Vol. 2 No. 4 (2024)

Spectrum of Engineering Sciences

SPECTRUM OF ENGINEERING SCIENCES

Online ISSN

Print ISSN

Strategic Planning for Sustainable Energy Towards Greener Future: Geospatial Analysis of Hydroelectric Power Generation Sites in Pakistan

Saad Zaheer[1]

Centre of Excellence in Water Resources Engineering, University of Engineering and Technology (UET), Lahore, Pakistan

Civil Engineering Department, Bahauddin Zakariya University, Multan, Pakistan. saad.ahmad4456@gmail.com

Naheed Akhtar[2]

Abasyn University, Islamabad, Pakistan

naheed.akhtar@abasynisb.edu.pk

Ghassan Sattar Khan[3]

University of Engineering and Technology (UET), Taxila, Pakistan

gsk.engineerz@gmail.com

Arslan Soomro[4]

Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah, Pakistan. soomroarslan536@gmail.com

Muhammad Anwar Ullah[5]

Balochistan University of Engineering and Technology (BUET), Khuzdar, Pakistan. anwarullah98@gmail.com

Ubaid ur Rehman[6]

Quetta Electric Supply Company (QESCO), Quetta, Pakistan

ubd77us@gmail.com

Abstract

The unexploited possibilities of hydropower energy in Khyber Pakhtunkhwa (KPK) province, Pakistan, pose a considerable challenge to advancing sustainable energy solutions. This study performs an initial

Spectrum of Engineering Sciences
Online ISSN
Print ISSN
SPECTRUM OF ENGINEERING SCIENCES

feasibility evaluation to determine appropriate sites for runoff river hydropower initiatives in KPK. The study uses sophisticated geospatial tools like Geographic Information Systems (GIS), remote sensing, and satellite imagery data to pinpoint locations where adequate head and discharge are present. The findings aid in pinpointing potential locations for hydropower development, offering essential insights into sustainable energy alternatives for the region's advancement.

Keywords: Hydroelectric power generation, runoff river hydropower projects, GIS, remote sensing, satellite imagery, geospatial analysis.

Introduction

Pakistan has significant untapped hydroelectric power potential, estimated at over 60,000 MW, positioning it as one of South Asia's most attractive nations for hydropower development (Pakistan Water and Power Development Authority, 2020). Khyber Pakhtunkhwa (KPK) has a substantial capacity, with a projected potential of over 13,000 MW [1-2]. Nonetheless, hardly a portion of this potential has been used, with the hydroelectric capacity in KPK roughly 2,500 MW (Pakistan Water and Power Development Authority, 2020). This underutilization signifies a distinct possibility for more growth. Moreover, sophisticated Geographic Information Systems (GIS) technologies, like ArcGIS, provide a comprehensive platform for site selection and suitability evaluation for hydropower initiatives.

An illustrative instance is the research undertaken in Papua New Guinea, whereby GIS methodologies were utilized to pinpoint prospective locations for hydropower plant establishment in the Busu basin [5]. The increasing effects of climate change heighten the frequency and severity of natural catastrophes, particularly floods, in areas such as Pakistan [15]. This study aims to reproduce and modify this methodology to suit the distinct geographical and geological

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
Print ISSN

circumstances of KPK. Pakistan's Khyber Pakhtunkhwa (KPK) province has significant unexploited hydropower potential. Nevertheless, the absence of extensive research and the insufficient use of GIS technologies such as ArcGIS has resulted in this potential being largely unexploited. This project mitigates this deficiency by utilizing modern GIS methodologies to find, evaluate, and recommend viable locations for runoff river hydropower initiatives.

The project objectives are as follows:

Using geospatial research via ArcGIS, identify prospective locations for runoff river hydropower initiatives in Khyber Pakhtunkhwa, particularly within the Swat and Indus River basins.

Employ ArcGIS to evaluate the hydropower potential of designated locations by analyzing geological, geographical, and hydrological factors, encompassing land use, soil properties, precipitation patterns, and river flow.

Runoff river hydropower is essential for sustainable energy growth, especially in areas rich in water resources, such as Khyber Pakhtunkhwa (KPK), Pakistan. This section summarises current research and approaches to finding prospective hydropower locations on Runoff Rivers in the KPK region utilizing ArcGIS. Pakistan possesses considerable unexploited hydropower potential, with KPK accounting for a large portion of this capacity. The Pakistan Water and Power Development Authority (WAPDA, 2020) estimated that KPK possesses more than 13,000 MW of hydropower potential. Nevertheless, hardly a portion of this potential has been utilized, with the existing installed capacity at around 2,500 MW. This signifies a substantial prospect for more development in the region. ArcGIS, a robust geographical information system, has been widely utilized in several studies to ascertain viable locations for hydropower projects. Its spatial analytic skills and capacity

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN 3007-3138
Print ISSN 3007-312X

to incorporate geographic information provide it an essential tool for evaluating appropriateness and feasibility. Researchers illustrated the utilization of ArcGIS for site selection of small hydropower stations, highlighting its efficacy in pinpointing ideal places for hydropower initiatives [3].

