Application of ecological footprint in the construction of ecological campus

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Abstract. In order to help Shandong University of Science and Technology with the construction of Eco-campus, a study on the ecological status of the campus has been carried out. With the help of the component method of ecological footprint, the ecological footprint and efficiency of Shandong University of Science and Technology in 2016 has been analyzed well. The results showed that the ecological footprint of Shandong University of Science and Technology was 18058.46 hm² in total, and that the ecological efficiency was 2.22 person·hm⁻². The footprint of energy consumption, accounting for 46.2% of the total footprint, is the largest, followed by food consumption and garbage. The construction of Eco-campus should focus on the above-mentioned three aspects. Compared with other colleges and universities at home and abroad, the ecological carrying capacity of Shandong University of Science and Technology was higher while the ecological efficiency was much lower. Obviously, its construction of Eco-campus was lagged behind those first-class universities. The study showed that policy support and economic input would have an important impact on ecological construction of colleges and universities. According to the characteristics of the ecological footprint structure, this paper puts forward some reasonable suggestions from two aspects: campus ecological construction and “personnel training”, and provides reference for the construction of Eco-campus in colleges and universities.

1. Introduction

Climate change is a common concern in the world today, and low-carbon, energy-saving and emission reduction are regarded as the main ways of life all the time. Many domestic universities have responded to the proposal to build low-carbon campus. Sustainable development with low-carbon campus construction as the main content has become a trend to build a green campus [1]. Green campus based on ecological footprint is an effective method to measure the sustainable development of campus. At present, the study of campus ecological footprint in our country follows the international common method.

Many domestic scholars have measured and calculated the University ecological footprint, analyzed the profit and loss and proposed the corresponding countermeasure [2-6]. In the study of green campus environment assessment system based on ecological footprint method, Zhou Tianhan has found out the potential problems in the environmental evaluation of the ecological footprint and constructed the green campus evaluation system based on ecological footprint method by summarizing the existing green campus environment evaluation system[7-9]; Gu Xiaowei has adopted the ecological footprint analysis method including comprehensive and component method to evaluated the level of the green ecological campus of Northeastern University so as to conclude the general structure.
of the University of ecological footprint, and she has put forward the standard of measuring ecological efficiency in universities in the first time[10-11]; Yao Zheng has measured and calculated the ecological footprint of Peking University ranging from transportation, energy to daily life and drawn a conclusion that the ecological footprint of energy was a little higher while transportation and daily life were much lower when compared with other universities, and he has also called for the Low Carbon Campus[12]; Fu Yanfang has calculated the ecological footprint of Chizhou college by adopting the component method, evaluated the ecological footprint and ecological efficiency of resource consumption in Chizhou college, and pointed out more detailed conclusions and suggestion[13]; L.M. Nunes has proposed firstly the high uncertainty of ecological footprint and the great potential effects of the sensitive parameters on the calculated value in the basis of the analysis of uncertainty and variability of model parameter in order to provide the comparison of ecological footprint among universities a powerful framework and make the ecological footprint method more complete[14].

Shandong University of Science and Technology is a large-scale undergraduate institution in Shandong province. It covers an area of 243hm² and has more than 40,000 students. At present, there are few reports about the ecological footprint measurement in this school even in Shandong province. In view of this fact, we puts forward the ecological footprint component and ecological efficiency of Shandong University of Science and Technology by constructing the ecological footprint model of campus, quantitatively analyzes the ecological structure of Shandong University of Science and Technology, and offer the rational suggestion of ecological campus construction of Shandong University of Science and Technology by relating to the construction concept of low-carbon campus. In addition, this model is used to analyze the “ecological construction”[15] of campus operation, educational purpose and policy formulation, which provides a comprehensive reference for the ecological construction of universities.

