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RESEARCH ARTICLE

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Biomass dynamics of *Quercus aliena var. acutesrata* Community on Mountain Xiaolong in Gansu Province, China

Abstract The dynamics of tree layer biomass was studied by combining 35 sample plots of field census with biomass model estimation in a natural *Quercus aliena var. acutesrata* community on Mountain Xiaolong in Gansu Province, China. The tree layer biomass of *Quercus aliena var. acutesrata* community was 183 660 kg/ha, in which the slow growth group accounted for 64.89% of the total biomass. The fast-medium growth group accounted for 33.40% and the coniferous group accounted for 1.38%. The organs biomass was found to be in the following order: trunk > root > branch > leaf. The total biomass accumulated with the development of the community. The total biomass and the biomass of the organs were highest in the mature community and became stable as the community developed. The relative growth rate of organs was in the following order: trunk > branch > root > leaf. The biomass ratio of the slow growth group trees tended to increase and the fast-medium group trees tended to decrease as the community developed, which was reveresed in the decline development stage. The biomass of the coniferous group was very small throughout the development process.

Keywords Mountain Xiaolong, *Quercus aliena var. acutesrata* community, biomass, tree layer

1 Introduction

As one of the main constructive species in the warm temperate zone in China, *Quercus aliena var. acutesrata* is widely distributed in Liaoning, Shanxi, Gansu, Henan, and Shandong Provines in China (Liu and Wu 2001). Mt. Xiaolong lies on the northern slope of west Mt. Qinling in Gansu Province, China. It is the most northwest part of the natural *Quercus aliena var. acutesrata* distribution region. It is also an important natural forest distribution region in northwest China. *Quercus aliena var. acutesrata* is a main forest species in Mt. Xiaolong and its community is the most important forest community in the region. Thus, *Quercus aliena var. acutesrata* plays a very important role in the regional ecosystem.

Studies on biomass and productivity of the forest community have been reported throughout China (Liu and Ma 1994; Jiang 1998; Yin and Liu 1997), but there are few reports on the biomass of natural *Quercus aliena var. acutesrata* community in Mt. Xiaolong (Zhang 1997), though some local managers have always been engaged in forest community protection, management, and study. These managers have also made basic research on composition, construction, and dynamics of *Quercus aliena var. acutesrata* community in the region (Ju 1993, 1994, 1995; zhong 1988). In this paper, we choose a typical *Quercus aliena var. acutesrata* community in Mt. Xiaolong and estimate its tree layer biomass in 35 plots. The objective of this paper is to determine the following: (a) how the biomass distributes in different growth group trees, (b) how the biomass distributes in different organs of these trees, (c) how the biomass of different organs changes with the developing community, and (d) how the biomass composition (different growth group trees) changes with the developing community.

2 Study area

The study area lies in 34° 0′~34° 40′ north latitude, 105° 30′~106° 30′ east longitude. The relative elevation is 500~1 000m. The region lies in the transition belt from the northern part of the subtropical zone to the southern part of the warm temperate zone in China. The climate at Mt.

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Xiaolong is Asian semi-arid and most of the region has a continental monsoon climate with the average daily temperature at –7℃ in winter and 22℃ in summer. The minimum temperature is –23.2℃ and the accumulative temperature above 10℃ is 2 444℃~3 825℃. The annual precipitation ranges from 460 mm to 800 mm in various years and rain is usually from July to September, which accounts for 70%~80% of rainfall all year round. The annual evaporation is 989~1 658 mm and the relative air humidity is 68%~78%. Soils of the region have a loamy texture and of a brown-cinnamon skeletal type developed on Eocene limestone, dolomite, and chalk. Soils are brown-cinnamon on the north of Mt. Qinling and yellow-cinnamon in the south of Mt. Qinling. The soil depth is 30~60 cm and the pH is 6.5~7.5 (Zhang 1997). There are about 2 700 species in the region which belong to 954 families. Among these species, herbaceous plants are about 1 900 species and most of them belong to Gramineae, Compositae, Leguminosae, Ranunculaeae, Orchidaceae, Labiatae, and Scrophulariaceae. Trees are about 800 species, most of which are temperate species. Most tree species come from Fagaceae, Betulaceae, Pinus, Saxifragaceae, Ulmaceae, Aceraceae, and Rosaceae.

3 Methods

3.1 Field methods

The field investigation was concentrated in the natural reserve forest of Maicaogou and the forest experiment base of Shaba. Thirty-five plots with 20 m×20 m dimension were selected at regular intervals of 50 m along the elevation on both south and north facing slope in August and September in 2002. All trees with DBH larger than 2.0 cm were tagged and their species name, DBH, height of tree, and coverage in the tree layer were recorded. Dead trees (standing and fallen) were also measured if possible. Plots were subdivided into 25 4 m×4 m and 400 1 m×1 m quadrants for herbaceous with grass as reference(Ma et al., 1998; Shen et al., 2001). The elevation, aspect, and the location of every plot were recorded with GPS.

