TWENTY-FIVE YEARS EXPERIENCE IN PEATLAND DEVELOPMENT FOR AGRICULTURE IN INDONESIA

Tejoyuwono Notohadiprawiro

Tropical peat was first discovered by Kooders in 1895 in a swamp forest along the east coast of Sumatra. The extent was estimated then at almost one-fifth of the total area of Sumatra. A more extensive exploration afterwards discovered an immense areas of thick peat on the west and south coastal plains of Kalimantan and on the south coastal plain of Irian Jaya. Including the peat area on the coastal plains of Malaysia, the area of tropical peat in this part of the world is perhaps the largest ever found (Polak, 1950).

The discoveries deny the at the time trusted theory that peat can only be formed in a low temperature environment, thus a specific formation of temperate and cold climates. The Indonesian findings have proved beyond question that temperature is not the sole factor of peat formation. Peat can be formed also in high temperature regimes in places where an oxygen-scarce environment exist, associated with a waterlogged condition occurring yearly over a long period.

Recently another mode of peat formation has been observed among others in Central Kalimantan, where peat exists in upland condition. In such an area peat is found overlying a mineral substratum poor in nutrients. The vegetation which grow in such a medium tend to produce a biomass containing more lignin and less ash constituents, carbohydrates, and water soluble proteins. More nitrogen is fixed in the stable lignoprotein compound. The specific composition of the biomass results in a less biodegradable organic matter, thus leading to the accumulation of peat.

The Indonesian findings have contributed importantly to the expansion of the theory of peat formation to cover the three principles of low temperature, of oxygen scarcity, and of nutrient deficiency.

Since tropical peat has been associated uniquely with waterlogged condition, it has been postulated that only topogenous peat can exist in the tropics. If ombrogenous peat may develop in a tropical climate, the temperate climate theory dictates that its occurrence

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will be restricted to high altitude areas where *Sphagnum* moss may be found rather generally. The Indonesian facts told us another story. Many parts of the coastal swamps of Indonesia are covered by ombrogenous peat with its typical dome-shaped relief. Evidently the presumed role of *Sphagnum* moss can be replaced by tropical forest plants, (Polak, 1950).

**Conception of Peatland for Agriculture Production in Indonesia**

The theory of oxygen scarcity of peat formation implies that the lowering of groundwater to improve aeration in the rooting zone will incite the shrinking and subsidence of the peat. The theory of nutrient deficiency of peat formation implies that fertilization and/or liming to improve the nutrient status of the peat will accelerate the cultivation may degrade peatlands. But on the other hand the agricultural potential of these lands, especially for lowland rice, cannot be ignored. The points in favor of peatland cultivation are: (1) the needed water is already there naturally, so that no high-cost schemes to bring in water are required, (2) the immensity of the area comprising million of hectares making them a real national asset, (3) they may be developed by applying just simple techniques like the traditional canalling systems of the Banjarese and Buginese, thus they lend themselves to small-farming enterprises one for preservation.

The two opposing views of peatlands use, one is concerned about the safety of peatlands while the other is looking more at the advantages of peatland development, have complicated the formulation of peatland use policies ever since. Whatever the decision may be, it should address the whole system tidal swamp land. Most of the Indonesian peatlands are found in coastal areas, thus ecologically they constitute a subsystem of the entire system of tidal swamp lands. In addition, the distribution pattern of peatlands within the area of tidal swamp land is not clearly definable. Therefore, to manage peatlands apart from the other parts of tidal swamp land will give no added advantage.

Tidal swamp land development efforts already begun at the beginning of the twentieth century. Indonesia faced a rice shortage during and just after World War I. The first to attract the attention of the colonial government was the coastal swamp lands of Kalimantan, where the Banjarese succeeded in producing rice supplies with their traditional water control system of the so-called "sawah bayar". This had set off a comprehensive exploration of the tidal swamp plain of south coast of Kalimantan. The
objective to know more about the bayar system and its soil requirements. The work started in 1936 through 1937 by van Dijk, and continued covering a larger area by van Wijk in 1938-1941. The effort to expand land for lowland rice production was put in line with colonization/transmigration program of Javanese and Madurese to other islands (van der Voort, 1951; van Mijk, 1951).

