UNIVERSITI PUTRA MALAYSIA

REGENERATION POTENTIAL OF THE NORTH SELANGOR PEAT SWAMP FOREST (NSPSF)

MOHD. PUAT BIN DAHALAN

FH 2001 18

REGENERATION POTENTIAL OF THE NORTH SELANGOR PEAT SWAMP FOREST (NSPSF)

MOHD. PUAT BIN DAHALAN

MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA
2001

UPM

REGENERATION POTENTIAL OF THE NORTH SELANGOR PEAT SWAMP FOREST (NSPSF)

By

MOHD. PUAT BIN DAHALAN

A project report submitted in partial fulfillment
of the requirements for the Degree of Master of Science
(Tropical Forest Resource Management)
in the Faculty of Forestry, Universiti Putra Malaysia

April 2001

UPM

ACKNOWLEDGEMENTS

IN THE NAME OF ALLAH THE MOST GRACIOUS MOST MERCIFUL

Many people were involved in this project and contributed to its success. First and foremost I would like to extent my greatest thanks to my supervisor, Dr. Mohd. Zaki bin Hamzah and my examiner Assoc. Prof. Dr. Awang Noor bin Abd. Ghani for their guidance and supports throughout the study and preparation of this project paper.

I am most grateful to Y. Bhg. Datuk Zul Mukhshar bin Dato' Md. Shaari, Director General Forestry Department Peninsular Malaysia, Mr. Shaharuddin bin Mohamad Ismail, Deputy Director General Forestry Department Peninsular Malaysia (Forest Operation) and Mr. Thang Hooi Chew, Deputy Director General Forestry Department Peninsular Malaysia (Planning and Development) for their espousal and encouragement throughout my period of study.

Thanks are also extended to Mr. Razani bin Ujang, State Director of Forestry, Selangor and his officers for their cooperation and support in making possible the field inventory exercise.

I would also like to express my sincere gratitude particularly to Tuan Hj. Dahlan bin Taha, Dr. Borhan bin Mohd, Dr. Shamsuddin bin Ibrahim, Dr. Abd. Rahman bin Kassim and Mr. Ismail bin Parlan for their professional advice during the preparation of this manuscript.

Acknowledgements are also due to Mr. Abd. Wahid bin Md. Saleh, Zulkifli bin Zakaria and Hj. Masuri bin Abd. Manan for their excellent printed maps of the North Selangor Peat Swamp Forest.

Special thanks are deserved by Assoc. Prof. Dr. Faridah Hanum bt. Ibrahim for her invaluable advice especially prior my enrollment to Universiti Putra Malaysia (UPM).

I am very much indebted to Mr. Gan Boon Keong and his family members for their kindness, support and courage that helped make my study a successful endeavour.

Finally, my utmost appreciation and respects are due to my wife Che Rosnah bt. Saidin and our wonderful kids Ahmad Qamaruzzaman, Siti Shahirah, Ahmad Taufiq, Nurul Husna, Luqman Hanif, Nur Shamimi Raihan and Nur Aisya Mazween for their support, patience and sacrifices throughout the period of my study.

May Allah S.W.T. bless you all.

SPECIALLY DEDICATED TO MY :

BELOVED PARENTS, WIFE AND KIDS
YOU ARE ALWAYS PART OF MY SUCCESS

TO MY KIDS:
(ABAH SAYANG KAMU SEMUA)

