



International Journal of Environment and Geoinformatics (IJECEO) is an international, multidisciplinary, peer reviewed, open access journal.

GIS and hydrological model based Hydropower potential assessments of Temcha Watershed

Walelgn DILNESA

Chief in Editor

Prof. Dr. Cem Gazioğlu

Co-Editors Prof. Dr. Dursun Zafer Şeker, Prof. Dr. Şinasi Kaya,
Prof. Dr. Ayşegül Tanık and Assist. Prof. Dr. Volkan Demir

Editorial Committee (March 2022)

Assoc. Prof. Dr. Abdullah Aksu (TR), Assoc. Prof. Dr. Uğur Algancı (TR), Assoc. Prof. Dr. Aslı Aslan (US), Prof. Dr. Levent Bat (TR), Prof. Dr. Paul Bates (UK), İrşad Bayırhan (TR), Prof. Dr. Bülent Bayram (TR), Prof. Dr. Luis M. Botana (ES), Prof. Dr. Nuray Çağlar (TR), Prof. Dr. Sukanta Dash (IN), Dr. Soofia T. Elias (UK), Prof. Dr. A. Evren Erginal (TR), Assoc. Prof. Dr. Cüneyt Erenoğlu (TR), Dr. Dieter Fritsch (DE), Prof. Dr. Ç; Prof. Dr. Manik Kalubarme (IN), Dr. Hakan Kaya (TR), Assist. Prof. Dr. Serkan Kükrer (TR), Assoc. Prof. Dr. Maged Marghany (MY); Prof. Dr. Micheal Meadows (ZA), Prof. Dr. Nebiye Musaoğlu (TR), Prof. Dr. Masafumi Nakagawa (JP), Prof. Dr. Hasan Özdemir (TR), Prof. Dr. Chyssy Potsiou (GR), Prof. Dr. Erol Sarı (TR), Prof. Dr. Maria Paradiso (IT), Prof. Dr. Petros Patias (GR), Prof. Dr. Elif Sertel (TR), Prof. Dr. Nüket Sivri (TR), Prof. Dr. Füsün Balık Şanlı (TR), Dr. Duygu Ülker (TR), Prof. Dr. Seyfettin Tsaş (TR), Assoc. Prof. Dr. Ömer Suat Taşkın (TR), Assist. Prof. Dr. Tuba Ünsal (TR), Assist. Prof. Dr. Sibel Zeki (TR)

Abstracting and Indexing: TR DIZIN, DOAJ, Index Copernicus, OAJI, Scientific Indexing Services, International Scientific Indexing, Journal Factor, Google Scholar, Ulrich's Periodicals Directory, WorldCat, DRJI, ResearchBib, SOBIAD

Research Article

GIS and hydrological model based Hydropower potential assessments of Temcha Watershed

Walelgn Dilnesa 

DMU, IOT, and Hydraulic and water Resources Engineering Ac/program

E-mail: abinet_addis@dmu.edu.et

Received 20.08.2020

Accepted 20.09.2021

How to cite Dilnesa (2022). GIS and hydrological model based Hydropower potential assessments of Temcha watershed, *International Journal of Environment and Geoinformatics (IJEGEO)*, 9(1):097-101 doi. 10.30897/ijegeo.783157

Abstract

Hydropower is one of the major and sustainable energy production centers across the world. Energy production has several challenges and uncertainty to alleviate poverty in our country. The main aim of this study was selecting the hydropower potentials of Temcha watershed with integrated approaches of using GIS and hydrological models (SWAT). For the hydropower potential selection, it was used weather (metrological), hydrological and geospatial data. The result shows that a high discharge amount with a corresponding head has been identified in the upper course of the river and its associated values 300m³/year. In the middle course of the river, the power potential would be 126 MWmw/year. Generally, the overall hydropower potentials of Temcha Watershed were 2500 MWmw/year.

