Applied Energy 230 (2018) 31–41

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Practicality of using solar energy for cassava irrigation in the Guangxi Autonomous Region, China

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HIGHLIGHTS

- The situation of cassava planting and water requirement was analyzed.
- The solar power-based irrigation system was discussed.
- An innovative method to evaluate the feasibility of sola irrigation was proposed.
- The congruence of solar energy, slope and cassava planting was analyzed.
- The appropriated region for solar power-based cassava irrigation was counted.

ARTICLE INFO

Keywords:
Water pumping system
Solar energy
Cassava irrigation
Feasibility

ABSTRACT

Cassava is an important cash crop in the Guangxi Autonomous Region. However, the water required to sustain it is not consistent with the temporal and spatial distribution of local precipitation, and hence irrigation is necessary. Solar water pumping is an effective method for cassava irrigation. This study analyzes the temporal and spatial distribution of cassava; discusses the potential and distribution for the use of solar energy for irrigation; and finally considers the main factors, such as precipitation and slope, influencing the feasibility of using a solar water pumping system to irrigate cassava. The results indicate that solar water pumping would be appropriate to irrigate a notional total of 718,500 ha of cassava, with the results currently applicable to a region of 623,000 ha.

1. Introduction

The uneven distribution of precipitation has meant that irrigation is necessary in modern agriculture, and solar energy is well established as a renewable, environmentally friendly resource with which to power it. Solar powered irrigation is regarded as a useful tool for maintaining crop growth and conserving pasture. It is an effective way to apply solar energy to agricultural production and ecological protection. Experts have been working on solar powered irrigation for a long time. Some researchers studied the economic feasibility of solar pumping irrigation. Niajalili et al. [1] analyzed the economic feasibility of solar irrigation for a rice paddy in Iran, with results indicating that the solar photovoltaic (PV) pumping irrigation is economical and feasible. Lorenzo et al. [2] made an economic assessment of PV irrigation in the ECOWAS region. All the economic indicators show that the PV irrigation systems is better than the diesel-powered and grid-powered systems. Santra et al. [3] made an economic analysis of solar PV pumping system for irrigation, It indicates that solar PV pumping system has additional advantages over other pumping systems. In addition, many scholars have done much work on the solar irrigation technology. Luque et al. [4] introduced a Photovoltaics Opportunity Irrigation system for the irrigation of the olive orchards. The new approach can reduce the investment cost and save water. Burney et al. [5] proposed a solar-powered drip irrigation in the Sudano–Sahel. It is found that the solar-powered drip irrigation significantly augments both household income and nutritional intake. Wazed [6] evaluated the efficiency of different solar technologies for irrigation in remote rural areas. The results indicate that solar thermal systems are the most effective system for solar irrigation in Sub-Saharan Africa. Furthermore, many scholars have studied the suitability of solar water pumping irrigation for consideration of regional characteristics. Ali [7] assessed the potential for solar irrigation in Sudan, analyzing the feasibility of three solar water

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https://doi.org/10.1016/j.apenergy.2018.08.060
Received 9 January 2018; Received in revised form 11 August 2018; Accepted 16 August 2018
0306-2619/

pumping systems with different unit operations. Kumar et al. [8] applied the solar irrigation system to dryland agriculture in India, showing that the system was suitable for that terrain and that the developed system could be applied similarly in most regions of the world. Islam [9] reviewed the application of irrigation pumps for agriculture in Bangladesh. They also indicate that solar irrigation could be a crucial option to promote sustainable development in agriculture. García [10] proposed a smart irrigation system using solar energy and irrigation scheduling. The system has been successfully applied to simulate the management of photovoltaic irrigation in a real olive orchard in Southern Spain.

Solar energy is also used in agriculture ecological protection and gas emission reduction. Atam and Arteconi [11] introduced a conceptual framework for using solar PV to prevent the formation of frost on crops, particularly in apricot orchards. Hassanien et al. [12] reviewed the application of solar energy in agricultural greenhouses and found that the feasibility of this technology depends upon the control system and solar collectors used at each facility. Finally, Jain and Tewari [13] developed and analyzed the effectiveness of a solar crop dryer.

The application of solar irrigation in China has been the focus of several researchers. Xu et al. [14] analyzed the feasibility of solar energy for pasture conservation in Inner Mongolia by calculating the optimum amount of irrigation for the region and developing the main steps for the system required. Gao et al. [15] evaluated a solar system irrigation system by considering the water table and showed that the sustainability of groundwater was not affected by the application of such a system. Campana et al. [16] proposed a new way to assess suitable locations for PV water pump irrigation systems in China. However, these studies mainly focused on using solar irrigation on pastures or dryland. Few scholars have focused on the application of solar irrigation for cassava cultivation. The suitability evaluation system of solar irrigation system is still lacked. Therefore, this study aims to propose an innovative method to analyze the feasibility of solar system for cassava irrigation in the Guangxi Autonomous Region, China.