TABLE OF CONTENTS

CONTENT	PAGE
TITLE PAGE	
APPROVAL SHEET	
ACKNOWLEDGEMENT	i
DEDICATION	ii
LIST OF TABLES	v
LIST OF FIGURES	viii
ABSTRACT	x
ABSTRAK	xi
CHAPTER ONE - INTRODUCTION	1
General Background	1
Objectives of Study	5
Justification of Study	6
Depleting Resource	6
Social Economic Importance	6
Fragile Ecosystem	6
Management of the Resources	7
CHAPTER TWO - LITERATURE REVIEW	9
The Formation of Peat Swamp Forest	9
Geographic Distribution	10
The Extent of Peat Swamp Forest in Malaysia	12
Vegetation and Stand Structure	18
Species Diversity	19
Tree Density	21
Regeneration	23
Management of the Peat Swamp Forest	24
CHAPTER THREE - RESEARCH METHODS	27
General Description	27
Location of Study Site	28
Historical Utilisation of NSPSF	31
Inventory Design	33
Distribution of Inventory Plots	35
Field Sheet	36
Field Checks and Verification	36
Data Processing and Analysis	36

CHAPTER FOUR - RESULTS AND DISCUSSIONS.....38
Stand Analysis.....38
General Stand Structure 38
Distribution of Stems per Hectare
for All Forest Classes by Size Class 44
Quality of Poles 48
Number of Stems Per Hectare (sph)
by Timber Density Group.....49
DBH Distribution of Poles
by Timber Density Group 51
Distribution of Poles
by Species Group.....53
DBH Distribution of Poles
by Species Group.....55
DBH Distribution of Poles
by Forest Class 56
DBH Distribution of Poles by Species.....59
Availability of Seedlings.....61
Distribution of Larger DBH Trees.....66
Relationship Between the Number of Trees and Size Class 68

CHAPTER FIVE - CONCLUSION & RECOMMENDATIONS.....77
Conclusion.....77
Recommendations.....79

References.....81

LIST OF TABLES

TABLE	TITLE	PAGE
1	Estimate of peat soil resource in Southeast Asia (excluding Malaysia)	11
2	Distribution and extent of major forest types in Malaysia, 1999 (Million ha)	13
3	The extent of conversion of peat swamp forest in Peninsular Malaysia	17
4	Comparison of species composition of selected families between the peat swamp forests in Pahang and Selangor	19
5	Species composition/diversity in several sites in Peninsular Malaysia	23
6	Operations to be carried out as part of selective felling system (SFS)	26
7	North Selangor Peat Swamp Forest Classification	30
8	Summary of the stems per hectare (sph) of the different species and sizes in Forest Class 1 for size class 5.0 – 14.9 cm dbh	40
9	Summary of the stems per hectare of the different species and sizes in Forest Class 2 for size class 5.0 – 14.9 cm dbh	40
10	Summary of the stems per hectare of the different species and sizes in Forest Class 3 for size class 5.0 – 14.9 cm dbh	41
11	Summary of the stems per hectare of the different species and sizes in Forest Class 4 for size class 5.0 – 14.9 cm dbh .	41

12	Summary of the stems per hectare of the different species and sizes in Forest Class 5 for size class 5.0 – 14.9 cm dbh	42
13	Summary of the stems per hectare of the different species and sizes in Forest Class 6 for size class 5.0 – 14.9 cm dbh	42
14	Summary of the stems per hectare of the different species and sizes in Forest Class 7 for size class 5.0 – 14.9 cm dbh	43
15	Summary of number of stems per hectare by diameter class and forest class.....	43
16	Number of stems per hectare for all forest classes by Size Class (expressed in %).....	45
17	Number of stems per hectare for all forest classes by size class.....	47
18	ANOVA species group by strata (unique method).....	47
19	No. of stems per hectare by quality for all forest classes expressed in percentage.....	48
20	Number of trees per hectare based on timber group	50
21	Dbh of poles inventoried for all forest classes by timber density group for size class dbh 5.0 – 14.9 cm	52
22	No. of stems/ha by forest class and species group for size class 5.0 – 14.9 cm dbh	54
23	Dbh of poles inventoried for all forest classes gouped under dipterocarp and non-dipterocarp for dbh size class 5.0 – 14.9 cm.....	55
24	Mean dbh of poles for all species inventoried by forest class for dbh class 5.0 cm to 14.9 cm	56
25	ANOVA between forest classes	58

