GIS techniques as applied for planning small hydro projects in remote areas

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Introduction

- Assessment of SHP sites for development represents a high proportion of overall project costs. Moreover, the sites are often located in remote areas with limited access to engineering teams.
- The advent of GIS technologies has enormous use to capture the range of spatial information at a catchment level for hydropower purposes. The assessment is carried out automatically using the GIS tool (e.g., ArcGIS Spatial Analyst etc.).

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Introduction

- A number of countries using advanced GIS technology developed interactive web-based maps of hydropower resources (e.g., US ORNL HydroSource Data Explorer; GECOsistema: Pan-European small hydropower atlas).
- Available at online platforms indicating individual site locations and various key datasets - energy, hydrology, environmental and economic parameters, enabling users to freely and instantaneously obtain the necessary information.
- Hydropower atlases (map viewers) are primarily published on commercial ESRI ArcGIS, ArcGIS Online, Google Earth or open-source QGIS software.
- In some parts and countries of the African continent GIS-based hydropower resource mapping viewers are available in West Africa (e. g., ECOWAS ECREEE & Pöyry: GIS Hydro Resource Mapping in West Africa), Tanzania, and Madagascar. In Colombia (Latin America): Atlas of Colombia's Hydropower Potential.

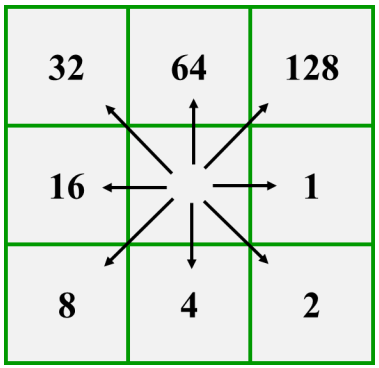
Objective: To develop a web-based map of hydropower resources (or interactive hydropower atlas) in the selected countries of Africa and Latin America (Cameroon and Uganda, Bolivia, Colombia and Ecuador).

Specific objectives:

- To collect topographic, hydrographic, hydrological, climate, hydropower and environmental data in geospatial format.
- To create the digital elevation model (DEM) and delineate river network and catchment and sub-catchment areas and develop longitudinal profiles of streams.
- To model stream-reach theoretical hydropower potential.
- To identify some 2,500 potential hydropower sites with their key datasets.
- To publish collected and modelled geospatial data onto an open-access web-based platform.

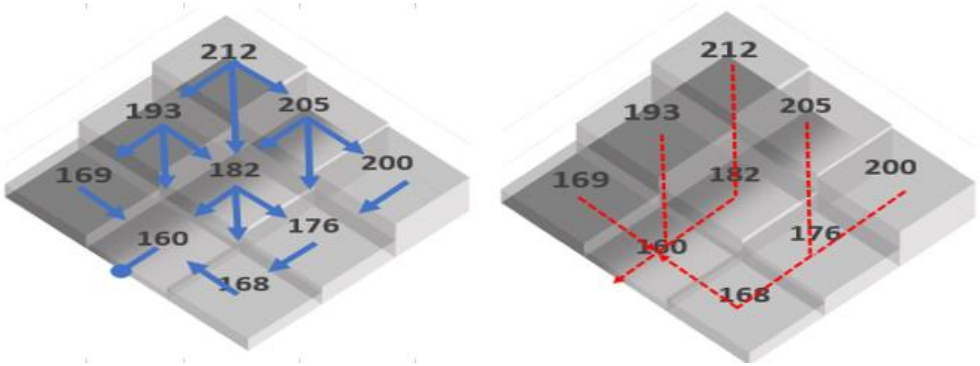
Methodology

River network generation and catchment delineation. To solve this task we applied well known gravitation-based model.



Flow direction procedure based on the D8 flow method.

D.G. Tarboton, R.L. Bras, I. Rodriguez-Iturbe
On the extraction of channel networks from digital elevation data
Hydrol. Process. (1991), pp. 81-100



212	193	169	160
205	182	160	165
200	176	168	122
208	187	166	150

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205	182	160	165
200	176	168	122
208	187	166	150

212	193	169	160
205	182	160	165
200	176	168	122
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"Hydrologically correct" DEM is required for this procedure. Pits must be "filled up", otherwise flow stops at the pit.

This method assigns flow direction to the steepest downslope neighbor using 3*3 cell filter.