3.2 Definition of developing phases

Four developing phases were defined according to the maximum DBH of *Quercus aliena var. acutesrata* in each plot (Hong 2000): plots with the maximum DBH of *Quercus aliena var. acutesrata* with a range of 4.0~18.0 cm was young community - the initial phases; plots with the maximum DBH of *Quercus aliena var. acutesrata* with a range of 18.1~32.0 cm was adult community - the middle phases; plots with the maximum DBH of *Quercus aliena var. acutesrata* above 32.1 cm was mature community; and, additionally, a decline community was picked out from the mature community according to the community structure of the investigated community and its maximum DBH of *Quercus aliena var. acutesrata* was above 38.0 cm. The maximum year of each phase was 30 years, 50 years, 100 years, and 130 years which corresponded to young community, adult community, mature community, and decline community, respectively.

3.3 Biomass estimation

All investigated tree species which were investigated were divided into three growth groups according to their physiological characteristics. These were the slow growth group, such as *Quercus aliena var. acutesrata*, the fast-medium growth group, such as *Populus davidiana,* and the coniferous growth group, such as *Pinus armardi*i. The biomass regression models of each group are shown in Table 1.

Table 1 The biomass models for tree layer in the *Quercus aliena var. acutesrata* community

Growth groups	Organs	Regression models	Correlation coefficient	Scope
Slow growth group	Trunk	$W_S = 0.02231 \times (D^2H)^{0.37755}$	$r = 0.977$	D = 4.0~25.0 cm① H = 4.0~20.0m
	Bark	$W_{BK} = 0.01033 \times (D^2H)^{0.81367}$	$r = 0.962$	
	Branch	$W_B = 0.00616 \times (D^2H)^{0.96951}$	$r = 0.979$	
	Leaf	$W_L = 0.03694 \times (D^2H)^{0.66156}$	$r = 0.921$	
	Root	$W_R = 0.01469 \times (D^2H)^{0.93446}$	$r = 0.969$	
Fast-medium growth group	Trunk	$W_S = 0.2268 \times (D^2H)^{0.6933}$	$r = 0.96$	D = 4.0~28.0 cm② H = 4.0~20.0 m
	Branch	$W_b = 0.0247 \times (D^2H)^{0.7378}$	$r = 0.97$	
	Leaf	$W_l = 0.0108 \times (D^2H)^{0.8181}$	$r = 0.94$	
	Root	$W_r = 0.1553 \times (D^2H)^{0.5951}$	$r = 0.93$	
Coniferous group	Trunk	$W_S = 0.02697 \times (D^2H)^{0.91858}$	$r = 0.989$	D = 4.0~25.0 cm① H = 4.0~20.0 m
	Bark	$W_{bk} = 0.00604 \times (D^2H)^{0.83368}$	$r = 0.926$	
	Branch	$W_b = 0.01394 \times (D^2H)^{0.92327}$	$r = 0.979$	
	Leaf	$W_l = 0.00760 \times (D^2H)^{0.92464}$	$r = 0.988$	
	Root	$W_r = 0.01373 \times (D^2H)^{0.94785}$	$r = 0.937$	

①(Zhang 1997), ②(Feng et al., 1999), D: diameter at breast height (DBH), W_S: biomass of trunk, W_b: biomass of branch, W_r: biomass of root

4 Results

4.1 Composition of biomass

Species composition of the tree layer in *Quercus aliena var. acutesrata* community was very complex. There were 43 species in the 2 096 trees which were surveyed. Among these trees, 12 common species accounted for 86.12% total individual number and the other 31 species were all rare.

Table 2 Biomass composition in tree layer in *Quercus aliena var. acutesrata* community

Groups	Slow growth group	Fast-medium growth group	Coniferous growth group	Total
Number	1033	1002	61	2096
Ratio / %	49.28	47.81	2.91	100.00
Biomass/ (kg • ha^{-1})	119180	61340	2510	183660
Ratio / %	64.89	33.40	1.37	100.00

The biomass of the different groups is calculated in Table 2. The biomass of the slow growth group trees was 119 180 kg/ha, which accounted for 64.85% of the total biomass and the number ratio was 49.28%. While the biomass of the fast-medium growth group trees only accounted for 33.71% of the total and 47.81% of its number, the coniferous group took a very small part in both biomass and tree number ratio. This implied that the slow growth group trees were dominant not only in their number but also in their biomass in the natural *Quercus aliena var. acutesrata* community. The slow growth group trees were constructive species in the *Quercus aliena var. acutesrata* community in the region. It was also found out that the tree layer biomass of the *Quercus aliena var. acutesrata* community in the region was higher than that of the single *Quercus aliena var. acutesrata* community in other regions (Liu and Wu 2001).