The research undertaken in Papua New Guinea exemplifies the application of GIS methodologies for pinpointing prospective locations for hydropower plant development in the Busu basin. The authors utilized a multi-criteria analysis methodology, using several geographical layers, such as topography, land cover, and hydrological characteristics, to identify optimal sites for hydropower initiatives. This research provides a significant reference for modifying GIS approaches to the distinct geographical and geological circumstances of KPK [11].

This study employed the Collection 6 MODIS Land Cover product, created by Damien Sulla-Menashe and Mark A. Friedl, for land use and land cover (LULC) categorization. The offering, consisting of MCD12Q1 and MCD12C1 datasets, delivers worldwide land cover categorization at a spatial resolution of 500 meters and supplies essential information on diverse land cover types [14]. The researchers efficiently delineated and categorized various land use categories using tables. This method utilized the extensive coverage and thematic intricacies of MODIS data, enabling an in-depth examination of landscape dynamics. This work enhances the literature on remote sensing land cover categorization and illustrates the effectiveness of the Collection 6 MODIS Land Cover product for monitoring and comprehending land use changes [6-10]. This research utilizes the Global Hydrologic Soil Groups (HYSOGs250m) dataset [4] to ascertain curve values for a particular study region. HYSOGs250m offers a globally uniform, gridded collection of hydrologic soil groups (HSGs) with a remarkable spatial resolution of roughly 250

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

meters. The categorization of Hydrologic Soil Groups (HSGs) inside HYSOGs250m is designed to enhance USDA-based curve-number runoff modelling at regional and continental levels, utilizing soil texture classes and bedrock depth data obtained from the Food and Agriculture Organization's soilGrids250m system. This research computes curve numbers by following the procedural recommendations provided with the dataset, enhancing understanding of runoff dynamics and improving water management techniques in the study region. Global Hydrologic Soil Groups (HYSOGs250m) for Curve, no date [12-13].

This study meticulously investigates the intricate relationship between land use and land cover changes, specifically the transformation of natural landscapes into urban areas and the escalating risk of floods in the Swat Watershed. Its goal is to ascertain the fundamental causes and consequences of flooding in the region. Additionally, it provides substantial insights and recommendations for enhanced flood control, land use planning, and mitigation strategies [16].

Methodology and Technique

We utilize ArcGIS software to retrieve hydrological data, including river flow rates (discharge). Our discharge estimations correlate significantly with rainfall intensity, directly affecting regional water availability. Mapping discharge patterns provide insights into river flow's temporal and geographical changes. This knowledge constitutes a crucial input for the following phases. Subsequently, we concentrate on pinpointing locations with advantageous topography for hydropower production. These sites demonstrate a considerable disparity in elevation (head) between the upstream and downstream locations. By utilizing elevation data from remote sensing and satellite images, we identify places where the natural topography offers the requisite head for optimal turbine performance. These regions provide ideal prospects for hydropower

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

initiatives, guaranteeing maximal energy conversion. We aim to assess the potential energy available for harnessing by utilizing discharge data and head values. Utilizing existing hydropower equations, we compute each location's potential electrical energy output. Our methodology incorporates geospatial analysis, hydrological modelling, and remote sensing approaches.

Our research systematically integrates geospatial analysis, hydrological modelling, and remote sensing approaches. Below are the essential stages:

Hydrological Analysis

We create flow accumulation and flow direction raster maps with ArcGIS hydrology capabilities. These maps illustrate the flow patterns throughout the terrain. Flow accumulation denotes the number of cells contributing to each cell, whereas flow direction specifies the trajectory of water flow from one cell to its adjacent cells. Using the flow accumulation data, we identify stream channels and river pathways. These canals represent prospective sites for hydropower production.

Stream Channel Identification

Stream channels are extracted from the flow accumulation map by establishing a threshold value. This threshold delineates substantial flow buildup. The stream channel network's raster data is transformed into polyline vector data, facilitating efficient representations of river courses.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

