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CGIAR

Wetland hydrology and relevant data for NWI

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National wetland inventories support mechanism to Contracting Parties

Innovative water solutions for sustainable development

Food · Climate · Growth

Introduction – wetland hydrology

Inland wetlands are **rainwater "harvesters"**; stores of water in landscapes.

Water storage is the defining characteristic of all wetlands

Wetlands occur across a wide range of climatic zones and under a wide range of hydro-ecological conditions.

Wetland distribution is influenced through the interaction of a number of different factors - relative relief, climate, geology etc. – that influence water movement.

Wetlands influence the movement of water within catchments, with implications for patterns of flow downstream.

Boreal/temperate climate peatland

Tropical swamp

Hydrological cycle

Five main hydrologic processes influence all riparian and wetland ecosystems:

(1) the amount, timing, and type of precipitation,

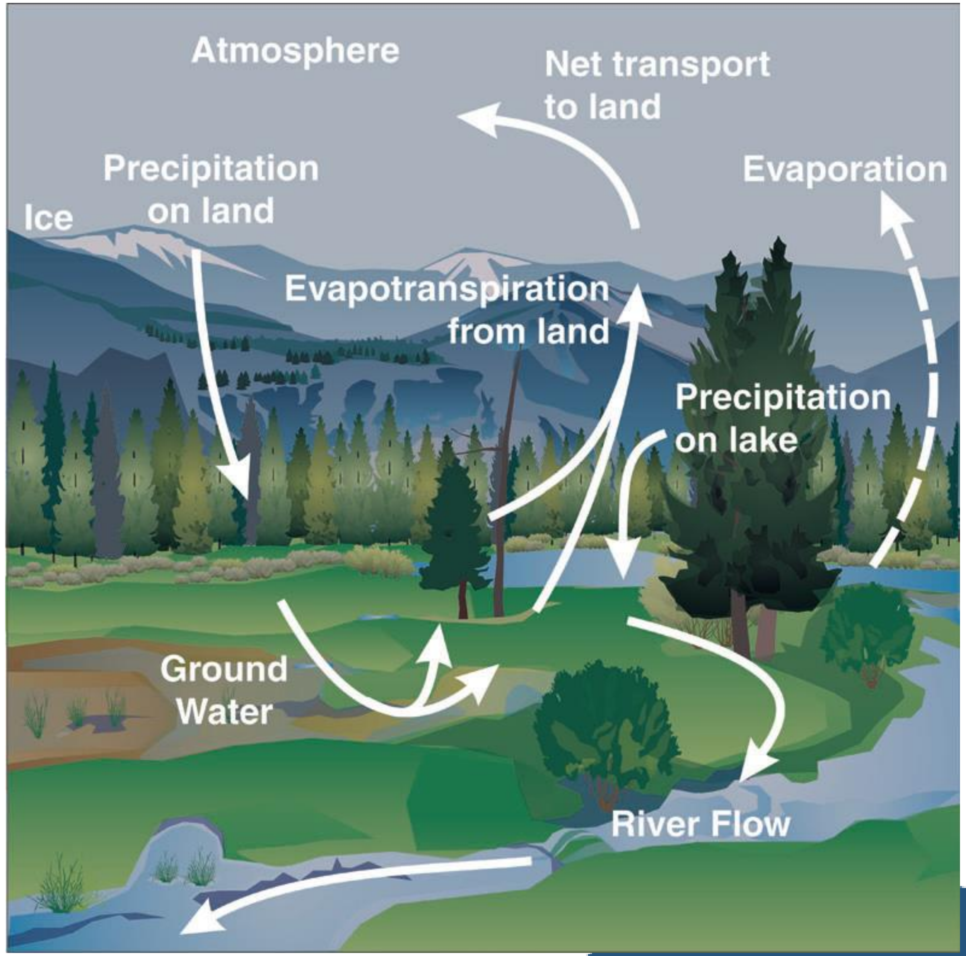
(2) groundwater recharge,

(3) groundwater discharge,

(4) surface water runoff, including stream flow, and

(5) evapotranspiration

Regions with higher total annual precipitation typically have higher annual stream flows, a higher proportion of perennial streams, and, in many areas, perennial groundwater flow systems.



