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# Sustainability of Cultivated Land in Henan Province Based on Ecological Footprint

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**Abstract** This paper summarizes the regional situation of Henan Province, China, and introduces the principle of ecological footprint mode, as well as computing formulas of ecological footprint and ecological capacity. According to the related data of Henan Province from 1998 to 2007, this paper firstly calculates the per capita ecological footprint and per capita ecological capacity of Henan Province. Result indicates that cultivated land in Henan Province shows ecological surplus with sustainable land use. And ecological surplus has increased since the year 2003. Secondly, dynamic analysis of ecological footprint of arable land is carried out in Henan Province. Thirdly, this paper also studies on the per capita ecological demand and supply in 18 districts and cities of Henan Province in 2007. And cultivated land in these areas is sustainable. Zhumadian City has the highest ecological surplus and per capita ecological capacity, while Nanyang City has the highest per capita ecological footprint. Based on this, this paper puts forward five proposals on ensuring the increase of grain yield.

**Key words** Ecological footprint; Cultivated land; Sustainable utilization; China

Population, food, energy, resources and environment are the top five issues confronted by human beings. These five problems are closely related to land resources and their utilization. Cultivated land resource, the essence of land resources, is the most basic means of food production. Limited resource of cultivated land determines that the use of cultivated land resources must implement the strategy of sustainable development. At present, there are 3 types of evaluation index system for sustainable development, which are index system based on system theory and method instruction, index system based on method of environmental economics, and specific measure index of biophysics. Ecological footprint mode is a sustainable evaluation method based on biophysics, which is put forward by an ecological economists, professor William · Rees in Canada, and improved by his student doctor M · Wackernagel. Calculation result of this mode is intuitive and has regional comparability, which is recognized by relevant international agencies, government departments and research institutions. And this mode has become an important method for measurement of international sustainable development. This paper tries to apply this method in researching and discussing sustainable use of cultivated land in Henan Province.

## 1 Research area and method

**1.1 Overview of the research area** Henan Province is located in 31°23′–36°22′ N, 110°21′–116°39′ E with 530 kilometer in length from south to north, 580 kilometer in width from east to west, connecting Anhui and Shandong provinces in the east, Hebei and Shanxi provinces in the north, Shanxi Province in the west, and Hubei Province in the south. Henan Province is mostly located in warm temperate with subtropical zone in

south, belonging to continental monsoon climate, a transitional region from subtropical zone to warm temperate zone. It also has the characteristics of transition from plain climate to hill and mountain climate from the east to west with distinct four seasons, diverse and frequent weather disasters and synchronization of high temperature and ample precipitation. Annual average temperature from south to north in Henan Province is 15.7–12.1 °C, with annual average precipitation of 1 380.6–532.5 millimeters, annual average sunshine of 1 848.0–2 488.7 hours, and annual frost-free period of 189–240 days suitable for the growth of many crops. Henan Province has complete stratum, complex geological structure, and abundant mineral resources. Thus, Henan Province is one of the largest mineral resources in China.

Total land area of Henan Province is 167 thousand square kilometers, accounting for 1.73% of the national land area, and governing 17 cities and 1 city administrated by province. Total area of cultivated land at the end of 2007 is 7 926.1 thousand hectares, accounting for 6.5% of the total cultivated land in China. Per capita cultivated land area is 0.08 hectare. And the grain output is 52 452 thousand tons, accounting for 10.46% of national grain output.

**1.2 Research method** Starting from the concrete situation, ecological footprint uses bio-productive land area to represent the human consumption of natural resources and ecosystem services function of natural system. Thus, the utilization degree of resources by human can be analyzed effectively. This method classifies bio-productive land area into 6 types, which are farmland, forest land, grassland, fossil energy land, water area and construction land. The accounting formula for ecological footprint is

$$EF = N \times ef = N \times r_i \times \sum_{i=1}^n (c_i/p_i),$$

where  $EF$  is total ecological footprint,  $N$  is population number,  $ef$  is per capita ecological footprint,  $r_i$  is equivalence factor,  $c_i$  is

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the per capita consumption of product  $i$ ,  $p_i$  is the world average production capacity of product  $i$ . Accounting formula for ecological carrying capacity is

$$EC = N \times ec = N \times \sum_{i=1}^6 (a_{ij} \times r_j \times y_j),$$
where  $EC$  is regional total ecological carrying capacity,  $ec$  is per capita ecological carrying capacity,  $a_{ij}$  is per capita bio-productive land area,  $y_j$  is yield factor.

