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PRODUCING A DIGITAL HYDROGRAPHIC MAP AIMING AT RENEWABLE ENERGY POTENTIAL MAPPING OF LESOTHO

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ABSTRACT:

Some of the first outcomes of a project aiming at mapping the renewable energy potential in Lesotho are hereby presented. In particular, the present paper deals with the task of the project devoted to produce a digital hydrographic map of Lesotho and an associated geographic database. Different geographical, meteorological and hydrological data were collected in the first steps of the project. The hydrographic network was derived in vector format from a digital elevation model of Lesotho using geoprocessing tools in GIS environment. Results were compared with existing cartography and satellite images. Moreover, a methodology proposed in literature for the assessment of the theoretical maximum hydroelectric producibility at watershed level in Italy was applied to one of the main catchment areas of Lesotho. The activities planned to fulfil the objectives of the project are finally outlined.

1. INTRODUCTION

1.1 Country Context

The Kingdom of Lesotho (Figure 1), lying between latitude 28-31 South and longitude 27-30 East, is an independent state entirely surrounded by the Republic of South Africa, covering an area of about 30,550 km^2, with a population of 2,007,201 people according to 2016 census (Bureau of Statistics, 2020). Lesotho is the only country in the world entirely lying above 1000 m altitude, with elevations in the range 1300-3500 m above sea level. The central and eastern parts of the territory (about 65% of the extension of the country) are the "Highlands", where the highest mountain ranges are present (Maloti and Drakensberg Mountains). The remaining western part of Lesotho is referred to as "Lowlands" and mainly consists of plateaus where most of the arable lands are concentrated and where the capital Maseru and the main cities are located.

The climate in Lesotho is temperate, with two well-defined seasons: a hot, wet summer (October to April) and a cool to cold, dry winter (May to September). Due to its altitude, the temperatures throughout the year are generally lower than most of the other regions located at the same latitudes. Mean annual rainfall in the country is on average of the order of 800 mm, ranging from about 300 mm in the Lowlands up to more than 1600 mm in the Highlands. Precipitations are mostly concentrated in the Summer season, when about the 85% of the annual rainfall normally takes place (Commissioner of Water, 2018).

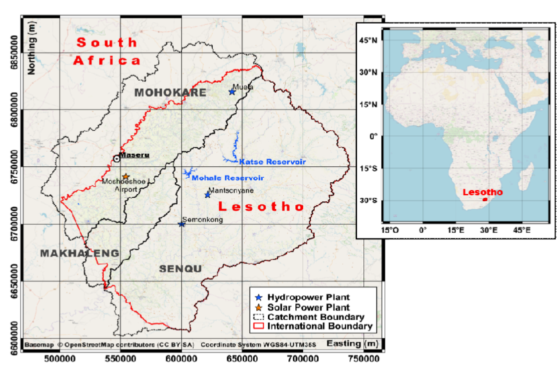

Figure 1. Geographical setting of Lesotho

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Water can be considered among the most important natural resources in Lesotho. The entire territory of the country is comprised within the Senqu-Orange watershed (Del Sette and Arduino, 1994). Three major river catchment can be distinguished in Lesotho, namely: the Senqu, the major river in Lesotho (catchment area about 21,000 km^2); the Makhaleng (catchment area about 3,300 km^2), draining into the Senqu river; and the Mohokare-Caledon, that marks the north-west border between Lesotho and South Africa (catchment area about 14,000 km^2, of which about 7,000 km^2 in Lesotho).

The Lesotho Highlands Water Project (LHWP), established in 1986, is a multi-phased bi-national infrastructure project aiming at providing water to South Africa and generating hydroelectric power for Lesotho. The project, implemented by the Lesotho Highlands Development Authority (LHDA), involves the construction of dams and tunnels to impound and divert water from the Senqu river catchment in the Lesotho Highlands to the Gauteng Region in South Africa (Lesotho Highlands Development Authority, 2020). The Phase I of LHWP ended in 2004 and entailed the construction of the Katse dam, the Mohale dam, the Matsoku weir, the Muela dam and hydropower station, transfer tunnels (Katse-Muela and Mohale-Katse), the Matsoku diversion tunnel and delivery tunnels to South Africa borders. The Phase II of LHWP is currently underway and will entail the construction of the Polihali dam, a water transfer tunnel and associated infrastructures.