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Ramsar Wetland Types

Marine/Coastal

Inland Wetlands

L. Permanent inland deltas.
M. Permanent rivers/streams/creeks; includes waterfalls.
N. Seasonal/intermittent/irregular rivers/streams/creeks.
O. Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.
P. Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes.
Q. Permanent saline/brackish/alkaline lakes.
R. Seasonal/intermittent saline/brackish/alkaline lakes and flats.*
Sp. Permanent saline/brackish/alkaline marshes/pools.
Ss. Seasonal/intermittent saline/brackish/alkaline marshes/ pools.*
Tp. Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.
Ts. Seasonal/intermittent freshwater marshes/pools on inorganic soil; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.*
U. Non-forested peatlands; includes shrub or open bogs, swamps, fens.
Va. Alpine wetlands; includes alpine meadows, temporary waters from snowmelt.
Vt. Tundra wetlands; includes tundra pools, temporary waters from snowmelt.
W. Shrub-dominated wetlands; Shrub swamps, shrub-dominated freshwater marsh, shrub carr, alder thicket; on inorganic soils.*
Xf. Freshwater, tree-dominated wetlands; includes freshwater swamp forest, seasonally flooded forest, wooded swamps; on inorganic soils.*
Xp. Forested peatlands; peatswamp forest.*
Y. Freshwater springs; oases.
Zg. Geothermal wetlands.
Zk. Subterranean karst and cave hydrological systems.
** As appropriate, includes: floodplain wetlands such as seasonally inundated grassland (including natural wet meadows), shrublands, woodlands or forest.*

"Man-made" wetlands

Duration
Source

Wetland classification based on water source

Wetland Classification – Sri Lanka

Wetland Category	Types
Freshwater (Inland wetlands)	Rivers and streams
	Floodplains
	Freshwater swamp forests
	Villus
	Peatlands
	Freshwater marshes
Saltwater (Coastal and marine wetlands)	Sea grass beds
	Coral reefs
	Mangroves
	Salt marshes
	Lagoons
	Estuaries
Man-made	Hydropower reservoirs
	Irrigation tanks
	Salt pans

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Key Aspects of Wetland Hydrology

1. **Water Sources**: Water comes from various sources, including precipitation, surface water (rivers, lakes), groundwater, and tidal waters. The balance between these sources influences the hydrology and type of wetland.
2. **Hydroperiod**: The seasonal pattern of the water level in a wetland. Includes the timing, duration, frequency, and depth of flooding or saturation. A critical factor in determining the plant and animal species that can inhabit a wetland.
3. **Water Flow**: The movement of water through wetlands is influenced by topography, soil characteristics, and vegetation.
4. **Water Quality**: Wetland hydrology affects water quality by influencing processes such as sediment deposition, nutrient cycling, and pollutant removal.


Bale Mountains – water tower, Ethiopia

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Hydrogeomorphic Classification of inland wetlands - based on hydrology/landscape position

Surface water dependency

- Precipitation – primary source of water for many wetlands, particularly in regions of high rainfall (e.g. bogs)
- Surface runoff from surrounding landscape (catchment)
- Flooding and Inundation – periodic flooding from adjacent rivers (e.g. floodplains riparian wetlands)

Groundwater dependency

- Many wetlands depend on groundwater as primary water source

(e.g. fens, g/w–fed marshes and springs)

Hydrological connectivity

Most wetlands depend on a combination of surface water and groundwater, with varying degrees of dependence depending on the wetland type and hydrological setting.

Interplay between surface water and groundwater creates complex hydrological conditions that shape wetland/ecological character and functions.