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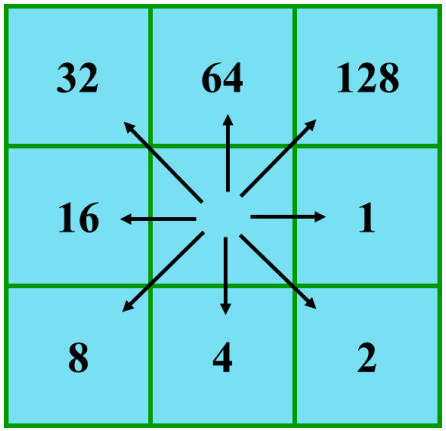
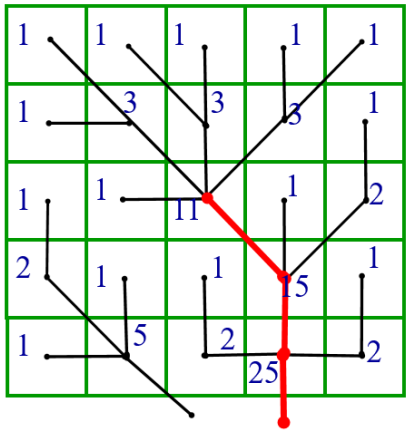
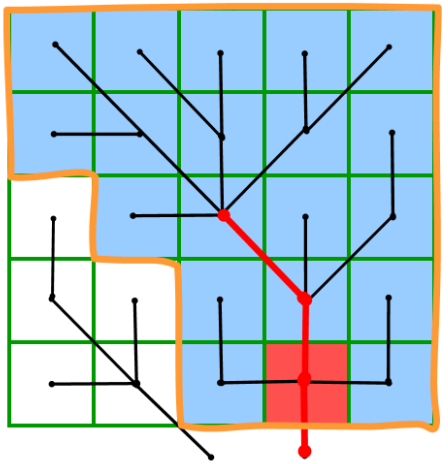
Methodology

Schematics

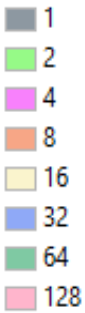


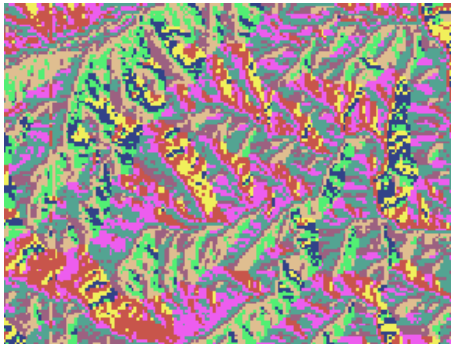




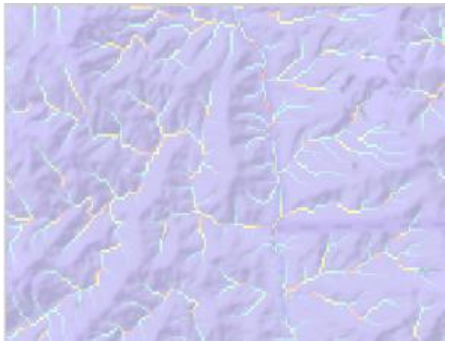
How it looks using real data

Real image

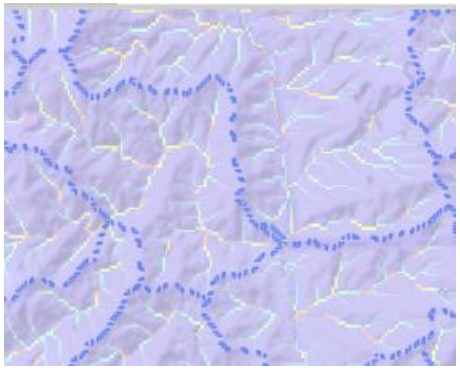




Flow direction



Flow Accumulation



River network and catchments

This algorithm is realized in number of GIS software like ESRI ArcGIS or open source QGIS.

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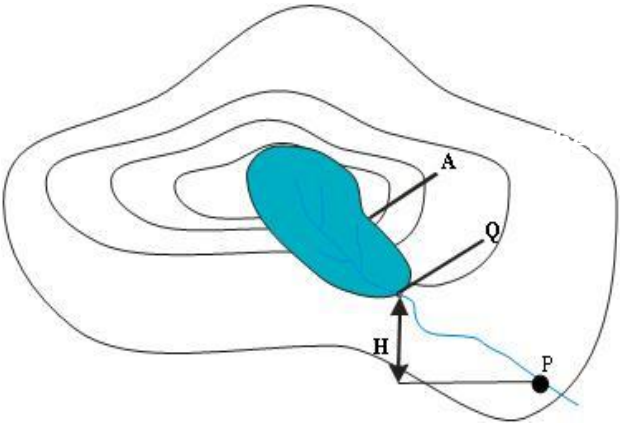
Methodology



$$P = g*Q*H$$

A – catchment area, km²
Q - flow rate (monthly or annual)
H – elevation head, m
P – stream reach power, kW
g – gravitational acceleration

What attributes we have today:
For each 2500 m length segment
At the start and at the end

Attributes for each river segment

$$Q = q*A$$

Averaged sub catchment theoretical HP potential (MW)

At both ends of segment	Averaged value for segment
Elevation m	Gradient H m
Catchment area km²	Slope
Flow rate Q m³/s	Theoretical hydropower potential (MW)
	Specific HP potential MW/km

