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Improvement Effects of Solar Photovoltaic Facilities on Desert Environments: An Analysis Based on the Case of Bayannur, China

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ABSTRACT
In the arid regions of northwestern China, Bayannur City has long struggled with extreme drought and land degradation. In recent years, the city has implemented an innovative "solar photovoltaic power generation + ecological restoration" model in the Ulan Buh Desert to achieve both desert greening and renewable energy production. This approach offers a sustainable solution that integrates environmental improvement with clean energy development.

1. Introduction

In the arid regions of northwestern China, severe desertification has been a persistent issue for many years. Among these areas, Bayannur City in the Inner Mongolia Autonomous Region faces the compounded challenges of an extremely dry climate and land degradation, which have exerted serious impacts on both the local ecosystem and residents' livelihoods. Under such circumstances, traditional sand-control measures alone have proven insufficient, calling for a more integrated and sustainable approach. In recent years, Bayannur City has introduced an innovative model of "solar photovoltaic power generation + ecological restoration," which aims to achieve two objectives simultaneously: desert greening and renewable energy production. This paper examines the initiatives in the Ulan Buh Desert within Bayannur to explore how solar photovoltaic facilities contribute to the improvement of desert environments.

Fig.1 The Map of China

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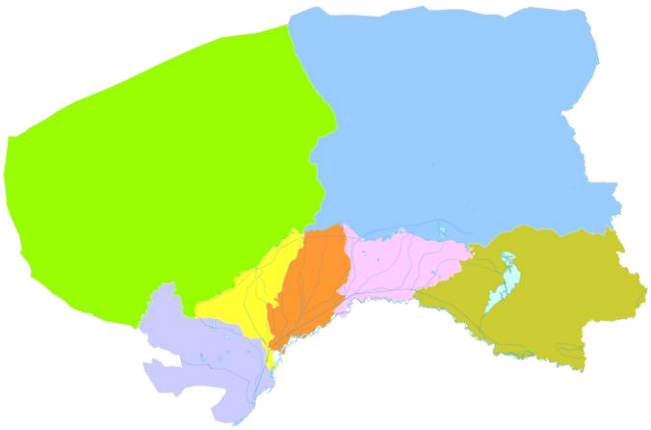
Source: Wikipedia, n.d.

2. Natural Environment and Current State of Desertification in Bayannur

Bayannur City is located in the western part of the Inner Mongolia Autonomous Region, bordering Mongolia to the north and the Yellow River to the south. Its terrain is dominated by plains and deserts, with the eastern edge of the Ulan Buh Desert, one of China's eight major deserts, extending across its territory. Approximately 3.86 million mu of this desert are located in Dengkou County, accounting for 77% of the county's total land area. The region's extremely arid climate, with an annual precipitation of only about 130 mm and an annual evaporation rate reaching 2,258 mm, makes securing water for both agricultural and domestic use highly challenging, thereby exacerbating ecological degradation.

Fig.2 The Map of Bayannur



Source: Wikipedia, n.d.

3. Conventional Desertification Control Measures and Their Foundations

In 1978, the Chinese government launched the “Three-North Shelterbelt Program” to promote large-scale afforestation across the northeast, north, and northwest regions. In Bayannur City, the state-owned Xinhua Forest Farm was established in the 1960s, and to date, it has completed afforestation over a total of 39,000 mu and planted 4.3 million trees. While these efforts have produced certain positive outcomes, technical and managerial constraints have limited their effectiveness in addressing the vast expanses of desert land.

4. Introduction of Solar Photovoltaic Facilities and Their Ecological Effects

Since the 2000s, Bayannur City has actively promoted the adoption of renewable energy, implementing a large-scale plan to install solar photovoltaic (PV) facilities across the Ulan Buh Desert. The region’s long hours of sunshine and abundant solar resources make it highly suitable for PV power generation.

