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# Disturbance Status of Secondary Forest of *Castanopsis* on Jiangle Forest Farm, Fujian Province, China

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## ABSTRACT

The study was conducted on the secondary forest of *Castanopsis* on Jiangle Forest Farm in Sanming City, Fujian Province, China to determine the vegetation disturbance status. Twenty one quadrats (20 m × 30 m) were sampled and recorded the vegetation parameters such as DBH, height, seedling and sapling density of woody species, and location and altitude of each quadrat. An evaluation system was established to assess the disturbance to the secondary forest based on the standard quadrat of the Jiangle Forest Farm. Using the evaluation system, we found that the *Castanopsis* forests on the farm were mostly pristine or sustained minor disturbance. These results suggest that secondary forests of *Castanopsis* must be managed and protected according to the disturbance status. More basic and applied researches should be conducted, for sustainable development of the forest and its products.

## INTRODUCTION

The need to identify and protect threatened evergreen broad-leaved forests (EBLFs) in the subtropics is gaining attention. EBLFs are zonal climax community and mostly found in south China (Cao 2010), composed of various tree species, suitable for plants and animals. EBLFs have complex biologically diversity, present notable ecological benefits, especially in water and soil preservation, maintaining balance and relative stability of forest ecosystem, improving soil fertility, and regulating microclimates (Jiang-guo 1985, Zeng 1990, Wenyao 1991). In recent years, the area of EBLFs has been less than 5% of China's subtropical area, due to long-term anthropogenic disturbances. In subtropical regions, particularly in southern China, large areas of natural EBLFs have been cut and burnt for the establishment of fast-growing coniferous forests because of their higher economic benefits in recent decades (Wu et al. 2008). *Castanopsis* is the main constructive species in EBLFs. Many scholars have studied and described *Castanopsis* forests, mostly focused on forest regeneration (Kira 1991, Diehl et al. 2008, Komatsu et al. 2008, Wu et al. 2008, Wu, Liu et al. 2013), forest management (Ovington & Pryor 1983, Wardle et al. 1983, Cannon et al. 1998, Meadows & Jcg 2001, Lundqvist 2004), and forest functions (Leak 1964, Tarasov et al. 2007, Chazdon 2008, Pretzsch et al. 2014), but few on the assessment of disturbance of *Castanopsis* forests.

Disturbance is a major ecological force affecting the structure, dynamics, productivity and biodiversity of ecosystems (Turner et al. 1998, Nyström et al. 2000), and communities, populations, changing resource pools, substrate availability and the physical environment (White 1985). Disturbance regimes encompass a wide range of temporal and spatial scales, and are characterized by their extent, spatial arrangement, frequency, predictability and intensity. While many studies have taken into account other systems (Nath et al. 1998, Prescottallen 2001, Hassan et al. 2005, Van Beynen & Townsend 2005, Tarasov et al. 2007, EPA 2008, Science 2008, Van Beynen & Bialkowska-Jelinska 2012), and generally focused on biotic, geomorphic, or economic values. A more systematic and holistic manner is required to measure the impact of disturbances, and effectively assess the threats to *Castanopsis* forest. It can be very difficult to determine appropriate indicators to assess disturbance status of *Castanopsis* forests. Effective indicators must include the following criteria: 1) relevancy-serve a clearly defined purpose; 2) reliability-of sound scientific basis; and 3) reasonability-can be measured by available data (OECD 2004).

Jiangle County, a unique subtropical county in China, is one of 45 national designated key forestry counties. It has 724.4 ha of EBLFs, mainly of public forests. Though the forest has been under protection, it has been continuously exploited by surrounding people for agricultural land expansion, timber harvesting, charcoal production, woodcutting for construction and other purposes. The present study has the following objectives: (1) attempting to develop an evaluation system for assessing grades of disturbance of EBLFs; (2) testing and applying this system in the secondary forest of Jiangle forest farm.

