暖温带落叶阔叶林动态变化的模拟研究

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摘要：用森林动态林窗模型 FORET1 模拟了暖温带落叶阔叶林的长期变化特征。模型参数取自暖温带地区长期森林研究和经营的历史数据，对过去数据中缺少的参数进行了实地测定，并用观测的数据对模型作了检验。结果表明模型能较好地模拟暖温带落叶阔叶林的长期动态变化特征。通过模拟可以看出，森林的净初级生产力没有明显变化规律且极度不稳定，峰值出现在30a左右，相似于世界上其它地区森林动态格局变化，生物量格局呈循环状态变化，循环周期大致在110a左右。

关键词：暖温带落叶阔叶林；森林木窗动态模型

Modelling changes of a deciduous broad-leaved forest in warm temperate zone of China

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Abstract: A warm temperate deciduous forest in Dongling Mountain of Beijing was simulated with forest gap dynamics model, FORET1, in order to predict its future changes. The model parameters were derived from both historical and currently measured data; and the model was tested against observed data. Results showed that the model simulation of forest species composition, biomass and production matched well with observed data. Model simulation of the dynamics of this warm temperate deciduous forest indicate that the changes in net primary production was clearly unregulated and extremely unstable, with a peak around 30 years and repeated patterns of dynamics in biomass production every 110 years. The patterns of temporal dynamics of this forest are comparable to other forest ecosystems worldwide.

Key words: warm temperate zone; deciduous broad-leaved forest; forest gap dynamic model

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Models are simplifications of more complex realities[1]. During recent decades, simulation of forest growth has become a major research field[2], and numerous computer models have been developed[3,4]. Models range from simple to complex in function and operation, from simulation of growth of single plants to dynamics of whole ecosystems in applications, and from days to centuries in temporal scales. The simplest models are highly concrete, yield-oriented empirical models that are more often intended for use as management tools. Those models depend on huge database. Some other conceptually simple models are highly abstract and require little data.

Gap-models are also known as forest community dynamics models[4]. Those models have mostly been derived from the JABOWA model[5], which was developed to simulate gap-phase dynamics in a northern hardwood forest of the northeastern United States. Gap-models simulate the annual change in the tree population of a small patch of forest by calculating growth increments of single trees, adding new saplings, as well as by allowing natural mortality. The first process is deterministic, and the other two stochastic[6].

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In this study, we could not establish a very complex model concerning all processes that a forest ecosystem has because of lack of research results and data on the warm temperate and deciduous broad-leaved forest. Therefore we could not develop the Type III model. The Type I model is too simple, unrealistic, to use as forest management tool. Consequently, we developed a forest dynamics model similar to the Type II model.

The purposes of this study were to (1) test the model against observed data from field surveying, (2) predict the long-term dynamics of deciduous broad-leaved forest in terms of forest biomass, net production, leaf area index, etc. , in the warm temperate zone), and (3) through analysis of the observed and simulated results, understand long-term dynamics of forests in warm temperate zones.

1 Study site

1.1 Location and Climate

This study was carried out in the Beijing Forest Ecosystem Research Station (BFERS) of the Chinese Academy of Sciences (CAS) (latitude 40°00′N, longitude 115°26′E), located 114 km southwest of Beijing. This area belongs to the Dongling Mountain range, with a warm temperate and continental monsoon climate. The 10-year mean of the annual temperature of the site is 4.8℃, and the annual precipitation is 611.9mm, about 78% of which occurs in June, July and August. The mean annual potential evaporation (*ET*), however, reaches 1,077.7mm. Maximum of monthly mean temperature occurs in July (18.3℃), with mean daily air temperature recorded at 24.9℃ in June and the minimum at −12.8℃ in December. The mean annual soil temperature is 13.4℃. The soil could freeze down to a depth of 110cm for more than half a year.

Several soil types are found in the study region, including sub-alpine meadow soil, mountainous brown soil, mountainous plaggen brown soil, luvic cinnamon soils, typical cinnamon soils, and carbonate cinnamon soils, *etc*[7].

The vegetation of the study area is deciduous broad-leaved forest with oak (*Quercus liaotunensis*) as dominant species, mixed with birch (*Betula*, *dahurica* and *platphyyla*), *Tilia mongolica*, *Acer mono*, and *Fraxnus rhynphyyla* and other tree species such as popular (*Populus davidiana*) and walnus (*Juglans mandshurica*). Tree species composition varied greatly at different stages of the forest development[8].