2. Summary of Ecological Footprint

2.1. Ecological Footprint and Ecological Efficiency

The ecological footprint of a region refers to the productive area of land needed to produce all the resources consumed by these people and to absorb all the wastes produced by these people[16]. The global productive land is divided into 6 types: fossil energy land, arable land, forest land, pasture land, built area and water area. The ecological footprint is finally expressed as the land area with the average level of global biological productivity. First, count the ecological footprint consumption and ecological footprint supply respectively through the establishment of ecological accounts; second, judge the regional sustainable development by comparing the two; finally, obtain the total area of land occupation, in which global hectare as a measuring unit, that is, the ecological footprint, by using the equal factor of various kinds of land multiplies by the occupied area of the corresponding type of land. However, for those small range of research objects (such as schools and individuals), it is right to add up the 6 types of land area without any converting.

There are two methods to calculate the ecological footprint: comprehensive method and component method. The comprehensive method is based on the macroscopic statistics of all kinds of substances, aims to count the overall consumption of the various regions or groups and their corresponding ecological footprint, applies to the global, national and regional level of large-scale ecological footprint research, while the component method calculates the material consumption and ecological footprint of the study object on the basis of the monomer measurement that constitutes the consumption component and applies to small objects, such as towns, villages, schools, companies, individuals or individual activities etc..Therefore, this paper will adopt the component method to calculate the ecological footprint, transferring the school's energy, food, garbage, transportation, paper, water resources and other annual consumption into six types of global bio-productive land, then adding together and drawing the campus ecology Resources.

For universities, the output of ecological resources is students. The number of students in the unit ecological footprint can be defined as the ecological efficiency. It quantitatively describes the amount of talents that can be supported by the unit ecological resources. At the same time, the amount of
ecological resources that universities need to consume for training unit personnel can be defined as the ecological consumption intensity.

2.2. Ecological Footprint Component Model

2.2.1. Calculation of ecological footprint. Where: A is the area of an ecological footprint required by a particular part of the year; Q represents the annual consumption of this component; P is the average annual yield or carrying capacity of ecological land; for some specific land, when they are converted, it is necessary to refine the formula, such as the calculation of energy consumption in the year and a variety of types of energy to a final standard, which needs to determine the different Equivalent coefficient and deduce the formula.

\[ A = Q / P \] (1)

2.2.2. The establishment of various ecological land models

1) The ecological footprint of energy

The main energy resources are coal, petroleum, gas and electricity. The impact of energy consumption on the ecological environment is mainly manifested by the greenhouse effect caused by CO2 emission; there needs to be enough woodland to absorb CO2 in order to offset the impact, so the occupied land of energy consumption is woodland. Because this kind of land is devoted to absorb CO2, not take the purpose for producing forest products, it belongs to the independent list, known as the "fossil fuels". The 4 kinds of energy consumption mentioned above require fossil energy land area:

\[ A_c = Q_c \eta C_c \beta / P_a \] (2)
\[ A_o = Q_o \rho C_o \beta / P \] (3)
\[ A_g = Q_g \rho G_g \beta / P_a \] (4)
\[ A_e = Q_e E_{CO2} \rho / P \] (5)

Where: \( A_c, A_o, A_g, \) and \( A_e \) are the areas of fossil energy land of coal, oil, gas and electricity consumption during the year respectively; \( Q_c, Q_o, Q_g \) and \( Q_e \) are the consumption of coal, oil, gas and electricity during the year respectively; \( \eta \) is the average coal-fired boiler combustion rate; \( C_c, C_o, C_g \) and \( E_c \) are the C emission factors of coal, oil and gas respectively; \( \beta \) is the transforming factor for C to CO2; \( \rho \) is the density of gas; \( E_{CO2} \) is the CO2 emission per unit generating capacity of an ordinary thermal power plant; \( P_a \) is the average amount of absorbed CO2 per hectare of forest land per year (i.e., the average productivity of fossil energy sources).

2) The ecological footprint of food

The general formula for the land occupation of a particular kind of food consumption is:

\[ A_f = Q_f / P_f \] (6)

Where: \( A_f \) is the land occupation area for a certain category of food consumption in a year; \( Q_f \) is the the amount of the consumption of this food in the year; \( P_f \) is the average productivity of the land for the production of such food. In the main food categories, the land occupied by cattle and sheep (milk) products is grassland; the land for pigs, poultry, eggs, grains, sugar and vegetables, etc. is cultivated; the land for fish is water.