Key words: SWAT , GIS, Temcha watershed

Introduction

Urbanization, economic development, Industrialization and rapid increase in population growth have raised the demand for power generation manifolds. A hydropower project generates electricity from the available flow of the river. Around 16% of the world's energy production and over 80% of the world's renewable energy is generated through hydropower sector (Mathi and Desmukh, 2016; Essien, et al., 2019). Ethiopia has a vast hydropower potential, which is estimated to be about 15,000 - 30,000 MW. So far very little percentage (less than 2%) of the vast potential has been harnessed. In order to develop this vast potential of power several projects have been initiated to generate hydroelectric power. Some 300 hydropower plant sites in the whole eight river basins of the country with a total technical power potential of 159,300 Gwh/year have been identified. Out of these potential sites, 102 are large scale (more than 60 MW) and the rest are small (less than 40 MW) and medium scale (40-60 MW) hydropower plant sites (Dilnesa, 2018; Corobov et al., 2016; Yücel et al., 2002; Gazioğlu et al., 1998).

Flows in many rivers vary considerably during a year. In storage, based hydropower projects, a reservoir of water (or potential energy) created behind a dam is used to regulate the inflows and generate energy in accordance with demands. There can be opposition to storage projects from social and environmental groups, due to submergence of forests or places of importance, displacement of population, and adverse impacts on biotic life in rivers. However, hydropower projects can

generate energy with minimal or negligible damage to the environment, though they also have limited benefits. Correct assessment of hydropower potential at a site requires realistic information on topography (particularly elevation) and flows followed by careful analysis of these data. Recent advances in remote sensing (RS), geographic information system (GIS) and hydrological modeling provide realistically, up-to-date and useful information for the assessment of hydropower potential. The combination of GIS and RS techniques provides a powerful tool for studying hydrology in watersheds and for the assessment of hydropower potential.

Therefore, the aim of this study too, to identify the hydropower potential sites of Temcha watershed. The application of the SWAT hydrological model to assess the temporal and spatial variability of hydropower potential in the Temcha watershed in the upper Blue Nile basin. The assessment of the head, site selection, and simulation of flow at each selected site was carried out using the SWAT model (Zahou, et al., 2013; Strauch, et al., 2012; Cüceloğlu et al., 2021). The SWAT model generates stream network characteristics, the length of the river, and elevation difference for each stream within the watershed boundary. The model has provision for addition or deletion of outlets and inlets by user intervention, which affects the delineation and number of sub-watersheds created by the model, and this facility was utilized in assessing the head variation along the river, by placing sub-basin outlets at different locations.

Methodology

Study area

Hydroelectric power is the cheapest source of power whenever the natural resources are readily available. Ethiopia has plenty of favorable sites where hydroelectric power can be economically generated (Deudney, 1981). The exploitation and development of these untapped hydropower resources of the country need careful planning (short and long term), proper timing, coordinated efforts among all relevant government bodies, technical assistance, and most of all financial resources in order to transform the hydropower potentials into reality. The wealth of experiences gathered during the reconnaissance studies, pre-feasibility studies and feasibility studies of all the hydropower potential sites within Tekeze, Gojeb and Abbay River Basin would, no doubt, very much facilitate and benefit all concerned bodies and need to be recorded and documented for ease of reference in future use for projects coming in the pipeline (Bartle, 2002).

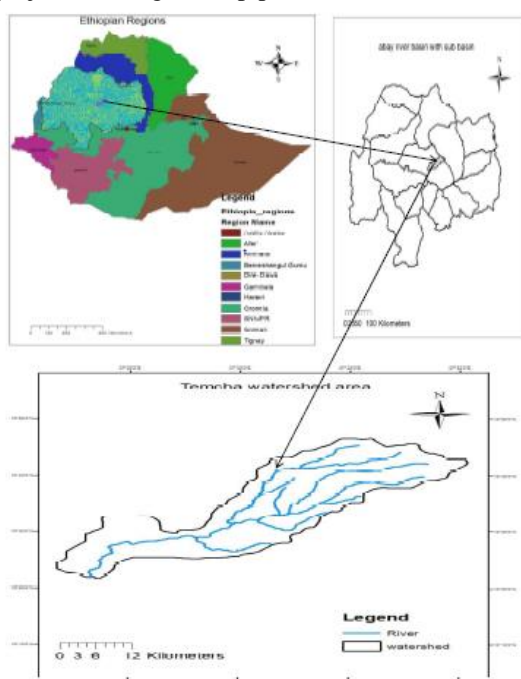


Fig. 1. location of the study area

Table 1. Data

data type	source
Land use/cover	USGS
Soil	FAO
Metrological data	NEMA of Ethiopia
Stream flow	Ministry of irrigation, electricity and water resources of Ethiopia
DEM	usgs

