Thai J. For. 18 : 9–29 (1999) วารสารวนศาสตร์ 18 : 9-29 (2542)

การเปลี่ยนแปลงด้านความหลากหลายทางชีวภาพของเห็ดราไมคอร์ไรซ่าและเห็ดราที่ทำให้ไม้ผุในพื้นที่ป่าต้นน้ำภาคตะวันตกของประเทศไทย

BIODIVERSITY DYNAMICS OF ECTOMYCORRHIZAL AND WOOD-ROTTING FUNGI IN FORESTED WATERSHED AREAS OF WESTERN THAILAND

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บทคัดย่อ

การวิจัยเรื่องนี้ได้มุ่งเน้นการศึกษาการเปลี่ยนแปลงความหลากหลายทางชีวภาพของเห็ดราไมคอร์ไรซ่าและเห็ดราที่ทำให้ไม้ผุในป่าเขตร้อน ท้องที่สถานีวิจัยต้นน้ำแม่กลอง อำเภอทองผาภูมิ จังหวัดกาญจนบุรี ภาคตะวันตกของประเทศไทย การวิจัยได้ดำเนินการระหว่างปี พ.ศ. 2536-2540 รวม 5 ปี โดยได้ทำการวิจัยในป่าธรรมชาติ (แปลงที่ 1 – ป่าเต็งรัง ป่าดิบแล้ง และป่าผสมผลัดใบ) ในป่าที่ผ่านการทำไม้มาก่อน (แปลงที่ 2 – ป่าผสมผลัดใบ ป่าทุ่งหญ้า (แปลงที่ 3) สวนป่าไม้สักปลูกใหม่ (แปลงที่ 4) และสวนป่าไม้สักเก่า (แปลงที่ 5) ผลการวิจัยพบว่า การเกิดความเปลี่ยนแปลงด้านชีวภาพของเห็ดราไมคอร์ไรซ่าและเห็ดราที่ทำให้ไม้ผุมีความสัมพันธ์อย่างใกล้ชิดกับประเภทและคุณภาพของระบบนิเวศป่าไม้ ความหลากหลายของพืชอาศัย ความสัมพันธ์ระหว่างเห็ดราและพืชอาศัย ความเฉพาะเจาะจง ความรุนแรงในการทำลายป่า และคุณภาพของระบบนิเวศป่าไม้แต่ละประเภทที่ถูกผลกระทบ จากผลการวิจัยปรากฏว่าได้พบเห็ดราไมคอร์ไรซ่าเพียงประมาณ 50 ชนิดเท่านั้นที่เกิดและพบในป่าธรรมชาติ และป่าที่ผ่านการทำไม้มาก่อน ชนิดเห็ดราที่พบบ่อยได้แก่ *Russula sanguinea, R. brevipes, Amanita caesarea, A. coccora, A. calyptrata, R. brunneoviolacea, R. virescens, Astraeus hygrometricus, Lactarius deliciosus, Cantharellus cibarius, Boletellus emodensis, Coltricia cinnamomea, C. perennis, Pisolithus tinctorius, Scleroderma areolatum* และอื่นๆ ส่วนเห็ดราที่ทำให้ไม้ผุได้พบประมาณ 125 ชนิด ส่วนใหญ่จะพบในบริเวณป่าธรรมชาติและป่าที่ผ่านการทำไม้มาก่อนแล้ว และส่วนมากเป็นเห็ดราในกลุ่ม Basidiomycota และ Ascomycota. ส่วนชนิดในกลุ่ม Basidiomycota ที่พบบ่อยได้แก่ *Microporus xanthopus, Phellinus rimosus, P. gilvus, P. senex, Polyporus grammocephalus, Ganoderma australe, G. lucidum, Hexagonia tenuis, Pycnoporus sanguineus, Stereum ostrea, Trametes flavidum, Earliella scabrosa, Dictyophora indusiata*, และอื่นๆ ส่วนเห็ดราในกลุ่ม. Ascomycota ที่สำคัญได้แก่ *Cookeina tricholoma, C. sulcipes,*

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Daldinia concentrica, Xylaria longipes var *tropica X. carpophila* และ *X. juruensis* จำนวนที่เพิ่มขึ้นของไมคอร์ไรซ่า และปริมาณเห็ดราที่ทำให้ไม้ผุจะเป็นดัชนีที่ช่วยบ่งชี้ถึงความสามารถในการหมุนเวียนธาตุอาหารต่างๆ ให้มีประสิทธิภาพดีขึ้นได้แก่ ฟอสฟอรัส (P) คาร์บอน (C) ไนโตรเจน (N) และแร่ธาตุอื่นๆ ในระบบนิเวศวิทยาป่าไม้

ศัพท์หลัก : เห็ดราไมคอร์ไรซ่า เห็ดราที่ทำให้ไม้ผุ ป่าเขตร้อน และประเทศไทย

Abstract

This study was carried out to investigate the biodiversity dynamics of ectomycorrhizal (ECM) and wood – rotting fungi (WRF) in tropical forest at Mae Klong Watershed Research Station, Thong Phaphoom District, Kanchanaburi Province, Western Thailand during 1993 – 1997 (5 years period). Studies were made in natural forest (Plot 1 : dry-deciduous dipterocarp forest, dry-or semi-evergreen forest and mixed deciduous forest); secondary forest (Plot 2 : logged-over mixed deciduous forest); grassland (Plot 3); young teak plantation (Plot 4); and old teak plantation (Plot 5). Results showed that the occurrence and biodiversity dynamics of ectomycorrhizal and wood-rotting fungi were strictly correlated with types and quality of forest ecosystems, diversely host plants, host – fungus compatibility and specification, degree of disturbance and degradation of forest ecosystems. About 50 species of ectomycorrhizal fungi were examined and found only in natural and secondary forests. The frequent species were *Russula sanguinea, R. brevipes, Amanita caesarea, A. coccora, A. calyptrata, R. brunneoviolacea, R. virescens, Astraeus hygrometricus, Lactarius deliciosus, Cantharellus cibarius, Boletellus emodensis, Coltricia cinnamomea, C. perennis, Pisolithus tinctorius, Scleroderma areolatum*, etc. Approximately 125 species of wood-rotting fungi were identified and mostly found in natural and secondary forest ecosystems. Most of them belonged to the phyla Basidiomycota and Ascomycota. The prominent species of Basidiomycota were *Microporus xanthopus, Phellinus rimosus, P. gilvus, P. senex, Polyporus grammocephalus, Ganoderma australe, G. lucidum, Hexagonia tenuis, Pycnoporus sanguineus, Stereum ostrea, Trametes flavidum, Earliella scabrosa, Dictyophora indusiata*, etc. The predominant species of Ascomycota were *Cookeina tricholoma, C. sulcipes, Daldinia concentrica, Xylaria longipes* var *tropica X. carpophila* and *X. juruensis*. The higher biodiversity of ectomycorrhizal and wood-rotting fungi respectively indicates the ability of phosphorus (P), carbon (C), nitrogen (N) and other nutrient cyclings in forest ecosystems.

Key Words : Ectomycorrhizal fungi, wood-rotting fungi, tropical forest, Thailand.

Introduction

The build-up of greenhouse gases especially carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the TROPOSPHERE, in which the atmospheric region we live-from ground level up to about 15 km from the Earth's surface, coupled with the pronounced depletion by chlorofluorocarbons (CFCs) of ozone (O_3) in the STRATOSPHERE (19-48 km above the Earth's surface), in which the ozone (O_3) layer observed in the Antarctica in recent years, has heightened public awareness on global warming and climate changes. Although O_3 and CO_2 have received a great deal of attention, but there are a number of trace gases, including methane, nitrous oxide, nitric oxide, carbon monoxide, carbon-sulfur gases, and halocarbons, that also have an important impact in global climate. The impact of these trace gases may equal that of carbon dioxide (Rogers and Whitman 1991).

Global warming is being treated the way it is now, the polar ice caps would gradually melt, resulting in climate changes, more hurricanes and tropical storms and mass flooding on Earth. Climate change is a complex and pressing environmental global challenge, Scientific studies indicate that climate change could have serious impacts on our environment, economy, society and our way of life.

