Endangered biodiversity in tropical peat-swamps in relation to their ecological risk*

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Peat-swamp-forest ecosystems in the Tropical Asia contain unique vegetation with a high proportion of indigenous taxa. Large areas of natural peat-swamp forests remained in their natural state in Southeast Asia until the 1970s. From that time, however, development activities in these areas, such as large-scale irrigation projects, began to increase, introducing many environmental and social problems. Tropical forests are drawing worldwide attention from researchers, but only a small proportion of them and their ecosystems have been catalogued. In this paper we focus on Asian tropical swamp vegetation from the ecological point of view, and consider possibilities for establishing a sustainable land use system in order to protect endangered tropical biodiversity.

Key Words : ecological risk, biodiversity, tropical swamp, endemic, endangered species

INTRODUCTION

Earth's biodiversity is the result of several thousand million years of evolutionary change. The diversity of species on Earth constitutes a natural heritage and life-support system for all species. Many biologists estimate that over the next 25 years, more than a million species of plants and animals will become extinct. Most of these extinctions will occur in the humid tropics such as tropical regions of Asia and South America. To conserve tropical biodiversity and promote sustainable usage of biological or ecological resources, it is necessary to understand how tropical forests are structured or how tropical forest ecosystems naturally remain and develop. Tropical forests themselves -vast in size and rich in diversity- are the least undestood of the world's ecosystems.

In the following paper we focus on Asian tropical swamp vegetation from the ecological point of view, and consider possibilities for establishing a sustainable land use system in order to protect endangered tropical biodiversity. Southeast Asian coastal areas along the Malay Peninsula contain large areas of swamps composed of peat soil. In Thailand, natural peat-swamp forests can be found only in Narathiwat Province near the border with Malaysia. Plant ecological censuses (systematic inventorying and classification) were carried out at natural peat-swamp forests and throughout many types of substitutional swampy vegetation in Narathiwat, Thailand. Some sections of this report are quoted from Suzuki & Hara (1996), and Suzuki & Niyomdham (1992).

ECOLOGY OF TROPICAL SWAMPS

Role of natural swamps

Much of Earth's land area currently used as paddy

* This paper is a revision and expansion of a report presented at the 2nd International Workshop on Risk Evaluation and Management of Chemicals at Yokohama (January, 1999).

fields was originally natural swampland. The total global area of swampland that is not influenced by seawater is approximately five hundred million hectares (Aselmann & Crutzen, 1989). Swamp land plays a significant role in Earth's environment, not only with regard to controlling drainage systems, but also when talking about coastline preservation, micro-climate control, water purification, soil formation, animal and plant habitats and natural resources for human use.

Large areas of swampland and other wetlands are found in the wet tropics. Because of its humid climate, Southeast Asia, in particular, has vast areas of peat-swamps. The question as to why these swamps escaped development prior to the 1970s' has not yet been addressed. However, during the past 20 to 30 years, peat-swamp forests in the coastal areas of Southeast Asia have gradually been converted to agricultural land for large-scale cultivation. Most of the agricultural areas that were developed several decades ago have already been abandoned. Over time these abandoned areas became savanna-like open landscape areas, which are poorly suited for cultivation, posing serious social and economic problems in countries such as Thailand and Malaysia.

Distribution of swamps by latitude

Freshwater swamp forest is widely distributed across the globe in the tropical regions of Southeast Asia, Africa, and Central America and is found in large scale in the Amazone basin (Richards, 1952). The world's swamp distribution is shown in Figure 1, where we can see the global distribution and concentration of swamp areas per each 10-degree parallel. The term "swamp" includes frigid zone swamps, swampy grasslands, reed fields and peat moss areas, all typically characterized by an open landscape. Current estimates show that between 48.9 % (Matthews & Fung, 1987) and 51.3% (Aselmann & Crutzen, 1989) of the world's swamplands are concentrated in the high-latitude region above the 50 degree North parallel. Most of these swamp lands are peat-swamps, which consist of the decay from *sphagnum* (mosses) and sedge species. But peat-swamps are also prevalent in low latitude areas of the humid tropics. The sources for the peat material in tropical peat-swamp areas are the forest trees, and most of these areas are covered by a thick natural forest with trees over 30 meters tall. According to Aselmann & Crutzen (1989), 27% of the world's swamps (5.7 million sg. km) are located in the tropics. About two-thirds of these are found in the lowlands of humid tropical Asia. The term "tropical swamp" sometimes includes mangroves and salt marshes, but in this we focus on the Asian fresh water swamps.

