Study on the Influence of Straw Resources and Comprehensive Utilization on Green Agricultural Development in Yantai

Feifei Du [a], Geng Lu [b]

China Agricultural University YanTai Institute, Shandong Yantai, China

[a] caudff@163.com, [b] 529225082@qq.com

Abstract. To explore the impact of comprehensive utilization of straw resources on green agricultural development in Yantai, this thesis comprehensively analyzes the crop straw resources and utilization in Yantai in recent five years according to the Yantai Statistical Yearbook (2017-2021), which estimates the number of straw resources and comprehensively assesses the potential of straw fertilizing and biogas utilization during that period in Yantai. Moreover, reasonable suggestions are put forward for the comprehensive utilization of straw in Yantai in the future based on its current situation and existing problems of straw resource utilization. Through the research and integrated analysis of this paper, it can provide relevant advice for the development of comprehensive straw utilization in Yantai, so as to develop green agriculture sustainably and promote the building of a resource-saving and environment-friendly society.

Key Words: Estimation of Straw Resources, Energy Utilization Potential, Biomass, Comprehensive Utilization of Straw.

1. Introduction

Straw refers to the remaining part of wheat, rice, corn, potato, rape, and other crops (usually coarse grains) after removing the grain and chaff. In 2021, Central Document No.1 proposed to comprehensively boost rural revitalization and accelerate the modernization of agriculture and rural areas, including enhancing the green development of agriculture and fully implementing the comprehensive utilization of straw. Therefore, the utilization of straw resources is particularly important in this trend. According to the data on crop straw production and collectible resources in China from 2010 to 2020 by Prospective Industry Research Institute (as shown in Figure 1), the average annual output of crop straw in China is nearly 800 million tons and that of the average annual collectible resources is 670 million tons. With the rich straw resources in China, reasonable collection and utilization of straw resources will be beneficial to the environmental protection and energy supply in China.

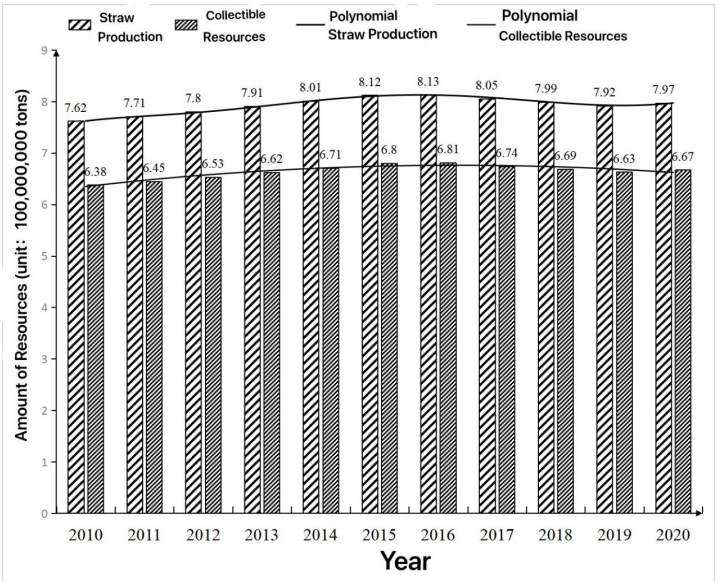

Figure 1. Crop Straw Production and Collectible Resources Scale in China from 2010 to 2020

This paper summarizes and analyzes the straw utilization and related policies at home and abroad from the end of the 20th century to the present. Premised on the amount of crop production recorded in the Yantai Statistical Yearbook from 2016 to 2020, coefficient and formula are used to estimate the amount and potential of straw resources in Yantai during this period. In addition, by drawing lessons from the experience of straw utilization at home and abroad in recent years, the author also sorted out and analyzed the current situation of straw utilization in Yantai as well as put forward reasonable suggestions on the straw energy utilization for the city in the future.