Scientific evidence is gathering that human activities may be accelerating climate changes. Level of greenhouse gases such as CO_2, CH_4, N_2O and CFCs have increased significantly since the industrial age. Each year, the world releases 5-5.5 billion tonnes of CO_2 by burning fossil fuels. Another important source of climate change is deforestation. Our terrestrial forests and wetlands actually absorb and store greenhouse gases as sink and naturally regulate the atmosphere in appropriate patterns. Each year the world releases 1-1.5 billion tonnes of CO_2 through deforestation.

Thailand is geographically situated in the tropical region of equatorial zone among Southeast Asian countries. Therefore Thailand is a domain of fertile center of global biodiversity of plant, animals, mankinds, ecosystem and microorganisms. A century ago, Thailand was covered by 80 % of forests. By way of over-exploitation, the forests of Thailand today are remained merely 25% of the whole country (Royal Forest Dept. 1997), This evidence may be led to change a population number and biodiversity dynamics in various forest ecosystems of the country.

Biodiversity is the variety and variability of all life (plants, animals, mankinds, microorganisms) on earth and includes genetic, species and ecosystem diversity (Groombridge 1992, Wilson 1988). Forests are widely recognized as the major reservior of world terrestrial biodiversity and forest ecosystems represent a crucial component of biodiversity. Most of the world people are directly and indirectly depended on the components of forest biodiversity for their daily livelihoods and sustenance. Forest biodiversity also play a key role in providing life- supporting ecological services, along with a wide range of other benefits and values to human societies; economic, environmental, social, cultural, aesthetic, scientific, spiritual, educational and recreational.

Unprecedented and accelerating rates of deforestation, along with forest degradation and fragmentation, lead to major threat to forest biodiversity, Today we have reached an important crossroads in addressing this threat for ultimate success or failure on biodiversity loss by decision made in the millennium year 2000.

Biodiversity of fungi is a major component of forest ecosystems, they play very important roles and activities in decomposition processes on plant litters and animal residues and play very important part in nutrient cycling in the forest ecosystems. They are also rendering and providing food reserves and growth elements to plants, animals, microorganisms and even mankinds. They also provide pharmaceutical products for human well-beings, and sustain the stability and conservation of forest ecosystems.

Global biodiversity of living organisms is estimated about 5-30 million species on Earth, but only fungi are possibly accounted 1.5 million. Today about 69,000-70,000 species including 5,100 genera of world fungi have been named and described (Hawksworth and Mound 1991). Approximately 3% of global described numbers or about 3,000 fungi have been reported in Thailand so far (Chalermpongse 1997).

Very few researches have been attempted to investigate the biodiversity of fungi in Thailand. Unlike green plants, fungi lack chlorophyll and must live on organic matters. Many fungi break down and decompose various kinds of dead plants and animals, while others attack living organisms. Still others form a unique association with the roots of higher forest plants and are known as formers of mycorrhizas. Fungi thus play three basic roles and activities in forest ecosystems : as saprophytes, parasites and mycorrhizal associates. Wood-rotting fungi are grouped into saprophytes and parasites. Therefore global changes and changes of forests actually impact the role of fungal biodiversity including population dynamics, composition, structure, function, and stability of forest ecosystems.

The purpose of this research is to identify and wherever possible quantify, the ways in which biodiversity regulates ecosystem function ; to understand and predict how particular ecosystem processes will change and why, in response to loss of biodiversity especially the roles of ectomycorrhizal and wood-rotting fingi in natural forests and disturbed watershed areas of Western Thailand.

Materials and Methods

A. Study Site

(1) Location

The study site called Mae-Klong Watershed Research Station (MWRS) has an approximate area about 109 km^2. It is situated in Thong Phaphoom District, Kanchanaburi, Province, Western Thailand. It is located at latitude 14° 30' and 14° 45' N and longtitude 98° 45' to 99° E. It stands about 130 km from Kanchanaburi Province and 250 km from Bangkok.

The MWRS consists of several small watersheds : namely Linthin, Nikuhu, Tatha, Ta-ue, Thai-yae and Yapira. The site elevation ranges from 100-950 m (msl). The entire basin has about 109 km^2.

The experimental study plots have been designed and located at the Southwestern aspect with elevation ranging from 100-950 m (msl). The average slope is about 30% ranging from 10-60% (Suksawang 1995).

(2) Geology and Soils

Geologically speaking, the watershed area of MWRS is underlain by the parent material of the Ratchaburi and Kanchanaburi soil series. The Ratchaburi series is based on middle area of the entire watershed, which composed of granite, limestone, sandstone and shale. Based on the rock samples collected from this watershed, the geological age falls into the Permian and Carboniferous periods. The Kanchanaburi series is based on the left side of the entire watershed, the geological age falls into the Devonian period and conposed of shale and sandstone, Some areas are metamorphosed to phyllite and quartzite.

Surface soils collected from the study area are sandy loam to sandy clay loam, high in organic matter, phosphorus, potassium, calcium nd magnesium and pH about 6.2-6.8.

(3) Climate

As in other parts of Thailand, The site receives two major air streams namely the Northeast and the Southwest monsoons. The former blows from November/December to March while the latter from May to September / October. Transition periods between the two monsoons usually occur in April and also in October / early November.

The climate is usually affected by monsoons. The mean temperature is about 27.5 °C with the maximum 39° C in April and the minimum 14° C in December. Annual precipitation normally exceeds 1,650 mm and monthly mean relative humidlity (RH) is 68%.

(4) Vegetation

The plant vegetations of the study site can be classified into 4 ecosystems as follows :

4.1 Mixed Deciduous Forest with Bamboo

This forest ecosystem is scattered all over the study site and formed about 97% of the watershed area. The dominant tree species are *Xylia xylocarpa* var. *kerrii*, *Schleichera* *oleosa*, *Pterocambium cuspidata*, *Dillenia ovata*, and *Cratoxylum formosum*. The lower storey is composed of bamboos ; such as *Cephalostachyum pergracile*, *Bambusa arundinacea*, *Gigantochloa albociliata*, etc.

4.2 Dry Dipterocarp Forest

This forest ecosystem is mainly found on the terrace formation at the ridge top of watershed area. The dominant tree species are *Dipterocarpus* spp., *Shorea siamensis*, *Careya arborea*, *Dalbergia spp.*, etc.

4.3 Dry or Semi-Evergreen Forest and Scallery Forest

This forest ecosystem occurs and scatters in the areas along the creeks. It is composed of trees such as *Hopea odorata*, *Walsura trichostemon*, *Sterculia spp.*, *Duabanga grandiflora*, *Wrightia spp.*, etc.

4.4 Disturbed Forest

This type of forest ecosystem is originated from illegal felling with subsequent burning and agricultural cultivation. This forest type is found on the gentle slope areas and composed of grassland, wild bananas, bamboos, climbers, and some small trees.

(5) Wildlife

An environmental impact assessment survey in the area of MWRS was carried out by EGAT team of consulting engineers in 1979. It was reported that 155 animal species (mammals 35, birds 60, reptiles 10, amphibians 4) occurred within and around the watershed station. However, the Royal Forest Department surveyed in the same area in 1984 and found a total of 154 species (mammals 39, birds 100, reptiles 11, amphibians 4).

From the surveyed results, Benteng (*Bos banteng*), Elephant(*Elephas maximus*), Barking deer, Sambar deer, Tiger (*Panthera tigris*), Leopard (*P. pardus*), Serow (*Capricornis sumatraensis*), Hornbill, Chivets, and Asiatic wild dog were also found.

B. Experimental Design

Five experimental plots were designed and surveyed at Mae Klong Watershed Research Station (MWRS) as shown in figure 1. Details of experimental plots were as the followings ;

Plot 1. Natural Forest

It included mixed-deciduous forest, dry-semi-evergreen forest, and dry-dipterocarp forest. The plot size was 200 x 200 m^2 (4 ha). The 4 ha area was divided into 100 of 20 x 20 m^2 sub-quadrats. A steel post was set on every corner of 20 x 20 m^2 grid.

Plot 2. Secondary Forest

It included logged-over forest area of mixed deciduous forest with bamboos and dry or semi-evergreen forest. The size of this plot was 200 x 200 m^2 (4 ha) and divided into 100 of 20 x 20 m^2 sub-quadrats as of Plot 1.

