Academic Journal of Environment & Earth Science
ISSN 2616-5872 Vol.5, Issue 10: 26-30, DOI: 10.25236/AJEE.2023.051004

Analysis of the Site Selection of Yarlung Zangbo Hydropower Station Based on GIS

Li Qiang[1,a], Liao Jiahao[1,b], Song Zerui[2,c]

[1]Geophysical Institute, Chengdu University of Technology, Chengdu, China
[2]College of Materials and Chemical Engineering, Chengdu University of Technology, Chengdu, China
[a]2813998748@qq.com, [b]19160303820@163.com, [c]320723406@qq.com

Abstract: *The Yarlung Zangbo River is the longest plateau river in China, with huge potential hydraulic energy. In order to make better use of hydraulic resources, we conduct research on the siting of hydropower stations.We analyze this issue based on the obtained geoscience and spatial information. For the problem, we extracted 999 sampling points on the main stream of the Yarlung Tsangpo River using ArcGIS, selected 50 of them. We have extracted key indicators for establishing hydropower stations based on various research reports, including economic cost, river width, geological foundation, drop, etc and used the Topos method to find the coordinates of the most suitable point for establishing a hydropower station, longitude 85.1312544645258 and latitude 29.3017619417134, and have marked them on the map.*

Keywords: *Spatial Information Analysis, Topsis, Entropy Weighting Method, Hydropower- Station Site Selection*

1. Introduction

The Yarlung Tsangpo River has very rich hydro energy reserves and is a good natural battery, but its exploitation is controversial in academic circles. Some argue that it is time to increase hydroelectric power generation and reduce thermal power generation in order to achieve carbon neutrality. The Yarlung Tsangpo River has a large drop-off, which is ideal for establishing hydroelectric power stations. But some argue that the costs are significant and that the construction of hydroelectric power stations would damage the environment. Meanwhile, the Red Flag River project, which supplies water to the west, is under lively discussion.

2. Data preparation

Question requires us to site a hydropower plant on the main stream of the Yarlung Tsangpo River. There are many factors that affect the capacity and efficiency of a hy- dropowerplant. The literature[1][2][3] 1]mentions economic costs, river widths, geological foundations, drop-offs, etc. Firstly, we site the hydr power plant only for the upper reaches, and the data we have are the elevations and geographic information of N discrete points on the main stream of the Yarlung Tsangpo River[3], using ArcGIS software to visualise the sampling points and elevation data for the upper reaches of the river, the sampling points are shown in Figure1.

Figure 1: Elevation map of the Yarlung Tsangpo sampling site.

ISSN 2616-5872 Vol.5, Issue 10: 26-30, DOI: 10.25236/AJEE.2023.051004

3. Geographic information analysis of site selection superiority

We can obtain the longitude X_i,latitude $Y_i$and elevation H_i of these N points, and thus derive the Euclidean distance between two adjacent points. We define a variable d that represents the total distance along the centreline direction of the main stream of the Yarlung Tsangpo River, then the elevation *H = H(d)* of any point is a one-dimensional continuous function with d as the independent variable. Since it is not convenient for us to derive a continuous expression for *H(d)*, the slope k_i of each sampling point can be derived by using a resampling method to extract N sampling points and performing some interpolation algorithm that guarantees second-order smoothness, and then the slope of the *i*th sampling point can be solved for either in a discrete way or in a continuous way.

The current distance d from the origin of the river is plotted against the elevation *H(d)* as Figure 2.

