

The analysis of ecological footprint in typical agriculture and pasture overlapped zone of Baicheng region

WANG Yang¹, WANG Mingquan¹, LIU lei², XIAO Yanbo²

¹ Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, 4888 Shengbei Street, Changchun 130102

² Changchun Institute of Technology, 395 Kuanping street Changchun 130012

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Abstracts: The nearly 30 years of natural resource utilization and ecological carrying capacity (ECC) of Baicheng region, Jilin province was calculated on the basis of ecological footprint (EF) method within different modes. The results showed that the growth rate of consumptive ecological footprint (EFC) was 48.76% within Baicheng region from 1986 to 2013. The accounts of cultivated land EFC was fallen from 60.04% to 45.75%, whereas, cultivated land was the largest component of EFC. Meanwhile, cultivated land was still the largest component of ECC, which accounted for more than 66.13%~80.69%. The ecological deficit was gradually decline, and the ECC from 2006 began to have a surplus. The growth rate of productive ecological footprint (EFP) of Baicheng region in 2013 was 2.235 times higher than that of 1986, and the EFP of cultivated land was the largest part which accounted for 36.12%~62.58% of the total, followed by the EFP of energy land and pasture land. As the approach of EFP was more suitable for the ECC evaluation in the ecological vulnerability region, our results showed that the increase rate of EFP was far higher than that of EFC, indicating that resource production was higher than its consumption, and resource output was undertaken more pressure in the region. Consequently, the policy and plan of land utilization and resources exploit should be taken for the regional sustainable development.

Introduction

As human activities and the development of industry and agriculture, resources and ecological environment problems, and the contradiction between economic development and resources and environment become increasingly prominent. Consequently human survival and the sustainable development of social economy is threatened [1]. Ecological Footprint (Ecological Footprint, EF) was put forward by Canadian ecological economist William Rees, etc. in 1992, based on the human survival and society sustainable development, and further developed into the EF model by Wackemagel [2,3]. The EF method can measure the regional ecological carrying capacity (ECC) status through the consumption and capacity of natural resources [4]. This study calculated the natural resource utilization and capacity of Baicheng city of western Jilin province based on the different style of EF, and quantitatively analyzed the regional sustainable development status, which could provide scientific basis for resource sustainable exploit, economic and ecological environment coordinated development.

Overview of the study area

Baicheng city is located in the Midwest of Jilin province in China (E121°38 '-124°22', N44°13'57"-46°18'), belonging to the temperate continental monsoon climate, with dry and windy spring, hot and rainy summer, cool and early frost autumn, cold and dry winter. The regional annual average temperature is 4.9 °C. The annual average rainfall is 400~500 mm, whereas the annual evaporation is 1600~2000 mm, which is seasonally uneven of rainfall accounting for only about 9% in spring (April~May), and 70% in summer (June~August), usually with the form of local waterlogging [5]. The region is the typical agriculture and pasture interlaced zone with worsening ecological environment, unreasonable industrial structure due to fast resource consumption and low utilization efficiency, which hinder the social economic improvement and its sustainability.

Research methods and data sources

Research methods

The resources of social and economic system and necessary support services for human life could be provided by the productive land or by the corresponding equivalent transformation of productive land [6]. EF refers to the biological productive land which is equivalent transformed by the resource production and waste generated by the population. The biological productive land is divided into six types: cultivated land (CL), pasture land (PL), water region (WR), forest land (FL), building land (BL) and energy land (EL), including that the ecological consumption of resources and the waste can be dated back, and converted to the required biological productive land area [6].

The ecological footprint analysis based on consumption

1) EFC

Consumptive ecological footprint (EFC) is calculated by per capita EF and the per capita ECC, the EFC method is calculated as Eq.1.

$$EFC = \sum r_j A_i = \sum r_j c_i / Y_i = \sum r_j (P_i - E_i + I_i) / Y_i \quad (1)$$

EFC is the per capita EF (g/ha), A_i is per capita EF for the i kind resource (g/ha), r_j is the balance factor, c_i and P_i are the consumption and production of i kind resource (kg), Y_i is the global average yield of i kind resource (kg/ha), E_i and I_i are the output and input of i kind resource.

2) Ecological deficit

The Ecological deficit (ED) is calculated as Eq.2.

$$Ec = \sum a_j \times r_j \times y_j \quad (2)$$

EC is per capita ecological capacity (g/ha), a_j is the per capita biological productive land area, y_j is production factor. According to the world commission on environment and development (WCED) recommendation, regional ecological capacity should be set aside 12% to maintain the necessary biodiversity [7]. The part that EFC exceeds its EC is defined as the ecological deficit (ED). And then $ED = (1-12\%) EC - EFC$.