4.2 Distribution of biomass in organs

The tree layer biomass of the *Quercus aliena var. acutesrata* community was calculated with the different organs (Table 3). The total biomass of the tree layer was 183 660 kg/ha and the trunk biomass accounted for 57.11%. The order of other organs biomass was as follows: root > bark > leaf. There was a great difference in the organs biomass distribution among three growth groups. The biomass percentage was 53.16%, 5.74%, 13.21%, 4.84%, and 23.05% in the slow growth group corresponding to trunk, bark, branch, leaf, and root, respectively. Percentage of the trunk biomass was largest and that of the root biomass was only 15.96% in the fast-medium growth group trees. In the coniferous group trees, the trunk biomass was lowest, while the leaf biomass was the largest compared to the biomass distribution of other growth groups.

Table 3 Tree layer biomass and its distribution in the *Quercus aliena var. acutesrata* community

Groups			Trunk	Bark	Branch	Leaf	Root	Total
Slow group		Biomass/(kg • ha^{-1})	63350	6840	15740	5770	27470	119180
		Percentage/%	53.16	5.74	13.21	4.84	23.05	100.00
	Quercus aliena var. acutesrata	Biomass/(kg • ha^{-1})	59250	6220	1450	5730	26350	112040
		Percentage/%	52.88	5.55	1.29	5.11	23.52	100.00
Fast-medium group	Biomass/(kg • ha^{-1})		40100	7360	—	4080	9790	61340
	Percentage/%		65.37	12.00	—	6.65	15.96	100.00
Coniferous group	Biomass/(kg • ha^{-1})		880	120	550	300	660	2510
	Percentage/%		35.06	4.78	21.91	11.95	26.30	100.00
Total	Biomass/(kg • ha^{-1})		104890	30640	—	10150	37980	183660
	Percentage/%		57.11	16.68	—	5.53	20.68	100.00

The biomass distribution in different organs among the three growth groups implies that each species has its own growth strategies in resource competition in the natural *Quercus aliena var. acutesrata* community. The slow growth group trees grew very slow and they accumulated more biomass in the trunk and root so that they could be dominant in the intense competition. For example, *Quercus aliena var. acutesrata* distributed 76.04% of its biomass in trunk and root, which could increase their capacity in space resource competition. Because the whole community was controlled by the slow growth group trees, the fast-medium growth group trees had to concentrate more biomass in the trunk to increase their height to get more sunshine. Thus, there was less biomass distributed in the root in the fast-medium growth group trees and this weakened the root system. So, the fast-medium growth group trees only develop rapidly in the forest gap and their growth declines when they compete with the slow growth group trees. The coniferous growth group trees need to get more sunshine, so they distributed 33.86% of their biomass in the branch and leaf.

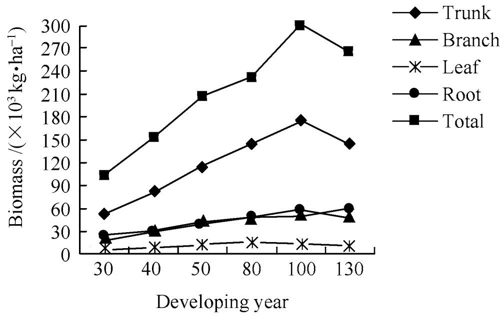
The biomass increased with the improving community structure and reached a stable phase in the forest community development process (Liu and Wu 2001). The organs biomass showed a different increase ratio for species changed their growth strategies in the different development phases (Bormann and Likens 1981). We made the development dynamics of organs biomass in space-time replacement method, which took the individual plot as typical plots in different development phases in Table 4

(Zhang 1997).

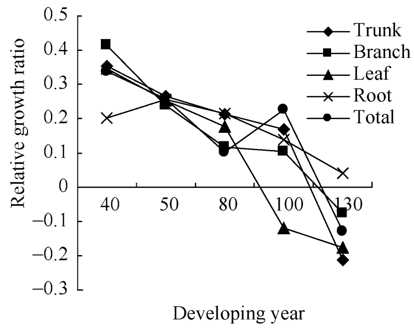
Table 4 Biomass of different organs at different development ages in the *Quercus aliena var. acutesrata* community