Plot 3. Grassland or Deforestation Area

It included grassland and deforested area. The pot size was 100 x 400 m^2. This area was deforested over 20 years ago and it was ensured by aerial photographs. Reforestation was tried in this open area about 10 years ago but success had failed.

Plot 4. Young Teak Plantation

It included young teak plantation which planted in 1992. The plot size was 30 x 40 m^2. Teak age was about 7-8 years.

Plot 5. Old Teak Plantation

It included old teak plantation which planted about 20 years ago. The plot size was 30 x 60 m^2.

Methods

(1) Field Expedition

Surveys were carried out on biodiversity dynamics and the occurrence of ectomy-corrhizal (ECM) and wood-rotting fungi (WRF) during fiscal year 1993-1997 (5 yrs period). Fruiting bodies of macro-fungi were collected and kept in paper and polythene ags. Collected specimens were

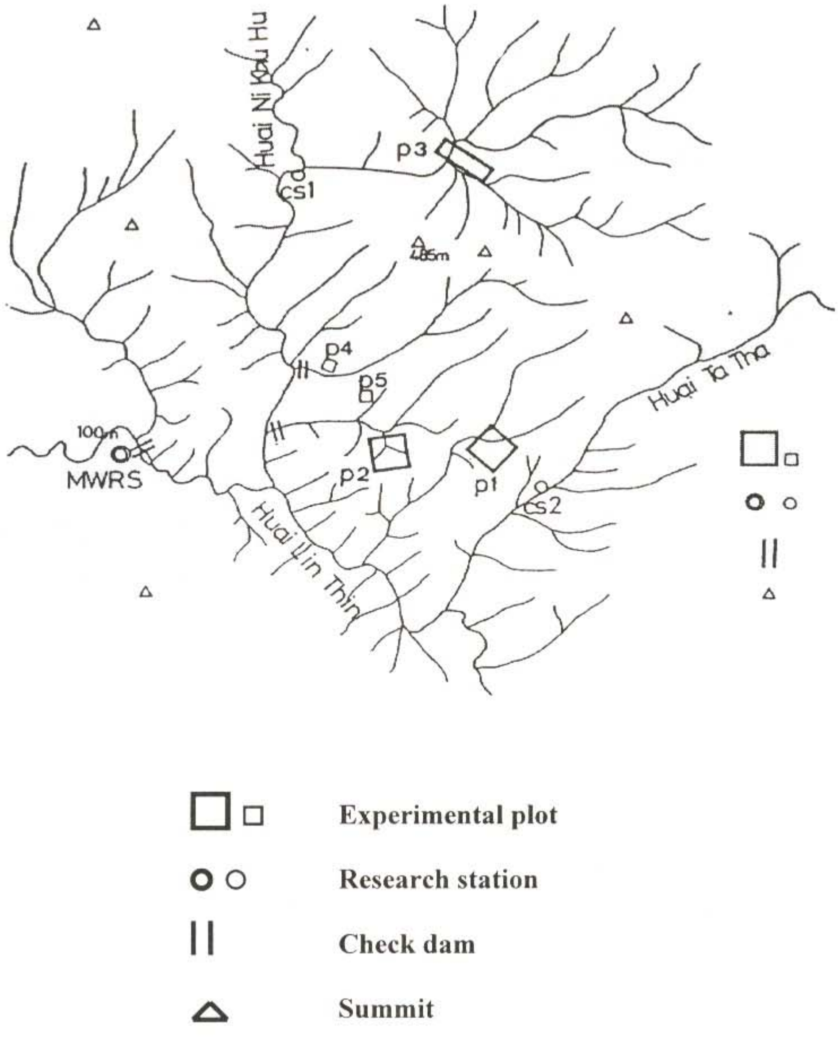

Figure 1. Study location of Mae-Klong Watershed Research Station, Thong Phaphoom District, Kanchanaburi Province.

labelled and dried at room temperature (30° C) for 12-46 hrs before oven-drying at 40-60°C depending on sizes of fruiting bodies until moisture content of fungal basidiocarps remained about 12-16 %. Isolations and identifications of collected fungi were also conducted both in the fields and laboratory. Field expeditions were investigated in Plot 1 (natural forest), Plot 2 (secondary forest or logged-over area), Plot 3 (grassland or disturbed area), Plot 4 (young-teak plantation), and Plot 5 (old-teak plantation).

(2) Isolation

Freshly collected specimens were isolated and cultured in Potato Dextrose Agar (PDA) and Modified Melin Norkran Agar (MMNA) *vice versa* containing in test tubes for gene bank, genetic resources, further studies and economic uses, Three to five isolates per species were made for pure cultures and preservation.

(3) Symbiotic Relationships of Mycorrhizas

Mycorrhizas are symbiotic relationships between soil fungi and plant roots ; the term means literally "fungus root". Mycorrhizas are divided into two types : 1) ENDO-MYCORRHIZAS, also called VESICULAR-ARBUSCULAR MYCORRHIZAS(VAM) are actually associated with inside roots of mostly higher plants and fungi in Phylum ZYGOMYCOTA which currently belonged to six genera : *Acaulospora, Entrophospora, Gigaspora, Glomus, Sclerocystis* and *Scutellospora* including more than 160 species worldwide. They also seem to be obligate symbionts and none of them can be grown in axenic culture in the absence of their hosts ; and 2) ECTOMYCORRHIZAS (ECM), sometimes term ECTOTROPHIC MYCORRHIZAS, are usually associated with temperate and tropical forest plants of the world. They generally associate with external roots of woody vascular plants and fungi in the Phyla BASIDIOMYCOTA, ASCOMYCOTA, and DEUTEROMYCOTA (Fungi Imperfecti). There are about 3,000-5,000 species of ectomycorrhizal fungi associated with over 2,000 species of woody plants worldwide (Miller 1982).

Detection of symbiotic relationships between ectomycorrhizal fungi and plant lateral or short roots was conducted at MWRS in various experimental plots. Common tree or plant roots were dug out and collected at about 10-20 cm depth from the surface soils. Roots were washed out by clean water, fixed and kept in vials containing 3% glutaraldehyde. Modified Phillips and Hayman (1970) method was employed for rapid clearing and staining roots and assessed for mycorrhizal associations. Stereo-and compound microscopes were used for examination of symbiotic relationships of mycorrhizas.

(4) Identification

Collected specimens of ectomycorrhizal and wood-rotting fungi were identified up to genera and species both in the fields and laboratory by using taxonamic keys published by Ainsworth *et.al.* 1973, Arora 1986, Coker and Couch 1969, Chalermpongse 1987, 1992, Chalermpongse and Ramanwong 1997, Hanlin 1990, Moser 1983, Ryvarden and Johansen 1980, Miller 1979, Hawksworth *et.al.* 1995, Imazeki and Hongo 1987, 1989, Imazeki *et.al.*1988, Hongo 1994, Ji-Ding and Xiao-Qing 1992, Gilbertson and Ryvarden 1986, 1987, Pegler 1977, 1983, 1986, Phillips 1981, Teng 1996, Zhishu *et.al.* 1993 and many others. Morphological characteristics of macro- and microstructures of fruiting bodies of collected fungi were examined and recorded for necessarily taxonomic works such as spore print, size, color, shape, smell, taste, lactation, pileus, lamellae, tubes, stalk, annulus, volva, universal and partial veils, trama, hymenium layer, basidia, cystidia, setae, size and spore shapes, ornamentation, and other necessary characteristics.

(5) Preservation of Specimens

The collected specimens were actually air-dried at room temperature ($30^{\circ} \pm 2^{\circ}$ C) or oven-dried at about 40^{o}-60^{o} C for 6-48 hrs depending on size of fruiting bodies. Specimens should remain about 12-16% moisture content. Some agarics were preserved in 90% ethanol for preventing decay. The isolates of genetic resources of gained fungi were actually preserved and kept according to the international methods (Kisop and Snell 1984, Smith and Onions 1994) for the purposes of gene bank, further studies and utilizations. The studied specimens were entirely labelled and kept in the Herbarium of the Royal Forest Department, Bangkok, Thailand.