In the 1960s Indonesia again was challenged by a rice shortage, this time more serious, to become the world's largest importer. Various intensification programs lowland rice on Java to increase the total production of this staple food had not succeeded as expected because of the limited availability of land with adequate irrigation facilities. Once again we turned to the tidal swamps for a ready solution. Much more efforts was then put on the development of these land, using a more systematic, soil science approach, and involving much large areas of Sumatra, Kalimantan and Irian Jaya. This time the source of inspiration was the traditional technique of the Buginese. It became a national program of the highest priorities, started in 1968 and lasted until around 1983. It was then continued until today with in depth studies in some selected areas. The program was also executed in association with transmigration to settle experience farmers, in lowland rice cultivation on the newly developed lands.

Although entirely different in political situation, the two development efforts, one under colonial rule and the other under a national government, show two striking similarities: (1) the act was motivated by food shortage and exemplified by technological product of a traditional R & D system, and (2) the objective was in fact regional development as it combined increasing agricultural production with mitigating population distribution.

In a further development, the improved Buginese traditional system of water control had been coupled with the Javanese traditional system of water management known as the "surjan system". The Buginese system controls water at a zonal scale. The result is astonishing. Not only rice can be grown, but palawija (secondary crops) and vegetables as well. It became possible to establish perennials like fruit trees, coconut, coffee, and clove.
Agricultural Value of Lowland Peatland

The inherent conditions of lowland or wetland peatlands that directly constrain agricultural development efforts are:

1. The susceptibility to change of the physical, chemical, and biological properties of peat following removal of the natural vegetation and drainage, leading to:
   - subsidence
   - accelerated decomposition of organic matter
   - desiccation which may develop irreversible hydrophobicity in peat
   - very strong acidification of peat if it contains enough sulphidic compounds to produce a large amount of sulphuric acid upon oxidation.

2. Extremely rapid lateral water conductivity which accelerates the leaching of nutrients into natural streams or drainage channels.

3. Very slow upward water conductivity, restricting the water supply to the rooting zone.

4. Small effective rooting volume, especially in fibric peats which contain much wood.

5. Weak load-bearing capacity, enabling only limited access and causing canopy tree instability.

6. High heat capacity and slow heat conductivity causing, in open spaces, large variations in surface temperatures over short distances.

(Soepraptodihardjo & Driessen, 1976; Notohadiprawiro, 1987)

Drajad, et al., (1986) reported an average monthly subsidence rate of an initially 45-63 cm thick sapric peat in Barambai (South Kalimantan) of 0.36 cm during period of 12-21 months after hydroreclamation. In Talio (Central Kalimantan) the figure in an initially 180-240 cm thick sapric peat was 0.78 cm, whereas in an initially 179-236 cm thick hemic-sapric peat it was 0.9 cm. Apparently, the thinner and/or the more decomposed the peat is, the slower the subsidence rate is. A slower subsidence rate in more decomposed peat was reported also from Sumatra by Haridjaja & Herudjito (1979). This may be related to the more stable structure acquired by thinner and more decomposed peats. This means that those peats are better adapted for agriculture.

That more mature peats have a more stable structure was experimentally proved by Setiawan (1991) using an ombrogenous peat from Pinang Luar (West Kalimantan). To compress fibric, hemic, and sapric peats to the same degree, a greater force was needed in that order (see Table 1).
Table 1: Force needed to compress peat of different degrees of decomposition

<table>
<thead>
<tr>
<th>Degree of decomposition</th>
<th>Degree of Compression, % of initial volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>The needed compression force, kg cm$^{-2}$</td>
</tr>
<tr>
<td>Fibric</td>
<td>0.1</td>
</tr>
<tr>
<td>Hemic</td>
<td>0.4</td>
</tr>
<tr>
<td>Sapric</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Pore size distribution according to the criteria of storage and delivery of nutrient solution and water becomes better with higher degree of decomposition. Setiawan's experiment showed that compaction can improve the pore size distribution, but in the case of fibric and hemic peats the improvement was still not as good as even an uncompacted sapric peat (see Table 2). The experiment shows that compaction may be employed on peat to control nutrient leaching, to enlarge the effective rooting volume, and to improve the soil moisture regime. Thus compaction may compensate for whatever harmful effect may come from the application of drainage.

Setiawan was able to show that more advanced decomposition brought about better nutrient status of peat based on the ash content. The organic matter content also increased (see Table 3). A similar trend was found by Notohadiprawiro (1986) in other peat areas of Kalimantan, and by Leiwakabessy & Wahjudin (1979) in Sumatera generally.