Forest year	30	40	50	80	100	130
Trunk/(kg • ha^{-1})	54200	83910	14370	145330	174920	144160
Branch/(kg • ha^{-1})	18760	32070	42160	47720	53290	49520
Leaf/(kg • ha^{-1})	6180	9460	12670	15380	13740	11680
Root /(kg • ha^{-1})	22930	28720	38590	49160	57090	59490
Total/(kg • ha^{-1})	102070	154160	207790	231590	299040	264850

Total biomass was accumulated with the development of the community and reached a climax (299 040 kg/ha) in the mature community phase in 100 years (Fig.1a). The biomass became stable as the community developed. The organ biomass of trunk, branch, leaf, and root showed different increment in the process and biomass was lost in some organs in the decline community phase. Relative growth ratio is larger in the trunk and branch than that in the root in the middle development phase (Fig.1b). This implies that the community was concentrating in building the trunk and branch in this phase. The relative growth ratio of root ran ahead in the later development phase with a stable community structure. Some old trees declined and the biomass of the branch and leaf was lost as these organs faded, so the relative ratio became negative in the decline community phase. Because the decline began with the leaf and branch, this affected the root biomass and the growth ratio of root did not fall as much as that of branch and leaf.



(a)



(b)

Fig. 1 a) Biomass increment in *Quercus aliena var. acutesrata* community; **b**) Relative growth rate at different development age in *Quercus aliena var. acutesrata* community

4.3 Change of biomass composition

Biomass of the slow growth group trees was the largest and accounted for 61.73% of the total biomass. Biomass of *Quercus aliena var. acutesrata* took a great part (61.60%) in the adult community phase. The other 36.88% of the biomass came from the fast-medium growth group trees. Ratio of the slow growth group trees biomass increased to 85.90 % and that of the fast-medium growth group trees fell to 11.99% in the mature community phase. The community developed and was a decline community phase. The biomass of the slow growth group trees fell to 81.32% and that of the fast-medium trees increased to 18.68%. Biomass of the coniferous trees was very small and there was no significant change throughout the developing process.

The *Quercus aliena var. acutesrata* community was changing from the fast-medium growth trees to the slow growth trees in the young and adult community phases. The slow growth trees, such as *Quercus aliena var. acutesrata*, have become dominant in the community in these phases, but there were still more fast-medium growth trees in the community. The dominance of slow growth trees was enhanced as the community developed and this pressed most of fast-medium growth trees dying and the community came into the mature community phase. The dominance of *Quercus aliena var. acutesrata* was lost with the community decline, so did its biomass, while fast-medium growth trees flourished with the increase of its biomass.

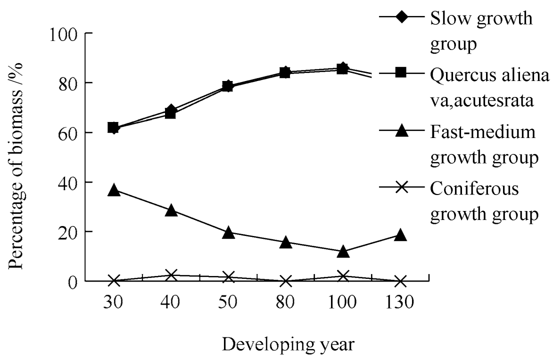


Fig. 2 The composition dynamics of biomass with the development in *Quercus aliena va, acutesrata* community

5 Conclusion

Biomass of tree layer in natural *Quercus aliena var. acutesrata* community in Mt. Xiaolong was 183,660 kg/ha. Among this, the slow growth group trees, dominated of *Quercus aliena var. acutesrata*, accounted for 64.89%. The fast-medium growth group trees accounted for 33.40% and the coniferous growth group trees accounted for 1.38%. Tree layer biomass was distributed in the organs in the following order: trunk > root > branch > leaf. There was significant difference in the different growth groups. The biomass distribution ratios were 53.16%, 5.74%, 13.21%, 4.84%, and 23.05% corresponding to the trunk, bark, branch, leaf, and root in the slow growth group trees. While the distribution ratio were 65.37% (trunk), 12.00% (branch), 6.65% (leaf), 15.96% (root) in the fast-medium growth group trees and 35.06% (trunk), 4.78% (bark), 21.91% (branch), 11.95% (leaf), 26.30% (root) in the coniferous growth group trees.

Tree layer biomass increased as the community developed and reached a climax when the community was mature and the biomass was stable as the community developed. The relative growth ratio of organs was in the following order: trunk > branch > root > leaf in all the development phases. It decreased with the community development and some organs biomass was lost in the decline community phase. Biomass ratio of the slow growth group trees increased, while that of the fast-medium growth group trees decreased in the community development process. The ratio in the slow growth group trees decreased and that of the fast-medium growth group trees increased again as the slow growth group trees declined in declining community phase. Biomass ratio of the coniferous growth group trees was very small throughout the development process.

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