In Southeast Asia, it is found in the Indochina Peninsula, Thailand, and Burma along the Mekong, Chaophraya, and Irrawaddy Rivers, and in the

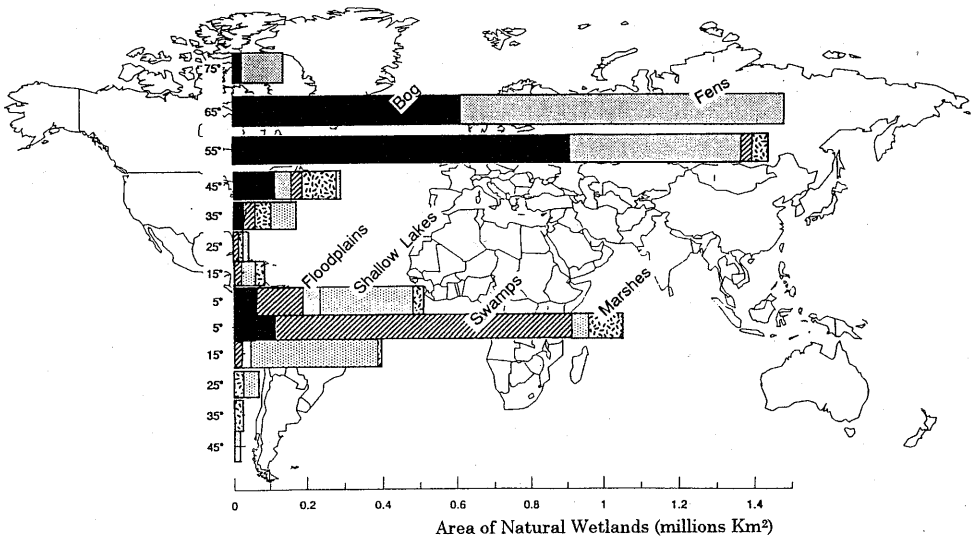

Fig. 1. Latitudinal distribution of natural wetlands (Aselmann & Crutzen, 1989).

archipelago, it covers large areas on the lower reaches of the Fly, Sepik, and other rivers in New Guinea (Yamada, 1998). In the Malay Peninsula, the peat-swamp forests occur under varying degrees of inundation and show enormous variation in flora and structure, and form a sparse scattering of large trees to sense pole forest. Because of its prevalence and location on coastal lowlands, much has now been cleared for use as rice fields and oil palm and rubber plantations, and only small areas remain.

Floristic character of Narathiwat swamps

The peat-swamp forests and grasslands contain unique vegetation with a high proportion of endemic taxa. Anderson's study (1963) represented the first copious survet of the peat swamp forest in Southeast Asia, and it uncovered mamy species. *Litsea palustris*, which was the most significant discovery, was found in Sarawak and Brunei. The fact that such new species had not until then been collected shows how limited the surveying of peat swamp had been (Yamada, 1998). Difficulty of approach and the prevalence of insect-borne disease are probably the mail deterrents to survey.

The swamp vegetation in Narathiwat, Thailand covers an area of about 8,000 hectares (see Figure 2).

A study of floristic composition of the peat-swamp forest and the adjacent vegetation in Narathiwat province, began in 1983, conducted by the Forest Herbarium staff, Royal Forest Department, Thailand. So far, 88 families containing 298 species of flowering plant and 13 families containing 18 species of ferns have been recorded, 48 species of which are regarded as new records for Thailand.

