# Chapter 14
# The Ecological Footprint and Carrying Capacity in Northeast Asia

**Zhang Bai and Liu Weijie**

**Abstract** Under the goal of sustainable development, optimum population rests on the comprehensive carrying capacity of many factors, such as ecology, economy, and land, etc. Recently, the ecological environment of the Northeast Asia has been deteriorating seriously, because of the fall of its ecological carrying capacity resulted from human activities. The ecological carrying capacity of the Northeast Asia is directly related to its ecological environment and socioeconomic sustainability. The ecological carrying capacity is based on the net primary productivity (NPP) of natural vegetation which can reflect the productive and recovery capacity, and thus is the index of the ecological integrity of natural system. Based on the above purposes and the assessment method, this paper studies the distribution and the change of the ecological footprint (EF) and the ecological carrying capacity in the Northeast Asia. The change of per capita EF shows a trend of decline in the Far East of Russia, Japan, and Mongolia, but the original value is still higher in the front row. It is more than 3 $hm^2$ and showed an upward trend in the Northeast China and South Korea. North Korea is the most stable and the lowest EF is about 2 $hm^2$. As a whole situation of the Northeast Asia, we can see in addition to a small part where its ecological carrying capacity is near 0, in the northern areas and the most regions of Northeast Asia, the ecological carrying capacity is between 0 and 30 $hm^2/km^2$. In the most central region of the Northeast Asian the ecological carrying capacity is between 30 and 50 $hm^2/km^2$. In the southeastern and midwestern areas, the ecological carrying capacity is between 80 and 100 $hm^2/km^2$. The ecological carrying capacity even exceeded 150 $hm^2/km^2$ in southern areas. In the southwest region there is a large bareland area, the ecological carrying capacity is near 0.

**Keywords** Ecological footprint · Ecological carrying capacity · Northeast Asia

Z. Bai (✉) · L. Weijie
Northeast Institute of Geography and Agro-ecology, CAS, Changchun, China
e-mail: zhangbai@iga.ac.cn



Y. Himiyama (ed.), *Exploring Sustainable Land Use in Monsoon Asia*,
Springer Geography, https://doi.org/10.1007/978-981-10-5927-8_14

## 14.1 Basic Concept and Assessment Method

The ecological environment is the cradle of human survival and development, and the foundation of economic development, and the source for social progress (Costanza et al. 1992). In recent two decades, with the population proliferation and science progress, human beings have changed the environment at great scale and speed, and ecological environment has been affected and damaged unprecedentedly. The ecological environment problem is not just point source problem, but also has developed into regional, and national or even global problem. Northeast Asia is very rich in natural resources. However, with its rapid economic development, the regional environment problems have become more and more serious.

Northeast Asia is an important ecological protective screen in the eastern of Eurasia; its eco-environment quality has the direct impacts on the national and regional environment safety. This thesis is on the basis of the land use data and satellite remote sensing data, with the method of ecological carrying capacity, calculated the ecological carrying capacity in the Northeast Asia from 1990 to 2010.

### *14.1.1 The Model of Ecological Footprint*

The ecological footprint (EF) is a measure of human demand on the Earth's ecosystems. It was developed in the early 1990s by M. Wackernagel and W. Rees. It is a standardized measure of demand for natural capital [(manufactured means of production) to goods and services relating to the natural environment] that may be contrasted with the planet's ecological capacity to regenerate. It represents the amount of biologically productive land and sea areas necessary to supply us with the resources for consumption, and to assimilate all the accompanied wastes (Rees 1992). Using this assessment model, it is possible to estimate how much of the Earth it would take to support our human beings if everybody followed a given lifestyle. For 2010, our human being's total ecological footprint was estimated at 1.5 planet Earths; that is, all of our human beings used ecological services 1.5 times as quickly as Earth can renew them. Every year, this number is recalculated to incorporate the 3-year lag due to the time it takes for the UN to collect and publish statistics and relevant researches (Yue et al. 2005).

The ecological footprint is a significant accounting tool for overall assessment of the status of sustainable development, and a comprehensive indicator for human resources consumption. The value of ecological footprint is based on the population, living condition, technical level, eco-production, and so on. According to the method of ecological footprint the ecological productive area is divided into five kinds: farmland, grassland, forest, water, and fossil energy land. The area's total EF formula is as follows:

$$\mathrm{EF} = N \times \mathrm{ef} = N \times \sum(a \times ai) = N \times \sum(ci/pi) \quad (1)$$

$N$ population;
ef EF of per capita;
$i$ different consumption item;
$ai$ consumption item of per capita;
$i$ ecological productive area;
$Ci$ consumption of per capita in $i$ consumption item;
$Pi$ globe average productivity in $i$ consumption item.