Results and Discussion

1. Biodiversity and Dynamics of Ectomycorrhizas

The relationships of symbiotic mycorrhizas with forest plants in various forest types and experimental plots were illustrated in Table 1. The results found that forest plants were mostly associated with vesicular-arbuscular mycorrhizas (VAM) or endomycorrhizas, but the lesser extents were closely related with ectomycorrhizas (ECM). These ectomycorrhizas were commonly occurred in natural forest (Plot 1) and secondary forest (Plot 2) by moderate to high frequencies. Very rare incidence was found in grassland (Plot 3). No evidences were found on the occurrence of ectomycorrhizal relationships in young teak plantation (Plot 4) and old teak plantation (Plot 5) except only associations of versicular – arbuscular mycorrhizas.

It was obvious from this study that ectomycorrhizal associations with tree plants were strictly correlated with host specifications, species richness and biodiversity of forest plants, quality of forest ecosystems, types of forests, degradution of forests, biodiversity of ectomycorrhizal fungi, climate changes, edaphic and geological characteristics and other abiotic factors such as soil pH, soil moisture, soil nutrients, etc. The more diverse plants would affect the more stable in ecosystems of ectomycorrhizas.

As indicated in Table 1, ectomycorrhizas were obviously shown to association with forest plants in the families Dipterocarpaceae *(Dipterocarpus alatus, D. turbinatus, Shorea obtusa* and *S. siamensis)*, Fagaceae *(Castanopsis argyrophylla, Lithocarpus polystachyum,* and *Quercus kerrii)*, and Myrtaceae *(Engenia megacarpa, E. cumini)*, but the families Papilionaceae *(Dalbergia dongnaiensis, D. oliveri, Erythrina subumbrans, Millettia brandisiana, M. nigrescens, M. leucantha, Pterocarpus macrocarpus)*, Mimosaceae *(Xylia kerrii, Albizia chinensis, Acacia farnesiana, A. leucophloea, A. megaladena, A. catechu)*, Rubiaceae *(Hymenodyctyon excelsa, Randia dasycarpa)*, Euphorbiaceae *(Croton oblongifolius, Sapium baccatum, Phyllanthus emblica)*, Anacardiaceae *(Spondias pinnata, Mangifera caloneura, Lannia grandis)*, Lauraceae *(Litsea grandis)*, Moraceae *(Artocarpus rigidus, Ficus hispida)*, Bignoniaceae *(Markhamia stipulata)*, Stilaginaceae *(Antidesma bunius*, Magnoliaceae *(Michelia champaca)* and Sapindaceae *(Schleichera oleosa)* were firstly associated with vesicular – arbuscular mycorrhizas and nitrogen – fixing microorganisms (bacteria and actinomycetes), and in the secondary stage of growth, ectomycorrhizal fungi had then colonized on their feeder roots afterwards. Evidences were also indicated the same trends with forest plants which studied in Sakaerat Environmental Research Station, Pak Thongchai District, Nakon Ratchasima Province, Northeastern Thailand as reported by Chalermpongse (1987, 1992, 1993) and Jülich (1988) in Indonesia.

2. Species Richness of Ectomycorrhizal Fungi

Species richness and biodiversity of ectomycorrhizal fungi (ECM), studied at Mae-Klong Watershed Research Station were shown in Table 2. It was evident that fifty species of ectomycorrhizal fungi were examined. Of which 31 species actually occurred in natural forest (Plot 1) and 38 species were found in secondary forest (Plot 2). No evidence of ectomycorrhizal fungi was found in grassland (Plot 3), young teak plantation (Plot 4) and old teak plantations (Plot 5) respectively. These changes and dynamics of biodiversity of ectomycorrhizal fungi might be dealed with many factors such as deforestation of ecosystems, biodiversity loss of host plants, climate changes, loss of soil microorganisms, changes of edaphic condition and other abiotic factors.

As depicted in Table 2, results showed that most of detected EMC fungi belonged to Phylum Basidiomycota in the families : Amanitaceae (8), Astraeaceae (1), Boletaceae (5), Cantharellaceae (1), Clavaria (1), Clavulinaceae (2), Entolomataceae (3), Geastraceae (1), Hymenochaetaceae (2), Lycoperdaceae (2), Melanogastraceae (1), Russulaceae (13), Sclerodermataceae (3), Strobilomycetaceae (1), Tricholomataceae (2) and Xerocomaceae (4). The most abundant and richest species were respectively classified into the families Russulaceae, Amanitaceae, and Boletaceae. The prominent species were *Russula Sanguinea, R. brevipes, Amanita caesarea, A. coccora, A. calyptrata, R. brunneoviolaceae, R.virescens, Astraeus hygrometricus, Lactarius deliciosus, Cantharellus cibarius, Boletellus emodensis, Coltricia cinnamomea, C. perennis, Pisolithus tinctorius, Scleroderma areolatum,* etc. Mostly richness species of ECM fungi found in this study were likely indicated as well as reported by Chalermpongse (1987, 1992) in Northeastern Thailand.

3. Occurrence of Wood-Rotting Fungi

Species diversity of wood-rotting fungi expedited at Mae-Klong Watershed Research Station was demonstrated in Table 3. Totally about 20 species were found in the overall study sites. Approximately 11 species were tabulated in the Phylum ASCOMYCOTA. Out of which 114 species were grouped into Phylum BASIDIOMYCOTA. Most of species detected in the Phylum ASCOMYCOTA were belonged to the families Sarcoschyphaceae (7), Dermateaceae (1) and Xylariaceae (3) collected from dead wood, twigs, branches and dead logs. The common species were *Cookeina sulcipes, C. tricholoma, Daldinea concentrica, Xylaria carpophila, X. juruensis* and *X. longipes* var. *tropica.*

As illustrated is Table 3, detected wood-rooting fungi mostly found in all study plots. With high frequencies were examined in natural forest (Plot 1) and secondary forest (Plot 2). Moderately to rarely wood-rotting fungi were also found in grassland (Plot 3), but they were always collected from remaining dead logs, wood, branches, stumps and wood debrises. Very few to none was detected in young teak plantation (Plot 4) and old teak plantation (Plot 5). This was why in timely disturbed or deforested areas employed for reforestation programs oftenly lacked of organic matters and nutrient deficiencies.

In phylum BASIDIOMYCOTA, most species of wood-rotting fungi belonged to families Coriolaceae (24), Ganodermataceae (7) and Hymenochaetaceae (7) and others, respectively. The frequent species were *Microporus xanthopus, Ganoderma australe, G. lucidum, Phellinus rimosus, P. gilvus, P. senex, Polyporus grammocephalus, Hexagonia tenuis, Pycnoporus sanguineus, Stereum ostrea, Trametes flavidum, Earliella scabrosa, Dictyophora indusiata,Lentinus polychrous, L. sajor-caju* and *Lenzites acuta.* Most species found in this study seemed to be similar with those detected in upper Khao Soi Dao Wildlife Sanctuary, Prachinburi, Eastern Thailand as reported by Klingesorn *et. al.* (1998) and at Mae-Nam Pachi Wildlife Sanctuary, Ratchaburi, Western Thailand as carried out by Chalermpongse *et.al.* (1997).

4. Decomposition and Nutrient Cyclings

Fungi decompose wood in order to gain food materials for their metabolism, growth and reproduction. Wood-rotting fungi act as SAPROPHYTES and PARASITES. Saprophytes decompose dead organic matter including leaves, branches, twigs, grasses, roots, stumps, wood, barks, logs, fruits, flowers, dung or even dead fungi. Parasites invade or sometimes kill living plants and animals. *Ganaderma lucidum* will attack and kill the butts and roots of wide range of tees, but it is also able to survive quite well as a saprophyte. Some of woody polypores are parasitic on trees. A number of fungi are weak parasites and are able to attack and kill only a host previously weakened by other factors.

There are two main types of wood-rooting fungi : white rots and brown rots. White rots are usually caused by Basidiomycetes, Ascomycetes and Mitosporic Fungi. Hardwoods are more susceptible than softwoods. The wood becomes whitish after decay because white rots can decompose both cellulose and lignin in wood at the same rate. As cellulose is more higher content than lignin in wood, therefore the wood remains whitish as cellulosic materials after decay. Brown rots are mostly caused by Basidiomycetes. Only cellulose is utilized and decayed. The wood becomes brownish and crumbles when handled.

All wood is mainly composed of cellulose (40 – 50%) hemicellulose (20 – 35%), lignin (23 – 35%), extractives (10%) and ash (0.2 – 1.0%). Over 90% of dry weight of wood consists of the elements of 44.4% carbon (C), 6.2% hydrogen (H) and 49.4% oxygen (O) and simplest formular expressing this relationship is $(C_6 H_{10} O_5)$ n – cellulose (Farmer 1969).