Vegetation character of Narathiwat swamps

Natural forests and many types of secondary vegetation, which are affected by human activities, remain in the peat-swamp areas of Narathiwat, Thailand. All types of peat-swamp vegetation were studied in the field and phytosociological classification of the vegetation was proposed in accordance with the concepts and methods of the Zurich-Montpellier School (Suzuki & Niyomdham, 1992). As a result of the investigation and the classification, it was possible to establish 22 communities as follows :

1. Natural Forest

Baccauria bracteata-Endiandra macrophylla-community (TNF 1)

Schima wallchii-Fagraea fragrans-cummunity

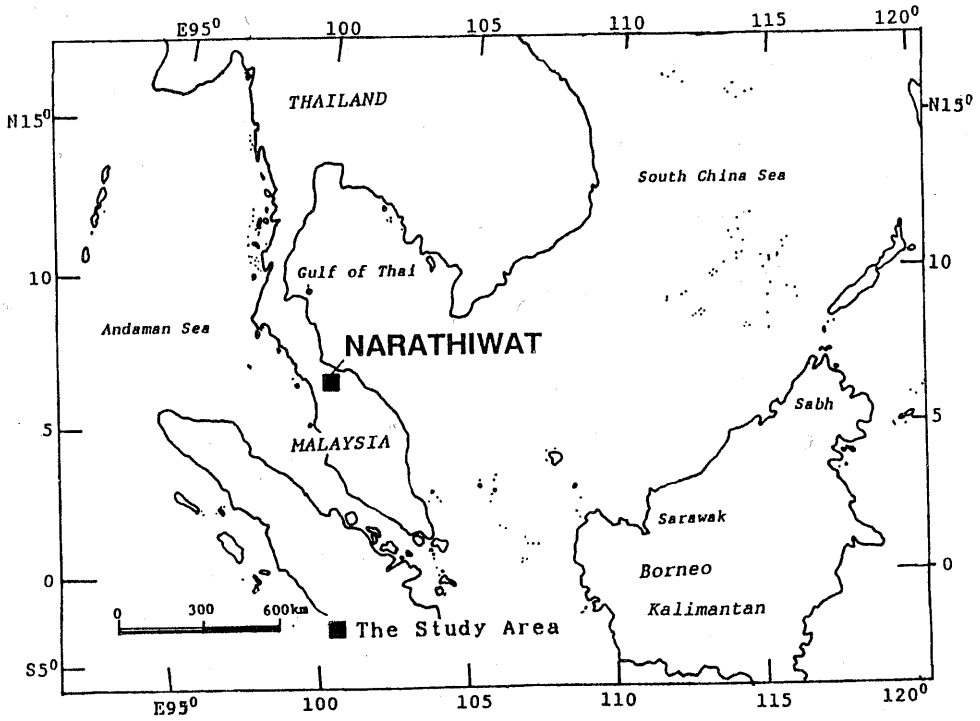

Fig. 2. Map showing the location of the survey area.

Table 1. Data per vegetation type (peat-swamp ecosystem at Narathiwat, Thailand)

Vegetation type(1)	Number of investigated sites	Av. number of species	Height of vegetation(m)	Investigated area(sq.m)	Number of component species	Number of endemic species (2)
TNF1	4	45.8	35-42	1200-1600	94	65
TSF1	2	45	21-22	1400-1500	47	16
TNF2	2	24.5	22	220	32	5
TSF2	5	18.4	6-11	150-300	42	15
TSF3	5	23	9-20	200-500	53	16
Palm1&2	4	10	4-5	25-30	29	5
SS1	7	9.1	1.8-4.5	9-15	18	5
SS2	6	5.8	1.2-2	6-8	10	6
SG1	2	3	0.2-0.3	4	3	0
SG2	4	3.5	0.4-0.8	4-6	6	3
SG3	7	2.8	0.2-0.8	9-12	6	1
SG4	5	3.4	0.4-0.7	9-14	7	1
SG5	3	4.3	0.1-0.15	8-12	7	1
SG6	5	4	0.4-0.6	2-9	9	2
SG7	3	3	0.1-0.2	2-4	5	1
SG8	2	6	0.8-1	12	9	2
SG9	2	6	0.8-2	4-6	9	1
SG10	5	6	0.4-0.7	6-16	9	3
SG11	6	4	0.07-0.1	4-6	5	0
SG12	8	3.7	1.5-2	4-20	6	1
SG13	7	1.6	0.6-0.8	25	4	1

*(1) see the text 2.4, (2) Endemic species means the species which donot occur the other vetetation types.