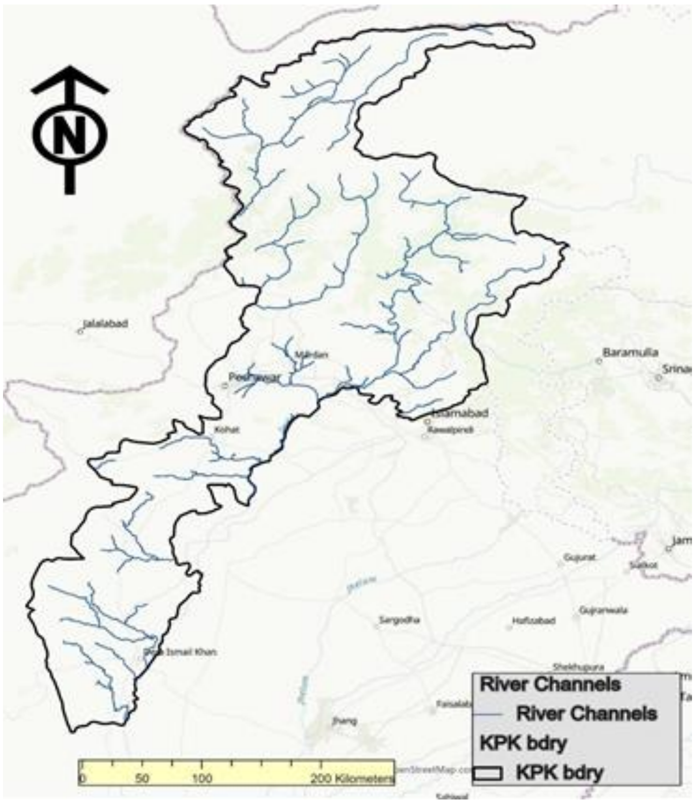

Figure 1: Streams/ Rivers Network

Global Mapper Integration

The DEM and stream channel vectors are imported into Global Mapper, a geospatial analysis program. Global Mapper generates longitudinal profiles for all river and stream courses. These profiles depict variations in elevation over their lengths. Through the analysis of longitudinal profiles, locations with significant available heads are discovered. These areas demonstrate considerable elevation variations over brief distances.

Vol. 2 No. 3 (2024)
Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN 3007-3138
Print ISSN 3007-312X

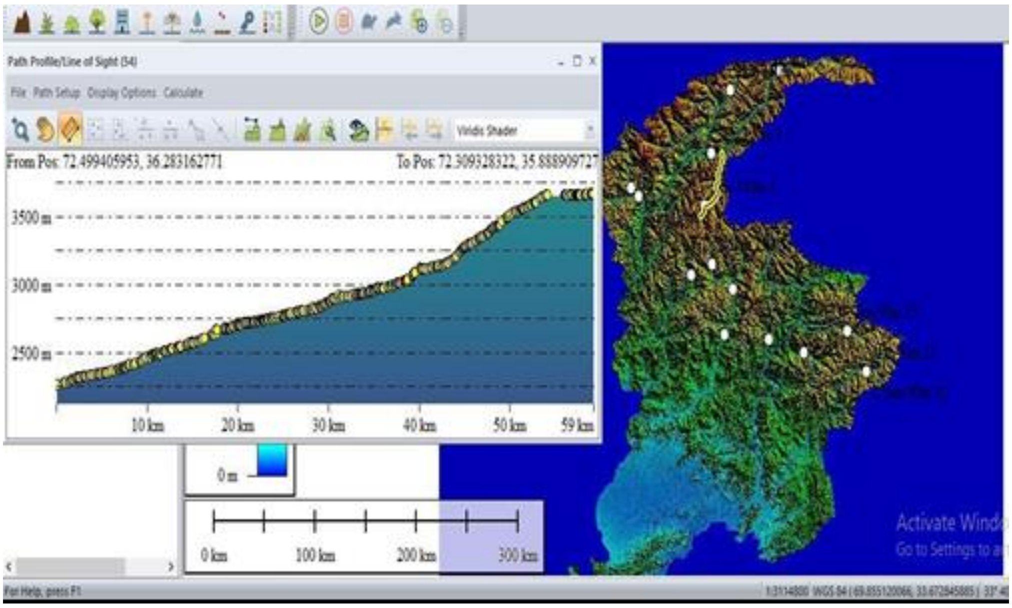

Figure 2: Longitudinal River Profile in Global Mapper

We compute the total available head at each designated location. The elevation differential between upstream and downstream locations signifies the potential energy for hydropower. Concise diverging channels (penstocks) are advantageous for reducing construction expenses.

Table 1: Calculation of Head

Locations	Head (m)	Distance (Km)	Latitude	Longitude
1	100	2	36.79	73.02
2	150	1	36.67	72.58
3	100	3	36.28	72.42
4	175	3	36.06	71.70
5	70	2	36.03	71.41
6	100	2	36.01	71.77
7	100	2	35.95	72.35
8	25	1	35.59	72.42
9	125	5	35.52	72.23
10	125	3	35.43	72.61
11	90	2	35.17	73.62

Vol. 2 No. 3 (2024)
Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN 3007-3138
Print ISSN 3007-312X

12	50	3	35.15	72.53
13	90	1	35.12	72.92
14	200	3	35.01	73.23
15	90	1	34.92	73.79

The methodology combines elevation data, hydrological analysis, and geospatial tools to identify high-head hydropower sites.

Hydrological Assessment: Discharge Estimation

The primary purpose of this project phase is to ascertain water discharge in stream channels at designated places using Digital Elevation Models (DEMs). The procedure encompasses many essential stages: Initially, the curve number will be determined by examining land use, land cover categorization, and soil hydrologic groups throughout the research region. This measure is essential for comprehending the hydrological response of the catchment regions. Secondly, the average annual precipitation is calculated within the catchment regions of our designated locations since accurate rainfall data is crucial for evaluating water availability and stream flow. Subsequently, the aggregate catchment area of prospective locations is computed, yielding essential land surface data contributing to discharge. Ultimately, we compute the aggregate discharge volume and ascertain the discharge rate per unit of time at prospective locations, concluding our evaluation of water discharge in stream channels. The comprehensive technique for calculating discharge is delineated step by step as follows:

Land Use Land Cover Classification

I employed MODIS 8 data from the USGS Earth Explorer to categorize extensive land use and land cover for Pakistan's Khyber Pakhtunkhwa (KPK) area. The classification entailed identifying and categorizing several land cover categories, including forests, barren regions, and water bodies. The investigation included many land use categories to depict

Vol. 2 No. 3 (2024)
Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X
SES

the region's geography comprehensively.