26	Multiple comparison of mean dbh using Duncan range test .	58
27	Mean dbh of poles inventoried for all forest classes by species for dbh class 5.0 – 14.9 cm	60
28	Number of seedlings per hectare by forest class.....	62
29	Number of dipterocarp and non-dipterocarp seedlings per hectare by forest class	64
30	Ranking of first 15 species for all forest classes by highest occurrence number of seedlings per hectare	65
31	Number of trees per hectare by size class and forest class	66
32	Summary of statistics by forest class for dbh class 15.0 cm and above.....	67
33	ANOVA between and within forest class for dbh class 15.0 cm and above	67
34	Results of non-linear regression analysis.....	70
35	q-values based on forest class.....	71

LIST OF FIGURES

FIGURE	TITLE	PAGE
1	Location of peat swamp forests in Peninsular Malaysia	15
2	Location of peat swamp forests in Sabah and Sarawak	16
3	Plot design and measurement specifications	33
4	Inventory field sheet	37
5	Number of stems per hectare for all forest classes by size class	45
6	No. of stems per hectare by quality for all forest classes	49
7	No. of trees per hectare by timber groups	51
8	Mean dbh of poles inventoried for all forest classes by timber density group for size class dbh 5.0 – 14.9 cm	53
9	No. of stems per hectare by forest class and species group for size class 5.0 – 14.9 cm dbh	54
10	Mean dbh of poles for all species inventoried by forest class for dbh class 5.0 cm to 14.9 cm	57
11	Mean dbh of poles inventoried for all forest classes by species for dbh class 5.0 – 14.9 cm	60
12	Number of seedlings per hectare by forest class	62
13	No. of dipterocarp and non-dipterocarp seedlings per hectare by forest class	64
14	Number of trees per hectare by size class and forest class	67

15 Observed and predicted non-linear regression of no. of trees and dbh Class (Forest Class 1) 72

16 Observed and predicted non-linear regression of no. of trees and dbh Class (Forest Class 2) 72

17 Observed and predicted non-linear regression of no. of trees and dbh Class (Forest Class 3) 73

18 Observed and predicted non-linear regression of no. of trees and dbh Class (Forest Class 4) 73

19 Observed and predicted non-linear regression of no. of trees and dbh Class (Forest Class 5) 74

20 Observed and predicted non-linear regression of no. of trees and dbh Class (Forest Class 6) 74

21 Observed and predicted non-linear regression of no. of trees and dbh Class (Forest Class 7) 75

22 Observed non-linear regression no. of trees and dbh class (All Forest Classes) 76

23 Predicted non-linear regression no. of trees and dbh class (All Forest Classes) 76

ABSTRACT

Peat Swamp Forest is known for its unique ecosystem and having a high proportion of endemic species. The logging activities in peat swamp forests has significant impacts on residual trees. A study was undertaken to determine the status of regeneration of logged-over forest of a peat swamp forest in Selangor. The study was conducted in the North Selangor Peat Swamp Forest (NSPSF), covering an area of approximately 72,816 hectares. The NSPSF was classified by the Forest Department to 7 categories of Forest Classes based on crown coverage. Based on this forest classification, a forest management inventory was carried out using cluster sampling technique. A total of 550 plots arranged in 110 clusters were randomly located within the seven forest classes. Data on tree species, diameter at breast height, height, quality of poles, etc. were collated.