1.2 Model and parameter

The model (FORET1) used in this study is the same as Shugart[4]. Model parameters were derived by both direct and indirect methods. Parameters insensitive to changing conditions were estimated by indirect methods. Those parameters were mortality, suppression, maximum age, maximum *DBH*, and maximum tree height. Other parameters were estimated from observed data. The data came from two sources: one was from the historical management data, and the other from the field observations. Physical and mathematical methods were used to calculate parameters, such as, solving equations, and performing non-linear regression analysis.

2 Result analysis

2.1 Comparison between observed and simulated data

Model Testing Observed data were used to test the model. First we compared observed biomass and tree species composition with predicted results(Table 1). The results showed that the observed biomass was very similar to the predicted values, especially for oak. The predicted values for minor species *B. platyphylla*, *B. dahurica* were not markedly different from observed data. Thus, the model can simulate forest tree composition and biomass dynamics.

Table 1 Comparison between observed and predicted tree composition and biomass of a oak forest at age 80

	Quercus liaotunensis	*Acer mono*	*Betula dahurica*	*Betula platyphylla*	*Tilia mongolica*	Others
* Observed biomass	135.63	1.16	16.93	5.19	11.37	5.08
* Predicted biomass	137.29	5.90	20.41	0.94	0.35	2.24

* Observed biomass was calculated by summing each tree's biomass that was estimated allometrically from *DBH*. The unit for biomass is t/hm^2 of dry mass

Comparison between observed and modeled values showed that tree species composition greatly changed with forest development. If measured by biomass and composition change, oak dominated the forest in all the successional stages, but the composition structure of tree species varied greatly at different stages. The oak population was initially low, but increased with the stand development until it became a pure oak Forest. For example, at the middle stage of the succession, oak accounted for 66% in tree composition, but reached 81% at later stage, and finally 100% at the end of the succession.

2.2 Discussion

The simulation started with secondary bare ground, which we assumed that seed was not a limiting factor. Tree species in the forest included *Q. liaotunensis*, *B. dahurica*, *A. mono*, *F. rhynphyyla*, *T. mongolica*, and *B. platyphylla*. The model was run for 400 years using the derived parameters, resulting in a simulated stand of 1 hm^2 that was divided into 10 cells of equal areas. The simulation was repeated for each cell of 0.1hm^2. Output variables are biomass, *LAI*, net primary production.

Model simulations showed that total biomass increased with forest succession. It reaches maximum, then decreases. Biomass is not linearly related with forest development. Based on biomass, we can see that *Q. liaotunensis*, *A. mono*, *B. dahurica*, *F. rhynphyyla* existed at the early stage of succession. At the middle stage, there were only *Q. liaotunensis*, *F. rhynphyyla*, B. platyphylla, indicating that habitats changed greatly. Figure 1 shows the biomass change of each species with forest development. During the initial 30 years, *Q. liaotunensis* did not dominate the forest, but became dominant species after