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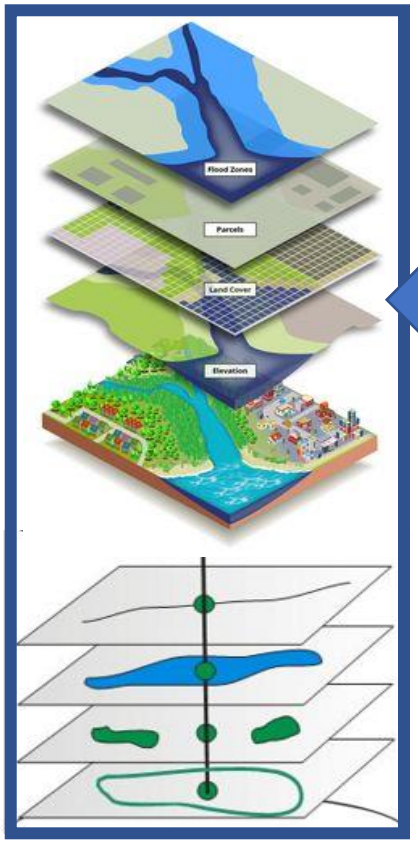
HYPOSO Map Layers (ca 40)



No	Group	1st layer	
1	Base map	1.1	Open Street Map (OSM)
		1.2	Open topo map
		1.3	Satellite imagery
2	Background & Infrastructure	2.1	National Boundaries
		2.2	Protected Areas
		2.3	Power Grid
3	Operational Hydropower plants (HPP) and under construction	3.1	Large Hydro (>100 MW)
		3.2	Medium Hydro (>50 to 100 MW)
		3.3	Intermediate Hydro (>10 to 50 MW)
		3.4	Small Hydro (>1 to 10 MW)
		3.5	Micro and Mini Hydro (500 kW to 1MW)
4	Climate and Hydrology	4.1	Climate Zones
		4.2	River Basins
		4.3	Stream Order
		4.4	Catchments
		4.5	Gauging Stations
		4.6	Mean Annual Precipitation
		4.7	Mean Annual Flow

No	Group	1st layer		2nd layer
5	Hydropower (HP) Resources (Potential)	5.1	HP potential sites	5.1.1. Planned HPP
				5.1.2. New site
				5.1.3. Retrofitting of existing dams (non-powered dam, weir,
				5.1.4. Obsolete HP plant
		5.2	HP potential from New Stream-Re Development (NSD) in MW	
		5.3	Aggregated catchment HP potential	
		5.4	Specific HP potential MW/km	
6	Climate change impact on Hydropower resources /Climate change projections	6.1	Near Future HP potential at catchment level (short term)	
		6.2	Far Future HP potential at catchment level (long term)	

Target: ca 2,500 sites

TDB

HYPOSO Map

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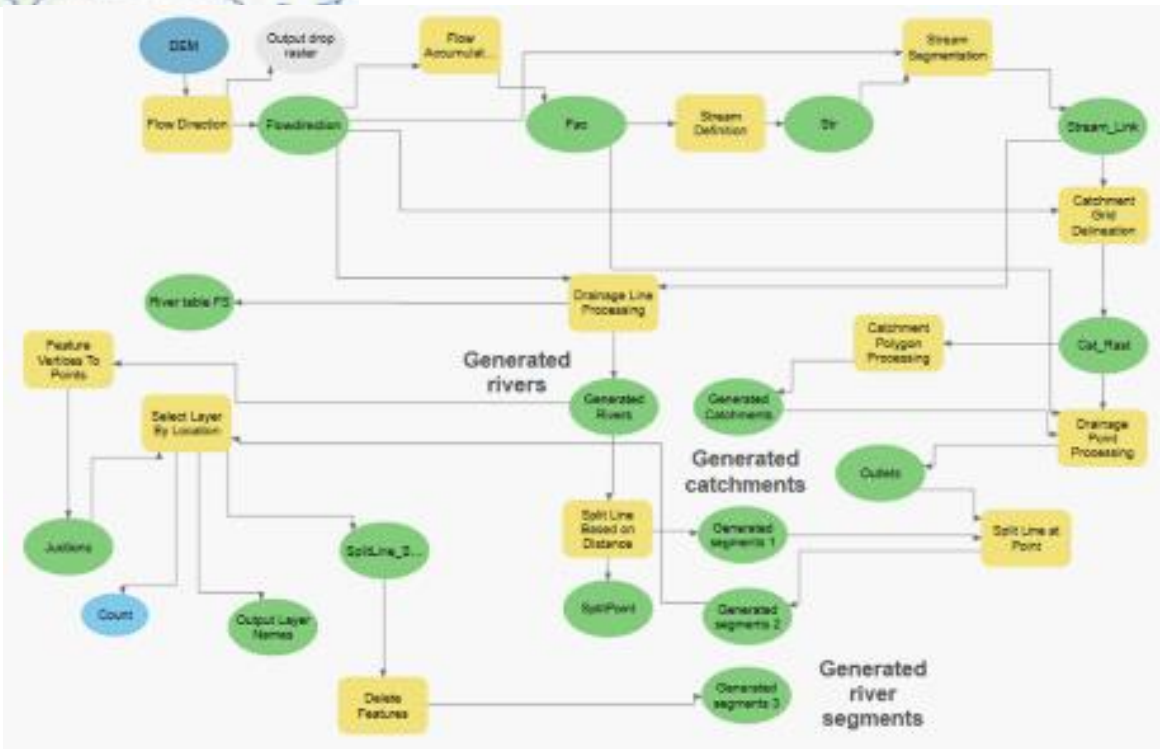
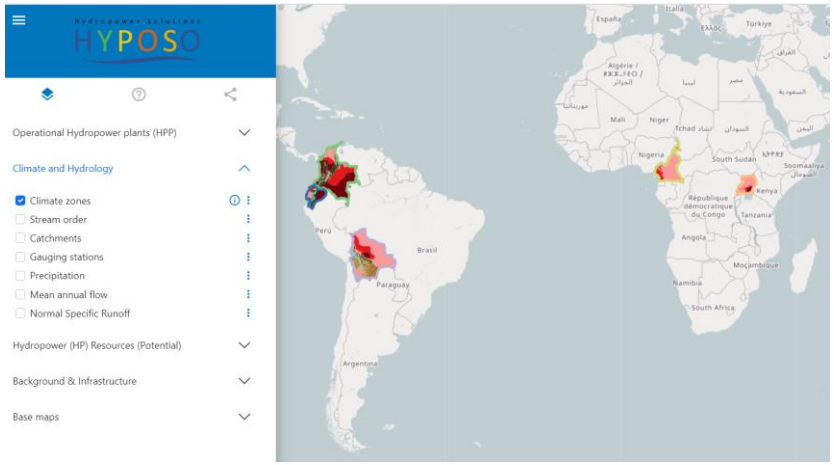
Splitting rivers into segments of 2.5 km

