Impacts of human-induced disturbances on forest dynamics and ecosystem functions in tropical forests across Thailand

人為攪乱がタイ熱帯林の森林動態と生態系機能に与える影響

生態システム生命科学専攻　植物生態分野

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Disturbances, both human-induced and natural, shape forest systems by influencing their composition, structure, and functional processes. Some human-induced disturbances have caused serious impacts on tropical forests in the world. Human-induced disturbances affect dynamics and function of forests in different way interacting with climate, composing tree species and micro-organisms. Disturbance varies among climatic condition, typically from dry to wet climate. The response of disturbance forests to decreased water availability from increased drought conditions is considered an issue in climate change scenarios, and concerns about vegetation impacts have been amplified. Forest ecosystems respond in a different way to disturbance and cause a difference in function. Human intervention has greatly decreased the area of naturally functioning ecosystems worldwide. The extent and pattern of this disturbance is a major determinant of the present distribution of species and ecosystems.

The first focus of my study was to determine the effect of human disturbance as fire on bamboo species regeneration, which eventually affects dynamics of tree species. In this study, I compared culm dynamics of the bamboo species, *Cephalostachyum pergracile*, in the early regeneration stage after its dieback for 3 years between a site protected from forest fires since 1995 and a site that burned almost annually in Mixed Deciduous Forest (MDF) at Sri Nakarin National Park, Thailand. Although the repeated fires distinctly decreased the number and basal area of culms per clump and the proportion of surviving culms throughout the study period, this bamboo species represents an adaptation to fire disturbance. A greater number of thin culms and many small branches produced by the fire-disturbed bamboos may have maximized photosynthesis with minimum allocation of photosynthate after they lose their aboveground parts. Further, the ratio of surviving clumps was higher at the unprotected site than at the protected site where self-thinning among clumps occurred. In addition, the RGR of middle-sized clumps was generally larger at the unprotected site than at the protected site, probably because the higher density of culms at the protected site causes strong competition for light among the culms. These results suggested that the repeated fires can delay the dominance of *C. pergracile* by slowing the development of large culms at their early stage of regeneration. A relatively low fire frequency or low intensity fire could allow bamboos to grow with thin culms after producing many branches. However, bamboos reconciled more trees to establish at the unprotected site. Therefore, bamboos would be replaced or suppressed by more fire-resistant trees if the intensity and frequency of fire exceeded the resistant capacity of bamboo against fire, and also might be replaced or suppressed by late successional tree species in a complete absence of fire disturbances. Thus, the timing, frequency, and intensity of fire disturbances determine the growth and establishment of bamboos and consequently determine the structure of the MDF community.

The second focus of my study was to the effect of human-induced disturbance such as agricultural land-use on functional composition of tree communities, which eventually affect forest ecosystem functions. The main question was how the functional composition to such disturbance differ depending on the different types of tropical forests along a drought gradient in Thailand. I used four types of forests; Dry Deciduous Forests (DDF), Dry Evergreen Forests (DEF), Mixed Deciduous Forests (MDF) and Moist Evergreen Forests (MEF). In each forest type, I compared the eight microenvironments and the community weighted mean (CWM) of nine functional traits of composed species between old-growth (O) and secondary (S) forests (about 30 years old) and investigated how the CMWs of functional traits were affected by the microenvironments and disturbance. The eight microenvironments included annual soil temperature, soil moisture, canopy openness, soil pH, NO^-_3, NH^+_4, available P and exchangeable K in soils. The nine functional traits included leaf mass per area (LMA), leaf area (LA), leaf nitrogen concentration (LNC), leaf total phenolics (Phenol), leaf condensed tannins (Tannin), leaf lignin (Lignin), leaf toughness (LT), leaf $^{13}C/^{12}C$ ratio (^{13}C) and wood density (WD). I found that all the microenvironment variables measured in this study had two components. The first component was negatively associated with canopy openness and annual soil temperature, and was positive with soil moisture, NO^-_3, NH^+_4 in soils, which could reflect the drought gradient. The second one was positively associated with soil pH, available P and exchangeable K in soils, which could reflect the negative relationship between soil acidity and macronutrients. The microenvironment variables were all affected by forest types, while the effect of disturbance was different depending on the microenvironments and on the types of forests. As to the functional composition, I found that the CWMs of functional traits of tree communities had three components. The first component was positively associated with LMA, LT, and WD, and was negatively associated with LA, which could reflect a trade-off in abundance between acquisitive (fast-growing, highly productive) species and conservative (slow-growing, less productive) species. The second one was positively associated with Tannin and Lignin, and negatively with ^{13}C, which could reflect the negative relationship in abundance between species with high leaf defense, slow litter decomposition, and low water use efficiency and species with the opposite feature. The third one was negatively associated with LNC and leaf phenol. Thus, species with high production or growth didn't necessarily have less defensive leaves, high decomposability litter, and high water use efficiency. The CWMs of all the functional traits except for LT and LNC were affected by forest types. On the other hand, the disturbance only affected the CWMs of WD, Tannin, and LNC. The disturbance always increased the abundance of species with higher leaf nitrogen and higher leaf tannin in secondary forests, while the response of the CWM of WD differed depending on the forest types. Further, the first component of the CWMs of functional traits was only negatively related to the first component of microenvironments; conservative species (with higher LMA, LT, and WD) tended to increase in forests with a closed canopy, higher soil moisture and mineral nitrogen irrespective of disturbance. Species with higher Tannin and Lignin and lower water use efficiency tended to increase in tree communities with acidic and less macronutrients soil for both old-growth and secondary forests, and in the secondary forest when these soil variables were same. Species with higher nitrogen and phenol in leaves tended to increase in tree communities with an open canopy, higher soil temperature and lower soil moisture, NO^-_3 and NH^+_4 in soils for both old-growth and secondary forests, and in secondary forests when the measured microenvironment variables were same. This study suggested that the response of the species to disturbance seems to have complex interactions along with climate gradient from dry to humid.