When cellulose is completely decomposed by fungi, it give rise to almost the theoretical yield of glucose $(C_6 H_{12} O_6)$ n according to the equations :-

$$(C_6 H_{10} O_5)\,n + H_2O \xrightarrow[\text{Decay}]{\text{Enzymatic}} (C_6 H_{12} O_6)\,n$$

$$C_6 H_{12} O_6 + 6O_2 \xrightarrow[\text{Decay}]{\text{Enzymatic}} 6\,CO_2 + 6\,H_2O + \text{Energy}$$

Wood-rotting fungi have played very important role in decomposition of wood and other plant litters in forest ecosystems. Fungi break down and metabolize the depoly-merized materials from high molecular weight polymers which make up wood cells. Fungal enzymes split long chain polymers of wood substrates into short chain molecules and then fungi are able to utilize as their food sources of energy. Glucose is the backbone polymers which fungi can utilize for their food sources as well as forest plants. If further decomposition takes place, the glucose will be broken down into carbon dioxide (CO_2), water H_2O) and energy as demonstrated in the above equation. Therefore, carbon cycle will circulate in the forest ecosystems and some fractions are released to the atmosphere (Spurr and Barnes, 1973; Krebs, 1985; UNESCO/UNEP/FAO, 1978).

Mycorrhizas, vesicular–arbuscular mycorrhiza (VAM) and ectomycorrhiza (ECM), have also played a key role in nutrient cycling in forest ecosystems. Phosphorus (P), nitrogen (N) and other nutrient cyclings are essential and known to be as the potential elements for forest plant growth by the activities of VAM and ECM fungi (Gray and Williams, 1977; Jackson and Raw, 1970).

TABLE 1. Symbiotic relationships of mycorrhizas with forest plants in various forest types and experimental plots at Mae-Klong Watershed Research Station, Thong Phaphoom District, Kanchanaburi Province, Western Thailand.

Plot No.	Forest Plants and Forest Types	Family	Mycorrhizal Association	Occurrence of ECM Fungi
1	**Natural Forest**			
	(1) Dry dipterocarp forest			High
	Berrya ammonilla Roxb.	Tiliaceae	VAM	
	Bombax anceps Pierre	Bombacaceae	VAM	
	Careya arborea Roxb.	Barringtoniaceae	VAM	
	Castanopsis argyrophylla King	Fagaceae	ECM	
	Dalbergia dongnaiensis Pierre	Papilionaceae	VAM/NF/ECM	
	D. oliveri Gamble	Papilionaceae	VAM/NF/ECM	
	Dillenia parviflora Griff.	Dilleniaceae	VAM	
	Diospyros ehretioides Wall.	Ebenaceae	VAM	
	Dipterocarpus alatus Roxb.	Dipterocarpaceae	ECM	
	D. turbinatus Gaertn. f.	Dipterocarpaceae	ECM	
	Lithocarpus polystachyum Rehd.	Fagaceae	ECM	
	Millettia brandisiana Kurz	Papilionaceae	VAM/NF/ECM	
	M. leucantha Kurz	Papilionaceae	VAM/NF/ECM	
	Phyllanthus emblica Linn.	Euphorbiaceae	VAM/ECM	
	Pterocarpus macrocarpus Kurz	Papilionaceae	VAM/NF/ECM	
	Quercus kerrii Craib	Fagaceae	ECM	
	Randia dasycarpa Bakh. F.	Rubiaceae	VAM/ECM	
	Shorea obtusa Wall.	Dipterocarpaceae	ECM	
	S. siamensis Miq.	Dipterocarpaceae	ECM	
	Spondias pinnata Kurz	Anacardiaceae	VAM/ECM	
	Sterculia macrophylla Vent.	Sterculiaceae	VAM	
	Terminalia chebula Retz.	Combretaceae	VAM	
	Xylia kerrii Craib & Hutch.	Mimosaceae	VAM/NF/ECM	
	(2) Mixed-deciduous forest			Moderate
	Bambusa arundinacea Willd.	Gramineae	VAM	
	Canarium subulatum Guill.	Burseraceae	VAM	
	Cephalostachyum pergracile Munro	Gramineae	VAM	
	Cratoxylum formosum Dyer	Guttiferae	VAM	
	Dillenia ovata Wall. Ex Hook.f.&.Th.	Dilleniaceae	VAM	
	Dipterocarpus latus Roxb.	Dipterocarpaceae	ECM	
	D. turbinatus Gaertn.f.	Dipterocarpaceae	ECM	
	Eugenia megacarpa Craib	Myrtaceae	VAM/ECM	
	Garuga pinnata Roxb.	Burseraceae	VAM	
	Garuga pinnata Roxb.	Burseraceae	VAM	
	Gigantochloa albociliata Back.ex.K.Heyne	Gramineae	VAM	
	Mangifera caloneura Kurz	Anacardiaceae	VAM/ECM	
	Pterocymbium javanicum R. Br.	Sterculiaceae	VAM	
	Pterocarpus macrocarpus Kurz	Papilionaceae	VAM/NF/ECM	
	Schleichera oleosa Merr.	Sapindaceae	VAM/ECM	

TABLE 1. (Cont.)

Plot No.	Forest Plants and Forest Types	Family	Mycorrhizal Association	Occurrence of ECM Fungi
	Terminalia chebula Retz.	Combretaceae	VAM	
	Vitex peduncularis Wall. ex Schauer	Verbenaceae	VAM	
	Wrightia tomentosa Roem. & Schult.	Apocynaceae	VAM	
	Xylia kerrii Craib & Hutch.	Mimosaceae	VAM/NF/ECM	
	(3) Dry-or semi-evergreen forest			High
	Acacia megaladena Desv.	Mimosaceae	VAM/NF/ECM	
	Aglaia odoratisima Bl.	Meliaceae	VAM	
	Albizia chinensis Merr.	Mimosaceae	VAM/NF/ECM	
	Anogeissus acuminata Wall.	Combretaceae	VAM	
	Artocarpus rigidus Bl.	Moraceae	VAM/ECM	
	Bambusa tulda Roxb.	Gramineae	VAM	
	Cephalostachyum pergracile Munro	Gramineae	VAM	
	Croton oblongifolius Roxb.	Euphorbiaceae	VAM/ECM	
	Dalbergia nigrescens Kurz	Papilionaceae	VAM/NF/ECM	
	D. oliveri Gamble	Papilionaceae	VAM/NF/ECM	
	Dillenia ovata Wall.ex Hook.f.&Th.	Dilleniaceae	VAM	
	Dipterocrapus alatus Roxb.	Dipterocarpaceae	ECM	
	D. turbinatus Gaertn. f.	Dipterocarpaceae	ECM	
	Duabanga grandiflora Walp.	Sonneratiaceae	VAM	
	Erythrina subumbrans Merr.	Papilionzeae	VAM/NF/ECM	
	Gigantochloa hasskarliana Back. ex K.Heyne	Gramineae	VAM	
	G. albociliata Munro	Gramineae	VAM	
	Gmelina arborea Roxb.	Verbenaceae	VAM	
	Hopea odorata Roxb.	Dipterocarpaceae	ECM	
	Lagerstroemia calyculata Kurz	Lythraceae	VAM	
	L. tomentosa C.B. Robinson	Lythraceae	VAM	
	Litsea glutinosa C.B. Robinson	Lauraceae	VAM/ECM	
	Premna latifolia Roxb.	Verbenaceae	VAM	
	Pterocarpus macrocarpus Kurz	Papilionaceae	VAM/ECM	
	Sterculia foetida Linn.	Sterculiaceae	VAM	
	Walsura trichostemon Miq.	Meliaceae	VAM	
	Wrightia tomentosa Roem. & Schult.	Apocynaceae	VAM	
2.	**Secondary forest (Logged-over area of mixed deciduous forest)**			High
	Acacia farnesiana Willd.	Mimosaceae	VAM/NF/ECM	
	A. leucophloea Willd.	Mimosaceae	VAM/NF/ECM	
	A. megaladena Desv.	Mimosaceae	VAM/NF/ECM	
	Aglalia chaudocensis Pierre	Meliaceae	VAM	
	Albizia chinensis Merr.	Mimosaceae	VAM/NF/ECM	
	Anogeissus acuminata Wall.	Combretaceae	VAM	
	Antidesma bunius Spreng.	Stilaginaceae	VAM/ECM	

TABLE 1. (Cont.)