The ecological footprint includes two parts, the consumption of the living resources and the energy sources. The consumption of the living resources can be divided into agriculture production, animal husbandry production, forestry and aquatic production (FAO 1997). The consumption of the energy sources is divided into raw coal and oil (Chen et al. 2007).

### *14.1.2 The Model of Ecological Carrying Capacity*

The concept of the ecological carrying capacity came from ecology. It was first applied in the field of human ecology in 1921 by Park and Burgess. It is the maximum value of individual existence under a particular environmental conditions (mainly refers to the combination of living space, nutrients, climate and other ecological factors).

In 1991, Hardin further clarified the definition of ecological capacity in the condition of the undamaged productivity and the function of ecosystem integrity, unlimited duration of maximum utilization of resources, and waste rate. Based on the scholars of ecological footprint, the ecological capacity of the region is defined as the land ecological productive area in a region for human beings, and as the indication of ecological capacity in a region.

According to the remote sensing data, the various biological productive land area of per capita and the ecological capacity of per capita are calculated (Seidl and Tisdell 1999). Based on the adjustment of equivalence factor and yield factor, the ecological capacity of per capita is adjusted. Then, based on the calculated data, the characteristics of ecological carrying capacity of per capita is presented and analyzed in each region and different years. In the Northeast Asia the ecological carrying capacity can be calculated by the following formula:

$$\mathrm{EC} = N \times \mathrm{ec} = N \times \sum aj \times rj \times yj \quad (j = 1, 2, 3 \ldots 6) \quad (2)$$

EC total capacity region;
ec regional ecological carrying capacity per capita;

*aj* a per capita bio-productive land area;
*rj* equilibrium factors of different land types;
*yj* the yield factor of some productive land.

GIS spatial analysis and visualization techniques provided the combination method for the remote sensing image interpretation and the net primary productivity (NPP) grid data. According to the type of land data in each grid, the ecological carrying capacity is calculated. Then, the different color is used to show the different ranges of ecological carrying capacity. The spatial differences and characteristics are displayed and analyzed on the more visual angle.

In this study, the spatial calculation of ecological carrying capacity is obtained by the spatial calculation of the equilibrium factors. The net primary productivity (NPP) reflects the production capacity of plant communities in a natural environment which directly refers to the amount of organic matter accumulation in green plants of unit time and unit area. The calculation results of the ecological carrying capacity can reflect the differences of the land cover types and production capacity.

The ecological carrying capacity of 1 $km^2$ land is calculated according to the following formula:

$$\mathrm{ec} = \sum aj \times rj \times yj = \sum aj \times \mathrm{NPP}j/\mathrm{NPP} \times yj \times 100 \times 0.88 \quad (j = 1, 2, 3 \ldots 6) \tag{3}$$

ec regional ecological carrying capacity per capita;
*aj* a per capita bio-productive land area;
*rj* equilibrium factors of different land types;
*yj* the yield factor of some productive land;
0.88 the coefficients of the protective biodiversity.

## 14.2 Spatial Distribution and Temporal Change

### *14.2.1 The Basic Natural Eco-environment and the Land Use Change*

Based on the characteristics of physical geography, the Northeast Asia including the Far East and East Siberia of Russia, Mongolia, Japan, D.P.R. Korea, R. Korea, and the Northeast of China. Its location is in the East longitude 87°45′–162°51′, North latitude 27°34′–74°37′. Its land area is about $10^7$ $km^2$ and the population is about $450 \times 10^6$. There are the abundant forest, land, energy, mineral resources in this region. The forest area reaches $10.3 \times 10^8$ $hm^2$, accounts for 26.1% of the world in total. In 2007, the wood yield was $3.8 \times 10^8$ cubic meters, accounting for 17.2% of the world production in total. Oil, natural gas, and coal products, respectively, account for 17.4, 23, and 45.8% of the global output. Particularly, the timber production is more than