Table 2: Distribution of three classes of pore size in relation to the degree of peat decomposition and compaction

<table>
<thead>
<tr>
<th>Degree of decomposition</th>
<th>Pore size distribution, % of total pore volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 300 um</td>
</tr>
<tr>
<td></td>
<td>original</td>
</tr>
<tr>
<td>Fibric</td>
<td>33.4</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemic</td>
<td>1.7</td>
</tr>
<tr>
<td>Sapric</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Notohadiprawiro found from field observing that the large part of fibric peat had a thickness of more than 200 cm, hemic peat 150 to 200 cm, and sapric peat less than 100 cm. Within the thickness range of 100 to 150 cm the frequency of occurrence of the three kinds of peat was about equal. Based on field findings which later on were verified by laboratory experiments, Notohadiprawiro (1986) proposed a critical limit of peat thickness.
for agriculture of 150 cm. It was defined in a sense that if less than this limit it will be better, while above this limit it may be less good. The Agricultural Department of Serawak, Malaysia, has set the critical limit at 100 cm, although some local farmers can still obtain good yields on peat of more than 200 cm thick (Geurts & Andriesse, 1986). For lowland rice Leiwakabessy & Wahjudin (1979) suggested the best thickness range of 30-60 cm.

**Table 3: Relationships of ash and organic matter contents to degree of peat decomposition**

<table>
<thead>
<tr>
<th>Degree of decomposition</th>
<th>Ash content, %</th>
<th>OM content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibric</td>
<td>3.09</td>
<td>46.9</td>
</tr>
<tr>
<td>Hemic</td>
<td>8.04</td>
<td>51.7</td>
</tr>
<tr>
<td>Sapric</td>
<td>12.04</td>
<td>78.3</td>
</tr>
</tbody>
</table>

Regression equation,  
X is degree of decomposition  
Y is content of substance  

\[
Y = 0.60 + 1.19 X  \\
r^2 = 0.91
\]

\[
Y = 31.12 + 4.64 X  \\
r^2 = 0.98
\]

Because of peatland are commonly waterlogged, lowland rice is the best adapted crop. Rice also tolerates acid condition as low as pH 4. The crop can stand salinity sufficiently. Thus in peatlands where the pH tends to decline as a result of improved drainage, or the salinity tends to increase due to sea water intrusion or during high tides, rice can still give good yields. The soft substrate of water saturated peat and the accompanying low redox potential are no problems for rice as it usually grows in anaerobic mud.

Rice growing on peatland sometimes suffers from Cu deficiency, particularly on peat which is too thick and inundated by stagnant water. Cu deficiency causes empty grains. The symptoms may gradually disappear by itself with the progress of peat maturation.

Sihombing & Sebayang (1986) reported the good potential of peatland for lowland rice. It responded well to amelioration to make it adaptable for improved rice varieties. Table 4 summarizes the report. Sihombing & Sebayang also reported several experiments with local varieties of cassava, and with local and improved varieties of corn peatland in Barambai, South Kalimantan. The cassava gave a yield of 12.2 - 19.6 tons ha\(^{-1}\) with an average of 16.6 tons ha\(^{-1}\). For comparison, farmers' yields on uplands fields in the same locality was 8-10 tons ha\(^{-1}\). The national average yield is 9.5 tons ha\(^{-1}\) (Brotonegoro, et al.,
The corn yield was 0.5-1.1 tons ha\(^{-1}\) with an average of 0.9 ton ha\(^{-1}\). With fertilizers at a rate of N 90, P 45 and K 30 kg. ha\(^{-1}\), and 2 tons ha\(^{-1}\) of lime, the improved variety Harapan could give a yield of 1.6 tons ha\(^{-1}\). The national average yield is 1.7 tons ha\(^{-1}\) (Basa et al., 1986).

**Table 4:** The effects of improved variety and cultural practice, and hydroreclamation on yield of lowland rice on peatland with peat depth of more than 50 cm.

<table>
<thead>
<tr>
<th>Cultivation system</th>
<th>Yield of unhulled grain ton ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional, long growth local variety of ca 10 mo</td>
<td>av. 1.8</td>
</tr>
<tr>
<td>Ditto, after several years of hydro-reclamation</td>
<td>2.2 - 2.6</td>
</tr>
<tr>
<td>Traditional, short growth improved of 116 - 135 days</td>
<td>2.7 - 3.6 (average 3.1)</td>
</tr>
<tr>
<td>Improved variety, high dose fertilizers of 90 - 11.25 kg N, 45 - 90 kg P and 45 kg K per ha; the effect of fertilizer detectable after third year of cultivation</td>
<td>3.6 - 6.0 av. 4.7</td>
</tr>
</tbody>
</table>