Plot No.	Forest Plants and Forest Types	Family	Mycorrhizal Association	Occurrence of ECM Fungi
	Artocrapus rigidus Bl.	Moraceae	VAM/ECM	
	Bauhinia viridescens Desv.	Caesalpiniaceae	VAM/ECM	
	Bombax anceps Pierre	Bombacaceae	VAM	
	Colona floribunda Craib	Tiliaceae	VAM	
	Croton oblongifolius Roxb.	Euphorbiaceae	VAM/ECM	
	Dillenia ovata Wall.ex Hook.f. & Th.	Dilleniaceae	VAM	
	Dipterocarpus alatus Roxb.	Dipterocarpaceae	ECM	
	D. turbinatus Gaertn. f.	Dipterocarpaceae	ECM	
	Duabanga grandiflora Walp.	Sonneratiaceae	VAM	
	Ficus hispida Linn.f.	Moraceae	VAM/ECM	
	Garuga pinnata Roxb.	Burseraceae	VAM	
	Gmelina arborea Roxb.	Verbenaceae	VAM	
	Hopea odorata Roxb.	Dipterocarpaceae	ECM	
	Hymenodyctyon exelsum Wall.	Rubiaceae	VAM/ECM	
	Lagerstroemia calyculata Kurz	Lythraceae	VAM	
	L. tomentosa Presl.	Lythraceae	VAM	
	Lannea grandis Engler	Anacardiaceae	VAM/ECM	
	Litsea grandis Hook. f.	Lauraceae	VAM/ECM	
	Mangifera cochinchinensis Engler	Anacardiaceae	VAM/ECM	
	Markhamia stipulata Seem.	Bignoniaceae	VAM/ECM	
	Michelia champaca Linn.	Magnoliaceae	VAM/ECM	
	Millettia brandisiana Kurz	Papilionaceae	VAM/NF/ECM	
	Musa acuminata Colla	Musaceae	VAM	
	Premna latifolia Roxb.	Verbenaceae	VAM	
	Pterocarpus macrocarpus Kurz	Papilionaceae	VAM/ECM	
	Sapium baccatum Roxb.	Euphorbiaceae	VAM/ECM	
	Schleichera oleosa Merr.	Sapindaceae	VAM/ECM	
	Spondias pinnata Kurz	Anacardiaceae	VAM/ECM	
	Sterculia macrophylla Vent.	Sterculiaceae	VAM	
	Streblus elicifolius Corner	Moraceae	VAM/ECM	
	Toona ciliata M. Roem.	Meliaceae	VAM	
	Trema orientalis Bl.	Ulmaceae	VAM/ECM	
	Vitex canescens Kurz	Verbenaceae	VAM	
	Xylia kerrii Craib & Hutch.	Mimosaceae	VAM/NF/ECM	
3	**Grassland (Disturbed forest area)**			Rare
	Acacia catechu Willd.	Mimosaceae	VAM/NF/ECM	
	A. megaladena Desv.	Mimosaceae	VAM/NF/ECM	
	Albizia chinensis Merr.	Mimosaceae	VAM/NF/ECM	
	A. lucidior Nielsen	Mimosaceae	VAM/NF/ECM	
	Careya arborea Roxb.	Barringtoniaceae	VAM	
	Croton oblongifolius Roxb.	Euphorbiaceae	VAM/ECM	
	Dalbergia volubilis Roxb.	Papilionaceae	VAM/NF/ECM	
	Dipterocrapus turbinatus Gaertn.f.	Dipterocarpaceae	ECM	
	Eugenia cumini Druce	Myrtaceae	VAM/ECM	
	Eupatorium odoratum Linn.	Compositae	VAM	
	Ficus hispida Linn.f.	Moraceae	VAM	
	Garuga pinnata Rox.	Burseraceae	VAM	

TABLE 1. (Cont.)

Plot No.	Forest Plants and Forest Types	Family	Mycorrhizal Association	Occurrence of ECM Fungi
	Gigantochloa hasskarliana(Kurz) Back.ex K.Heyne	Gramineae	VAM	
	Gmelina arborea Roxb.	Verbenaceae	VAM	
	Grewia paniculata Roxb.	Tiliaceae	VAM	
	Imperata cylindrica Beauv.	Gramineae	VAM	
	Lagerstroemia speciosa Pers.	Lythraceae	VAM	
	Litsea glutinosa C.B. Robinson	Lauraceae	VAM/ECM	
	Musa acuminata Colla	Musaceae	VAM	
	Pterocarpus macrocaipus Kurz	Papilionaceae	VAM/NF/ECM	
	Saccharum spontaneum Linn.	Gramineae	VAM	
	Trema orientalis Bl.	Ulmaceae	VAM/ECM	
	Xylia kerrii Craib & Hutch.	Mimosaceae	VAM/NF/ECM	
4	**Young teak plantation**			None
	Tectona grandis Linn.f.	Verbenaceae	VAM	
	Gmelina arborea Roxb.	Verbenaceae	VAM	
5.	**Old teak plantation**			None
	Tectona grandis Linn.f.	Verbenaceae	VAM	
	Many weed species	-	VAM	

Remark : ECM = Ectomycorrhizas
VAM = Vesicular - Arbuscular Mycorrhizas (Endomycorrhizas)
NF = N_2 – Fixing Microorganisms (Bacteria, Actinomycetes)

Table 2. Species richness and biodiversity of ectomycorrhizal fungi in natural forest and secondary forest at Mae-Klong Watershed Research Station, Thong Phaphoom District, Kanchanaburi Province, Western Thailand.

No.	Species of Ectomycorrhizal Fungi	Family	Forest Ecosystems	
			Natural Forest	Secondary Forest
1	*Alpova trappei* Fogel	Melanogastraceae		x
2	*Amanita caesarea* (Fr.) Schw.	Amanitaceae	x	x
3	*A. calyptrata*	Amanitaceae		x
4	*A. coccora*	Amanitaceae	x	x
5	*A. hemibapha* (Berk.et Br.)Sacc. ssp. *javanica* Corner et Bas	Amanitaceae	x	
6	*A. hemibapha* (Berk.et Br.)Sacc. ssp. *hemibapha* Corner et Bas	Amanitaceae		x
7	*A. hemibapha* (Berk.et Br.)Sacc. ssp. *similis* Corner et Bas	Amanitaceae		x
8	*Amanita sp.* (edible white lusty cap)	Amanitaceae	x	x
9	*Astraeus hygrometricus* (Pers.) Morg.	Astraeaceae	x	
10	*Boletellus ananas* (Curt.) Murr.	Xerocomaceae	x	
11	*B. chrysenteroides*(Snell) Sing.	Xerocomaceae	x	
12	*B. emodensis* (Berk.) Sing.	Xerocomaceae		x
13	*B. obcurecoccineus* Hochn.	Xerocomaceae	x	x
14	*Boletus colossus* Heim	Boletaceae	x	x

Table 2. (Cont.)