Fig.3 Solar PV Facilities

Source: Xinhuanet, 2024

Solar panels serve not merely as power-generating devices but also play an important role in improving the local ecosystem. By blocking direct sunlight from reaching the ground surface, the panels reduce soil moisture evaporation, thereby creating a cooler and more humid microclimate beneath them. This environment is conducive to plant growth, while the supporting structures help stabilize the sand and enhance surface stability. In addition, water used in panel cleaning operations flows directly onto the ground and is effectively utilized for irrigating vegetation.

5. Straw-Checkerboard Technology: Tradition and Innovation as Keys to Desert Restoration

Another important technique supporting ecological restoration is the "straw checkerboard" method. This involves arranging wheat or rice straw on sandy terrain to form a grid structure measuring one square meter per cell.

Fig.4 Straw Checkerboard

Source: National Ecosystem Research Network of China, 2018

The technique reduces wind speed and promotes the stabilization of shifting sands. First introduced during railway construction in the 1950s, it later spread nationwide as a traditional sand-control method. In recent years, research institutions such as the Chinese Academy of Sciences have developed a "brush-shaped mesh-rope straw checkerboard" design, which, through mechanized installation, has increased work efficiency by over 60% and extended its lifespan to six years.

This method is often combined with the planting of drought-tolerant species such as *Caragana korshinskii* and *Calligonum mongolicum*, raising their survival rate to over 80%. Through the synergistic effects of straw checkerboards and solar photovoltaic panels, the desert ecosystem has been steadily recovering.

6. Formation of the "Photovoltaics + Agriculture + Ecology" Integrated Model

In addition to contributing to ecological restoration, solar photovoltaic (PV) facilities have opened up new opportunities for local agriculture and economic development. In particular, "under-panel farming" (also known as solar sharing) has gained attention as an innovative agricultural model tailored to the challenges of arid regions.

Fig.5 Bayannur's Green Miracle

Source: Xinhuanet, 2024

Beneath the PV panels, direct sunlight is blocked, ground temperatures are lowered, and moisture retention is enhanced. Leveraging this microclimate, forage crops such as alfalfa (*Medicago sativa*), medicinal plants such as honeysuckle (*Lonicera japonica*), and even halophytes are cultivated, strengthening linkages with the livestock industry and traditional Chinese medicine sectors.

This model generates a virtuous cycle of "power generation → environmental improvement → crop cultivation → economic revitalization," which in turn increases local employment opportunities and household incomes. A tripartite collaborative framework involving the government, enterprises, and local residents has been established: the government provides policy support and infrastructure development; enterprises manage PV facilities and agricultural operations; and residents engage in fieldwork and maintenance, thereby supporting sustainable development.

Beyond economic benefits, this model has yielded multiple positive outcomes, including sand stabilization through vegetation, biodiversity restoration, and the revitalization of local communities. As such, the "photovoltaics + agriculture + ecology" approach has emerged as a new strategy for regional regeneration.

7. Achievements and Future Prospects

As of 2023, approximately 3,000 mu of sandy land in Bayannur City have been equipped with solar photovoltaic (PV) facilities, of which 1,600 mu have been afforested. A total of 2.65 million trees and shrubs have been planted, with the

restoration area reaching 5,000 mu. Vegetation coverage of forests and grasslands has increased from 65% in 2021 to 88% at present.

In terms of power generation, the facilities produce 200 million kWh of green electricity annually, reducing standard coal consumption by 62,000 tons. Emissions of carbon dioxide, sulfur dioxide, nitrogen oxides, and other pollutants have been significantly curtailed, realizing a "triple benefit" across environmental, economic, and social dimensions.

This integrated model of "photovoltaics + desertification control" holds the potential to serve as an effective response to the global challenges of climate change and land degradation. Looking ahead, further technological advancements and institutional improvements are expected to position it as a replicable and sustainable development model for other arid regions worldwide.

Conflict of interests

The authors declare that they have no conflict of interest.

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