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Can the Sorghum Planting Industry in Less-Favoured Areas Promote the Income Increase of Farmers? An Empirical Study of Survey Data from 901 Samples in Luquan County

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Abstract: Poverty alleviation is the basic requirement of human social development. However, there is still a lack of quantitative research on the poverty alleviation effect of regional, characteristic industries. Few studies have focused on the increase of micro individual income and used more advanced policy evaluation tools for comparative analysis based on a quasi-experimental perspective. In addition, the existing research ignores the critical question: can characteristic industries really achieve sustainable development goals while bringing poverty alleviation results? We studied regional, characteristic industries from a new perspective, taking into account the poverty alleviation effect and regional sustainable development. Based on the survey data of 901 households of representative village committees of Tanglang and Dache in Luquan Yi and Miao Autonomous County, this study quantitatively analyzed the poverty alleviation effect of the sorghum planting industry by using the Propensity Score Matching Difference-in-Differences (PSM-DID) model. The adoption of the industrial alleviation policy has significantly increased the per capita net income of rural households in Tanglang and Dache village committees, by 2171.64 CNY and 1945.06 CNY, respectively. The estimation results of the whole sample show that the effect of the policy to the per capita net income of households is 1726.87 CNY. The development of the sorghum planting poverty alleviation industry in Luquan County has promoted income increase of households significantly, creating economic, social and ecological sustainability, and can provide a reference for less-favoured areas.

Keywords: sorghum planting; sustainable development; poverty alleviation; quasi-experimental; PSM-DID model; less-favoured areas

Citation: Yang, R.; Yang, Z. Can the Sorghum Planting Industry in Less-Favoured Areas Promote the Income Increase of Farmers? An Empirical Study of Survey Data from 901 Samples in Luquan County. *Agriculture* **2022**, *12*, 2107. https://doi.org/10.3390/agriculture12122107

Academic Editors: Roberto Furesi and Fabio A. Madau

Received: 11 November 2022
Accepted: 6 December 2022
Published: 8 December 2022

1. Introduction

Poverty is a serious challenge in the world today, and restricts local sustainable development to a great extent. Poverty alleviation is a basic requirement of human social development [1,2]. In September 2015, the United Nations proposed to eliminate poverty in all forms and manifestations in the world by 2030 [3–5]. However, there are still many impoverished people in the world who have insufficient food and clothing. How can absolute poverty be completely eliminated? As one of the largest developing countries in the world, China shoulders a heavy responsibility in fighting poverty. Since the reform and opening up, China has had problems such as unclear poverty alleviation strategies and unclear poverty alleviation targets, leading to the existence of a large number of impoverished people in a long period of time. To ensure that no one falls behind on the road to building a moderately prosperous society in all respects, China urgently needs targeted poverty alleviation [6]. Since 2014, the targeted poverty alleviation policy implemented

by China has effectively changed this situation. The targeted poverty alleviation policy requires the "six elements of targeted poverty alleviation" in poverty alleviation, implements "five-pronged poverty alleviation measures", solves the "four key issues", and becomes a Chinese solution of poverty reduction in the world.

China's targeted poverty alleviation policy has attracted worldwide attention. Many scholars have studied China's poverty reduction from different perspectives. For example, Xu Guoyin et al. (2022) studied the effect of e-commerce in China's region and its spillover effect on poverty alleviation from the perspective of sustainable development [7]. In addition, Zou Qi et al. (2019) analyzed the effects of poverty reduction policy on health services utilization among the rural poor by a quasi-experimental study [8]. Zou Cunming et al. (2019) took Tongyu County as an example to analyze the effect of poverty alleviation in different places [9]. Although there are various perspectives to study the effectiveness of poverty alleviation, industrial poverty alleviation plays a decisive role [10–12], ranking first among the "five-pronged poverty alleviation measures" [13–15]. It is urgent to make an accurate and scientific assessment of how much poverty alleviation effect the development of poverty alleviation industries may bring. This is because developing rural industries is not only an important measure to develop production and increase income in rural areas, but also an important path to achieve sustainable development in less-favoured areas and achieve the primary goal of "industrial prosperity" in the Rural Revitalization Strategy. In depth analysis of the poverty alleviation effects brought by local characteristic industries can not only provide useful references for clarifying the implementation effect of China's targeted poverty alleviation policy, but also draw on the experience of implementing the Rural Revitalization Strategy and formulate more specific and thorough policies for industrial prosperity. Practice has proven that the development of rural characteristic industries is not only a path for impoverished households in mountainous areas to get rid of poverty and become well-off, but also an inexhaustible driving force for promoting industrial prosperity and rural revitalization. It is of greater significance to study the poverty alleviation effect of local characteristic industries [16].

However, through a literature review, we can found there is still a lack of research on the poverty alleviation effect of local characteristic industries, and scholars have conducted research on local characteristic industries from other perspectives. For example, Guo Xiaoming et al. (2018) took Cangxi County, Sichuan Province as an example to analyze the kiwifruit industry for poverty alleviation and advantages [17]. Lu Hanwen (2016) analyzed the development paths of characteristic agriculture in eastern China from the cross perspective of the industrial chain and stakeholders [18]. Although some scholars also tried to analyze the poverty alleviation effect brought by industrial development, most of them conducted qualitative analysis, and it is difficult to quantitatively evaluate the poverty alleviation effect brought by these characteristic industries. For example, Ma Nan (2016) analyzed the targeted poverty alleviation effect of specific industries in ethnic areas, with the development of Chinese herbal medicine as an example [19]. Through a literature search, we found that more and more scholars are also trying to solve the problem by quantitative analysis. For example, Wu Junqian et al. (2021) used a spatial econometric model to analyze the effect of industrial clusters on rural poverty alleviation [20]. Liu Mingyue et al. (2021) analyzed the effect of poverty-alleviation-based industry on improving farmers' livelihood and capital [21]. Hu Lian et al. (2017) discussed the effect of targeted poverty alleviation based on the survey data of 12 counties in Anhui Province [22]. Wang Lijun et al. (2018) analyzed the poverty alleviation effect of the bamboo industry [23]. Zhang Dongli et al. (2020) studied the impact of rural land consolidation on poverty alleviation and income increase under different modes [24]. Scholars from other countries are also trying to quantitatively analyze the impact of industrial development on poverty alleviation, with substantial research results. Motsi, Hamond et al. studied the adaptability of sweet sorghum and applied it to poverty alleviation [25]. Mwangi, Backson et al. evaluated the impact of improved sorghum varieties on poverty reduction in Kenya [26]. Fikadu, Mitiku

et al. analyzed the poverty alleviation effect of different coffee certification schemes in Ethiopia [27].

Although the existing studies have achieved substantial results, there are still some fields that need to be improved. First, although many studies have analyzed the poverty alleviation effect brought about by characteristic industries, some studies only focus on the reduction of the impoverished population by the characteristic industries, or the improvement of product output, and do not focus on the increase of household income. In addition, many scholars have studied the macro results brought by the development of characteristic industries within a large region, and have not focused on micro individuals. Even though there are still a small number of studies focusing on the income of individual households, there is no advanced policy evaluation tool based on a quasi-experimental perspective to divide individual households into the control group and the treatment group for comparative analysis. More importantly, the existing research ignores a critical question: can characteristic industries really achieve sustainable development while bringing poverty alleviation effects? In other words, the existing research has not developed an alternative perspective to focus on the poverty alleviation effect and sustainable development brought about by characteristic industries.

Although scholars from other countries have studied similar problems and made some progress, China's national conditions cannot be ignored. Protecting cultivated land, preventing non-grain production (NGP) on cultivated land, and ensuring food security are also China's major strategies [28,29]. How to effectively solve the low comparative benefits of grain planting, improve the enthusiasm of households to grow grain, make the development of rural characteristic industries and the prevention non-grain production on cultivated land more "compatible" or even "win-win", so as to truly achieve "multi-dimensional" sustainable development, requires a strategic development perspective. There are 88 poverty-stricken counties in Yunnan Province; the highest number in China. Luquan Yi and Miao Autonomous County (hereinafter referred to as Luquan County) is one of them, located in the dry-hot valley of Jinsha River in the upper reaches of the Yangtze River [1,30]. Based on many field investigations, it was found that Luquan County's promotion of the sorghum planting industry on poverty alleviation in the dry-hot valley area of the Jinsha River since 2017 initially had the dual objectives of developing characteristic industries to promote income growth and preventing non-grain production on cultivated land. Therefore, this study analyzed the poverty alleviation effect of promoting the sorghum planting industry in typical villages of Luquan County from the perspective of sustainable development. The research contribution of this study lies in studying regional characteristic industries from a new perspective, and taking into account the poverty alleviation effect of characteristic industries and regional sustainable development goals.

2. Analysis on Theory, Study Area and Poverty Alleviation Mode

2.1. Theoretical Analysis

Many famous economists have put forward the theory of poverty from the perspective of poverty formation. Ragnar Nurkse (1953) believes that the reason why developing countries are poor is that there is a vicious circle between demand and supply [31]. In 1956, the economist Richard R. Nelson proposed a famous theory: the low-level equilibrium trap [32]. Gunnar Myrdal (1957) proposed the theory of circular accumulation causality [33]. However, how should poverty be eliminated after its formation? Albert Otto Hirschman proposed the "Trickle-down effect" theory. He believed that with the passage of time, developed countries would have positive effects on developing countries to narrow the gap and eliminate poverty [34]. Amartya Sen proposed the anti-poverty theory of equal rights [35]. Gunnar Myrdal also tried to discuss anti-poverty from the perspective of institutional reform.

