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Temporary Stability Characteristics and Influencing Factors of *Abies faxoniana*-Dominated Communities in the Wanglang Nature Reserve

Dongwei Kang * and Junqing Li *

School of Ecology and Nature Conservation, Beijing Forestry University, Beijing 100083, China
* Correspondence: kangdw@bjfu.edu.cn (D.K.); lijq@bjfu.edu.cn (J.L.)

Abstract: Specialized studies on the stability of *Abies faxoniana* (AF) communities are lacking. In order to fill this gap, a field survey of AF communities was conducted in the Wanglang Nature Reserve. Temporary stability is the possibility of the most dominant species to remain unchanged in a short period, reflecting the persistence of community stability to some extent. In this study, the temporary stability characteristics and influencing factors of the AF-dominated communities were analyzed. The results showed that the dominance of AF over the second dominant tree species became more pronounced as the temporary stability of the AF-dominated communities increased. Communities with the largest temporary stability value were dominated by AF alone. Furthermore, temporary stability had a significant linear positive relationship with the number of AF trees but not the AF size. There was no significant difference in the temporary stability between communities with and without large AF trees. It was concluded that with the increase in temporary stability, AF became more impossible to be replaced by other tree species in the short term, and the number of AF trees significantly affected the temporary stability of the AF-dominated communities. This study provides new insights into the stability characteristics of AF communities.

Keywords: dominant species; large tree; linear relationship; plant community

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1. Introduction

Abies faxoniana (AF) is an important tree species in China. AF forests are crucial for water resource protection, water and soil conservation, and climate regulation. AF forests also provide important habitats for many rare animals; thus, these forests benefit biodiversity conservation [1]. AF forests have been extensively cut in the last century [2]; therefore, it is vital to protect existing AF forests.

In the past several decades, numerous studies investigated AF forests, focusing on population characteristics [3,4], interspecific associations [5,6], community dynamics [7,8], regeneration and growth [9,10], and climate change [11,12]. These studies provided important insights into the biological and ecological characteristics of AF. Relatively few studies were conducted on the community ecology of AF, mainly focusing on interspecific relationships and spatial patterns [6,13,14], as well as community structure and succession [7,8,15]. No specialized studies have been conducted on the stability of AF communities, and we lack an understanding of the survival and maintenance mechanism of AF forests. Thus, it is urgent to research this topic to fill this gap.

Many indicators and methods have been used to characterize the stability of forest communities, such as the age structure [16], markov chain [17], improved M. Godron method [18], cybernetic system [19], fuzzy synthetic evaluation [20], spatial structure index [21], and changes in stand density [22]. These approaches are useful for describing the community stability characteristics, but their widespread use is limited by some conditions and factors, e.g., knowledge of dendrology and ecology, representativeness of the selected indicators, and continuous and comparable monitoring data.

Stability is a very complex concept; it involves many aspects, such as resilience, persistence, resistance, and variability [23–25]. Recently, a new indicator of temporary stability (TS) was proposed; it is defined as the possibility of the most dominant species in the community to remain unchanged in a short period, reflecting the ability of the community to resist change over time [26]. Furthermore, the calculation of TS is simple and convenient [26], which is easier to calculate than other indicators and can quickly provide quantitative results; thus, it is worth exploring the stability characteristics of different forest plant communities using this indicator.

In order to explore the stability of AF communities, a field survey of AF communities was conducted in Wanglang Nature Reserve of China. We select Wanglang for three main reasons. First, AF is a constructive species in the local forest, which is widely distributed in the reserve [8,27], and the status of the AF community deserves attention. Second, the AF forest is an important habitat for many wild animals [28], and the stability of the AF community is very important for local biodiversity protection. Third, Wanglang is a well-known giant panda reserve and has attracted wide attention. The study in Wanglang provides an important reference for other giant panda reserves and forest areas with AF distribution.

The objectives were to describe the TS characteristics of the AF-dominated communities and determine the factors affecting the TS of the AF-dominated communities. The goal was to provide insights into the stability maintenance mechanism of the AF community.