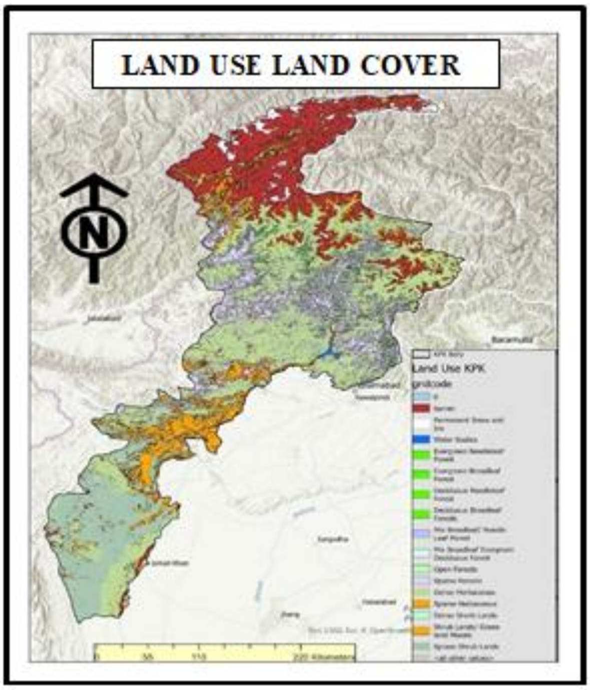

Figure 3: Land Use Land Cover Cl

Soil Classification Based on Soil Hydrographs

A comprehensive soil classification of the Khyber Pakhtunkhwa (KPK) region in Pakistan is conducted using Global Hydrological Soil Groups (HYSOG) data at a 250 m resolution, dividing the area into Hydrological Soil Groups A, B, C, and D. This categorization is essential for runoff modelling. Subsequently, Curve Numbers (CN) are computed for each soil group, serving as a critical input for runoff calculations. The procedure entailed the amalgamation of land use and land cover categorization maps with soil hydro group maps utilizing the union tool in ArcGIS. This collaboration enabled the calculation of cumulative curve numbers for the whole area. The cumulative curve number, obtained from integrating soil groups and land cover data, is crucial for runoff estimates utilizing the discharge method. This thorough methodology establishes a solid basis for evaluating and controlling runoff in the KPK area, including the interplay between soil qualities and land cover

Vol. 2 No. 3 (2024)

Spectrum of Engineering Sciences

SPECTRUM OF ENGINEERING SCIENCES

Online ISSN 3007-3138

Print ISSN 3007-312X

attributes.

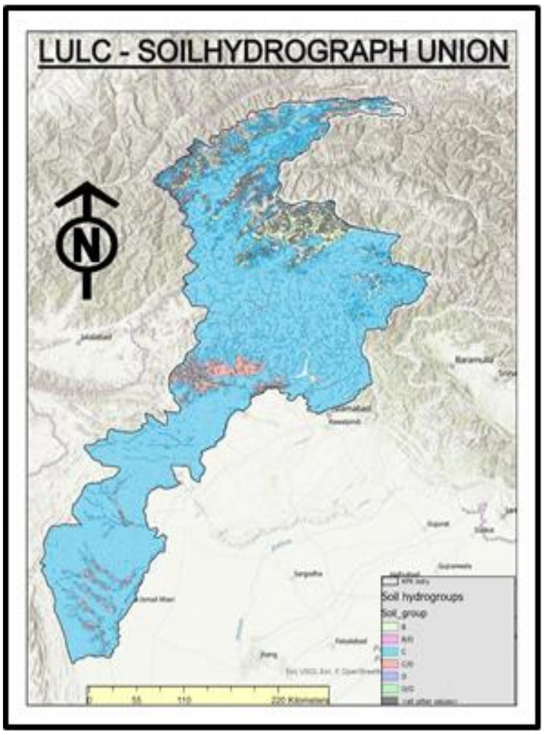

Figure 4: Soil Hydrograph Union

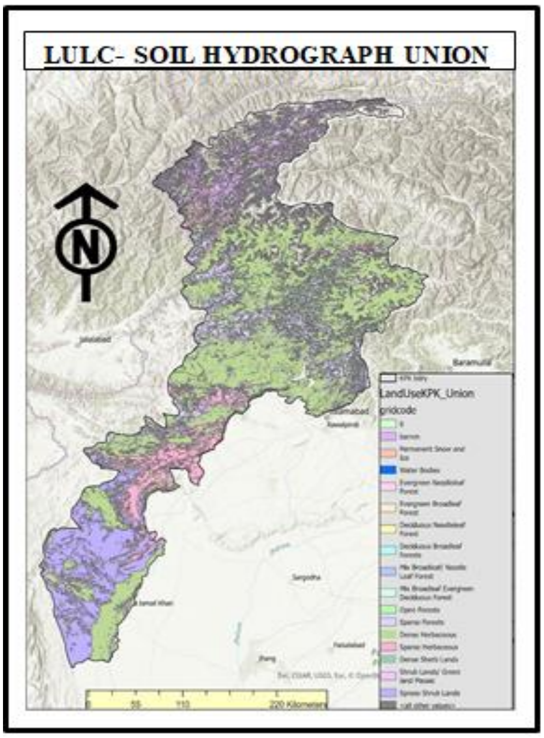

Figure 5: LULC Soil Hydrograph Union

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN 3007-3138
Print ISSN 3007-312X