Table 2. Similarity between Natural forest and the substitutional vegetation.

Vegetation type (1)	Total number of component species 2)	Common species to TNF1
Natural Forest(TNF1)	94	94
Secondary Forest(TSF1)	120	21
Soecndary Forest(TSF2)	130	6
Shrub(SS1)	103	9
Shrub(SS2)	103	1
Secondary Grassland(SG12)	99	1

Location:Peat-swamp ecosystems at Narathiwat, Thailand. Original Data: Suzuki and Niyomdham, 1992.
* (1) see the text 2.4, This means number of indentified species in the natural forest(TNF1) and/or the vegetation.

(TNF 2, on sandy conditions)

2. Secondary Forest

Macaranga pruinosa-community (TSF 1)

Lygodium microphylla-Melaleuca cajuputi-community (TSF 2)

Evodia roxburghiana-Melaleuca cajuputi-community (TSF 3)

3. Palm-Vegetation and Shrubs

Eleiodoxa conferta-Licuala longecalycata-community (Palm 1)

Eleiodoxa conferta-Metroxylon sagus-community (Palm 2)

Lygodium microphyllum-Melastoma malabathricum-community (SS 1)

Rhodomyrtus tomentosa-community (SS 2)

4. Secondary Grassland

Eleocharis congesta-community (SG 1)

Echinochloa stagnina-community (SG 2)

Chrysopogon aciculatus-Rottboellia exaltata-community (SG 3)

Axonopus compressus-Mimosa pudica-community (SG 4)

Isachne confusa-community (SG 5)

Axonopus compressus-Chrysopogon aciculatus-community (SG 6)

Eragrostis malayana-community (SG 7)

Chrysopogon orientalis-Massia triseta-community (SG 8)

Monochoria vaginalis-Fuirena umbellata-community (SG 9)

Scripodendron ghaeri-community (SG10)

Rhynchospora corymbosa-Rottoellia exaltata-community (SG11)

Chrysopogon aciculatus-community (SG12)

Blechnum serratum-Scleria sumatrensis-community (SG13)

The natural peat-swamp forests in Narathiwat were summarized phytosociologically into the *Baccauria bracteata-Endiandra macrophylla*-community. The total number of plant species in the community ranges from 38 to 51 per 1,050-1,600 square meters. The genera *Campnosperma, Horsfieldia, Elaeocarpus, Eugenia,* etc., which normally occur in riparian forests, are found in the community.

In the forests that cover the peat-swamps in Narathiwat, trees over 30m high and large-sized palm plants of a variety of species are observed. Compared with a tropical rain forest, growth is sparse, and depending on the location, sunlight can be seen to reach deeper into the forest. Moreover, the plant layer that grows on the forest floor is very poor, with the exception of tree seedlings and some species of palms. The fact that at least some species of climbers grow to the tree crown, and that there is active photosynthesis occurring in a 5 to 6 m-high layer, mainly in large-sized palms, are characteristic of the peat-swamp forests. Peat is highly acidic, with pH of 3.8-4.3 and extremely oligotrophic. Below the peat is thin layer of black mud, and below this is bluish gray or bleached clay.