2. Materials and Methods

2.1. Study Area

The Wanglang Nature Reserve is located in Pingwu County of Sichuan Province, China. Wanglang was established in 1963 and had an area of 323 km^2 [29], with altitude ranges from 2300 m to 4980 m. Wanglang plays an important role in connecting different nature reserves [30].

Wanglang is one of the first giant panda nature reserves established in China [31]. According to the fourth giant panda survey, the population size of giant panda in Wanglang is 28, and the habitat area is 14,727 ha [30]. The main food source of giant pandas in the reserve is arrow bamboo (*Fargesia denudata*). The main tree species in the reserve includes *Abies faxoniana*, *Picea purpurea*, *Betula albosinensis*, and *Sabina saltuaria*.

In the 1950s, before the establishment of the reserve, a large area of forest cutting occurred within the scope of the reserve. After 1962, there was no forest cutting in the reserve [1]. Furthermore, the landslides and mudslides caused by earthquakes, and human activities such as roads and grazing, also have varying degrees of disturbance to the local forest.

2.2. Field Survey

Under the guidance of the staff of the Wanglang Nature Reserve, we conducted surveys to collect data in AF communities mainly in July and August of 2016 and 2017, based on the distribution and presence of AF in the reserve. In order to ensure the independence of the investigated plots, the distance between any two plots was at least 500 m. The plot size was 20 m $\times$ 20 m. In each plot, all tree individuals with a DBH $\geq$ 5 cm were recorded and measured, including the species name and DBH (diameter at breast height (1.3 m)). A total of 33 AF plots (including a plot outside the reserve but adjacent to the reserve) were surveyed (Figure 1). The elevation of these plots ranged from 2449 m to 3227 m, with a mean slope of 14°. These plots were located in main valleys (such as Dawodang, Zhugencha, and Changbaigou) and many branch valleys (such as Yangdonggou, Tianranmiaopugou, Wuzhuagou, Nangou, Chujiamo, Shuizhagou, Qikeshu, Jixiegongpenggou, Jiefanggou, and Baozigou) of Wanglang.

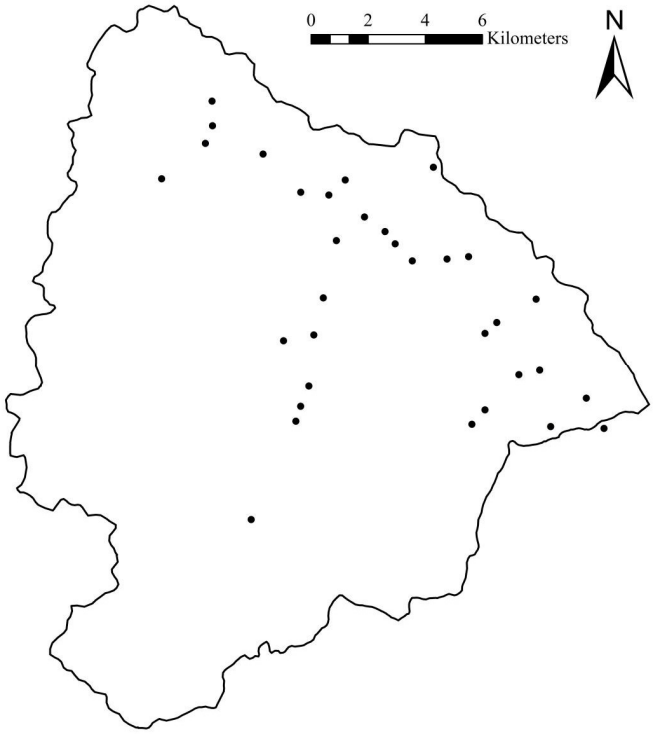

Figure 1. Distribution of *Abies faxoniana* (AF) plots in the Wanglang Nature Reserve.

2.3. Data Analysis

The indicator that can reflect the dominance of a species in the community is not unique. Considering the important value of the tree layer in the forest community can be expressed by the relative basal area (RBA) [32], the basal area was used to reflect the dominance of species.