To make easy this cumbersome job, the ArcGIS Pro tool was developed, which can complete all these procedures

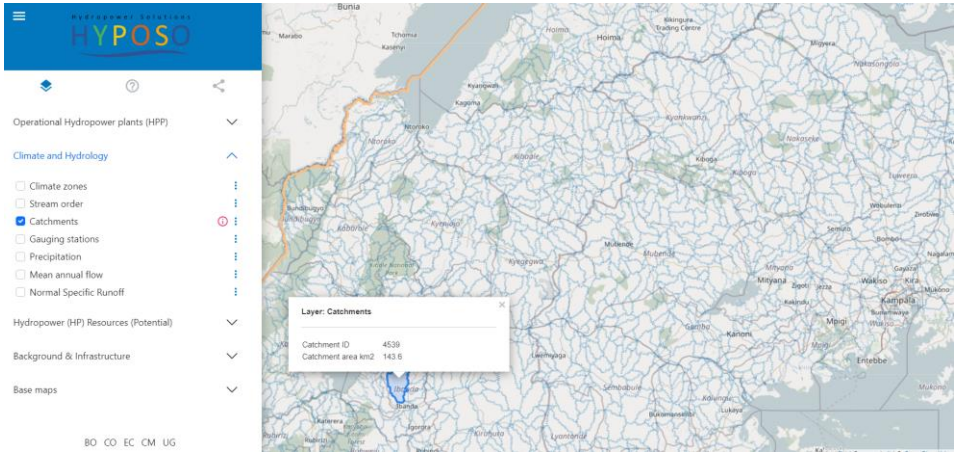


HYPOSO WEB BASED INTERACTIVE MAP

Frontpage of the HYPOSO web map viewer



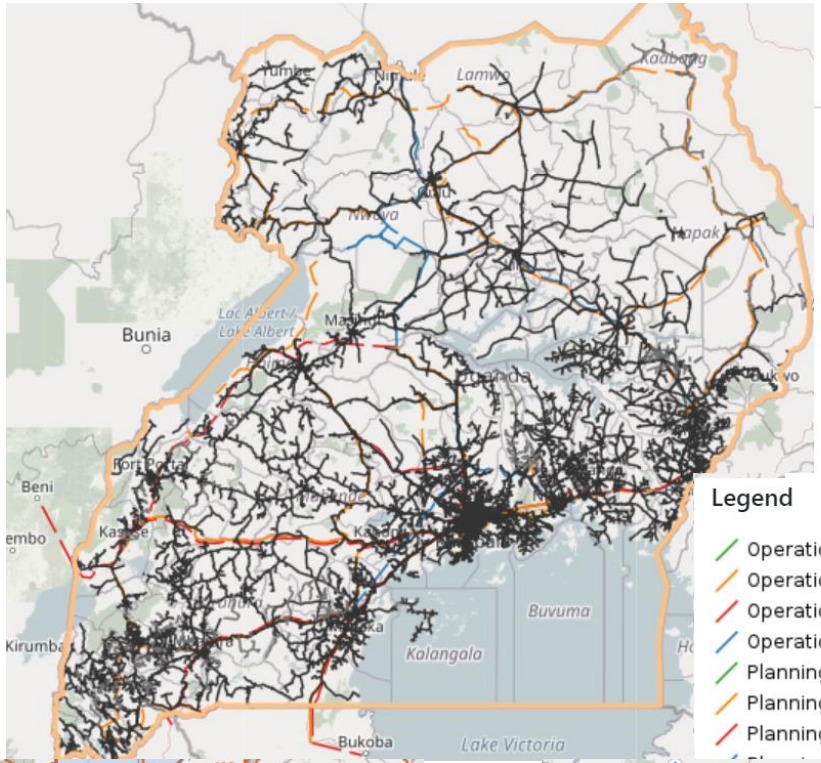
Generated small catchments for Uganda. A 143.8 square kilometres catchment boundary is shown.