Table 2: Curve Number Calculation

LU-Soil	Frequency	Sum-Area	CN	CN-Area
1_B	3886	1789.243651	79	141350.25
1_B/D	539	123.4487158	86	10616.58984
1_C	5518	4772.702527	86	410452.4063
1_C/D	1258	312.0425508	92	28707.91406
1_D	4484	1821.726316	89	162133.6406
1_D/D	364	43.72876711	89	3891.860352
11_B	220	67.55266491	55	3715.396484
11_B/D	23	2.159756802	70	151.1829834
11_C	771	605.5992025	70	42391.94531
11_C/D	105	9.844995822	74	728.5296631
12_C	6	0.923860748	70	64.6702499
12_C/D	1	0.209701136	73	15.3081827
13_C	2	0.429317355	70	30.0522156
14_C	29	8.141325399	77	626.8820801
15_B	98	8.747779605	60	524.8667603
15_B/D	9	0.602140856	70	42.1498604
15_C	492	429.4540068	73	31350.14258
15_C/D	77	17.54130531	76	1333.13916
16_C	5	1.073293388	73	78.3504181
2_B	114	6.497372231	98	636.7424927

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

2_B/D	1	0.011608468	98	1.1376299
2_C	476	61.0003196	98	5978.03125
2_C/D	6	0.155099416	98	15.1997423
2_D	181	11.02599189	98	1080.547241
2_D/D	2	0.019277134	98	1.8891591
21_B	569	173.9575816	60	10437.45508
21_B/D	76	7.336852565	70	513.5796509
21_C	2409	2158.103765	2	4316.20752
21_C/D	596	79.86776823	76	6069.950195
21_D	1	0.030428177	80	2.4342542
22_B	656	145.0624509	60	8703.74707
22_B/D	103	9.208561493	70	644.5993042
22_C	4695	10329.48548	73	754052.4375
22_C/D	2891	1396.876299	76	106162.6016
3_C	6	0.292906916	98	28.7048779
3_C/D	2	0.022163124	98	2.1719861
3_D	5	0.148070605	98	14.5109196
31_B	1736	1374.425977	98	134693.75
31_B/D	388	87.50938499	98	8575.919922
31_C	5368	19150.63103	98	1876761.875
31_C/D	3202	3674.876913	98	360137.9375

Spectrum of Engineering Sciences
Online ISSN
3007-3138
Print ISSN
3007-312X
SPECTRUM OF ENGINEERING SCIENCES

31_D	715	57.71668614	98	5656.235352
31_D/D	36	2.300764746	98	225.4749451
32_B	2043	877.6551998	98	86010.21094
32_B/D	414	71.94373347	98	7050.48584
32_C	5036	8034.883632	98	787418.625
32_C/D	1830	680.192746	98	66658.89063
32_D	1890	216.0010948	98	21168.10742
32_D/D	103	6.387438746	98	625.9689941
41_B	2	0.093608011	66	6.1781287
41_C	31	7.455477066	77	574.0717163
41_C/D	3	0.261737969	80	20.9390373
42_B	9	1.125270718	66	74.267868
42_C	148	71.89405584	77	5535.842285
42_C/D	10	0.583938871	80	46.7151108
43_B	6	1.091462649	66	72.0365372
43_C	1095	9520.582055	77	733084.8125
43_C/D	413	886.6665073	80	70933.32031
43_D	1	0.031064341	83	2.5783403
	Total	**69118.58365**	**4089**	**5902201.468**

Curve Number = ∑ (Curve Number X Area) / ∑ Areas

Vol. 2 No. 3 (2024)

Spectrum of Engineering Sciences

SPECTRUM OF ENGINEERING SCIENCES

Online ISSN 3007-3138

Print ISSN 3007-312X

= (5902201 / 69118) = 85.39

Estimation of Average Annual Rainfall

- **Data Collection:** The satellite precipitation data for Khyber Pakhtunkhwa Province was directly acquired from the DataPortal in GeoTiff format. This data presents statistics on precipitation around the region.
- **Conversion to Point Vector Data:** The GeoTiff data was transformed into point vector data. In this format, each data point signifies a distinct place inside the territory.
- **Rainfall Calculation in Catchment Area:** The mean rainfall data from various locations within that area were computed to evaluate precipitation in a designated catchment region. This method offers insights into regional precipitation patterns.