Also characteristics are the huge roots of tall trees. In the forests, the development of peculiarly shaped root formations, the so called buttresses, stilt-roots and pneumatophores can be observed, but also in addition, most of the trees have developed several

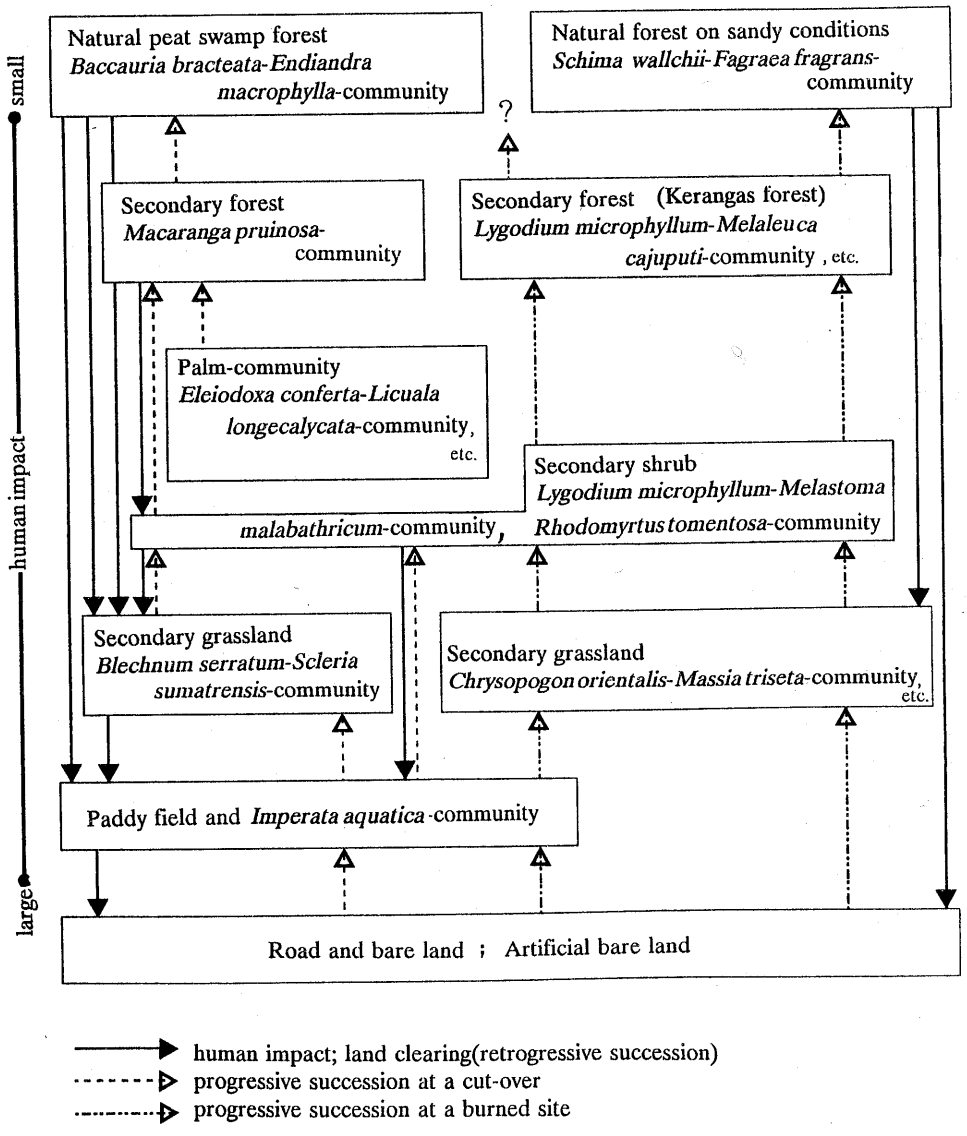

Fig. 3. Community ring on the swampy area at Narathiwat, Thailand. (Suzuki and Niyomdham, 1992).

forms of roots whose sole function is, for example, support or breathing. Occasionally, trees with huge buttress root linkages reaching more than 4 m high are found. Over 90% of the investigated trees with diameter breast height (dbh) more than 10cm had developed some kind of special root linkage form. It can be presumed that the still-root, buttresses and pneumatophore linkages have developed because of several factors, such as the need to support the tree on soft ground, or the need to have an organ to supply the oxygen and nutrients lacking below the water level. From the mangrove forest to the peat forest, the development of unique roots is a distinct characteristic of tropical swamp forests.

