China Geology 5 (2022) 549–552

China Geology

Journal homepage: http://chinageology.cgs.cn
https://www.sciencedirect.com/journal/china-geology

News and Highlights

An carbon neutrality industrial chain of "desert-photovoltaic power generation-ecological agriculture": Practice from the Ulan Buh Desert, Dengkou, Inner Mongolia

Xi-jie Chen, Li-qiong Jia, Ting Jia, Zi-guo Hao

Development and Research Center of China Geological Survey, Ministry of Natural Resources, Beijing 100037, *China*

Deserts, the sea of death, are the places where life ends. However, they will become a different scene if there is electricity in the deserts: vegetation will regenerate, crops will grow in rows, the sky will be blue and full of birds, and flowers will be fragrant. This is the scene of the Ulan Buh Desert in Dengkou County, Inner Mongolia, China. The local government's achievements and experience in sand control can be summarized into four items: (1) Photovoltaic power generation, saving coal resources; (2) Developing deserts: expanding land resources; (3) Finding uses for water flowing through deserts and below them; (4) Improve the environment and eliminate the poverty of the people in the sand area.

1. Overview of Ulan Buh Desert

The Ulan Buh Desert is located in the western Inner Mongolia, with geographical coordinates of 106°09′–106°57′E and 39°16′–40°57′N. It is bounded by the Langshan Mountain in the northwest and the Helan Mountain in the south. It is 170 km long from north to south and 110 km wide from east to west, with a total area of 129.8 km^2 and an altitude of 1028–1054 m. It is one of the eight deserts in China.

The Ulan Buh Desert is a faulted basin in terms of geological structure. The Yellow River flows through its southeastern edge at an altitude of approximately 1048–1053 m. Since the entire terrain of the Ulan Buh Desert is lower than the water surface of the Yellow River, there are multiple layers of high-quality groundwater under the desert near the river, laying a foundation for agricultural development.

The Ulan Buh Desert is mainly derived from the alluvial-diluvial deposits in the Helan Mountain and the Langshan-Bayinwula Piedmont Basin, with quicksands distributed in the south, ridge-shaped dunes in the middle, and fixed and semi-fixed dunes in the north. In the past 40 years, the Ulan Buh Desert has expanded eastward and southward at an astonishing speed. In the early 1960s, the eastern edge of the Ulan Buh Desert was still nearly 30 km away from Wuhai City, nearly 1/3 of land was engulfed by the desert less than 40 years later, suggesting quite serious sand advancing.

The climate of the Ulan Buh Desert is controlled by westerly winds all year round, with an average annual wind speed of 4.1 m/s. The desert has an annual precipitation of 33.3–150.3 mm (average: 102.9 mm), an annual temperature of -29.6°C –39°C (average: 7.8°C), and an average annual evaporation of 2258.8 mm. Moreover, it has a frost-free period of 168 days, illumination of 3181 hours, solar radiation of 150 kcal/cm^2, and an effective accumulated temperature over 10°C of 3289.1°C. This area is rich in photothermal resources and is not far away from the Yellow River. Therefore, it has the potential to develop photovoltaic power generation and ecological agriculture (Fig. 1).

2. "Desert + Photovoltaic Power Generation + Ecological Agriculture and Animal Husbandry" Planting Model

In recent years, with the rise of photovoltaic power generation, the unique lighting conditions of the Ulan Buh Desert and the water source conditions under the desert have attracted attention. In September 2012, State Power Investment Corporation Beijing Electric Power Co., Ltd. (also referred to as the SPIC) proposed the concept of "photovoltaic desertification control and ecological restoration", aiming to achieve economic and ecological win-win outcomes by combining the development of photovoltaics with desert control and water-saving agriculture. It invested RMB 0.42 billion in Dengkou County, where the desert is located, with the invested projects covering an area of approximately 1700 mu (Chinese unit of land area; one mu equals 666.7 m^2) and

* Corresponding author: *E-mail address*: xijiechen2020@163.com (Xi-jie Chen)

Literary editor: Xi-jie Chen
doi:10.31035/cg2022053
2096-5192/© 2022 China Geology Editorial Office.

