvial plains. While groundwater discharge plays a key role in maintaining the base extent[2] of wetlands, wetlands also work as collectors of the catchment's rain and runoff. Wetlands support small-scale farming (e.g., vegetables, cereals, and tubers), orchards (e.g., mango, guava, citrus, and banana), livestock farming, and pastoralism. During the dry season, when surface water reservoirs dry up, groundwater allows the production of crops (e.g., tomatoes, onions, and potatoes) to continue.

[1] A valley, gully, or streambed in northern Africa and southwest Asia that remains dry except during the rainy season.

[2] This occurs during the dry season, when no rain/surface water contributes to the extent of the wetland and evaporation is high.

2. Coastal and marine ecosystems

These ecosystems are found onshore and offshore along the coast.



Coastal and marine ecosystems

Fishermen from the Imraguen ethnic group in the Banc d'Arguin National Park in Mauritania. ©PNBA

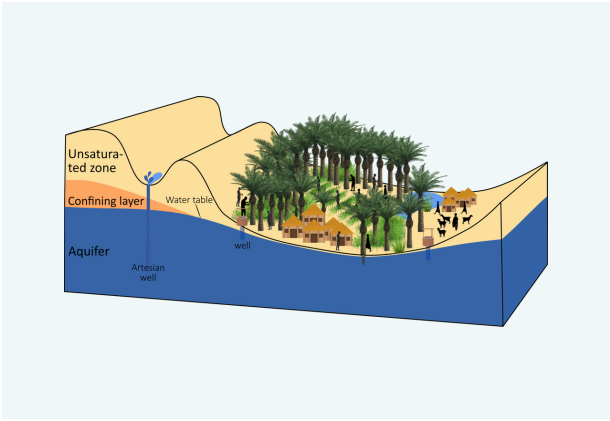
2.1. Coastal ecosystems

Onshore, these ecosystems encompass sandbanks, sand dunes, marshes, lagoons, and mangroves and are sustained by seawater, rainfall, surface water, and groundwater stored in aquifers. Mangroves are supported by saline and brackish water and provide habitat to several aquatic and semi-aquatic species and deliver important ecosystem services such as carbon sequestration and methane reduction, water filtration, and protection against coastal erosion and storm surge. Coastal ecosystems support hunting, fish farming, salt extraction, and commercial forestry. High-yield agriculture and horticulture are also common along Sahelian coastlines, often drawing from perched aquifers of freshwater lenses above saline groundwater.

2.2. Near-shore marine ecosystems

Offshore, the mixing of fresh groundwater discharge with coastal seawater creates ripe conditions for spawning grounds and overall coastal fishing.

3. Oases and springs ecosystems



Oasis and spring ecosystems

Groundwater sustains oases and springs of the Sahelo-Saharan deserts, mostly through sub-outcropping or outcropping water tables and sometimes artesian groundwater flow from confined aquifers. This groundwater can be mineralized or fresh. In this arid context, the surface water in gueltas[3], lakes, ponds, and swamps depends entirely on groundwater and is only rarely supplemented by precipitation.

Oases and springs ecosystems can be highly anthropized ecosystems, in which groundwater supports domestic uses and irrigated agriculture, the major subsistence and economic activity in the Sahel. The combination of fertile soils and groundwater enables commercial plantations of date palm groves and orchards, vegetable gardens, cereal and fodder production, aromatic and medicinal herbs, and livestock rearing (e.g., camels, sheep, goats, and zebus).

Oasis of Taouaz, Mauritanian Adrar. ©François Bertone

[3] A guelta is a depression or natural pool of water in the exposed rock, without apparent flow. It may last year-round through the dry season if fed by a spring often not visible (usually below the surface water level).

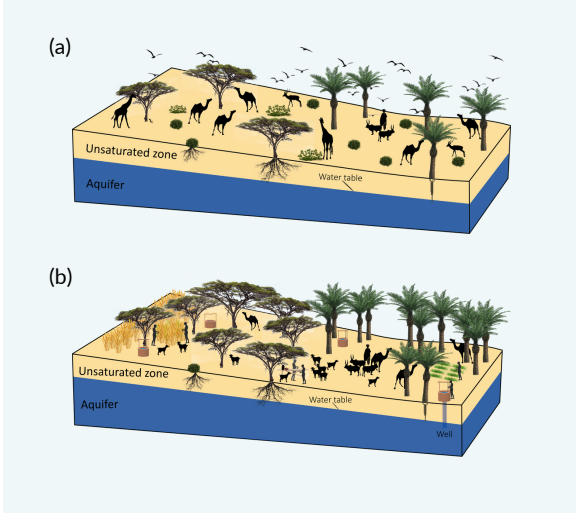
Some oases have become commercial hubs and cultural crossroads. Most also have an ancient cultural history and traditional arts and crafts, which attract cultural tourism and ecotourism.