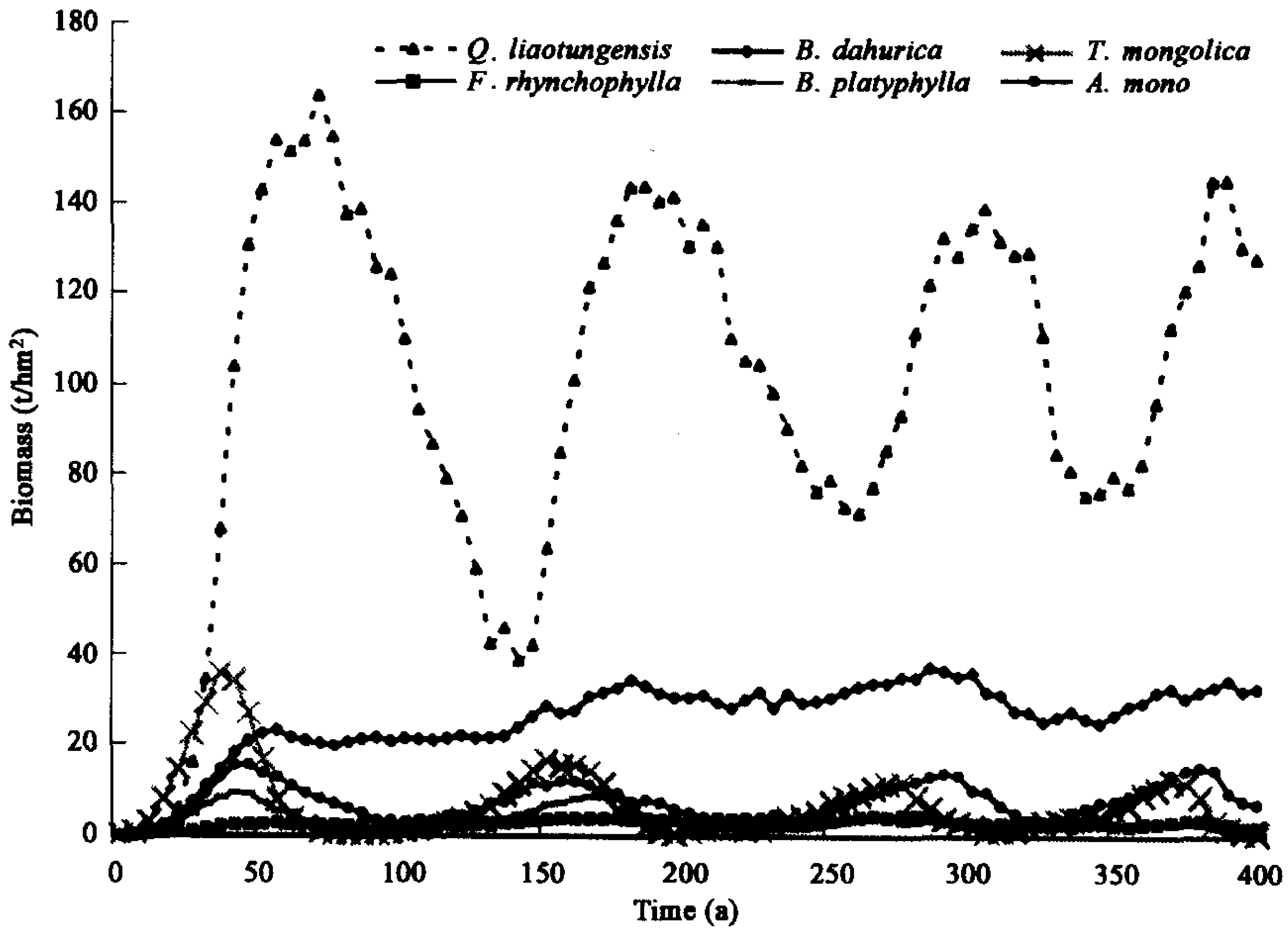

Fig. 1 Biomass changes simulated of different species in *Q. liaotungensis* forest

35 years. The biomass of *Q. liaotunensis* reached maximum between 75～90 years, and then fluctuated until reaching steady state. *B. dahurica* existed throughout the forest development in model simulations, with its biomass reaching 25t/ha at 50 years and becoming constant thereafter. *T. mongolica* was a dominant species at the early stage. After 70 years, there were very little *T. mongolica*, but with the decline of *Q. liaotunensis*, *T. mongolica* began to increase. So *T. mongolica* and *Q. liaotunensis* are inter-replacing species. Other species always existed in simulated forest, but the populations were very small. Figure 2 shows the changes of total biomass. Simulated forest reaches its maximum biomass at 40 years, and decreasesto a minimum at 130 years, and then increases again. Thereafter it changes following a repeatable pattern every 110 years.