After comparing the calculation results of ecological footprint and ecological carrying capacity, ecological deficit occurs if ecological footprint is bigger than ecological carrying capacity, indicating that human pressure on natural ecosystem exceeds the ecological carrying capacity of this region, and *vice versa*<sup>[1-2]</sup>.

2 Calculation and analysis of ecological footprint of cultivated land in Henan Province

2.1 Calculation of ecological footprint of cultivated land in Henan Province This paper obtains relevant data from the 1998 –2007 *Henan Statistical Yearbook* by using the top-down method. According to the corresponding relationship between resource consumption and required bio-productive land, corre-

sponding consumer goods of ecological footprint of cultivated land in Henan Province are mainly the consumption of agricultural products. Combining with the actual situation of Henan Province, consumption projects of major agricultural are food, oil, cotton, hemp, tobacco, vegetable, fruit, carbohydrate (sugarcane), tea, and fruit. But in this research, there are only statistical data of main food consumption. Therefore, project data not listed in statistical data is converted by the ratio of existing main food consumption to regional output of corresponding products in current year (consumption ratio). World average output in the conversion of production area of biological resources is obtained according to relevant biological resources data offered by the Food and Agriculture Organization. Equivalence factor of arable land adopted now is 2.82, and yield factor is 1.66<sup>[3]</sup>. Table 1 reports the demand and supply of cultivated land ecological footprint in Henan Province from the year 1998 to 2007.

Table 1 indicates that cultivated land in Henan Province shows ecological surplus within the ten years. Cultivated land use is in the state of sustainable development. And ecological surplus has been in a state of sustained growth ever since the year 2003.

Table 1 Demand and supply of per capita cultivated land ecological footprint in Henan Province from 1998 to 2007

Year	Per capita ecological footprint//hm <sup>2</sup>		Per capita ecological carrying capacity//hm <sup>2</sup>		Ecological surplus//hm <sup>2</sup>
	Per capita ecological demand	Equilibrium area	Per capita ecological supply	Equilibrium area	
1998	0.099 7	0.281 2	0.073 4	0.343 4	0.062 2
1999	0.101 7	0.286 9	0.072 7	0.340 4	0.053 5
2000	0.113 5	0.320 1	0.072 5	0.339 2	0.019 1
2001	0.100 2	0.282 5	0.072 3	0.338 4	0.055 9
2002	0.105 9	0.298 5	0.075 6	0.353 7	0.055 1
2003	0.101 1	0.285 1	0.074 3	0.348 0	0.062 9
2004	0.095 4	0.269 1	0.074 0	0.346 2	0.077 2
2005	0.085 8	0.242 1	0.081 1	0.379 9	0.137 8
2006	0.084 8	0.239 2	0.080 7	0.377 9	0.138 7
2007	0.077 0	0.217 1	0.080 3	0.376 0	0.158 9

2.2 Dynamic analysis on ecological footprint of cultivated land in Henan Province It is calculated that the ecological footprint of total cultivated land in Henan Province is 26 195 542.31 hectares in the year 1998, 21 423 808.83 hectares in the year 2007, a decrease of 4 771 733.48 hectares within 10 years. The highest ecological footprint of cultivated land reaches 30 369 582.03 hectares in the year 2000; and the least is 21 423 808.83 hectares in the year 2007. Ecological footprint of cultivated land basically shows a decreasing trend, indicating that peoples' dependence degree on regional cultivated land is decreasing. Ecological carrying capacity of cultivated land is 31 991 320.8 hectares in the year 1998, and 37 103 659.32 hectares in the year 2007, up by 5 112 338.52 hectares within ten years. Cultivated land in Henan Province has shown ecological surplus in the ten years. Per capita ecological surplus is above 0.05 hectare, except the year 2000, showing a increasing trend year by year.

2.3 Spatial analysis on ecological footprint of cultivated land in Henan Province Zhengzhou, Kaifeng, Luoyang,

Pingdingshan, Anyang, Hebi, Xinxiang, Jiaozuo, Puyang, Xuchang, Luohe, Sanmenxia, Nanyang, Shangqiu, Xinyang, Zhoukou, Zhumadian and Jiyuan Cities all belong to Henan Province. Table 2 reports the per capita ecological footprint demand and supply of cultivated land in the 18 cities in the year 2007.