After famous economists had put forward anti-poverty theories, many Chinese scholars added Chinese elements to the classic anti-poverty theories based on concrete practices, thus gradually forming a series of anti-poverty theories and modes that conform to China's

national conditions. Yan Kun et al. (2013) found that many scholars have studied China's anti-poverty problem from the practical level and refined the anti-poverty theoretical modes from the practical perspective [36]. For example, according to China's actual situation, Zhang Yansong (2004) divided anti-poverty into ten modes: regional development, infrastructure construction, production development, development of characteristic economy, poverty alleviation through science and technology, labor export, relocation and development in other places, microcredit, mobilization of social forces, and foreign capital assistance [37]. Fan Xiaojian found that China has formed six effective poverty alleviation modes: whole village promotion, the rain dew plan, the industrialization poverty alleviation, the continuous development, the immigrant poverty alleviation, and the comprehensive management of extremely poor areas [38]. Zhao Changwen et al. (2000) summarized and compared various poverty alleviation modes, and evaluated in detail the development-based poverty alleviation mode, the micro credit poverty alleviation mode, the remote development poverty alleviation mode, the counterpart poverty alleviation mode and the enterprise poverty alleviation mode, pointing out that poverty alleviation and development work should select suitable poverty alleviation modes according to the different characteristics of less-favoured areas [39].

Theoretical research shows that developing the economy and increasing income is one of the main lines of China's anti-poverty modes [40]. There is a complex relationship between anti-poverty and economic development. Theoretical research shows that in the initial stage of economic development, the income gap will expand, and the effect of economic development on anti-poverty is not very obvious, because the social income gap is still expanding [41]. However, with the further development of the economy, the role of economic development in fighting poverty has become increasingly prominent. Economic development is diverse, and industrial development is an important aspect. Industrial poverty alleviation plays a decisive role, and is the key route that must be taken, ranking first among the "five-pronged poverty alleviation measures". Practice has proved that the development of characteristic poverty alleviation industries plays a decisive role in driving households to increase their income and promoting transformation from "blood transfusion poverty alleviation" to "hematopoiesis poverty alleviation". The anti-poverty mechanism of industrial development mainly plays a role by establishing leading industries, supporting leading enterprises, providing policies that benefit the people, and establishing production bases. It also increases the income of impoverished groups, profits of enterprises in cooperation, and tax revenue of the government. Promoting poverty alleviation through industrial development requires the government to take leading enterprises as the main carriers and implement policies such as credit poverty alleviation, tax preference, land use, social assistance and financial discounts. Leading enterprises can form a risk-sharing community with impoverished households through share dividends, agriculture, cooperation and mutual benefit, to obtain greater benefits while providing employment and opportunities of increasing income for impoverished households, and promote the adjustment of the industrial structure and the development of leading industries in less-favoured areas.

For assessment of targeted poverty alleviation, the authors have gone to impoverished mountain areas in more than 10 counties and learned about their industrial development modes. For example, Debao County in Guangxi has built a poverty alleviation chain through production and marketing integration, and promoted the large-scale development of industries such as navel oranges, hawthorn and silkworms [42]. Midu County, Yunnan Province, has taken advantage of its unique natural conditions to develop the vegetable industry, and strives to expand the sales market, forming a poverty alleviation mode for the vegetable industry [42]. The main poverty alleviation industries in typical villages and towns of Xundian Hui and Yi Autonomous County in Yunnan Province include cantaloupe, pork, and morel mushrooms, and have formed a unique industrial development mode [43]. In general, many poverty-stricken counties use their unique resource endowments to develop their own characteristic industries in line with local conditions, forming a unique industrial development mode. However, there are some aspects worth thinking about in

many existing industrial poverty alleviaton modes. For example, to develop characteristic industries and increase household income, most of the cultivated land for long-term planting of traditional food crops such as corn has been replaced with cash crops with higher output value, such as fruits and seedlings [44]. Although the economic benefits are significant, there has also been a trend of non-grain production on cultivated land. Can the industrial development mode of introducing the "Langzhitang" distillery and promoting sorghum planting to households in Luquan County effectively increase households' income and achieve the goals of sustainable development on the premise of effectively ensuring the planting of traditional food crops on cultivated land? This needs to be tested using the empirical methods.

2.2. Overview of the Study Area

In the dry-hot valley of the Jinsha River in China, there are many poverty-stricken counties; Luquan County is one of them. Luquan County is one of the counties under the jurisdiction of Kunming, Yunnan Province. The layout of Luquan County is similar to a leaf, narrow on the left and right, long on the top and bottom. The maximum horizontal distance between the east and west is about 70 km, and the maximum vertical distance between the south and north is about 105 km, with a land area of 4233.91 km^2. Luquan County has jurisdiction over 16 townships, namely: Pingshan, Cuihua, Jiulong, Zhuanlong, Wumeng, Zhongping, Xueshan, Tuanjie, Sayingpan, Zehei, Maoshan, Yunlong, Jiaopingdu, Malutang, Wudongde and Tanglang. Luquan County has many mountains and little flat land. The terrain is generally high in the northeast and low in the southwest. The altitude differences between regions are large, showing very obvious characteristic of a three-dimensional climate.

According to the statistics of Luquan County, by the end of 2020, the total population of the county reached more than 487,000 people, including a large agricultural population of more than 371,000 people (about three-quarters of the total population) and a non-agricultural population of more than 116,000 people (about one quarter of the total population). In addition, the population of 23 ethnic minorities in Luquan County, including Yi, Lisu and Miao, accounts for about 33%. In 2020, the GDP of the county reached 14.65 billion CNY, of which the output values of the primary industry, secondary industry and tertiary industry were 4.164 billion, 2.204 billion and 8.282 billion CNY, respectively. The output value ratio of the three types of industries is about 2:1:4. In 2020, the county's per capita GDP reached about 38,600 CNY, ranking 83rd among 129 counties (cities and districts) in Yunnan province. In 2020, the total output value of agriculture, forestry, animal husbandry and fishery reached 6.574 billion CNY, and the total agricultural output value will reach 3.121 billion CNY.

Luquan County is a typical national poverty-stricken county in the upper reaches of the Yangtze River and the middle reaches of the Jinsha River (which has gotten rid of poverty). It is characterized by a large proportion of mountains, steep terrain, significant poverty, and a large number of ethnic minorities [2]. Its economic development is relatively backward, with a wide range of rural poverty. The per capita disposable income of rural residents has always been at a low level in Yunnan province (Table 1), and in 2020 it was only 10,553 CNY, ranking 113th among 129 counties (cities and districts) in Yunnan Province. In addition, the cumulative number of the officially registered poverty-stricken people in the county reached 91,586 people (26,083 households) over the years from 2015 to 2020. Luquan County, as a key county included in the national plan for poverty alleviation through development, had a poverty incidence rate of 22.21% in 2014 (Table 2). Xueshan Township having the highest poverty incidence rate of 45.00%.

From the perspective of climate conditions, the temperature difference in the dry-hot valley of Jinsha River is minor in four seasons, with an annual rainfall of 850~1200 mm, but the dry and wet are distinct in four seasons. It has a subtropical monsoon climate, which is suitable for planting sorghum. Sorghum is one of the traditional "five grains", favouring temperature and light. Optimum temperature for the growth period is 20~30 °C, and it is

mainly distributed in areas with higher temperature and lower latitude. Sorghum rice can be used for brewing Baijiu and making sugar [45].

Table 1. Rural Per Capita Disposable Income and Its Ranking in Luquan County from 2015 to 2020.

Year	Per Capita Disposable Income of Rural Residents (Unit: CNY)	Proportions Compared with Yunnan Province (Unit: %)	Proportions Compared with the Whole Country (Unit: %)	Ranking in 129 Counties (Cities, Districts) of Yunnan Province
2015	6595	80.02	57.74	115
2016	7301	80.94	59.06	114
2017	8046	81.59	59.90	114
2018	8802	81.74	60.22	114
2019	9691	81.42	60.49	114
2020	10,553	82.18	61.60	113

Table 2. Poverty Population and Poverty Incidence Rate in 2014 in Luquan County.

Townships	The Accumulative Number of the Officially Registered Poverty-Stricken People in 2014		Number of Agricultural Registered Residence Population in 2014 (Unit: Person)	Poverty Incidence Rate (Unit: %)
	Number of Households (Unit: Household)	Number of People (Unit: Person)		
Pingshan	1113	3934	40,373	9.74
Sayingpan	1921	6240	43,903	14.21
Zhuanlong	2305	8335	34,222	24.36
Maoshan	1654	5560	35,734	15.56
Tuanjie	509	1598	24,294	6.58
Yunlong	787	2492	9617	25.91
Zhongping	1521	5365	18,002	29.80
Jiaopingdu	1558	5740	21,677	26.48
Tanglang	1507	5452	13,820	39.45
Malutang	1550	5013	19,387	25.86
Wudongde	1957	6630	15,776	42.03
Zehei	2074	7804	27,614	28.26
Cuihua	2776	9575	35,989	26.61
Jiulong	2310	7992	42,480	18.81
Wumeng	1174	4545	17,633	25.78
Xueshan	1367	5311	11,802	45.00
Total	26,083	91,586	412,323	22.21

Note: Data from the Poverty Alleviation and Development Office of Luquan County People's Government.

2.3. Sustainable Mode of Sorghum Planting Industry Leading Poverty to Alleviation in the Dry-Hot Valley of Jinsha River in Luquan County

In order to win the battle against poverty, Luquan County, in accordance with the general requirements of "one-pronged poverty alleviation measures by developing industry", took industrial poverty alleviation as the primary goal, and made every effort to develop a characteristic planting industry to promote increase of farmers' income and poverty alleviation. In combination with the climatic characteristics of the Jinsha River Valley in Luquan and the previous experience of small-scale planting, Luquan County has introduced new sorghum varieties such as Hongyingzi, No. 1, Hongmaonuo, No. 2 and Jinliangnuo, No. 1 into the dry-hot river valley since 2017. Focusing on the fundamental path of poverty alleviation, sorghum planting has been regarded as a key industrial poverty alleviation project. The implementation plan for the development of high-quality sorghum industry in Luquan Yi and Miao Autonomous County (2018–2020) was formulated and issued. In the form of "enterprise + government + cooperative + poverty households", the Langzhitang distillery was built in Luquan, and Luquan County was developing large-scale, industrialized and characteristic sorghum planting, and adopting policies of protect price purchasing sorghum from households to promote households (especially poverty-stricken

households) to increase production and income. Figure 1 shows the sustainable mode of sorghum planting industry in Luquan County.