2. Overseas Straw Utilization

Since the end of the 20th century, some countries in the world have taken the lead in straw utilization. Denmark was the first to use the straw to generate electricity worldwide, burning 150,000 tons of straw every year to meet the heating and electricity demand of hundreds of thousands of users. At present, more than 130 straw bio-power plants have been established in Denmark, and renewable energy such as straw power generation accounts for more than 24% of the national energy consumption [1]. In the United States, straw can be used to make fertilizer, feed, building materials, and cellulose ethanol [1]. Thanks to the government subsidy policy and the promulgation of relevant environmental protection laws, the United States has achieved extraordinary results in straw utilization. Straw utilization in Japan includes mechanically crushing the straw to produce fertilizer recycling to the field (the main way of utilization), making roughage for livestock and poultry, and straw extracting ethanol from its cellulose, which greatly taps the potential of straw resources in agricultural production [2].

To sum up, the utilization of straw resources abroad mainly consists of conservation tillage (fertilizing utilization), straw feed, combustion power generation, straw reprocessing products (straw-extracted cellulose ethanol, straw-made building materials, etc.).

3. Analysis of the Present Situation and Utilization of Straw Resources in China

3.1 Distribution and Utilization of Straw Resources in China

Having studied the temporal and spatial distribution characteristics of crop straw resources in China for nearly 20 years, Ran Jiwei et al. found that the straw resources of major crops in China showed a steady growth trend. Affected by different economic development models, adjustment of planting structure, variations in planting conditions and production preferences, the spatial and temporal distribution of major crops such as rice, wheat, and corn was significantly diverse [3]. From the perspective of space, sharp differentiation can be seen in the density of straw resources for energy utilization in eastern and western China [4]. From the perspective of yield distribution, the total straw yield in the main grain-producing areas of northern and eastern China is relatively higher than that in southern and western China. In terms of grain variety, the yield of rice and wheat straw is the highest in East China, while that of beans and corn straw is highest in Northeast China [5].

In early years of the founding of China, straw was used as daily heating and feed for livestock and poultry [6]. After that, with the increase in straw yield, a large number of straws were burned in the open air, triggering serious environmental pollution. With the promotion of people's environmental awareness and the formulation of the policy prohibiting straw burning in modern times, the phenomenon of straw burning in the open air has been effectively reduced. Currently, the straw in China is mainly used in agriculture (fertilizing and feed utilization account for 77.35% of the total utilization), supplemented by the utilization of fuel (14.27%), base material (4.98%), and raw material (3.40%) [7]. Among them, straw fertilization mainly includes direct returning of straw, carbonization, and organic fertilizer recycling to the field [8]. Straw feed mainly adopts straw ammoniation, traditional silage, microbial silage, pellet feed, and other technologies [9]. At the same time, the government issued policy guidance and agricultural subsidies to encourage the utilization of agricultural waste straws. In 2021, the performance appraisal meeting of the straw comprehensive

utilization project pointed out that the comprehensive utilization rate of straw in China climbed to 87.6%.

3.2 Policies Related to Straw Utilization in China

With more and more emphasis on the utilization of straw resources, China has issued relevant laws such as the Agriculture Law of the People's Republic of China, Law of the People's Republic of China on the Promotion of Circular Economy, and Environmental Protection Law of the People's Republic of China to encourage and support the comprehensive utilization of crop straw and prevent environmental pollution and ecological damage [10]. In order to implement the straw agricultural utilization, the General Office of the Ministry of Agriculture issued the document in 2017 named Top Ten Models of Straw Agricultural Utilization[11], tailoring the utilization model to local conditions for six major straw producing areas, such as Northeast China, Northwest China, and Huang-Huai-Hai Region. To improve the comprehensive utilization of straw with higher quality and efficiency, the General Office of the Ministry of Agriculture and Rural Affairs and the National Development and Reform Commission issued the Catalogue of Straw Comprehensive Utilization Technology (2021), which specifically clarifies five utilization technologies including transforming straw into fertilizer, feed, fuel, base material, and raw material, as well as specific technical types and advice for implementation. The release of this document shows that China has a relatively complete technical system for the straw comprehensive utilization.