The ecological footprint analysis based on biological production

Human biological resources consumption is unequal to the production of biological resources for different regions owing to differences in the biological productive land area endowment and ecosystem management level. Regional biological resource production can reflect the EC level and EF based on biological production. The calculation method of EFP is as Eq. 3.

$$EFP = \sum_{i=1}^n r_i A_{ip} = \sum_{i=1}^n \frac{r_i p_i}{Y_i} \quad (3)$$

EFP is per capita productive EF (g/ha), A_{ip} is the per capita productive EF for i kind resource. Others are the same as above.

Data sources and processing

Data mainly come from Baicheng statistical yearbooks (1986-2013) and Jilin province statistical yearbooks (1987-2013). Biological resource productive area conversion adopts the world's average yield data issued by the United Nations Food and Agriculture Organization (FAO) in 1993. The balance factor is 2.8 for CL, 0.5 for PL, 1.1 for FL, 0.2 for WR, 1.1 for EL and 2.8 for BL.

Results and discussion

Consumptive ecological footprint analysis

Baicheng city EFC was shown as Fig.1. EFC were increased from 1.005 hm^2 in 1986 to 1.495 hm^2 in 2013 with the growth rate of 48.76%, mainly due to the relatively slow industrial development. EFC of cultivated land were slowly increased from 0.603 hm^2 in 1986 to 0.684 hm^2 in 2013, with the corresponding proportion to the total EF decreasing from 60.04% to 45.75%, but was still the biggest part of EF for Baicheng region. EFC of PL were increased from 0.120 hm^2 in 1986 to 0.339 hm^2 in 2013, with the corresponding proportion to the total EF increasing from 11.96% to 22.69%. The rest in turn were EL, FL, BL and WR ecological footprint.

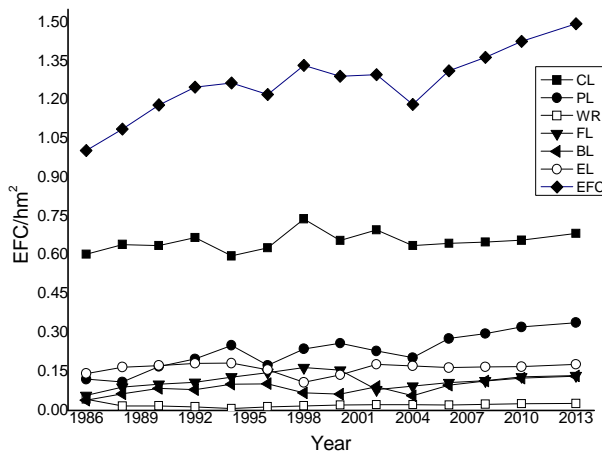


Fig. 1 The constituent of Baicheng region EFC

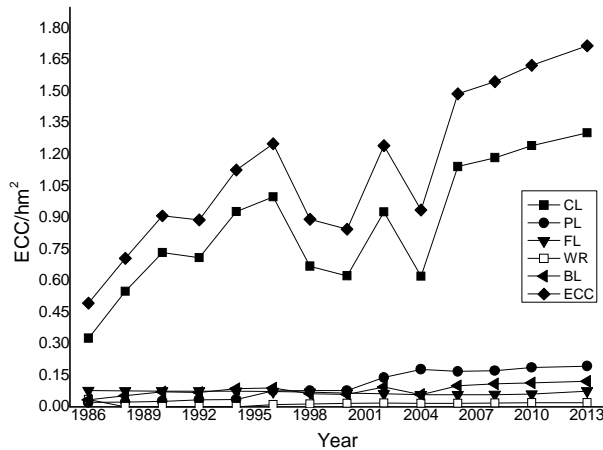


Fig. 2 The constituent of Baicheng region ECC

ECC of Baicheng region was shown as Fig. 2. The ECC were increased from 0.493 hm² in 1986 to 1.716 hm² in 2013. The ECC of CL was the largest component, accounting for 66.13%~80.69% of total. The ECC of PL was the second part, increasing from 0.021 hm² in 1986 to 0.195 hm² in 2013, accounting for 2.91% ~ 19.18% of total.

