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Integration optimization of biomass supply based on logit model

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Abstract: Considering the choice preference of farmers, this paper introduced a Logit-based discrete econometric analysis model to study the influence of straw purchase price, cost and government subsidy on the biomass supply choice behavior off armers. On this basis, this study applied the Stackelberg game model to analyze the decision-making among different stakeholders in the biomass supply chain, such as biorefinery, collection stations and farmers, and determined the optimal purchase price of biomass and the service radius of collection stations. Finally, it used a numerical example to verify the effectiveness of the optimal decision-making model. The research shows that the choice of farmer's supply mode is related to their sensitivity to utility; government subsidies can not only improve the enthusiasm of farmers to send straw directly to the biorefinery, but also improve the interests of the biorefinery and collection stations to different degrees.

1. Introduction

With the energy crisis and environmental problems, it is imperative to develop and design renewable energy to ensure energy consumption, protect the environment and promote regional development. China's biomass straw resources are abundant and the output is large, but the utilization rate is low. In view of the restrictions on agricultural time, straw collection and transportation costs, farmers usually incinerate the straw on the spot, which not only prevents the downstream collection stations and processing plants from obtaining enough straw resources, but also seriously pollutes the environment. According to the survey, some processing plants in the operation process, nearly 60% to 70% of the time can not function properly, most processing plants are in a state of loss, relying on government subsidies to barely maintain operations, straw purchase price is too high, raw materials supply is in short supply The root cause of this phenomenon. Straw collection has become the bottleneck for the comprehensive utilization of straw, and it is worthwhile to study how the price of biomass supply should be ensured by biomass processing plants and collection stations[1].

As a renewable alternative energy source for fossil energy, bioenergy has not only received the attention of countries all over the world, but also attracted extensive research by scholars at home and abroad. The current research mainly focuses on two aspects. Part of the research focused on “supply chain design”, which mainly includes transportation network design and site selection of biomass processing plants. Yue et al. analyzed the challenges and opportunities in the modeling and optimization of biomass supply chains and identified possible ways to focus on future research with multi-scale modeling and optimization. The initial study focused on single objectives and deterministic parameters to obtain key logistics decisions, such as site selection, optimal production, and transportation allocation for biomass processing plants. With the deepening of research, more and more scholars began to consider the impact of various uncertain factors on the optimization of biomass supply chain. Scholars such as Ahmed considered the impact of carbon emissions and uncertain conditions on the sustainable supply chain management of second-generation biofuels[2].

2. Problem Description

This paper examines a three-level biomass supply chain network consisting of multiple farmer groups, multiple collection stations, and a processing plant. As a supplier of biomass straw, farmers can choose to send the straw directly to the processing plant (Mode 1) or collect it by the collection station (Mode 2) after collecting the straw from the field and performing simple stacking treatment. The collection station pretreats the collected straw to produce densified straw and sell it to the processing plant. The processing plant processes the straw purchased from farmers and collection stations to produce biofuels. As an intermediary, the collection station usually purchases straw at a low price and sells straw at a high price in order to obtain maximum profits. This not only dampens the enthusiasm of farmers to supply straw, but also imposes a serious burden on the production and operation of the processing plant. Therefore, in order to encourage farmers to send straw directly to the processing plant, reduce the raw material costs of the processing plant, and maintain the stable operation of the processing plant, the government subsidizes farmers who send straw directly to the processing plant[3].

The grid overlay-coupling method divides the supply chain network area into multiple clusters, and the supply density in each cluster is almost constant. According to the supply of farmers, this paper uses the grid cover method to divide the straw collection area A of the processing plant into multiple clusters with similar supply structure. Assume that $Z_1, Z_2, \ldots, Z_N$ is the N farmer clusters in Region A. One or more collection stations can be built in each cluster. The collection range of the collection station is not always the regular geometry, but the shape irregularity has little effect on the optimal solution. Therefore, this paper assumes that the collection areas of the collection stations in the cluster are equal and approximately circular, and the collection stations are located at the center of each circular area. The average distance between the farmer points in the area and the collection station is $w_i^{t-1} \le w_i^t$, where βR_i is the collection radius of the collection station, $\forall i \in B$ is the country road tortuosity factor ($\forall t = 1, \ldots T$), and the optimal construction number of the collection station in cluster is $w_i^0 = 0$.