3.3 Problems in Straw Utilization in China

The biggest problem of straw utilization in China lies in the high cost. Due to its backward technology, the imperfect system of straw collection, storage, and transportation, and unreasonable structure, the economic benefits of straw utilization reduce [12]. In terms of straw utilization technology, there are 68,900 patents related to crop straw in the world by 2020. Among them, the institutions with a large number of patent applications in China are scientific research institutes and universities, while those in foreign countries are predominantly companies. Chinese patent applications that are inferior to foreign countries are characterized by their small scale and spatially scattered distribution [13]. In terms of straw collection, storage, and transportation system, there are two main modes in China: decentralized mode and centralized mode, both with farmers, specialized households, and farms as the main supply, straw brokers and professional straw collection, storage, and transportation companies as the main media. Nowadays, lacking unified acceptance criteria [14] and national standard is detrimental to the sound development of China's straw collection, storage, and transportation system. In the future, with the perfect straw collection, storage, and transportation systems in foreign countries featuring high density and large scale [15], the centralized mode will become the mainstream. In terms of straw utilization structure, the basic utilization without advanced technique accounts for a large proportion, while the energy and raw material utilization take up a small proportion. In China, 66% of straw is directly burned or returned to the field as domestic energy, 12% is processed into feed for feeding livestock and poultry, 19% is processed for building or covering materials for vegetable production, and only 3% is used to make handicrafts [12].

4. Estimation of Straw Resources and Analysis of Energy Utilization Potential in Yantai

4.1 Data Sources

Considering the planting species and structure of main crops in Shandong Province and the production situation in Yantai in recent years, this paper selects cereals (including wheat, corn, millet, and sorghum), beans (including soybean and mung bean), potatoes and oil crops (peanuts) as the main research objects. Crop planting data comes from Yantai Statistical Yearbook (2017-2021) issued by Yantai Statistics Bureau.

4.2 Straw Resources

As an important index to evaluate crop output efficiency, the crop straw coefficient refers to the ratio of crop straw yield to crop economic yield, which is also known as the grain-straw ratio. By consulting relevant data, the crop straw coefficient studied in this paper is shown in Table 1 [16-17].

Table 1. Figure of Straw Coefficient of Main Crops in Shandong Province

Crop Species	Wheat	Corn	Millet	Sorghum	Beans	Potato	Peanut
Straw Coefficient	1.33	0.96	2.03	0.85	1.36	0.42	0.89

According to the calculation formula: Crop Straw Yield = Economic Yield * Straw Coefficient [5]. Crop straw resources in Yantai in recent years are comprehensively evaluated and analyzed in this paper (as shown in Table 2, Table 3, and Figure 2).

Table 2. Estimation of Crop Straw Resources in Yantai (10,000 tons)

Year/Species	Wheat	Corn	Millet	Sorghum	Beans	Potato	Peanut	Total Crop Straw Yield
2016	127.26	137.82	0.52	0.06	4.46	4.33	37.04	311.47
2017	87.95	98.13	0.74	0.02	2.91	2.50	37.54	229.80
2018	98.15	95.45	0.85	0.01	3.57	2.87	36.67	237.56
2019	93.85	86.76	0.90	0.01	4.30	3.37	35.33	224.52
2020	89.20	90.56	0.87	0.01	3.73	4.16	36.97	225.50

According to Table 2, from the estimated results of straw yield and total yield of main crops in Yantai each year, straw resources of wheat, corn, and peanut are the majority in Yantai, with 40.4%, 41.4%, and 14.9% as their respective average annual shares of the entire straw resources in the city. In the future, straw utilization in Yantai can be targeted at these three crops.