Productive ecological footprint analysis

EFP of Baicheng city was shown as Fig. 3. EFP were increased from 0.795 hm² in 1986 to 2.572 hm² in 2013. The EFP of CL was the largest component, and increased from 0.408 hm² in 1986 to 1.217 hm² in 2013, accounting for 36.12% ~ 62.58% of the total. The EFP of EL and PL in 2013 were 0.5735 and 0.5627 hm², respectively, which were 3.57 and 6.55 times higher than those of in 1986. The EFP of FL, WR, BL and other aspects were accounted for 7.80%~17.57% of the total.

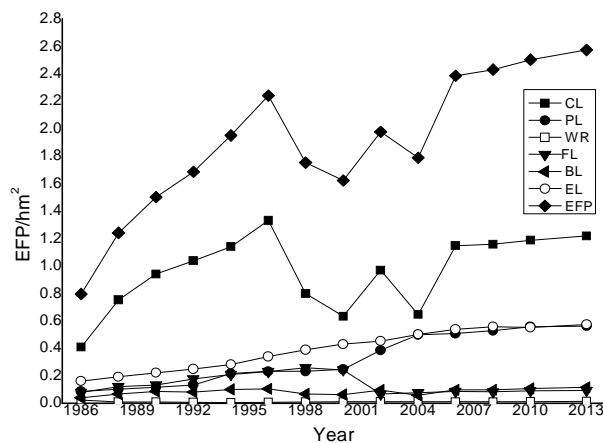


Fig. 3 The constituent of Baicheng region EFP

The comparison of EFC and EFP

The comparison of EFC and EFP evaluation was shown as Fig. 4. From 1986 to 2013, the ECC of Baicheng regions were increased from 0.493 hm² in 1986 to 1.716 hm² in 2013. The EFC were increased from 1.005 hm² in 1986 to 1.495 hm² in 2013, while the EFP were increased from 0.795 hm² to 2.572 hm². The EDs of Baicheng region that the ECC exceeded the corresponding EFC, were increased from -0.511 hm² to 0.221 hm², especially after 2006 the ED became surplus; the ecological overload (EO) that ECC exceeded the corresponding EFP were decreased from -0.301 hm² to -0.856 hm², indicating that the ecological environment of Baicheng region gradually became worse during natural resources exploit from 1986 to 2013, and the ecological sustainability was

gradually decreased.

The development measures of the productive land are mainly embodied in strengthening resource inputs and through increasing productivity and expanding cultivated land to improve the economic efficiency. But in the long run, the utilization way of productive land is not sustainable, especially for the ecological vulnerability region. Large-scale resources exploit can cause the ecological environment pressure rise, while the increasing of cultivated land aggregate the ecological vulnerability and even overload. Therefore, it was necessary for more effective measures to coordinate the development of the regional economy and environment. Traditional EFC cannot fully reflect the development of the productive land exploit and ECC conditions, mainly because that the EFC was founded on the basis of land use sustainability [8]. For the ecological environment vulnerability region, EFC results might cover up the veracity of ecological sustainability. While EFP can reflect the resource consumption from the angle of resource production, owing to resource production has close relations with the productive land exploit. Therefore, EFP method is more suitable for the resource ECC evaluation in the ecological vulnerability region.

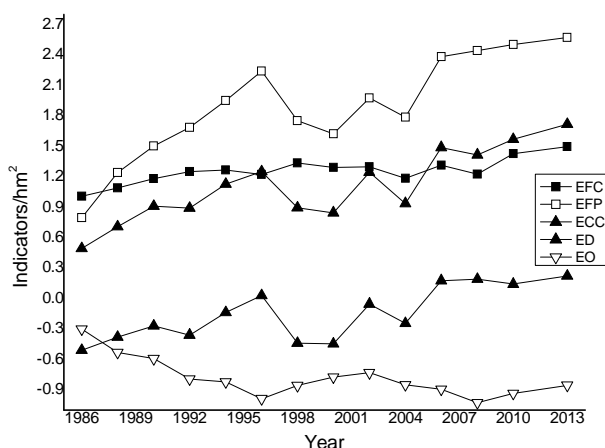


Fig. 4 The comparison of Baicheng region EFC and EFP

Conclusions

(1) EFC and ECC of Baicheng region were increased gradually from 1986 mainly due to the slow industrial development, and cultivated land EFC and ECC were all the largest components.

(2) EFP of Baicheng region was increased gradually from 1986, cultivated land EFP was the largest component, and followed by the EFP of EL and PL.

(3) The approach of EFP was more suitable for the ecological carrying capacity evaluation in the ecological vulnerability region. According to evaluation result of EFP, the policy and plan of land utilization and resource exploit should be taken for the regional sustainable development.

Acknowledgements

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