This is a very important aspect that needs to be given special attention. Temcha watershed has one of the tributaries of upper Blue Nile basin, located in Amhara region in Dembecha town district. The watershed area has annual flow/perennial river and a gauged station of its stream flow. The area has highland regions its most

appropriate for harnessing more small hydropower potentials and it's the discharge capability also suitable for energy production. The main things is that where is the suitable site for hydropower developments and identify the specific amounts of water potentials.

Data analysis

The identification of hydropower potential sites on Temcha river flows in the upper Blue Nile basin was examined through simulations using the soil and water assessment tool (SWAT) and The simulations were based on observed daily climatic data from 1990 to 2010 (30 years). These climate data sets were input into the SWAT model for simulating daily flows at numerous points along the basin's rivers. The output flows from the SWAT model were fed into the regulated flows and power production for different levels of hydropower development scenarios and different operation rules.

Head assessment

To assess potential hydraulic head along the river, computations were started at the main outlet of the watershed and then proceeded in the upstream direction. A location is identified as a potential hydropower site when a head of 20 m or more is available in a stream and the distance between the current location and the site immediately downstream exceeds 500 m (Kusre et al., 2010). A low-head hydropower application uses river current or tidal flows falling through 20 m or less to produce energy. This is to ensure that the tail race of the upstream site is not influenced by the reservoir of the downstream site. The assessment for the next potential site is carried out from the last selected site and the process continues to the upstream end of the river.

Flow prediction

The Arc-SWAT ArcGIS extension is a graphical user interface for the SWAT model (Sisay et al., 2017). The SWAT model is a river basin or watershed-scale model developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in watersheds with varying soils, land use and management conditions over long periods of time. The SWAT model is physically based and computationally efficient, uses readily available inputs and enables users to study long-term impacts. To simulate discharge from the Arc-SWAT model, spatial inputs relating to the DEM, land-use/land cover map and soil map are required for the study watershed. Other inputs required for the model are long-term weather data and soil properties.

A 30-m resolution DEM and the land-use map for the area were supplied by the USGS and the land sat images classified by super vided classification system under in the ERDAS imagine software. The SWAT model also requires long-term weather data (rainfall, temperature, humidity, solar radiation and wind velocity) of some representative weather stations located in the vicinity of the study watershed and these were obtained from four weather stations. Finally by running the SWAT model to predict the simulated flow of the watershed area.

Criteria for site identification

Minimum distance between two successive sites should not be less than 1000 meters in order to ensure that sufficient gap is present between the tailrace of one site and the diversion arrangement of the next site.

1. This also ensures that the river ecosystem will have sufficient time to rejuvenate.
2. A head of greater than or equal to 10meters, so that sufficient power is generated even for low flows.
1. Fourth and higher order streams having sufficient flow of water have been considered for selection of

sites, as for lower order streams the flow is too less for generation of power

Result and discussion
Sensitivity Analyses

A careful study of input parameters and their sensitivity is required before calibration so as to identify which input parameters affect the output of the model most. 8 sensitive parameters were identified to have a significant influence in controlling the stream flow in the watershed.