The RBA of all tree species in each plot was calculated to identify AF-dominated communities, and the most dominant tree (tree species with the largest RBA value) was identified. Only plots in which the most dominant trees were AF were retained for analysis to prevent the influence of different forest types. In this study, the RBA value was calculated by dividing the total basal area of a tree species by the total basal area of all tree species in a plot. The AF-dominated community was defined as the plot where the most dominant tree species is AF. The dominant trees were defined as those with RBA values ≥ 0.10 in a plot [8].

Temporary stability (*TS*) was used as an indicator of the stability characteristics of the AF-dominated communities. It represents the potential of the most dominant species in a community to remain unchanged in the short term [26]. The *TS* value of each plot was calculated as follows:

$$TS = 1 - \frac{d_2}{d_1} \quad (1)$$

where *TS* is the temporary stability of the plant community; d_2 is the total basal area of the tree species with the second-largest basal area; d_1 is the total basal area of the tree species with the largest basal area. A larger *TS* value indicates higher stability, that is, the less likely the most dominant species will be replaced in the short term [26].

TS is defined based on the dominance relationship between the first two most dominant species in the community, without considering other factors outside the community, such as disturbance, soil, meteorology, etc. Viewed from the time scale, TS is an instantaneous stability indicator, that is, the dominance relationship state between the first two most dominant species at a certain moment. To some extent, the TS can be used to predict the possible changes in community properties in a short period in the future. The TS reflects the persistence of community stability to some extent.

All AF-dominated plots were ordered by the TS value, and the RBA of the AF and the second dominant tree species in each plot were listed. The trend of the dominance relationship between AF and the second dominant tree species with an increase in the TS value was analyzed [26].

The number and size of AF trees in each plot were calculated to determine the factors affecting the TS of the AF-dominated communities. The number of AF denoted the total number of AF individuals in a plot, and the AF size was the mean diameter at breast height (DBH) of all AF individuals in a plot. Different linear models of TS were established using the number and size of AF. Analysis of variance (ANOVA) tests were conducted, and the determination coefficient (R^2) was calculated to evaluate the linear relationship [33]. Furthermore, the correlations between TS and the number and size of AF trees were obtained.

We investigated whether large trees had a significant effect on the TS of the AF-dominated communities. The DBH data of AF trees in all AF plots were extracted and ranked by size; trees in the top 5% [34] were defined as large AF trees. All AF-dominated plots were divided into plots with and without large AF trees. The mean TS values in the AF-dominated plots with and without large AF trees were compared using ANOVA or a Mann–Whitney U-test, depending on the statistical assumptions [35]. The significance level was set to $p < 0.05$.

3. Results

3.1. General Information on AF Plots

A total of 33 AF plots were surveyed in the field; 69.7% (23 of 33 plots) of them were dominated by AF, 15.2% (5 of 33 plots) were dominated by *Betula albosinensis*, and 6.1% (2 of 33 plots) were dominated by *Picea purpurea*. The remaining proportion was shared by other species, such as *Sabina saltuaria*, *Salix wallichiana*, and *Acer caudatum* (Figure 2).