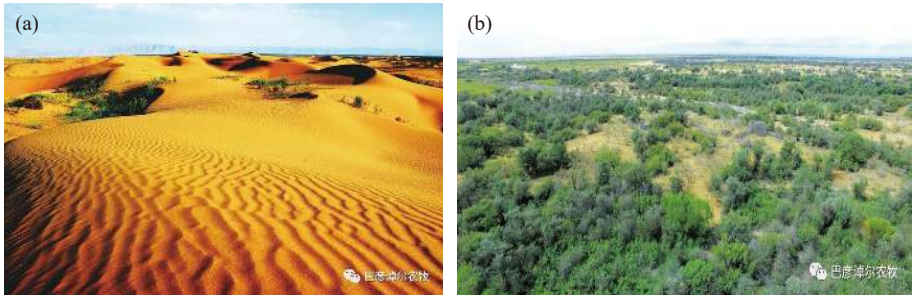


Fig. 1. Twenty miles of Salix in the Ulan Buh Desert (from the website of Dengkou County Government); a–before governance; b–after governance.



Fig. 2. Photo showing the photovoltaic power generation - sand control in Dengkou County (from the website of State Power Investment Group Beijing Electric Power Co., Ltd.).

having a construction scale of 50 MW, including 30 MW monocrystalline and 20 MW polycrystalline photovoltaic power plants (Fig. 2).

In the second year after the installation of photovoltaic panels, the ecological effects of sand control began to appear. The photovoltaic module itself has a windproof function, which can effectively prevent the dunes from moving. Given that the desert cannot hold water, making it difficult for vegetation to survive, 20–30 cm thick clay and cow dung were laid under the photovoltaic modules, and drip irrigation facilities were set up to ensure the survival of plants. After many experiments, the experts finally identified suitable plants to be planted in the desert. More than 800 mu of sand-controlling plants, such as *Alfalfa* and *Artemisia,* were planted between the photovoltaic panels. This characteristic planting mode of "desert + photovoltaics + facility pasture" has greatly improved the conversion efficiency of solar energy and photoelectricity and increased the economic benefits of enterprises, while fixing sands, greening, and preventing the desertification from expanding. According to the calculation of the Forestry Bureau of Wuhai, the vegetation cover in the photovoltaic power generation area was only approximately 5% before the installation of photovoltaic panels but has increased to around 80% at present.

The availability of electricity in desert areas makes long-distance water transfer feasible and lays the foundation for the development of large-scale agricultural planting and animal husbandry.

(1) Photovoltaic planting greenhouses in the desert

At the base of Huasheng Green Energy Dengkou Agricultural Technology Co., Ltd. (also referred to as Huasheng Green Energy) (Fig. 3), 330 greenhouses for power generation and planting are neatly arranged. Taking advantage of the improved desert soil and plentiful sunshine, the fruits of the planted *Cucumis melo L.* are high-quality and are very popular in the market. Using this new model that integrates "desert control + solar power generation on sheds + green and pollution-free planting under sheds", 3500 mu of sandy land will be developed, bringing great benefits to the local area.

(2) Desert ranches

Shengmu Hi-Tech Company has built 23 organic pastures and one organic fertilizer processing plant in the desert, forming an organic forage base of 140×10^3 mu with 85×10^3 dairy cows and a daily raw milk output of 1180 t, making it the second largest organic milk production base in the world (Fig. 4).

(3) Desert wineries

At present, 19 companies (including Nuomin, Yaoshun, and Xingtaochuan) are settled in the sandy area of the desert



Fig. 3. The Dengkou Photovoltaic Agricultural Industrial Park project of Huasheng Green Energy and its products (from the website of Dengkou County Government); a–photovoltaic agricultural greenhouses; b–fruits produced in the greenhouses.

to develop the wine grape industry, with thousands of acres of green vineyards embedded in the vast sandy sea (Fig. 5). Since 2016, they have produced 300 t of grapes and more than 100 t of wine. In recent years, the quality and quantity of wine have been improved simultaneously, and now the wine has reached a scale of 300 t.

(4) Cistanche production base

Cistanche deserticola, also known as Dayun, is a parasitic plant in sands. It is a valuable Chinese medicinal material and is called "desert ginseng" (Fig. 6). In 2004, Dengkou County successfully introduced ***Cistanche deserticola*** into the roots of Haloxylon ammonium. In 2005, the county succeeded in inoculating *Cistanche deserticola* into the roots of Salix babylonica. The inoculation technique for ***Cistanche deserticola*** in Dengkou County has now shifted from experiments to popularization and application. According to reports, 330 kg of *Cistanche* can be harvested per mu in the second year after it is inoculated. Calculated at the current market price, the income per mu is about RMB 3300. At present, there are 19 enterprises engaging in planting *Cistanche* ***deserticola*** in the county, and it is planned to build an artificial inoculation base of ***Cistanche*** with an area of 300×10^3-mu. When that happens, Dengkou County will become the largest production base of artificially inoculated ***Cistanche*** in China.