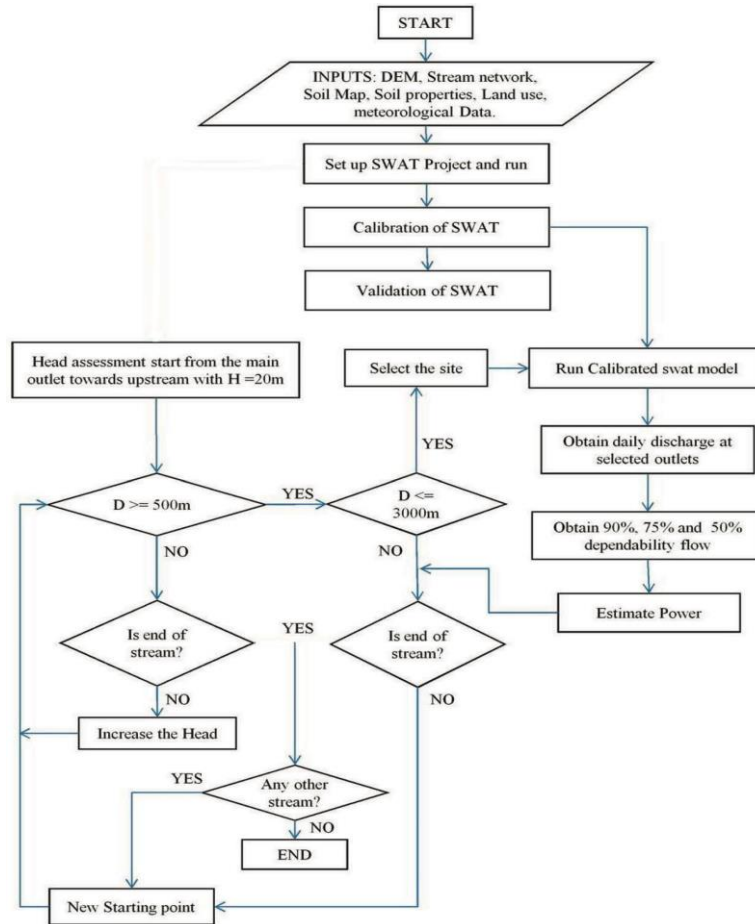


Fig. 2. the assessment of potential hydropower by SWAT model , source (Pandey et al., 2015)

Table 2. Sensetive Parameters

Rank	Sensitive parameter name	Min. and max. range	t-stat value	p-value	Fitted value
1	CN2	-0.2 to 0.2	2.77	0.00032	0.19
2	ALPHA_BF	0 to 1	2.54	0.0057	0.11
3	SOL_BD	-0.5 to 0.6	2.34	0.013	-0.22
4	SOL_K	-0.8 to 0.8	1.60	0.113	-0.44
5	EPCO	0 to 1	-1.36	0.175	0.12
6	CANMX	0 to 100	-1.13	0.262	10.50
7	GWQMN	0 to 2	1.00	0.316	1.49
8	REVAPMN	0 to 0.25	0.434	0.665	0.02

