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Research on Site Selection Planning of Photovoltaic Power Plants Based on Multi Source Data

Jilili·Xieraili[1,2], Junwei Xuan[1,2,*], Jinzhi Gu[1,2], Jitong Yin[1,2], Yiting Ge[1,2]

[1]*School of Resources and Environment, Xinjiang Agricultural University, Xinjiang Uygur Autonomous Region, Urumqi, 830052, China*
[2]*Xinjiang Key Laboratory of Soil and Plant Ecological Processes, Urumqi, 830052, China*
[*]*Corresponding author: sd1900@163.com*

Abstract: *With the development of urbanization and the deepening of people's awareness of environmental protection, China's demand for green energy is increasing, and the site selection of photovoltaic power plants is a relatively complex process. Taking Turpan as an example, as a typical continental warm zone desert climate, China, with abundant sunshine and scarce rainfall, it is more suitable for building photovoltaic power plants compared to other areas. In the process of site selection and planning, factors such as local sunshine intensity, rainfall, land use type, slope, and transportation convenience need to be considered. In addition, support from national or local policies is also needed. By using GIS technology to weight and overlay climate data, land use data, power grid distribution, and other data from Turpan City, the optimal site selection plan can be determined to maximize the benefits of photovoltaic power generation and reduce costs. In summary, the site selection planning of photovoltaic power plants based on diverse data requires a comprehensive analysis of various factors to ensure the optimal location and achieve sustainable energy utilization. The research results show that the Turpan region is particularly unsuitable for the majority of the area (82.80%), which may be related to extreme climate conditions, terrain limitations, or other ecological protection needs in the region. The areas of the basic suitable zone and the most suitable zone are relatively small, accounting for 14.13% and 1.88% of the total area, respectively. However, these areas have good natural conditions and infrastructure, making them suitable for priority development and further optimization. The small area and proportion of unsuitable areas indicate that there may be some limiting factors in these areas that require more technological or economic investment to overcome.*

Keywords: *Turpan, Multi-source Data, Site Selection Planning, Geographic Information System (GIS)*

1. Introduction

In the field of photovoltaic (PV) power station site selection, a variety of methods have been proposed to evaluate and optimize the location of the stations. For instance, Geographic Information Systems (GIS) and remote sensing technologies are widely used due to their ability to provide macro-level data on land use and lighting conditions. However, these methods often overlook the impact of local microclimate conditions on the performance of photovoltaic panels, such as shadows, reflections, and local wind speed variations, which can lead to inaccurate predictions of energy output [1]. Moreover, traditional GIS and remote sensing technologies rely on static data and lack adaptability to dynamic environmental changes, which is particularly evident in regions with high climate change and environmental dynamics [1].

Meteorological data is crucial for assessing lighting conditions, but it often suffers from insufficient temporal resolution, making it difficult to capture rapid changes in daylight, which is essential for real-time performance optimization of PV power stations (Zhang & Wang, 2021). Additionally, existing energy policy analyses tend to focus on the direct economic incentives of policies, while neglecting the indirect effects of policies on market confidence, investment stability, and social acceptance [2].

In response to the limitations of existing methods, this paper proposes a PV power station site selection evaluation model based on the integration of multi-source data. This model innovatively integrates GIS, remote sensing technology, high-resolution meteorological data, and real-time environmental monitoring data, optimizing the data processing workflow through machine learning algorithms to enhance the accuracy and dynamic adaptability of site selection evaluations. Furthermore, this paper introduces a quantitative analysis of policy impacts, assessing the long-term effects on the feasibility of PV projects by simulating market responses under different policy scenarios. These innovative points not only make up for the deficiencies of existing methods but also provide more comprehensive and in-depth decision support for the site selection of PV power stations[2].

