Ecological footprint and biological capacity time series assessment for a forest region in northeastern China

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SUMMARY

Anthropogenic disturbances have caused major landscape changes in the forests of northeastern China during the past 50 years. In particular, continuous over-deforestation has greatly decreased the region’s forest quality. Ecological footprint analysis generates aggregated information about a population’s demand on nature and the population regional biological capacity. To show the forest change and the population’s ecological demand on the study area, this paper presents an ecological footprint time series for the Songling Forestry Bureau in northeastern China from 1965 to 2000. The paper shows conventional ecological footprint time series and area demand time series – under global, Chinese and local yearly yields – to study the biological productivity of Songling. In this study, biological capacity was calculated based on a conventional approach. The results demonstrate that the ecological footprint has increased slightly and continuously during the 35-year timespan, while the biological capacity has decreased dramatically. These effects have been caused mainly by the depletion of forest resources. The results also yield much information about natural changes and socioeconomic dynamics, as well as the driving factors for these changes, of which the most important is forest management policy.

INTRODUCTION

Ecological footprint (EF), a concept developed by Wackernagel and Rees (1996), has received considerable attention in recent years. Ecological footprint analysis is designed to track the amount of natural resources a population uses in a given region, and these amounts are compared to the biological capacity (BC) of that region. The conventional methods used to calculate EFs are based on ‘global hectares,’ which are calculated based on global standardized biological productivity (bioproductivity) (Montfeda and Wackernagel 2004). EF calculations try to assess how much biologically productive area is needed to produce the yearly resource flows consumed by the population, to absorb wastes or emissions (especially CO2), and to host the infrastructure of the region under analysis.
(whether a city, a country, or the world). If the EF is larger than the available BC of a region, then human consumption exceeds ecological limits for that region. This is referred to as ‘overshoot’ in EF research (Wackernagel and Rees 1996).

Conventional EF analysis is used to determine whether and by what order of magnitude human consumption exceeds the biosphere’s regenerative capacity (Wackernagel and Lewin 1999). The conventional EF is a useful guide for cross-country comparisons because it renders the consumption levels of different countries comparable, regardless of local or regional variables affecting the productivity of land, such as climate, soil characteristics or technology (Wackernagel et al. 2004). However, the EF approach to global average productivity has been criticized as ‘false concreteness’ (Van den Bergh 1999; Verbruggen and Smeets 2000). In order to resolve this issue, Haberl and colleagues (2001) analyzed the effect of different yields on the results of EF calculations by assuming: constant global yields as of 1995; variable global yields; variable local yields for domestic extraction; and variable global yields for imported biomass. Erb (2004) developed the approach of ‘actual land demand’, which substitutes global productivity with yields for a given study area. ‘Actual land demand’ is calculated based on local yields of a defined community instead of productivity; this calculation reflects the human pressure on the ecosystem within the defined community (Erb 2004). Since the ‘actual land demand’ approach focuses on the consumption and bioproductivity of a given area, it is more valuable as a measure of sustainability (Ferguson 1999). ‘Actual area demand’ is an EF approach, which simply substitutes global average bioproductivity with that of a local average. ‘Actual area demand’ uses inputs of bioproductivity at different administrative levels to calculate an area’s demand. For example, the bioproductivity of a country should be used to calculate the area demand at the national level, the bioproductivity of a state should be used at the state level, and so on. This approach can better reflect effects at a given community level.

EF analysis is a ‘snapshot’ approach, which can only reflect static socioeconomic and natural information. EF time series can effectively capture changes in a population’s socio-economy and lifestyle over time. Until now, EF time-series calculations were chiefly based on ‘stable’ bioproductivity for a given region, which is held constant over time. However, an EF time series with ‘stable’ bioproductivity cannot reflect the effects of technological advances. To overcome this limitation, we calculated the conventional EF and ‘area demand’ with yearly changing bioproductivity.