Table 3. Distribution of Crop Straw Resources in Yantai from 2016 to 2020 (10,000 tons)

Area/Year	2016	2017	2018	2019	2020
Laizhou City	78.56	65.88	66.66	62.86	61.40
Laiyang City	69.77	51.80	52.52	50.03	52.19
Haiyang City	48.75	35.37	39.81	37.97	36.33
Zhaoyuan City	41.37	27.74	29.66	28.83	29.98
Qixia City	19.39	13.46	13.22	12.03	11.55
Muping District	18.15	13.96	12.93	12.53	13.02
Longkou City	14.86	11.12	11.89	10.56	11.25
Penglai City	14.72	6.32	7.20	6.44	6.45
Fushan District	2.32	1.73	1.48	1.45	1.87
Lai Shan	1.65	1.12	1.13	1.02	1.06
Development Zone	0.90	0.77	0.59	0.32	0.18
Kunyu District	0.75	0.37	0.37	0.34	0.13
High-tech Zone	0.19	0.06	0	0.06	0.05
Zhifu District	0.05	0.05	0.05	0.04	0.03
Changdao County	0.05	0.04	0.04	0.03	0.02

Note: The sowing data of crops in the High-tech Zone is 0 in Yantai Statistical Yearbook in 2019.

It can be seen from Table 3 that the areas rich in straw resources in Yantai from 2016 to 2020 are Laizhou City, Laiyang City, Haiyang City, and Zhaoyuan City in descending order, with average annual straw resources of 67.07, 55.26, 39.65 and 315,200 tons. The output of straw resources in these four regions accounts for 78.73% of the total straw resources in Yantai.

Generally speaking, the estimated sum of straw resources in the whole city from 2016 to 2020 shows a decreasing trend (Figure 2). Except for about 3.115 million tons of straw resources in 2016,

the estimated amount of straw resources from 2017 to 2020 is only around 2.2 million tons. Implementing the Master Plan of Territorial Space in Yantai which leads to the drop of cultivated land and the increase of current forest land may result in this phenomenon [18]. Therefore, the cultivated land where crops are planted is used for planting trees, inciting the decline of crop straw resources.

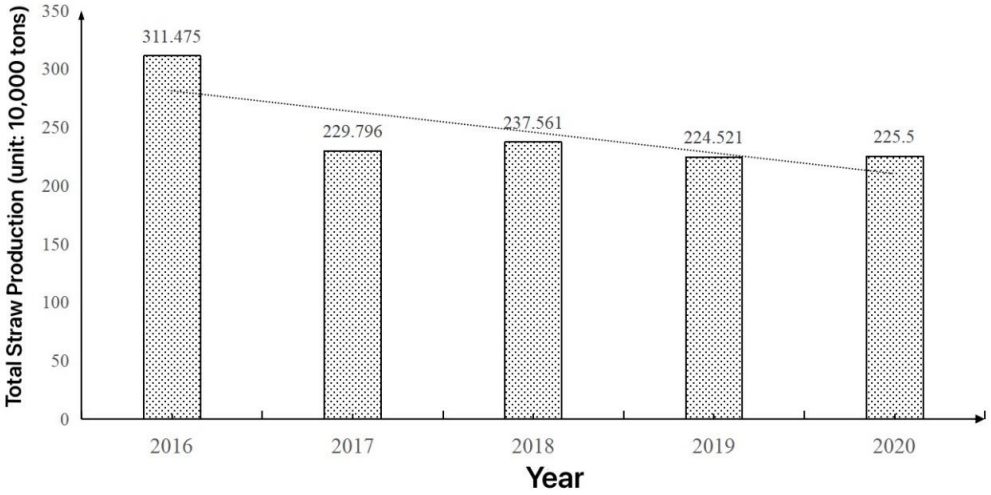

Figure 2. Estimation of Annual Straw Output in Yantai (10,000 tons)

4.3 Energy Utilization Potential of Straw

According to the above estimation of relative resources of various crop straws in Yantai, this paper selects wheat, corn, millet, beans, potatoes, and peanuts as the research objects, mainly involving the analysis of fertilizer and biogas utilization.

