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# Composition, dynamics and disturbance regime of temperate deciduous forests in Monsoon Asia

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## Abstract

Temperate deciduous forests in Monsoon Asia are classified into three forest types which differ in floristic composition, dynamics and disturbance regime. The cool temperate mixed deciduous broadleaf/conifer forest, dominated by *Quercus* spp. (mainly *Q. mongolica* or *Q. crispula*) and conifers, is distributed in northern parts of the temperate zone. The cool temperate deciduous forest, dominated by *Fagus crenata,* is distributed in Honshu, Japan under a humid climate through the year. The warm temperate deciduous forest dominated by *Quercus* spp. (mainly *Q. acutissima* or *Q. serrata*) occurs in the continental areas, the Korean Peninsula, and the Pacific Ocean side of Japan. The species diversity of cool temperate deciduous forest was lower than the other two types because of the intensive dominance of *Fagus crenata.* The disturbance regimes also varies among the three types; small scale treefall gaps are prevailing in the cool temperate deciduous forest, while larger scaled disturbances are important in the other two forest types. Fire seems to be important in the warm temperate deciduous forest, and both fire and large scale blowdowm seems important in the cool temperate mixed broadleaf/conifer forest. These differences in forest composition and disturbance regimes associated with climatic conditions and ancient human impacts have a close analogy with the Northeastern Hardwood forests in North America.

## Introduction

Deciduous broadleaf forest is the representative vegetation type in the humid temperate zone of Monsoon Asia. It covers the range of latitude from 30° to 50°N on the eastern coast of the Eurasian Continent and the islands of the Pacific Ocean (Ohsawa 1993). A number of researches on the forest types in this region have been made (Hou 1983; Tatewaki 1958; Yim 1977; Shidei 1974), and several good reviews on the distribution and climatic features of forest types are now available (Fang & Yoda 1989, 1990; Ching 1991; Kira 1991; Ohsawa 1993). In respect to forest dynamics, many works have appeared recently for this forest zone (Nakashizuka 1987; Yamamoto 1989; Ohkubo 1992).

This paper characterizes the three main types of the temperate deciduous forests in this region. Particularly the species diversity, forest dynamics and disturbance regimes of them are compared. The importance of disturbance regimes affecting the organization of the forest tree communities, which may be subject to shift relating to global climatic change, is also discussed.

## Temperate deciduous forests types

Most researchers have recognized three main types of the deciduous broadleaf forests in this region, however, different classification systems and terminologies have been applied (Table 1). In this paper, we wish to compare three types of deciduous broadleaf forests which have quite similar physiognomy. Ohsawa (1993) used the word 'cool-temperate' including all the deciduous forest types in this region, while Kira (1991) included only the northern two forest types. Here, we have tentatively followed the classification and terminology of Kira (1991).

Kira's system is fundamentally a classification based on thermal climate. The cool temperate mixed

*Table 1.* Classification and terminology of temperate deciduous forests in Monsoon Asia.

| China | Korea | Japan | | Whole area |
|---|---|---|---|---|
| Hou (1956) | Yim (1977) | Shidei (1974) | Nozaki & Okutomi (1990) | Kira (1991) |
| Mixed coniferous and deciduous broad-leaved forest | Northern part of deciduous broad-leaved forest | Boreal mixed coniferous and deciduous broad-leaved forest | Upper-temperate forest | Cool-temperate mixed deciduous broadleaf/conifer forest |
| | | Temperate deciduous broad-leaved forest | *Fagus crenata* forest | Cool-temperate deciduous broadleaf forest |
| Deciduous broad-leaved forest | Central part of deciduous broad-leaved forest | | Intermediate-temperate forest | Warm-temperate deciduous broadleaf forest |
| | Southern part of deciduous broad-leaved forest | | | |

*Table 2.* Floristic composition of temperate deciduous forest types. Species names with underlines are coniferous species.