Chinese forests have undergone significant changes in the past several decades. According to the sixth Chinese forest resources survey (1999–2003), forest area in China covers approximately 1.75 × 109 ha, whereas the per capita area is only 0.132 ha, less than one-quarter of the global average. Forest coverage in China is 18.12%, which is 61.52% of the global average. The forest volume is 124 × 109 m3 and the per capita volume is only 9.421 m3. Between 1965 and 2000, forest area increased from 1.21 × 109 ha to 1.75 × 109 ha and forest volume increased from 9.03 × 109 m3 to 1.25 × 1010 m3 (first forest resources survey, 1973–1976); however, forest volume per area decreased from 90 m3/ha to 84.73 m3/ha, and the area of natural forest decreased sharply, especially that of mature natural forest. These changes can be traced to over-harvesting and large areas of artificial forest planting during recent decades.

Chinese forest resources are concentrated in northeastern and southwestern China. Northeastern forest resources are mostly distributed within Heilongjiang Province. According to forest resource surveys (first through sixth), natural forest area decreased by 1.59 × 108 ha on average every year in Heilongjiang Province. The Songling Forestry Bureau is a typical forest region in China, and is therefore representative of the forest and socioeconomic changes of most forest regions throughout China.

In this study, we calculated the EF, actual area demand and BC time series of the study area from 1965 to 2000, with a global constant, global yearly, Chinese yearly, and local yearly average bioproductivities. There were almost no human activities within the Songling Forest Bureau prior to 1965. We determined socioeconomic and forest changes by first calculating EF and BC, then further analyzing driving factors. The results reflect trends not only for the study area, but also for most Chinese forest regions. The analysis provides policy-makers with useful information for sustainable forest utilization and management. More broadly, we hoped to analyze the EF and extract more detailed information by comparing the
results of EF in different years and with different bioproductivities.

STUDY AREA DESCRIPTION

The Songling area is in the north of Heilongjiang Province, from 50°37'30"N to 51°39'32"N, and from 123°29'13"E to 125°56'07"E. The study region had an area of 743034 ha in 1965. In 1990, boundaries in this region were changed, and the resulting area also changed. The administrative region is chosen as the study area because the statistical data used in our study are based on the administrative boundary. The area lies within the cold temperate zone, and annual rainfall in the region is approximately 350–500 mm. The most typical vegetation is boreal forest; forest coverage accounted for about 77.52% in 1965. Human activities in the region were minimal prior to 1965, when the Songling Forestry Bureau was first created. The following years have seen a significant increase in the number of human residents, most of them lumberjacks. In 1965, the region had a population of only 0.7 per km², by 2000, the value increased to 4.0. Typical of the region had a population of only 0.7 per km², by 2000, the value increased to 4.0. Typical of most forest bureaus in China, Songling had been exporting wood every year since 1965, and the forest resources of Songling decreased dramatically due to over-harvesting. In 1998, the Chinese government initiated its Natural Forest Protection Project, which forbids deforestation throughout the country; subsequently, harvesting ceased within Songling and the planting of artificial forest began. Since then, forest resources in the Songling area have recovered.

METHODS

Based on the works of Wackernagel and Rees (1996), Haberl et al. (2001) and Erb (2004), we used four methods to calculate the EFs and compared the results.

Conventional EF (Gha)

We calculated a conventional EF based on the methodology of Wackernagel and Rees (1996). In this calculation, we used the global average bioproductivity given in Wackernagel and Rees (1996). These results reflect only changes in consumption levels, not changes in agricultural technology or forest management (Ferguson 1999). However, the results among different regions and different years can be compared. The conventional footprint is calculated as follows (Wackernagel and Rees 1996):

\[
EF_{ij} = \frac{DE_{ij} + Im_{ij} - Ex_{ij}}{Y_{gha_{ij}}}
\]  

(1)

Where \( EF_{ij} \) denotes the EF of one item (i) in a certain year (j), and the unit is a hectare; \( DE_{ij} \) denotes local extraction of this item (local production) in tonnes [t]; \( Im_{ij} \) denotes Imports [t], and \( Ex_{ij} \) denotes Exports [t]; and \( Y_{gha_{ij}} \) represents a one item (i) yield of its global average. Yields were assessed in ton per ha per year for agricultural products, in m³ per ha per year for forestry products, and in GJ per ha per year for fossil energy and electricity imports.