## MATERIALS AND METHODS

**Study area:** The study was conducted at the Jiangle Forest Farm (117°05'E-117°40'E, 26°26'N-27°04'N), located in Sanming City, Fujian Province, China. Elevations range from 400 to 800 m a.s.l. The area is characterized by a subtropical monsoon climate, with annual temperature of 18.7°C. The annual precipitation was 1700-1900 mm according to the observations from a local weather station. The soil in major part of the region is red earth. The main tree species include *Castanopsis fargesii* Franch, *Castanopsis eyrei* (Champ. ex Benth.) Tutch, *Castanopsis sclerophylla* (Lindl. et Paxton) Schottky, *Castanopsis carlesii* (Hemsl.) Hayata and *Cyclobalanopsis chungii* (F.P. Metcalf) Y.C.Hsu et H.W. Jen ex Q.F. Zheng, and shrubs primarily are composed of *Eurya loquaiana* Dunn, *Ilex pubescens* Hook. et Arn and *Adinandra millettii* (Hk. Et Arn.) Benth. Et Hk.f. ex Hance. The *Castanopsis* in study area is a natural secondary forest after clear-cutting in 1956, suffered no severe disturbances such as fire and meteorological disaster. The management is mainly forest reservation with few developed as timber forests. Main are near-mature and mature forest.

**Data collection and sample collection:** To assess the disturbance status of the secondary forests of *Castanopsis* at the Jiangle Forest Farm, numerous data sources were utilized. Field surveys consisted of sample quadrats (0.06 ha) which were randomly selected in secondary woodlands of *Castanopsis*. A total of 21 quadrats (total 1.26 ha) was sampled and GPS locations, slope inclinations, slope aspects, slope positions, origins of stand, and the site types were recorded for future reference, and subsequently permanently marked with stony stakes in the southwest corner of each quadrat.

In each quadrat, all living trees with diameter at breast height (1.3 m above the ground) (DBH) >=5 cm were surveyed. If the tree branched at breast height or below, the diameter was measured separately for each branch and averaged. For each tree, the following data were collected: scientific name; x, y geographic coordinates; DBH; total tree height and height-to-base of the live crown; and crown projection.

Five 5 m × 5 m subplots, one at each corner and one at the centre of the main quadrat were set up to sample shrubs. In each plot, the diameters and heights of all individual shrubs were counted and measured.

**Data analyses:** This article takes a holistic, ecosystem approach to EBLFs, and recognizes that the space diversity,

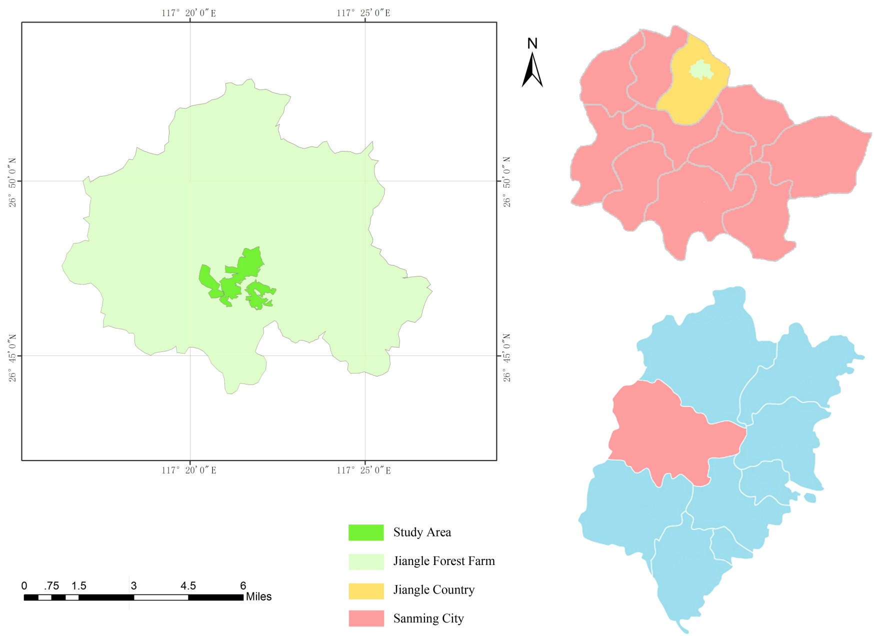


Fig. 1: Location map of the study forest.

vigour, stand structure, forest health and human disturbance both influence and are influenced by EBLFs. Hence, disturbance of any component of ecosystem is considered part of impact of EBLFs. The EBLFs disturbance index presented in this report is divided into five categories, each recognizing a distinct part of system. An overview of suitable indicators measuring the secondary forest of *Castanopsis* is given in Table 1. We selected 19 indicators and calculated each weight by referring to the experts and by use of the Analytic Hierarchy Process (AHP).