| | Warm-temperate | Cool-temperate | |
|---|---|---|---|
| | Deciduous broadleaf forest | Deciduous broadleaf forest | Mixed broadleaf/ conifer forest |
| China[1] | *Quercus acutissima*<br>*Q. aliena*<br>*Q. dentata*<br>*Q. variabilis*<br>*Q. serrata* | | *Betula costata*<br>*Tilia amurensis*<br>*Quercus mongolica*<br>*Picea jezoensis*<br>*Abies nephrolepis*<br>*Pinus koraiensis* |
| Korean Peninsula[2] | *Carpinus tschonoskii*<br>*Quercus acutissima*<br>*Q. variabilis*<br>*Q. dentata*<br>*Q. serrata* | | *Acer mono*<br>*Betula chinensis*<br>*B. schmidtii*<br>*Quercus mongolica*<br>*Carpinus cordata*<br>*Pinus koraiensis* |
| Japan[3] | *Fagus japonica*<br>*Quercus serrata*<br>*Carpinus laxiflora*<br>*C. tschonoskii* | *Fagus crenata*<br>*Quercus crispula*<br>*Acer japonicum*<br>*Betula maximowicziana* | *Quercus crispula*<br>*Abies sachalinensis*<br>*Picea jezoensis*<br>*Acer mono*<br>*Tilia japonica* |

[1] Ching (1991); [2] Yim (1977); [3] Nozaki & Okutomi (1990).

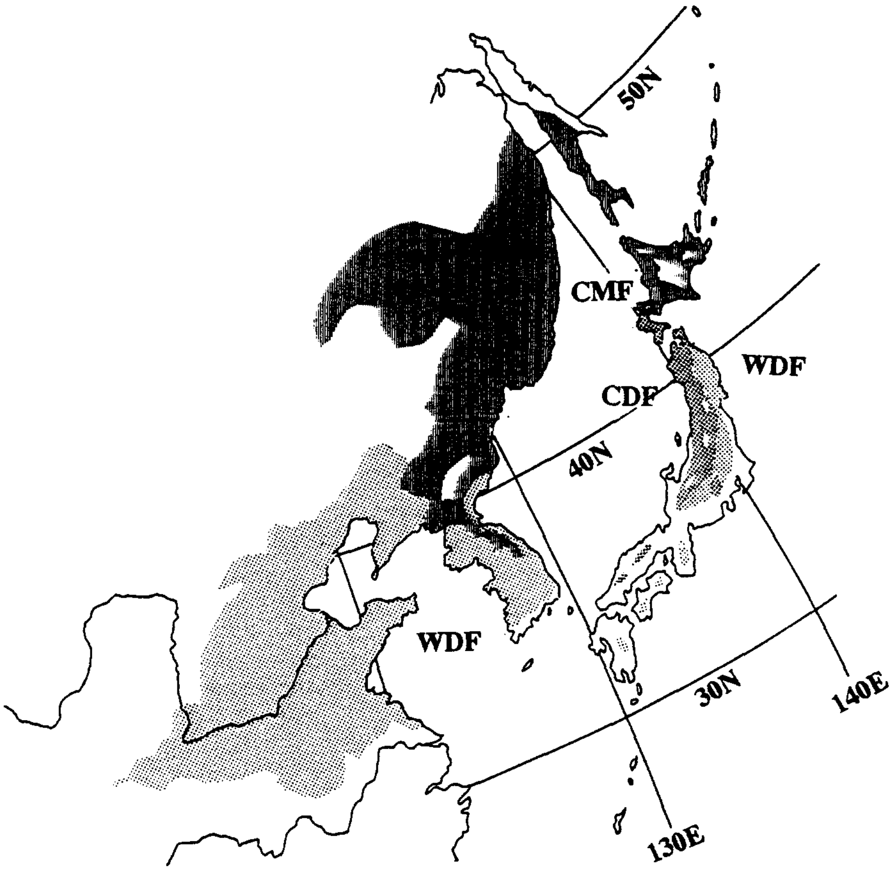


*Fig. 1.* Geographical distribution of the temperate deciduous forests in Monsoon Asia. CMF: cool temperate mixed broadleaf/coniferous forest, CDF: cool temperate deciduous forest, WDF: warm temperate deciduous forest. Based on Hou (1983), Tatewaki (1958), Shidei (1974), Yim (1977) and Nozaki & Okutomi (1990).

broadleaf/conifer forest (CMF) occurs in the coldest areas in temperate Monsoon Asia, followed by cool temperate deciduous forest (CDF), then warm temperate deciduous forest (WDF). In the area of WDF, summer is warm enough, but winter is too cold (large difference in maximum and minimum temperature) for the warm temperate lucidophyll (evergreen) forest. Together with the thermal conditions, the water balance is also important for the classification of these forest types (Fang & Yoda 1990); CMF and WDF, which Kira (1991) suggested to be continental types, develop in the regions with greater water deficit.