	R ²	ENS
Calibration	0.84	0.76
Validation	0.78	0.73

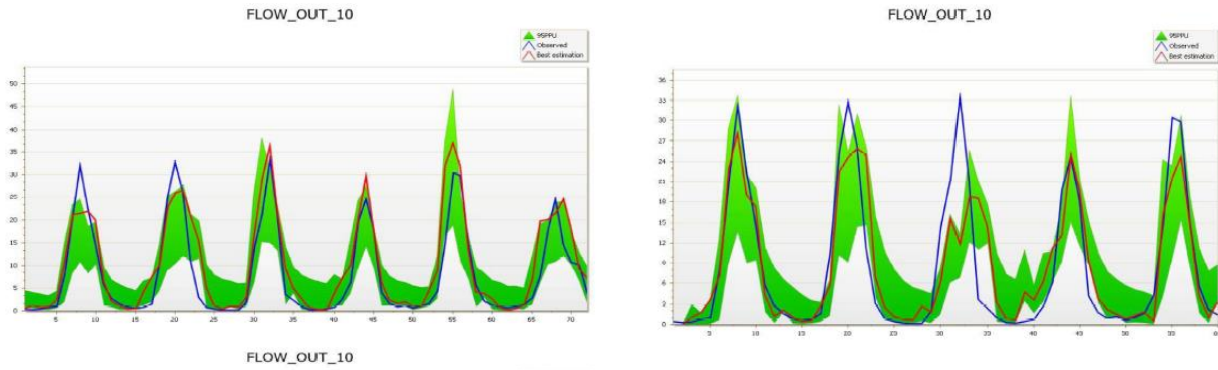


Fig.3. hydrographs of calibrated and validated flow

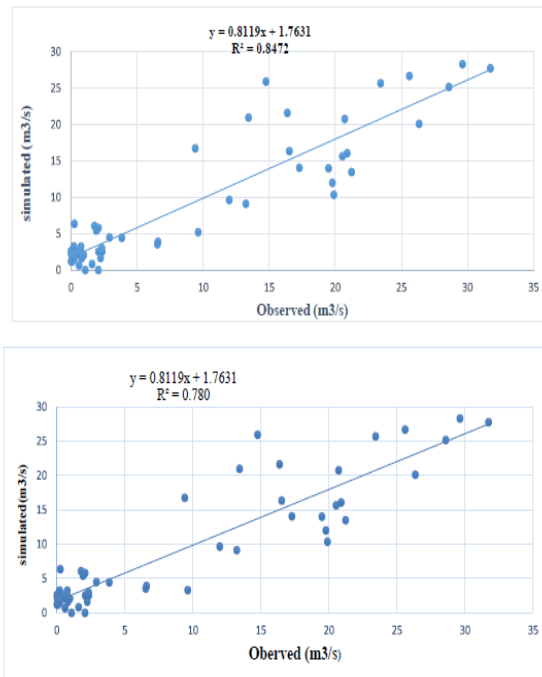


Fig. 4. the scatter plot of calibration and validation period

Flow Calibration and validation

The watershed was divided into 21 sub basins, which were further subdivided into 129 Hydrological response units (HRUs). A threshold value of 5% for land use, soil and slope was specified for defining the HRUs. The flow duration curves developed for the identified potential sites and the final result of the study in the form of power estimates corresponding to 50%, 75% and 90% dependability, also explained by using the hydrograph of the validated by the stream flow of the watershed area.

Identification of potential sites and estimation of

Hydropower potential A 30-m DEM was used to identify potential sites in the Temcha watershed. A site is identified as a potential site when a head of 20 m or more is available in the stream, with a separation of at least 500 m between two sites. The assessment for the next potential site is carried out from the last selected site and the process continued until the stream end; thus 33 potential sites were identified in the Temcha watershed and their locations along with the stream network are presented . It needs to be highlighted that, as

well as hydrological, many other criteria (e.g. geological suitability, vicinity to important places) have to be met to finalize the site of hydropower projects. The methodology presented here is a systematic way to identify potential sites from a hydrological angle and these sites could be further examined using other criteria to arrive at a different list. An optimization study could also be carried out by varying the norm for the head (20 m in the present case) and spacing (500 m) to develop an optimal basin development plan. The flow for a 90% dependable year (the year when flow has a 90% probability of exceedance) is used in the design of hydropower projects. The SWAT model was used to generate the flow for 30 years from 1990 to 2010 . The runoff was simulated for the main watershed outlet to identify the 90% dependable year, which was calculated by rearranging the annual runoff data in descending order and applying the Weibull formula (MNRE 2008). This ensures that enough flow is available 90% of the time for hydropower generation. Once the 90% dependable year is found, the flow is generated separately for each selected potential site in the 90% dependable year. This makes it possible to have a more

realistic knowledge of the potential flow, as both spatial and temporal changes in catchment features and inputs are taken into consideration by the model. The hydropower generation was estimated considering 3 levels of dependability, 90%, 75% and 50% (MNRE 2008), resulting in a total hydropower generation capacity of 3039, 1127 and 805 kW, respectively.

Conclusion

Use of SWAT model along with Arc GIS has been shown to be an effective tool in identification of suitable site for hydropower plants. This methodology will be especially beneficial for assessing the hydropower potential of Temcha Catchments. A total of 20 potential sites were identified for runoff river plants in Temcha watershed under in upper Blue Nile basin tributaries, considering fourth and higher order streams with a minimum head criteria of 10m and keeping the minimum distance between two consecutive sites as 1000m. The total estimated theoretical power potential was 12744KW, 2538 KW and 603.1 KW with 50%, 75% and 90% dependable flows respectively.