3) The ecological footprint of garbage

The occupied land of garbage usually consists of two parts: the fossil energy land, indirect occupied land, which is used to absorb CO2 of the degradation of waste, and the land that is directly occupied by the rubbish (usually cultivated land). The waste in the rubbish dump produces so-called waste gas through the action of bacteria. The volume of the waste gas is about half of CO2 and half of CH4 [18]. Global warming is not only related to CO2, but also related to CH4 [19-20]. The amount of
CH₄ can be converted into global warming latent heat GWP which is equivalent to greenhouse effect, that is to say, the CO₂ amount of which produces the same greenhouse effect [21]. The indirect occupied land for calculating garbage should be calculated separately according to the composition of the garbage:

\[
A_w = \frac{1}{P_a} \sum_{i=1}^{N_w} Q_i \left( q_i^{CO_2} + q_i^{CH_4} \chi \right)
\]

(7)

Where: \(A_w\) is the indirect land occupation area for annual garbage discharge; \(Q_i\) is the the emission of the \(i\)th waste components during the year; \(q_i^{CO_2}\) is the CO₂ production rate of the \(i\)th waste components; \(q_i^{CH_4}\) is the CH₄ production rate for the \(i\)th waste components; \(\chi\) is the GWP equivalent coefficient of CH₄; \(P_a\) is identical to (2).

4) The ecological footprint of traffic

The ecological footprint of traffic consists of direct land occupation and indirect land occupation. The direct occupation of land including roads, stations, airports, parking lot. Due to the mobility of vehicles and the sharing of traffic facilities such as roads, the calculation of the direct land occupation is a little complex and needs to share the area of the relevant facilities with the study object according to traffic regional ownership and utilization degree, transportation quantity and mileage statistics. Indirect land occupation refers to the fossil energy required for the absorption of greenhouse gas emissions from various modes of transportation. The main greenhouse gases in the exhausting gas are CO₂, CH₄ and N₂O, etc. CH₄ and N₂O can be converted to CO₂ equivalent according to their GWP. The general formula for land is:

\[
A_t = \frac{D}{P_a} \sum_{i=1}^{N_t} q_i \chi_i
\]

(8)

Where: \(A_t\) is the area of indirect land occupation of a certain type of vehicle during the year; \(D\) is the mileage of this kind of vehicle during the year; \(q_i\) is the emission of the \(i\)th greenhouse gas per unit of mileage; \(\chi_i\) is the GWP equivalent coefficient of the \(i\)th greenhouse gas; \(P_a\) equation (2).

5) The ecological footprint of paper

The area of paper consumption is mainly woodland, and the formula is:

\[
A_p = Q_p q_w / P_w
\]

(9)

Where: \(A_p\) is the land occupation area of paper consumption in the year; \(Q_p\) is the paper consumption during the year; \(Q_w\) is the timber consumption of per unit paper; \(P_w\) is the average timber productivity of forest land.

6) The ecological footprint of water

The ecological footprint of water is mainly generated by the energy produced by the transportation of water and the treatment of the sewage, and the energy consumed by the two operations is electricity, so it is necessary to calculate the power consumption of the water and the sewage for the year firstly, and then use the formula (5) calculate the land occupied area. The land type is fossil energy.

3. Ecological Footprint Calculation of Shandong University of Science and Technology in 2016

In the calculation of the ecological footprint of Shandong University of Science and Technology, energy (mainly electricity), food, garbage, paper, water and traffic have been taken into account. Electricity and water data are from the school energy management section; food data comes from the school logistics diet center; the vehicle data are provided by the Shandong University of Science and Technology security service; the amount of rubbish is estimated by sampling; a portion of the paper is provided by the school office, and part of it is obtained from a personal survey. The data collection and survey covers the teaching area and student living quarters of the campus, excluding family residential areas (except for vehicle surveys). The related factors, emission parameters and equivalent coefficients in the calculation were obtained from the IPCC Guidelines for National Greenhouse Gas
Inventories (2006) [22] and relevant reports of the World Conservation Fund; the world's average productivity of land is taken from FAO Statistics (http://www.fao.org).