The Muela hydroelectric plant, operated by LHDA, is the major power station in Lesotho, with three turbines rated at 24 MW each (total power 72 MW). Moreover, the Lesotho Electricity Company (LEC), that is the monopoly electricity transmission, distribution and bulk electricity supply company in the country, operates small scale power plants aiming to provide energy to rural and mountainous areas (Lesotho Electricity Company, 2020). Currently, two small plants are operating, namely: Semonkong (mini-hydro/diesel) and Mantsonyane (mini-hydro), with a total power of almost 3 MW, while two other plants were decommissioned due to technical and operational problems. Overall, the maximum peak electricity demand in Lesotho is up to 155 MW (Lesotho Electricity Company, 2017), that can be only partially covered by the internal production. With the exception of limited periods of low electricity demand when a minor amount of excess energy is exported from Muela plant to Eskom electrical company (South Africa), internal electricity production is insufficient and the deficit is compensated by imports from both Eskom and EDM (Electricidade de Moçambique). Figure 2 illustrates the total electricity purchased by LEC during the last financial years (Bureau of Statistics, 2019).

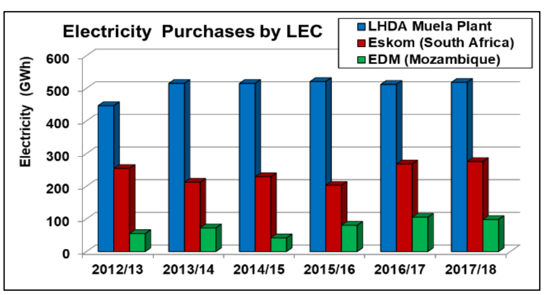

Figure 2. Total electricity purchases for distribution in Lesotho during the last financial years

As regards the total energy demand in Lesotho, the residential sector is by far the largest energy consumer (about 85%), as illustrated in Figure 3 (Department of Energy, 2017). On the other hand, despite the huge effort devoted to electrification and the significant annual development since 2000s, most of the households in Lesotho do not yet have access to electricity and mainly rely on biomass, coal and oil for their typical needs. The most recent data indicate a percentage of people with access to electricity estimated either as 38% (Department of Energy, 2017) or 34% (Tracking SDG7, 2020), mostly concentrated in urban areas, thus electricity accounts only for a minor part of the energy demand in Lesotho. As a consequence, the mix covering the total energy demand is composed of biomass (52%), coal (28%), petroleum (16%) and electricity (4%), as illustrated in Figure 4.

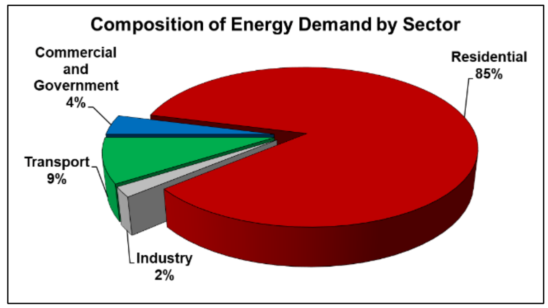

Figure 3. Composition of energy demand in Lesotho by sector

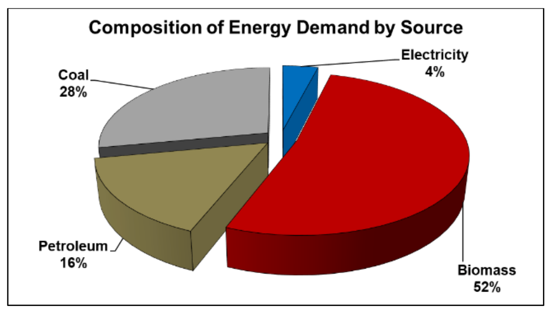

Figure 4. Composition of energy demand in Lesotho by source

The above data identify the major challenges of the energy sector in Lesotho, i.e. the low access to electricity and modern clean forms of energy, the huge dependence on imported electricity and fossil fuels not present in Lesotho, and the expected declining of forest and biomass stock due to unsustainable consumption for residential use. To cope with the above challenges, the Government of Lesotho (2000), in line with the "Lesotho Vision 2020", intends to significantly expand the access of population to electricity and increase the electric power generation, essentially using the Renewable Energy (RE) sources available in the country. It is worth noting that, despite the Muela hydropower station, minor plants and the recent solar photovoltaic installation at Moshoeshoe I International Airport (281 kW), the RE potential in Lesotho is still largely unexploited.

1.2 The Project "Renewable Energy Potential Maps for Lesotho"

Considering the above described context, in fulfilment of the Paris Agreement (United Nations, 2015), under the United

Nations Framework Convention on Climate Change (UNFCCC, 2020) the Governments of Italy and Lesotho established in 2016 a Memorandum of Understanding (MoU) on "Co-operation in the field of climate change vulnerability, risk assessment, adaptation and mitigation". The deployment of RE was identified in the MoU as a priority sector of cooperation.