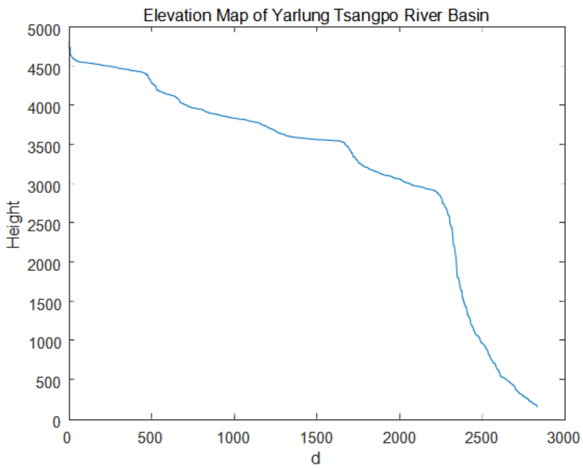

Figure 2: Elevation Map of Yarlung Tsangpo River Basin.

The approximate slope (the opposite of the difference quotient in elevation) of a river and the distance d are related as Figure 3.

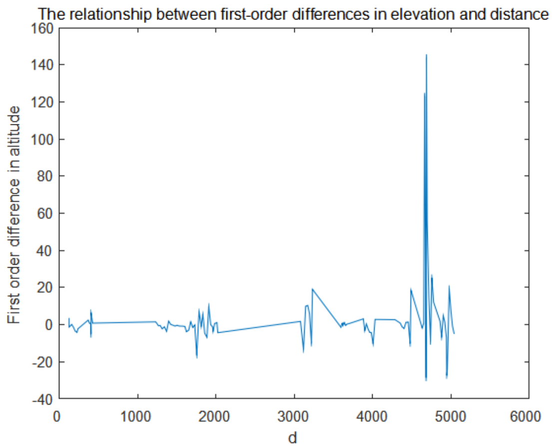

Figure 3: The relationship between first-order differences in elevation and distance.

Discrete situation:

$$k_i = \frac{H_{i+1} - H_i}{\sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}} \tag{1}$$

Continuous situation:

ISSN 2616-5872 Vol.5, Issue 10: 26-30, DOI: 10.25236/AJEE.2023.051004

$$k(d) = \lim_{\Delta d \to 0} \frac{\widetilde{H}(d+\Delta d) - \widetilde{H}(d)}{\Delta d} \tag{2}$$

where $\widetilde{H}(d)$ represents the interpolation function for $\{H_i\},\{d_i\}(i = 1,\cdots,N)$.

For these N sampling points, we can derive the river width W_i at that point based on latitude and longitude, using platforms such as Google Earth. Let the economic cost of building a hydropower station at the *i*th sampling point be C_i. There are many factors that influence the economic cost, the most direct being the width of the river. If the point is closer to the county town, it is more accessible and the economic cost is relatively low. Let the distance of the *i*th sampling point from the nearest county centre be r_i. The geological base of different points is also an influential factor in construction costs, but it is a large undertaking to try to figure out and quantify the geological base of all points. Therefore, we do not consider the geological base as an influencing factor. That is, $C = C(W(d), r(d))$.

In summary, the influencing factors for siting a hydropower plant are river width W_i, economic cost C_i, and slope (drop) k_i , where $C_i=C(W_i,r_i)$ and the functional form of $C(W, r)$ is to be determined.

These N sampling points are known for these variables, and the weights of each independent variable can be determined according to the entropy weighting method, which in turn selects the optimal site selection point according to the Topsis method[6]. In this case, the idea of the Topsis[4] method is as follows:

Step 1: data cleaning. We use the raw data W_i, k_i, r_i from these N sampling points. Since the economic cost of building the station at the *i*th sampling point is unknown, but we can specify that the economic cost C increases with the width of the river and increases with the distance from the county, we set $C_i=c_0 r_i W_i$,where $c_0$is a constant and take c_0=1.This gives us a matrix $X= [W_i , k_i , r_i , C_i]_{i=1}^{N}$ of $N \times 4$.