*Quercus* (mainly *Q. mongolica* or *Q. crispula*) and coniferous species are important in CMF (Table 2). *Acer mono* and *Tilia* spp. are also important in some forests. These forests are mainly distributed around the Amur River, in the mountainous regions of Korea and Hokkaido Island, Japan (Fig. 1). The genera *Picea* and *Abies* are dominant conifers both in Hokkaido and the continental area, while *Pinus koraiensis* is important in the Korean Peninsula (Kira 1991).

Cool temperate deciduous forests are unique to the western side of the Japanese main mountain ranges. The area of this forest type is characterized by a humid climate throughout the year, and heavy snowfall in winter. *Fagus crenata* is almost monodominant, accounting for more than 80% in basal area (Nakashizuka 1987).

The main region of WDF is the plain of the River Huang He (Yellow River). This type of forests have been extensively exploited by human activity in the long history of China (Ching 1991). *Quercus* species (*Q. acutissima*, *Q. serrata*, *Q. dentata* and *Q. variabilis*) are important in this forest type as well as CMF. It has been debated WDF occurs in Japan or not. Shidei (1974) regarded this as a sub-type of cool temperate deciduous forest (in his sense, Table 1), with lesser dominance of *Fagus crenata*. Recently, Nozaki & Oku-

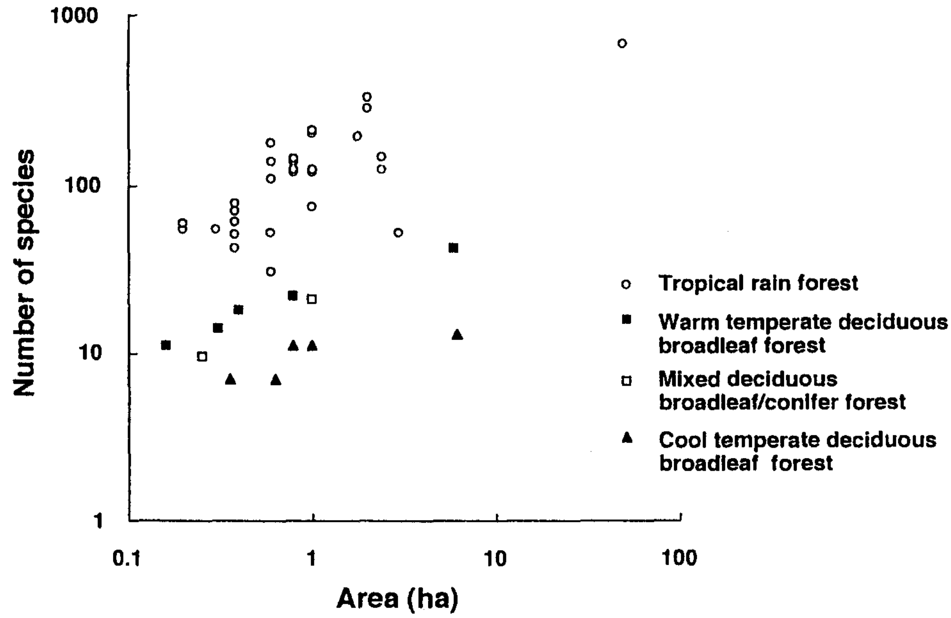


*Fig. 2.* Species-area relationships in different forest types in Monsoon Asia. Trees over 10 cm dbh were studied. Data from Whitmore (1984) for tropical forests, Watanabe (1983), Mukaide (1983), Nakashizuka (1987), Ohkubo et al. (1988), Maruyama et al. (1989) for temperate forests.

tomi (1990) surveyed the distribution of these forests, which are now very fragmented on the eastern side of the Japanese main ranges, and concluded that there are large areas which potentially belong to this type (Fig. 4).

The temperate forests of Monsoon Asia are basically richer in tree species than those in Europe and North America (Latham & Ricklefs 1993). In general, the species numbers are about one tenth of that in tropical rain forest in Southeast Asia (Fig. 2). The species richness in WDF and CMF are about twice of that in CDF for the same stand area, in which *Fagus crenata* has an overwhelming dominance.