Fauna and flora can develop and find shelter in the desert landscapes surrounding springs and oases. In the Sahara and Sahel, these surrounding zones are usually not associated with human settlement; no human activity is found other than transit or pastoral transhumance.

Guelta d'Archeï, Chad. ©Isabelle Boutriau

4. Terrestrial vegetation ecosystems

These ecosystems consist of continuous or intermittent groundwater-dependent species that develop under a wide range of climates and support other non-groundwater-dependent species.



Terrestrial vegetation ecosystems: sparse vegetation ecosystems (a) and forest and woodland ecosystems (b)

4.1. Sparse vegetation ecosystems

Sporadic terrestrial ecosystems consisting of trees and shrubs are found in deserts (outside wetland zones) or in climates with long dry seasons. Many of these species are deep-rooted to tap into deep groundwater layers. They perform several landscape and ecosystem functions such as dune stabilization, soil water redistribution, soil fertility improvement, and shelter and food for fauna and transhumant livestock.

4.2. Forest and woodland ecosystems

These ecosystems are a human-enhanced version of the previous typology consisting of managed and/or planted agroforestry and agropastoral parks with selected species that provide such uses as fodder, food, timber, and medicines. These systems are also associated with transhumant pastoralism.

Cattle herd in the shade of an Accacia tree in Kanem, Chad. ©Alexandre Ickowicz

GROUNDWATER-DEPENDENT ECOSYSTEMS AT THE DESERT'S FRINGES: HYDRAULIC LIFT MECHANISM

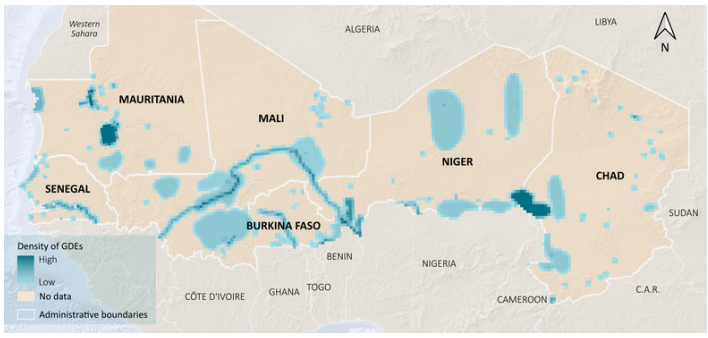
Hydraulic lift is the process by which some deep-rooted plants take in water from lower, wetter soil layers and exude that water into upper, drier soil layers. This mechanism, which is beneficial to both the tree transporting water and neighboring shallow-rooted plants, is found in many natural tree-grass mixtures and ecosystems. Recent measurements of sap flow in taproots and lateral roots of trees have demonstrated that roots can also redistribute water downward or laterally from moist surface soils to drier regions of soil.

Several tree species in the Sahel use this mechanism. For example, the amount of water redistributed by the *Vitellaria Paradoxa* (karité) and *Parkia Biglobosa* (néré) trees could be as much as 73 liters and 247 liters per tree per day (Bayala *et al.*, 2008). The *Vachellia Tortilis* (acacia) tree can pump up more than 20 liters of groundwater per day and make it available for life at the surface (Do *et al.*, 2008). Many palatable grasses grow beneath its crown, and humans consume and market its nutritious pods and seeds.

These species—together with other groundwater-dependent trees and shrubs—form the Sahelian open woodlands and provide shade and fodder for transhumant livestock for most of the dry season.

Mapping GDEs in Western and Central Sahel

Mapping conducted in 2020 and 2021 identified 123 GDEs in Western and Central Sahel (Rambhunjun *et al.*, in press). The map below locates some of them across the six Sahelian countries but many more need identification and description.



Density of groundwater-dependent ecosystems in the Western and Central Sahel (Author P. Rambhunjun). ©World Bank

WAY FORWARD

1. **Improving knowledge about the hydrogeological and ecological features of GDEs in Western and Central Sahel and the impacts of their degradation for human well-being and economies is urgently needed.** These GDEs and their contribution to the regional economy are essential but still poorly identified, understood, and characterized. As a result, they are rarely integrated into land-use and natural resources policies and plans.

2. **Systematic assessment is required for major GDEs** to understand their dependency on groundwater and determine their chemical baseline and the socioeconomic contribution of their ecosystem services in a changing climate.

3. **Protection of GDEs in the Sahel** and their integration into the regulation, planning, development, and management of land and water resources, will unlock their potential and avoid activities that affect their integrity and functions.

4. **Appropriate legal provisions and institutional arrangements are required** for GDE protection. Monitoring of GDEs should be implemented to identify anthropogenic pressure trends and take necessary measures to preserve ecosystem services. Legal provisions may include creating protection zones around GDEs to safeguard groundwater quality and reduce groundwater degradation.

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