STUDY ON THE GAP DYNAMIC FEATURES OF THE SUBTROPICAL FOREST COMMUNITIES

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Abstract

The present paper deals with the gap dynamic features of the subtropical forest communities in southwest area of China. The seral succession stages of the forest gap during the progress of regeneration could be divided into three main stages. The gap feature in the different seral succession stages is quite different. The results show that the gap size, the fluctuation of the ecological factors and the gap edge effect decreases to disappear during the course of succession; in the contrast, the species diversity in the gap increases. The results also show that the index of gap effect of forest community is affected not only by its size, but also by its aspect and succession stage. The importance of gaps for keeping trees regeneration and species diversity as well as the application of the gap edge effect in forest practice are discussed.

Introduction

Forest gaps refer to patches in a forest created by the death of canopy trees. Gap disturbances provide the principal or only means by which most the species can maintain their representation in closed canopy forest. The great structural diversity of gaps produces similarly great in gap microclimates, and makes the gap itself have the special structure, floral and dynamic features. Gaps are considered to be great importance for the regeneration and subsequent growth of forest species. Therefore understanding the gaps structure and knowing the rules of gaps development for trees replacement processes are fundamental to understanding the structure and dynamics of forest communities. The edge zone in the transition area of a gap and surrounding mature forest, become localized sites of the maintenance of species diversity. However, there are few studies linking gap succession data with the regeneration and species diversity of a forest communities. Such seemingly simple events as tree replacement and gap stage succession are actually complex processes that are still poorly understood.

The present study deals with the forest gap characteristics, especially the gap species and its dynamic features during the progress of forest regeneration. The data were collected during a survey of canopy gaps in the subtropical forest communities of Jinyun mountain of Sichuan, southwest area of China.

Study Area

The study area lies in the Jinyun mountain which is situated about 50 km northwest of Chongqing of Sichuan, China. (lat. 29° 46′~ 54′N; long. 106° 22′~ 29′E). All the stands are located between 680–935 m altitude, and belong to the typical midsubtropical evergreen broad–leaved forest region. This area has a typical subtropical monsoon climate. The mean annual precipitation is 1143 mm, and the annual mean temperature is 18.2℃. The major soil is a forest yellow soil. The vegetation consists mainly of evergreen broad–leaved forest communities and mixed needle–leaved and broad–leaved forest communities. In the mixed needle broad–leaved forest, the dominants on the top layer are *Pinus massonina, Cunninghamia lanceolata, Gordonia acumenata, Castanopsis fargesii, Symplocos setchuensis, Daphniphyllum glaucescens.* The evergreen broad–leaved forest which the dominant species are *Symplocos setchuensis, Machilus pinhii, Engelhardtia roxburghiana* and *Elaeocarpus japonicus.* Canopy heigh varies from 15~ 25 m. The topography of the area is characterized by steep slope (19~ 55°). Descriptions of the flora, vegetation and ecology of forest of Jinyun mountain can be found in book with the title of Ecological study on evergreen broad–leaved forest(Zhong 1988).

Methods

The forest gaps are measured by using the plot method. In each gap, we measured the gap size on the rectangle method, and setup 3 plots separately at the gap centre, gap edge and nongap area. The species, the number of individuals, height and the canopy size of the small trees and shrubs are measured in each plot (size: 4m× 4m). The species, number of individuals and the degree of coverage of the herbs and young trees are counted within the same plots. The total sample area is $1390m^2$.

The species diversity for the different size of each forest gap plot is illustrated by the Shannon–Wiener index (D):

$$D = 3.3219(lgN - \frac{1}{n}\sum_{i=1}^{s} n_i lgn_i) \quad (1)$$

(N = No. of all individuals; S = No. of species; n = No. of individuals of the i species)

The ecological dominance for the different area of each forest gap plot is calculated by the Simpson index (C):

$$C = \sum_{i=1}^{s} (\frac{n_i}{N})^2 \quad (2)$$

(N, S, n are all the same as (1))

The gap edge effect in each plot is calculated by the Wang index (E):

$$E = mY / \sum_{i=1}^{m} y_i \quad (3)$$

(m = No. of communities; Y = Population quantitative index of transition area; y_i = Y of No.i communities)