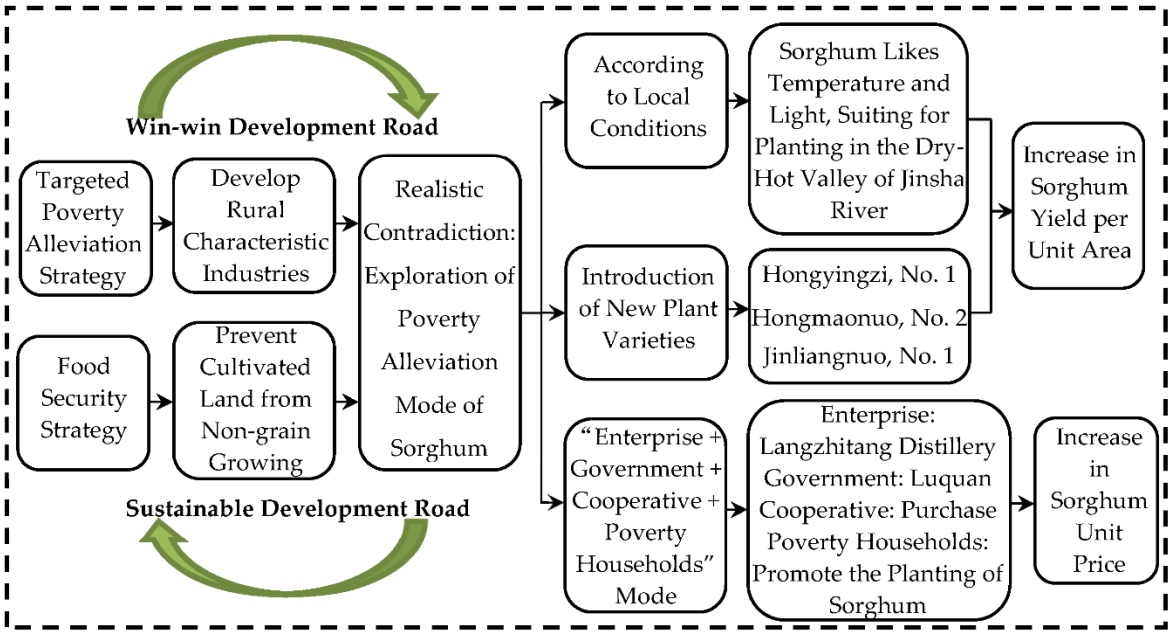


Figure 1. Sustainable Mode of Sorghum Planting Industry Leading Poverty Alleviation in the Dry-Hot Valley Area of Jinsha River in Luquan County.

There is an obvious contradiction between the development of characteristic industries and the prevention of non-grain production on cultivated land. How to solve this from a sustainable perspective? It can be seen from Figure 1 that Luquan County did not choose to avoid this contradiction, nor did it choose to develop fruit, vegetables and breeding industries to drive household income increase as in other regions, but considered non-grain production on cultivated land, and chose to develop sorghum as its own characteristic industry. Although ordinary grain crops do not have high value, Luquan County Government highlighted the industrial characteristics from at least three aspects, improving the value of grain crops, and achieving sustainable production. (1) Growing crops according to local conditions. Sorghum favours higher temperature and light, while most areas of Luquan County are distributed in the dry-hot valley of Jinsha River. The perennial high temperature makes it very suitable for planting sorghum. The practice of planting sorghum according to local conditions can significantly increase unit yield. (2) Introducing new varieties. Luquan County has introduced new sorghum varieties in the dry-hot valley since 2017. These varieties of sorghum have the characteristics of short growth cycle, high yield and adaptability to a variety of climates. (3) Adopting the form of "enterprise + government + cooperative + poverty households". Although the above method can increase the output of sorghum, if there is no market, the produced sorghum would be difficult to sell. Luquan County's practice is quite ingenious: the introduction of the Langzhitang distillery factory in Luquan, and the development of large-scale, industrialized and characteristic sorghum planting. Luquan County has invited enterprises to set up distilleries by attracting investment and recruiting high-level winemakers. Through the efforts of Luquan County government and cooperatives, the sorghum planting pilot project has been carried out in many places in Luquan County. Farmers have signed contracts to stipulate that the Langzhitang distillery will purchase sorghum planted by farmers at a guaranteed price.

It can be seen that this development mode can significantly enhance the enthusiasm of farmers to grow grain, which has certain significance for protecting cultivated land and preventing non-grain production on cultivated land, and initially has social sustainability. However, we paid more attention to the economic sustainability of this development

mode. In other words, does this mode really promote the increased farmers' income, especially in impoverished households? How much effect has the development of sorghum planting industry in Luquan County brought to farmers' income? This is because only by accurately evaluating the poverty alleviation effect brought by this development mode can we better recognize the actual effect of this development mode, so as to provide reference for the industrial development of other regions. Therefore, we adopted the method of a questionnaire survey to collect the relevant data of households who planted sorghum, and households that did not plant sorghum, and then calculated the poverty alleviation effect brought by the promotion of sorghum to households by comparing the differences between the two.

3. Materials and Methods

3.1. Household Investigation Scheme of the Poverty Alleviation Effect of Sorghum Planting

After consulting the opinions and suggestions of leaders and cadres of relevant industry departments of Luquan County, Tanglang and Dache village committee, which are typical areas of sorghum planting industry, are selected sample villages committee for household investigation.

Since Luquan County has introduced new varieties of sorghum in the dry-hot valley since 2017, and adopted protected price to purchase sorghum, we adopted a questionnaire investigation method of comparisons between typical households that planted sorghum and households that did not plant sorghum, and divided the households' samples into two groups, namely, the treatment group (sorghum planting was promoted in 2017~2019) and the control group (sorghum planting was not promoted). The reason why this study selected households who did not plant sorghum, and those who planted sorghum in 2017~2019, as the control group and the treatment group, respectively, is that the study more conveniently compare the impact of the policy of promoting sorghum planting and purchasing sorghum from households at protective prices. In the experimental design, to study the implementation effect of a policy or a measure, it is usually necessary to compare the gap of the experimental results between the group not included in the policy experiment and the group included in the policy experiment. By ensuring that external factors controlled as far as possible and other relevant conditions and factors are not significantly different between the two groups, the gap of the results between the group affected by the policy and the group not affected by the policy is the actual effect of the policy. The Difference-In-Differences (DID) model is based on this idea. By controlling the influence of external interference and other variables, it uses rigorous mathematical logic and exact calculation to obtain the net effect of the policy (see the following for details). Based on this, we designed a questionnaire according to the limits and requirements of the DID model for data collection, and selected the households that did not grow sorghum as the control group, and the households that grew sorghum in 2017~2019 as the treatment group for analysis and study. For comparative analysis, the household survey data in this study was divided into two time limits, namely 2016 and 2020. The year 2016 was the year before the promotion of sorghum planting in Luquan County, and 2020 was the year of China's poverty elimination and after the promotion of sorghum planting. With the coordination of relevant leaders and cadres in Luquan County, and the assistance of the Tanglang village committee in Tanglang and the Dache village committee, we carefully carried out household surveys and obtained survey data of 901 effective samples (Table 3).

Considering the benefit of sorghum planting is affected by family situation, population structure, planting area and other factors (local governments might be more likely to promote sorghum planting to households with impoverished family conditions, more labor force, larger contracted land area and other characteristics), the survey included three aspects, namely: per capita net income of households, basic family situation, sorghum planting and income status. The survey indicators of the basic family situation mainly included the number of family populations, the labor force (aged 18–65), the area of contracted land, and the category of households (poverty-stricken households or ordinary households).

Sorghum planting and income status were investigated and included indicators such as sorghum planting area, sorghum planting net income, the proportion of sorghum planting net income in the total household net income, and we calculated the variable indicators according to the survey results (Table 4). Table A1 shows the statistical description of each variable.

Table 3. Sample Scale of Household Survey on Poverty Alleviation Effect of Sorghum Planting.

Name of Village Committee	Effective Sample Size (Households)		
	Treatment Group	Control Group	Total
Tanglang Village Committee	200	466	666
Dache Village Committee	72	163	235
Total	272	629	901

Note: the treatment group refers to the households who did not plant sorghum in 2016 but have planted sorghum since 2017. The control group refers to the households that did not plant sorghum during 2016 and 2020.

Table 4. Selection of Variables of Household Survey in 2016 and 2020.

Variables	Symbols	Attribute	Calculation Formula or Explanation	Unit
Per capita net income of households	*income*	Dependent Variable	Total household income/Total household population	CNY/person
Treatment group or control group	*treat*	Dummy Variable	0 means No, 1 means Yes	None
Before or after the implementation of the policy	*time*	Dummy Variable	0 means before, 1 means after	None
Officially registered poverty-stricken households or not	*poverty*	Control Variable	0 means No, 1 means Yes	None
Proportion of income from work	*per work*	Control Variable	Total income from work/Total household income × 100%	%
Proportion of income from breed	*breed*	Control Variable	Total income from breed/Total household income × 100%	%
Proportion of income from sorghum planting	*sorghum*	Control Variable	Total income from sorghum planting/Total household income × 100%	%
Contracted land area	*land*	Control Variable	Contracted land area of households	Mu
Proportion of people aged 18~65	*population*	Control Variable	Number of households aged 18–65/Total household population × 100%	%

Note: "mu" is an area unit commonly used in the questionnaire survey, and 1 hectare (ha) is equal to 15 mu. This means that 1 mu is about 0.067 ha.

3.2. Model Introduction and Selection

Since 2017, Luquan County has focused on the path of industrial poverty alleviation, taken sorghum planting as a key industrial poverty alleviation project, relied on the establishment of the Langzhitang distillery, vigorously promoted sorghum planting and adopted a protective price purchasing policy to promote households (especially poverty-stricken households) to increase production and income. Whether this measure can significantly increase household income, and how much it can drive household income increase, need to be answered by empirical analysis. Therefore, we used the Propensity Score Matching Difference-In-Differences (PSM-DID) model to analyze the poverty alleviation effect of the industrial policy.