Global yearly EF (Gyha)

We calculated global yearly average yields from 1965 to 2000. For example, corn consumption in 1965 is calculated using the world average yield for this year. These results reflect not only consumption changes but also advances in agricultural technology and forest management worldwide, irrespective of regional deviations from global bioproductivity trends. Global yearly EF is calculated as follows:

\[
EF_{ij} = \frac{DE_{ij} + Im_{ij} - Ex_{ij}}{Y_{gha_{ij}}}
\]  

(2)

Where \( Y_{gha_{ij}} \) represents the global yield average of a given item (i) yield of global average for a given year (j).

Chinese yearly EF (Cyha)

We calculated Chinese yearly average yields from 1965 to 2000. China possesses a long agricultural history, the productivities of which are greater than the global average in each year. With this method, the results can reflect the trend of Chinese bioproductivity and be compared with the EF of other regions in China. Chinese yearly EF is calculated as follows:

\[
EF_{ij} = \frac{DE_{ij} + Im_{ij} - Ex_{ij}}{Y_{china_{ij}}}
\]  

(3)

Where \( Y_{china_{ij}} \) represents a given item (i) yield of a Chinese regional average for a given year (j).
Local yearly EF (Lyha)

Local yearly yield calculations reflect the effects of socioeconomic activities on the local environment, as well as consumption and local productivity changes. By comparing these results with those of conventional EF, Global yearly EF and Chinese yearly EF, it is possible to identify relationships between bioproductivities at different levels. In this study, local BC was calculated using the conventional EF method; however, we substituted local yields for global average yields and calculated ‘yield factors’ and ‘equivalence factors’.

Local yearly EF was calculated with the following equation:

\[
\text{EF}_{i,j} = \frac{\text{DE}_{i,j} + \text{LY}_{i,j}}{\text{LY}_{i,j}} - \frac{\text{E}_{i,j}}{\text{LY}_{i,j}},
\]

(4)

Where \( Y_{loc,i,j} \) represents a given item \((i)\) yield of the Songling region for a given year \((j)\), and \( Y_{avg,i,j} \) represents a given item \((i)\) yield of the region where the goods are produced for a given year \((j)\).

Calculating equivalence factors

EF analysis examines six categories of bioproductivity area: cropland, pasture, forest, fossil land, built-up land, and water area. These area categories are weighted through equivalence factors. The equivalence factors represent the world average potential productivity of a given bioproductivity area relative to the world average potential productivity of all bioproductive areas.

Because no data are available on equivalence factor calculation for Gyha and Cyha calculation, we obtained equivalence factor values based on the factors of conventional EF approach (Wackernagel and Rees 1996). The equivalence factors for conventional EF calculation are shown in Table 1. Equivalence factors for Lyha calculation were calculated based on local yields for Songling between 1965 and 2000 in 10 year averages (Table 1).

Energy EF calculation

EF of fossil energy was calculated with the method in conventional EF calculation (Wackernagel and Rees 1996). The calculation method suggests calculating the land needed for fossil energy consumption by assessing the forest area that is necessary to absorb the CO2 emissions generated by burning fossil fuels. We used the global average forest productivity in calculating conventional EF. Global yearly EF and Chinese yearly EF. Based on preliminary EF calculations, we found that the amount of CO2 absorbed by forests in Songling is much greater than the amount generated. Therefore, the forest productivity of Songling was taken to calculate energy land demand, which more reasonably assesses effects on a local environment resulting from human activities.