In this paper, we use D and C subtitute Y in (3), and get 2 kind of gap edge effect indexes:

$$E_D = mD / \sum_{i=1}^{m} d_i \quad (4)$$

$$E_C = mC / \sum_{i=1}^{m} c_i \quad (5)$$

Results

The division of successional seral stages of the forest gaps

The division of successional seral stages of the forest gaps are mainly on the basis of the forming time, while taking the information of the species organization and the vegetation height within the gap for reference. Hence, the successional seral stages of the subtropical forest gaps could be classified into 3 main stages according to their features from the purpose of dynamic study: the pioneer stage, the developmental stage and the climax stage. Among the 29 forest gaps are found, 10 of them belong to the pioneer stage, 7 of them belong to the developmental stage and 7 of them belong to the climax stage. Another 5 gaps belong to the evergreen broad–leaved forest. The forming time of the pioneer stage is not long, the dominants within the forest gaps are few heliophilic herbs, such as *Dicrenopteris glauca;* the cover degree of the vegetation within the gap is quite high and the vegetation height is generally less than 2 m. The dominants within gaps of the developmental stage are the woody species, and the vegetation heigh is between 2~ 8 m. The vegetation height at the climax stage is near the height of the top–layer of the forest communities, and the species in the gap central area generally are the same as in the gap border area.

Size of forest gaps

The size of forest gaps, their species diversity and the ecological dominance as well as the edge effect in those plots are compared and summarized in Tab. 1~4.

The size of gaps is the basic character of forest gaps, it is about 50~ 500 m^2in forest communities of Jinyun mountain. In the mixed needle broad–leaved forest, the mean size of forest gaps in the pioneer stage is 189 m^2; the mean size in the developmental stage is 155.71 m^2, and in the climax stage is 134 m^2. The gaps size decreased during the course of development. The mean gaps size of the evergreen broad–leaved forest is 327.2m^2; the smallest one is about 176 m^2. The results show that the mean gaps size in the subtropical forest communities is larger than the gaps size in the tropical forest, which is about 89 m^2.

Species diversity and ecological dominance

The ecological feature,quantitative character, richness and distribution pattern of species are the important content of the gaps study and also the basis for other gaps features studying . The species diversity and ecological dominance at different successional seral stages of gaps are compared.

The results show that the ecological structure of gaps produces similary great diversity of species, and the richness features are different at different successional stages. The order of richness at the successional seral stage is: climax stage > developmental stage > pioneer stage. In the gap of pioneer stage, the species diversity is rather low, and the main species are few heliophilic herbs, such as *Dicrenopteris glauca.* In the developmental and the climax stages the species diversity shows a tendency to increase. Within the gaps, the dominants are the shade–tolerant species. The results also show that the species diversity in different area of the gaps is quite different. In the gaps centre area of the mixed needle broad–leaved forest, *Dicrenopteris glauca, Neolitsea aurta var. glauca, Gordonia acumenata* are the dominants and the species diversity is rather low. In the contrast, the ecological dominance is high. Species diversity increases in the plots located at edge area of gaps, *Gordonia acumenata, Symplocos setchuensis, Lindera kwangtungensis, Dryopteris sp.* are the common species. In the evergreen broad–leaved forest, the regularity is the same, but species are different. In the gaps centre area, *Lysimachia paridiformis* is the common species; while in the edge area of gaps, *Engelhardyia roxburghiana, Maesa japonica, Castanopsis carlesii var. spinulosa* are the main component species.

Tab. 1 Testing results in the pioneer stage gaps of needle–, broad–leaved mixed forest

No. of plot	Alt. (m)	Aspect	Slope (°)	Size (m^2)	Sample Zone	No. of Species (S)	No. of individual (N)	Species diversity (D)	Ecological dominance (C)	Edge effect	
										E_D	E_C
24	810	45	45	60	A	4	55	0.894	0.607	1.774	0.248
					B	17	40	3.694	0.100		
					C	12	33	3.271	0.120		
13	840	350	20	80	A	9	62	1.845	0.443	1.388	0.416
					B	15	43	3.418	0.124		
					C	12	38	3.001	0.153		
29	855	335	40	167	A	4	54	0.905	0.704	1.408	0.499
					B	10	83	2.576	0.220		
					C	9	37	2.753	0.177		
19	870	350	50	176	A	3	54	0.441	0.861	2.023	0.140
					B	19	81	4.015	0.069		
					C	15	44	3.528	0.123		
12	800	65	36	199	A	9	63	1.648	0.524	1.301	0.476
					B	16	71	3.160	0.159		
					C	13	40	3.209	0.144		
16	880	10	25	218	A	8	55	1.518	0.545	1.518	0.297
					B	17	59	3.596	0.103		
					C	14	42	3.219	0.148		
10	820	225	35	221	A	2	51	0.139	0.961	2.906	0.269
					B	16	72	3.072	0.172		
					C	5	14	1.975	0.316		
8	800	290	38	248	A	2	51	0.139	0.916	1.890	0.309
					B	14	46	3.069	0.169		
					C	10	16	3.109	0.134		
38	880	115	60	255	A	5	58	0.661	0.813	1.965	0.264
					B	16	62	3.325	0.133		
					C	9	28	2.724	0.196		
23	800	70	10	270	A	13	155	1.814	0.457	1.453	0.347
					B	17	40	3.694	0.100		
					C	12	33	3.271	0.120		
Mean value				189.4	A	5.98	65.00	1.000	0.691	1.763	0.329
					B	15.70	59.70	3.362	0.135		
					C	11.10	32.50	3.014	0.163		
Standard deviation				67.5	A	3.48	30.29	0.633	0.183	0.453	0.097
					B	2.28	15.89	0.391	0.042		
					C	2.77	9.82	0.415	0.056		