In recent years, the Difference-In-Differences (DID) model has been widely used to quantitatively analyze the net effect of an issued policy and the actual effect of a project [46].

The DID model divides the variables into the control group and the treatment group. It requires that both groups have a parallel trend before the policy experiment, and the policy experiment is only for the treatment group. By comparing the differences before and after the experiment, we can analyze and calculate the net effect of the implementation of a policy. For two phases of panel data, its setting form is as follows:

$$income_{it} = \beta_0 + \beta_1 \cdot time \times treat + \beta_2 \cdot time + \beta_3 \cdot treat + \sum_{j=1}^{m} \delta_j \cdot control_j + \varepsilon_{it} \quad (1)$$

where $control_j$ represents each control variable in Table 4, β and δ are the parameters to be estimated, and ε_{it} is the disturbance term. β_1 indicates the net effect of the policy, which is the most important parameter of this study (Table 5).

Table 5. Principle of Estimating Policy Effect by DID Model.

Items	Before Policy Implementation (*Time* = 0)	After Policy Implementation (*Time* = 1)	Difference
Households that Were Promoted to Plant Sorghum (*treat* = 1)	$\beta_0 + \beta_3$	$\beta_0 + \beta_1 + \beta_2 + \beta_3$	$\beta_1 + \beta_2$
Households that were not Promoted to Plant Sorghum (*treat* = 0)	β_0	$\beta_0 + \beta_2$	β_2
Difference	β_3	$\beta_1 + \beta_3$	β_1

Table 5 shows why the intersection terms of *time* and *treat* are the policy effect. Because the above method uses the twice difference approach, this model is also called Difference-In-Differences model. However, for the promotion of sorghum planting industry, the government may be more willing to promote it among the poverty-stricken households to help them get rid of poverty. In addition, the promotion of sorghum planting varies from household to household, and households who work less may be more willing to plant sorghum. On the whole, the government is more likely to promote sorghum planting to households with low income, with the planting industry as the main income, resulting in certain differences between the samples of the treatment group and the control group. Therefore, the simple use of DID model may have some shortcomings because DID model ignores selection deviation.

If an individual chooses to plant sorghum, we cannot estimate the income of the same individual who does not choose to plant sorghum. Assuming that the per capita net income of the household after choosing to plant sorghum on a large scale is $income_{1i}$, and the per capita net income after not choosing to plant sorghum on a large scale is $income_{0i}$, we can only observe one of these values, which is actually a "data loss" [47]. Therefore, it is necessary to match the two groups of samples in the estimation, matching the values of variables such as the officially registered poverty-stricken households or not, the income level of breeding, the income level of working, and select similar samples of households for estimation, to better avoid the problems of selective deviation. The Average Treatment Effect on the Treated (ATT) calculated by PSM method is the net effect of the policy. ATT can be expressed as [48]:

$$\tau_{ATT}^{PSM} = \frac{1}{n} \sum_{i \in I_1 \cap S_P} \left\{ Y_{1i} - \sum_{j \in I_0 \cap S_P} W(i,j) Y_{0j} \right\} \quad (2)$$

where, I_1 and I_0 represent the treatment group and the control group, respectively, n represents the number of samples falling into the control group, y_{0j} and y_{1i} represent the

per capita net income of households in the control group and the treatment group, and W represents the weight. The weights are calculated according to different matching methods.

Propensity Score Matching (PSM) can be done by several methods, such as Markov Matching, K-order Nearest Neighbor Matching, Caliper Matching, and Kernel Matching. In this study, various matching methods in PSM were used to estimate the income increasing effect of sorghum planting on farmers in two sample villages. However, the above Propensity Score Matching (PSM) estimators all rely on the assumption of negligibility, and are not applicable to the case of selection according to unmeasurable variables. For the observed data, if it was suspected there was selection according to unmeasurable variables, it was better to use the Propensity Score Matching Difference-in-Differences Estimator. The Propensity Score Matching Difference-in-Differences model can be abbreviated as PSM-DID model, which was proposed by Heckman et al. in 1998. It is applicable to two phases of the panel data. The establishment of the PSM-DID model is based on the following negligible assumptions:

$$E(Y_{0t} - Y_{0t\prime}|x, D = 1) = E(Y_{0t} - Y_{0t\prime}|x, D = 0) \tag{3}$$

Thus, the ATT of the consistency estimation can be obtained as:

$$\tau_{ATT}^{PSM} = \frac{1}{n}\sum\nolimits_{i \in I_1 \cap S_P} \left\{ (Y_{1ti} - Y_{0t\prime i}) - \sum_{j \in I_0 \cap S_P} W(i,j)\left(Y_{0tj} - Y_{0t\prime j}\right) \right\} \tag{4}$$

where $Y_{1ti} - Y_{0t'i}$ represents the change of individual i in the treatment group before and after the experiment, and $Y_{1tj} - Y_{0t'j}$ represents the change of individual j in the control group before and after the experiment. The rest is the same as in Formula (2).

In general, the method steps of PSM-DID model are as follows:

(1) Estimate propensity scores by using variables and covariates.

(2) For all the individuals in the treatment group, determine all the control group individuals matched with them.

(3) For all individuals in the treatment group, the changes of the outcome variables are calculated before and after.

(4) For all the individuals in the treatment group, calculate the changes before and after all the matched individuals in the control group.

(5) For the calculation results of (3) and (4), use the kernel matching method according to Formula (4) to obtain the estimated ATT.

The advantage of the PSM-DID model is that it can control the differences between groups that are not observable and do not change with time. For example, the fact that treatment group and the control group come from different regions can be solved by using the PSM-DID model. In general, the PSM-DID model is more advanced than DID and PSM. It combines the advantages of the PSM model and the DID model, avoids the shortcomings of the PSM model and DID model as much as possible, and has a better effect and credibility.

After obtaining the correct estimation results of these models, it is necessary to conduct various tests, such as a placebo test and robustness test.

(1) After using the PSM-DID model to estimate the results and analyze them, it is also necessary to conduct a robustness test. If the model is not robust, changing the estimation method will make the estimation results of the net effect of the policy significantly different and affect the credibility of the conclusion. Therefore, it is first necessary to ensure the robustness of the model when estimating.

(2) In addition, the placebo test is an indispensable and important step. "Placebo" usually refers to experimenters giving ordinary sugar pills (which have the same shape and taste as real drugs, but have no actual effect) to experimental subjects rather than effective pills. Its purpose is to eliminate the effects of unobservable factors such as psychological effects. The reason for the placebo test of our model was to exclude the interference of other unobservable factors on the model estimation results. If there are other policies implemented at the same time, and these other policies are closely related to the policy to

be studied in this study, then the estimation results in this study will inevitably be affected, leading to estimation bias. Therefore, this paper used a placebo test to inspect this affect. If placebo test was passed, this means that there were no other unobservable factors causing major interference to the results and no major deviation in the results of the model.

Some software can estimate and calculate PSM, DID and the PSM-DID model, such as E-views, SPSS, and MATLAB. Stata software has some advantages over other software. It is not only more professional in the estimation of econometric models, but also simple to operate and very powerful. It is professional software specially designed for the estimation of econometric models. It can easily estimate and test various models by inputting different commands, and is very convenient and flexible to use. Therefore, this study used Stata 15 software to estimate and the calculate models.

4. Results

4.1. Statistical Description

We calculated the changes in the per capita net income of households in each sample group of Tanglang and Dache village committee from 2016 to 2020 (Table 6).

Table 6. Statistical Description of Household per Capita Net Income.

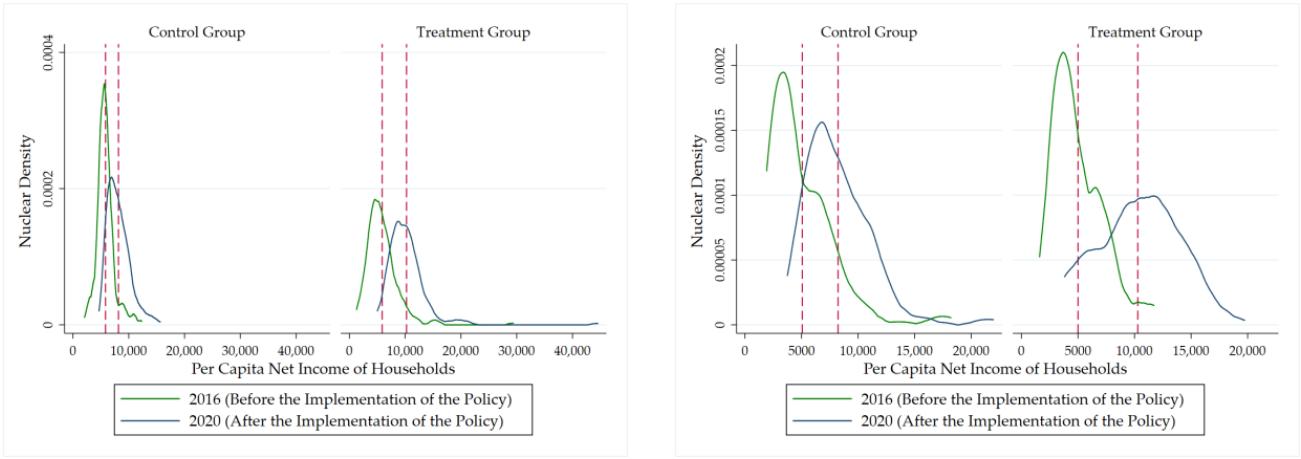
Village Committee Name	Year	Mean Value (Standard Error in Brackets)			Difference
		Total Samples	Treatment Group	Control Group	
Tanglang Village Committee of Tanglang Township	2016	5843.87 *** (80.67)	5877.61 *** (210.47)	5829.38 *** (71.87)	48.23 (176.12)
	2020	8783.23 *** (109.04)	10,248.10 *** (263.82)	8154.52 *** (93.21)	2093.58 *** (223.76)
	Δt	2939.36 *** (84.43)	4370.49 *** (193.82)	2325.14 *** (70.49)	2045.35 *** (166.36)
Total	—	666	200	466	—
Dache Village Committee of Zehei Township	2016	5047.84 *** (173.06)	5005.17 *** (259.98)	5066.69 *** (221.99)	−61.53 (376.20)
	2020	8857.32 *** (214.40)	10,288.84 *** (432.90)	8224.99 *** (226.70)	2063.85 *** (446.05)
	Δt	3809.47 *** (236.02)	5283.67 *** (435.29)	3158.30 *** (266.04)	2125.38 *** (493.82)
Total	—	235	72	163	—

Note: Δt refers to the difference between the income in 2020 and income in 2016. *** indicates that the original hypothesis is rejected at the significance level of 1%.