## Forest dynamics and disturbance regimes

Three types of disturbance are predominant in the temperate deciduous forests in Monsoon Asia, i.e. treefall gap, large-scale blowdown, and fire. Few studies are available on forest dynamics and disturbances in the temperate deciduous forests in the eastern Eurasian Continent and the Korean Peninsula, while for those in Japan, many quantitative researches have been conducted recently. Thus most of the discussion here is based on the latter.

Treefall gaps are observed in all the types of temperate deciduous forests in this region (Ishikawa & Ito 1989; Nakashizuka 1987; Yamamoto 1989; Nakashizuka et al. 1992). The main causes of treefalls in this area are typhoons (Yamamoto 1989). The maximum sized gap is about 3,000 $m^2$ (Nakashizuka 1987), and gaps smaller than 100 $m^2$ are abundant (Nakashizuka 1988; Yamamoto 1989). Gap formation rates in old-growth forests ranged from 0.3 to 0.8% $yr^{-1}$ (Table 3). Other parameters which suggest the speed of the forest turnover rate are also of comparable ranges. Very small values in tree recruitment in some forests are the result of the inhibition of tree regeneration by dwarf bamboos on the forest floor (Nakashizuka 1987).

Large-scale blowdowns are caused by a episodically big typhoons, but restricted to the CMF region (The Scientific Investigation Group of the Wind-damaged Forests in Hokkaido 1958; Forest Agency Japan 1959; Tamate et al. 1977; Watanabe *et al.* 1990). The coniferous trees in these forests fall easier than broadleaf trees by strong winds (The Scientific Investigation Group of the Wind-damaged Forests in Hokkaido 1958). The forest stands which have fewer coniferous trees tended to have less damage in the same typhoon (Forest Agency Japan 1959; Tokyo Regional Forest Office 1960). In the most extensive case, the area blown down each time was more than several square kilometers (Tamate

*Table 3.* Parameters on forest dynamics of old-growth forests in Japan

| Study site (forest type) | Gap formation rate (percent/year) | Tree density Recruitment (percent/year) | Mortality (percent/year) | Basal area Gain (percent/year) | Loss (percent/year) |
|---|---|---|---|---|---|
| Moriyoshi, Akita[1] (CDF) | *0.32–0.62** | | | *1.35** | *0.97** |
| Kayanodaira, Nagano[2] (CDF) | | 0.31 | 0.42 | 0.84 | 0.62 |
| Ohdaigahara, Nara[3] (CMF) | 0.31 | 0.10 | 0.74 | 0.61 | 0.68 |
| | *0.41–0.82** | | | | |
| Ogawa, Ibaraki[4] (WDF) | 0.42 | 1.19 | 1.20 | 1.12 | 0.88 |

* Estimation from forest structure.
[1] Nakashizuka (1984); [2] Watanabe (1993); [3] Nakashizuka (1991); [4] Nakashizuka et al. (1992).

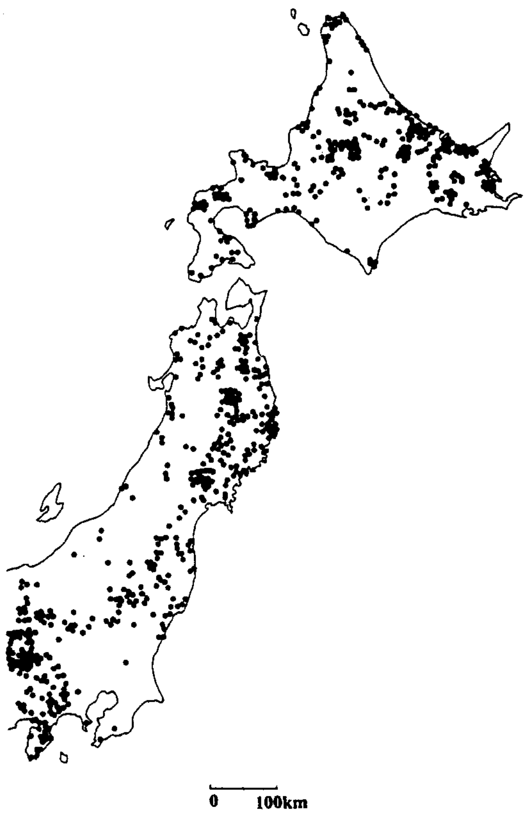


*Fig. 3.* Distribution of forest fires between 1945–1949 in eastern Japan (Inoue 1950). Each dot represents the burnt area greater than 10 ha.

et al. 1977), but the return interval of the disturbances are not known in detail.