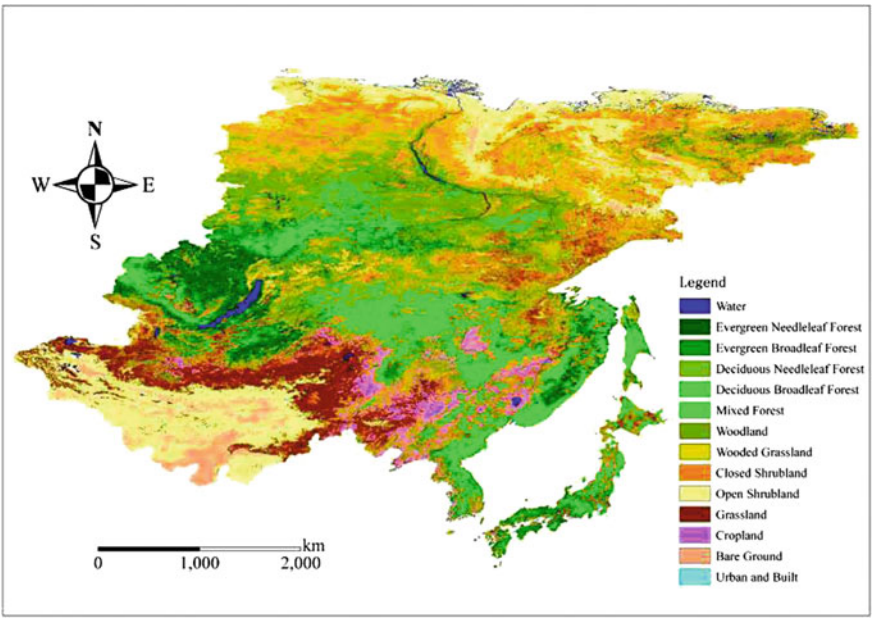



**Fig. 14.1** Land use maps of Northeast Asia in 1990

one-fourth and one-fifth of the global timber volume and yield in the region. The forest resources have huge development potential in the area. Compared to the following situations, such as a widespread destruction and substantial reduction in the global forest resources, resource accumulation, the climate warming, and the international protection of forest resources and environment, the supply and demand of forest products will significantly increase in the Northeast Asia.

Using ArcGIS software to cut the global land use classification data in 1990 and generate the Shp. file. According to the classification standards of existing in 1990, the two classification land use data of Northeast Asia in 2010 was merged into one class category to ensure the comparability, as shown in Figs. 14.1 and 14.2.

### *14.2.2 The Ecological Footprint*

According to the EF formula (1) and the statistical data of the yearbooks, the ecological footprint in Northeast Asia in 2010 is calculated. The results can be seen from Fig. 14.3, the figure shows the overall change situation of ecological footprint in the Northeast Asia from 1990 to 2010. The per capita EF is shown a trend of decline in the Far East of Russia, Japan, and Mongolia, but the original value is still higher in the front row. It is shown an upward trend in the Northeast China and

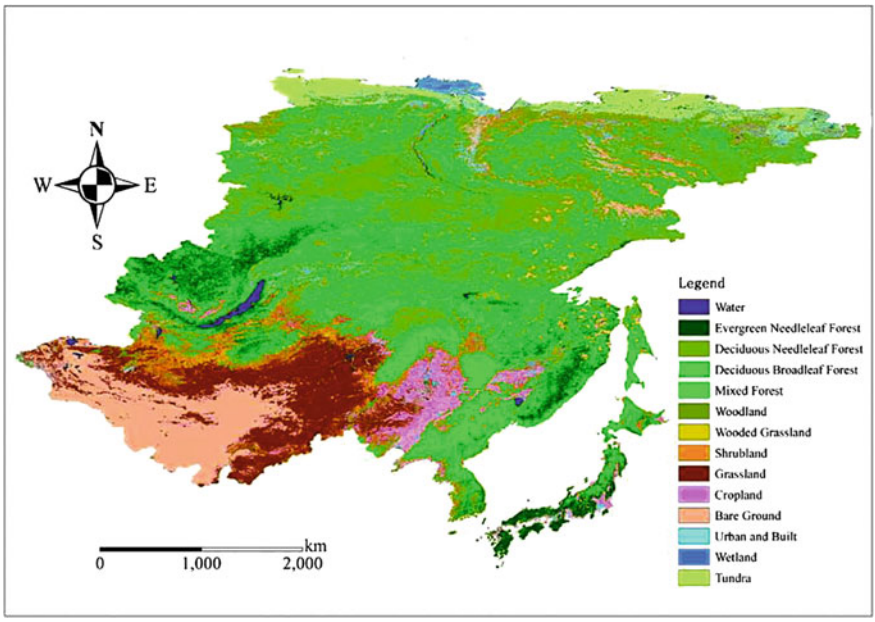
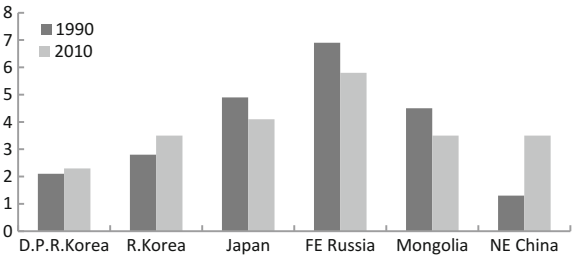



**Fig. 14.2** Land use maps of Northeast Asia in 2010

**Fig. 14.3** The change of ecological footprint in Northeast Asia from 1990 to 2010 ($hm^2$/per capita)




South Korea where is more than 3 $hm^2$ in 2010. The ecological footprint in North Korea is the most stable and the lowest, where it is about 2 $hm^2$.