This paper uses the master-slave game to describe the relationship between the various levels of the “farmer-collection station-processing plant” supply chain network, in which: the processing plant is the leader, and the straw purchase price paid to the farmers is determined with the goal of minimizing the total cost. P; the collection station is the follower, and the profit is maximized by determining the radius iR and the straw collection price Si P paid to the farmer; the farmer's supply decision is used as a reflection function of the master-slave game, according to the processing plant and the collection station. Given the purchase price, determine its supply plan to maximize its own earnings. In particular, the decision to collect radius in this study involves the construction of the collection station, which is a strategic decision; the decision to collect the price of straw is an operational decision, which is based on strategic decision-making and can be adjusted according to actual conditions. Therefore, in terms of time, strategic decision-making must be prior to operational decision-making. Due to the timing of decision-making, many scholars believe that strategic decision-making and operational decision-making need to be decided in stages, not simultaneous decision-making. Based on this, this paper will determine the collection radius of the collection station and the decision of pricing problem in stages, and determine the optimal collection radius. After that, the corresponding straw collection price is decided.

3. Model building

3.1. Model building for leaders (processing plants)

The processing plant aims to determine the optimal straw purchase price based on the government's subsidy to farmers, in order to attract farmers to send straw directly to the processing plant to minimize the total cost. The objective function of the processing plant is:

$$Y = \left(\alpha E_F^{\frac{\sigma-1}{\sigma}} + (1-\alpha) E_R^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

4. Model solving

4.1. Sensitivity analysis of farmers' perception parameter of utility

The sensitivity of farmers to utility affects the supply decision of farmers. The greater the value of, the more sensitive the farmers are to utility, and the more favourable the choice of efficient supply options. According to the the utility of self-sending by farmers in cluster 2 is higher than that collected by the collection station. Therefore, with the increase of sensitive parameters, farmers are more inclined to choose a scheme with greater utility. The amount of straw 2S B transported directly to the processing plant increases, and the amount of straw 2SS selected by the collection station is continuously reduced. Therefore, the processing plant is the first to reduce the purchase price of straw raw materials to save the cost of straw purchase. As a follower, the collection station will also reduce the straw collection price to save costs. And because of the reduction in collection, the collection station will increase the collection radius to reduce the number of collection stations, save construction investment costs, and make up for the loss of profits due to the reduction in collection. It can be seen that the higher the sensitivity of farmers to utility, the more dominant the processing plant as a leader and the ability to use agriculture.

4.2. Sensitivity analysis of road tortuosity factor

Due to the wide distribution of straw and the tortuous and uneven rural roads, this has increased the cost of straw collection and transportation at the collection station to some extent. Therefore, this paper introduces the road tortuosity factor to indicate the degree of tortuousness of the country road. The larger the value of, the more the road is tortuous and the more difficult the transportation, the higher the unit transportation cost. Table 2 and Figure 4 show the impact of on each decision maker.

5. Conclusions

Based on the current situation of crop straw utilization in China, this paper considers the preferences of farmers based on the traditional biomass supply chain network, and constructs a master-slave game model based on the choice behavior of farmers, which is the formulation and collection of reasonable price incentives for processing plants and collection stations. The layout optimization of the station and the government's subsidy mechanism provide the basis for decision making. Finally, through the example and parameter sensitivity analysis, the following management inspirations are obtained: a) The closer the average distance of farmers to the processing plant, the more likely they are to send the straw directly to the processing plant, and the farmer who is farther away from the average is due to Collection and transportation costs are too high, and they are more likely to be collected by collection stations. Therefore, the large-scale cluster construction collection station can make the middlemen get more benefits, while in the smaller clusters, the processing factory can provide the farmers with the relatively high price to directly send the straw to the processing plant. Reduce the cost of straw purchases while increasing the income of farmers. b) Farmers' sensitivity to utility has a great influence on the choice of supply mode. Processing plants can use farmers' sensitivity to utility, give full play to their advantages in the supply chain, and develop a reasonable price incentive system to improve The enthusiasm of the farmers to directly send the straw to maximize their own benefits. c) The degree of tortuousness of the rural roads is inversely related to the profit of the collection station. The more tortuous the road, the more unfavorable the operation of the collection station. Therefore, the collection station must fully consider the influence of the geographical environment and road conditions, and reasonably carry out the site selection. d) The government plays an important role in the biomass supply chain. The reasonable subsidy mechanism has different degrees of improvement for the interests of farmers, collection stations and processing plants. When the subsidy is between 15~25 yuan/ton, It can greatly improve the enthusiasm of farmers to send straw directly to the processing plant, and will not impose an excessive burden on the government.

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