Gynotroches axillaris, which a component species of the natural peat-swamp forests (*Baccauria bracteata-Endiandra macrophylla*-community), is like the mangrove forest representative species component *Rhizophora apiculata,* a tree of the Rhizaphoraceae family. It is a relatively small tree, and its occurrence frequency is very low. But as it belongs to the same family as the tree, which is the principal constituents of mangrove forest, it can give interesting information regarding the geo-historical and ecological relationships between the mangrove ecosystem and the tropical swamp ecosystem, or about the ecological equality rank of different plants living in this habitat.

Community rings of Narathiwat swamps

Community rings (Figure 3) are the relationships between the natural and substitutional vegetation in the coastal wetlands of Narathiwat. The upper categories of the figure are less influenced by human activities. The directions of the arrows indicate successive vegetation changes.

Secondary forests consist of a *Macaranga pruinosa*-community, *Lygodium microphylla-Melaleuca cajuputi*-community and an *Evodia roxburghiana-Melaleuca cajuputi*-community. The *Lygodium microphylla-Macaranga pruinosa*-community and *Evodia roxburghiana-Melaleuca cajuputi*-community are dominated by *Macaranga pruinosa* of about 20-25 meters in height, which are widely distributed in peat-swamp areas. The physiognomy and component species of the natural forest community and the secondary *Macaranga pruinosa*-community are similar. However, due to deforestation, cultivation, burning, and pasturage, most of the peat soil disappeared within a short period of time. Deforestation and burning have extensively degraded the swampy vegetation habitat to open woods of *Melaleuca cajuputi* or treeless grasslands (see Figure 4, 5).

When the peat layer was still present, rice cultivation was possible. However, after the loss of the peat layer, ground subsided decreased and the

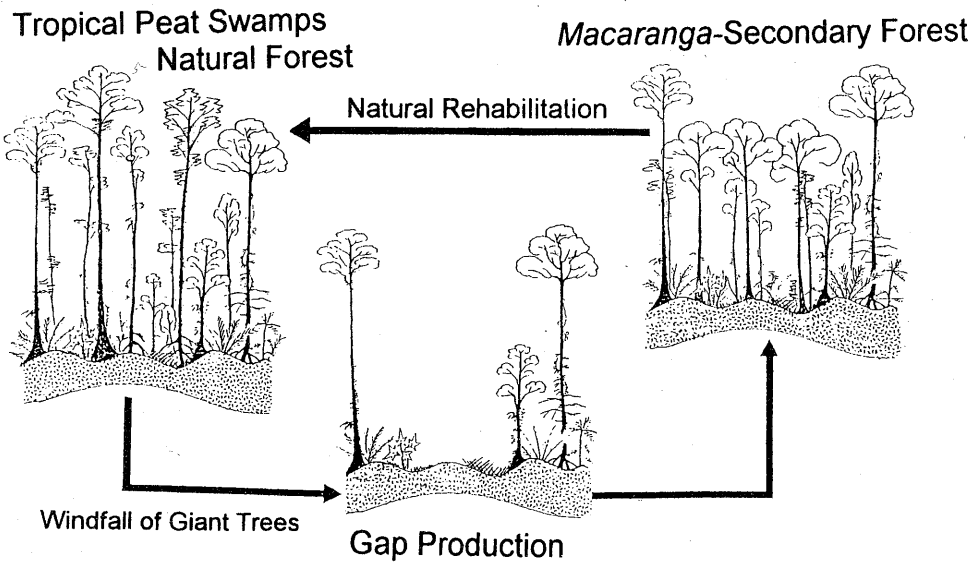

Fig. 4. Gap production of giant trees and its rehabilitation in peat swamp forest ecosystem in Thailand.

composition of the soil changed to contain a higher concentration of sulfates, making the recovery or reconstruction of original vegetation impossible.

BIODIVERSITY AND ECOLOGICAL RISK IN THE TROPICAL SWAMPS

The word 'biodiversity' is a contraction of " biological diversity. " It has become a widespread practice to define biodiversity in terms of genus, species and ecosystems, corresponding to fundamental and hierarchically related levels of biological organization.