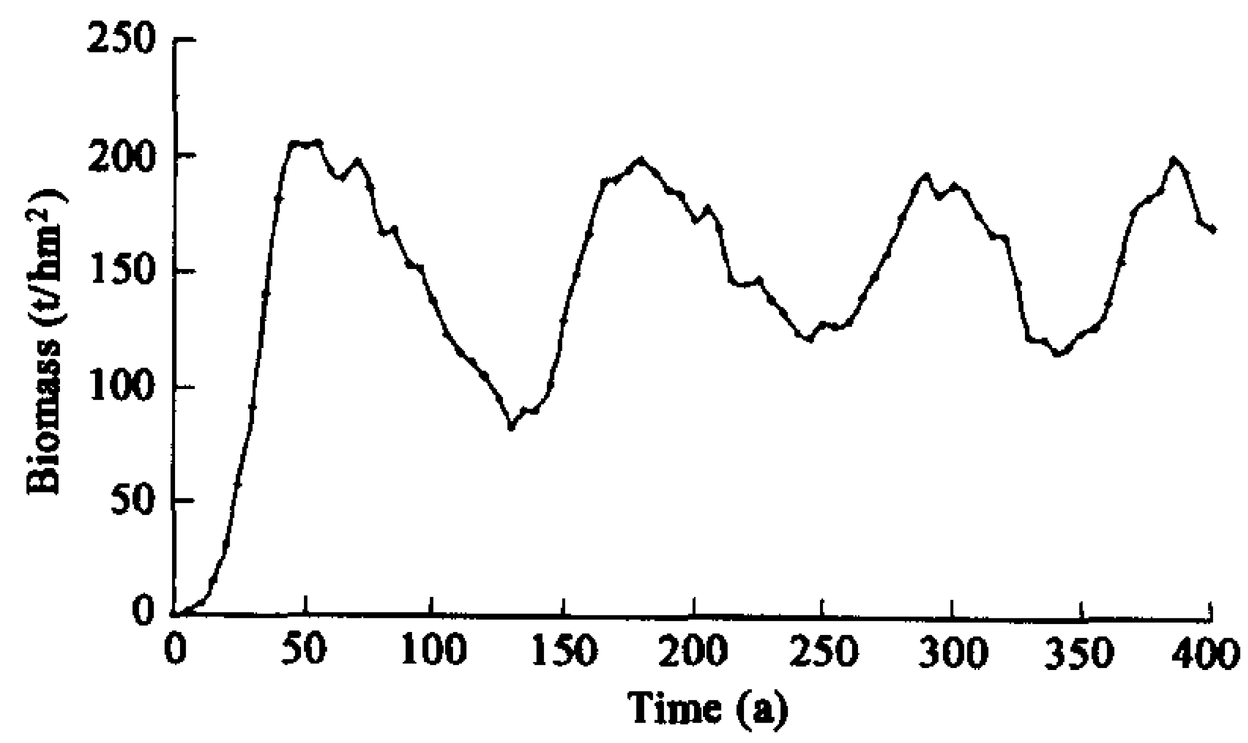

Fig. 2 Total biomass dynamics of simulated *Q. liaotunensis* forest

From the above, it is clear that changes of composition are closely related to the biological characteristics of tree species dominated in forest. If the forest is dominated by shade-intolerant species, such as *Q. liaotunensis*, the change would be great. If the dominated tree species in forest are shade-tolerant, and then change of species composition would be little, and the forest becomes stable.