Some small fragments of CMFs are distributed also in Honshu, Japan (Nozaki & Okutomi 1990), and also have big blowdown phenomena (Takahashi & Matsuoka 1963; Takahashi & Hibino 1971). In these cases, the damaged forests were located on steep slopes or on shallow soils (Takahashi & Hibino 1971). Many trees were uprooted (Takahashi & Matsuoka 1963) and the conifers regenerate well on uprooted mounds and on fallen boles (Nakashizuka 1989). The occurrence of coniferous species especially in CMF in Honshu may be associated with this type of disturbance.

The importance of fire disturbance has not been studied well in this region. The areas of CMF and WDF are very dry in winter to the beginning of spring (March to May), and many fires occur in this season (Inoue 1950). In Japan, the areas of fires burning over 10 ha area are concentrated in the area of CMF and WDF regions (Fig. 3, also see Fig. 4). The region of CDF has very wet winters and heavy snowfall because the monsoon winds from the continent pick up moisture over the Japan Sea and rises against the main range of Japan. In March or April, the forest floors of some CDFs are still under deep snow, and do not burn easily.

The CMF and WDF regions have suffered from fire probably the activities of ancient people for thousands of years. Pollen analyses in a WDF area indicate fire ash in most of the peat layers since about 3,000 BP, maintaining tree composition similar to an adjacent existing old growth forest (Ikeda, unpublished). The distribution of black soil, originating from former grassland vegetation and fire (Kawamuro & Torii 1986), coincides with the CMF and WDF regions (Society of Forest Environment 1972).

The regime of fire disturbance is not well understood. Hundreds of forest fires greater than 10 ha in area occurred within a period of only 5 years in eastern Japan (Inoue 1950), However, they were recorded just

*Table 4.* Summary of deciduous temperate forest types

| | Warm-temperate | Cool-temperate | |
|---|---|---|---|
| | Deciduous broadleaf forest | Deciduous broadleaf forest | Mixed broadleaf/ conifer forest |
| Dominants | *Quercus* | *Fagus* | *Quercus* Conifers |
| Species richness | High | Low | High |
| Disturbances | Treefall gaps Fire | Treefall gaps | Treefall gaps Fire Big blowdowns |

after the Second World War, and the frequency or disturbance scale estimated from this value seems to be over-estimated. Some remaining old-growth *Quercus* forests in CMF and WDF areas have trees greater than 1 m dbh, suggesting that catastrophic disturbaces were not frequent, sometimes of interval longer than 100 years.

The geographical distribution of disturbance regimes drawn from these studies available shows a certain trend (Fig. 4). The large-scale blowdowns have taken place only in the regions of CMF. In the CDF region, only treefall gaps, except for geomorphological disturbances, have been reported. The studies in WDF region are not many, but some of them indicate the effect of fire disturbance. The regions of CMF and WDF on the Eurasian Continent and the Korean Peninsula are also under dry climates, and have historically suffered from fires (Miyashita 1932; Ching 1991).

## Conclusions

The relationship between forest types and disturbance regimes in the three forest regions may be characterized in Table 4. These characteristics are somewhat analogous to those in the Northeastern Hardwood forests in North America (Runkle 1990). He showed that large-scale blowdowns occur only in forests with conifers, and *Quercus* spp. are suggested to be associated with fire disturbance. In the central part of the Northern Hardwoods, where *Fagus grandifolia* dominates, the major disturbance is treefall gaps. These associations between disturbance regimes and abundance of conifers, *Quercus* and *Fagus* are also found in Monsoon Asia.

One important difference between the deciduous forests in Monsoon Asia and North America is the dominance of the *Acer* spp. in canopy composition. In the deciduous forests of Monsoon Asia, *Acer* species do not dominate except for some forests in CMF regions, and most of them do not attain canopy height. On the contrast, in North America, *Acer succharum* is distributed almost whole the region of Northern Hardwoods with considerable abudance in canopy layer, and is able to regenerate without large-scale disturbance as well as *Fagus grandifolia* (Woods 1984). The cause of this difference is not clear and further studies are required to understand the analogies between the deciduous forests in two regions.