Biodiversity is very commonly used as a synonym of species diversity, in particular of 'species richness, ' which is the number of species living in an area or habitat. The ecological importance of a species can have a direct effect on the structure of a community, and on the overall biological diversity. The loss of biological diversity may take many forms, but at its most fundamental and irreversible, it involves the extinction of species within an area.

As argued previously, most the flora and plant communities of Narathiwat swamps are endemic at the country (Thailand), regional (Southeast Asia) and global levels. These indigenous species are significant for the conservation of biodiversity, habitats and characteristic species. They must not be neglected in terms of either quantity or quality. The number of individuals of such species and their habitat must be conserved.

Natural vegetation at Narathiwat

In the natural peat-swamp forests categorized phytosociologically as *Baccauria bracteata-Endiandra macrophylla*-community, four plots (a total of more than 4000 sg. m) were examined and 94 component species were recorded. Within the recorded 94 component species, the development of 65 species has not been detected in other communities. That is, if extinction of *Baccauria bracteata-Endiandra macrophylla*-community in Thailand occurs, there is an ecological risk that of the component species, 74 will become endangered or threatened plant species. Forested wetlands have important roles in global biochemical cycles, supporting fresh-water commercial fisheries, and in providing a place for wildlife of all kinds to flourish.

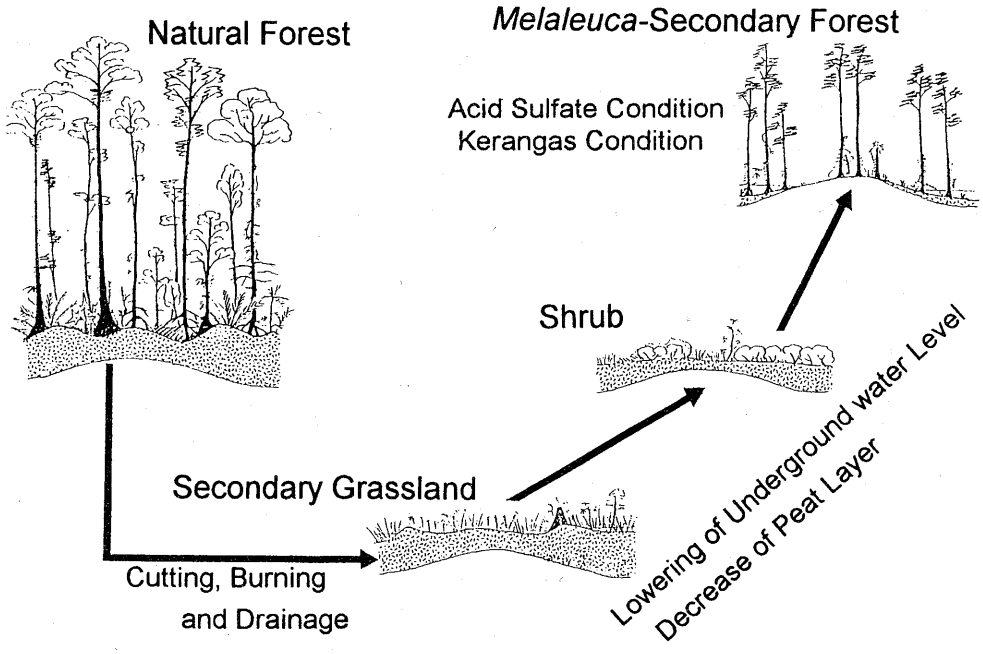

Fig. 5. Degradation process by human impact of peat swamp forest ecosystem in Thailand.