2. Overview of the research area and current status of resources and environment

2.1 Overview of the research area

Turpan City is located in the central part of Uygur Autonomous Region, between 41° 12′ -43° 40′ N and 87° 16′ -91° 55′ E. It borders Hami City to the east, Hejing County, Heshuo County, Yuli County, and Ruoqiang County of Bayingolin Mongol Autonomous Prefecture to the west and south, and Wulumuqi City and Qitai County, Jimsar County, and Mulei County of Changji Hui Autonomous Prefecture across the Tianshan Mountains to the north. It is approximately 240 kilometers wide from north to south and 300 kilometers long from east to west, with a total land area of 69713 square kilometers (2085 square kilometers below sea level), accounting for 4.2% of the total land area. Turpan City is 183 kilometers away from Urumqi, the capital of Uygur Autonomous Region.

This article collects data including elevation data of Turpan City, land use type data of Turpan, annual average temperature data of Turpan, rainfall data of Turpan, solar radiation data of Turpan, and other data[3][4].

2.2 Current situation of resources and environment

2.2.1 Land Resources

The total land area of Turpan City is 6.9759 million hectares (approximately 4.1% of the total area of the autonomous region). Among them, the agricultural land area is 1.3444 million hectares, accounting for 19.27% of the total area (58100 hectares of arable land, 45000 hectares of garden land, 95600 hectares of forest land, and 1.1457 million hectares of grassland); The construction land area is 80000 hectares, accounting for 1.16% of the total area (39900 hectares for urban villages and industrial and mining land, 16800 hectares for transportation land, and 23300 hectares for water conservancy land); The unused land area is 5.5515 million hectares, accounting for 79.57% of the total land area (the above data is from the 2011 land change survey, including the Corps). The city is experiencing drought and water shortage, with only 14.17% of the total land area being utilized and concentrated in oasis areas with guaranteed water sources. The severe scarcity of water resources severely restricts the development and utilization of land resources, making it difficult to develop and utilize reserve land resources. The most prominent feature of the current land use situation in our city is the large total amount of land resources and low land utilization rate[5].

2.2.2 Water Resources

Turpan has a total water resources of 1.26 billion cubic meters, including 1.06 billion cubic meters of surface water resources (660 million cubic meters domestically produced and 400 million cubic meters imported from overseas) and 200 million cubic meters of groundwater resources (non duplicated). The available water resources are 1.226 billion cubic meters, including 632 million cubic meters of surface water resources and 594 million cubic meters of groundwater resources[6][7].

2.2.3 Ecological Environment

The number of days with good or above air quality in Turpan city reached 210 days (2023), with a good rate of 57.5% (AQI 6 indicators). The forest coverage rate is 3.31%, and the oasis coverage rate is 18.5%.

3. Site selection system and evaluation methods

3.1 Elevation data processing

(1) Elevation data

Download 30 meter resolution DEM data from the geospatial data cloud, and then use Turpan's shp range to search for the submergence extraction tool in the search box of ArcGIS 10.2 software to crop the DEM data and obtain the DEM of Turpan city. As shown in Figure 1.