Indicators of forest structure were composed of canopy closure, vertical structure and level structure. Multi-storeyed, even-distributed stands present good structure stability and low risk of being disturbed.

Indicators of forest health are composed of flammable species proportion, elevation, slope, and slope aspect. According to the proportion of flammable species, the higher the proportion of flammable, the higher is the proportion of forest fire disturbance. Elevation is one important factor of forest health, the risk of fire disaster declines as the elevation rises. Generally, weak sunlight, low temperature and slow evaporation in ubac, strong sunlight, high temperature and fast evaporation in adret, so that the risk of fire and the speed of fire spread in ubac are more than those in adret. Based on the construction standards of National Ecological Public Welfare Forest (GB/T26424-2010), slop was classified into three grades and then scored accordingly.

Accessibility, tending strength, tending mode, cutting models and cutting intensity are the main sub-indictors of human disturbance. The accessibility reflects the human disturbance; more convenient the accessibility is, more frequently the human disturbance occurs. Tending modes and cutting models are part of human disturbance to forests. According to the actual situation of tending strength and cutting intensity of the study area, indicators were assigned numerical values from 0 to 1.

**Scoring system:** The composite disturbance score (DS) of forest condition was then calculated by using weighted indices to attain a value between 0 and 1 which was then classified by status of disturbance. These classifications are: 0.0-0.27 (pristine), 0.28-0.34 (minor disturbance), 0.35-0.41 (moderate disturbance), and 0.42-1 (high disturbance). DS was calculated as follows:

$$DS = \sum_{r=1}^{n} (W_1 x_1 + W_2 x_2 \cdots + W_n x_n)$$

Where, DS was disturbance score; $W_1,W_2,\ldots W_n$ were the weight; $W_1+W_2+\ldots+W_n=1$; $x_1,\ldots x_2$, were the standardized relative values, with threshold [0~1].

## RESULTS

We identified four forest types reflecting the variation in the degree of disturbance in the study area (Table 2). In the study area, the widespread and dominant species of most forest types were *Castanopsis fargesii* Franch, *Castanopsis sclerophylla* (Lindl.) Schott, *Schima superba* Gardn. et Champ and *Alniphyllum fortunei* (Hemsl.) Makino. The most ubiquitous genus was *Castanopsis fargesii* Franch in the Jiangle Farm.

High disturbance stands (DS is 0.474) accounted for one quadrat. This forest type was dominated by *Castanopsis sclerophylla* (Lindl.) Schott, accompanied by *Sapium discolor* (Champ. ex Benth.) Muell. Arg, *Castanopsis fargesii* Franch, *Liquidambar formosana* Hance and *Machilus thunbergii* Sieb. et Zucc etc.

Moderate disturbance stands (DS is 0.345) accounted for 4.76%. These stands were dominated by *Castanopsis fargesii* Franch which was accompanied by *Schima superba* Gardn. et Champ and *Castanopsis sclerophylla* (Lindl.) Schott.

Minor disturbance stands (DS is 0.276~0.322) accounted for 33.34%. These stands were dominated by *Castanopsis fargesii* Franch accompanied by *Alniphyllum fortunei* (Hemsl.) Makino and *Castanopsis sclerophylla* (Lindl.) Schott.

Pristine stands (Ds is 0.204~0.270) accounted for 57.14%. The stands were also dominated by *Castanopsis fargesii* Franch which was accompanied by *Cunninghamia lanceolata* (Lamb.) Hook, *Castanopsis sclerophylla* (Lindl.)Schott, *Alniphyllum fortunei* (Hemsl.) Makino and *Schima superba* Gardn. et Champ.