The Hyposo map – a web-based platform, is an open-source GeoServer software.

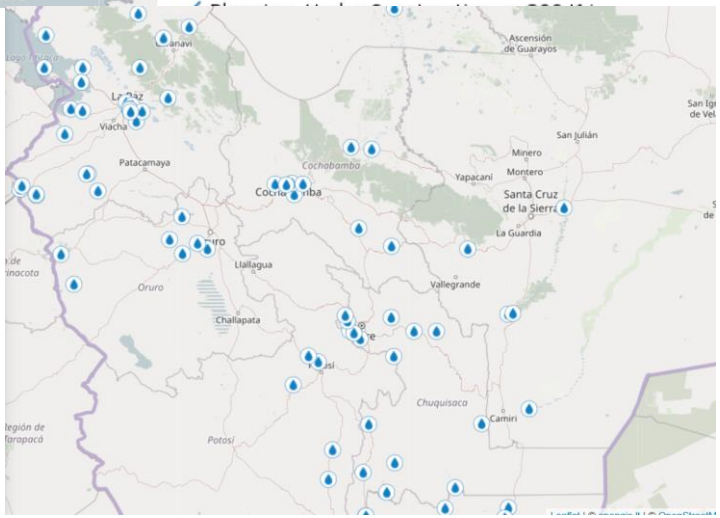
It allows users to input, process and publish geospatial data and supports data interchange from most spatial data sources using open standards.

