Methodology for Mini Hydro Power potential based on a GIS approach

The following methodology has been developed in order to assess the mini hydropower potential on a regional and global level, based on a GIS (Geographic Information System) approach which utilizes publicly available GIS datasets. The result is expected to be used as an input in the overall electrification model in order to assess the potential penetration of mini hydro in the electrification mix for the selected countries.

The methodology has been developed in ArcGIS and RivEX environment and is basically connecting and combining a number of attributes retrieved by the following components:

- Digital elevation map (DEM-SRTM)
- Global river network (HydroSHEDS)
- Global Streamflow Characteristics Dataset (GSCD)
- Additional vector and raster layers (administrative boundaries, inland water bodies, restriction zones etc.)

The first step of the methodology includes the acquisition of high resolution elevations maps. Digital elevation maps (DEM) at 90 meters spatial resolution (0.00083^{o}) were obtained by NASA/JPL Shuttle Radar Topography Mission (SRTM). The maps were collected in 5 degrees tiles and merged in order to offer global coverage for land surfaces with latitude between 60 degrees North and 56 degrees South.

Then, the digital elevation map was further processed using the Hydrology toolbox in ArcGIS in order to obtain the flow direction and the flow accumulation raster layers. These functions take the surface elevation value as input and yield raster layers showing the direction of flow for each individual cell as well as the cumulative number of cells arriving at each cell. Knowing the spatial resolution of the accumulation flow raster layer, an estimation of the drainage area for each cell can be obtained.

In parallel, the global annual mean runoff raster layer was obtained as a product of the Global Streamflow Characteristics Dataset (GSCD) provided by the European Joint Research Center (JRC). The map was available at 0.5^{o} (approx. 55 km) spatial resolution and therefore a resampling process was essential. This process yielded a raster layer showing the mean annual runoff stream flow (mm/year) on a global scale at a spatial resolution of 0.00083^{o}.

As a consequent step, the flow accumulation raster was combined with the resampled annual mean runoff raster layer in order to yield a high resolution raster layer (0.00083^{o} – 90 meters) illustrating an estimation of the average discharge values (m^3/sec) for each individual cell.

In order to assign the obtained discharge values to actual rivers, the global river network from HydroSHEDS dataset was used. The river network was processed in RivEX environment in order to be assigned a number of attributes, which are essential for the hydropower potential estimation. Each particular stream was assigned a source point, a mouth point and several sample points located in a defined distance of 5 km from each other. The river network connectivity was also obtained.

Every point was assigned a potential discharge value and an estimated head, which was based on the elevation difference between the point and its closest upstream neighbor, which in this case was at least 5 km. The potential power could eventually be estimated through the hydropower equation under certain assumptions as shown below:

$$P_p = \rho \times g \times n_t \times n_g \times conv \times \dot{Q}_{point} \times (H_p - H_{p.up}) \qquad \text{where}$$

P_p: Potential power output at sample point in W

ρ: Water density set as 1000 kg/m^3

g: Gravity constant (9.81 m/s^2)

n_t: Turbine efficiency set as 0.88

n_g: Generator efficiency set as 0.96

$\dot{Q}_{point}$: Discharge flow at sample point in m^3/s

H_p: Elevation at sample point

$H_{p.up}$: Elevation at neighbor upstream point

$conv$: Conversion factor accounting for the environmental flow deduction (set as 0.6).

Figure 1, illustrates the methodological flowchart of the described process.