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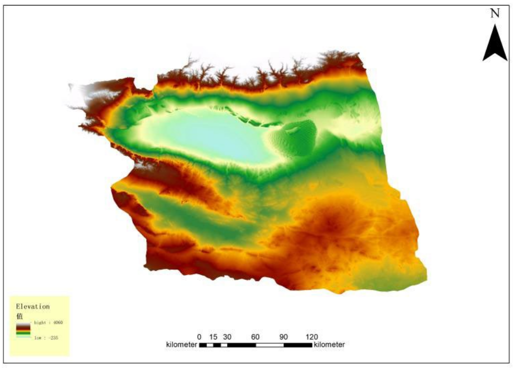
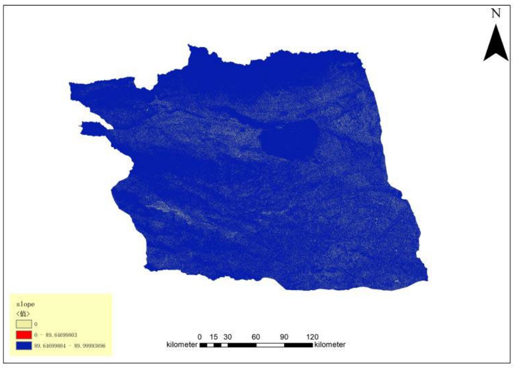
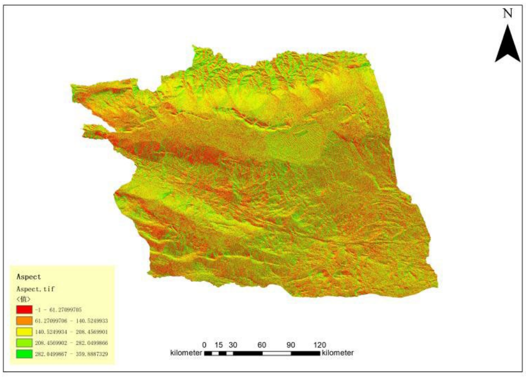
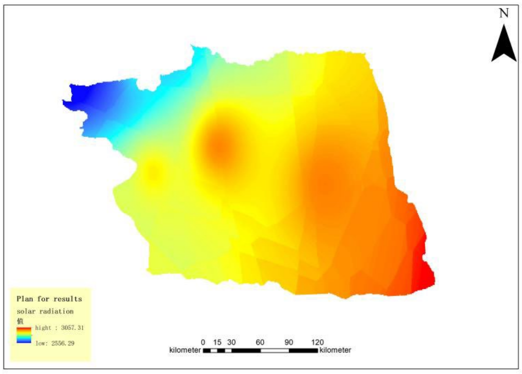


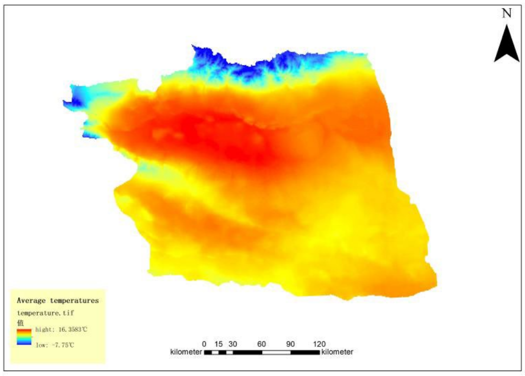


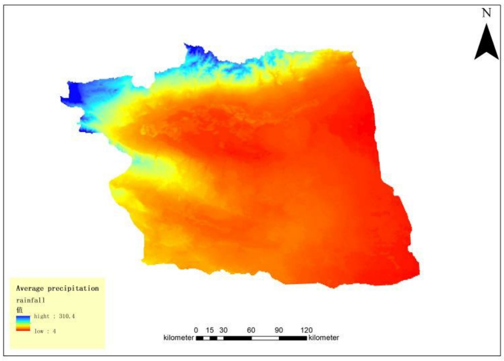
(a)Turpan elevation map *(b)Turpan slope map*



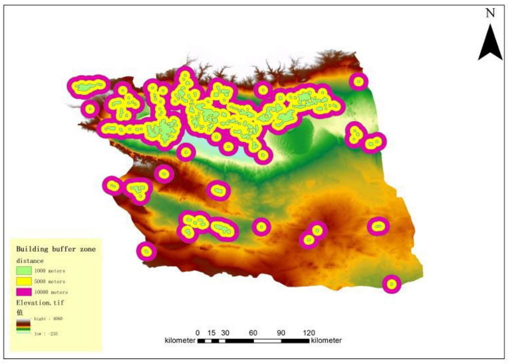


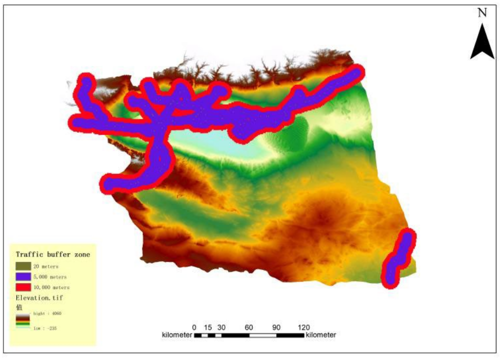
(c)Turpan Aspect map *(d)Solar radiation map of Turpan*