Transmission and distribution grid



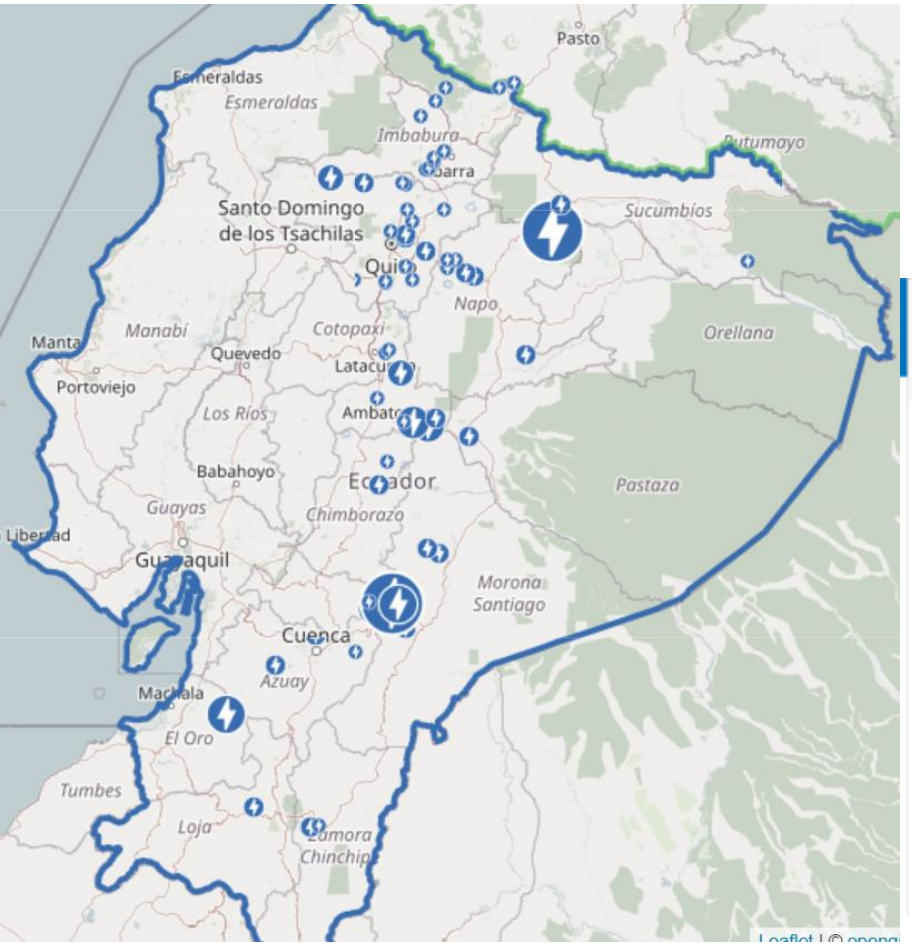
HYPOSO Map

River basins

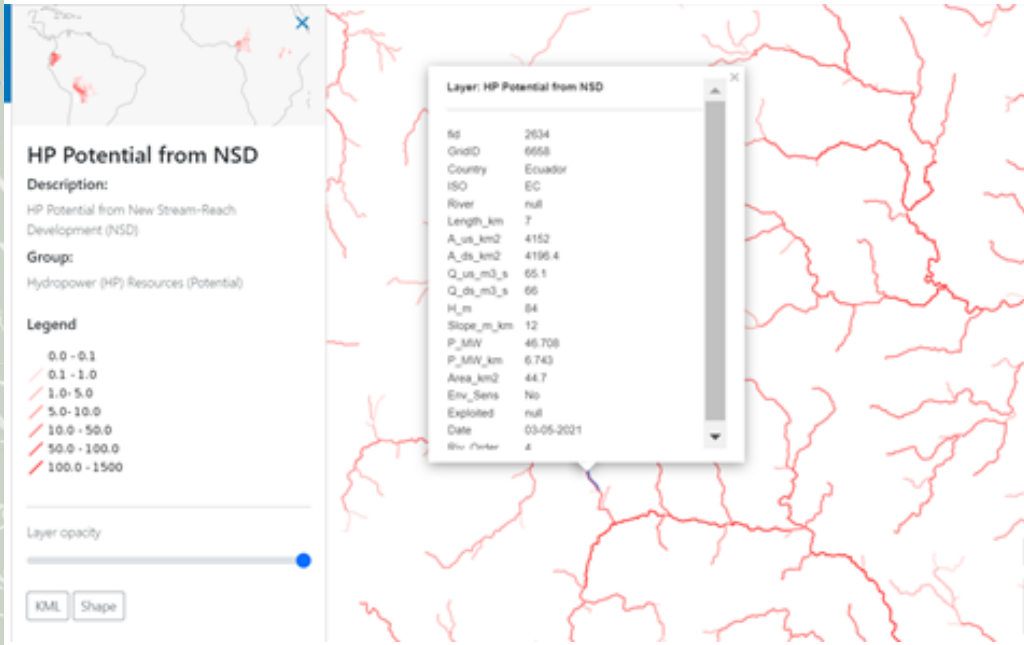


Gauging stations

Operational hydropower plants in Ecuador

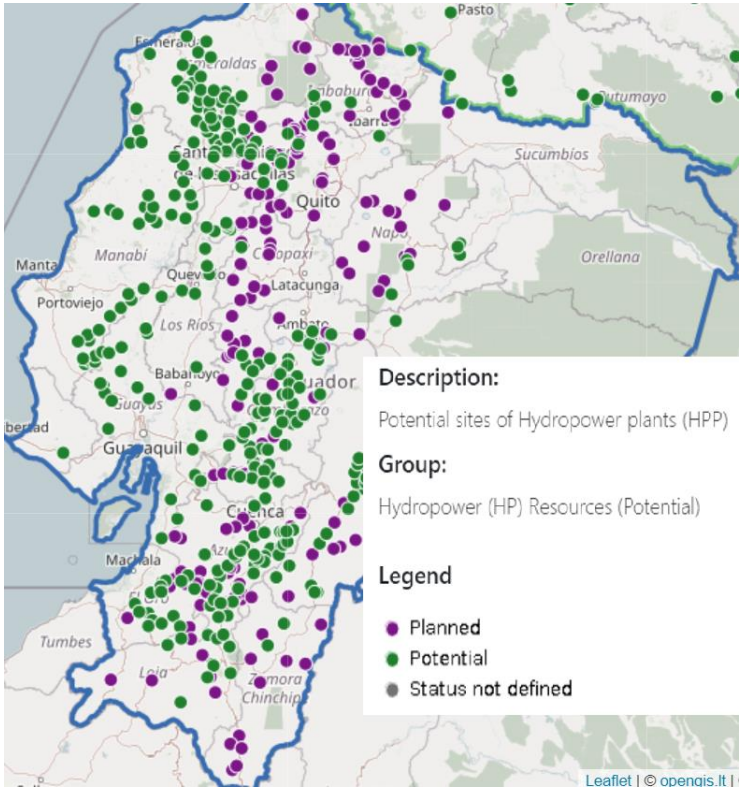


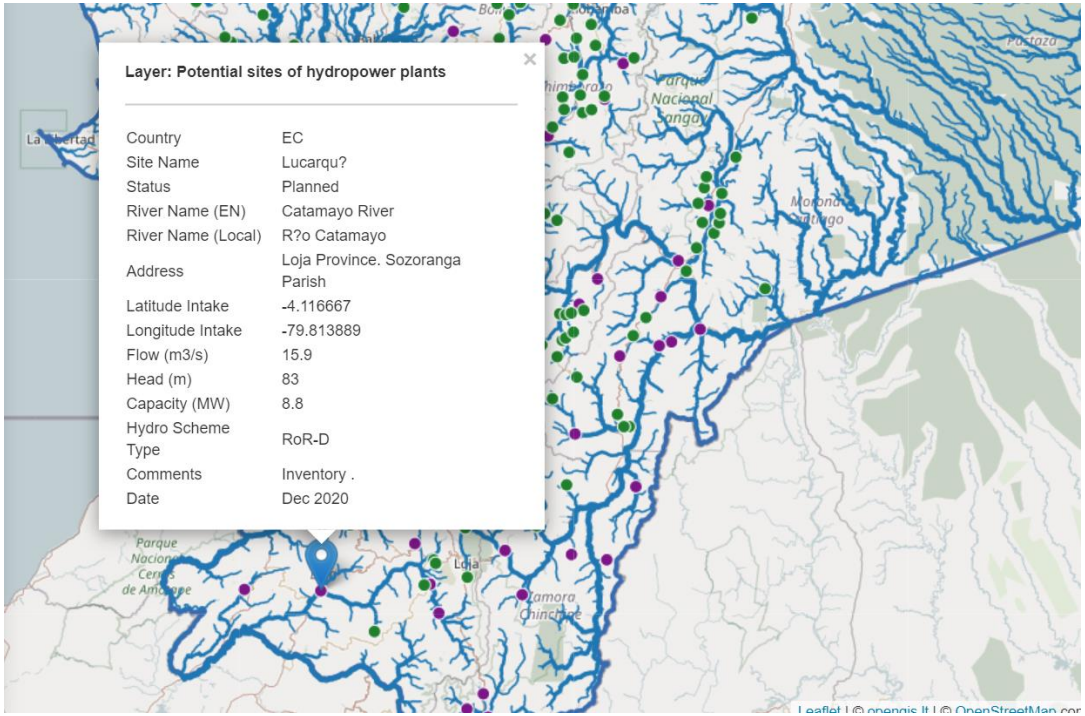
The theoretical potential of a river reach (new stream-reach development) with a pop-up providing a brief description in Ecuador