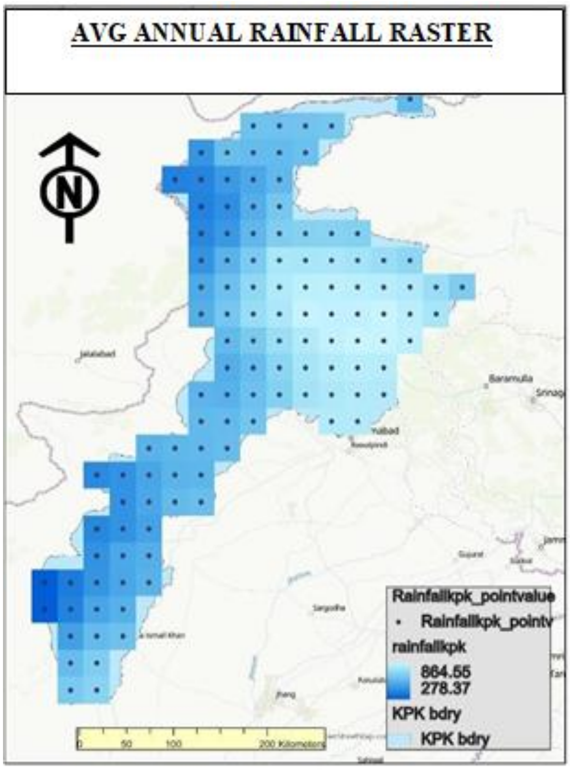

Figure 6: Average Annual Rainfall Raster

Vol. 2 No. 3 (2024)

Spectrum of Engineering Sciences

SPECTRUM OF ENGINEERING SCIENCES

Online ISSN 3007-3138

Print ISSN 3007-312X

Calculation of Catchment Area of Identified Locations

In our hydrological evaluation, identifying the catchment area for each prospective site is essential. We do this by analyzing the flow accumulation raster. This is the method for calculating the catchment area:

Flow Accumulation Raster: The flow accumulation raster illustrates the total water flow across the terrain. Every cell in the raster collects flow from its upstream adjacent cells.

Cell Contribution: For each prospective site, we ascertain the central cell associated with that place. We navigate upstream from this centre cell, accounting for all contributing cells. The aggregate number of cells contributing to the central cell constitutes the catchment area.

Calculation: Aggregate the contributing cells inside the flow accumulation raster. Transform this count into an area measurement (e.g., square kilometres) according to cell dimensions and resolution.

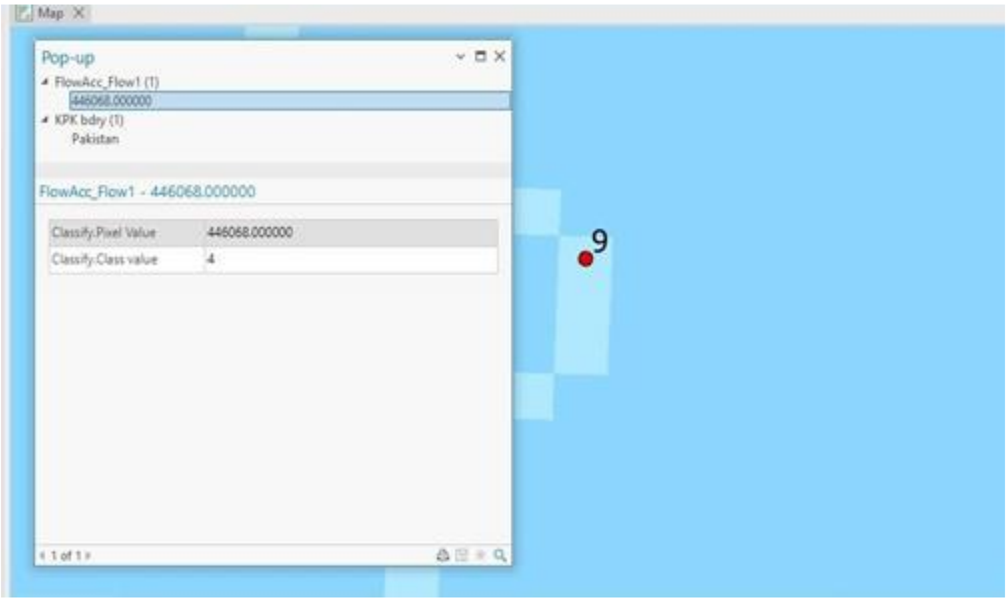

Figure 7: Number of contributing cells at each site

Vol. 2 No. 3 (2024)

Spectrum of Engineering Sciences

SPECTRUM OF ENGINEERING SCIENCES

Online ISSN 3007-3138

Print ISSN 3007-312X

Catchment Area Calculation

Table 3: Calculation of Catchment Area

Locs	No. of Contributing Cells	Area (m^2) (No. of Cells X 30 X 30)
1	688101	619290900
2	736240	662616000
3	4311122	3880009800
4	1146284	1031655600
5	456709	411038100
6	2648792	2383912800
7	506217	455595300
8	489626	440663400
9	446068	401461200
10	2566486	2309837400
11	611939	550745100
12	369742	332767800
13	462148	415933200
14	1075080	967572000
15	823543	741188700

Calculation of Discharge

Discharge at potential sites was determined by using the formula.

This is the water loss before runoff begins by soil and vegetation in infiltration or rainfall interception by vegetation.

$$S = (25400 / CN) - 254.$$

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

This discharge value is converted into water volume by multiplying it with the catchment area of each site. The rate of discharge is calculated by dividing the volume of water by the total number of seconds in a year.