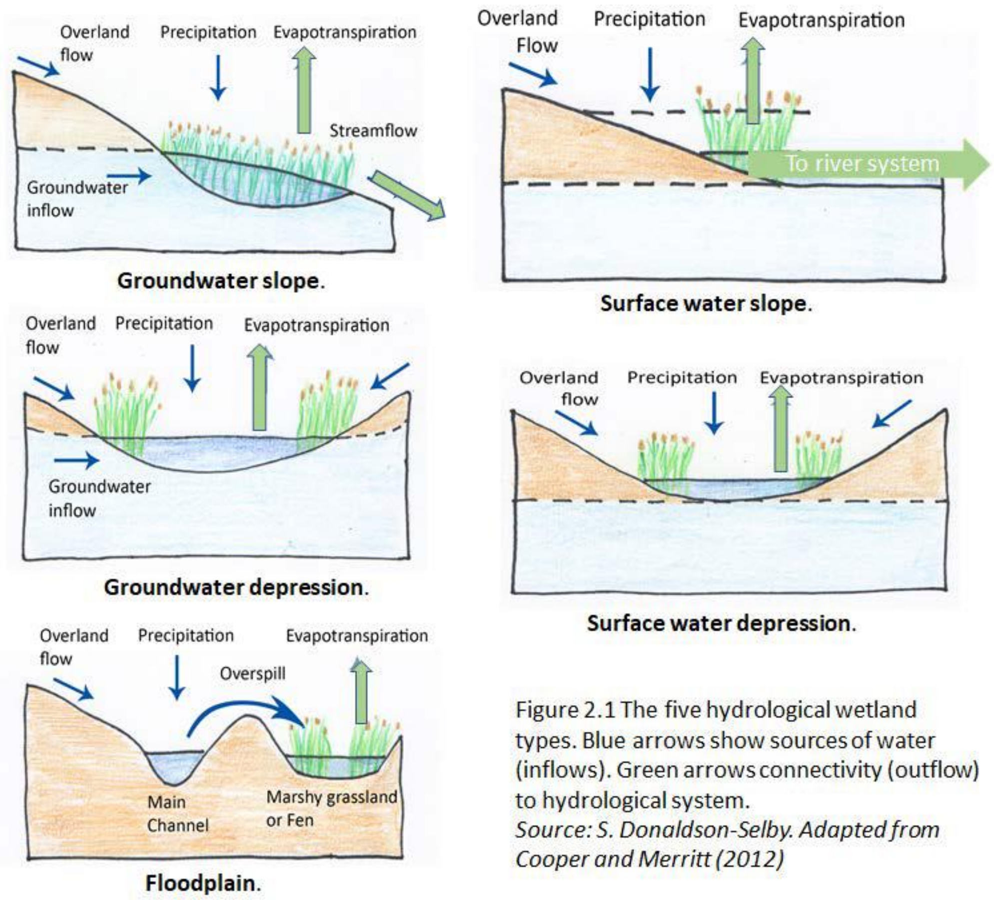

Figure 2.1 The five hydrological wetland types. Blue arrows show sources of water (inflows). Green arrows show connectivity (outflow) to hydrological system.
Source: S. Donaldson-Selby. Adapted from Cooper and Merritt (2012)

Hydrological function: impacts of wetlands on hydrology

Perception: wetlands = "**sponges**" - absorbing, storing and slowly releasing water

- Attenuates downstream flooding
- Contributes to groundwater recharge
- Releases water in dry periods thereby maintaining baseflows in rivers and streams
- Filters sediments, nutrients and pollutants thereby purifying water

Reality: more complex – actual impacts depend on exact context, including antecedent conditions

- Many headwater wetlands contribute to runoff/flood generation
- Many wetlands exist because they impede groundwater recharge
- Evaporation from many wetlands is vey high, reducing downstream flows
- If chemical loadings exceed physiological tolerances of microbes and plant species then degradation occurs (e.g. eutrophication when overloaded with agricultural nutrients).

Need is to understand **temporal and spatial dynamics** of wetland functions and not to assume certain responses