Available geospatial data sets can be explored and visualised by zooming, panning, and clicking on the map layers or icons to open the legend to this map.
In addition, there is a possibility to download the geodata in KML or Shape format.

HYPOSO Map





Potential hydropower sites (a pop-up providing a brief description)

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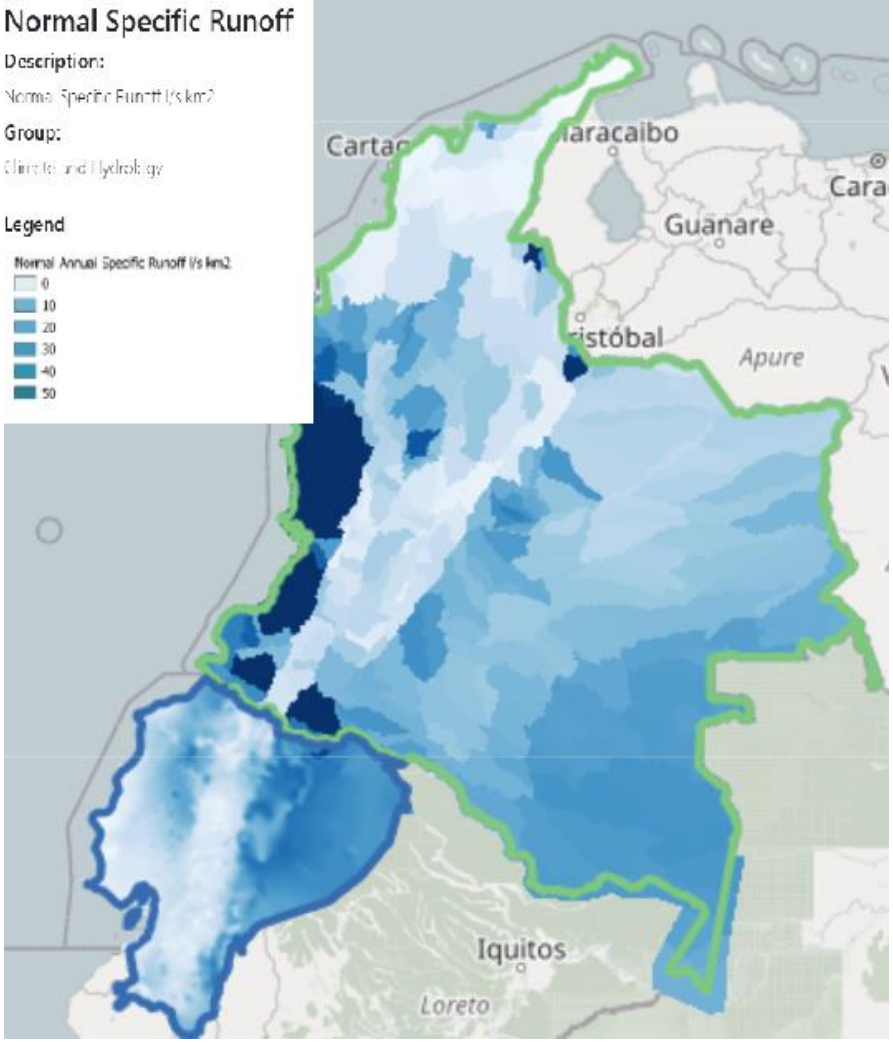
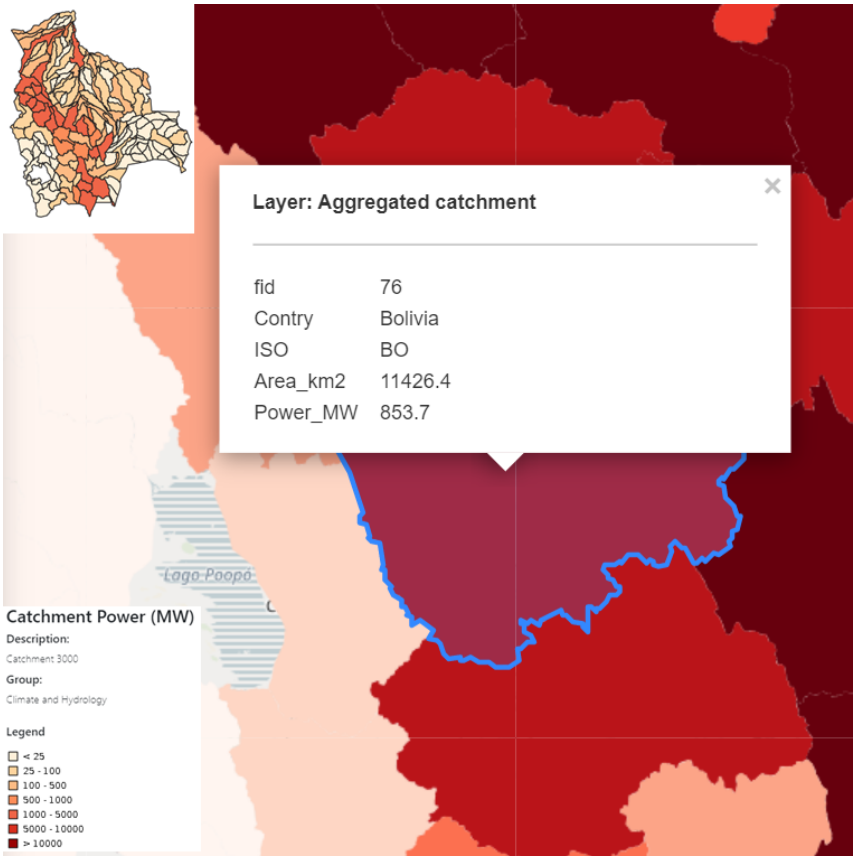
HYPOSO Map