Table 6 shows that the income of the control group of Tanglang village committee increased by an average of 2325.14 CNY from 2016 to 2020, while the income of the treatment group increased by an average of 4370.49 CNY from 2016 to 2020, with a difference of 2045.35 CNY; this passed the significance level test of 1%. This shows that after Tanglang village committee promoted the planting of sorghum and adopting the policy of protection price purchasing, the per capita net income of households in the treatment group significantly increased. The average income of the control group of Dache village committee increased by 3158.30 CNY from 2016 to 2020, while the average income of the treatment group increased by 5283.67 CNY from 2016 to 2020. The difference between the two was 2125.38 CNY, and passed the significance level test of 1%. This also indicates that the policy increased household income in the treatment group significantly.

Figure 2 more intuitively reflects the changes of households planting sorghum and households not planting sorghum before and after the implementation of the policy (the red vertical dotted line is the sample mean value of the control group and the treatment group in Table 6 before and after the implementation of the policy). It can be seen from Figure 2

that not only the differences of distance of the red vertical dotted line in the samples of treatment group of Tanglang and Dache before and after the implementation of the policy is longer than that of the control group, but also the change of the nuclear density function of the treatment group after the implementation of the policy is more obvious than that of the control group (the nuclear density curve of the treatment group after the implementation of the policy is further apart than before compared with the control group).



(**a**) (**b**)

Figure 2. Nuclear Density of per Capita Net Income of Households in the Control Group and the Treat Group Before and After the Implementation of the Policy. (**a**) Tanglang Village Committee of Tanglang Township; (**b**) Dache Village Committee of Zehei Township.

4.2. Model Estimation Results and Analysis

The results in Table 6 and Figure 2 make a simple comparison. In reality, there are other factors that restrict the per capita net income of households. Once these factors change, the per capita net income of households may also change. Therefore, the results in Table 6 only preliminarily reflect the changes of per capita net income of the sorghum planting group (treatment group) and the non-sorghum planting group (control group) before and after the implementation of this policy, and it ignores the influence of other factors. Therefore, we used a DID model to analyze the impact of the policy on the per capita net income of households (see Table 7).

Table 7. Impact of Promoting Sorghum Planting Policy on per Capita Net Income of Households: Estimation Results Based on DID Model.

Variable	Tanglang Village Committee		Dache Village Committee	
	(1)	(2)	(3)	(4)
time × *treat*	2045.35 *** (206.14)	5469.26 *** (1015.57)	2125.38 *** (509.85)	3990.35 *** (1022.18)
Control Variable	No	Yes	No	Yes
Sample	666	666	235	235
R^2	0.3166	0.5889	0.3262	0.4189

Note: the robust standard errors of clustering at the individual level are in the brackets of the estimation results. *** indicates that the original hypothesis is rejected at the significance level of 1%.

Table 7 shows that when the control variable is not added, the estimation results of the cross-multiplication term of *time* and *treat* are consistent with Table 6 (see columns (1) and (3) of the estimation results), but the clustering robust standard error estimation is used in Table 7, and the significance level of the estimation results changes.

Columns (2) and (4) of the estimation results in Table 7 consider the influence of other factors (control variables). From the estimation results, the control variables added changed greatly compared with the original, and the estimated results of *time* × *treat* are larger than when control variables are not added, and the estimated results are significant, indicating that after considering the impact of other important factors, the implementation of the policy still significantly increases the per capita net income of households of the treatment group.

However, there is still some deviation in the above results. As mentioned earlier, the government is likely not to treat all farmers equally in promoting the industry of sorghum planting. The government may be more willing to promote it among the poverty-stricken households. In addition, the government may be more willing to promote the sorghum industry policy to households with less workers or more land. This means the DID model ignores selection deviation. Therefore, households need to be matched in the estimation.

Table 8 shows the descriptive statistical results of control variables and the estimated results of the Probit model. It can be seen from Table 8 that there are obvious differences in most control variables between the treatment group and the control group, and the simple use of the DID model causes estimation bias. Therefore, it is necessary to use the Probit model to estimate whether the household is selected into the treatment group, and to match the two groups of samples according to the estimation results.

To more intuitively reflect the changes of various samples before and after matching, we considered the kernel density distribution of propensity scores before and after sample matching (see Figure 3).

Figure 3 shows that there are great differences in the kernel density function between the treatment group and the control group before the matching, but the distribution of the kernel density function tends to be similar after PSM. In the kernel density functions after matching, the treatment groups and the control groups have a common increasing and decreasing trend. It can be seen that using the PSM method to analyze the income benefits brought by the policy is more scientific and reasonable. According to the results of PSM, after removing some inappropriate samples, we used Kernel Matching, Five-nearest Neighbor Matching and Caliper Matching methods to calculate the Average Treatment Effect on the Treated (ATT) of promoting sorghum planting policies in two representative village committees (see Table 9).

Table 9 shows that the difference of ATT estimated by different methods was small. The results of Kernel Matching, Five-nearest Neighbor Matching and Caliper Matching methods showed that the effect brought by the promotion of sorghum planting and the purchase policy of protection price to the per capita net income of households in Tanglang village committee were 1591.90 CNY, 1364.19 CNY and 2181.96 CNY respectively, passing the significance level test of 1%. The average value of effect was 1712.68 CNY, equivalent to 42.82% of the national poverty alleviation standard line (4000 CNY/person) in 2020, indicating that the sorghum planting industrial policy significantly increased income of farmers in the Tanglang village committee. The results of the three methods for the Dache village committee were also very similar. The ATT calculated by Kernel Matching, Five-nearest Neighbor Matching and Caliper Matching method were 2168.75 CNY, 1986.16 CNY and 2320.51 CNY respectively, passing the significance level test of 5%, 10% and 1%, respectively. The average income increase value was 2158.47 CNY, equivalent to 53.96% of the national poverty eradication standard line (4000 CNY/person) in 2020. This shows that the sorghum planting industrial policy significantly increased income of households in the Dache village committee.

The significance level of the results of the Dache village committee was lower than that of the Tanglang village committee. The reason may be that the sample data size of the Tanglang village committee was larger (615 households after the Propensity Score Matching), while the sample size of the Dache village committee was 204 households after the Propensity Score Matching. Therefore, the robust standard error of the estimated results of the Dache village committee was higher, which reduced the significance level.

Nevertheless, the results of the model still show that the policy of promoting sorghum planting significantly increased the per capita net income of rural households in Tanglang and Dache village committees.

Table 8. Descriptive Statistics of Control Variables and Probit Model Estimation Results in 2016.

Village Committee Name	Control Variables	Mean Value (Standard Error in Brackets)			Difference	Probit Model Estimation Results
		Total Samples	Treatment Group	Control Group		
Tanglang Village Committee of Tanglang Township	*poverty*	0.37 *** (0.02)	0.53 *** (0.04)	0.30 *** (0.02)	0.23 *** (0.04)	0.7295 *** (0.1502)
	perwork	54.28 *** (1.02)	52.04 *** (1.37)	55.24 *** (1.34)	−3.20 (2.23)	0.0043 (0.0070)
	breed	32.68 *** (0.98)	36.56 *** (1.19)	31.01 *** (1.29)	5.55 *** (2.12)	0.0274 *** (0.0076)
	land	8.69 *** (0.16)	12.70 *** (0.29)	6.97 *** (0.14)	5.73 *** (0.28)	0.4044 *** (0.0299)
	population	77.07 *** (0.97)	82.60 *** (1.31)	74.70 *** (1.25)	7.90 *** (2.09)	0.0383 *** (0.0047)
Total Samples	—	666	200	466	—	—
_cons	—	—	—	—	—	−8.9107 *** (0.9195)
Pseudo R^2	—	—	—	—	—	0.5409
Dache Village Committee of Zehei Township	*poverty*	0.89 *** (0.02)	0.90 *** (0.04)	0.88 *** (0.03)	0.03 (0.05)	0.5131 (0.3596)
	perwork	29.18 *** (2.03)	32.43 *** (3.93)	27.74 *** (2.36)	4.68 (4.40)	0.0087 * (0.0049)
	breed	42.87 *** (1.97)	44.56 *** (3.28)	42.12 *** (2.44)	2.44 (4.27)	0.0089 * (0.0053)
	land	9.05 *** (0.17)	6.40 *** (0.15)	10.21 *** (0.18)	3.81 *** (0.27)	−0.5870 *** (0.0767)
	population	81.76 *** (1.14)	71.55 *** (2.32)	86.27 *** (1.12)	14.72 *** (2.29)	−0.0330 *** (0.0080)
Total Samples	—	235	72	163	—	—
_cons	—	—	—	—	—	5.7676 *** (0.9809)
Pseudo R^2	—	—	—	—	—	0.5570

Note: The "_cons" represents the constant term estimated by the model. *, ***, respectively, indicate that the original hypothesis is rejected at the significance level of 10% and 1%.

However, the Propensity Score Matching (PSM) model relies on the assumption of negligibility, and is not applicable to the case of selecting according to unmeasurable variables. For the observed data, if it is suspected that there is selection according to unmeasurable variables, it is better to use the Propensity Score Matching Difference-in-Differences (PSM-DID) estimator. The advantage of PSM-DID model is that it can control the differences between groups that are not observable and do not change with time. It combines the advantages of PSM model and DID model, avoiding the shortcomings of PSM model and DID model as much as possible, and has better effect and credibility.