Results show that the number of stems per hectare (sph) for size class 5.0 cm diameter at breast height (dbh) and above and size class 5.0-10.0 cm dbh are in Forest Class 5. Whereas for size class 10.1-14.9 cm dbh the highest number of sph is in Forest Class 4. The lowest number of sph for all size classes are in Forest Class 7. It is also found that more than 80% of the inventoried poles in all the Forest Classes are of Quality 1 and 2. As for poles of Quality 3 and 4, the highest percentage is in Forest Class 5 and the lowest in Forest Class 4. The number of seedlings per hectare are generally high with Forest Class 5 recording the highest at 19,621 and the lowest in Forest Class 7 at 7,133. The stocking of dipterocarp seedlings is very small with respect to all Forest Classes i.e. between 0 per cent in Forest Class 7 to 2.81 per cent in Forest Class 6. The non-dipterocarp seedlings seem to dominate all Forest Classes in the NSPSF with an overall percentage of more than 97.0 per cent. The NSPSF suprisingly possess high q-value, calculated at an average of 1.73. The highest being recorded for Forest Class 4 at 1.93 and the lowest for Forest Class 7 at 1.65.

The results of this study show that the NSPSF appears to have most of the elements of a forest undergoing regeneration process. Based on the q-value findings, the NSPSF has a good representation of smaller diameter size trees for all Forest Classes, thus further supporting the fact that the NSPSF is in a dynamic stage of recovering from the effect of forest disturbance. The only element which is absent as compared to a natural successional Peat Swamp Forest, is the lacking of sufficient number of high value commercial species for all size classes, which in this case refers to *Shorea uliginosa, Gonystylus bancanus, Kompassia malaccensis* and *Shorea platycarpa*. Some suggestions for future management of this type of forest are also highlighted.

ABSTRAK

Hutan paya gambut dikenali melalui ekosistemnya yang unik serta mempunyai bilangan spesies endemik yang tinggi. Aktiviti pembalakan yang dijalankan di dalam hutan paya gambut memberi impak ketara kepada pokok-pokok tinggal. Satu kajian telah dijalankan bagi mengenalpasti status regenerasi hutan paya gambut dibalak di negeri Selangor. Kajian ini dijalankan di Hutan Paya Gambut Selangor Utara (HPGSU), yang meliputi kawasan seluas lebih kurang 72,816 hektar. HPGSU diklasifikasikan oleh Jabatan Perhutanan kepada 7 kategori Kelas Hutan berdasarkan kepada litupan silara. Berdasarkan pengkelasan hutan ini, satu inventori pengurusan hutan dijalankan menggunakan teknik pensampelan kluster. Sejumlah 550 plot diatur di dalam 110 kluster dan ditentukan secara rawak di dalam tujuh Kelas Hutan. Data mengenai spesies, perepang paras dada, ketinggian, kualiti jaras, dan lain-lain telah diperolehi.

Keputusan menunjukkan bilangan pokok sehektar (bps) tertinggi bagi kelas saiz 5.0 sm perepang paras dada (ppd) dan ke atas dan kelas saiz 5.0 – 10 sm ppd adalah di dalam Kelas Hutan 5. Namun, bagi kelas saiz 10.1 – 14.9 sm ppd bilangan bps tertinggi adalah di dalam Kelas Hutan 4. Bilangan terendah bps bagi semua kelas saiz adalah di dalam Kelas Hutan 7. Didapati lebih daripada 80% jaras yang diinventori bagi semua Kelas Hutan adalah dari Kualiti 1 dan 2. Bagi jaras yang mempunyai Kualiti 3 dan 4, peratus tertinggi adalah di dalam Kelas Hutan 5 dan yang terendah adalah di dalam Kelas Hutan 4. Bilangan anak benih sehektar umumnya adalah tinggi dengan Kelas Hutan 5 mencatatkan jumlah tertinggi iaitu 19,621 dan terendah di dalam Kelas Hutan 7 iaitu 7,133. Stok anak benih dipterokarpa adalah rendah bagi semua Kelas Hutan di HPGSU iaitu di antara 0% di dalam Kelas Hutan 7 kepada 2.81% di dalam Kelas Hutan 6. Anak benih bukan dipterokarpa mendominasi semua Kelas Hutan di HPGSU dengan peratus keseluruhan melebihi 97.0%. HPGSU memiliki nilai-q yang tinggi, iaitu pada kadar purata 1.73. Kelas Hutan 4 mencatatkan nilai-q tertinggi iaitu 1.93 dan yang terendah oleh Kelas Hutan 7 iaitu 1.65.