Figure 3 shows changes of *NPP* in each species in

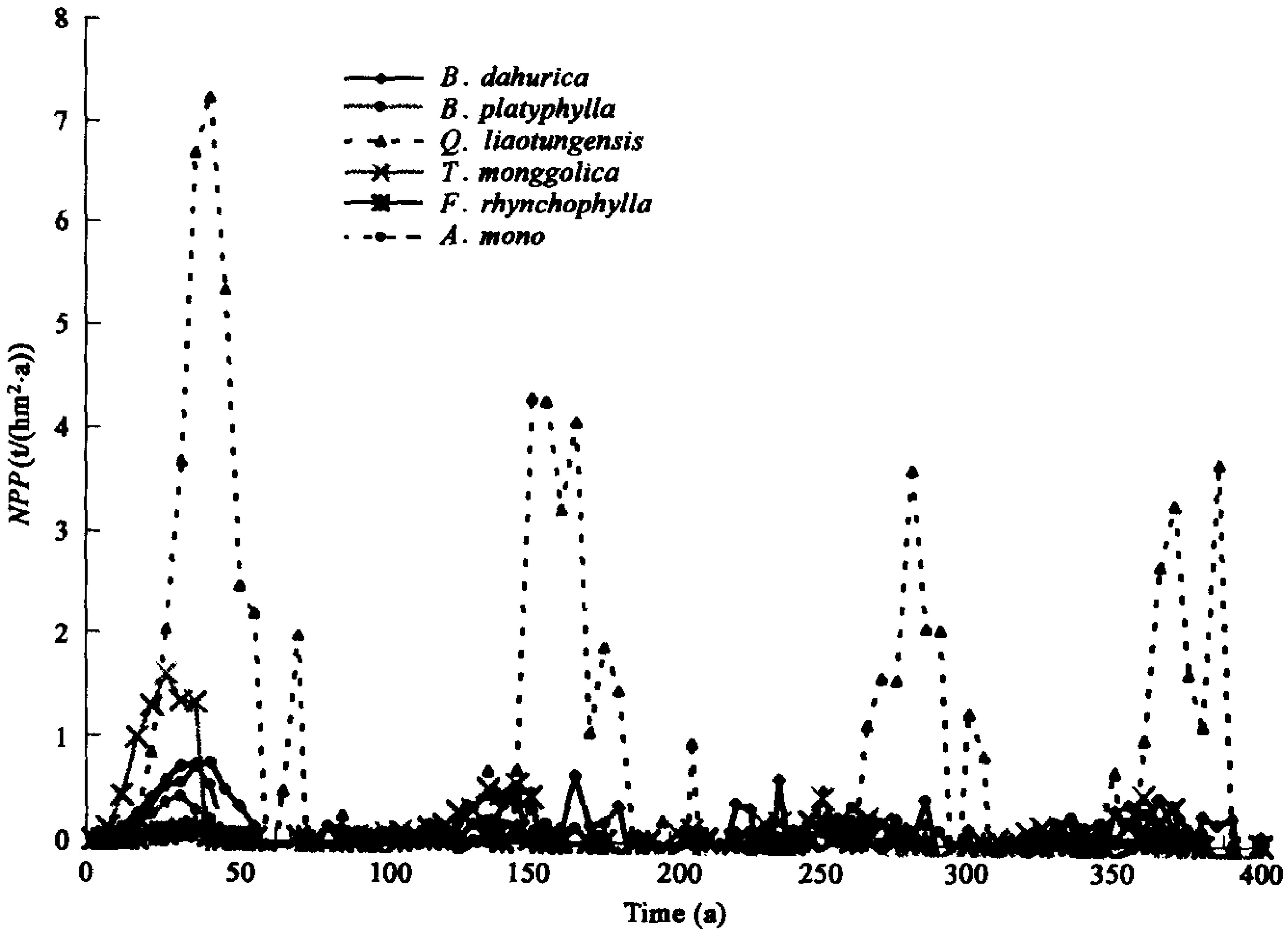

Fig. 3 Modelled net productivity dynamics of *Q. liaotumensis* forest

simulated forest, which showed marked variations in production. The production was greatest in *Q. liaotunensis*, but others were small. There was no general tendency. Figure 4 shows net primary production of the forest, which indicated a very unstable pattern. The *NPP* of the simulated forest reached its peak at 30 years, and changed in the same pattern every 100 years. Figure 5 shows changes of *LAI* in dominated tree species. From the figure, 's *LAI* increased rapidly during the first 100 years, but subsequently decreased. The *LAI* of *Q. liaotunensis* became relatively stable after 140 years, but with slight fluctuations. The *LAI* of other tree species changed also greatly with very similar patterns to *Q. liaotunensis*. Figure 6 shows dynamics of total *LAI* in simulated forest. In the first 100 years, *LAI* increased rapidly, but subsequently declined until reaching equilibrium at 145 years.