No.	Species of Ectomycorrhizal Fungi	Family	Forest Ecosystems	
			Natural Forest	Secondary Forest
15	*B. edulis* Bull.ex.Fr.	Boletaceae		x
16	*B. hemichrysus* Corner	Boletaceae	x	x
17	*B. olivaceirubens* Corner	Boletaceae		x
18	*B. peltatus* Corner	Boletaceae		x
19	*Cantharellus cibarius* Fr.	Cantharellaceae		x
20	*Clavulina cristata*(Fr.) Schroet.	Clavulinaceae		x
21	*Clavulinopsis helvola* (Fr.) Corner	Clavulinaceae		x
22	*Coltricia cinnamomea* (Pers.) Murr.	Hymenochaetaceae	x	x
23	*C. perennis* (L.ex Fr.) Murr.	Hymenochaetaceae	x	x
24	*Entoloma congrenatum* Steven.	Entolomataceae		x
25	*E. puroides* Horak	Entolomataceae		x
26	*E. serrulatum*(L.ex Fr.) Hesler	Entolomataceae		x
27	*Lactarius deliciosus*(L.ex Fr.) Gray	Russulaceae	x	x
28	*Lycoperdon echinatum* Pers.ex Pers.	Lycoperdaceae		x
29	*L. perlatum* Pers.ex Pers.	Lycoperdaceae		x
30	*Pisolithus tinctorius*(Pers.) Coker & Couch	Sclerodermataceae	x	
31	*Russula albidula* Peck	Russulaceae	x	x
32	*R. brevipes* Peck	Russulaceae	x	x
33	*R. brunneoviolacea* Crawshay	Russulaceae	x	x
34	*R. cyanoxantha* Schaeff.ex Fr.	Russulaceae	x	x
35	*R. delica* Fr.	Russulaceae	x	x
36	*R. densifolia* (Secr.) Gillet	Russulaceae	x	x
37	*R. lepida* Fr.	Russulaceae	x	x
38	*R. mariae* Peck	Russulaceae		x
39	*R. rosacea* Pers.ex Gray	Russulaceae	x	
40	*R. sanguinea* (Bull.) Fr.	Russulaceae	x	
41	*R. subnigricans* Hongo	Russulaceae	x	
42	*R. virescens* Fr.	Russulaceae	x	x
43	*Scleroderma areolatum* Ehrenb.	Sclerodermataceae	x	x
44	*S. flavidum* Ell.& Ev.	Sclerodermataceae	x	x
45	*Tricholoma crassum* (Berk.) Sacc.	Tricholomataceae		x
46	*T. lobagensis* Heim	Tricholomataceae		x
47	*Strobilomyces seminudus* Hongo	Strobilomycetaceae	x	
48	*Geastrum saccatum* Fr.	Geastraceae	x	
49	*Clavaria purpurea* Muell.x Fr.	Clavariaceae	x	
50	*Amanita virosa*(Fr.) Bert.	Amanitaceae	x	
			31	38
	Total frequency			

Table 3. Species diversity of wood-rotting fungi in tropical forests of Mae-Klong Watershed Research Station, Thong Phaphoom District, Kanchanaburi, Thailand.

No.	Phylum / Species	Family	Substrates / Uses
	Phylum : ASCOMYCOTA		
1	*Bulgaria javanicum* (Rehm.) Lè Gal	Sarcoschyphaceae	on dead wood
2	*Chlorosplenium aeruginascens* (Nyl.) Karst.	Dermateaceae	on dead wood
3	Cookeina colensoi *(Berk.) Seaver*	Sarcoschyphaceae	on twigs
4	*Cookeina indica* Pfister & R. Kaushal	Sarcoschyphaceae	on twigs
5	*Cookeina insititia* (Berk. & Curt.) Kuntz.	Sarcoschyphaceae	on dead wood
6	*Cookeina sulcipes* (Berk.) Kuntz.	Sarcoschyphaceae	on dead branch
7	*Cookeina tricholoma* (Mont.) Kuntz.	Sarcoschyphaceae	on dead wood
8	*Daldinia concentrica* (Bolt. ex Fr.) Ces et de Not.	Sarcoschyphaceae	on dead log
9	*Xylaria carpophila* (Pers.) Fr.	Xylariaceae	on dead wood
10	*Xylaria juruensis* P. Henn.	Xylariaceae	on dead branch
11	*Xylaria longipes* Nits. var. tropica S. Mart. & Rogers	Xylariaceae	on dead wood
	Phylum : BASIDIOMYCOTA		
1	*Agaricus praeclaresquamosus* Freem.	Agaricaceae	on soils
2	*Agaricus silvicola* (Vitt.) Sacc.	Agaricaceae	on soils
3	*Amauroderma rugosum* (Bl. et. Nees ex Fr.) Torr.	Ganodermataceae	on buried wood
4	*Amauroderma subrugosum* (Bres.et Pat.) Torr.	Ganodermataceae	on buried soils
5	*Auricularia auricula* (Hk.) Underw	Auriculariaceae	on dead wood
6	*Auricularia delicata* (Fr.) P. Henn.	Auriculariaceae	on dead wood
7	*Auricularia glandulosa* Fr.	Auriculariaceae	on dead wood
8	*Auricularia polytricha* (Mont.) Sacc	Auriculariaceae	on dead wood
9	*Boletopsis atrata* Ryv.	Thelephoraceae	on dead wood
10	*Calocera viscosa* (Pers. ex Fr.) Fr.	Dacrymycetaceae	on dead wood
11	*Calvatia craniiformis* Coker ex Couch	Lycoperdaceae	on soils
12	*Campanella junghuhnii* (Mont.) Sing	Tricholomataceae	on dead twig
13	*Caprinus cinereus* (Schaelf. ex Fr.) Gray	Coprinaceae	on soils
14	*Chlorophyllum molybdites* (Meyer ex Fr.) Mass.	Agaricaceae	on soils
15	*Clavaria vermicularis* Swartz. ex Fr.	Clavariaceae	on soils
16	*Clavariadelphus pistillaris* (Fr.) Donk.	Clavariaceae	on soils
17	*Clavulinopsis miyabeana* (S. Ito) S. Ito	Clavulinaceae	on soils
18	*Coprinus disseminatus* (Pers. ex Fr.) S. F. Gray	Coprinaceae	on dead log
19	*Coprinus leiocephalus* P.D. Orton	Coprinaceae	on soils
20	*Corticium spathulata* (Hook.) Murr.	Corticiaceae	on dead twig
21	*Craterellus cornucopioides* (L. ex Fr. Pers.)	Craterellaceae	on soils
22	*Crepidotus* op.	Crepidotaceae	on dead twig
23	*Crinipellis stipitaria* (Fr.) Pat.	Tricholomataceae	on dead twig
24	*Crinipellis zonata* (Peck.) Pat.	Tricholomataceae	on soils
25	*Cyanthus striatus* Willd ex Pers	Nidulariaceae	on dead twigs
26	*Cyathus olla* (Batsch.) Pers.	Nidulariaceae	on dead twigs
27	*Daedalea quercina* Fr.	Coriolaceae	on dead log
28	*Daedaleopsis confragosa* (Bolt. ex Fr.) Schroet.	Coriolaceae	on dead log

Table 3. (Cont.)