Therefore, the project "Renewable Energy Potential Maps for Lesotho" was launched with the main aim to produce maps to facilitate the Government of Lesotho in the planning and development of RE exploitation. Consistently with the general philosophy of the cooperation program, QGIS free and open software (QGIS, 2020) was used for the mapping and geoprocessing needs of the project. The project is composed of 6 work packages, as listed below:

- WP0: Project management
- WP1: Wind energy map for Lesotho
- WP2: Solar energy map for Lesotho
- WP3: Hydrological map for Lesotho
- WP4: GIS database - WebGIS
- WP5: Human capacity building

The present paper is focused on the WP3 of the project, aiming at the production of a digital hydrographic map of Lesotho, provided with the main information that could be useful for energy planning purposes. The collected data, the methodology for data processing and the major results are described and discussed in the following, as well as the next developments of the activities.

2. MATERIALS AND METHODS

2.1 Data Collection

In the first steps of the project the availability of suitable data was checked at the main Lesotho's and international Institutions. The following Lesotho's organizations provided major data for the project: Lesotho Meteorological Services (LMS), Land Administration Authority (LAA), Department of Water Affairs (DWA), Lesotho Highlands Development Authority (LHDA), Department of Mines and Geology (DMG) and Bureau of Statistics (BoS). Among the international institutions, a major contribution came from the Food and Agriculture Organization of the United Nations (FAO), that provided the Lesotho Land Cover Database and a wide dataset of ancillary data. A comprehensive description of all the collected data is beyond the aim of the present paper. In the following, partial details are provided on the data of major interest for the specific purposes of the work hereby presented.

The DEM (Digital Elevation Model) is the basic input information needed to derive the hydrographic map. Among the different available datasets, the SRTM (Shuttle Radar Topography Mission) Global DEM at 1 arc-second resolution (about 30 m) was first selected for the aim of the project. The SRTM DEM, approximately covering 80% of the Earth's landmass (latitudes from 60 North to 54 South) was derived from Interferometric Synthetic Aperture Radar observations taken from the NASA Space Shuttle Endeavour in February 2000 (Farr et al. 2007; NASA JPL, 2020). SRTM data are available for public download at the USGS EarthExplorer website (USGS, 2020) as a collection of GeoTIFF images, each covering a 1deg×1deg extension.

A 3D elevation map of Lesotho derived from SRTM data is plotted in Figure 5.

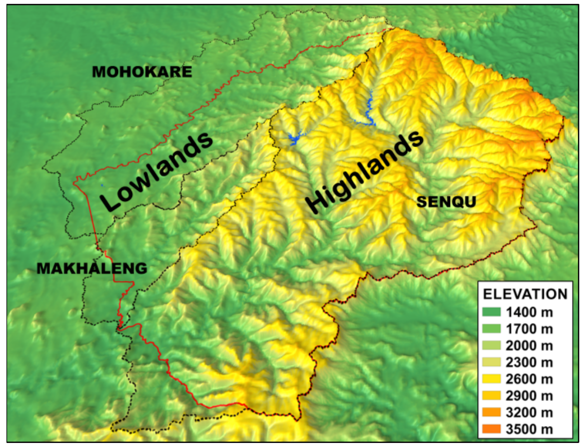

Figure 5. Elevation map of Lesotho derived from SRTM DEM

Time series of daily rainfall and min/max temperature observations from 13 meteorological stations were provided by LMS. With a few exceptions, LMS time series cover the period 1980-2015. Moreover, rainfall data from 12 stations located in the Senqu watershed were provided by LHDA. The observation periods are different for the different LHDA stations, with start year varying from 1974 to 2011, while end year is 2016 for almost all the stations. Time series of flow data at 19 hydrometric stations were provided by LHDA, with observation period 2004-2015 for most of the stations. Finally, DWA provided a list of 105 hydrometric stations covering different observation periods. A comprehensive map of the above meteorological and hydrometric stations is plotted in Figure 6.