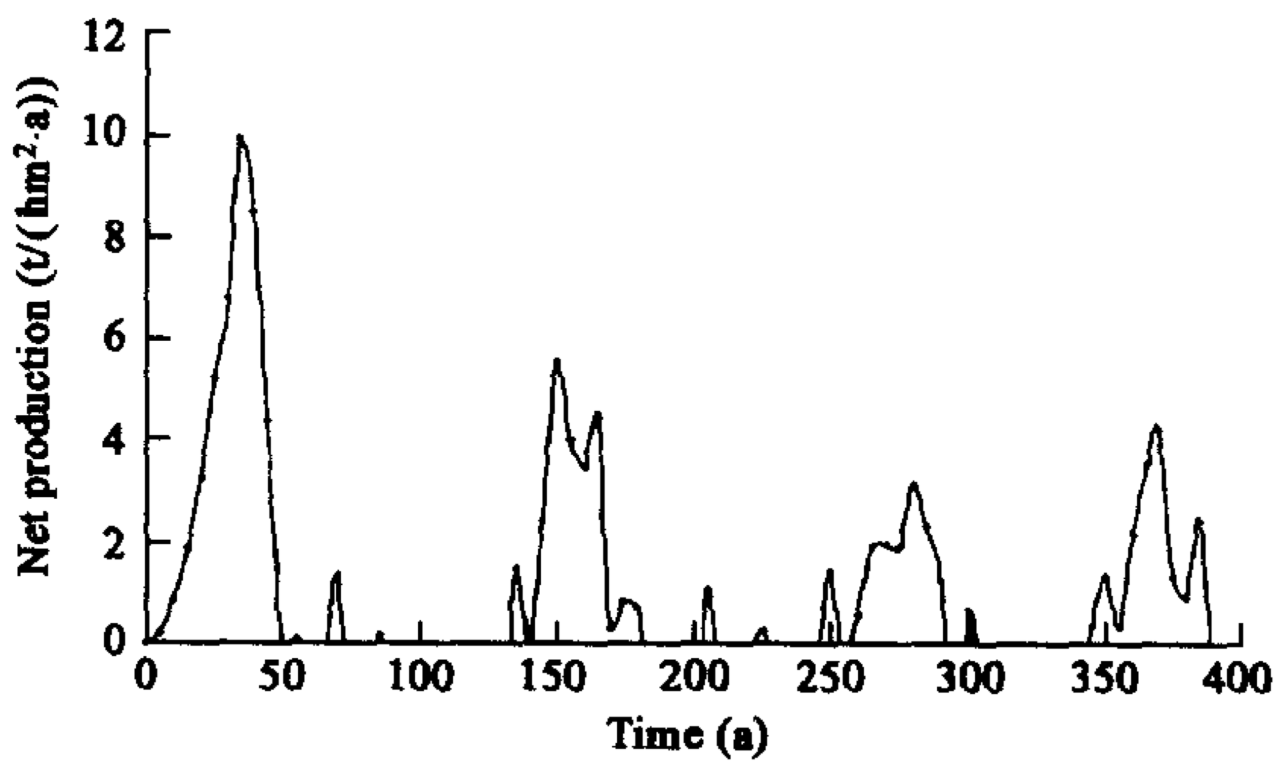

Fig. 4 Modelled net production dynamics of *Q. liaotunensis* forest

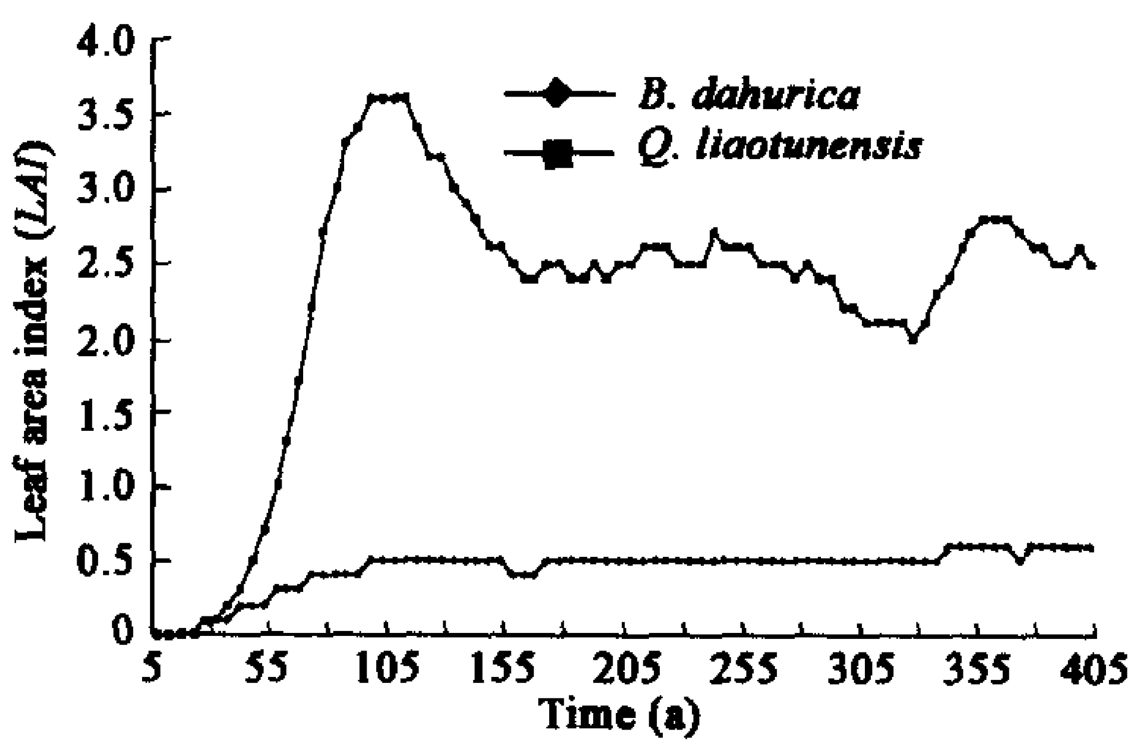

Fig. 5 Modelled changes of *LAI* of domanited tree species

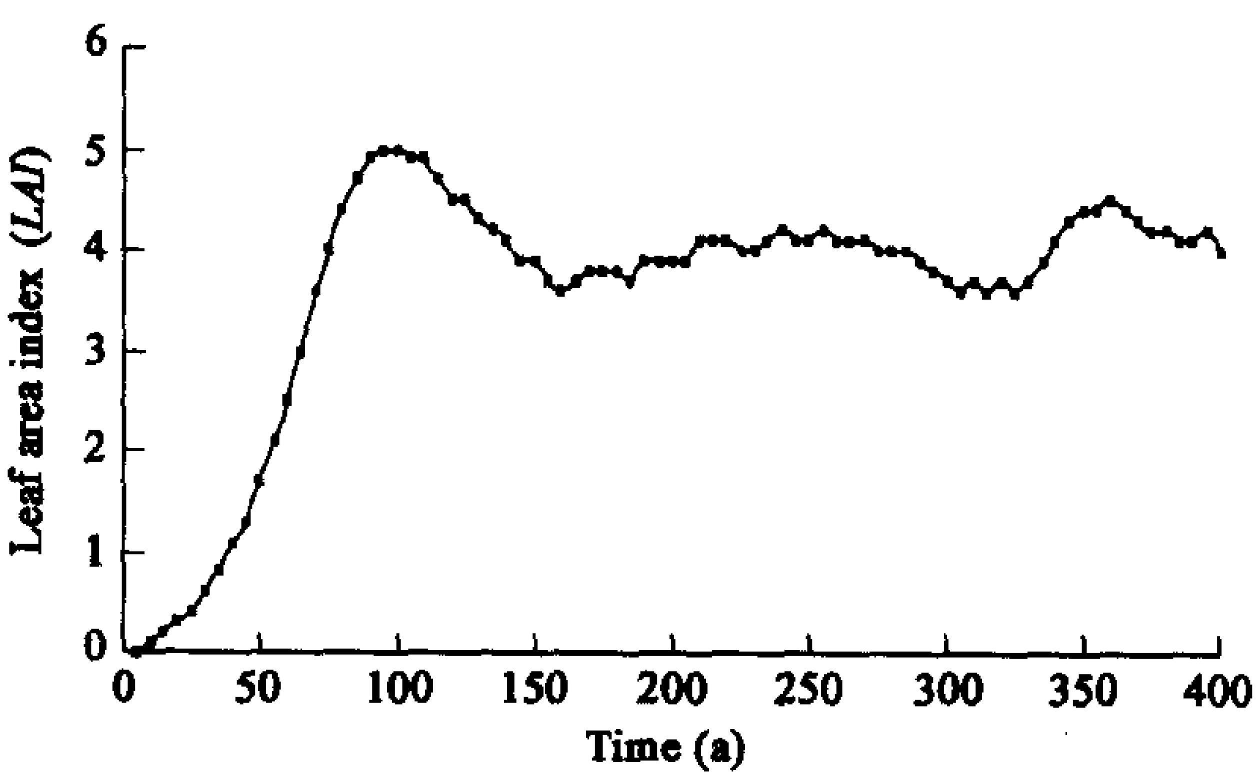

Fig. 6 Total *LAI* chang of simulated forest

2.3 Conclusions

Through analyzing the results of simulated forest dynamics, we can see that biomass was little at bare ground, so the competition was very weak in such area. This type of forests has high production, so *LAI* would increase greatly. Following the initial period of rapid increase in *LAI*, the forest became closed. After then, leaf production slowed down until reaching equilibrium consistent with species composition and environment. Testing of the model simulation against observed values showed that model accurately simulated the forest composition and biomass. It can be concluded from this study that changes of net production are obviously unregulated and extremely unstable, with a peak at 30 year, which are consistent to results from other regions world-wide[10,11]; the pattern of biomass dynamics is cyclic at 110 years or so. Conclusion can be drawn that the succession of warm temperate and deciduous broad-leaved forest is a cycling process.

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