No.	Phylum / Species	Family	Substrates / Uses
29	*Daedaleopsis tenuis* (Hk. & Fr.) Imaz.	Coriolaceae	o n dead wood
30	*Dictyophora indusiata* (Vent. ex Pers.) Fisch.	Phallaceae	on soils
31	*Earliella scabrosa* (Pers.) Bilbn. & Ryv.	Coriolaceae	on dead log
32	*Favolus spathulata* (Jungh.) Lev.	Polyporaceae	on dead wood
33	*Fayodia bisphaerigera* (Lang.) Kuhn.	Tricholomataceae	on dead twigs
34	*Filoboletus manipularis* (Berk.) Sing.	Tricholomataceae	on dead log
35	*Flavodon flavus* (Klotz.) Ryv.	Steccherinaceae	on dead wood
36	*Fomitopsis rhodophaeus* (Lev.) Imaz.	Coriolaceae	on tree trunk
37	*Ganoderma applanatum* (Pers. ex Wallr.) Pat	Ganodermataceae	Butt & heart rots
38	*Ganoderma australe* (Fr.) Pat.	Ganodermataceae	Butt & heart rots
39	*Ganoderma hainanense* Zhao, Xu et Zhang	Ganodermataceae	Root & Butt rots
40	*Ganoderma sessile* Murr.	Ganodermataceae	on dead log
41	*Ganoderma subresinosum* (Murr.) Hump.	Ganodermataceae	Butt rot
42	*Geastrum drummondii* Berk.	Geastraceae	on dead wood
43	*Geastrum lageniforme* Vitt.	Geastraceae	on decay wood
44	*Geastrum minimum* Dring.	Geastraceae	on termite mound
45	*Geastrum pulverulentum* Wakefield.	Geastraceae	on decay wood
46	*Grammothele delicatula* (Henn.) Ryv.	Grammotheleaceae	on dead twig
47	*Guepinia spathularia* (Schw.) Fr.	Dacrymycetaceae	on dead wood
48	*Heterobasidion insularis* (Murr.) Ryv.	Coriolaceae	on dead wood
49	*Hexagonia apiaria* (Pers.) Fr.	Coriolaceae	on dead wood
50	*Hexagonia speciosa* Fr.	Coriolaceae	on dead wood
51	*Hexagonia subtenuis* Berk. ex Cke.	Coriolaceae	on dead wood
52	*Hexagonia tenuis* (Hook.) Fr.	Coriolacea	on dead wood
53	*Hohenbuehilia aurantiocystis* Pegl.	Tricholomataceae	on dead branch
54	*Hygroaster nodulisporus* (Denn.) Ing.	Hygrophoraceae	on dead log
55	*Hymenochaete rubiginosa* (Dicks. ex Fr.)Lev.	Hygrophoraceae	on dead wood
56	*Inonotus dryadeus* (Pers. ex Fr.) Murr.	Hygrophoraceae	on dead wood
57	*Laetiporus sulphureus* (Bull. Ex Fr.) Murr.	Coriolaceae	on dead log
58	*Lentinus giganteus* Bi.	Lentinaceae	on dead branch
59	*Lentinus polychrous* Lev.	Lentinaceae	on dead wood
60	*Lentinus sajor-caju* (Fr.) Fr.	Lentinaceae	on dead branch
61	*Lentinus similis* Berk. & Br.	Lentinaceae	on dead log
62	*Lenzites acuta* Berk.	Coriolaceae	on dead wood
63	*Lenzites betulina* Fr. ex Fr.	Coriolaceae	on soils
64	*Lenzites elegans (Fr.) Pat.*	Coriolaceae	on soils
65	*Leucocoprinus birnbaumii* (Corda) Sing.	Agaricaceae	on soils
66	*Leucocoprinus fragilissimus* (Rav.) Pat.	Agaricaceae	on soils
67	*Lloydella subpileata* (Berk. & Curt.) Hoehr.	Stereaceae	on dead branch
68	*Lycogalopsis solmsii* E. Fischer	Lycoperdaceae	on dead wood
69	*Marasmiellus candidus* (Bolt.) Sing.	Tricholonmataceae	on dead twig
70	*Marasmiellus subcorocinum* (Berk.) Curt. ex Sing.	Tricholomataceae	on dead twig
71	*Marasmirus rotuloides* Denn.	Tricholomataceae	on dead branch
72	*Marasmius rotula* (Fr.) Kummer	Tricholomataceae	on dead branch
73	*Micromphale brassicolens* (Romang.) Orton	Tricholomataceae	on dead branch
74	*Microporus affinis* (Bl. & Nees ex Fr.) Ryv.	Polyporaceae	on dead wood
75	*Microporus vernicipes* (Berk.) Kuntz.	Polyporaceae	on dead wood

Table 3. (Cont.)

No.	Phylum / Species	Family	Substrates / Uses
76	*Microporus xanthopus* (Fr.) Kuntz.	Polyporaceae	on dead branch
77	*Oudemansiella radicata* (Rehl. ex Fr.) .Sing.	Tricholomataceae	on soils
78	*Perenniporia ochroleuca* (Berk.) Ryv.	Coriolaceae	on dead wood
79	*Perenniporia tephropora* (Mont.) Ryv.	Coriolaceae	on dead branch
80	*Phellinus gilvus* (Schw. ex Fr.) Pat.	Hymenochaetaceae	on dead log
81	*Phellinus griseoporus* Reid	Hymenochaetaceae	on dead wood
82	*Phellinus linteus* (Berk. et Curt.) Teng	Hymenochaetaceae	on dead log
83	*Phellinus melanodermus* (Par.) Fidalgo	Hymenochaetaceae	on dead log
84	*Phellinus orientalis* Bond. et Herr.	Hymenochaetaceae	on dead wood
85	*Phellinus pachyphloeus* (Pat.) Pat.	Hymenochaetaceae	on dead log
86	*Phellinus rimosus* (Berk.) Pil.	Hymenochaetaceae	on living tree
87	*Phellinus senex* (Nees et Mont.) Imaz.	Hymenochaetaceae	on tree trunk
88	*Pleurotus mitis* (Pers. ex Fr.) Quel	Lentinaceae	on dead wood
89	*Polyporus grammocephalus* Berk.	Polyporaceae	on dead branch
90	*Polyporus leprieurii Mont*	Polyporaceae	on dead branch
91	*Polyporus squamosus* Fr.	Polyporaceae	on dead wood
92	*Polyporus tenuiculus* (Beauv.) Fr.	Polyporaceae	on dead twig
93	*Psathyrella tristis* Sing.	Coprinaceae	on soils
94	*Psilocybe cubensis* (Earl.) Sing.	Strophariaceae	on dung
95	*Pterygellus polymorphus* Corner	Cantharellaceae	on soils
96	*Pycnoporus coccineus* (Fr.) Bond. et Sing.	Coriolaceae	on dead wood
97	*Pycnoporus sanguineus* (Fr.) Murr.	Coriolaceae	on dead wood
98	*Rigidoporus lineatus* (Pers.) Ryv.	Coriolaceae	on decay root
99	*Schizophyllum commune* Fr. ex Fr.	Schizophyllaceae	on dead wood
100	*Schizopora flavipora* (Cook.) Ryv.	Hyphodermataceae	on dead wood
101	*Stereopsis burtianum* (Peck) Reid	Podoschyphaceae	on dead wood
102	*Stereum ostrea* (Bl. et Nees) Fr.	Stereaceae	on dead wood
103	*Termitomyces clypeatus* Heim	Amanitaceae	on soils
104	*Termitomyces microcarpus* (Berk. et Br.) Heim	Amanitaceae	on soils
105	*Termitomyces striatus* (Beeli) Heim	Amanitaceae	on soils
106	*Trametes cotonea* (Pat. & Har.) Ryv.	Coriolaceae	on dead wood
107	*Trametes elegans* (Spreng. ex Fr.) Fr.	Coriolaceae	on dead wood
108	*Trametes flavidum* (Lev.) Aosh.	Coriolaceae	on dead wood
109	*Trametes menziezii* (Berk.) Ryv.	Coriolaceae	on dead wood
110	*Trametes spragnei* (Berk. & Curt.) Ryv.	Coriolaceae	on dead wood
111	*Tremella fuciformis* Berk.	Tremellaceae	on dead wood
112	*Volvariella speciosa* (Fr. ex Fr.) Sing.	Pluteaceae	on banana stem
113	*Volvariella volvacea* (Bull. ex Fr.) Sing.	Pluteaceae	on soils
114	*Wolfiporia cartilaginea* Ryv.	Coriolaceae	on dead wood

Conclusion

It could be concluded from this study that most ectomycorrhizal and wood-rotting fungi were abundently found in natural forests far more than in disturbed forests. Quantitative and qualitative biodiversity dynamics of ectomycorrhizal and wood-rotting fungi were closely correlated with the degradation of forest ecosystems, host specification, plant diversity, climate changes, edaphic conditions, abiotic and biotic factors. The more diverse plant communities express the more stable domains of ectomycorrhizal association and wood-rotting fungi within a unique forest ecosystem.

It would be recommended from this study that much gaps were still remained and awaiting researchers to carry out research dealing with the expedition of ectomycorrhizal and wood-rotting fungi in details. More studies should be done further with particular references to other roles and biodiversity of microorganisms such as viruses, bacteria, fungi, algae, lichens, protozoa and other microscopic life – forms in Mae-Klong Watershed Research Station. All of these microorganisms have directly and indirectly played the integrated parts in food chains and nutrient flows in tropical forests of Thailand.

Acknowledgements

The author was grateful to the Thai and Japanese governments for supporting this study under the Joint Research Project on the Changes of Tropical Forests and Their Influences; Sub–Project on the Relationship of Soil Microorganisms, SOM Dynamics and Nutrient Cycling in Tropical Forest, through the National Research Council of Thailand (NRCT), Japan Science and Technology (JSTA), and Japan International Science and Technology Exchange Center (JISTEC) of Government of Japan. Thanks were also conveyed to Dr. Songtam Suksawang in providing excellent facilities during data expeditions, Dr. Kazuhiro Ishizuka and Dr. Masamichi Takahashi from Forestry and Forest Products Research Institute, Tsukuba, Ibaraki, Japan for providing financial support. Much thanks were also highly appreciated to Mr. Suttipong Kesjinda for helping manuscript preparation.

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