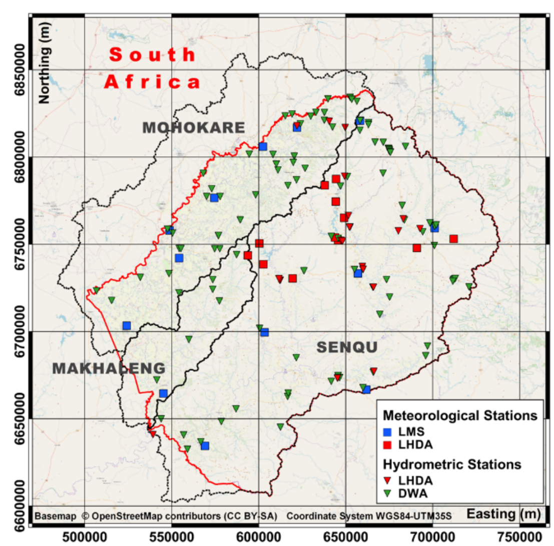

Figure 6. Map of meteorological and hydrometric stations

Official cartographic and elevation data were provided by LAA. Topographic maps of Lesotho at 1:250,000 and 1:50,000 scale were made available in raster format. Moreover, shapefiles of high detailed digital elevation contour lines (2 m elevation interval for the Lowlands and 10 m interval for the Highlands) were provided.

The land cover of Lesotho was recently investigated by FAO (2017). A detailed land cover database and an extensive dataset of ancillary data (administrative boundaries, hydrological data, roads, settlements and villages) were made available by FAO in vector format for the aims of the project. Figure 7 illustrates a land cover map of Lesotho, while in Figure 8 the statistics of aggregated land cover classes at national level are described. It can be observed that about half of Lesotho is covered by grasslands (49.6%), followed by shrublands (19.1%), agricultural lands (18.9%), barren lands (5%) and built-up areas (4.1%), with forests, water bodies & rivers and wetlands accounting each for about 1% of the territory.

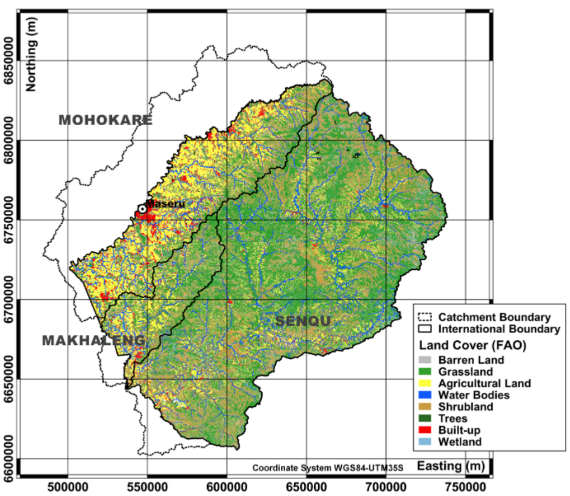

Figure 7. Land cover map of Lesotho (FAO, 2017)

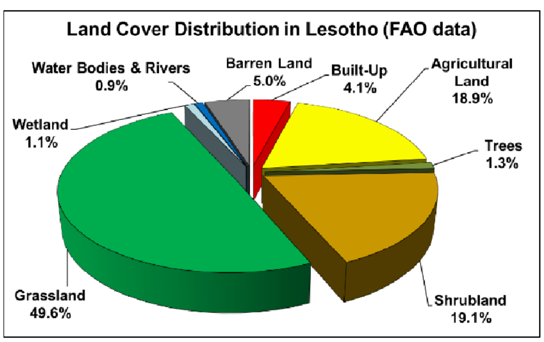

Figure 8. Statistics of aggregated land cover classes in Lesotho at national scale (FAO, 2017)

In addition to the above data, the Hydrogeological Map of Lesotho (Arduino et al., 1994) and the final report of the "Ground Water Project" (Del Sette and Arduino, 1994) were assumed as key references for the present study. These documents synthesize and organize geological, hydrological and meteorological information collected in the framework of an Italy-Lesotho cooperation program (1983-1994). In particular, time series of mean annual and monthly precipitations and temperatures collected in Lesotho and South Africa (reference period 1930-1989) were analysed and isohyet maps of annual rainfall were produced. The mean and minimum annual discharges and the catchment areas of the major hydrometric stations are also indicated on the map.

2.2 Methodology for the extraction of river network and delineation of catchment areas

The river network and catchment areas were derived from the DEM using state-of-the-art geoprocessing tools operating in GIS environment. Among the available specialized tools, the TauDEM (Terrain Analysis Using Digital Elevation Models) suite (Tarboton, 2020) was used for the present work. TauDEM is composed of 30 geoprocessing algorithms specifically conceived for the DEM-based hydrological analysis. TauDEM is distributed as a free software under the GNU general public license and can be fully integrated in QGIS environment. The computational steps followed for the present work are summarized below:

1. **DEM pre-processing for pits removal**. The input DEM was processed to remove all the possible anomalous depressions due to artefacts or outliers of the elevation grid that could induce unrealistic disconnections in the hydrographic network.
2. **Mapping of flow directions**. The direction of water moving from each cell of the grid to the neighbouring cells was derived assuming that water drains following the steepest downward slope. A raster map was then derived, in which the value of each cell is a conventional code (from 1 to 8) indicating the flow direction towards one of its either adjacent or diagonal surrounding cells.
3. **Computation of contributing areas**. Based on results of the previous step, the number of cells contributing to the flow in each cell of the grid was computed through a recursive procedure. A "flow accumulation" grid was then generated, in which the contributing area (or, equivalently, the number of contributing cells) for each cell is given as the summation of its own contribution plus the contribution from upslope cells.
4. **Streams and watersheds definition.** Stream channels and catchment divides were derived from the flow direction and flow accumulation grids. A "threshold value", i.e. the minimum extension of contributing area was adopted as discriminating parameter to select the cells of the grid to be considered part of the stream network or not. Vector shapefiles of stream reaches and watersheds were finally derived, with major hydrological information contained in the associated attribute tables.

In the computation of contributing areas, a weighting factor given by a supplementary input grid can be optionally imposed to multiply the contribution of each cell. A significant case is when the weighting factor is the effective rainfall distribution over the study area in a reference period (e.g. annual), so the value in each cell of the grid is indicative of the volume of water conveyed to the cell during the reference period.

As regards the streams and watersheds delineation, a key issue is the appropriate choice of the threshold value. High threshold values give rise to lower detailed networks in which only the main streams are plotted, whereas low threshold values return a high number of segments, with the risk that some of them can be physically not significant. An objective and universally accepted criterion for the optimal choice of the threshold value does not exist and the procedure is inevitably affected by a certain degree of arbitrariness. A reasonable solution is to perform different computations with variable thresholds and compare the results with existing cartography or other data (e.g. remote sensing images) assumed as a reference. In this latter case, however, additional uncertainties are introduced, essentially due to the scale, age and the general reliability of the reference maps. This issue is addressed in the section devoted to presentation and discussion of results.

2.3 Methodology for the estimation of theoretical maximum hydroelectric producibility

A digital hydrographic map can serve as an essential knowledge basis for studies aiming to derive information for planning purposes, in particular in the view of a possible exploitation of water and land for hydropower production. It is worth observing, in this regard, that the evaluation of the hydropower potential and, more in general, the investigation of the best siting for hydropower plants is a complex task that, besides topography and hydrology, involves a number of different issues (e.g. geology, geotechnics, geomorphology, soil texture, sediment production and transport, as well as water use policy, technological and environmental issues) that normally require detailed site-specific studies. However, consistently with the general aim of the project, a methodology for a first estimation of theoretical hydroelectric producibility at watershed scale already applied to Italian catchments (Alterach et al., 2008; 2009) was investigated, as synthetically outlined in the following.

The reference watershed illustrated in Figure 9 and Figure 10 is considered, draining into the stream reach comprised between the upstream section U and the closure section C.

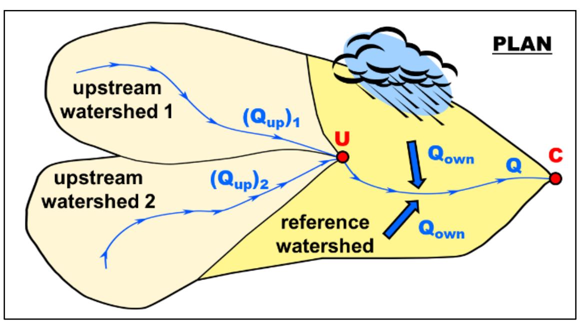

Figure 9. Plan of the reference watershed and upstream tributaries

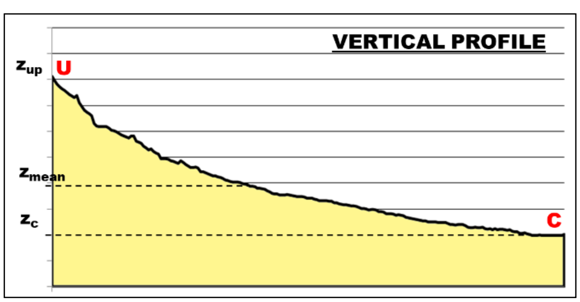

Figure 10. Vertical profile of the reference watershed

An ideal plant with a sufficient water storage capacity is implicitly considered, so the average hydroelectric producibility is assumed to be independent on the runoff variability. In this case the annual hydroelectric producibility basically depends on two main factors: the mean available flow rate and the hydraulic head, i.e. the drop in elevation between the upstream source and the closure section where an ideal turbine is located.