Table 4: Calculation of Discharge in Cumecs with locations 1 to 15, respectively

Q (m^3/sec)	Q (m^3)	Q (m)	Q (mm)	IA = 0.4 S	S = (25400/CN) - 254	CN	Avg. Annual Rainfall (Mm)	Area (m^2)	Cells
11.45	3.6×10^8	0.58	582.99	17.38	43.46	85.39	641	6.1×10^8	6.8×10^5
11.91	3.7×10^8	0.57	567.06	17.38	43.46	85.39	625	6.6×10^8	7.3×10^5
69.16	2.1×10^9	0.56	562.08	17.38	43.46	85.39	620	3.8×10^9	4.3×10^6
11.37	3.5×10^8	0.35	347.55	17.38	43.46	85.39	404	1.0×10^9	1.1×10^6
4.47	1.4×10^8	0.34	342.6	17.38	43.46	85.39	399	4.1×10^8	4.5×10^5
31.82	1×10^9	0.42	420.9	17.38	43.46	85.39	478	2.4×10^8	6.4×10^5
7.9	2.4×10^8	0.55	547.15	17.38	43.46	85.39	605	4.5×10^8	5.0×10^5
8.54	2.6×10^8	0.61	610.87	17.38	43.46	85.39	669	4.4×10^8	4.8×10^5
7.16	2.2×10^8	0.5	562.	17.	43.46	85.	620	4.0×10	4.4×10^5

Vol. 2 No. 3 (2024)

Spectrum of Engineering Sciences

SPECTRUM OF ENGINEERING SCIENCES

Online ISSN 3007-3138

Print ISSN 3007-312X

SES

		6	08	38		39		8	
49.93	1.5×10^9	0.68	681.62	17.38	43.46	85.39	740	2.3×10^8	2.5×10^6
12.9	4×10^8	0.74	738.45	17.38	43.46	85.39	797	5.5×10^8	6.1×10^5
8.11	2.5×10^8	0.77	768.37	17.38	43.46	85.39	827	3.3×10^8	3.6×10^5
10.31	3.2×10^8	0.78	781.34	17.38	43.46	85.39	840	4.1×10^8	4.6×10^5
24.71	7.7×10^8	0.81	805.28	17.38	43.46	85.39	864	9.6×10^8	1.0×10^6
16.98	5.3×10^8	0.72	722.50	17.38	43.46	85.39	781	7.4×10^8	8.2×10^5

Calculation of Hydropower Energy Capacity at Potential Sites

The calculation of hydropower potential at various sites involves assessing the power output using the formula:

$$Ppot = q * m * g * h.$$

Here, 'Ppot' represents the power potential in Watts, 'q' stands for the density of water (1000 kg/m3), 'm' denotes the river discharge measured in cubic meters per second (m3/s), 'g' signifies the acceleration due to gravity (9.81 m/s2), and 'h' represents the falling height or head measured in meters.

By applying this formula, the power potential at each site can be quantified in terms of megawatts (MW), which provides valuable insights into the feasibility and capacity for hydropower generation in those locations.

Vol. 2 No. 3 (2024)
Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Table 5: Calculation of Hydropower Generation Capacity at Each Site

LOC	Head (M)	Discharge (Q) (m^3/sec)	Power (MW)	10% of Discharge (Q)	Power (MW @ 5% of Q)
1.00	100.00	11.45	11.23	1.14	1.12
2.00	150.00	11.91	17.53	1.19	1.75
3.00	100.00	69.16	67.84	6.92	6.78
4.00	175.00	11.37	19.52	1.14	1.95
5.00	70.00	4.47	3.07	0.45	0.31
6.00	100.00	31.82	31.21	3.18	3.12
7.00	100.00	7.90	7.75	0.79	0.78
8.00	25.00	8.54	2.09	0.85	0.21
9.00	125.00	7.16	8.77	0.72	0.88
10.00	125.00	49.93	61.22	4.99	6.12
11.00	90.00	12.90	11.39	1.29	1.14
12.00	50.00	8.11	3.98	0.81	0.40
13.00	90.00	10.31	9.10	1.03	0.91
14.00	200.00	24.71	48.48	2.47	4.85
15.00	90.00	16.98	14.99	1.70	1.50

Conclusion and Recommendations

Conclusion

Unexploited Hydropower Potential

The KPK province possesses considerable unexploited hydropower potential. To capitalize on this potential, we must investigate sustainable energy-generating techniques utilizing hydropower and run-of-river initiatives to meet the nation's energy requirements.

Satellite Imagery and Remote Sensing

Satellite imaging and remote sensing are essential for geospatial hydrological modelling. This facet has yet to be extensively examined in Pakistan. Enhancing data accuracy and resource management associated

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN 3007-3138
Print ISSN 3007-312X

with these technologies is crucial.

Designated Locations for Hydropower

Utilizing GIS techniques, we have discovered 15 locations capable of producing around 30 megawatts of hydropower. This figure needs to be more comprehensive; more inquiry may uncover additional feasible locations.

Site Assessment and Geotechnical Investigations Designated Locations for Hydropower

To augment our findings and corroborate research outcomes, it is essential to undertake on-site inspections and geotechnical investigations.