Table 2 shows that ① cultivated land ecology of 18 cities in Henan Province shows sustainable development in 2007. Among them, Zhumadian City has the biggest ecological surplus of cultivated land, followed by Shangqiu, Kaifeng, Xinyang, Xinxiang, Xuchang, Hebi and Luohe, which are all higher than the average ecological surplus of the whole province. Jiaozuo City has the least ecological surplus of cultivated land, followed by Pingdingshan, Jiyuan, Zhengzhou, Puyang, Luoyang, Sanmenxia, Nanyang, Anyang and Zhoukou. ② Zhumadian City has the highest per capita ecological carrying capacity, followed by Xinyang, Nanyang, Kaifeng, Shangqiu and Xinxiang, which are all higher than the ecological carrying capacity of the whole province. Zhengzhou City has the lowest

per capita ecological carrying capacity of cultivated land, followed by Jiaozuo, Jiyuan, Pingdingshan, Luoyang, Hebi, Luohe, Puyang, Xuchang and Anyang. ③ Nanyang City has the highest per capita ecological footprint, followed by Xinyang, Sanmenxia, Xhumadian, Puyang, Pingdingshan and Kaifeng,

which are all higher than the per capita ecological footprint of Henan Province. Zhengzhou City is lowest in per capita ecological footprint, followed by Hebi, Xuchang, Luohe, Luoyang, Xinxiang, Shangqiu, Jiaozuo, Jiyuan, Zhoukou and Anyang.

**Table 2 Per capita ecological footprint demand and supply of cultivated land in 18 cities of Henan Province in the year 2007**

City	Per capita ecological footprint//hm <sup>2</sup>		Per capita ecological carrying capacity//hm <sup>2</sup>		Ecological surplus//hm <sup>2</sup>
	Per capita ecological demand	Equilibrium area	Per capita ecological supply	Equilibrium area	
Zhengzhou City	0.051 0	0.143 8	0.050 0	0.233 9	0.090 1
Kaifeng City	0.077 9	0.219 6	0.088 8	0.415 6	0.196 0
Luoyang City	0.067 5	0.190 2	0.065 4	0.305 9	0.115 7
Pingdingshan City	0.081 4	0.229 7	0.063 2	0.295 9	0.066 2
Anyang City	0.076 7	0.216 3	0.075 8	0.354 8	0.138 5
Hebi City	0.062 5	0.176 4	0.072 7	0.340 3	0.163 9
Xinxiang City	0.068 1	0.192 1	0.081 4	0.381 0	0.188 9
Jiaozuo City	0.072 3	0.204 0	0.055 8	0.261 2	0.057 2
Puyang City	0.083 1	0.234 4	0.074 7	0.349 9	0.115 5
Xuchang City	0.064 7	0.182 4	0.075 8	0.354 7	0.172 3
Luohe City	0.064 9	0.183 1	0.073 7	0.344 9	0.161 8
Sanmenxia City	0.089 7	0.253 1	0.079 8	0.373 4	0.120 4
Nanyang City	0.103 2	0.291 1	0.091 6	0.428 9	0.137 8
Shangqiu City	0.071 2	0.200 7	0.087 4	0.409 0	0.208 4
Xinyang City	0.096 5	0.272 2	0.099 0	0.463 6	0.191 4
Zhoukou City	0.074 9	0.211 1	0.079 0	0.369 9	0.158 8
Zhumadian City	0.089 3	0.251 8	0.105 0	0.491 5	0.239 7
Jiyuan City	0.074 7	0.210 7	0.061 2	0.286 4	0.075 7