The mean annual flow rate at section C due to the watershed's own contribution Q_{own} can be estimated as:

$$Q_{own} = P_{mean} \cdot c \cdot A \quad (1)$$

being P_{mean} the mean annual precipitation over the watershed, c the runoff coefficient (ratio between runoff and rainfall over the watershed) and A the catchment area. If upstream tributaries are present, the flow rate Q at the closure section C is given by the summation of the watershed's own contribution plus the contributions from upstream watersheds:

$$Q = Q_{own} + \sum_i (Q_{up})_i \quad (2)$$

in which $(Q_{up})_i$ indicates the contribution from the i^{th} upstream watershed, draining into the section U of the reference watershed. The flow rates $(Q_{up})_i$ can be computed using formulae analogous to either equation (1) or (2), depending on the hierarchical position of the watersheds in the river network.

Assuming each watershed draining into a single stream of the hydrographic network as an elementary reference territorial unit, the maximum annual hydroelectric producibility (E_{max}) can be expressed as the summation of the watershed's own contribution (E_{own}) plus the contribution from upstream watersheds (E_{up}), that drain into the confluence section U:

$$E_{max} = E_{own} + E_{up} \quad (3)$$

in which the terms E_{own} and E_{up} can be estimated as:

$$E_{own} = \eta \cdot \rho \cdot g \cdot Q_{own} \cdot (z_{mean} - z_c) \quad (4)$$

$$E_{up} = \eta \cdot \rho \cdot g \cdot \sum_i (Q_{up})_i \cdot (z_{up} - z_c) \quad (5)$$

where η = energy conversion efficiency (assumed as 0.8)
ρ = water density (1000 kg/m^3)
g = gravitational acceleration (9.81 m/s^2)
z_{mean} = mean elevation of the watershed
z_{up} = elevation at the upstream section U
z_c = elevation at the closure section C

If there are no upstream watersheds, the term E_{up} is equal to zero. In the equation (4) it is assumed, as a simplified hypothesis, that the precipitation and the runoff coefficient are constant in the reference basin and coincident with the respective mean values. This is consistent with the adopted methodological approach, in which the watershed is considered as an elementary homogeneous territorial unit.

The E_{max} value computed by equation (3), referred to as a maximum hydropower potential, is to be considered as a purely theoretical indication of the possible hydroelectric producibility. A more realistic assessment should include a number of different factors as e.g.: water consumption for human activities (irrigation, drinking, industry, etc.); environmental constraints (in particular, the need to maintain a minimum flow rate to preserve the ecological quality of a river); technological constraints (i.e. engineering issues and, in general, all the factors affecting the viability of a power plant). Economic and social issues should finally be considered in the overall planning process.

3. RESULTS AND DISCUSSION

3.1 Hydrological Map

The hydrological map derived from the SRTM DEM is plotted in Figure 11. The stream reaches were derived in shapefile vector format and are plotted over the elevation map. The boundaries of the Mohokare, Makhaleng and Senqu river catchments were also delineated and are in agreement with the existing cartography.

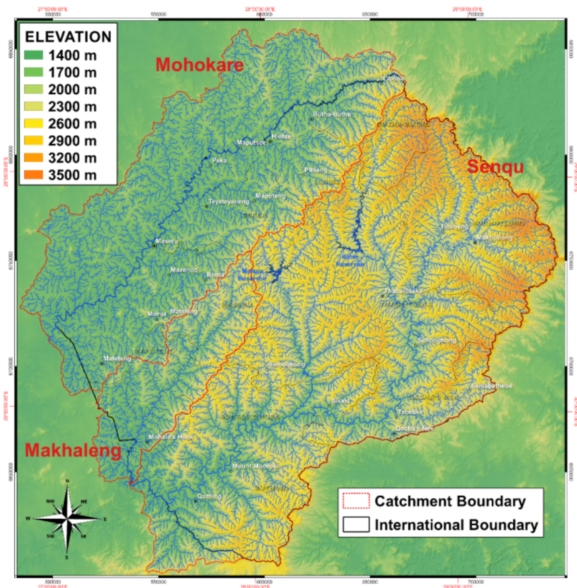

Figure 11. Hydrological map derived from SRTM DEM

The hydrographic network and catchment divides were derived using QGIS and TauDEM algorithms, following the steps described in the previous section. Different values of the threshold for stream detection were tested, and results were visually compared with the available cartography. In particular, the blue lines plotted on the 1:50,000 official topographic map of Lesotho were adopted as a major reference. As expected, the main differences between cartographic and computed data were substantially observed for the up-valley streams, that normally require low threshold values to be adequately captured. However, after a number of attempts with lowering threshold values it was observed that a sort of critical condition seems to exist, beyond which a further reduction of threshold value induces a little improvement in terms of data agreement causing, at the same time, a dramatic increase in computation time and size of output dataset. On the other hand, it is worth noting that even the drawing of the blue lines on a map is unavoidably subjected to a certain subjective judgement of the cartographer and it is possible that a number of them may, in practice, represent intermittent and little significant torrents, especially considering the regime of precipitations in Lesotho.