4.3.1 Potential of Straw fertilizing Utilization

Based on the results of Pang Lihao's research, this paper analyzes the fertilizing utilization potential of main crop straw resources in Yantai from 2016 to 2020 by referring to the proportion of dry matter, organic matter, nitrogen, phosphorus, and potassium in crop straw as well as their calculation methods [16]. Analysis results of converting nitrogen to urea (46-0-0), phosphorus to calcium superphosphate (0-12-0), and potassium to potassium sulfate (0-0-50)[19] can be seen in Table 4.

Table 4. Estimation of N, P, and K Contents in Straw and Fertilizer Production in Yantai in Recent 5 Years (10,000 tons)

Year	Nitrogen	Urea	Phosphorus	Calcium superphosphate	Potassium	Potassium sulfate
2016	2.47	5.37	0.33	2.72	3.00	5.99
2017	1.89	4.12	0.24	2.03	2.20	4.39
2018	1.93	4.21	0.25	2.07	2.27	4.54
2019	1.84	4.01	0.23	1.96	2.15	4.30
2020	1.88	4.08	0.24	2.00	2.18	4.35

In 2020, the fertilizing utilization of straw in Yantai can produce nearly 40,800 tons of urea, 20 million tons of calcium superphosphate, and 43,500 tons of potassium sulfate. According to the chemical fertilizer input, urea costs 1600 yuan per ton, calcium superphosphate 1000 yuan per ton, and potassium sulfate 3000 yuan per ton [19], thus the fertilizing utilization of straw returning to the field saved about 216 million yuan and effectively cut the production cost of farmers in Yantai in 2020. Straw returning to the field can also enrich soil nutrients, consolidate soil microbial activity, enhance farmland fertility, and upgrade crop growth quality. In addition, straw fertilization is able to reduce soil compaction, water pollution, and accumulation of toxic substances caused by chemical fertilizer application, further realizing circular agricultural development.

4.3.2 Potential of Straw Biogas Utilization

The formula of straw biogas utilization is Biogas Yield = Straw Quantity * Ratio of Straw Dry Matter * Biogas Conversion Coefficient. The biogas conversion coefficient of straw in this paper is selected as follows: the straw dry matter of bean and potato is 0.4 m^3/kg, and that of wheat, corn, and peanut is 0.45 m^3/kg, 0.5 m^3/kg, and 0.4 m^3/kg respectively [20]. The conversion coefficient between biogas and standard coal is 0.714 kg/m^3 [20].

Table 5. Output Estimation of Straw Biogas and Replaced Standard Coal in Yantai from 2016 to 2020

Year	Biogas Production (100 million cubic meters)	Replaced Standard Coal (10,000 tons)
2016	12.21	87.17
2017	8.93	63.79
2018	9.22	65.82
2019	8.68	62.00
2020	8.73	62.30

According to the calculation, the straw in Yantai can produce 873 million cubic meters of biogas in 2020, playing a positive role in the energy supply and ecological environment protection of Yantai. In addition, its by-products such as biogas slurry and biogas residue as natural pollution-free organic fertilizers can improve the physical and chemical properties of soil, boost the ability of soil to retain fertilizer and water, and drive the green circular development of agriculture. On the other hand, the biogas utilization of straw in Yantai has replaced 3,410,900 tons of standard coal in the past 5 years, which effectively undercuts the emissions of greenhouse gas such as CO_2, harmful gas including SO_2 and CO, clearing the city's atmospheric environment and mitigating the global warming.

5. Analysis and Suggestions on the Current Situation of Straw Utilization in Yantai

5.1 Current Situation of Straw Utilization in Yantai

According to the investigation by Yantai Agriculture and Rural Bureau, the straw utilization technologies in Yantai include fertilizing utilization (directly returning straw to the field and residue compost application), feed utilization, energy utilization, and base material utilization. Moreover, the construction of straw collection, storage, and transportation system and mechanization of straw utilization is on the rise.