Hasil kajian menunjukkan HPGSU mempunyai elemen bahawa hutan ini sedang melalui proses regenerasi. Berdasarkan nilai-q yang diperolehi, HPGSU mempunyai representasi yang baik bagi pokok-pokok bersaiz jaras bagi semua Kelas Hutan, ini menyokong fakta bahawa HPGSU adalah di dalam peringkat dinamik kesan pemulihan akibat gangguan ke atas dirian hutan tersebut. Elemen yang masih tercicir jika dibandingkan dengan sesaran semulajadi hutan paya gambut, adalah kekurangan dari segi bilangan spesies komersil bernilai tinggi di dalam semua kelas saiz, di mana dalam kes ini merujuk kepada *Shorea uliginosa, Gonystylus bancanus, Kompassia malaccensis* dan *Shorea platycarpa*. Beberapa cadangan untuk pengurusan masa hadapan bagi hutan ini turut di utarakan.

CHAPTER ONE

INTRODUCTION

General Background

Forest is a highly valuable economic resource in many developing countries particularly in the tropics. In addition to its main role of providing timber for domestic use and export, it also provides a wide range of intangible goods and services including protection of environmental conditions, biodiversity conservation, recreation, education, and research activities. The tropical forest has been recognised as a genetic reservoir and repository of many plant species of pharmaceutical significance where further research needs to be conducted. Very often tropical forests in developing countries are being exploited for short-term financial gains without paying attention to long-terms economic and environmental benefits. This has resulted in unsustainable that leads to extensive degradation of the tropical forest areas.

Since the establishment of the Forestry Department in 1901, the forests in Peninsular Malaysia have been systematically managed. Over the years,

ecologically and environmentally-sound forest conservation and management practices have also been developed and implemented to ensure sustainable production of forest goods and services and continuous forest renewal. For instance, the lowland and hill dipterocarp forests in Malaysia have been systematically managed under the Malayan Uniform System (MUS) and the Selective Management System (SMS), respectively. Both systems were introduced in the late 1940's and late 1970's respectively, aimed towards a sustained yield forest management so that timber production can be carried out in perpetuity and without the lost of other services (Wyatt-Smith, 1995). Comprehensive guidelines on these two systems were developed by the Forestry Department of Peninsular Malaysia (Thang, 1987; Wan Razali, 1994). At present, the SMS is being practiced for the management of hill dipterocarp forest in Peninsular Malaysia.

The forests in Malaysia are classified according to their ecological and physical conditions into montane, lowland and hill dipterocarps, peat and freshwater swamp, and mangrove forests (Wyatt-Smith, 1995). Lowland and hill dipterocarp forests have always been the most important especially for timber production in Peninsular Malaysia. However, the extent of lowland diterocarp forests have declined considerably due to rapid conversion to other land uses. The extent of the remaining lowland dipterocarp forests in the country is not known precisely and

since late seventies they ceased to be a major source of timber (Shamsudin, 1997).

With regards to peat swamp forest, sustainable management and conservation has attracted much attention at both national and international levels. Peat swamp forest is known for its unique ecosystem with high proportion of endemic timber species thriving in water-logged, anaerobic and nutrient-deficient areas (Wyatt-Smith, 1995). Many of these endemic species have high quality timber values.

It is the preponderance of high quality commercial timber species as well as the services it provides that supports the retention of the remaining peat swamp forests for long-term forestry management. Although peat swamp forests have been regularly logged for timber production, the productivity in terms of stocking per hectare of trees greater than 40 cm dbh and estimated timber volume is low compared to dryland forests in Peninsular Malaysia (Wyatt-Smith, 1995).