(5) Desert rice – a new granary

Rice grown in deserts can be found in all desert areas in China and the technology has been already mature. The rice yield per mu can reach more than 500 kg (Fig. 7), and the evaporation of water in the rice is much lower than that in high-stalk crops such as corn, sorghum, and wheat. Rice grows in the vast sand sea thanks to the use of a new type of material: waterproof and breathable sands. A layer of waterproof breathable sands has been laid 80 cm below the desert farming layer to retain moisture and w**as** then transformed into the current paddy field. In the Ulan Buh Desert, Renchuang Technology Company planted 1500 mu of rice and achieved high returns.

3. Ecological and environmental benefits

The Ulan Buh Desert covers an area of 4.269×10^6 mu in Dengkou County. By 2018, the desert control area in the county had reached more than 2.8×10^6 mu, and the forest cover had increased from 0.04% at the beginning of the founding of the People 's Republic of China to 20.2% at present. Moreover, the number of bird species had increased to more than 200, and the place where no grass grows in the past has become a paradise for animals. In August 2018, the Ulan Buh Desert in Dengkou was approved by the State Forestry and Grassland Administration as a comprehensive demonstration area for desertification prevention and control.

4. Carbon emission reduction

Since the photovoltaic system of SPIC was connected to the grid for power generation (Fig. 2), significant environmental benefits have been achieved, saving approximately 25.37×10^3 t of standard coal and reducing



Fig. 4. Shengmu high-tech organic pastures (from the website of Dengkou County Government).



Fig. 5. Desert grapes (from www.360.cn).



Fig. 6. Desert ginseng - Cistanche (from www.360.cn).



Fig. 7. Desert rice (from www.360.cn).

carbon dioxide emissions by 93023 t every year. Six photovoltaic power generation enterprises are settled in the desert at present, and it is estimated that approximately 152×10^3 t of standard coal can be saved and 558×10^3 t of carbon dioxide emissions can be reduced every year.

It is estimated that the Huasheng Green Energy has 330 sets of "desert control + solar power generation + green pollution-free planting" greenhouses, which have a total installed photovoltaic capacity of 50 MW, an average annual power generation of 72.2591×10^6 kWh, and an average annual coal saving of roughly 24568.09 t. At present, 72 modern agriculture and animal husbandry enterprises are operating in this desert area and can save 1.77×10^6 t of coal and 6.5×10^6 t of CO_2 emissions per month.

The Ulan Buh Desert Optimization Development Zone has introduced more than 130 sand control enterprises to mainly develop five major industries of *Cistanche deserticola*, wine grapes, modern agriculture and animal husbandry, desert eco-tourism, and photovoltaic power generation. These enterprises comprise 23 companies engaging in *Cistanche* cultivation and deep processing, 19 in grape cultivation, 72 in modern agriculture and animal husbandry, seven in desert ecotourism, six in photovoltaic power generation, and three in professional seedling, covering a total area of 1736700 mu. The infrastructures constructed in the sand area include 1534.8 km of roads, 756.1 km of electricity facilities, and 1193 wells. By 2015, the enterprises in the sand area of the Ulan Buh Desert had invested a total of RMB 2.83 billion. The investment projects completed by Dengkou County in the sand industry in 2021 are: (1) Invested 660×10^6 yuan to transform 12 Mengniu Shengmu milk production lines, with a daily processing capacity of 2500 t of organic milk. (2) Yuantai Animal Husbandry invested 100 million yuan to build a 5000-head dairy farming project; (3) invested 240×10^6 yuan to put into operation the second phase of Yiqun pig project; (4) invested 250×10^6 yuan to plant 50000 mu of protein mulberry; (5) invested 40×10^6 yuan to build sand control + afforestation + planting grass + Chinese herbal medicine project; (6) with an investment of 500×10^6 yuan, Guoneng completed the full-capacity grid-connected power generation of the 100 megawatt photovoltaic power generation project; (7) invested 140×10^6 yuan to build two 220 kV substations; (8) invested 155×10^6 yuan to complete sewage Treatment and Constructed Wetland Water Purification Project (From "2021 Dengkou County Government Work Report" Inner Mongolia People's Government website: www.nmg.gov.cn/zwgk/zfggbg/ms/BayanNur/202103/t20210318_1193269.html).

Today, the Ulan Buh Desert in Dengkou County, Inner Mongolia, has formed a complete industrial chain of "desert - photovoltaic power generation - ecological agriculture" and has initially achieved the goal of transforming the desert in the old days into a present granary. The Ulan Buh Desert serves as a typical model for human beings to use nature, achieve carbon emission reduction, and create a beautiful living space.