Table 1. Ecological footprint of energy sources in Shandong University of Science and Technology (SDUST) in 2016 (The density of gas is $0.75 \times 10^{-3} \text{t/m}^3$)

| Component        | Consumption $/10^3 \text{m}^3$ | C emission factor | $\text{C-CO}_2$ Transforming factor | Unit CO$_2$ emission | $P_v/\text{(thm}^2)$ | Footprint $/\text{hm}^2$ | Land type             |
|------------------|---------------------------------|-------------------|-------------------------------------|-----------------------|----------------------|--------------------------|------------------------|
| gas              | 780                             | 0.409             | 3.67                                | 1.12                  | 5.2                  | 168.9                    | Fossil energy sites     |
| Power /GWh       | 12.82                           |                   |                                     | 1054                  | 5.2                  | 2598.5                   | Fossil energy sites     |
| Thermal energy /GWh | 27.53                           |                   |                                     | 1054                  | 5.2                  | 5580.1                   | Fossil energy site      |
| Total            |                                 |                   |                                     |                       |                      | 8347.5                   |                        |

3.1. The Ecological Footprint of Energy

In the campus of Shandong University of Science and Technology, the main energy consumption for electricity and heat, specifically, the electricity includes lighting and living electricity, the teaching building and student apartments in the winter heating facilities for heating. In addition, the school cafeteria also uses gas for energy. According to the data provided by the water and electricity warming Office of Shandong University of Science and Technology, the ecological footprint of energy of Shandong University of Science and Technology in 2016 was calculated. The relevant calculation data and results are shown in table 1.

3.2. The Ecological Footprint of the Food

The ecological footprint of the research includes the total amount of food consumed by the Shandong University of Science and Technology, including the cafeteria purchase, supermarket, apartment building service department of food purchases, the outside supermarket and the amount of buying food negligible. By calculating the total consumption of six categories of grain, meat, eggs, milk, fruit and vegetables and the global average amount of them, you can get the ecological footprint of food in Shandong University of Science and Technology in 2016. The relevant data and results of the calculation of food ecological footprint are shown in table 2.

Table 2. Ecological footprint of food in SDUST in 2016

| Component       | World production capacity $/\text{kg.hm}^{-2}$ | Average Consumption $/\text{kg}$ | Ecological footprint $/\text{hm}^2$ | Land type             |
|-----------------|-----------------------------------------------|---------------------------------|-----------------------------------|------------------------|
| Pork            | 74                                            | 156434                          | 2113.97                           | Cultivated land        |
| Beef and mutton | 33                                            | 4221                            | 127.91                            | Grassland              |
| fish            | 44                                            | 95753                           | 2176.20                           | waters                 |
| chicken         | 200                                           | 223000                          | 1115                              | Cultivated land        |
| foodstuff       | 3077                                          | 968434                          | 314.73                            | Cultivated land        |
| Fruits          | 9562                                          | 7032                            | 0.74                              | Cultivated land        |
| Sugar           | 18000                                         | 5725                            | 0.32                              | Cultivated land        |
| Vegetables      | 16846                                         | 1264219                         | 75.05                             | Cultivated land        |
| Eggs            | 400                                           | 260707                          | 651.77                            | Cultivated land        |
| Peas and beans  | 1856                                          | 128312                         | 69.13                             | Cultivated land        |
| milk            | 502                                           | 10524                           | 20.96                             | Grassland              |
| Total           |                                               |                                 | 6665.8                            |                        |
3.3. The Ecological Footprint of Rubbish

According to the survey, there is a large gap between the number of daily garbage production in Shandong University of Science and Technology campus; the general amount of garbage on weekends is obviously more than working days, and the amount of garbage in graduation season, before and after winter and summer vacation is more than the general time. In addition, food waste needs orientation treatment and is distinguished with non-food waste. According to the statistics, the average daily non-food waste production is 10t in the general working days while the average daily garbage generation is 15t on weekends. The garbage production of special periods (before and after the holiday or graduation season) is 25t. However, the special periods exist as a minority, so it can be calculated in accordance with the amount of garbage on weekends. Within one year (excluding 84 days off) the proportion of working days and holidays within one year is about 5: 2, resulting in the total amount of non-food waste for the year is 3223.2t. The annual output of food waste is 1539t. Because the direct land occupation of garbage is small and lacks detailed data, it is neglected in the calculation of this paper. The relevant data and calculation results of indirect land use are shown in figure 1. The calculated garbage ecological footprint data are shown in table 3.