<table>
<thead>
<tr>
<th>Year</th>
<th>Conventional EF (10 year averages)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1965</td>
</tr>
<tr>
<td>Forest</td>
<td>1.14</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.54</td>
</tr>
<tr>
<td>Cropland</td>
<td>2.82</td>
</tr>
<tr>
<td>Water area</td>
<td>0.22</td>
</tr>
<tr>
<td>Fossil land</td>
<td>1.14</td>
</tr>
<tr>
<td>Built-up land</td>
<td>2.82</td>
</tr>
</tbody>
</table>

Conventional: the factors used in conventional EF calculation (Wackernagel and Rees 1996)

BC calculation

In the EF calculation, carrying capacity is expressed as biological capacity, which is translated into units of surface area and can thus be compared with the EF. In the calculation, 12% is subtracted from carrying capacity to protect biodiversity, according to the United Nations World Commission for the Environment and Development (Bundtland Report, World Commission for the Environment and Development 1987).

In conventional BC calculation, five categories of ecologically productive area are distinguished: crop land, pasture, forest, water area, and built-up land. The result of the carrying capacity is aggregated for the five categories by equivalence factors and yield factors, and called biological capacity or ecological capacity (Wackernagel and Rees 1996). The yield factor of each category is the ratio of biocapacity and ecological capacity (Wackernagel and Rees 1996). The yield factor is the ratio of biological productivity of a given region to the global average biological productivity (Wackernagel and Rees 1996). In Erb’s calculation (2004) of ‘actual land demand’, biocapacity was not assessed, and biocapacity was taken as the biologically productive area.

In our study, BC is much greater than EF for all years examined, and BC is calculated only to reflect temporal changes. Moreover, BC without...
aggregation (Erb 2004) is not convenient to compare different years or with EF. Thus, the conventional BC calculation (Wackernagel and Rees 1996) was taken, and was calculated with the following equation:

$$BC = \sum_{i} \left( \frac{Y_{\text{loc},i,j}}{Y_{\text{glob}}} \right) \times \alpha_{\text{loc},i,j} \times \nu_{\text{loc},i,j}$$  \hspace{1cm} (5)

where $Y_{\text{loc},i,j}$ represents a given item $(i)$ yield for Songling region for a given year $(j)$; $Y_{\text{glob}}$ denotes the global average yields used in Gha calculation; $\alpha_{\text{loc},i,j}$ represents the area of land cover for category $i$ in year $j$ within Songling; and $\nu_{\text{loc},i,j}$ represents a given item’s $(i)$ equivalence factors in year $j$.

**DATA COLLECTION**

We derived all required data from the following data sources: (1) global average yields for agricultural and forestry products from 1965 to 2000 were obtained from databases of the UN Food and Agricultural Organization (FAO 2004a); (2) yields for Chinese agricultural and forestry products from 1965 to 2000 were obtained from the Chinese Academy of Sciences Scientific Database; (3) data on Songling were obtained from statistical yearbooks of Songling. Consumption data were obtained both from per family average consumption data recorded in statistical yearbooks and from 150 questionnaires distributed to local residents within the study area.

**RESULTS**

**EF and land area demand**

The calculation results of the four approaches are displayed in Figure 1. Because the data for global yearly forest and grass yields and Chinese grass yearly yields were not available, we substituted these with the yields used in the Gha calculation.

The four methods produce different results, which are shown in ha in per capita EF over a given area. The results show that the EF steadily, though slowly, increased during in all 35 years (Figure 1). The Gha, Gyha and Cyha calculations transitioned smoothly. The Lyha, however, fluctuated dramatically over the study years. The Gha increased rapidly during two periods: from 1974 to 1975 and 1980 to 1986. The Gyha and Cyha experienced similar overall trends to Gha. EF reflects economic activities and consumption levels, and these can be viewed as a function of two factors: consumption level and pattern, and the yield per hectare to sustain this consumption (Erb 2004). The Gha can capture the consumption dynamics due to the constant bioproductivity used, and the consumption of the study area slowly increased throughout the study period, but two rapid increases occurred, in 1975 and from 1980 to 1986. The results for Lyha were much smaller than those for the other methods. Four evident peaks appeared, in 1969, 1975, 1980 and 1982; this fluctuation of Lyha indicates the unstable bioproductivity of Songling during the study period. The same consumption data were used in each of the four calculation approaches, so the inverse...
relation of the results and bioproductivity can be easily obtained from equations 1 to 4. As Figure 1 illustrates, global average productivity, global yearly bioproductivity and Chinese yearly bioproductivity remained relatively stable, but the annual bioproductivity of Songling was much larger than these values in corresponding years, with the exception of the four years where peaks occurred. Chinese yearly bioproductivity was greater than global yearly bioproductivity for every year in the study period, and greater than the global average bioproductivity used in Gha calculations since 1977. Global average bioproductivity was greater than global yearly bioproductivity prior to 1995.