We estimated the average treatment effect on the treated (ATT) of the promotion of sorghum planting policy using the PSM-DID model (Table 10).

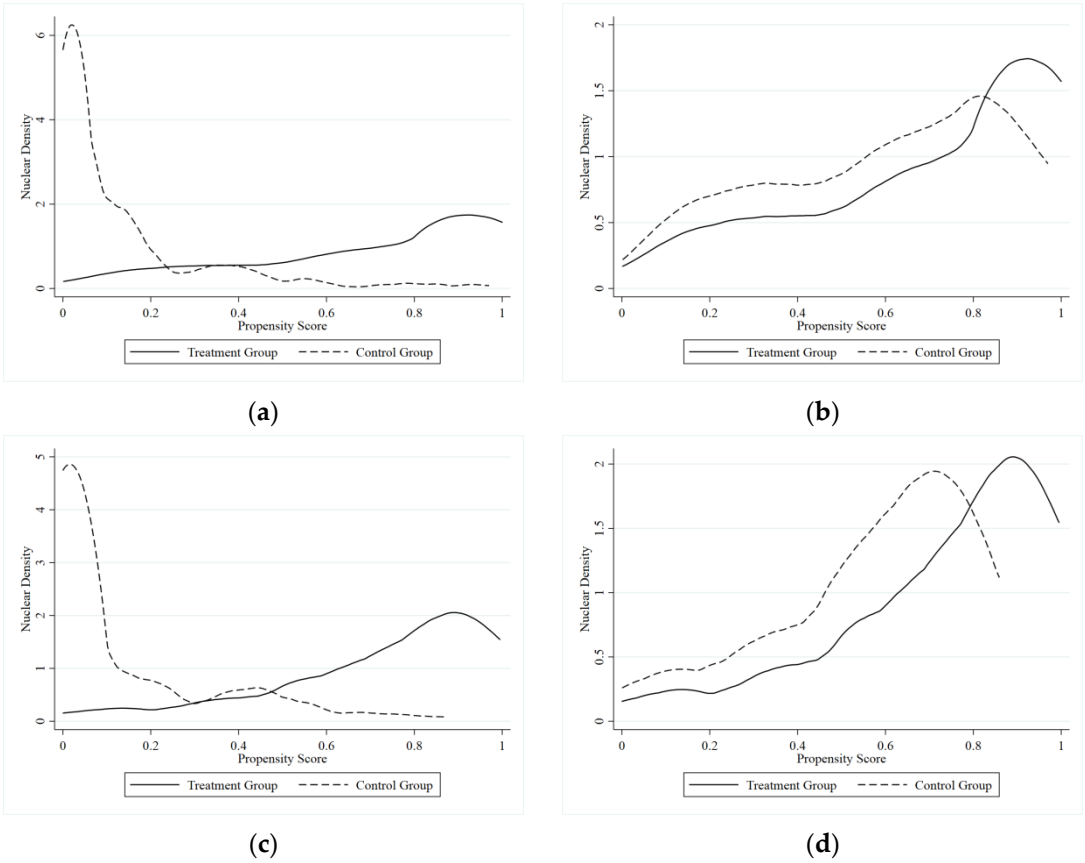


Figure 3. Kernel Density Function of Propensity Score. (**a**) Samples before matching in Tanglang Village Committee of Tanglang Township; (**b**) Samples after matching in Tanglang Village Committee of Tanglang Township; (**c**) Samples before matching in Dache Village Committee of Zehei Township; (**d**) Samples after matching in Dache Village Committee of Zehei Township.

Table 9. Average Treatment Effect on the Treated (ATT) of Promoting Sorghum Planting Policy.

Items	Tanglang Village Committee			Dache Village Committee		
	Kernel Matching	5 Nearest Neighbor Matching	Caliper Matching	Kernel Matching	5 Nearest Neighbor Matching	Caliper Matching
ATT	1591.90 *** (323.18)	1364.19 *** (348.59)	2181.96 *** (243.32)	2168.75 ** (932.20)	1986.16 * (1117.87)	2320.51 *** (654.01)
Treatment Group Samples	149	149	149	41	41	41
Control Group Samples	466	466	466	163	163	163
Total Samples	615	615	615	204	204	204

Note: the robust standard errors of clustering at the individual level are in the brackets of the estimation results. *, **, ***, respectively, indicate that the original hypothesis is rejected at the significance level of 10%, 5%, and 1%.

Table 10 shows that the ATT estimated by the PSM-DID model passed the significance level of 1%. The results show that the ATT brought to the per capita net income of households by the promotion of sorghum planting and purchase price guarantee policies of Tanglang and Dache village committee was 2171.64 CNY and 1945.06 CNY, respectively, equivalent to 54.29% and 48.63% of the national poverty alleviation standard line (4000 CNY/person) in 2020.

Table 10. Average treatment effect on the treated (ATT) estimation results obtained using the PSM-DID Model.

Items	Tanglang Village Committee	Dache Village Committee	Total
ATT	2171.64 *** (400.53)	1945.06 *** (642.53)	1726.87 *** (375.43)
Treatment Group Samples	195	56	267
Control Group Samples	430	145	626
Total Samples	625	201	893
R^2	0.26	0.67	0.34

Note: the robust standard errors of clustering at the individual level are in the brackets of the estimation results. *** indicates that the original hypothesis is rejected at the significance level of 1%.

The results of all samples further show that the sorghum planting industrial policy increased the income of households. The advantage of the PSM-DID model is that it can control differences between groups that are not observable and do not change with time, for example, the treatment group and the control group are from different regions. The results of the whole sample show that the ATT of the policy of promoting sorghum planting in Luquan County to the per capita net income of households was 1726.87 CNY, which is equivalent to 43.17% of the national poverty alleviation standard line (4000 CNY/person) in 2020, significantly increasing the income level of rural households.

4.3. Test of Model Estimation Results

4.3.1. Robustness Test

After using PSM-DID model to estimate the results and analyze them, it was first necessary to ensure the robustness of the model. Therefore, this study used the method of bilateral tail cutting to verify the robustness of the model. The results of two typical village committees were processed by 1.5%, 2.0% and 2.5% bilateral tail cutting respectively, and the average treatment effect on the treated (ATT) was obtained (Table 11).

Table 11. Robustness Test Results.

Items	Tanglang Village Committee			Dache Village Committee		
	1.5%	**2.0%**	**2.5%**	**1.5%**	**2.0%**	**2.5%**
ATT	2070.21 *** (306.94)	2080.17 *** (290.27)	2064.71 *** (282.66)	1823.16 *** (624.63)	1679.15 *** (605.23)	1679.15 *** (605.23)
Treatment Group Samples	195	195	195	56	56	56
Control Group Samples	430	430	430	145	145	145
Total Samples	625	625	625	201	201	201
R^2	0.36	0.38	0.39	0.68	0.69	0.69

Note: the robust standard errors of clustering at the individual level are in the brackets of the estimation results. *** indicates that the original hypothesis is rejected at the significance level of 1%.

Table 11 shows that after 1.5%, 2.0% and 2.5% bilateral tail cutting of the sample, the average treatment effect on the treated (ATT) results of the Tanglang village committee of Tanglang Township and Dache village committee of the Zehei Township both passed the significance level test of 1%, and the difference of estimation coefficients under different bilateral tail cutting was very small, which indicates that the model is robust.

4.3.2. Placebo Test

There are many methods for the placebo test, among which the most usual is to randomly set a control group and treatment group to test whether the experimental effects deviate significantly from other hypothetical results [49,50].

For samples from the Tanglang village committee, we randomly selected 200 samples from 666 samples as the treatment group, and the remaining 466 samples as the control group, added various control variables, and conducted random trials 500 times. Similarly, for the samples of the Dache village committee, 72 samples were randomly selected from 235 samples as the treatment group, and the remaining 163 samples were regarded as the control group. All control variables were added, and random trials were conducted 500 times. Figure 4 shows the placebo test results of the samples from the two village committees.

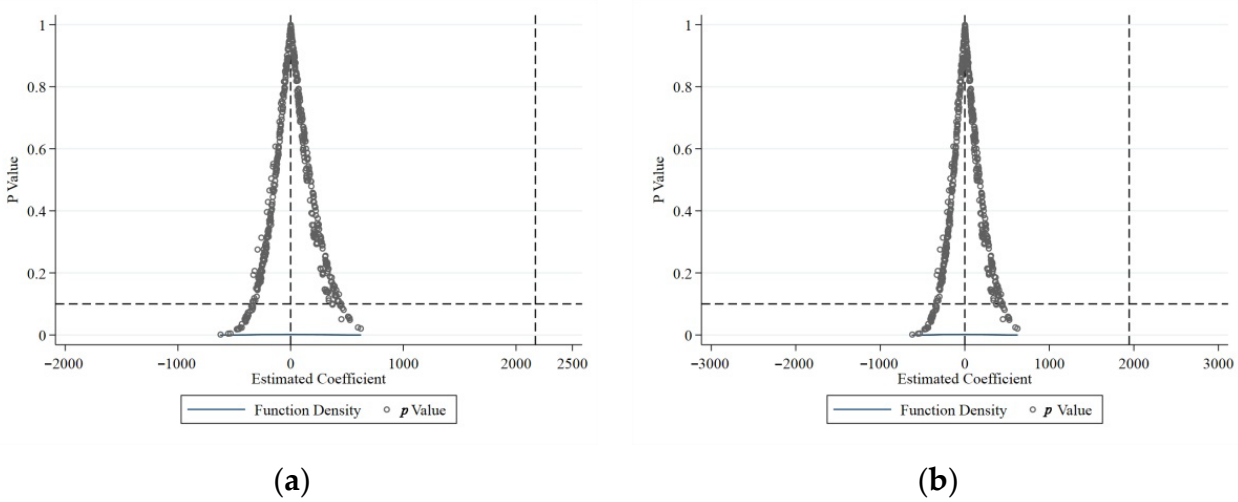


Figure 4. Placebo test results. (**a**) Samples in Tanglang Village Committee of Tanglang Township; (**b**) Samples in Dache Village Committee of Zehei Township.