For the hydropower potential assessment, they should have ratified certain tips to add values with that of particularly area selections. During hydropower potential assessment further studies like, land use/cover change, river morphological analysis, hydrology of the area and other related issues should be done. In this investigation several, tracks were talked and some of those focused on the priority of the site condition, interventions of the society, so they would be support by making a community service mechanisms and by ratifying other projects to support the nearest living society.

References

- Bartle, A. (2002). Hydropower potential and development activities. *Energy policy*, 30, 1231-1239.
- Cüceloğlu, G., Seker, D. Z., Tanık, A., Öztürk, İ. (2021). Analyzing Effects of Two Different Land Use Datasets on Hydrological Simulations by Using SWAT Model, *International Journal of Environment and Geoinformatics*, 8(2), 172-185, doi.10.30897/ijegeo.828112
- Corobov, R., Syrodov, G., Trombitsky, LD., Galupa, D. Deudney, D. (2016). *Rivers of Energy: The Hydropower Potential. Worldwatch Paper No. 44*, ERIC. Anthropogenic factors as an element of uncertainty in hydrological modelling of water yield with SWAT, *Journal of Engineering Science and Technology Review* 9(2):138-145
- Dilnesa, W. (2018). Assessing the Impacts of Land use/cover Change on the Hydrological Response of Temcha watershed, upper Blue Nile basin, Ethiopia, *International Journal of Scientific Research in Civil Engineering*, 2(5):10-19.
- Essien, E., Jesse, E., Igbokwe, J. (2019). Assessment of Water Level in Dadin Kowa Dam Reservoir in Gombe State Nigeria Using Geospatial Techniques, *International Journal of Environment and Geoinformatics*, 6(1), 115-130, doi. 10.30897/ijegeo.487885
- Gazioğlu, C., Yücel, Z.Y., Doğan, E. (1998). Uydu Verileri İle İstanbul Boğazi ve Yakın Çevresindeki İçme Suyu Havzalarına Genel Bir Bakış., *Büyükşehirlerde atık su yönetimi ve deniz kirlenmesi kontrolü sempozyumu*. 18-20 Kasım 1998,
- Kusre, B., Baruah, D., Bordoloi, P., Patra, S. (2010). Assessment of hydropower potential using GIS and hydrological modeling technique in Kopili River basin in Assam (India). *Applied Energy*, 87, 298-309.
- Mathi, R. S., Desmukh, T. (2016). Spatial Technology for Mapping Suitable Sites for Run-of-River Hydro Power Plants.
- Pandey, A., Lalrempuia, D., Jain, S. K. (2015). Assessment of hydropower potential using spatial technology and SWAT modelling in the Mat River, southern Mizoram, India. *Hydrological Sciences Journal*, 60, 1651-1665.
- Sisay, E., Halefom, A., Khare, D., Singh, L., Worku, T. (2017). Hydrological modelling of ungauged urban watershed using SWAT model. *Modeling Earth Systems and Environment*, 3, 693-702.
- Strauch, M., Bernhofer, C., Koide, S., Volk, M., Lorz, C., Makeschin, F. (2012). Using precipitation data ensemble for uncertainty analysis in SWAT streamflow simulation. *Journal of Hydrology*, 414-415, 413-424.
- Yücel, Z.Y. Gazioğlu, C., Doğan, E., Kaya, H. (2002). Uzaktan Algılama ve CBS/B ile Ömerli Barajı ve Yakın Çevresinin İzlenmesi, *Türkiye'nin Kıyı ve Deniz Alanları IV Ulusal Konferansı Bildiriler Kitabı*.
- Zhou, F., Xu, Y., Chen, Y., Xu, C. Y., Gao, Y., Du, J. (2013). Hydrological response to urbanization at different spatio-temporal scales simulated by coupling of CLUE-S and the SWAT model in the Yangtze River Delta region. *Journal of Hydrology*, 485, 113-125.