### 3 Conclusion

Empirical calculation and analysis on the ecological footprint of cultivated land in 18 cities of Henan Province shows that cultivated land in Henan Province and its cities shows a state of sustainable development. Per capita ecological surplus of cultivated land has been increasing since the year 2000. According to the calculation result mentioned above, under the current consumption level and structure, Henan Province not only can feed the existing population, but also can import grain to other provinces and is able to accept ecological footprint of cultivated land from other provinces. This is in accordance with its status of big grain province. To become the core area of national grain and to ensure increase of food production, Henan Province needs to do a better job in the following areas. Firstly, further carry out intensive use of land; and deal with contradictions between economic development and occupation of cultivated land. Secondly, strengthen the development, sorting and reclamation of reserve resources; and increase the amount of cultivated land. Thirdly, strengthen the research and application of agricultural science and technology; implement large-scale operation; and improve the output efficiency of cultivated land. Fourthly, greatly improve low or middle yield field; enhance the quality and utilization of cultivated land; and improve the ecological carrying capacity of cultivated land. Fifthly, establish land dynamic monitoring and management system; enhance the dynamic monitoring of land resources; implement the most strict land management system; and promote the sustainable

use of cultivated land resources.

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of Huaihe River, valley and tableland in southern hills of Shandong Province. If we accept the theories of Holocene's catalysis on Neolithic Age and the agriculture originating in woodland, the earliest origin time of broomcorn millet in sandy loess zone should be the middle or the end of early Holocene in eastern Qinghai, which is along the line of mid-eastern Gansu, Ningxia, northern Shaanxi, mid-northern Shanxi, northern Hebei, eastern Inner Mongolia, and mid-western Liaoning.

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## 中国北方旱作农业带状起源论

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**摘要** 探讨了更新世环境变迁和旧石器时代晚期原始农业的发展情况。第四纪以来, 中国的自然环境发生了显著变化。在更新世末期寒冷的气候条件下, 中国北方大部分地方不适宜于喜温暖的黍、粟等作物生长, 但其东南边缘温暖地带的一些细石器地点已进入采集农业阶段, 可能成为后来黍作和粟作农业起源地带的一部分。分析了全新世早期北方环境变迁与旱作农业的产生。介绍了麦克尼什农业起源的3种模式和中国的3个文化地带。3个模式分别为初级模式、次级模式和三级模式。石兴邦认为这3个起源模式与中国的3个文化带, 即黄河流域、淮河中介生态带和长江及其以南地区无界生态带的情况是大体相若的。全新世早期(大约12~8 kaBP)为不稳定升温期, 黄土高原东南边缘的沟谷、山前坡地和台地, 秦岭山地的河谷阶地, 淮河上游山地和平原, 山东丘陵南部的河谷和台地即有黄土分布, 又相对温暖湿润, 森林草原交错分布, 植物资源丰富, 处于北方细石器工艺和南方琢制石器工艺的交汇地带, 有可能率先开始粟作农业; 全新世早期末段或中期, 从青海东部经甘肃中东部、宁夏、陕西北部、山西中北部、河北北部、内蒙古中东部至辽宁中西部的沙性黄土地带, 由于自然条件的改善, 可能成为黍作农业最重要的起源地带。

**关键词** 农业起源; 旱作农业; 起源地带

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## 基于生态足迹模型的河南省耕地可持续性研究

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**摘要** 简述了中国河南省的区域概况, 介绍了生态足迹模型的原理及生态足迹与生态承载力的计算公式。当生态足迹大于生态承载力时, 会出现生态赤字, 表明人类对该区域自然生态系统的压力超过了区域的生态承载力; 反之, 亦然。根据河南省1998~2007年的相关数据, 首先计算了河南省人均生态足迹和人均生态承载力。结果表明: 1998~2007年, 河南省耕地表现为生态盈余, 耕地利用处于可持续发展状态, 且生态盈余自2003年以来一直处于持续增长状态。其次, 对河南省耕地生态足迹进行了动态分析。10年间, 耕地生态足迹基本呈减少趋势, 说明人们对区域内耕地的依赖程度在逐渐降低, 耕地生态承载力总体呈增加趋势。再次, 研究了2007年河南省18个地市的人均耕地生态足迹需求与供给情况。18个地市的耕地生态呈可持续发展状态, 耕地生态盈余和人均生态承载力最多的是驻马店市, 人均生态足迹最高的是南阳市。基于此, 提出了保证粮食增产的五点建议: 一是进一步集约利用土地; 二是加强后备资源的开发、整理、复垦与整治; 三是加强农业科技的研究与应用, 提高耕地的产出效率; 四是大力改良中低产田, 增强耕地的生态承载力; 五是建立耕地动态监测管理体系, 促进耕地资源的永续利用。

**关键词** 生态足迹; 耕地; 可持续利用