Currently, SMS as a system for managing the natural forest has been extended to peat swamp forests in Peninsular Malaysia. SMS is basically a forest management system based on minimum diameter cutting limits. In the peat swamp forests, the cutting limits of 45.0 cm dbh and above for all species, as being practiced in the hill forest has also been applied here. Such an approach can only be considered arbitrary and has not been derived from any scientific

considerations such as the dynamics of the forests, species distribution patterns, regeneration, growth characteristics, logging system, and so forth. None of these factors have been examined in detail in the peat swamp forests, thus contributing minimum input to the formulation of the current management practices.

Without an appropriate system, the management of the forest resource may lead to a level of degradation whereby the forest cannot regenerate fast enough to meet the expectation of the system requirement, wholly in relation to the rotation age. In any case, the degree of destruction is closely associated with the method and intensity of logging. In the past, timber species harvested were highly selective since logging were carried out manually resulting in a minimal damage to residual stands. But now major changes have taken place in harvesting operations of the peat swamp forests in Peninsular Malaysia, in particular with the introduction of suitable heavy machinery such as traxcavator to extract timber out of the forest. The use of this machine has been regarded as being more efficient and cost-effective since more timber can be harvested and removed from the interior of peat swamps, once considered inaccessible and difficult through manual timber harvesting technique. However, the damage to the forest stand is still severe, especially along extraction routes (Chan, 1990), but it has never been quantified. It has been observed that an excessive removal of large trees creates large gaps which promote rapid colonisation by non-commercial tree species such as *Ilex macrophylla*, *Syzygium* spp. and *Macaranga* spp. (Chan, 1990).

PERPUSTAKAAN
UNIVERSITI PUTRA MALAYSIA

The location of peat swamp forest, which is relatively near to human settlements has often resulted in its utilisation and development by state or the local villagers. The North Selangor Peat Swamp Forest (NSPSF) is a typical example of utilisation of peat swamp forest for various purposes such as agriculture, timber harvesting, hunting, and etc. Forest utilisation often affects local livelihood of residents in the vicinity. While much studies only focused on the forest management aspects of NSPSF, there is a general lack of research on the regeneration potential of the peat swamp forest.

Objectives of Study

The general objective of this study was to assess regeneration potential of the logged over North Selangor Peat Swamp Forest (NSPSF).

The specific objectives of the study were:-

i. To examine the stand structure and status of species composition of logged-over peat swamp forest in North Selangor Peat Swamp Forest.

ii. To determine the regeneration potential of the NSPSF and to recommend silvicultural options.

Justification of Study

Depleting Resource

Since the Malaysian Independence (1957) large areas of peat swamp forest have been converted for agricultural and other development purposes (Appanah, *et al.*, 1989; Appanah 1997). It was estimated that the peat swamp forests in Peninsular Malaysia have been reduced from 0.67 million ha in 1981 to 0.34 million ha in 1992 (Shamsuddin, 1997). In the state of Selangor alone, the area of peat swamp forests has been reduced from 122,000 ha in 1954 to 76,134 ha in 1997, a decline of 45,866 ha or 38% in 43 years (Shamsuddin, 1997; Appanah, 1999).

Social Economic Importance

Local communities make use of resources in NSPSF for various purposes, i.e. settlement, agricultural cultivation, fishing & hunting, and harvesting of non-timber forest products (NTFP). The peat swamp forest has been well known for its ecological function such as water retention, flood control, carbon sink, and so forth. Hence, the health of peat swamp forests need to be closely monitored and enhanced wherever possible to ensure its service is perpetually functional.

