ECOSYSTEM-BASED ADAPTATION

AS AN INTEGRAL COMPONENT OF SUSTAINABLE GROUNDWATER MANAGEMENT

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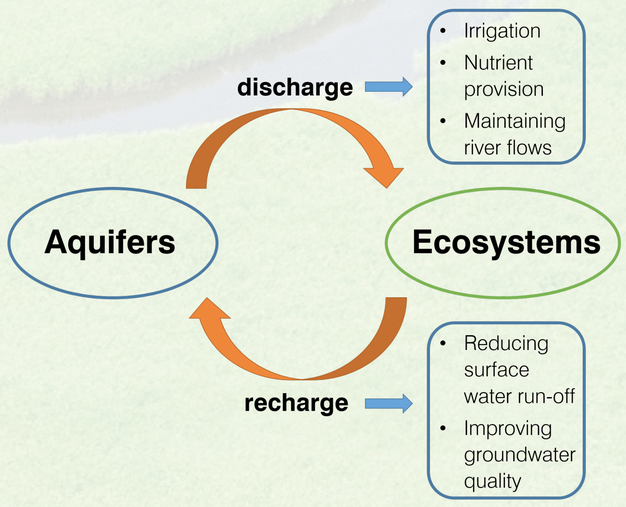
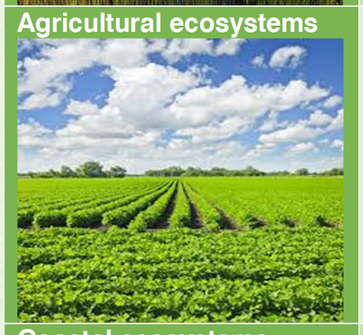
VULNERABILITY OF GROUNDWATER RESOURCES

Groundwater systems are affected by climate variability. Direct influences are due to changes in the distribution of global precipitation, of evapotranspiration patterns, of snowmelt regimes and sea level rise. Human activities such as groundwater development and land use change can further influence groundwater systems indirectly. Climate change and human activity affect groundwater properties like fluxes, levels and quality. Groundwater-dependent ecosystems (GDEs) are communities of plants, animals and other organisms whose extent and life processes are dependent on these groundwater properties.



Interdependence between ecosystems and groundwater systems

Smooth functioning of ecosystems is necessary for the sustained provision of services. Ecosystem services can be of direct or indirect benefit to humans and are classified as provisional, cultural, supporting, and regulating services. The use of these services as part of a broader climate change adaptation strategy is referred to as ecosystem-based adaptation.

Groundwater-dependent ecosystem	Main ecosystem services	Major climate change impacts	Major anthropogenic impacts
Wetlands 	**Supporting and regulating** Water quality improvement Flood mitigation, carbon capture Climate regulation	Increased evapotranspiration Changes in precipitation patterns	Increased input of contaminants Over-exploitation of groundwater
Agricultural ecosystems 	**Provisional** Food production Socio-economic benefits	Droughts Floods	Increase in fertilizers (nitrate and phosphate) leading to eutrophication Groundwater abstraction Irrigation salinity
Coastal ecosystems 	**Regulating and provisional** Buffer zones Flood mitigation Stabilize coastlines Fisheries	Salt water intrusion due to sea level rise and extended periods of droughts	Groundwater abstraction leading to salt water intrusion Coastal erosion
Karst ecosystems 	**Regulating and provisional** Water supply Carbon sequestration	Changes in precipitation patterns	Groundwater over-exploitation Increased input of contaminants

ECOSYSTEM-BASED ADAPTATION MEASURES FOR GROUNDWATER MANAGEMENT

The implementation of ecosystem-based adaptation measures can be based on either a certain ecosystem service, on part of an ecosystem or on several ecosystems. In many cases, ecosystem-based adaptation cannot replace the need for built infrastructure, but instead could provide a critical complement, multiplying the benefits received from healthy, functioning ecosystems.

Measure	Objectives	Components
Protecting groundwater recharge zones	Protecting the quality and quantity of groundwater resources Identifying threats Sustaining groundwater baseflow	Provide geological and hydrogeological information, so that developments can be located and controlled in an environmentally acceptable way Integrate the factors associated with the risk of contamination, focus attention on the higher risk areas and activities, and provide a structure within which control measures can be selected Assist public authorities to meet their statutory responsibilities for the protection and conservation of groundwater resources
Protecting and restoring riparian zones and floodplains	Improving (ground)water quality	Maintaining a vegetative cover over the soil throughout the year Avoiding overuse of fertilizers or manure that may be transported into riparian areas Protecting against loss of plant diversity and vitality in riparian areas Avoiding practices that artificially alter stream flow
Soil conservation and adaptation of vegetation cover	Improving groundwater recharge	Preventing soil erosion by implementing physical and vegetation-based barriers, various types of passive and active terracing on slopes, and soil management practices Agricultural adaptation to grow crops that are salt-tolerant crops (in areas affected by salt water intrusion)

FRAMEWORK FOR THE IMPLEMENTATION OF ECOSYSTEM-BASED ADAPTATION IN GROUNDWATER MANAGEMENT

To successfully implement and increase the effectiveness of ecosystem-based adaptation measures for groundwater management, it is important to understand and recognize the vulnerabilities and interdependencies between groundwater, ecosystems and services. The following steps describe the process required to create a framework for ecosystem adaptation strategies, based on the ecosystem of interest.

Integrated vulnerability assessment

1. Establishing present status and recent trends
   a. Validation and quantification of ecosystem services
   b. Validation and quantification of groundwater resources

2. Identify groundwater vulnerability and ecosystem resilience
   a. Indicate main drivers affecting groundwater dynamics and ecosystem services
   b. Determine ecosystem adaptive capacity to multiple pressures

Implementation of ecosystem-based adaptation

3. Draft ecosystem-based adaptation plan
   a. Formulate project design for adaptation strategy
   b. Measure and monitor impact of intervention
   c. Evaluation of effectiveness of adaptation strategy