Edge effect of gap

The gap edge effect of 29 gaps of forest communities which are in the different building phase is illustrated in table 1~4. Based on the measurement of species diversity, the index of the gap edge effect in subtropical forest communities in Jinyun mountain is about 1~3, and on the ecological dominance is about 0.1~1.2.

In the early building phase of development, the gap effect index based on the species diversity (E_D) in the gap centre area is relatively high, which is caused by the lower species diversity. In contrast, the gap effect index based on the ecological dominance (E_C) is low. The result showed that the gap effect decreased to disappear during the course of development. The variation of gap effect in the evergreen broad–leaved forest is similar to those in the mixed needle broad–leaved forest.

The gap edge effect of forest communities is affected not only by its building phase, but also by its size partly. Compared in terms of species diversity and gap edge effect of gaps which ranged in northeast aspect slope in the mixed needle broad–leaved forest, the species diversity increased in the gap centres of large gap of the early building phase; but the edge effect is contrast. There is no significant differences in species diversity between the small gaps and the large gaps. The results show that the species diversity of middle building phase at northwest aspect slope is high in either the gap centre or gap edge area, the edge effect index is the contrast. The gaps of late building phase at northeast aspect slope are the similar size, so no significant differences between them in either the species diversity or gap edge effect. Among the gaps at northeast aspect slope in the evergreen broad–leaved forest, the small gap has low species diversity in the gap centres, and has relatively high species diversity and edge effect in the edge area, while the large gap has the contrast changing regularity.

Aspect also affects the forest gaps characters. There are certain differences between the gaps which are ranged in different slope aspect. This results is illustrated also in table 1 ~4. Aspect differences among gaps are not large in the forest in Jinyun mountain, and seem to be related to the gap size.

Tab. 2 Testing results in the developmental stage gaps of needle–,broad–leaved mixed forest

No. of plot	Alt. (m)	Aspect	Slope	Size (m^2)	Sample Zone	No. of Species S	No. of individual N	Species diversity D	Ecological dominance C	Edge effect	
										E_D	E_C
17	850	10	20	51	A B C	11 16 14	106 52 20	1.284 3.155 3.684	10.062 0.188 0.085	1.270	0.503
15	830	10	30	56	A B C	16 19 13	82 77 55	3.371 3.581 2.917	0.119 0.120 0.194	1.139	0.773
43	890	275	43	91	A B C	11 17 14	22 47 28	3.193 3.561 3.512	0.127 0.109 0.107	1.062	0.932
28	855	330	40	161	A B C	6 9 9	53 43 44	0.938 1.735 2.019	0.727 0.502 0.3742	1.173	0.912
33	920	327	34	189	A B C	10 15 13	58 63 26	2.600 3.16 3.190	0.203 0.152 0.162	1.092	0.833
7	800	45	55	264	A B C	12 14 11	66 37 24	2.108 3.527 3.126	0.390 0.100 0.1390	1.327	0.378
18	820	30	35	278	A B C	9 13 15	94 79 47	1.867 3.053 3.268	0.435 0.164 0.159	1.189	0.552
Mean value				155.71	A B C	10.71 14.71 12.71	68.71 56.86 34.86	2.206 3.110 3.102	0.380 0.191 0.174	1.179	0.698
Standard deviation				86.95	A B C	2.83 2.98 1.93	26.08 15.38 12.53	0.850 0.600 0.502	0.230 0.130 0.089	0.085	0.201

Tab. 3 Testing results in the climax stage gaps of needle–, broad–leaved mixed forest