As for fertilizing utilization, in order to promote mechanical harvesting, crushing, rotary harrowing, application of decomposing agent, and deep plowing in Yantai, a demonstration area for rapid straw decomposition and a demonstration base for organic fertilizer composting have been established in Yantai to spread organic fertilizer composting technology, collect straw and ferment composting organic fertilizer. In the aspect of feed utilization, large silage ponds have also been built in Yantai based on local animal husbandry to develop silage technology and promote the development of ecological recycling agriculture. Concerning energy utilization, a straw granulation production line that produces 40,000 tons of straw granules per year for energy utilization is built to popularize the granulation technology of crop straw. In the aspect of base material utilization, thanks to local edible fungi planting enterprises making culture materials with crop straws and other raw materials, the annual consumption of straw is more than 12,000 tons, the annual cultivation of Agaricus bisporus is 100,000 square meters, and the annual output of fresh mushrooms is 2,500 tons. In order to optimize the straw collection, storage, and transportation system, Yantai has also established many straw storage centers and spots to enhance the industrialization of comprehensive straw utilization. Under the comprehensive straw utilization project, a district-level storage center and three storage spots have been set up in the Muping District, with annual storage of 45,000 tons of straw. Intending to speed up the mechanization of straw utilization in Yantai, Laizhou has undertaken the Pilot Project of

Comprehensive Utilization of Crop Straw in Shandong Province twice with the help of the intelligent agricultural machinery from many cooperatives, realizing the mechanized operation of straw harvesting, bundling, transportation, storage and utilization [21].

5.2 Problems of Straw Utilization in Yantai

Some problems exist in straw utilization in Yantai. Firstly, straw utilization in Yantai is characterized as scattered resource-producing areas and unbalanced straw utilization rate in different areas. Mainly related to the landform, crop species, and yields in various regions, the above-mentioned feature is also affected by the differences in local utilization methods of suitable straw and various levels of straw utilization technologies. At the same time, the development of the high value-added straw industry in Yantai accounts for a small proportion. Nowadays, the current situation of straw utilization in Yantai consists of straw returning to the field, feed processing, and other low-tech and easy-to-process straw utilization, while the scale of high value-added straw energy utilization and raw material utilization industry is small. In addition, straw utilization in Yantai lacks key technologies and talents, which leads to the inability to implement mechanized and efficient production on a large scale in straw utilization, hindering its efficient, scientific, and sustainable development.

5.3 Suggestions for the Future Development of Comprehensive Straw Utilization in Yantai

5.3.1 Constructing the Demonstration Zone for Straw Comprehensive Utilization

A demonstration zone for straw comprehensive utilization should be built in Yantai. Attaching significance to the government guidance, market orientation, enterprise as the main body, and farmers' participation, Yantai should also carry out rational distribution and scientific planning. Moreover, it ought to extend the straw material utilization such as transforming straw into feed, energy, raw materials, base materials, and fertilizers together with stimulating scientific research and development, so as to promote the utilization of straw resources [22]. Develop an organic and circular agriculture demonstration zone of planting and breeding with Yantai characteristics, taking the utilization of agricultural waste straw resources as the main body with a high-value and resource-based industrial chain of straw utilization. Meanwhile, the functional section of the international exchange center can be built in the zone to provide a platform for exchange activities such as meetings or forums about domestic and foreign straw utilization technology research, where straw utilization enterprises and farmers can learn and exchange their experiences.

5.3.2 Improving the Industrial Chain of Straw Comprehensive Utilization

With the advantage of Laizhou City in Yantai which has undertaken the Pilot Project of Crops Comprehensive Utilization in Shandong Province twice [23], it should utilize the support of provincial and municipal governments to improve the construction of the straw utilization industrial chain in Yantai. Local straw can be integrated with animal husbandry to operate straw manure composting and silage utilization technology. Also, resource recycling should be realized in combination with other industries like machinery manufacturing and packaging.