## DISCUSSION

In this paper, we used field data to determine the variations in disturbance degree of *Castanopsis* forests on the Jiangle Forest Farm. These variations across the *Castanopsis* population call for different management and conservation strategies.

**Disturbance status:** The secondary forest of *Castanopsis* in the Jianle Forest Farm was mainly in pristine or minor disturbed conditions. This is consistent with the reality where the local management authority closed hillsides for reforestation. It is necessary to manage and operate according to the stability of the *Castanopsis* species, avoiding negative disturbance, strengthening positive intervention in order to improve the stability of forest stands.

The highly disturbed stands (DS was 0.474) accounted for 4.76% of the quadrats. The areas were logged twice in

Table 1: Disturbance index for secondary forest of *Castanopsis* on the Jiangle forest farm, Fujian province.

| Objective | Criterion | Indicator | 1 | 0.5 | 0 | Weight |
|---|---|---|---|---|---|---|
| Forest Disturbance | Organization | Arbor Abundance | «5 | 5<AA«6 | >6 | 0.0133 |
| | | Shrub Abundance | «5 | 5<SA«10 | >10 | 0.0165 |
| | | Herb Abundance | «5 | 5<HA«10 | >10 | 0.0440 |
| | | Proportion of coniferous(%) | «4.2 | 4.2<R«8.3 | >8.3 | 0.0512 |
| | Vigour | Density (tree/ha) | «900 | 900<D«1500 | >1500 | 0.0365 |
| | | Volume Storage($m^3$/ha) | «1.0 | 1.0<V«1.8 | >1.8 | 0.0668 |
| | | Biomass per hectare(t/ha) | «95 | 95<B«165 | >165 | 0.0634 |
| | Stand structure | Canopy Closure | «0.6;>0.9 | 0.8<CC«0.9 | 0.6<CC«0.8 | 0.0085 |
| | | Vertical structure | Single story | | Compound story | 0.0381 |
| | | Level structure | Aggregated | Random | Even | 0.0036 |
| | Forest health | Flammable species proportion(%) | >0.29 | 0.15<FI«0.29 | «0.15 | 0.0339 |
| | | Elevation | «400 | 400<H«600 | >600 | 0.0537 |
| | | Slope(°) | 0<I«15 | 15<I«35 | >35 | 0.0371 |
| | | Slope aspect | Sunny slope | | Shady slope | 0.0335 |
| | Human disturbance | Accessibility | Accessible | Nearly accessible | Inaccessible | 0.0473 |
| | | Tending strength | >26% | 16%<$P_V$«25% | «15% | 0.0833 |
| | | Tending mode | tended | | untended | 0.0833 |
| | | Cutting models | Clear | Shelterwood | Selective | 0.1500 |
| | | Cutting Intensity | >26% | 16%<$P_V$«25% | «15% | 0.1361 |

Table 2: Disturbance status of *Castanopsis* secondary forest stand.

| Disturbance degree | Sample plots | Proportion | Dominant tree species | Disturbance score |
|---|---|---|---|---|
| High disturbance | 1 | 4.76 | *Castanopsis sclerophylla* (Lindl.) Schott(16.90)<br>*Sapium discolor* (Champ. ex Benth.) Muell. Arg(16.71)<br>*Castanopsis fargesii* Franch(16.27)<br>*Liquidambar formosana* Hance(12.61)<br>*Machilus thunbergii* Sieb. et Zucc(10.68) | 0.474 |
| Moderate disturbance | 1 | 4.76 | *Castanopsis fargesii* Franch(25.16)<br>*Schima superba* Gardn. et Champ(14.19)<br>*Castanopsis sclerophylla* (Lindl.)Schott(7.61) | 0.345 |
| Minor disturbance | 7 | 33.34 | *Castanopsis fargesii* Franch(20.8)<br>*Alniphyllum fortunei* (Hemsl.) Makino(9.96)<br>*Castanopsis sclerophylla* (Lindl.)Schott(7.44) | 0.276~0.322 |
| Pristine | 12 | 57.14 | *Castanopsis fargesii* Franch (12.20)<br>*Cunninghamia lanceolata* (Lamb.) Hook(9.42)<br>*Castanopsis sclerophylla* (Lindl.)Schott(8.11)<br>*Alniphyllum fortunei* (Hemsl.) Makino(7.41)<br>*Schima superba* Gardn. et Champ(7.17) | 0.204~0.270 |

the history. After logging, prompt afforestation measures were not put in place. As a result, the area had poor arbor growth and low timber volume. Thus, it is evaluated as highly disturbed.