No. of plot	Alt. (m)	Aspect	Slope	Size (m²)	Sample Zone	No. of Species S	No. of individual N	Species diversity D	Ecological dominance C	Edge effect E_D	Edge effect E_C
					A	5	7	2.129	0.266		
36	900	165	49	90	B	11	54	2.793	0.186	0.990	1.003
					C	14	29	3.513	0.105		
					A	16	84	2.802	0.259		
22	820	90	50	112	B	17	50	3.735	0.092	1.084	0.551
					C	22	62	4.087	0.072		
					A	10	42	2.674	0.212		
9	820	50	45	120	B	12	53	2.757	0.210	0.950	1.197
					C	11	24	3.126	0.139		
					A	8	14	2.807	0.163		
42	935	99	38	143	B	11	25	2.943	0.184	1.022	1.240
					C	8	14	2.958	0.133		
					A	9	29	2.787	0.169		
26	850	15	19	147	B	10	44	3.091	0.132	0.986	0.964
					C	13	20	3.487	0.105		
					A	14	57	2.014	0.239		
11	780	350	55	161	B	14	37	0.933	0.238	1.041	1.205
					C	8	15	2.823	0.156		
					A	10	24	2.991	0.150		
32	920	290	50	168	B	15	86	3.289	0.127	1.018	0.973
					C	15	58	3.471	0.111		
					A	10.29	36.71	2.715	0.208		
Mean value				134.4	B	12.86	49.86	3.077	0.167	1.013	1.019
					C	13.00	31.71	3.351	0.118		
					A	3.40	24.78	0.253	0.046		
Standard deviation				26.0	B	2.34	17.52	0.319	0.048	0.040	0.220
					C	4.47	18.54	0.395	0.024		

Tab. 4 Testing results in evergreen broad–leaved forest gaps

No. of plot	Alt. (m)	Aspect	Slope	Size (m²)	Sample Zone	No. of Species S	No. of individual N	Species diversity D	Ecological dominance C	Edge effect E_D	Edge effect E_C
					A	4	55	3.105	0.166		
5	840	155	20	176	B	22	101	3.658	0.127	1.280	0.692
					C	10	66	2.610	0.201		
					A	2	46	0.151	0.957		
6	890	65	43	264	B	16	40	3.795	0.081	1.984	0.154
					C	15	23	3.675	0.092		
					A	24	127	3.804	0.115		
1	825	135	40	280	B	21	42	4.099	0.070	1.153	0.571
					C	13	31	3.305	0.138		
					A	14	71	2.859	0.200		
3	680	100	30	405	B	22	67	3.794	0.114	1.286	0.632
					C	15	69	3.125	0.161		
					A	10	70	2.358	0.279		
39	740	85	35	511	B	15	41	3.356	0.135	1.239	0.641
					C	10	18	3.059	0.142		
					A	10.8	73.8	2.455	0.343		
Mean value				327.2	B	19.2	58.2	3.740	0.105	1.381	0.538
					C	12.6	41.4	3.155	0.145		
					A	7.86	28.21	1.244	0.312		
Standard deviation				117.4	B	3.06	23.66	8.247	0.027	0.334	0.196
					C	2.24	21.73	0.345	0.037		

A: Gap Centre Area, B: Gap Border Area, C: Non–gap Area

Discussion

The ecological significance of gaps for the keeping forest regeneration and species diversity

In a mature forest seemingly such simple events as tree replacement and gap regeneration are actually complex processes that are still poorly understood. Watt (1947) described the regeneration in the beech forest ,and predictively discussed the gap and patch dynamics of forest vegetation. From that time, the gap phase development and subsequent canopy tree replacement is of considerable interest in plant community ecology, because it touches the key point of the debate over whether forest communities are in species equilibrium (Hubell, 1984). The great structural diversity of gaps produces similarly great diversity in the microclimate. Gap size, shape, commpass orientation and the hight of surrounding vegetation, as well as the vegetation and tree fall litters in the gap itself, all influence the light, temperature and moisture in the gap (Brokaw, 1985). The continued creation of gaps and with the impact of gap edge effect made gaps to become the localized site of the maintenance of species diversity and forest regeneration.

The nature of forest gap edge effect and its research significance

This paper is one of the gap studies of forest in the world, and also the first report on the edge effect and dynamics of gaps of evergreen borad–leaved forest in China. Based on the results of this study, the nature of gap is surely direct one with dynamics. The forest gap edge effect rules provide a scientific basis for vegetation restoration of mixed needle broad–leaved forest, and for the better choice of cutting method and cutting intensity. The study suggests that keeping a certain intensity of gap edge effect and edge area is useful for trees regeneration.

The succession tendency of the forest gaps

The regularity of gap successional process and the tendency are the key problems in the gap dynamic study . The aim of this paper is to determine the forest gap succession tends based on the analysis of forest gap structure and the dynamics of the undershrub populations, which are the basic features for succession. In the developmental stage and the climax stage of a gap , the undershrub species are mainly the hygrophilous and shade–tolerant species, while the heliophilous young tree species are less and less and belong to the depauperate populations. Therefore it shows that the tendency of the gap succession is developing toward to a humid vegetation type. The natural succession of forest communities have the capability to use the ecological factors reasonably, so it could be get the better effect for forest regeneration to use the forest gap successional regularity. Such as the small cutting blank is much better than those large one. From the results, the tend acting is not need for the regenernation communities, except for the special forest purposes.

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