EF is a summation of arable land, pasture, forest land, built-up land, fossil fuel land and water area. The components of Gha and Lyha are displayed in Figure 2 (weighted with equivalence factors). Pasture, forest, fossil fuel land and arable land compose the majority of both Gha and Lyha. The rapid increase seen in Figure 2 is explained by the increase in grassland and fossil fuel area demand during the early 1980s. The rapid increase in 1975 was caused by increasing fossil fuel land demand. Forest area demand accounts for a large proportion in Gha and Lyha because residents of Songling burn copious amounts of wood for cooking and home heating. Water and built-up area demand account for a smaller proportion. The fluctuation in Lyha is explained by the cropland area demand change. Further analysis revealed that fluctuating cropland area demand corresponds with unstable local agricultural yields (Figure 2b).

To show the relationships between different land demands, the results of different area demands are displayed in Figure 3 (before weighting with equivalence factors). The area demand of water was significantly smaller than that of all the other factors represented and therefore was not included in the Figure. The area demand for built-up land was caused by consumption of electricity and heat, which both come from fossil fuel (mainly coal) within the study area. Consequently, built-up land area demand is combined with fossil fuel area demand in Figure 3c.

The results show that cropland area demand for Gha, Gyha and Cyha were very similar, but Lyha was greater and fluctuated dramatically (Figure 3a). The results show that the average agricultural productivity of Songling was smaller than the other areas, and the agricultural yields were not stable. The peaks in the Lyha calculation show that agricultural yields were much lower in several years and that these fluctuations were caused by natural disasters. Agricultural productivity based on Chinese yearly yields was greater than that of the global average for each year, and was greater than the productivity used in Gha calculation after 1972. The global average agricultural productivity is smaller than the productivity used in Gha.

In the forest area demand calculation, Gyha was not calculated due to lack of data. The forest area
demand of Gha, Cyha and Lyha are given in Figure 3b. These results showed that the forest average productivity of Songling was higher than that of China (the latter was already greater than the value used in Gha calculation). The forest yield of Songling was 1.39-times that of the world average in 1965, 0.84-times higher in 1990, 1.16-times higher in 1991 and 0.91-times higher in 2000. A sharp increase in forest yield in the study area occurred in 1991, caused by a change in the administrative region and incorporation of a much higher forest yield. The results also show that per capita wood consumption remained stable prior to 1995. After 1995, consumption began to decrease (Figure 3b). The forest area demand of Songling was significantly greater than that of other regions studied (as compared to the results given by Wackernagel and Rees 1996). This is because Songling is located within a cold region, and large amounts of wood were used by residents for home heating and cooking.

The energy area demand is given in Figure 3c. Since only the parameters of energy area demand in Gha were available, only Gha was calculated. The energy area demand of Songling increased sharply in 1975, caused by the start of electric power use in 1975. The rapid increase in energy area demand from 1979 to 1985 was caused by a significant change in production of goods made from lumber. Prior to 1979, Songling exported logs directly; in 1979, however, factories were set up to produce goods from available lumber, which caused increased energy consumption.

Grassland area demand reflects the degree of meat consumption and the available technology for domestic animal breeding. The grassland area demand of Gha and Lyha are given in Figure 3d. The increase in Gha reflects increased meat consumption over the 35-year time span. The relation between Gha and Lyha reflects an improvement in domestic animal breeding technology in Songling, and this value exceeded the world average yield in 1976.