Thirdly, I focused on the effect of the human-induced disturbance on leaf litter dynamics that is an important pathway of nutrient cycling in the forest ecosystem. I compared the litter dynamics (litter production, litter accumulation and decay efficiency (litter accumulation/litter production)) between old-growth (O) and young secondary (S) forests, and investigate how the microenvironments and functional composition, which was measured in Chapter 3, affect the litter dynamics for DDF, DEF, MDF, and MEF. I found that the litter dynamics were all affected by forest types, and the effect of disturbance differed depending on forest types. The leaf litter production was increased in secondary forests only in DEF, while that was rather higher in old-growth forest for the other three types of forests. The leaf litter production in secondary forest reflects above-ground net primary production during tropical forest succession, which would become stable in each community. Therefore, the secondary forests of DDF, MDF, and MEF in our study might be already stable in terms of net primary productivity. The response of leaf litter accumulation to disturbance also differed depending on forest types. The accumulation was slightly higher and lower in secondary forests for DEF and MEF, respectively. Consequently, the response of decay efficiency to disturbance differed depending on the forest types. The decay efficiency in DEF was higher in secondary forest than in old-growth forest, while the trend was opposite for the other forest types, even in secondary of DEF where the soil was drier than in old-growth forest. However, the decay efficiency was strongly affected by leaf functional traits as tannin, phenol lignin, ^{13}C and LNC. When environmental factors did not influence decomposition. Though the effects of some of environmental factors on decomposition were studied, the complexity of decomposition process makes any possible explanation difficult.

Fourth, I focused on how the factors, environments and species' functional traits those of which are changed due to disturbance, affect leaf litter decomposition that is one of the most important processes for controlling carbon cycle and nutrient availability in forest ecosystems. I conducted the litter-bag experimental using 15 species in each forest type to estimate leaf litter decomposition rate. The study plots were set in old-growth and secondary forest in DDF, DEF, MDF and MEF forest. Two microenvironments as annual soil temperature, soil moisture, and seven leaf trait which related to decomposition (LMA, LA, LNC, LT, Phenol, Tannin, and Lignin) were to analysis. The result showed that the decomposition without termite effect was largely affected by a drought condition with a higher rate in moist forests than in dry forests. However, the changes in microenvironments due to disturbance did not necessarily affect the decomposition without termite effect. The *decomposition* with termite effects in DDF and MDF was comparable to or even higher than that in MEF. My study confirms that the process of litter mass loss with termite and without termite is different. The litter mass loss without termite is caused by decomposition by microorganisms such as bacteria and fungi, while the litter mass loss with termite is caused by a removal of litter by mesofauna in addition to the decomposition by bacteria or fungi. The influence factor to decomposition without termite effect in each forest type were investigated by predicted model, I found that the factors selected in the predicting model were different depending on the forest types. The microenvironment factors as annual soil temperature and soil moisture were not affected to decomposition to wet forest (MDF and MEF) but it was influenced to dry forest (DDF and DEF). However, the decomposition is the result of complicated interaction between microenvironment, litter quality, and soil fauna, it hence to include the other factor and soil fauna to observe in the future.

In my study, I revealed the impact of human-induced disturbances on ecosystem dynamics and function and the factors affecting it among the different forest types along the drought gradient in Thailand. Climate, disturbance, and functional traits are interacting each other to determine the dynamics and function (particularly for decomposition) of forest ecosystems. Climate and disturbances affect species composition of the forest, and thus their functional traits. In turn, functional traits of trees and under-growing bamboo affect the dynamic feature of the forest, and then function like decomposition. Environment, disturbance, and functional traits are affecting together on the composition of decomposers, and the difference of decomposers, in turn, affect decomposition rate. The interactions vary among forest types and complicated.