Recommendations

Site Assessment and Evaluation

Following the successful identification of locations with significant hydroelectric potential, it is advisable to perform further research, including site surveys and analyses, to verify this project's findings.

Sociological and Ecological Factors

It is further advised to undertake another research to determine the social and ecological impacts that would arise following the implementation of these run-of-river hydropower projects at the identified sites.

Comprehensive Planning, Assessment, and Implementation of These Projects

Perform comprehensive assessments for each location. This involves evaluating the prospective energy construction expenses and ecological consequences. Formulate a detailed strategy for implementing the hydropower initiatives. Exploiting this hydropower potential will enable Pakistan to bolster its energy security, diminish its dependence on fossil resources, and promote sustainable development.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Acknowledgement

We start by conveying our deep appreciation to the Almighty Allah for endowing us with the power, wisdom, and resilience necessary to conclude this study project effectively. We extend our sincere gratitude to the senior academic members and laboratory administrators whose efforts have been essential to the success of our study. Their vision, encouragement, and support have motivated and facilitated our attainment of this milestone. This post is devoted to their excellent leadership and commitment.

Research Significance

This study is significant owing to its distinctive emphasis on hydropower generation, a domain that has yet to be examined in prior studies in Pakistan. Closing this gap offers a substantial motivation for pursuing more research in this field. Compared to manual and physical survey-based site selections, this study provides enhanced reliability, accuracy, and convenience. Furthermore, it facilitates an extensive examination of many elements and factors, rendering it a viable pathway for scientific inquiry and practical applications.

References

1. Awais, M., & Wajid, M. T. (2024). COMPREHENSIVE ANALYSIS OF PAKISTAN'S RENEWABLE ENERGY LANDSCAPE.
2. Aslam, H., Nazir, A., & Zia, U. (2021). Pakistan's way forward towards a green economy: Perspectives for a clean energy transition. JSTOR Sustainability Collection.
3. Board, P. P. (2022). Hydropower Resources of Pakistan. Islamabad: Ministry of Energy (Power Division).
4. Zhou, J., Wu, Y., Wu, C., He, F., Zhang, B., & Liu, F. (2020). A geographical information system based multi-criteria decision-making approach for location analysis and evaluation of urban photovoltaic charging station:

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN 3007-3138
Print ISSN 3007-312X

A case study in Beijing. Energy Conversion and Management, 205, 112340.

5. Sekac, T., Jana, S. K., & Pal, D. K. (2017). Identifying Potential sites for hydropower plant development in Basu catchment: Papua New Guinea. Research Gate, 1.
6. Sulla-Menashe, D., & Friedl, M. A. (2018). User Guide to Collection 6 MODIS Land Cover (MCD12Q1 and. 1-16.
7. Kusre, B. C., Baruah, D. C., Rodoliloi, P. K., & Patra, S. C.(2010). Assessment of hydropower potential using GIS and hydrological modelling technique in Kopili River basin in Assam. Applied Energy, 87, 298– 309.
8. GIS tools and the design of irrigation canals by herman depeweg, elga rocabado urquieta published in October 2003.
9. Selection of Canal Alignment and Fixing the Canal Cross-Section by Using GIS Techniques and BIM Tools by R.G. Gabbi, S.L. Atmapoojya , D.K. Agrawal published in June 2016.
10. K Voudouris, "Assessment of Intrinsic Vulnerability using the drastic model and GIS " European waters 2010
11. Papua New Guinea Energy Economic News. (2013). Papua New Guinea's plans to build power generation capacity.
12. Feizizadeh, B., & Haslauer, M. (2012). GIS-based procedures of hydropower potential for Tabriz Basin, Iran. In International Journal (pp. 495–502)
13. Carroll, M. L., Townshend, J. R., DiMiceli, C. M., Noojipady, P., and Sohlberg, R. A. (2009). A new global raster water mask at 250 m resolution. International Journal of Digital Earth, 2(4):291–308.
14. Friedl, M. A., McIver, D. K., Hodges, J., Zhang, X. Y., Muchoney, D., Strahler, A. H., Woodcock, C. E.,Gopal, S., Schneider, A., Cooper, A., Baccini, A., Gao, F., and Schaaf, C. (2002). Global land cover mapping from MODIS: algorithms and early results. Remote Sensing of

Spectrum of Engineering Sciences
Online ISSN 3007-3138
Print ISSN 3007-312X
SPECTRUM OF ENGINEERING SCIENCES

Environment, 83(1):287–30.

15. Mahmood, P., Khan, A. H., Haider, S., Syed, Z., Khaliq, M., & Zaheer, S. (2024). Application of Bio Sand Filters for improving drinking water quality in flood-affected areas of Pakistan, a case study of Shahdad Kot, Pakistan. Case Studies in Chemical and Environmental Engineering, 9, 100769.
16. Zaheer, S., Ullah, H., Khalil, M., Khan, Z. U., Aleem, A., & Badar, Y. (2024). Impacts Assessment of the Expanding Urban Land Development on the Discharge of the SWAT Perennial River Utilizing GIS-based Hydrological Models. Spectrum of engineering sciences, 2(3), 242-273.