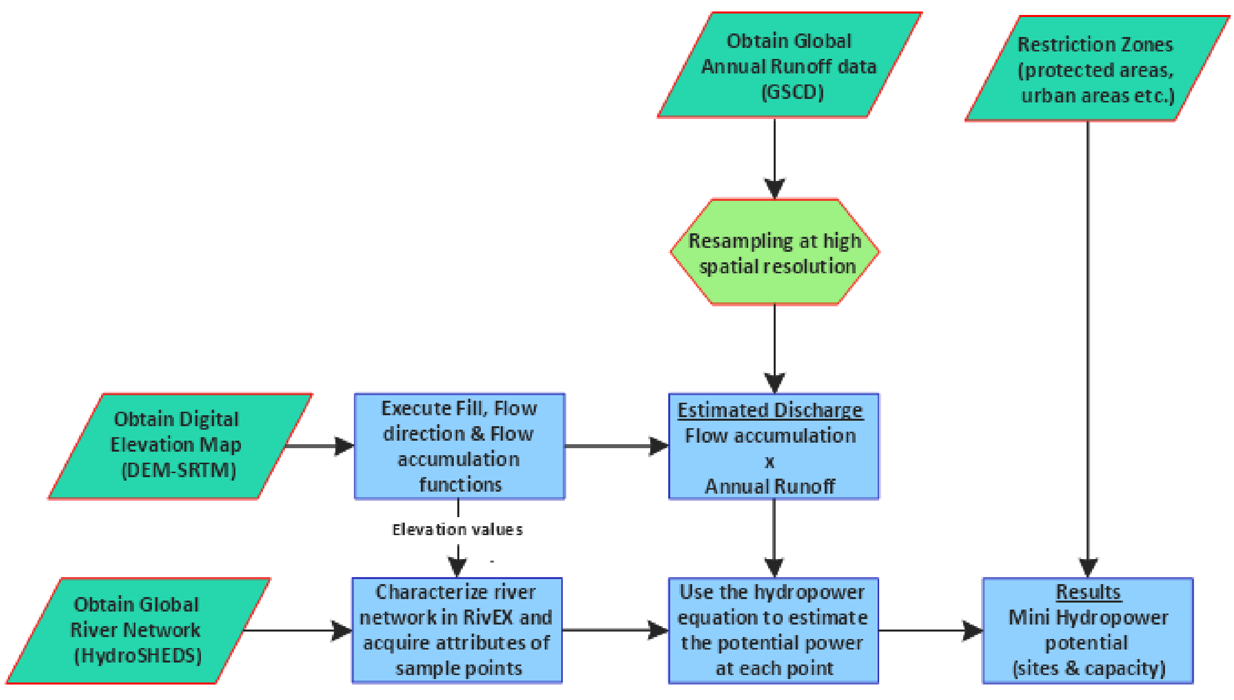

Figure 1. Mini Hydropower assessment methodology flowchart.

This methodology aims at estimating the mini hydro (100 to 1000 kW) (IRENA, June 2012) power potential of sites based on the diversion (run-off-river) technique and impulsive turbine (e.g. Pelton) characteristics suitable for applications with high head and relatively low volume flow.

Further, certain criteria regarding the localization of mini hydro are taken into account using relevant GIS layers. To illustrate, mini hydro power plants cannot be installed in protected areas or in very close proximity to residential areas.

It should be mentioned that this methodology has certain limitations (relatively low resolution of Runoff data, underground water is not taken into consideration, no seasonality of discharge is included etc.) and its results should be used only as an indication of potential sites and estimated power availability.

The proposed methodology makes use of high resolution geospatial data (DEM obtained by NASA, runoff processed by the author) and therefore the preparation of global maps showing the mini hydropower potential require significant computational time. While this is a work in progress, a case study was conducted in order to test the viability and accuracy of the methodology.

Figure 2, provides an illustration of the final results regarding the mini hydropower potential assessment for Zimbabwe. According to that, 461 sites where found suitable for mini hydropower deployment having an accumulative theoretical potential of 156.1 MW.

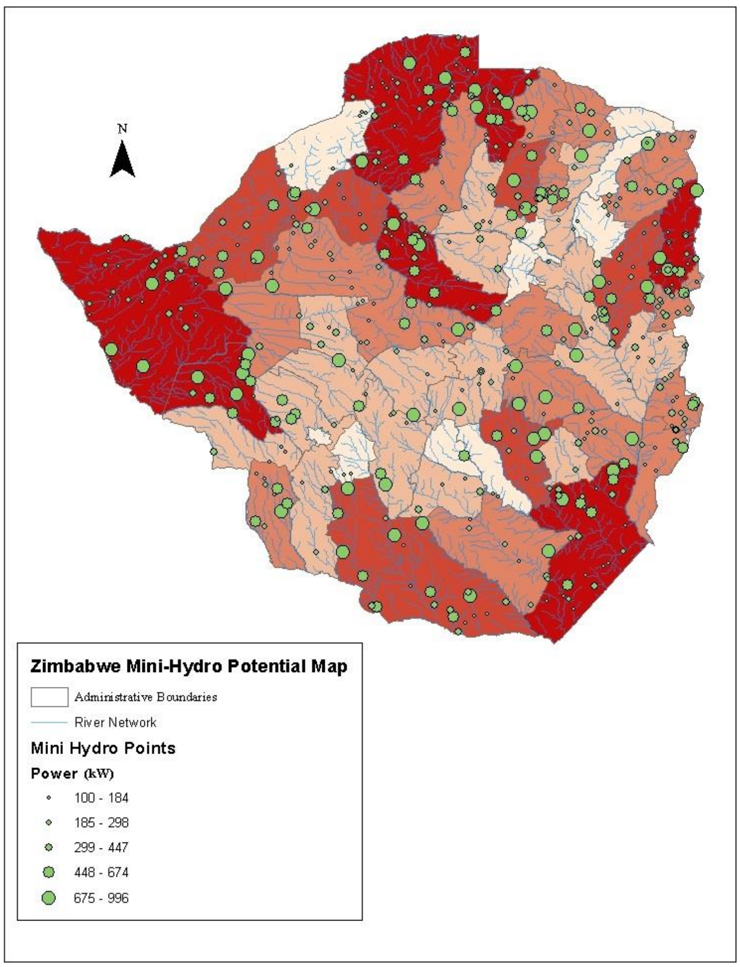

Figure 2. Mini hydropower potential for the case study of Zimbabwe.