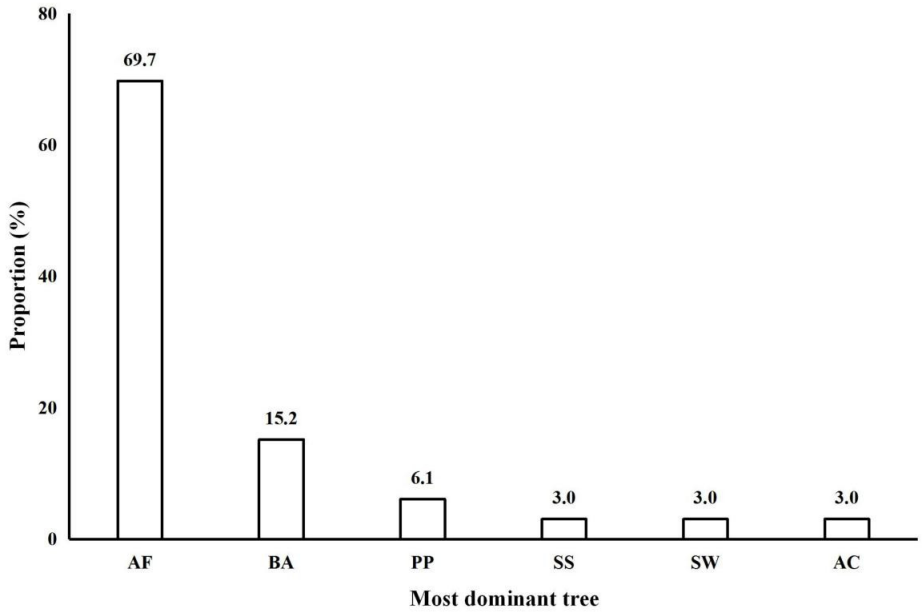

Figure 2. Composition of the most dominant trees in the Abies faxoniana plots (AF: Abies faxoniana; BA: Betula albosinensis; PP: Picea purpurea; SS: Sabina saltuaria; SW: Salix wallichiana; AC: Acer caudatum).

The most dominant trees in the 10 plots were not AF; thus, the temporary stability in these plots was more likely attributed to other species. These plots were excluded to avoid the impact of different forest types on the results. Finally, a total of 23 plots dominated by AF were retained for the analysis.

3.2. Temporary Stability Characteristics of AF-Dominated Plots

As the TS value increased in the AF-dominated plots, the trend of the dominance relationship between AF and the second dominant tree species was: weak dominance (plots 1 to 4), low dominance (plots 5 to 11), medium dominance (plots 12 to 19), and strong dominance (plots 20 to 23). The plots with the largest TS values had only one dominant tree species of AF (plots 20 to 23) (Table 1).

Table 1. Temporary stability (TS), relative basal area (RBA) of *Abies faxoniana* (AF), and the second dominant tree species in different AF-dominated plots.

Plot Number	TS Value	RBA Value of First Dominant Tree (AF)	Second Dominant Tree Species and RBA Value
1	0.14	0.43	SS (0.36)
2	0.18	0.30	BA (0.24)
3	0.18	0.28	AC (0.23)
4	0.23	0.40	AO (0.31)
5	0.36	0.44	PP (0.28)
6	0.46	0.55	BA (0.29)
7	0.48	0.65	PP (0.33)
8	0.57	0.58	BA (0.25)
9	0.59	0.63	BA (0.26)
10	0.61	0.64	BU (0.25)
11	0.62	0.53	PP (0.20)
12	0.70	0.75	PP (0.23)
13	0.71	0.70	PA (0.20)
14	0.72	0.75	PAV (0.21)
15	0.73	0.79	BA (0.21)
16	0.73	0.59	SW (0.16)
17	0.74	0.72	BA (0.19)
18	0.75	0.60	BA (0.15)
19	0.81	0.80	AC (0.15)
20	0.89	0.82	\
21	0.96	0.94	\
22	0.97	0.96	\
23	0.97	0.97	\

AF: *Abies faxoniana*; SS: *Sabina saltuaria*; BA: *Betula albosinensis*; AC: *Acer caudatum*; AO: *Acer oliverianum*; PP: *Picea purpurea*; BU: *Betula utilis*; PA: *Picea asperata*; PAV: *Padus avium*; SW: *Salix wallichiana*.

3.3. Relationship between Temporary Stability and Number and Size of AF

The number of AF individuals in different plots ranged from 2 to 47, with a mean (± SD) number of 17 (± 15) (n = 23). The R^2 of the relationship between TS and the number of AF trees was 0.23, and the *p*-value of the ANOVA was <0.05 (F = 6.42); the number of AF trees was significant in the model ($p < 0.05$; Table 2). There was a significant linear positive relationship between TS and the number of AF trees (r = 0.48, $p < 0.05$) (Figure 3).

Table 2. Linear regression model between temporary stability (dependent variable) and the number of *Abies faxoniana* (AF) trees (independent variable).