1.1. Study area

Guangxi (Fig. 1) is located in the middle of the southern subtropical region of China and has a total land area of 236,700 km^2. The total planting area is 4,217,333 ha, of which about 0.082 ha is capital arable land; this is about 54 percent of the average land area in China. Most of the cultivated land in Guangxi is dry sloping land, and there are no irrigation facilities for nearly 2,800,000 ha, of which about 266,667 ha are used for cassava cultivation. Guangxi is the main cassava producing center in China, accounting for about 2/3 of the production in the whole country [17]. Thus, cassava has become an important source of income for farmers and local fiscal revenue in this region.

A land use map of the Guangxi Autonomous Region in 2014 (Fig. 2) shows that the region is divided into six land use categories: cultivated land, woodland, grassland, water areas, residential land and unused land, with woodland accounting for the largest proportion.

1.2. Cassava planting

1.2.1. Conditions required for cassava growth

Cassava is a typical short photoperiod tropical crop that thrives in high temperatures, in sunny weather, and is not resistant to frost; therefore, it is planted mainly in spring in the Guangxi region. Areas that have an annual average temperature of above 18 °C, a frost-free season lasting more than eight months, and an annual rainfall between 600 mm and 3000 mm are ideal for growing cassava. The best weather conditions for cassava growth are annual average temperatures of more than 21 °C, average diurnal variations in temperature between 6 and 7 °C, and precipitation of 1000–2000 mm with a uniform spatial distribution. When the temperature

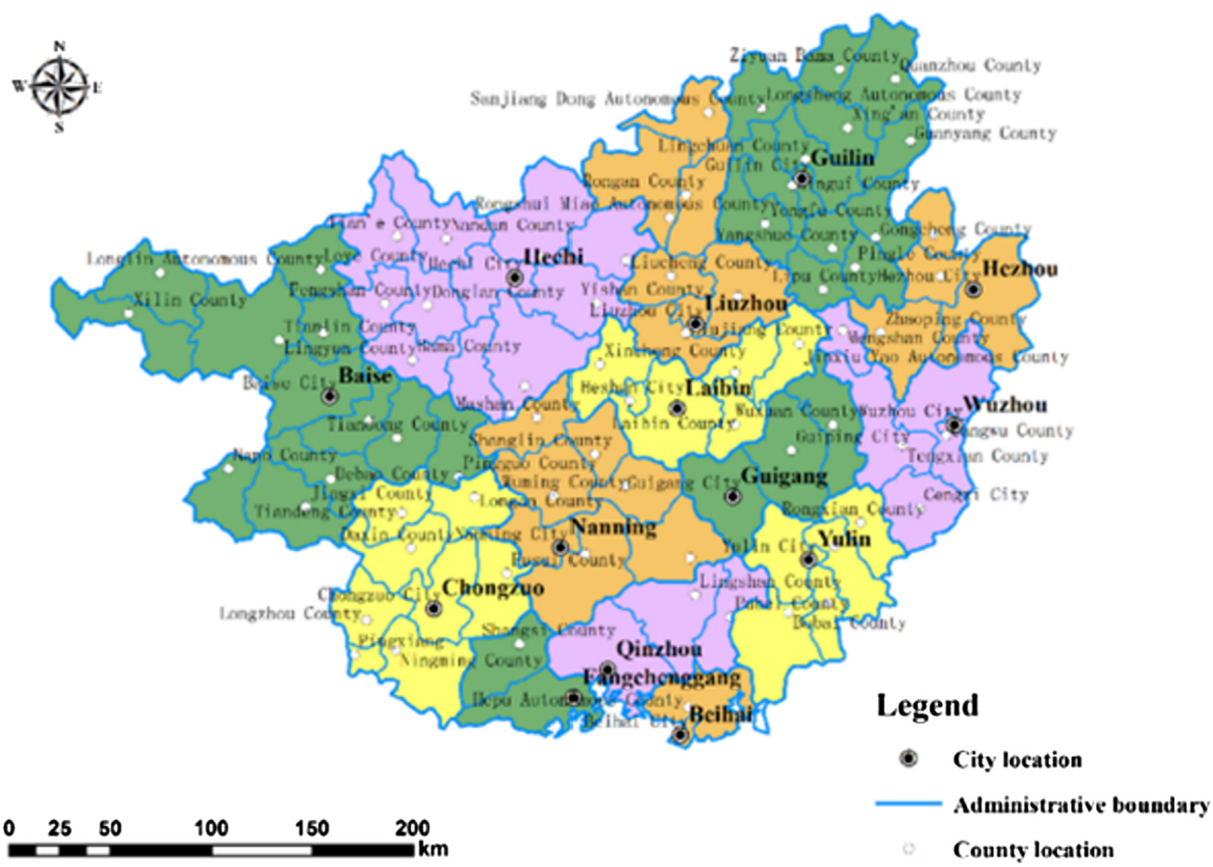

Fig. 1. Administrative zoning map of the Guangxi Autonomous Region.