(e)Average temperature in Turpan *(f) Average precipitation in Turpan*





(g)Building buffer zone *(h) Traffic buffer zone*

Figure 1: Data preprocessing results

3.2 Weighted superposition

Calculate the calculated results based on the weights in Table 1 using the grid calculator or weighted

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overlay tool in ArcGIS 10.2 version, as shown in Table 1.

In ArcGIS 10.2, to calculate the suitability index for photovoltaic (PV) power station site selection using the Weighted Overlay tool, each selection criterion such as solar radiation intensity, surface temperature, and land-use type must first be converted into raster layers and assigned appropriate grade ratings (3 for Suitable, 2 for More Suitable, and 1 for Unsuitable) based on their suitability levels. Then, each criterion is weighted according to the values provided in Table 1 (for example, the weight for solar radiation intensity is 0.4). By integrating all the criterion layers through the Weighted Overlay tool, a comprehensive suitability index is calculated, reflecting the overall suitability based on the overlay of all factors, with higher-weighted criteria having a greater impact on the final outcome. This index provides a scientific basis for the optimal site selection of PV power stations.

Table 1: Weight Criteria for Site Selection of Photovoltaic Power Stations

Serial Number	Index	Classification and grading	Suitability level	Grade rating	Weight
1	Solar radiation intensity	Strong	Suitable	3	0.4
		Same as	More suitable	2	
		Weak	Unsuitable	1	
2	Surface temperature	15℃ ~35℃	Suitable	3	0.13
		-10℃ ~ 15℃	More suitable	2	
		>35℃	Unsuitable	1	
3	Land-use type	Bare land	Suitable	3	0.13
		Woodland	More suitable	2	
		Farmland, grassland, construction land, rivers	Unsuitable	1	
4	Elevation	higher	Suitable	3	0.13
		same as	More suitable	2	
		Lower	Unsuitable	1	
5	Slope	<15 degrees	Suitable	3	0.02
		15~30 degrees	More suitable	2	
		>30 degrees	Unsuitable	1	
6	Slope direction	due south	Suitable	3	0.02
		Southeast and Southwest	More suitable	2	
		other	Unsuitable	1	
7	Residential area	300m ~ 10km	Suitable	3	
		10km ~20km	More suitable	2	
		<300m ,>20km	Unsuitable	1	0.04
8	Traffic	<5km	Suitable	3	0.13
		5km ~ 10km	More suitable	2	
		The road itself (20m), distance from the road>10km	Unsuitable	1	

4. Site selection results of photovoltaic power plants

Based on this statistical table, the area and proportion of regions with different suitability levels are provided, which helps to understand the suitability level of each region when selecting a location for a photovoltaic power plant. The total area of the most suitable area and the basic suitable area accounts for 16.01% of the total area, while the particularly unsuitable area accounts for the vast majority, at 82.80%. This may mean that special attention needs to be paid to the most suitable and basic suitable areas when selecting a site, as they may provide the best conditions for building a photovoltaic power plant. At the same time, it is necessary to conduct in-depth analysis of unsuitable and particularly unsuitable areas to determine whether there are any conditions that can be improved or why these areas are not suitable for building photovoltaic power plants. The results are shown in Figure 2 and Table 2[8][9][10].