Model	Unstandardized Coefficient	Standard Error	*t* Value	Significance Level	95% Confidence Interval of Unstandardized Coefficient
Number of AF trees	0.01	0.00	2.53	0.02	[0.00, 0.02]
Constant	0.47	0.07	6.49	0.00	[0.32, 0.63]

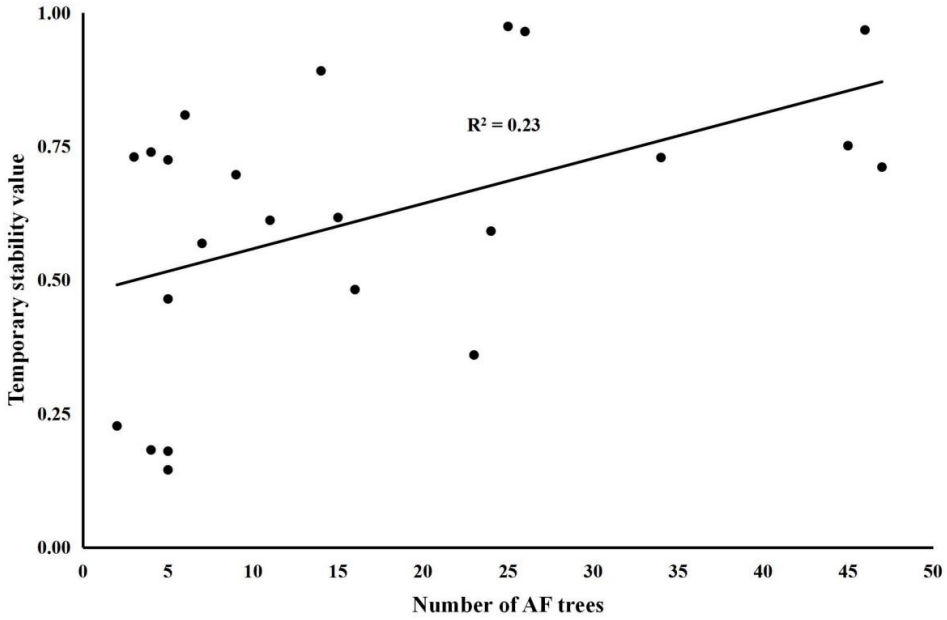

Figure 3. Scatter picture between temporary stability (TS) and the number of *Abies faxoniana* (AF) trees.

The DBH of AF individuals in different plots ranged from 12.1 cm to 52.8 cm, with a mean (± SD) size of 28.5 (± 11.7) cm (n = 23). The R^2 of the relationship between TS and the AF size was 0.08, and the *p*-value of the ANOVA was >0.05 (F = 1.87). There was no significant linear relationship between TS and the AF size (r = −0.29, $p > 0.05$).

3.4. Temporary Stability Characteristics of Plots with and without Large AF Trees

A total of 450 AF individuals (DBH ≥ 5 cm) were surveyed in the field; 22 trees fell into the top 5% in terms of size, with a DBH ranging from 55.1 cm to 112.0 cm. Thus, a DBH ≥ 55.1 cm was chosen to represent a large AF tree.

Large AF trees (DBH ≥ 55.1 cm) occurred in 14 out of 23 plots. The ANOVA results showed that the mean (± SD) TS of plots with large AF trees was 0.65 (± 0.29). This value was larger than that of plots without large AF trees 0.55 (± 0.19), but the result was not significant (F = 0.77, $p > 0.05$).

4. Discussion

4.1. Temporary Stability of AF-Dominated Communities

Stability is an important concept in ecology [36]. Due to different research fields, research objects, and research ideas, many different definitions of stability were proposed [37]. Various definitions can enrich the understanding of stability, but it also leads to the difficulty of reaching a unified understanding. For example, the definition of stability can be divided into different categories [23,25,37–39]. Simple indicators are more likely to be widely used, which may weaken the scattered understanding of stability.

Recently, a new indicator (TS) was proposed and evaluated in an area with several forest types in northeast China [26]. The present study tested the feasibility of using TS in a single forest type, the AF-dominated communities in Wanglang, to exclude the impact of different forest types on the results. The results showed that the dominance of AF over the second dominant species became more pronounced with an increase in TS. In communities with the largest TS, AF was the single dominant species, and it was unlikely that the AF-dominated communities would change in the short term. Thus, the higher the temporary stability value is, the less likely AF will be replaced by other species in the short term. Furthermore, in terms of the succession characteristics of plant communities in Wanglang, the AF community is the climax community [40]; thus, this community is

unlikely to be replaced. This result is consistent with a previous study [26], indicating that the new indicator of TS can be used to characterize the stability characterizes of the AF-dominated communities.