Step 2: normalisation and normalisation. Among them,k_i is the positive indicator, because the greater the slope, the greater the power generation; r_i is the positive indicator, because the farther the distance from the residents, the less the impact of the hydropower plant on the residents; W_i is the negative indicator, because the greater the width of the river, the more difficult to build and the lower the safety factor;C_i is the negative indicator, because the lower the construction cost, the better. We start by positivising the negative indicators

$$W_i' = \max_{1\leqslant j\leqslant N}\{W_j\} - W_i, \quad C_i' = \max_{1\leqslant j\leqslant N}\{C_j\} - C_i \tag{3}$$

The data can then be normalised. The standardised $X= [W_i , k_i , r_i , C_i]_{i=1}^{N}$is as follows

$$\widetilde{k}_i = \frac{k_i}{\sqrt{\sum_{i=1}^{m} {k_i}^2}}, \quad \widetilde{r}_i = \frac{r_i}{\sqrt{\sum_{i=1}^{m} {r_i}^2}}, \quad \widetilde{W}_i = \frac{W_i'}{\sqrt{\sum_{i=1}^{m} {W_i'}^2}}, \quad \widetilde{C}_i = \frac{C_i'}{\sqrt{\sum_{i=1}^{m} {C_i'}^2}}, \tag{4}$$

Step3: Entropy weighting method to determine weights. The matrix $X= [W_i , k_i , r_i , C_i]_{i=1}^{N}$ with negative numbers is first normalised once more to obtain a positive matrix, with the normalisation formula

$$Z_{ij} = \frac{\widetilde{X}_{ij} - \min\left\{\widetilde{X}_{1j},\widetilde{X}_{2j},\cdots,\widetilde{X}_{mj}\right\}}{\max\left\{\widetilde{X}_{1j},\widetilde{X}_{2j},\cdots,\widetilde{X}_{mj}\right\} - \min\left\{\widetilde{X}_{1j},\widetilde{X}_{2j},\cdots,\widetilde{X}_{mj}\right\}} \tag{5}$$

We calculate the probability matrix P, where each element p_{ij} of P can be calculated using the following formula

$$p_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{m} Z_{ij}} \tag{6}$$

For the *j*th indicator, its information entropy is calculated as

$$e_j = -\frac{1}{\ln n}\sum_{i=1}^{m} p_{ij}\ln(p_{ij}) \quad (j = 1, 2, 3, 4) \tag{7}$$

The information utility value is defined as $d_j = 1 - e_j$, then the weight of the *j*th indicator

$$\omega_j = \frac{d_j}{\sum_{k=1}^{4} d_k} \quad (j = 1, 2, 3, 4) \tag{8}$$

Step4: Calculating scores. Calculate the scores for each country on these 4 indicators (river width, gradient, distance to nearest county, economic cost) separately. The maximum and minimum values are

$$\widetilde{X}^{+} = \left[\widetilde{W}_i^{+}, \widetilde{k}_i^{+}, \widetilde{r}_i^{+}, \widetilde{C}_i^{+}\right] = \left[\max\{\widetilde{W}_i\}, \max\{\widetilde{k}_i\}, \max\{\widetilde{r}_i\}, \max\{\widetilde{C}_i\}\right]_{i=1}^{N} \tag{9}$$

$$\widetilde{X}^{-} = \left[\widetilde{W}_i^{-}, \widetilde{k}_i^{-}, \widetilde{r}_i^{-}, \widetilde{C}_i^{-}\right] = \left[\min\{\widetilde{W}_i\}, \min\{\widetilde{k}_i\}, \min\{\widetilde{r}_i\}, \min\{\widetilde{C}_i\}\right]_{i=1}^{N} \tag{10}$$

Let ω_W, ω_k, ω_r, ω_c be the weights of the four indicators of river width, slope, distance to the nearest county, and economic cost respectively (which can be assigned by entropy weighting method), then the distance between the *i*th evaluation object (sampling point) and the maximum and minimum values are defined as

$$D_i^{+} = \sqrt{\sum_{k=1}^{4} \omega_k \left(\widetilde{X}_k^{+} - \widetilde{X}_{ik}\right)^2} \tag{11}$$

$$D_i^{+} = \sqrt{\sum_{k=1}^{4} \omega_k \left(\widetilde{X}_k^{-} - \widetilde{X}_{ik}\right)^2} \tag{12}$$

With such an algorithm, the unnormalized score of the *i*th evaluation object (sampling point) can be derived

$$S_i = \frac{D_i^{-}}{D_i^{+} + D_i^{-}} \tag{13}$$

By ranking $\{S_i\}(i = 1, \cdots, N)$, the most suitable points for building hydroelectric power stations can be identified.