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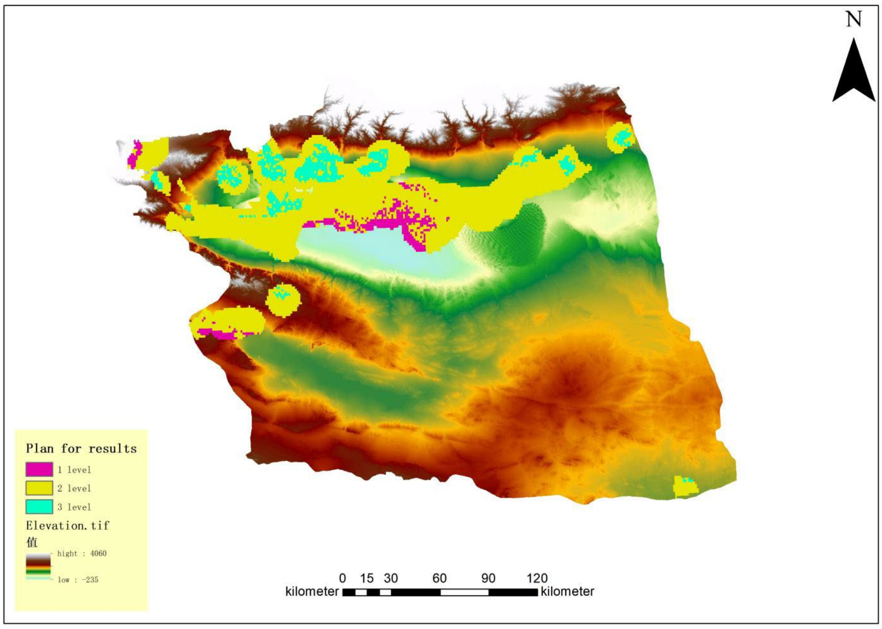

Figure 2: Diagram of site selection planning results

Table 2: Statistical Table of Site Selection Results for Photovoltaic Power Plants

Suitability level	The most suitable area	Basic suitability zone	Inappropriate area	Specially unsuitable area	Amount to
area/m2	1. 3042×10 ^{8}	9 . 7973×10 ^{8}	8 . 1963×10 ^{8}	5. 7387×10 ^{10}	6 . 930×10 ^{10}
proportion/%	1 . 88	14.13	1.18	82.80	100.00

5. Conclusions

This study systematically evaluated the site selection of photovoltaic power plants by comprehensively analyzing multi-source data in Turpan region. The research results indicate that although there is a high proportion of particularly unsuitable areas, the total area of the most suitable and basic suitable areas still provides feasible options for the planning of photovoltaic power generation projects. By considering various factors such as terrain, climate, resources, and policies, this study identified key areas suitable for the construction of photovoltaic power plants.

The classification of suitability levels provides decision-makers with a scientific reference framework, which helps optimize resource allocation and improve the economic and environmental benefits of photovoltaic power generation projects. The identification of particularly unsuitable areas helps to mitigate potential environmental and investment risks, ensuring the sustainable development of the project.

However, this study also has certain limitations. Firstly, the timeliness and resolution of the data may affect the accuracy of the evaluation results. Secondly, with technological advancements and policy adjustments, the cost-effectiveness and environmental impact of photovoltaic power generation may change. Therefore, future research needs to continuously update data, consider more dynamic factors, and explore more advanced analytical methods.

In addition, the site selection evaluation model in this study can be further optimized to better adapt to the characteristics and needs of different regions. It is recommended that future research consider a wider range of factors, including socio-economic factors, grid access conditions, and trends in photovoltaic technology development.

Finally, this study emphasizes the importance of interdisciplinary collaboration. The site selection planning of photovoltaic power plants not only requires the support of geographic information systems and remote sensing technology, but also requires knowledge and experience in multiple fields such as environmental science, energy policy, and economics. Through interdisciplinary collaboration, the

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feasibility of photovoltaic power generation projects can be evaluated more comprehensively, achieving the dual goals of energy transformation and environmental protection.

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