Lake, Ethiopia

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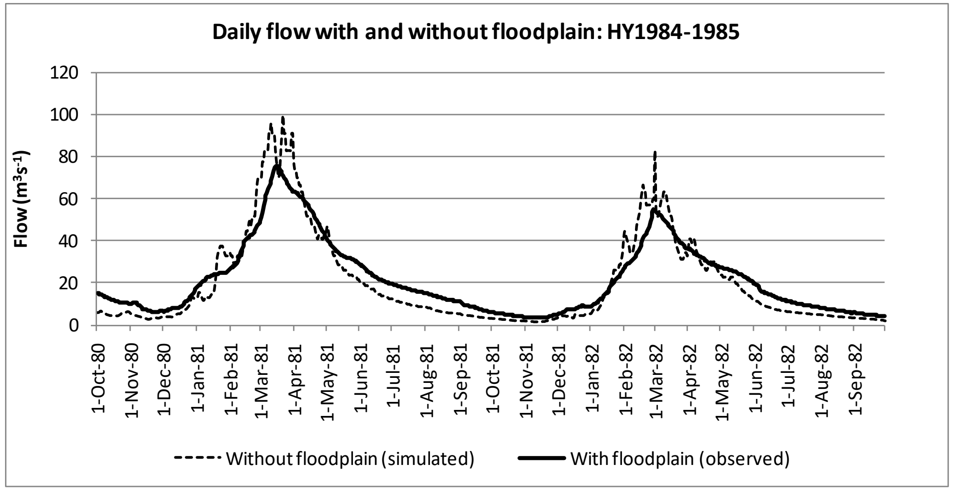
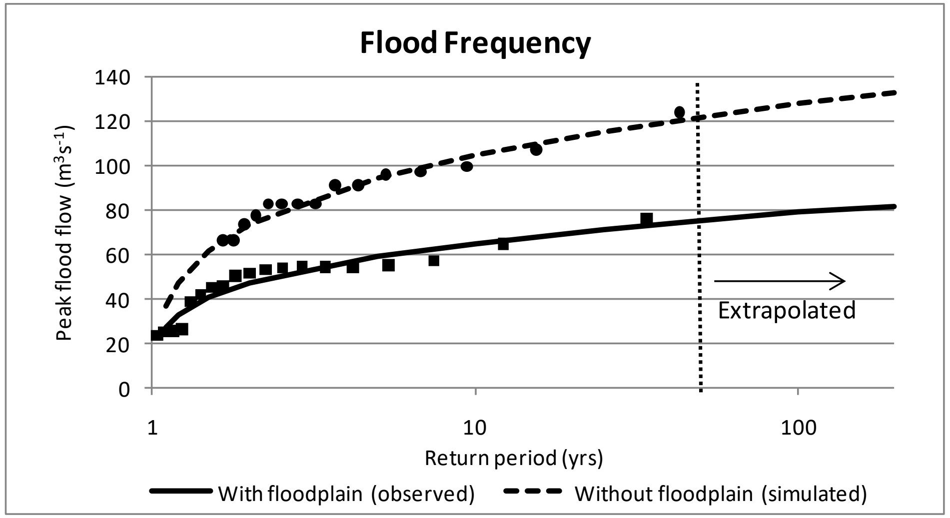
Impacts of wetlands on hydrology – floods





Luswishi Floodplain – Southern Africa

Return Period (yrs)	Flood peak (m^3s^{-1})	
	With floodplain	Without floodplain
2	47	73
10	65	105
25	71	115
50	75	122
100	79	128
200	82	133

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Colombo Wetlands

- Colombo is a city built around wetlands (Colombo Wetland Complex)
- Hydrological catchment is 227 km^2
- Wetlands cover of 20 km^2 in the CMR but declining due to landfill and waste disposal
- Reduce urban flooding – store 39% of flood waters.
- 232,000 people - greater flood protection
- Save 1% of the CMR's GDP loss

Urban wetlands, Colombo, Sri Lanka

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Wetland impact on baseflow
Dambos Southern Africa

Zimbabwe legislation to prevent their use for agriculture because they are the “source” of dry season flow.

Considerable volumes of water stored in the wetland at the end of the wet season but only small proportion (12%) converted to flow.