5.3.3 Optimizing Technical Equipment and Introducing Professional Talents

To vigorously promote the efficiency of straw utilization, Yantai should adhere to the principle of adapting to local conditions integrated with the current situation of straw utilization in the whole city, support advanced and realistic straw treatment equipment. In addition, it is necessary to introduce policies attracting talents to carry out high-tech research on straw utilization. Coordinating with local and surrounding university resources, Yantai should make efforts to foster talents in innovation training and attract college graduates in related fields to settle and develop in Yantai.

6. Summary and Discussion

This paper comprehensively analyzes the amount and utilization of straw resources in Yantai from 2016 to 2020, with 2.458 million tons as its average annual sum of straw resources in the past five years. During this period, a total of 561,400 tons of commonly used fertilizers urea, calcium superphosphate, and potassium sulfate can be converted, which is equivalent to saving the average annual cost of agricultural fertilizers by more than 200 million yuan. If taking biogas straw utilization into effect, a total of 4.777 billion cubic meters of biogas will be produced from 2016 to 2020, replacing 3.4109 million tons of standard coal in total. Generally speaking, Yantai is rich in straw resources and has great potential for straw utilization. However, through the investigation of the utilization status of straw resources, it is found that there are still some problems, such as unbalanced utilization rates of straw in different regions and transformation of straw into feed, energy, raw materials, base materials, and fertilizers. Apart from that, problems including the small proportion of high value-added straw industry development, insufficient key technologies and talents of straw utilization also exist in Yantai. In the future, fertilizing and feed utilization would be the mainstay of the comprehensive straw utilization in Yantai, with the raw material utilization of straw as its supplementation, fuel and base material utilization as its subsidiary [21]. It should also accelerate the comprehensive straw utilization with high-added value, such as commercial fertilizer processing, biogas fermentation of agricultural waste, straw gasification, edible fungi cultivation, biomass energy, and emerging straw materials. In addition, a perfect straw collection, storage, and transportation system and relevant regulations or standards for straw utilization can be established to strengthen the standardization and scale of straw utilization, building a long-term mechanism for comprehensive straw utilization.

Considering the varieties and quantities of crop planting, local economic development, and natural conditions in different regions, Yantai can also introduce relevant technical equipment and professional talents in view of specific area characteristics. The improvement of mechanization and the allocation of professional talents can not only promote the industrial, recycling, and efficient development of straw utilization but also effectively drive the employment of rural surplus labor force, achieving regions' efficient, green and sustainable development.

Through the evaluation of straw resources and the current situation of straw utilization in Yantai, it can be seen that its utilization of straw resources has scored certain results, but there is still room for development. Learning from the experience of straw utilization at home and abroad in the future, Yantai should also give full play to the advantages of the Mechanization Technology Project for Comprehensive Crop Straw Utilization in Shandong Province and Pilot Project for Comprehensive Crop Straw Utilization in Shandong Province, adapt to local conditions and learn cutting-edge technologies for comprehensive straw utilization. Besides, Yantai is ought to attract talents in related fields to study advanced technologies and explore roads suitable for comprehensive straw utilization in this city.

References

[1] Zhang, Q. & Gao, Y. (2019). Overview of waste straw recycling in foreign countries. World Environment, (02): 74-76.

[2] Xie, J. et al. (2022). Experiences of comprehensive utilization of crop straw in Japan. Chinese Journal of Agricultural Resources and Regional Planning. 1-13.

[3] Ran J. et al. (2021), Temporal and spatial patterns of crop straw resources and their influencing factors in China. Research on Agricultural Modernization. 42 (03): 418-429.

[4] Cai, Y., Qiu, H. & Xu, Z. (2011). Evaluation on potential of energy utilization of crop residual resources in different regions of China. Journal of Natural Resources. 26 (10): 1637-1646.