Table 3. Ecological footprint of garbage and paper in SDUST in 2016

| component            | Emission amount | CO₂ release amount per unit garbage/t | CH₄ release rate per unit waste | The GWP coefficient of CH4[23] | GWP equivalent CH₄/t | Total amount of CO₂ in unit garbage/t | Pa/(t·hm⁻²) | Ecological footprint/hm² | Land type          |
|----------------------|-----------------|---------------------------------------|---------------------------------|---------------------------------|----------------------|--------------------------------------|----------------|--------------------------|-------------------|
| textile              | 1050            | 0.1524                                | 0.0554                          | 25                              | 1.2742               | 1.5374                               | 5.2            | 310.4                    | Fossil energy sites |
| Plastic[24]          | 673.2           |                                       |                                 |                                 |                      |                                      |                | 776.8                    | Fossil energy sites |
| Park garbage         | 1500            | 0.0649                                | 0.0236                          | 25                              | 0.5428               | 0.6549                               | 5.2            | 188.9                    | Fossil energy sites |
| Food waste           | 1539            | 0.051                                 | 0.0208                          | 25                              | 0.4784               | 0.5551                               | 5.2            | 163.1                    | Fossil energy sites |
| Glass                | 40.85           |                                       |                                 |                                 |                      | 9.88                                 | 5.2            | 77.6                     | Fossil energy sites |
| Total                |                 |                                       |                                 |                                 |                      |                                      |                | 1516.8                   |                   |
3.4. The Ecological Footprint of Paper and Water

By giving away questionnaires (1500 copies) to teachers and students of various majors of different colleges in Shandong University of Science and Technology in order to obtain the consumption of paper (read and print), clothes and non-environmental products (plastic bags and disposable chopsticks), due to the relatively dispersing investigated objects, the data of the questionnaires can be taken for a reference in terms of the calculations of the whole teachers and students of the campus. The data shows that at Shandong University of Science and Technology, the amount of consumer paper is 350.4t in 2016, of which personal paper 312t, accounting for 89%, and office paper 38.4t, and accounting for 11%. Per ton of paper requires 4m³ wood, and a total of 1401.6m³ wood is needed. The world timber productivity of forest land is 1.99m³. It was concluded that the ecological footprint of paper in Shandong University of Science and Technology was 704.32 hm² in 2016 and tap water consumption was 1,540,000m³. During the same period, the price of the tap water in Qingdao was 3.55 yuan /m³ (including sewage treatment), and the industrial electricity price was 0.501 4 yuan / (kW • h). The power costs of tap water accounted for 1/4, converted to power consumption of about 1.8 kW • h/ m³. Therefore, the total electricity consumption of water supply is 2.78GW•h, and the corresponding CO₂ emission is 2930t, divided by the average absorption capacity of CO₂ (5.2t/hm²), and the ecological footprint of water supply is 563.5hm². Because of the lack of data, the ecological footprint of sewage treatment has not been calculated.

3.5. The Ecological Footprint of Traffic

The vehicles of the campus of Shandong University of Science and Technology are mainly the cars of the staffs. According to the survey, the number of registered vehicles on campus is 2992. And the number of unregistered temporary vehicles can be found by the security department record. In addition, a small number of students use electric cars and motorcycles. Private cars, temporary cars and motorcycles consume gasoline while those trucks which are used to transport the waste such as food waste and campus waste use diesel fuel. Because the displacement of CH₄ and N₂O is small and detailed data is difficult to obtain, only CO₂ is considered. The relevant data and results of the calculation of traffic ecological footprint are shown in table 4.
4. Comparative Analysis of Ecological Footprint between Shandong University of Science and Technology and Other Universities