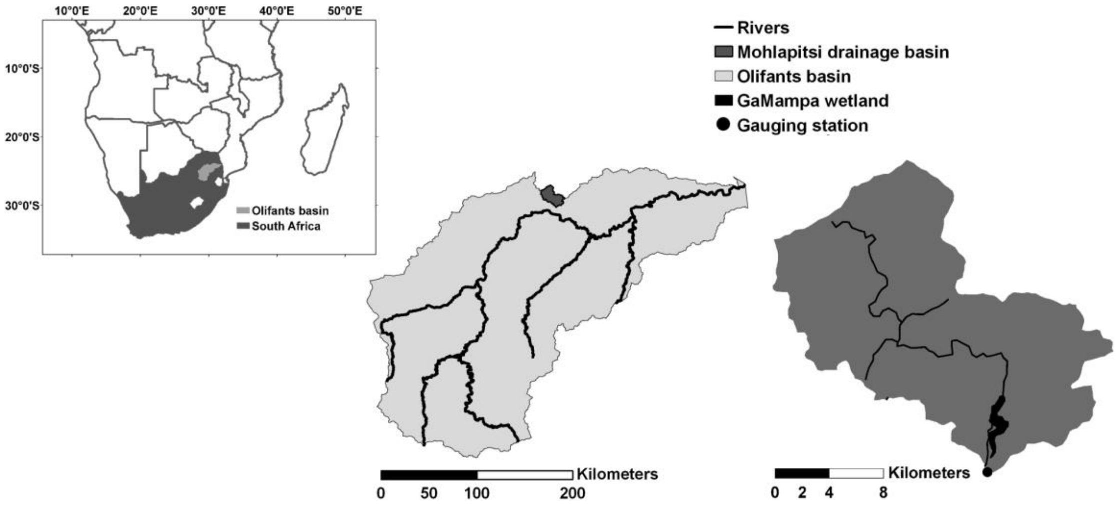
Depletion is primarily through evapotranspiration.

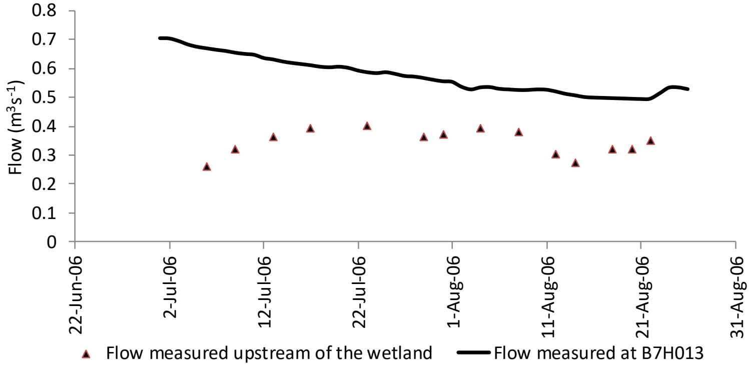
Dambo cultivation, Malawi

Muchindamu River in Zambia
(area of wetlands = 10% of the catchment)

	BFI	1-day minimum (m^3s^{-1})	10-day minimum (m^3s^{-1})
With wetlands	0.284	0.12	0.13
Without wetlands	0.444	0.24	0.27

GaMampa wetland, South Africa





Perception – the wetland is the source of very important dry season river flow.

Reality – the wetland itself contributes little to the dry season river flow. The flow is maintained by groundwater from the undisturbed upper catchment.

GaMampa Wetland, South Africa

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Hydrological Data Relevant to NWI

Hydrological Data:

- Sources of water
- Hydroperiods
- Flow patterns (inflow and outflow) – fluxes
  - Water budget
- Water Quality

Establishing a flow gauging station in Ethiopia

Measuring water level

Data Sources:

- On the ground measurement (stream gauges, weather stations etc)
- Remote sensing
- Hydrological models
- Citizen Science

AWS over a reedbed

Hydrometeorological (Hydromet) Data sources (1)

Government Agencies: in many countries data are collected/archived by national meteorological and hydrological services

UK:	Meteorological Office and Environment Agency
US:	National Oceanic and Atmospheric Administration (NOAA) and US Geological Survey (USGS)
Zambia:	Zambia Meteorological Department (ZMD) and Water Resources Management Authority (WARMA)
Ethiopia:	Ethiopian National Meteorological Institute (NMI) and Ministry of Water and Energy
Bhutan:	National Centre for Hydrology and Meteorology (NCHM)

Anemometer, Bhutan

Adhoc data collection by projects:

Grand Ethiopian Renaissance Dam (GERD) on Blue Nile
Gibe III Dam on Omo River

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Hydrometeorological (Hydromet) Data sources (2)

International Organizations:

Global: World Meteorological Organization

- World Hydrological Cycle Observing Systems (WHYCOS) – river basins

Global Runoff Data Centre (GRDC)
https://grdc.bafg.de/GRDC/EN/Home/homepage_node.html

- time series of daily and monthly river discharge data for over 10,000 stations

United Nations Environment Program (UNEP)

Regional: US National Weather Services
European Centre for Medium-Range Weather Forecasts (ECMWF)
International Groundwater Resources Assessment Centre (IGRAC)
https://www.un-igrac.org/
South African Development Community (SADC) Climate Services Centre
Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (IPAC)

River Basin: Zambezi Water Course Commission
Mekong River Commission
Nile Basin Initiative (hydromet program)
Incomati River Basin Authority

Measuring water-level, Ethiopia

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Challenges of Hydromet data collection and access

Limited monitoring infrastructure: lack of weather stations, flow gauges and groundwater monitoring wells. Many existing stations are poorly maintained resulting in incomplete and inaccurate data.

Data gaps and inconsistencies: spatial and temporal gaps due to uneven distribution of monitoring stations. In remote or conflict affected areas data collection is sporadic or non-existent (e.g. at high altitude in Bhutan). Historic data often incomplete makes it difficult to establish patterns and trends.

Financial Constraints: Many countries struggle to allocate sufficient funds for hydromet infrastructure, staffing, and capacity-building. To try and recoup funds many require payment for data.

Capacity Gaps and lack of expertise: Limited technical expertise and human capacity to operate and maintain hydromet equipment, analyze data, and interpret results.

Political and Institutional Barriers: Data sharing between different agencies, regions, or countries is often restricted by political, legal, or institutional barriers. National security concerns, lack of trust, bureaucratic procedures etc. prevent the exchange of data

Data Accessibility and Integration Issues: Collected data may not be easily accessible to end users. Often stored in incompatible formats, isolated databases and without proper integration. No quality control.

Meteorological Data records, Ethiopia

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Remote Sensing (RS) contribution to understanding wetland hydrology

Mapping and monitoring water extent

- Optical and radar imagery can map the extent and distribution of open and vegetated surface water (Landsat, Sentinel-1 and Sentinel -2) can differentiate between water and land and can track seasonal variation, floods and droughts.

Measuring Water-levels and elevation

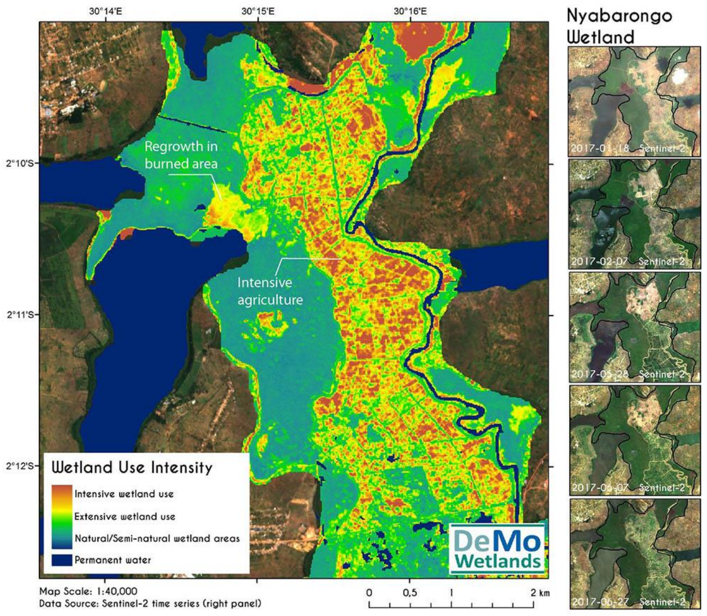
- Radar altimetry can measure water levels in large wetlands, lakes and rivers. Can be used to understand seasonal variation, short and long-term trends in water levels
- Light Detection and Ranging (LIDAR) provides high-resolution elevation data, allowing for detailed mapping of wetland topography. Helps understand the relationship between landforms, water flow, and storage in wetlands.