4. Conclusions

MATLAB was used to solve for the top 9 points in order of suitability for the construction of a hydroelectric power station as: Table 1

ISSN 2616-5872 Vol.5, Issue 10: 26-30, DOI: 10.25236/AJEE.2023.051004

Table 1: Add caption.

Point	Longitude	Latitude
1	85.13125	29.30176
2	85.14435	29.31286
3	87.07241	29.13951
4	85.11862	29.28999
5	86.22708	29.20296
6	87.31015	29.12039
7	87.29491	29.12743
8	86.48848	29.20898
9	86.34323	29.21008

We extracted 1000 points on the main stream of the Yarlung Tsangpo River, as well as the width of the river, slope, distance to the nearest county, and economic cost of these 1000 points, and finally determined the location of the hydropower plant construction[7] at the point of longitude 85.131254 and latitude 29.301761, as Figure 4.

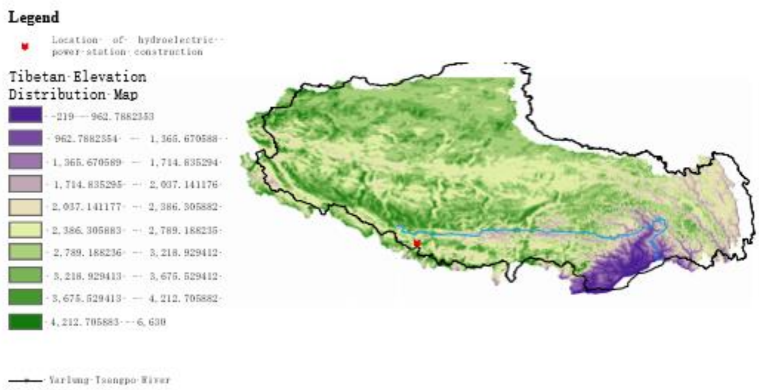

Figure 4: Hydroelectric power station planning for the main stream of the Yarlung Tsangpo River.

References

[1] Ren Xi, Kang Tianke. Application of multi-criteria analysis (MCA) in hy- dropower plant siting projects[J].Journal of Guizhou University (Natural Science Edition),2013,30(05):31-38.
[2] Luo Jiasong, Song Chongming, Wang Xinlei, etc A Preliminary Site Selection Method for Large Dam Hydroelectric Stations [P] Beijing: CN106284239A, 2017-01-04
[3] Ren Xi, Kang Tianke. Application of Multi Criteria Analysis (MCA) in Hydropower Station Site Selection Projects [J]. Journal of Guizhou University (Natural Science Edition), 2013,30 (05): 31-38 DOI: 10.15958/j.cnki. gdxbzrb. 2013.05.005
[4] Tangshan Song. Many factors to consider when selecting the location of small and medium-sized hydropower stations [J]. China Rural Water Resources and Hydropower, 2007 (02): 96-98
[5] Wang T., Li X. W. Energy conversion analysis and calculation for energy efficiency assessment of conventional hydropower plants [J]. Hydroelectricity, 2016,42(06):80-83.
[6] Yang Junru. Planning and Design of Comprehensive Energy Station Site Selection Based on Load Geography Model [D]. Shandong University, 2022 DOI: 10.27272/dcnki.gshdu.2022.005188
[7] Qiu Yuhua. Theoretical and Empirical Research on Geographical Design [D] Central China Normal University, 2014