4.1. Shandong University of Science and Technology Ecological Footprint of Each Component

The results of each component's footprint are summarized in Table 5. In 2016, the total footprint of Shandong University of Science and Technology University is about 18,058.46 hm², that is to say, 18,058.46 hm² of various types of land are required to support the consumption in Shandong University of Science and Technology teaching and students' living area as well as absorb the waste. It should be noted that the calculation of food footprint is lower than the actual value, because some food consumption occurs outside of the campus and there is no statistics; The garbage footprint is also lower than the actual value due to not calculates the direct occupancy area. Therefore, the results of this paper should be a conservative estimate of the actual ecological footprint.

| Component          | Annual mileage | CO2 release | Pa/(t·hm⁻²) | Ecological footprint /hm² | Land type           |
|--------------------|----------------|-------------|-------------|---------------------------|---------------------|
| Gasoline car       | 438147         | 0.205       | 5.2         | 17.3                      | Fossil energy sites |
| Diesel engine car  | 1730           | 0.72        | 5.2         | 0.24                      | Fossil energy sites |
| Total              |                |             |             | 17.54                     |                     |

In 2016, Shandong University of Science and Technology had more than 40,000 students (take 40,000 as the standard), thus the ecological efficiency is 2.22 person·hm⁻² and the ecological consumption intensity is 0.45hm²/person. The comparison among the ecological footprint of various components is shown in Figure 2, and the main components of the ecological footprints of Shandong University of Science and Technology are food, heat, electricity and garbage, respectively 36.9%、30.9%、14.4% and 8.4%, totally 90.6%. Therefore, to reduce the ecological efficiency and increase the average ecological footprint should be discussed from the four aspects. Improving energy structure and taking effective measures to save energy and reducing waste discharge are the main way to...
improve eco-efficiency of Shandong University of Science and Technology and build the green campus.

Based on the ecological footprint of Shandong University of Science and Technology, this paper analyzes the ecological structure of the campus and draws the focus of ecological campus construction. In order to gain a deeper understanding of the current situation of the ecological components of the campus and draw a more comprehensive conclusion, the paper obtains the characteristics of the ecological structure of Shandong University of Science and Technology so as to put forward reasonable proposals in the point of ecological construction by comparing with the ecological components of the universities at home and abroad.

Table 5. Total Ecological footprint of SDUST 2016

| Project     | Shandong University of Science and Technology | Ecological Footprint | Proportion |
|-------------|----------------------------------------------|----------------------|------------|
| Energy      |                                              |                      |            |
| Heating     |                                              | 5580.1               | 30.9       |
| Power       |                                              | 2598.5               | 14.4       |
| Gas         |                                              | 168.9                | 0.9        |
| daily life  |                                              |                      |            |
| Food        |                                              | 6665.8               | 36.9       |
| Garbage     |                                              | 1516.8               | 8.4        |
| Paper       |                                              | 704.32               | 3.9        |
| Water       |                                              | 563.5                | 3.1        |
| Traffic     |                                              | 17.54                | 0.1        |
| Campus Area |                                              | 243                  | 1.4        |
| Total       |                                              | 18058.46             | 100        |

4.2. Comparison with Foreign Universities

Table 6 is mainly reference data of ecological footprint of other foreign universities. The scale of these universities (where the scale of a school is the number of school people and the school area ratio) is similar with Shandong University of Science and Technology, except the differences of different indicators. As a result, the ecological footprint of Shandong University of Science and Technology has the following characteristics:

Table 6. SDUST eco-footprint compared with overseas universities

| Project     | Chicago USA [25] | Australia [26] | Canada[27] | China Shandong University of Science and Technology |
|-------------|------------------|----------------|------------|----------------------------------------------------|
| Energy      |                  |                |            |                                                   |
| Heating     | 70955.9          | 1688.2         | 878.3      | 8347.5                                             |
| Power       | 70955.9          | 1257.2         | 878.3      | 2598.5                                             |
| Natural gas | -                | 431            | -          | 168.9                                             |
| Daily life  | 15054.5          | 143.6          | 510.6      | 168.9                                             |
| Food        | 2537.6           | 71.8           | 291.7      | 6665.8                                            |
| Garbage     | 12516.9          | 71.8           | -          | 1516.8                                            |
| Paper       | -                | -              | 218.9      | 704.32                                            |
| Water       | 126.9            | 35.9           | 6.1        | 563.5                                             |
| Traffic     | 1356.7           | 1652.3         | 1610.7     | 17.54                                             |
| Total       | 97601            | 3592           | 3039       | 17815.46                                          |
(1) For similar-scale school, in the ecological footprint of Shandong University of Science and Technology, the daily consumption is more than half, far more than other foreign universities; The ecological footprint of traffic is as much as ten times as high as that of other universities. It should be noted that the listed colleges and universities are all from developed countries, which differ from our country in the economic and political aspects, while Shandong University of Science and Technology belongs to a general undergraduate university. Therefore, comparing with the listed universities, the comprehensive level of the school is lower. Because of insufficient data collection, universities in developing countries with the same scale of schooling have not been listed.

(2) Comparing with the energy structure of other universities, Shandong University of Science and Technology’s energy use is of diversity, but all these energy belong to clean energy and the consumption of fossil coal, oil and gas is very low even to 0. Therefore, from the point of the ecological structure, the ecological structure of Shandong University of Science and Technology energy is relatively healthy.

4.3. Compared with Domestic Universities

(1) From the total amount of the ecological footprint, Shandong University of Science and Technology is at a middle level in domestic universities. Compared with the first-class universities of the same scale, the total ecological footprint of Shandong University of Science and Technology is lower; compared with ordinary universities, the total ecological footprint is ahead.

Table 7. SDUST eco-footprint compared with home universities

| colleges and universities | Ecological footprint summary | Quant | Av- | References |
|---------------------------|-------------------------------|-------|-----|------------|
|                           | Energ | Food | Garbage | Paper | Water | Traffic | Campus Area | Total |       |           |
|                           | 17343 | 14120 | 177.9 | 176 | 211. | 88.19 | 177 | 33710 |       | 34395 | 0.98 | [12]  |
| First-class University    | Peking University            | 2     | 8     | 4    | 9.1  | 4      | 88.19 | 177 | 33710 |       | 34395 | 0.98 | [12]  |
|                           | Northeastern University      | 16849 | 5405.7 | 1422.4 | 490. | 489. | 19.3 | 110 | 24786 |       | 26369 | 0.94 | [10]  |
|                           | Shenyang University          | 8     | 7     | 828.1 | 5     | 1     | 2.3  | 90  | 17218 |       | 21523 | 0.8  | [10]  |
|                           | Liaoning University         | 8022  | 2434. | 790.8 | 305. | 240. | 11862 |     |       | 10053 | 1.18  | [11]  |
| General Undergraduate     | Shenyang University          | 5913  | 830.4 | 340.1 | 389. | 103. | 61711 |     |       |       | 31697 | 2.45 | [10]  |
| University of Technology  | Chizhou College              | 4748  | 2573. | 257. | 189. | 8301  |     |     |       |       |       |      |       |
|                           | 4     | 9     | 425.5 | 3     | 1    | 107.1 | 54  | 2   | 4800  | 1.73  | [13]  |
|                           | Shandong University          | 8347  | 6665. | 1516. | 704. | 563. | 17.5 | 243 | 18058 | 40000 | 0.44 |      |      |

(2) From the structure of the ecological footprint, in Shandong University of Science and Technology, the proportion of energy footprint is similar to the proportion of food footprint, which is similar to Peking University. However, compared with other universities, the proportion of energy ecological footprint is lower.

(3) From the per-capita ecological footprint, the per-capita ecological footprint of Shandong University of Science and Technology is much lower than that of other universities. According to the definition of the campus ecological efficiency, the smaller the ecological footprint, the more the number of students in the unit ecological footprint, thus the number of carrying students in ecological footprint of Shandong University of Science and Technology is large and the carrying capacity is great.
5. Conclusions and Recommendations

5.1. Conclusion

(1) The ecological footprint of Shandong University of Science and Technology in 2016 was about 18,058.46hm², and the ecological efficiency was 2.22person·hm⁻², that is to say, 1hm² eco-productive land at least needs to support the cultivation of two students to consume and absorb the waste generated. The school's ecological footprint mainly comes from food, heat, electricity consumption and waste emissions, accounting for 90.6% of the total footprint. Therefore, the construction of "green campus" should start with improving the energy structure, adopting effective measures to save energy and reducing waste emissions.