Hydromet data

- Missions like NASA's Global Precipitation Measurement and ESA's Soil Moisture missions, provide data on hydromet at regional/continental/global scales. Can be useful model inputs

Mapping and monitoring water quality

- Hyperspectral and multispectral sensors can estimate some water quality parameters such as chlorophyll-a, turbidity, and suspended sediments.



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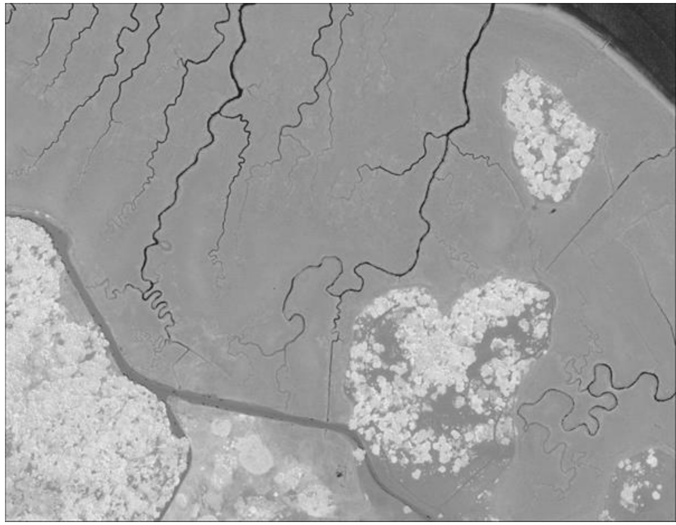
Challenges and limitations of RS

Resolution and Accuracy The resolution of RS imagery can limit the accuracy of wetland mapping and monitoring, especially for small or intricate wetland features. High-resolution sensors and advanced image processing techniques are needed for detailed analyses.



Data Processing and Interpretation Analyzing remote sensing data requires specialized knowledge and software. Accurate interpretation often involves combining data from multiple sources and applying complex algorithms.

Temporal Coverage The frequency of satellite passes and image availability can affect the ability to monitor dynamic wetland environments. Continuous or high-frequency monitoring may be needed for certain applications.

Cloud Cover and Atmospheric Conditions Optical imagery can be hindered by cloud cover and atmospheric conditions, limiting data availability and quality. Radar and LiDAR can mitigate some of these issues but have their own limitations.

Cost and Accessibility High-resolution and specialized remote sensing data can be expensive, and accessing certain types of imagery may be restricted. Budget constraints may limit the availability of data.