**Export and import EF**

Export and import land area demand were calculated based on available trade data in statistical yearbooks for Songling. Products made from wood were the chief exports of Songling. Export production amounts increased before 1975 and maintained an approximately stable level thereafter (Figure 4). The Gha line best represents the amount of export production because of the constant yields used (equation 1); however, Lyha includes information about the amount of production and yield changes. The gaps between Gha and Lyha values reflect yield gaps between global average and local yields. The exported Gha from Songling was 6.32-times greater than that of imported Gha in 1965, and was 2.89-times greater in 2000. Cumulative exports of Gha from Songling (5.66 million ha) from 1965 to 2000 were 4.32-times those of imported Gha (1.25 million ha), and 1.11-times those of exported Lyha (5.10 million ha). A sharp decrease in Lyha occurred in 1991 due to increased wood yields resulting from administrative area change.

The Lyha import was not calculated because insufficient data were available. Figure 4 illustrates how imported Gha increased steadily over the 35-year study period. Detailed analysis revealed that Songling was a net importer of agricultural and pasture products, such as bovine meat or milk, in earlier periods; however, it became an exporter of these goods in later years. The increased importation was mainly caused by the import of fossil fuels and daily necessities.

![Figure 4 Export and import EF: (a) per capita export and import EF and (b) summation of export and import EF](image-url)
Biocapacity change

Conventional EF assessments reserve 12% BC for biodiversity conservation (Wackernagel et al. 2004). The ‘biodiversity area,’ which is formally considered as either an increased area demand or a decreased BC, was taken into account in our study. The dynamics of BC, discounted by 12% for biodiversity conservation, are displayed in Figure 5. Results show that the BC of Songling in 1990 was 62.36% of that in 1965. In other words, the BC of Songling sharply decreased by 37.64% during the 25 years from 1965 to 1990, and decreased in per capita terms by 79.54% (161.77 ha in 1965 and 33.10 ha in 1990). The area of the administrative region increased 22.07% in 1991, which caused the seemingly dramatic increase in BC. In fact, BC had a decreasing trend from 1992 to 2000.

Songling’s EF was considerably smaller than its BC during the entire study period, and the ratio of BC to EF decreased greatly. The ratio was 110.75 in 1965 and, in 2000, it decreased to 24.51. The sharp decrease in the ratio was caused by a dramatic decrease in BC and an increase in EF. BC decreased throughout the study period, except for the increase in 1991 due to the change in administrative region. Decreasing BC was entirely caused by the decrease in forest quality – the dominant land-use type in the region – due to continuous over-deforestation. As Figure 6 demonstrates, deforestation did not result in a decrease in forest area because artificial afforestation and natural reproduction replaced forest area lost due to deforestation. Rather, the decreased BC was caused by a decrease in forest quality (i.e. wood volume per unit area) and forest yields. Figure 7 represents the forest yield of Songling and forest quality change. The forest yield was larger than that used in Gha, but followed a downward trend throughout the period, with the exception of the sharp increase in 1991. Forest quality had trends similar to those for forest yields.

The results show that, except for 1991, per capita BC decreased in a smooth trend prior to 1995 (Figure 5b). After 1995, per capita BC began to increase. The study area had been exploited since...
1965, but there were almost no human activities before 1965. There were only 5,146 residents in 1965, but the population rapidly increased to 31,094 in 1977. However, the increase in population has slowed since 1977. Population increase was the most important factor for the per capita BC decrease in this region.

**DISCUSSION**

**Driving force analysis**

The EF of Songling almost maintained a steady increase from 1965 to 2000, but increased even faster between 1979 and 1986 (Figure 1). The more rapid increase in EF reflects an enhanced consumption level, which was caused by the Chinese policy of ‘Reform and Opening Up to the Outside’ since 1979. Biocapacity decreased steadily after 1965, but increased in 1998. The change in this trend is the result of the Chinese government enacting the ‘Natural Forest Protection Project’ in 1998, which forbids the deforesting of natural forests in many regions of China. According to our analysis, policy dynamics are the most important driving factors of natural and socioeconomic changes within Songling.