### *14.2.3 The Ecological Carrying Capacity*

From Figs. 14.4 and 14.5, we can see the whole situation of the Northeast Asia. In addition, a small part of the ecological carrying capacity is near 0, in the most of the regions of the northern area of Northeast Asia, the ecological carrying capacity is between 0 and 30 $hm^2/km^2$. In the most central region of the Northeast Asia, the ecological carrying capacity is between 30 and 50 $hm^2/km^2$. In the regions of

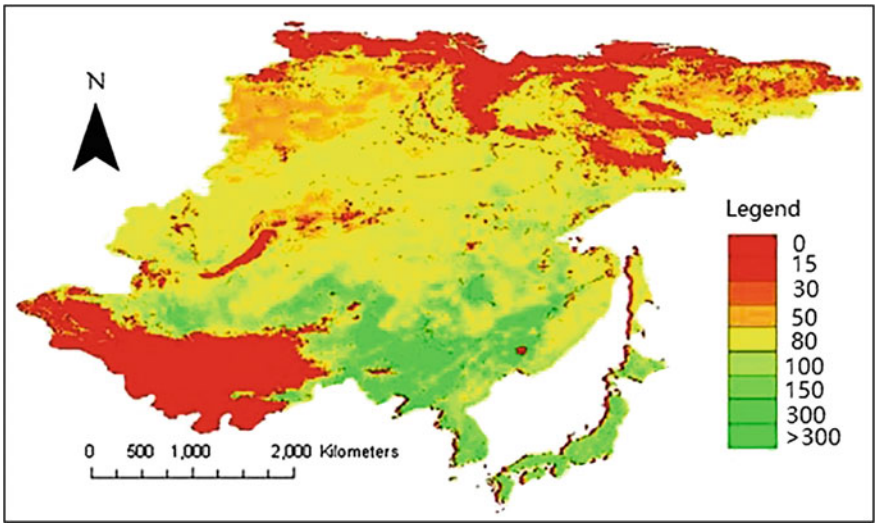



**Fig. 14.4** The ecological carrying capacity of the Northeast Asia in 1990

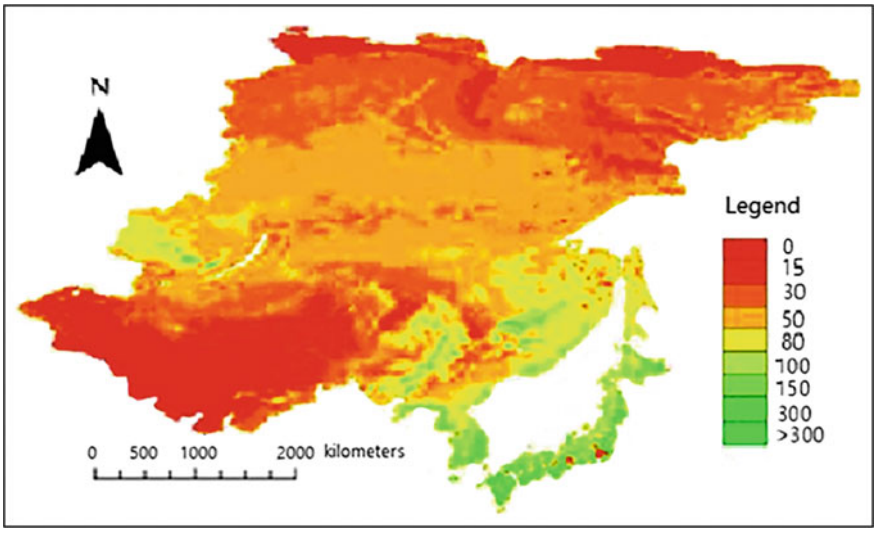



**Fig. 14.5** The ecological carrying capacity of the Northeast Asia in 2010

southeastern and mid-western, the ecological carrying capacity is between 80 and 100 $hm^2/km^2$. The ecological carrying capacity even exceeded 150 $hm^2/km^2$ in the southern areas. In the southwest region, there is a large bareland area, the ecological carrying capacity is near 0.