The moderately disturbed forest (DS was 0.345) accounted for 4.76% of all quadrats. This area was logged once in the history, and has a shady slope. Thus, arbor trees grew poorly. The arbors had a mean DBH of 9.15 cm. In addition, the area is close to residential sites, which also contributes to the disturbance.

**Implications for conservation and management:** It is difficult to make sound recommendations without thorough studies of the ecological context. Management practices must be attuned to the forest type of the local area, as we have done here. In this study, we have established a disturbance evaluation system according to the forest structure. The *Castanopsis* secondary forest on the Jiangle Forest Farm was assessed as pristine or of minor disturbance. In order to further reduce disturbance and to develop more stable and healthy stands, we offer the following recommendations for each forest disturbance type.

Combining with the disturbance status of the secondary forest of *Castanopsis*, it is necessary to apply appropriate tending measures to drive the forest development positively and to attain maximal efficiency. It is also advisable to preserve some species of high economical values or high water preservation capacity. Appropriate to the local status, coniferous trees may be increased so that the stands have appropriate ratios of coniferous and broad leaved trees.

The moderately disturbed area was small at the Jiangle Forest Farm. The moderate disturbance was mainly due to system vitality index and human activities. It is advisable to manage the system vitality so that major species are within appropriate density, volume stocking and biomass accumulation conditions, reduce as much as possible the influence of system vitality index to minimize its influence. We suggest planting conifers so that the forest stands have appropriate conifer to broad leaved ratios, enriching the biodiversity and increasing resistance to disturbance. For woodlands near residential areas, it is necessary to promote practically the publicity of hillside closure, establish rules for penalty. It is also recommended to plant evergreen shrubs such as holly or barberries along the boundaries of woodlands to prevent disturbance.

A very small proportion of forest stands at the Jiangle Forest Farm was highly disturbed. The major cause of the disturbance was broken practices of hillside closure and man-made interference. According to the specific disturbance level, different levels and types of hillside closure measures may be implemented. Accompanying hillside closure, tending measures may also be applied, including removal of shrubs and nuisance species. In order to ensure good growth, thinning of dense stands may be necessary. In addition, close attention must be paid to the growth of tree species. Pests and diseases must be prevented and controlled in a timely manner to stop the spread and damage propagation. Furthermore, the target tree species should be determined, and native trees and conifers may be replanted to maintain a proper proportion of conifers.

In addition to natural regeneration, auxiliary artificial regeneration may be implemented for the *Castanopsis* woodlands on the Jiangle Forest Farm. An appropriate proportion of native trees may be replanted, and selective cutting may be used to control the canopy density, to improve the understory light environment. Dry fallen woods may be retained to an appropriate level to promote natural regeneration of forest stands, so that the level of regenerating trees may be improved, and stand vertical level differentiation becomes more obvious.

## CONCLUSION

The secondary forest of *Castanopsis* at the Jiangle Forest Farm was evaluated for disturbance status. Results indicate that the forest was basically pristine or sustained minor disturbance. Each disturbance status was accompanied by regenerating tree populations that were different in composition, distribution and density. Tree species were assigned to different levels of protection based on their regenerating population distribution. Based on the study, different management and conservation strategies are recommended.

Theoretical and methodological improvement is needed for studying the disturbance and regeneration of *Castanopsis* forest. Through the evaluation of the disturbance status of the secondary forest on the Jiangle Forest Farm, we also recognized that some limitations need to be explored further. Although the main hypothesis was supported statistically, the criteria need to be expanded to other biological and non-biological factors (e. g. soil, microbes and birds) to further improve the evaluation system. Furthermore, the planning and management of the forest may be assisted by detailed ecological studies in relation to various environmental factors such as soil type and properties. It is necessary to conduct more basic and applied research for sustainable development of the forest and its products.

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