Secondary forest at Narathiwat

In the secondary forests at Narathiwat swampy area categorized phytosociologically as *Macaragna pruinosa*-community, *Lygodium microphylla-Melaleuca cajuputi*-community, and *Evodia roxburghiana-Melaleuca cajuputi*-community, 12 plots were examined and 47, 42 and 53 component species were recorded respectively. Within the recorded component species, the development of 15-16 species at every community has not been detected in other types of communities. Most of the characteristic species of the secondary forests were found in several vegetation types. The habitat of the secondary forests became drier than before. In the *Baccauria bracteata-Endiandra macrophylla*-community (TNF 1) and the *Macaragna pruinosa*-community (TSF 1), 120 component species were recorded totally. Within 120 component species, 21 species were in common. In the *Baccauria bracteata-Endiandra macrophylla*-community (TNF 1) and the *Evodia roxburghiana-Melaleuca cajuputi*-community (TSF 2), 130 component species were recorded totally. Within 130 component species, only 6 species were common. These mean that most of biodiversity of the peat-swamps will extinct as the destruction of the natural forests. The secondary forests will not be the sustainable habitat of the endemic endangered species.

In order to understand why degradation of biodiversity in tropical natural forests, especially in swampy ecosystems, is a problem, in the next section we discuss the relationship between human and green resource.

HUMAN LIFE AND GREEN RESOURCE

Between 1938 and 1987, the population of Thailand increased from 15 million to 54 million. During the same period of time, the area of forest per inhabitant has decreased significantly. The percentage of forest coverage was 72% in 1938, but now it is only 25.62% (131,485 sq. km in1995). Most people living in this region use firewood and charcoal as fuel and wood, making the degradation of the natural resources inevitable. Since the late 1970s, Thailand has imported more wood and wood products than it has exported.

Throughout history, man has put natural resources to practical use by mountain afforestation, moderate wood collection for firewood and charcoal purposes, use of lowland swamps as paddy fields, and collection and cultivation of marine products, but not by depleting these resources. Originally, man and nature did not have a relationship where the former depleted nature's supply of resources.

In Asia, agricultural land use has occurred in a 1- or 2-year cycle, rural use of coppice forests as firewood and charcoal in a 15- to 25-year cycle, and the even longer time range, afforestation has been employed as one more way to use the natural environment. The natural environment also has an ecological role of regulating natural and regional environmental preservation, a role that has not been appropriately assessed until environmental problems became tangible. We think that what will make the sustainable use of land possible, and achieving prosperity and stability for the regional community, is to make good use of the area's unique biological and social characteristics, and to construct diverse relationships between the natural environment and human activity. When discussing deforestation and the degradation of the natural environment degradation that is now taking place in Thailand and other countries, it is important to note that the traditional balance system between nature and man has been broken. Effects of innovations that deplete natural resources can cause immeasurable damage.

It is correct to assume that regions having tropical peat-swamp forests had, since long ago, the wisdom to save a great portion of peat-swamp areas as a method of preserving natural resources.

The best approach for development planning/ management of the tropical swampy areas is to combine the known tools of physical resource assessment and evaluation with traditional and novel approaches in economic valuation and analysis. This combined approach considers the ecological integrity of natural ecosystems while at the same time sustaining resources at optimal levels. This "eco-development" scheme considers both the trade-offs between ecology and economics for any type of allowable development in the humid tropics. The negative and positive effects of development on the tropical ecosystem are measured and evaluated in

both the long and short term. "Non-market" natural goods and services in addition to "ecological intangibles" are expressed in both qualitative and quantitative terms for planning/management purposes.

Tropical swamp forests are considered to be important ecosystems in tropics. To make optimum use of swamp-forest ecosystems, and promote the sustainable use of regional ecosystems, in other words, employing the knowledge gained by green, is the right way forward, and will ultimately lead to appropriate development of a symbiotic relationship between the man and the environment, that is the appropriate development.

SUMMARY

1. Peat-swamps are prevalent in low latitude areas of the humid tropics. 27% of the world's swamps are located in the tropics.
2. The peat-swamp vegetation at Narathiwat, Thailand was classified into 22 communities.
3. In the natural peat-swamp-forests categorized as the *Baccauria-bracteatat-Endiandra macrophylla*-community at Narathiwat, Thailand, 65 species out of 94 component species were innate in the natural forests. The development of 65 species has not been detected in other types of vegetation.
4. The best approach for development planning/ management of the tropical swampy areas is to combine the known tools of physical resource assessment and evaluation with traditional and novel approaches in economic valuation and analysis.

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