Following is the situation of the ecological carrying capacity which is further observed in different countries. The ecological carrying capacity is between 15 and 80 $hm^2/km^2$ in the most part of the Far East of Russia. In the small parts of the northern region, the ecological carrying capacity is near 0. Also, in some small parts of the southern region, the ecological carrying capacity is between 80 and 100 $hm^2/km^2$. But in most areas of the Mongolia, the ecological carrying capacity is 15–50 $hm^2/km^2$. In some small parts of the northern region, the ecological carrying capacity is more than 80 $hm^2/km^2$. The ecological carrying capacity is more than 80 $hm^2/km^2$ in the most areas of the D.P.R. Korea. It is more than 100 $hm^2/km^2$ in some small parts of the coastal areas. The ecological carrying capacity is more than 100 $hm^2/km^2$ in the most area of the Republic of Korea. Only in some small parts of the northern region, the ecological carrying capacity is about 80 $hm^2/km^2$. In most parts of Japan, the ecological carrying capacity is more than 100 $hm^2/km^2$. The ecological carrying capacity is about 80 $hm^2/km^2$ in the Hokkaido of Japan. It is even more than 150 $hm^2/km^2$ in the Southern Island of Japan.

In the Inner Mongolia Autonomous Region of China, the ecological carrying capacity is similar to Mongolia due to the similarity of the climate situation. The ecological carrying capacity is about 15–50 $hm^2/km^2$ in the most parts and more than 80 $hm^2/km^2$ in some small parts. In the half of Heilongjiang Province, the ecological carrying capacity is about 15–50 $hm^2/km^2$, and in another half, the ecological carrying capacity is higher than 80 $hm^2/km^2$. The ecological carrying capacity is 80–100 $hm^2/km^2$ in the western and middle of Jilin Province, meanwhile in the eastern part of Jilin Province, the ecological carrying capacity is between 30 and 50 $hm^2/km^2$. In Liaoning Province, the situation is similar to Jilin Province, ecological carrying capacity in general is about 80 $hm^2/km^2$ which is higher than that in western and mid-part.

Comparing the 2 years data of 1990 and 2010, the general trend of the ecological carrying capacity change can be seen. Following the climate change and the large-scale land development during the last 20 years, the ecological carrying capacity had been decreased significantly in most of the middle areas of the Northeast Asia. In the Northeast China, the land development and the urbanization are the major factors to the decrease of the ecological carrying capacity. In the Far East of Russia, major factors are deforestation and soil erosion. In the west coast of Japan and the Sakhalin Peninsula of Russia, it may be the climate warming increases the ecological carrying capacity.

## 14.3 Conclusion

After 1990, the EF of per capita showed the approach motive trends in the different countries of Northeast Asia. Particularly, at the beginning of twenty-first century, the EF value is growing in the R. Korea and NE China, however, over the same period, it is dropping in the FE Russia, Japan, and Mongolia. The EF value is lower, which was only near 4 $hm^2$/per capita until 2010, but with the rapid economic

development, the EF value will continue increase. Meanwhile, the huge population causes the total EF to be quite larger, even though the EF of per capita is at lower level, so that how to save the natural resources and protect eco-environment has become more and more important duty for the government and the public in the NE Asia.

The ecological carrying capacity holds a slightly different meaning when applied to human population growth. When discussing human populations, the ecological carrying capacity often refers to the number of individuals that the Earth could carry at different standards of living and levels of resource consumption (Zhang 2006). Thus, the Earth's ecological carrying capacity is smaller if the average living standard people achieved in the developed countries is closer to the average living standard people achieved in developing countries.

## References

Chen B, Chen GQ, Yang ZF (2007) Ecological footprint accounting for energy and resource in China. Energy Policy 35:1599–1699 (in Chinese)

Costanza R, Norton BG, Haskell BD (1992) Ecosystem health: new goals for environmental management. Island Press, Washington DC, pp 223–238

FAO Proceedings (1997) Land quality indicators and their use in sustainable agriculture and rural development. In: Proceedings the workshop organized by the Land and Water Development Division FAO Agriculture Department, No. 2:5

FAOSTAT. http://faostat.fao.org/

Rees WE (1992) Ecological footprint and appropriated carrying capacity: what urban economics leaves out. Environ Urban 4(2):121–130

Seidl I, Tisdell CA (1999) Carrying capacity reconsidered: from Malthus' population theory to cultural carrying capacity. Ecol Econ 31:395–408

Yue D, Xu X, Li Z (2005) Spatiotemporal analysis of ecological footprint and biological capacity of Gansu, China 1991–2015: down from the environmental cliff. Ecol Econ 1:1–14 (in Chinese)

Zhang Y, Yang Z, Yu X (2006) Measurement and evaluation of interactions in complex urban ecosystem. Ecol Model 1:1–13