(2) From the calculation of ecological efficiency, we can see that the ecological efficiency of Shandong University of Science and Technology is on the high side, which makes the output efficiency of the talents of Shandong University of Science and Technology higher, but too high efficiency will lower the quality of personnel. How to ensure to cultivate efficiently high-quality personnel should be an important aspect of the future discipline construction.

(3) By comparing with the ecological footprint of universities at home and abroad, we can conclude that the energy ecological structure of Shandong University of Science and Technology is at a healthy level; compared with the first-class universities of the similar scale, the total ecological footprint of Shandong University of Science and Technology is lower, and the ecological efficiency is great, and the ecological footprint of per capita is less; in the ecological footprint structure, the proportion of energy and food ecological footprint is similar, which is mainly related to the scale of the school. Shandong University of Science and Technology covers a large area and has a number of students in school. Coupled with the recent years, Shandong University of Science and Technology continue to discipline construction, student enrolment, Increase the size of the school staff, daily energy food consumption higher, but from the per capita ecological footprint is too small can be seen, Shandong University of Science and Technology service facilities to increase the pace of slow, so we need to strengthen the construction of service facilities.

(4) In the process of data collection and collation, we don’t guarantee absolutely the integrity of data of an area. On the one hand, the influence of external energy inflows, such as food affected by off-campus shops; on the other hand, there is a lack of statistical data, such as calculating traffic mileage ignoring the mileage of mobile in a small range, the amount of garbage calculation just calculating the garbage centralized processing. Therefore, it leads to a low computational result. In addition, the main drawback of the ecological footprint is the inability of the Ecological Footprint to track the human-induced depletion of natural capital stocks [25], which is a static method. And the component method covers a large range. We can refined the level further, clear the distinction between the use of stocks and the use of flows in order to make the calculation results achieve higher accuracy and reliability so that a systemic calculation method to promote the promotion of ecological footprint in the national university campus can be formed.

5.2. Recommendations

By analyzing the structure of the ecological footprint of Shandong University of Science and Technology and combining with the characteristics of comparison with domestic and foreign universities, it is concluded that Shandong University of Science and Technology is in a state of carrying capacity relatively saturated, high ecological consumption and low efficiency of talent construction. In this regard, we provide the following suggestions:

(1) Optimize the campus structure. Shandong University of Science and Technology has a large scale of construction, construction area of 1.45 million square meters, accounting for about half of the campus area with 40,000 students, from the ecological footprint calculation results can be seen that the per capita ecological footprint is too small; the school capacity is relatively saturated. By optimizing the structure of the campus, the rational use of land functions, increase space utilization, improve per capita ecological footprint, and reduce the burden on schools.

(2) Advocate energy-saving emission reduction; improving the rate of resource utilization. We should improve energy structure, adopt effective measures to save energy and reduce waste emissions.
Under the guidance of low-carbon theory, we should improve the utilization of resources and promote the recycling of material energy. Actively using solar energy, geothermal energy and other new energy sources in campus lighting, bathroom heating; strengthen energy-saving emission reduction, through reducing private cars, the use of "step on behalf of the car", "riding a bicycle-sharing " and other ways to reduce traffic ecological footprint; Making measures in heating, steam boiler room and catering kitchen equipment to reduce emission, by evaluating the equipment usage cycle, reducing the discharge of laboratory waste disposal and encouraging campus waste recycling and reuse of water etc to create "green campus".

(3) Formulate a reasonable plan for talent training. Provide equal opportunities for development, encourage students to actively carry out scientific and technological innovation, and improve the quality of students; strengthen the construction of service facilities; provide students with better learning platform and cognitive channels.

Acknowledgments
This study was supported by the National Natural Science Foundation of Shandong (ZR2017MEE055) and Ministry of Education School Planning and Development Center School Green Development Research Fund Project (LSFZ1601)

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