Taking the PSM-DID estimation results as an example, the ATT estimation results of the Tanglang village committee and Dache village committee were 2171.64 CNY and 1945.06 CNY, respectively. It can be seen from Figure 4 that the ATT estimation results were obviously abnormal values in each village committee, and the *p* values corresponding to 2171.64 CNY and 1945.06 CNY were far less than 0.10, which shows that the model passed the placebo test and was unlikely to be affected and driven by other factors.

5. Conclusions and Discussion

5.1. Conclusions

Poverty is a serious challenge facing the world today. As one of the largest developing countries in the world, China has a heavy responsibility in fighting poverty [44,50]. Since 2014, the targeted poverty alleviation policy implemented in China has effectively changed the poverty situation. Although there are various perspectives to study the effectiveness of poverty alleviation, industrial poverty alleviation plays a decisive role, ranking first among the "five-pronged poverty alleviation measures". An in depth analysis of the poverty alleviation effects brought by local characteristic industries can not only provide useful references for clarifying the implementation effect of China's targeted poverty alleviation policy, but can draw on the experience of implementing the Rural Revitalization Strategy, and formulate more specific and thorough policies for industrial prosperity. Based on the survey data of 901 households of representative village committee of Tanglang and Dache in Luquan Yi and Miao Autonomous County, this study quantitatively analyzed the poverty alleviation effect of the sorghum planting industry by using the Propensity Score Matching Difference-in-Differences (PSM-DID) model. In addition, this study developed an alternative perspective on poverty alleviation and sustainable development and supported empirically the Loewenstein-Bender model [51–53]. The results show that Luquan County's industrial poverty alleviation policy of promoting sorghum planting and guaranteeing its purchase price effectively increased the income of households. The results of the PSM-DID

model showed that the ATT of promoting sorghum planting and the guaranteed purchase price policy by Tanglang village committee of Tanglang Township and Dache village committee of Zehei township led to an increase in per capita net income of households of 2171.64 CNY and 1945.06 CNY, respectively, equivalent 54.29% and 48.63%, respectively, of the national poverty alleviation standard line (4000 CNY/person) in 2020. The estimation results of the whole sample show that the ATT of the policy to the per capita net income of households is 1726.87 CNY, which is equivalent to 43.17% of the national poverty alleviation standard line (4000 CNY/person) in 2020, which significantly promotes the income increase level of farmers. This has played an important role in improving the per capita net income of households and bringing about poverty alleviation of households. The effect of poverty alleviation is significant, and the model is robust and not affected by other factors in a great extent.

5.2. Discussion

Poverty is a serious challenge in the world today, restricting local sustainable development in a great extent. Poverty reduction is a basic requirement of human social development [44,50]. Yunnan Province is located in the southwest border of China, the ecological environment is relatively fragile, there are more mountains than flat land, and poverty is widespread [54–56]. Although existing research has provided useful data, there are aspects that need to be improved. First of all, many existing studies do not focus on the increase of farmers' income. Second, some scholars have focused on macro results concerning the development of characteristic industries within a large region, rather than on individuals, nor did they use sophisticated policy evaluation models to divide individual households into control groups and treatment groups for comparative analysis. In addition, the existing research ignored a critical question: can the characteristic industries achieve sustainable development while bringing about poverty alleviation? In other words, the existing research has not developed an alternative perspective focusing on the poverty alleviation effect and sustainable development brought by characteristic industries.

Luquan County, located in Kunming, is one of 88 poverty-stricken counties in Yunnan Province, and is located in the dry and hot valley of the Jinsha River in the upper reaches of the Yangtze River. Based on field investigations, our study found that the practice of promoting sorghum planting industry in the Jinsha River dry and hot valley area has led to poverty alleviation in Luquan County since 2017, with the double goals of developing characteristic industries to increase income and preventing non-grain production on cultivated land [44]. Based on the survey data of 901 households of Tanglang Village Committee in Tanglang Township and Dache Village Committee in Zehei Township, which are typical of Luquan County, this study quantitatively analyzed the poverty alleviation effect of the sorghum planting industry using the Propensity Score Matching Difference-in-Differences (PSM-DID) model. The results show that the industrial poverty alleviation policy of promoting sorghum planting and guaranteeing its purchase price in Luquan County effectively increased the income of households. Luquan County, during the period of consolidating poverty alleviation and implementing the rural revitalization strategy promoted the brand and influence of the Langzhitang distillery, expanded the scale of the distillery, set up Langzhitang distillery tasting stores in Yunnan Province and other regions around Yunnan Province, and gradually promoted Langzhitang products, which expanded the scale of sorghum planting accordingly. On the basis of rational distribution of sorghum planting land according to local conditions, more households should master the technology and methods of sorghum planting, widely participate in the development of sorghum industry, and promote households to increase production and income, exploring a new mode and new path for enterprises to drive income growth of impoverished households and achieve sustainable development.

Developing characteristic industries is a requirement for poverty alleviation and rural revitalization, but preventing non-grain production on cultivated land is also a major national strategy. In recent years, the authors have visited impoverished areas

in more than 10 counties to participate in third-party assessment of targeted poverty alleviation. According to field surveys and assessment, to develop characteristic industries and ensure increased income of farmers (especially those officially registered poverty-stricken households), most of the cultivated land for long-term planting of traditional food crops, such as corn, has been use to cultivated economic crops with higher output value, such as fruits, and even used for dug ponds to raise fish. Although the economic benefits are significant, there has also been a trend of non-grain production on cultivated land (some cultivated land is basic farmland), which is contrary to national policy. The contradiction between preventing non-grain production on cultivated land and developing characteristic industries (especially poverty alleviation industries) is major problem in rural revitalization, but it is not unsolvable. The conflict between the two needs to be resolved from a strategic perspective.

Sorghum planting in Luquan County shows that the selection of suitable crops, scientific development and planting in accordance with the principles of ecological suitability for suitable for planting and living, can not only prevent non-grain production on cultivated land, but also have economic benefits, create poverty alleviation and the requirements of the rural revitalization strategy for industrial support. This is an effective path to solving the problem of "What about grain?" by President Xi. Our results contribute to the development of characteristic industries in less-favoured areas, and to the exploration of a win-win path that takes into account the overall planning of developing characteristic industries to increase income, and preventing non-grain production on cultivated land, as well as the sustainable development of the economy, society and ecology.

6. Enlightenment

An in depth analysis of the poverty alleviation effects brought by local characteristic industries can not only provide useful references for clarifying the implementation effect of China's targeted poverty alleviation policy, but also draw on the experience of implementing the Rural Revitalization Strategy and formulate more specific and thorough policies for industrial prosperity. However, there is still a lack of quantitative research on the poverty alleviation effect of regional characteristic industries. Few studies have focused on the increase of individual income or use advanced policy evaluation tools for comparative analysis based on a quasi-experimental perspective. In addition, the existing research ignores a critical question: can characteristic industries really achieve sustainable development while bringing about poverty alleviation effects? In view of the shortcomings and the aspects that need to be improved of the current research, we studied regional characteristic industries from a new perspective, and took into account the poverty alleviation effect of characteristic industries and regional sustainable development. The contribution of this study lies in studying regional characteristic industries from a new perspective, and taking into account the poverty alleviation effect of characteristic industries and regional sustainable development. Land suitability evaluation results show that there are sufficient land resources suitable for planting sorghum [44]. We found that the sorghum planting characteristic poverty alleviation industry in Luquan County has economic, social and ecological sustainability. Figure 5 clearly shows the sustainability characteristics of this industry.

Since the 14th five-year plan, China's rural industrial development has entered a new development era. Although research on the effect of sorghum planting on poverty alleviation and development in the dry-hot valley of Jinsha River in Luquan County is preliminary attempt, it has achieved great results. At present, the sorghum planting industry in the dry-hot valley of the Jinsha River has been expanded to the surrounding counties in Sichuan Province and Yunnan Province, with a great development prospect.

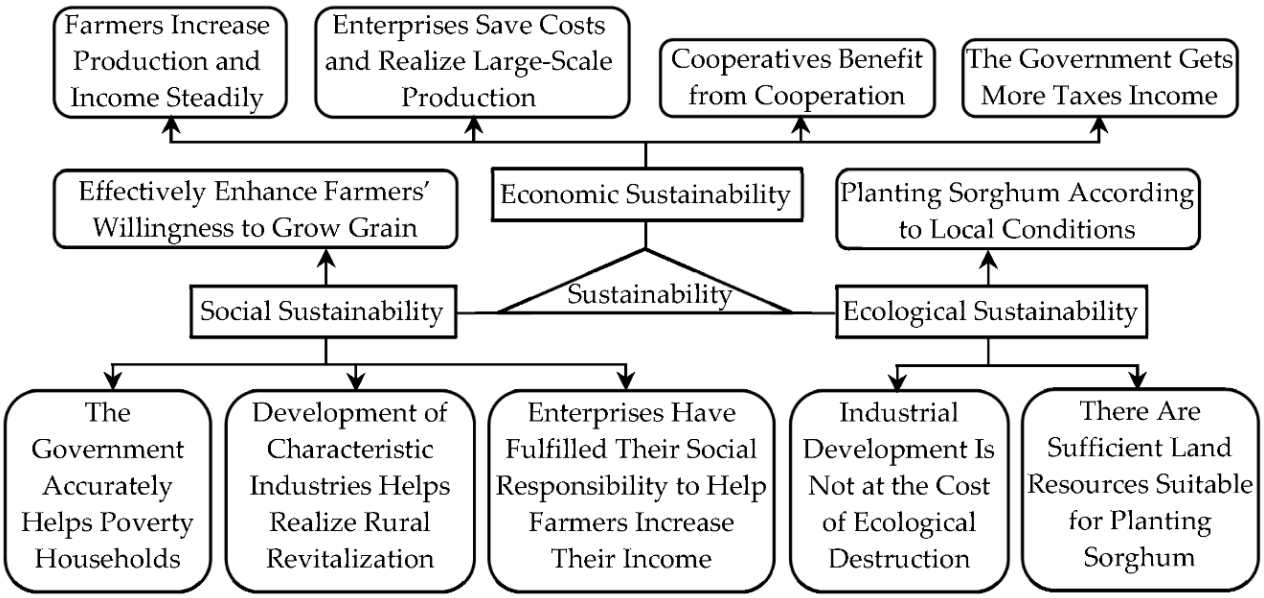


Figure 5. Sustainability of Poverty Alleviation Characteristic Industry of Sorghum Planting in Luquan County.