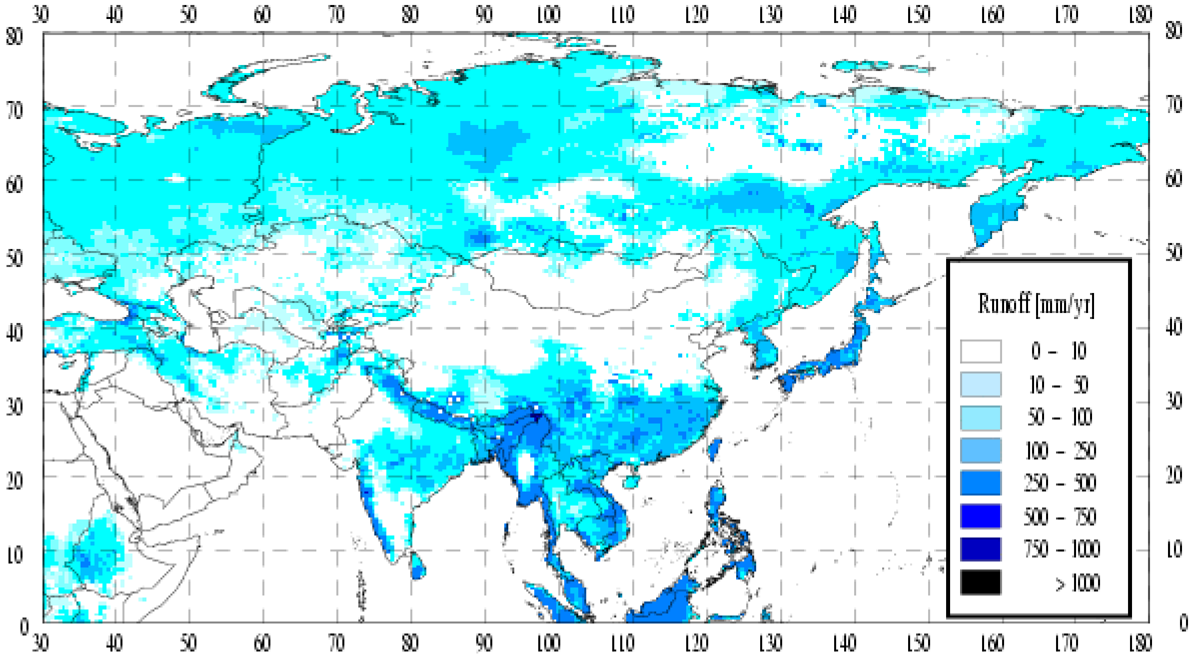
Hydrological Models: simulated data

Hydrological models simulate movement and water within a river basin and can be used to understand changes in wetland water budgets and the impacts of human water resource interventions.

Typically inputs are rainfall, temperature, land-use and soil and vegetation characteristics.

Models are calibrated and validated with observed data but can be used to fill gaps in time series and to estimate flow and water fluxes at locations where no data are collected.

There are hundreds of models (estimating plot to basin to continental runoff) with different characteristics.



GRDC – global gridded runoff data (30’ spatial resolution)

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Citizen Science (CS)

- Citizen scientists, often including local community members, volunteers, and non-professional scientists, can contribute to data collection and monitoring efforts.
- Simple tools to help understand hydrological and water quality dynamics
- Apps (fun to use) can facilitate contributions and foster public awareness and engagement
- Can be a cost effective and inclusive way of supplementing other data collection efforts
- CS adds to and complements data from other sources including RS

Instruments for citizen scientists

Wetland Health App – Sri Lanka

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Operationalizing

To operationalize hydrological data into a National Wetland Inventory (NWI) – to improve wetland management:

Data Collection and Integration

- **Remote Sensing and GIS Data**: Use remote sensing technologies and geographic information systems (GIS) to collect data on wetland hydrology - mapping water extent, flow, inundation patterns, and vegetation cover.
- **Hydrological Models**: Models can be used to predict hydrological dynamics in wetlands.
- **Ground-Based Data**: Combine ground-based hydrological data - field surveys, monitoring stations, and citizen science data.
- **Integration with Other Data**: Combine hydrological data with other ecological, socio-economic, and land use datasets to provide a comprehensive overview of wetland status and trends.

Data Harmonization and Standardization

- **Develop Standards and Protocols**: Establish standardized protocols for data collection, management, and analysis to ensure consistency across different datasets.
- **Use National or Regional Classification Systems**: Apply national or regional wetland classification systems (such as the Cowardin classification in the U.S.) to categorize wetland types, including through hydrology.

Data Processing and Analysis

- **Mapping and Spatial Analysis**: Use GIS (and machine learning?) to analyze hydrological data and create detailed maps of wetland boundaries, hydrological regimes, and ecological characteristics.
- **Change Detection and Trend Analysis**: Use temporal data to detect changes in wetland hydrology, such as shifts in water levels, inundation frequency, or changes in vegetation.

Stakeholder Engagement and Collaboration

- **Collaborate with Agencies and Institutions**: Collaborate with national and regional agencies, research institutions, and conservation organizations to share data, methodologies, and tools.
- **Data Sharing**: Make hydrological data publicly accessible through national data portals or platforms. This can facilitate its use.

Summary

- Wetlands are dynamic ecosystems that depend on both surface water and groundwater to maintain their hydrology, ecological functions, and biodiversity.

- The balance and interplay between these water sources shape wetland characteristics and determine their resilience to environmental changes.

- Hydrological regime is a key criteria for classifying wetland types

- With increasing pressure on water resources understanding their hydrology is a prerequisite for wetland conservation and long-term sustainability.

- Hydrology should be a fundamental component of NWI but hydrological functions are context specific and difficult to predict.

- Monitoring wetland hydrology is complex and expensive but modern techniques of RS and citizen science can contribute

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Thank you.

Useful websites/publications

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