[5] Zhang, X. et al. (2021). Analysis of crop straw yield and comprehensive utilization in China. Journal of China Agricultural University. 26 (09): 30-41.

[6] Jiang, B. & Chen L. (2019). Reference of straw utilization abroad and exploration of straw utilization in China. Green Technology. (24): 182-184.

[7] Shi, Z. et al. (2017). Comprehensive utilization status of crop straw and estimation of carbon emission from burning in China. Chinese Journal of Agricultural Resources and Regional Planning. 38 (09): 32-37.

[8] Xue, Y. et al. (2022), Bibliometric analysis of crop straw fertilizer utilization. Chinese Journal of Agricultural Resources and Regional Planning. 1-15.

[9] Gao, L. et al. (2009). Quantity estimation and utilization status of crop straw nutrient resources in China. Journal of Agricultural Engineering. 25 (07): 173-179.

[10] Tian, Y. (2020). Study on the Industrial Promotion Policy of Crop Straw Comprehensive Utilization in China. Chinese Journal of Agricultural Resources and Regional Planning. 41 (09): 28-36.

[11] The General Office of the Ministry of Agriculture. (2017). Ten models of straw for agricultural use introduced and released by the general office of the ministry of agriculture. Chinese Agricultural Technology Extension. 33 (05): 48.

[12] Gao, Z., Ni, J. & Li, N. (2022). Study on the quantity and utilization of crop straw resources in China. Research on Agricultural Mechanization. 44 (04): 1-6 , 25.

[13] Wang, H. et al. (2021). Analysis on the development trend of global straw utilization technology based on patent. Chinese Journal of Agricultural Resources and Regional Planning. 1-10.

[14] Bai, Y. (2010). Accelerating the construction of straw harvesting, storage and transportation system to promote the development of straw industrialization. Jiangsu Agricultural Mechanization. (05): 25-28.

[15] Xu, Y. et al. (2014). Analysis of the current situation of straw collection, storage and transportation at home and abroad. Research on Agricultural Mechanization. 36 (09): 60-64, 71.

[16] Pang, L. et al. (2018). Evaluation of main crop straw resources and analysis of economic benefit of fertilizer utilization in Shandong province. Shandong Agricultural Sciences. 50 (12): 80-85.

[17] The General Office of the Ministry of Agriculture and Rural Affairs. (2018). Notice of the general office of the ministry of agriculture and rural affairs on doing a good job in the construction of the national important agricultural resources account system in 2018. Bulletin of the Ministry of Agriculture and Rural Affairs of the People's Republic of China. (06): 26-28.

[18] Wang, L. (2020). Study on territorial spatial planning of municipal level based on natural resources management and implementation: Taking Yantai city as an example. Urban Development Research. 27 (03): 6-12.

[19] Chen, Y. et al. (2020). Evaluation of pruning branch resources and analysis of fertilizing utilization potential of fruit trees in Shandong Province. China Fruit Tree. (04): 92-95.

[20] Zhang, T. et al. (2014). Carbon footprint analysis of straw biogas utilization in China in 2011. Journal of Northwest Agriculture and Forestry University (Natural Science Edition). 42 (03): 124-130.

[21] Wang, B., Li, X. & Mao. Y. (2020). "Five Forces" together with "Five Utilizations" ―the full mechanization of comprehensive utilization of straw in Laizhou city. Agricultural Knowledge. (02): 45-47.

[22] Wang, Y. et al. (2021). Planning for emerging industry with abandoned resources ― a case study of Yongqiao straw comprehensive utilization demonstration park in Anhui as an example. Chinese Journal of Agricultural Resources and Regional Planning. 42 (04): 84-89.

[23] Wang, B., Li, X. & Mao, Y. (2020). Considerations on the selection of full mechanization mode of straw comprehensive utilization. Agricultural Machinery Quality and Supervision. (02): 33-34.