The development of sorghum planting in Luquan County shows that reasonable selection of suitable crops and scientific development, and planting in accordance with ecological principles of "suitable for planting and living" can not only prevent non-grain production on cultivated land, but also produce economic benefits, and ensure the consolidation of the results of poverty alleviation and the requirements of the Rural Revitalization Strategy for industrial support.

Author Contributions: Conceptualization, R.Y. and Z.Y.; methodology, R.Y.; software, R.Y.; validation, Z.Y.; formal analysis, R.Y. and Z.Y.; investigation, R.Y.; resources, R.Y.; data curation, Z.Y.; writing—original draft preparation, R.Y.; writing—review and editing, Z.Y.; visualization, Z.Y.; supervision, Z.Y.; project administration, Z.Y.; funding acquisition, Z.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China, grant number 41261018.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of Institute of Targeted Poverty Alleviation and Development, Yunnan University of Finance and Economics (protocol code: ITPAD-Que-Mar-002 and date of approval: 18 March 2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patients to publish this paper.

Data Availability Statement: The statistical data of Luquan County, Yunnan Province and the whole country can be obtained through the following links: "http://stats.yn.gov.cn/" or "https://www.epsnet.com.cn/index.html#/Index". The questionnaire data of this study cannot be obtained because many questions involve the privacy of 901 households and they are unwilling to disclose their questionnaire results officially.

Acknowledgments: For field investigations and analysis, we thank Fenglian Liu, Bosheng Zhang, Qiuju Wu, Yingying Huang and Yongdong Zhang of the Institute of Land & Resources and Sustainable Development, Yunnan University of Finance and Economics, Kunming 650221, China. Furthermore, we would like to deeply thank Fenglian Liu, Bosheng Zhang and Qiuju Wu for their contributions to data processing and drawing figures, Fenglian Liu for her suggestions and help in writing the manuscript, Yingying Huang and Yongdong Zhang for their contribution to the grammar check of the

manuscript. Finally, we sincerely thank Elkhan Richard Sadik-Zada for his support and affirmation of our manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1 shows the statistical description of each variable:

Table A1. Statistical description of independent variables and the dependent variable.

Symbols of the Variables	Village Committee Name	Year	MIN	MAX	MED	SD	CV	P25	P75
income	Tanglang	2016	1275.00	29,400.00	5629.00	2081.96	0.36	4732.83	6575.00
	Tanglang	2020	4666.67	44,550.00	8316.95	2814.01	0.32	6897.14	9993.33
	Dache	2016	1609.13	18,200.00	4100.00	2653.02	0.53	3106.51	6647.14
	Dache	2020	3744.78	21,965.88	8244.79	3286.76	0.37	6409.16	10,856.00
treat	Tanglang	2016	0.00	1.00	0.00	0.46	1.53	0.00	1.00
	Tanglang	2020	0.00	1.00	0.00	0.46	1.53	0.00	1.00
	Dache	2016	0.00	1.00	0.00	0.46	1.51	0.00	1.00
	Dache	2020	0.00	1.00	0.00	0.46	1.51	0.00	1.00
poverty	Tanglang	2016	0.00	1.00	0.00	0.48	1.30	0.00	1.00
	Tanglang	2020	0.00	1.00	0.00	0.48	1.30	0.00	1.00
	Dache	2016	0.00	1.00	1.00	0.32	0.36	1.00	1.00
	Dache	2020	0.00	1.00	1.00	0.32	0.36	1.00	1.00
perwork	Tanglang	2016	0.00	99.52	62.55	26.43	0.49	37.92	73.29
	Tanglang	2020	0.00	100.00	54.78	23.91	0.45	42.52	67.81
	Dache	2016	0.00	100.00	27.93	31.13	1.07	0.00	49.24
	Dache	2020	0.00	100.00	54.47	26.99	0.49	35.95	73.44
breed	Tanglang	2016	0.00	100.00	23.99	25.20	0.77	14.07	46.69
	Tanglang	2020	0.00	100.00	25.82	20.69	0.68	17.84	37.02
	Dache	2016	0.00	100.00	39.02	30.16	0.70	19.74	61.93
	Dache	2020	0.00	93.27	27.73	23.83	0.82	6.09	46.00
sorghum	Tanglang	2020	0.00	32.98	0.00	7.57	1.63	0.00	10.55
	Dache	2020	0.00	35.94	0.00	5.98	1.79	0.00	6.99
land	Tanglang	2016	2.00	24.00	8.00	4.25	0.49	6.00	12.00
	Tanglang	2020	2.00	24.00	8.00	4.25	0.49	6.00	12.00
	Dache	2016	5.00	15.00	9.00	2.68	0.30	7.00	11.00
	Dache	2020	5.00	15.00	9.00	2.68	0.30	7.00	11.00
population	Tanglang	2016	0.00	100.00	80.00	25.00	0.32	60.00	100.00
	Tanglang	2020	0.00	100.00	80.00	25.00	0.32	60.00	100.00
	Dache	2016	16.67	100.00	80.00	17.49	0.21	71.43	100.00
	Dache	2020	16.67	100.00	80.00	17.49	0.21	71.43	100.00

MIN represents the minimum value of the statistical data; MAX represents the maximum value in the statistical data; MED stands for the median of statistical data; SD represents the standard deviation of the statistical data; CV is the coefficient of variation in the statistical data; P25 represents the value at 25% after sorting the statistical data from low to high; P75 represents the value at 75% after sorting the statistics from low to high.

Appendix B

Table A2 shows the questionnaire of Tanglang Village Committee in Tanglang Township and Dache Village Committee in Zehei Township:

Table A2. Sample of questionnaire of Tanglang Village Committee in Tanglang Township and Dache Village Committee in Zehei Township.

Questions	Fill in Instructions or Options
I. Basic information of the household	
I-A. Name of the head of household	Fill in Chinese characters.
I-B. Gender of the head of household	(1) male (2) female
I-C. Contact information of the head of household	Fill in mobile phone number or landline number.
I-D. Family population	Fill in positive integer; unit: person.
I-E. Population aged 18–65	Fill in positive integer; unit: person.
I-F. Did the household plant sorghum in 2016 or before?	(1) Yes (2) No Note: Considering the preciseness of the research design, it is necessary to find households who did not plant sorghum in 2016 or before to conduct a questionnaire survey.
I-G. Was the household promoted to plant sorghum from 2017 to 2019 and purchased sorghum at a protective price?	(1) Yes (2) No
I-H. Was the household previously included in the officially registered poverty-stricken households?	(1) Yes (2) No
II. Income level of the household	
II-A. How much was the household's income from planting industry in 2016?	Unit: CNY.
II-B. How much was the household's expenditure from planting industry in 2016?	
II-C. How much was the household's income from planting industry in 2020?	
II-D. How much was the household's expenditure from planting industry in 2020?	
II-E. How much was the household's income from planting sorghum in 2020?	Unit: CNY; 0 if sorghum was not planted.
II-F. How much was the household's expenditure from planting sorghum in 2020?	
II-G. How much was the household's income from the breeding industry in 2016?	Unit: CNY.
II-H. How much was the household's expenditure from the breeding industry in 2016?	
II-I. How much was the household's income from the breeding industry in 2020?	
II-J. How much was the household's expenditure from the breeding industry in 2020?	
II-K. How much was the household's other productive and operational income from business and other ways in 2016?	Unit: CNY. Note: The income/expenditure of planting industry and the income/expenditure of breeding industry are included in the productive and operational income/expenditure. These statistical indicators here refer to other productive and operational income/expenditure except the income/expenditure of planting industry and the income/expenditure of breeding industry.
II-L. How much was the household's other productive and operational expenditure from business and other ways in 2016?	
II-M. How much was the household's other productive and operational income from business and other ways in 2020?	
II-N. How much was the household's other productive and operational expenditure from business and other ways in 2020?	

Table A2. *Cont.*

Questions	Fill in Instructions or Options
II. Income level of the household	
II-O. How much was the household's wage income obtained from going out to work in 2016?	Unit: CNY.
II-P. How much did the household's spend on going out to work in 2016?	
II-Q. How much was the household's wage income obtained from going out to work in 2020?	
II-R. How much did the household's spend on going out to work in 2020?	
II-S. How much was the household's property income in 2016?	Unit: CNY. Note: the property income includes land transfer, photovoltaic income, share dividend and other related income.
II-T. How much was the household's property income in 2020?	
II-U. How much was the household's transfer income in 2016?	Unit: CNY. Note: the transfer income includes the funds for guaranteeing a minimum standard of living (subsistence allowances), extreme poverty aid, various subsidies, child support and other related income.
II-V. How much was the household's transfer income in 2020?	
II-W. How much was the household's net income in 2016?	Unit: CNY. Note: the calculation method is all net income from production and operation in the current year (deducted the expenditure) + all net wage income obtained from going out to work in the current year (deducted the expenditure) + all property income in the current year + all transfer income in the current year.
II-X. How much was the household's net income in 2020?	
II-Y. How much was the per capita net income of the household in 2016?	Unit: CNY. Note: the calculation method is: the household's net income in the current year/total population of the household
II-Z. How much was the per capita net income of the household in 2020?	
III. Other related questions	
III-A. What was the contracted land area of the household in 2016?	Unit: mu. Note: "mu" is an area unit commonly used in the questionnaire survey, and 1 hectare (ha) is equal to 15 mu. This means that 1 mu is about 0.067 ha.
III-B. What was the contracted land area of the household in 2020?	

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