Based on the above considerations, the threshold value for stream detection was finally set to 1000 contributing cells, corresponding to a minimum catchment area of about 0.9 km^2. For example purposes, in Figure 12 and Figure 13 the extracted stream reaches are plotted, respectively, over the 1:50,0000 topographic map and over a 3D Google Earth satellite image.

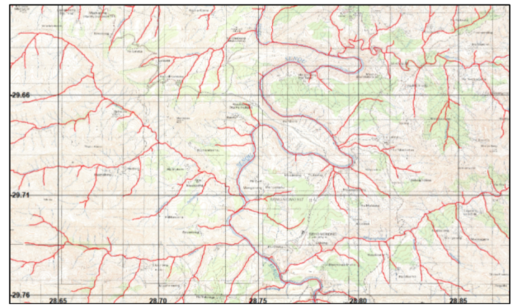

Figure 12. Derived stream reaches plotted over the 1:50,000 official topographic map of Lesotho

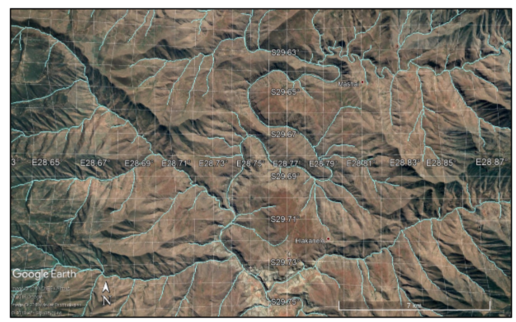

Figure 13. Derived stream reaches plotted over a 3D Google Earth satellite image

Overall, results show a good agreement with the available cartographic data. However, in order to achieve an even better agreement, a more detailed DEM was derived interpolating the contour elevation lines provided by LAA in shapefile vector format. It was planned to use this latter DEM to derive a more detailed hydrographic network in the final step of the project.

3.2 Hydroelectric producibility

The procedure for the estimation of the theoretical maximum hydroelectric producibility described in section 2.3 was applied, for example purposes, to the Makhaleng watershed.

For the present application, rainfall data were derived by digitizing and interpolating the isohyets reported on the Hydrogeological Map of Lesotho, referred to the period 1930-1989. The computed mean annual precipitation over the Makhaleng river catchment is about 820 mm. A map of mean annual rainfall distribution is plotted in Figure 14.

A first key issue of the adopted procedure is the estimation of the runoff coefficients. As well established in literature, the runoff coefficients depend on different factors as terrain slope, surface conditions, land cover and use, and hydrological soil type (e.g. McCuen, 2004; Liu and De Smedt, 2009; Dhakal et al., 2012). Impervious surfaces have runoff coefficients up to 1, as well as wetlands and water bodies, whereas for other typical land covers the following indicative values can be assumed: 0.10 for forests, 0.15-0.25 for grasslands and shrublands, 0.25-

0.30 for agricultural lands, 0.30-0.40 for barren lands and up to 0.70-0.90 for built-up areas. These reference values are normally modified considering the effects of slope and soil types. In the present example, for the sake of simplicity, a constant value ($c = 0.24$) was assumed for the runoff coefficient of the Makhaleng basin, derived from information reported in Del Sette and Arduino (1994). Despite this is to be considered as an approximation for example purposes, the adopted value is consistent with land cover distribution over the basin.

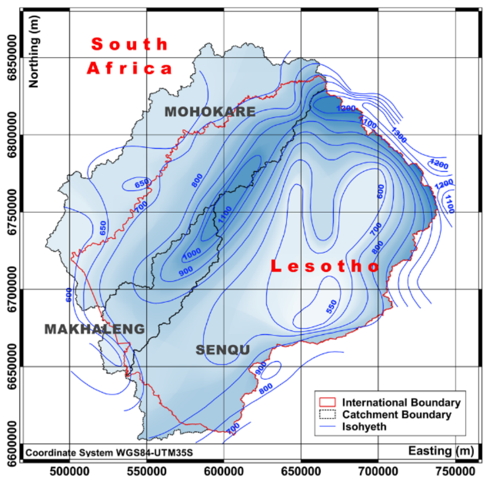

Figure 14. Map of mean annual precipitation in Lesotho derived from Arduino et al. (1994)