**Implications of the study results**

This study reports the results of area demand at three regional levels and the conventional EF of a typical forest area in northeastern China. The conventional EF method was adapted in order to calculate the area necessary to sustain a society’s biomass and energy metabolism (Erb 2004). Local land demand was used to assess the socioeconomic pressure on the local environment. The area demand at different regional productive levels can be used for comparison with other regions at the same level.

Our results indicate that Songling was a net EF exporter and mainly exported forest area during the entire study period. The huge EF export, however, came at the cost of depletion of local natural resources. The deforested regions were composed of forests of nearly mature and over-mature coniferous trees. The deforested area of Songling accumulated to 3,174,964 ha, which is 67.69% of the mature forest area in 1965. Only 32.31% of the mature and over-mature forests of Songling remain. If deforestation persists at the current rate, mature forest in Songling will disappear within 20 to 30 years. Because most of the conifer species in Songling need approximately 100 years to become mature and about 140 years to become over-mature, rapid deforestation prevents any lasting forest renewal in the region.

**Implications of the study methods**

In most EF calculations published to date, EF approaches are applied to evaluate sustainability, lifestyle and capacity. Time-series EF was used to show the dynamic demand of population on the nature environment. Haberl et al. (2001) discussed the problem of calculating a time-series EF and calculated an EF for Austria from 1926 to 1995. An ‘actual land demand’ approach was taken to reflect the impression of human activities on the local environment. Wackernagel et al. (2004) calculated EF time series for Austria, the Philippines and South Korea from 1961 to 1999, using a conventional approach and an ‘actual land area’ approach in 2004. Erb (2004) evaluated actual land demand of Austria from 1926 to 2000. These calculations evaluated socioeconomic metabolism and BC change, but more detailed information and driving factors evident from the results were not explored. Our study calculated not only conventional EF and ‘actual land demand,’ but also land demand based on global and Chinese average yields that allows more information to be discovered.

The global yield approach measures the proportion of global bioproductivity used by a population, while the local yield approach assesses the actual areas used for supplying a given population (Wackernagel et al. 2004; Van Vuuren and Smeets 2000; Haberl et al. 2001; Erb 2004). EF and BC are only ‘snapshots’ of socioeconomic metabolism and nature resources for a given year, but the longer time-series EF can reflect socioeconomic, natural and policy changes more effectively. The conventional EF approach reflects consumption well because constant yields are used and can be compared for different years, but the EF with yields for different years not only reveals consumption but also accounts for technological advances. EF is composed of several different consumptions – for example, food, fossil fuel, wood, and so on. Through analysis of their EF, people’s lifestyle,
consumption changes and other socioeconomic characteristics can be interpreted. Through long-term and multi-level EF detailed analysis, information on the effects of socioeconomic change, technological advances and policy dynamics can be discovered.

**CONCLUSION**

This study has reported the socioeconomic and forest resource changes in the Songling Forest Bureau using ecological footprint and 'actual land demand' approaches by analyzing a 35-year period from 1965 to 2000. The results show that the consumption level slowly increased during the entire period. Songling is a net exporter of forest EF, and the export EF is much larger than the import EF. The huge EF export comes at the cost of BC depletion. The decrease in BC was caused not by any change in forest area, but by a decline in forest quality and yield. Based on the comparison of EF and land demand in the study area with different regional levels of bioproductivity, we conclude that the average bioproductivity of Songling was greater than the national average. The dynamics of Songling were primarily caused by policy change. The time series analysis with EF and actual land demand approaches can be used to assess the socioeconomic and natural dynamics in a forest region. The historical EF analysis of Songling provides information on how to achieve sustainable development in a forest region. An EF approach combined with a forest landscape model and a social model would generate useful information for policymakers and residents.

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