Species richness seems to be related to disturbance regimes. The existence of large scale disturbances are important for some species to maintain populations (Ishikawa & Ito 1989; Masaki *et al.* 1992). The WDF and CMF at present are usually protected from fire, and only the treefall gaps are the prevailing disturbance. In such forests some species, especially *Quercus* spp. would not be able to maintain populations (Masaki et al. 1992; Nakashizuka et al. 1992; Iida unpublished). The effect of disturbance on the richness of the total flora in a region is not clear, but the forest composition on a scale up to several tens of hectares may be affected greatly by disturbance regimes.

The three forest types, differ not only in floristic composition but also in dynamics and disturbance regimes, are recognized in the temperate deciduous forests in Monsoon Asia. However, the regimes of large scale disturbances and their effects, especially on the Eurasian Continent and the Korean Peninsula are not yet been well known. Further studies in these areas seems necessary to understand the total picture

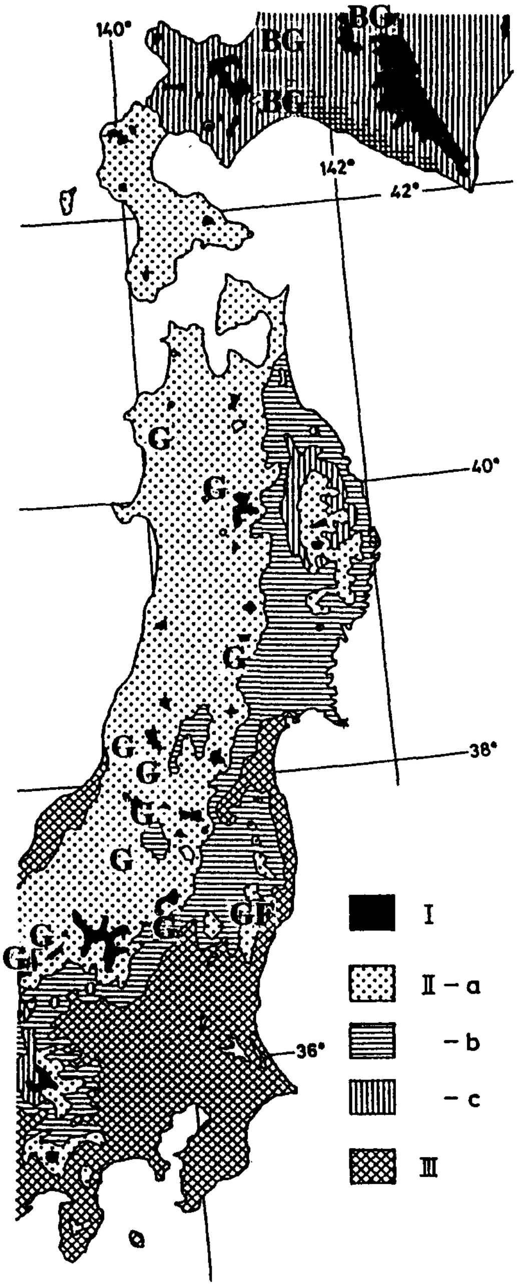


*Fig. 4.* Geographical distribution of the main disturbance in temperate deciduous forests in eastern Japan. The distribution of forest types from Nozaki & Okutomi (1990). Their classification is similar to that in this paper (in parentheses); I: Subarctic evergreen coniferous forest zone; II: Temperate summergreen broad-leaved forest zone, a: *Fagus crenata* forest (CDF), b: Intermediate-temperate forest (WDF), c: Upper-temperate forest (CMF); III: warm temperate lucidophyllous forest zone. Studies referred to : Watanabe et al. (1990), Ishikawa & Ito (1989) and Mishima et al. (1958) for CMF; Nakashizuka (1988), Nakashizuka & Numata (1982a, b), Hara (1983), Maruyama et al. (1989), Yamamoto (1989) and Honma & Kimura (1982) for CDF; Peters & Ohkubo (1990) and Nakashizuka et al. (1992) for WDF.

of the disturbance and forest structure in the temperate deciduous forests of Monsoon Asia.

These disturbance regimes may change in the event of global climatic changes. A change to drier climates would lead to more frequent fires, or a change in the pathways of typhoons may cause shifts in the regions of large-scale blowdowns. We should have a deeper understanding of the relationship between disturbance regimes and forest structure in this region to be able to predict any future effects of global changes.

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