This study excluded plots containing AF but not dominated by this species. Thus, we confirmed the TS characteristics of the AF-dominated communities. However, this result requires further analysis of other forest types.

4.2. Influencing Factors of Temporary Stability in the AF-Dominated Communities

Community stability is an important research topic in the study of forest ecosystem stability [41]; previous studies have shown that many factors may affect the stability of forest communities. For example, the stability of forest communities is not only related to some factors in the community, such as regeneration and species diversity but also affected by factors outside the community, such as soil and disturbance [42–45].

In this study, the TS of the AF-dominated communities was analyzed using the basal area. This parameter was closely related to the number and size of AF trees. The regression analysis showed that TS had a significant linear positive relationship with the number of AF trees. However, no significant linear relationship was obtained between TS and the AF size.

Communities with more AF trees had higher TS. An increase in TS with an increase in the number of AF trees suggests that a larger number of AF trees enables the AF community to maintain its dominant status. Thus, the number of AF trees significantly affects TS. However, the R^2 value was relatively low, indicating that the number of AF trees had low explanatory power. Thus, there may be more important factors than the number of AF trees affecting TS.

Other characteristics of the community were considered. For example, a large size tree can reflect the succession state [46,47], and it may be related to community stability. Thus, we investigated the influence of large AF trees. However, there was no significant difference in the mean TS value between plots with and without large AF trees, indicating that this factor did not have a substantial influence on the TS of the AF-dominated communities. Follow-up studies that consider other influencing factors are required.

The role of large trees has attracted significant attention in ecology [48]. In this study, we considered trees within the top 5% (DBH $\geq$ 55.1 cm) as large AF trees. Our results provide an important basis for further analysis of the role and function of large AF trees in the community.

4.3. Implication and Future Research Needs

Based on the definition of TS and the study of TS in a single forest type of the AF-dominated communities, it can be inferred that communities with single dominant species may have high stability. Therefore, afforestation by dense planting of single tree species in a large area should be cautiously used in forest restoration because once the plantation is formed, its community characteristics may be difficult to change within a short period.

Many factors may be related to community stability. We studied the TS of AF-dominated communities from different factors, such as the number of AF, AF size, and large AF trees, while some factors that may be very important were not considered. For example, the growth rate of different tree species, interspecific association, and correlation. Furthermore, many factors outside the community were not considered, such as soil nutrients and water. Therefore, more biological and abiotic factors should be considered in future research.

Different types of disturbance may also affect community stability. In Wanglang and many other giant panda nature reserves, human disturbance has always been frequent [49], and they affect the forest in different ways [50]. For example, logging leads to forest loss, roads lead to forest fragmentation, and grazing leads to forest degradation. As for Wanglang, it experienced large-scale forest logging in the last century [1], the total length of roads is 32 km [51], and there are livestock from surrounding communities [52]. All of these

human disturbances may affect the stability of the AF community. Furthermore, the forests in Wanglang are also affected by natural disturbances, such as landslides and mudslides caused by earthquakes [27]. Therefore, the influence of disturbance on community stability is worth studying.

The findings of this study are only based on a single survey in a single forest type. In order to track the dynamic change characteristics of the TS of the AF-dominated communities, studies based on long-term continuous and fixed-point monitoring will be more meaningful and valuable. Furthermore, for other types of forests, further research is needed to verify. In addition, AF forests provide important habitats for many rare wild animals, and it is worth discussing the relationship between the stability and change in AF communities and the habitat selection of different wild animals.

5. Conclusions

Specialized studies on the stability of AF communities are lacking. In order to fill this research gap, a field survey was conducted in Wanglang to evaluate the TS of the AF-dominated communities and assess the influencing factors. The dominance of AF over the second dominant species became more pronounced as the TS of the AF-dominated communities increased. Communities with large TS values were dominated by AF alone. TS and the number of AF trees had a significant linear positive relationship. The number of AF trees significantly affected TS but the AF size and the presence of large AF trees did not. The number of AF trees had low explanatory power, more studies that consider other influencing factors are required.

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