Fragile Ecosystem

Peat swamp forest is a unique ecosystem that are characterised by the accumulation of organic matter, which is produced and deposited at a greater rate

than it is decomposed, leading to the formation of peat (Gore, 1983). Thus, peat swamp forest comprised a few basic components, i.e. soil, peat, plant communities and the area is constantly inundated or saturated by surface water or groundwater (Paavilainen, 1995). Eliminating one of these components will immediately upset the whole ecosystem which certainly lead to further deterioration of the ecosystem itself such as loss of the capability of water retention, disturbing the growth and dispersal behaviour of plant communities, draw the potential of forest fire occurrence and so forth. Once the ecosystem is being upset it will take longer period to recover. Therefore, this fragile ecosystem needs a better understanding of its functions so that it can be managed without undue deterioration to the ecosystem.

Management of the Resources

The peat swamp forest is a renewable resource and its productivity can be maintained for longer period provided that it is managed based on scientific approach. Otherwise, the stocking tends to deteriorate and yield decreases after the first rotation. Forests are dynamic biological systems that are continuously changing. Unfortunately, so far little study has been done with regard to the regeneration potential of the peat swamp forests.

Theoretically, the regeneration status of the second rotation could be comparatively lower for the harvested peat swamp forests than the inland forests

due to its harsh ecosystem. This is because the heap of peat could be very thick and acidic which is resistant to seedling growth. Moreover, the deterioration of forest productivity may also be due to colonisation by pioneer species. It was observed that species such as *Ilex macrophylla*, *Syzygium* spp. and *Macaranga* spp. very adaptable to such condition will immediately colonise and increase their presence in clear felled peat swamp forests areas (Chan, 1990).

This study is also expected to help improve understanding of the silvicultural operations, and consequently improve the productivity of the peat swamp forest areas. Appropriate management system needs to be formulated to meet all present and future challenges. One of the most important factors of a good management system is the potential of the forest to regenerate within a specified time period.

CHAPTER TWO

LITERATURE REVIEW

The Formation of Peat Swamp Forest

The name 'peat swamp forest' still reflects an initial confusion between the freshwater swamp and the peat swamp forest in which rain is the only source of water. Hence, the peat swamp forest is always restricted to an ever-wet climate, to flat terrain and to substrates that are extremely poor in minerals. Peat swamp forest is one succession stage of mangrove forest and also freshwater swamp forest (Jacobs, 1978). It develops on peat which in turn often rest on stiff, impenetrable clay, originally covered with mangrove or freshwater swamp forest. Because of the low percentage of oxygen which the water contains, and the low pH which results from the lack of minerals it obstructs the natural process of decomposition of the litter. In general, peat in its natural state is considered infertile with high acidity (pH between 3 – 5) and has poor plant nutrients reserve (Vimala, 1979). As a result of the slow process of decomposition, gradually the peat soil formation rises above the original water level, a process which aggravates the lack of mineral nutrients (Jacobs, 1978). In the highly oligotrophic centre which is found on the highest elevations, the small quantity of litter available is almost

entirely converted into peat. Therefore peat can be defined as organic matter derived from vegetation having 25% or less inorganic matter on a dry mass basis. Peat typically consists of more or less fragmented plant residues sequentially deposited (Paavilainen, 1995). In the lower areas, close to the margins, several factors (such as occasional inundation by river water) may cause some decomposition of organic matter. The result is the development of lenticular peat areas, varying from few to many kilometres in diameter, and up to 15.0 and even 20.0 m deep (Shamsudin, 1997).

Each lenticular peat bog forms a separate ecological entity. The vegetation on such lenses can be divided into more or less concentric zones. On the outer edges mixed rain forest grows, whereas in the centre, on top of the faintly convex peat formation, a stunted, extremely poor forest grows. From the edges to the centre one sees the flora change in an irregular manner into a poorer type Shamsudin (1997).

Geographic Distribution

It is being estimated that worldwide peat soils cover some 436.0 million hectares out of which about 38.0 million hectares are found in tropical regions. On the other hand, in tropical Asia alone an estimated area of about 24.9 million hectares are covered by peat land, while the corresponding areas amounts to 4.9 and 8.7 million hectares in Latin America and Africa respectively. Today, only part of these