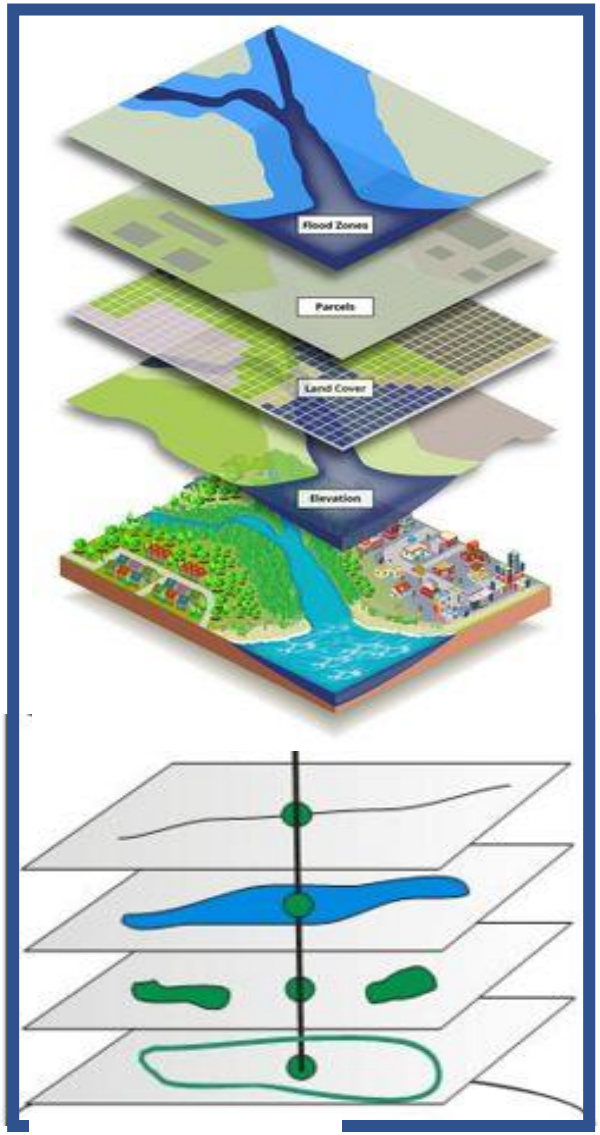


Specific discharge



Aggregated catchment power

HYPOSO Map



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This virtual hydropower atlas will be only a kind of discovery, identifying sites worthy of further investigation automatically.
The estimates modelled and derived will not represent the actual numbers feasible for engineering design.
It will be the users sole responsibility to determine whether any site or river reach is worthy of further investment.

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Concluding remarks

- The Hyposo web map viewer software is still a beta version and the geospatial data sets are being filled with new entries.

- Due to large areas of the countries and modest financial and human resources allocated for this project, detailed river basin hydrological modelling was not performed. To characterise the mean annual river flow the specific discharge ($l/s \cdot km^2$ or $m^3/s \cdot km^2$) was mapped.

- The anticipation of long-term trends in climate change is of utmost procedure for thoroughly planning hydropower development.

- Uncertainties in such hydropower assessment study will be addressed in the future.

- The Hyposo web map viewer will be available on the HYPOSO project website this year (https://www.hyposo.eu/en/home/).

Thank you for attention

Dziękuję za uwagę

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