A second important issue is the choice of the appropriate detail for the hydrographic map, that affects the extension of the sub-basins. A detailed map with a high number of small basins has the inconvenience to do not adequately consider the effects of the up-valley mountain basins, typically characterized by high drops in elevation, because their small drainage areas give rise to small flow rates. On the other hand, if the size of the basins is too large, the result runs the risk to be unrealistic and of limited practical use. In the cited previous assessments (Alterach et al. 2008; 2009) conducted in Italy at national and regional level, the average size of watersheds was on the order of 130-200 km^2, despite neither an objective criterion nor a general rule-of-thumb exists in this regard. Based on the above considerations, in the present application higher threshold values were adopted for stream detection than those adopted for the hydrographic mapping. Different values were attempted, comparing results of each computation. Actually, two different solutions are hereby presented: in the first, the Makhaleng catchment area was divided into 91 sub-basins (average area 37 km^2); in the second, 49 sub-basins (average area 68 km^2) were derived. It can be observed that the investigated basins extend beyond the administrative boundary of Lesotho, as also noted for the hydrological map.

Figures 15a-b illustrate the computed theoretical maximum annual hydroelectric producibility (in GWh per year) for the two considered details of watersheds subdivision. As expected, the highest values of producibility are mainly observed for the sub-basins located on the left-hand side of the Makhaleng river, which drain steep mountainous areas with the highest relief. The effect of the sub-basins sizes on results is also evident, with generally higher values of producibility plotted in Figure 15-b than in Figure 15-a. This is because the adopted methodology assumes that all the available water and geodetic gradient of the elementary watershed can be theoretically exploited, so an increase of the size normally induces an increase in producibility.

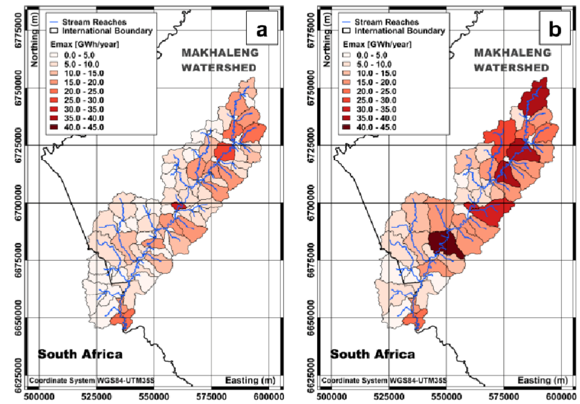

Figure 15. Computed theoretical maximum hydroelectric producibility for the Makhaleng watershed, subdivided in 91 sub-basins (a) and 51 sub-basins (b), respectively

The above results are to be considered merely indicative and for example purposes only, and extreme caution must be taken in their interpretation. This is due both to the inherent limitations in the formulation of the method and to the simplified assumptions adopted in the present application. Among these simplifications, it is worth to underline the use of a constant runoff coefficient and the simplified hydrological scheme for runoff generation which considers only the mean annual rainfall, neglecting the yearly rainfall distribution and duration and types of weather event. Moreover, as discussed in the previous sections, the effective water availability (i.e. considering water policy and consumptions due to different use) was not estimated in the present work, and engineering, geological and environmental issues were not considered.

4. CONCLUSIONS AND PERSPECTIVES

A digital hydrographic map of Lesotho was derived from the SRTM Global DEM at 1 arc-second resolution (about 30 m), using state-of-the art GIS tools. The derived stream network was compared with available cartography and satellite images and a good agreement was observed. For each stream reach the drainage basin was delineated and main morphological and hydrological information (stream drop, elevations, mean rainfall, hierarchical position in the hydrographic network) was included in a vector shapefile. A methodology from previous literature for the assessment of the theoretical maximum hydroelectric producibility at watershed level in Italy was applied to one of the main river catchments of Lesotho, for example purposes.

The hydrographic map reported in this paper was presented to Lesotho's Institutions and stakeholders as a preliminary outcome of the Italy-Lesotho cooperation project "Renewable Energy Potential Maps for Lesotho".

A follow-up of the project entails the extraction of a more detailed hydrographic network by the DEM derived from high resolution digital elevation contour lines, with the aim to obtain a better resolution and agreement with existing cartography. Moreover, hydrological data from different sources, along with different geographical data, could be integrated in a database that may be useful for planning purposes.

The main objective of the project is that the final outcomes, provided as maps, database and technology transfer, could be used for energy planning by Lesotho's Authorities, in the view to meet the dual needs to increase the energy production and to pursue, at the same time, the global target for reduction of greenhouse gas emissions.

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