**Table 5:** The effects of duration of reclamation and water management on soybean yield

<table>
<thead>
<tr>
<th>Peat thickness m</th>
<th>Land management</th>
<th>Yield ton ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>One year reclamation, improved variety Orba - water management less good - water management better</td>
<td>ca 0.3 ca 0.6</td>
</tr>
<tr>
<td>3 - 4</td>
<td>Two years reclamation, Americana variety - water management less good - water management better</td>
<td>ca 0.6 ca 1.3</td>
</tr>
<tr>
<td>3 - 4</td>
<td>Farmers' land, water management less good</td>
<td>0.7</td>
</tr>
<tr>
<td>3 - 4</td>
<td>Government estate land, good water management</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Observations done on peatlands of Lunang, West Sumatera, concluded that the duration of reclamation and the intensity of water management determined the yield of soybean. With good reclamation and water management, a peat of 3 to 4 meters deep can still be made productive for soybean. See Table 5 (Taker & Zaire, 1989). For comparison the national average yield of soybean is 0.85 ton ha\(^{-1}\) (Brotonegoro et al., 1986; Harnoto & Yurida, 1986). In the same area water management also plays an important role in
determining peanut yield, and thick peat was also not a problem as can be seen in Table 6 (Taher & Zaini, 1989). The average national yield of peanut is 0.98 ton ha\(^{-1}\) as recorded by Brotonegoro \textit{et al.} (1986) and Sutarto \textit{et al.} (1986).

**Table 6:** The yield of peanut as influenced by water management

<table>
<thead>
<tr>
<th>Peat depth m</th>
<th>Reclamation and water management</th>
<th>Yield ton ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 - 4</td>
<td>Three years reclamation, Kidang improved variety, depending on the level of water management</td>
<td>0.9 - 1.2</td>
</tr>
<tr>
<td>3 - 4</td>
<td>Farmers' land, without reclamation, depending on season of year and level of water management</td>
<td>0.6 - 1.1</td>
</tr>
<tr>
<td>3 - 4</td>
<td>Plantation land with good water management</td>
<td>1.1 - 1.7</td>
</tr>
</tbody>
</table>

The comparison of yield of the various crops obtained on peatland with the average national yield indicates the good prospect of peatlands for food crops. With an effective water management which can maintain the groundwater level at a depth of about 60 cm, pH control, fertilization, adapted varieties, and perhaps in combination with the surjan system, peatland can be developed into a productive farmland. With well adapted crops or varieties the control of pH needs not to be done strictly. It means no need for liming. Lime may still be given as a fertilizer to supply the needed Ca and Mg. To control pH rock phosphate is sufficient while at the same time it provides P (Suryanto, 1991). Suryanto & Lambert (1992) tested some peat pH correcting materials by field observation in Pontianak, West Kalimantan, and corroborated by laboratory and greenhouse experiments. They became to the conclusion that peat ash or wood ash is much better than lime. The ashes not only correct pH, but also considerably increase the nutrient uptake, notably of P and K, demonstrated by corn plants. Irrigation with brackish water, if possible, can also be recommended. Brackish water may have some degree of fertilization effect, as exhibited by the farmer's coconut plantations in Riau, Sumatra (Notohadiprawiro & Maas, 1991).

Vegetables growing on lowland peatland is a common practice, particularly among the Chinese farmers in West Kalimantan. The result are very good. Pineapples are produced in the peat delta of Pontianak are very much appreciated all over Indonesia for their sweet taste. But unfortunately serious studies on peatland for horticulture are still limited. So far too little attention has been paid to peatland use for horticulture, as most of
the efforts and available funds were allocated to peatland use for staple food crops, especially rice. Reports from Malaysia show the great potential of peatland for vegetable growing. The water management requirement is quite simple. The groundwater level needs only to be lowered 30-45 cm. Chilli can produce as high as 15.1-20.9 t ha\(^{-1}\), cabbage 21.1-22.7 t ha\(^{-1}\) and ginger 14.9-16.4 t ha\(^{-1}\). Other vegetables which can be grown successfully are spinach, shallots and pepper. Ivory Coast has been successful in producing banana on freshwater peatland. In a four yearly cycle of five times harvesting sequence they can get a yield of 250 tons ha\(^{-1}\) (Geurts & Andriesse, 1986; Leong, 1991).

In order to gain the most benefit out of peatlands without risking their wasteful use as a resource, a well designed peatland allocation scheme is imperative. The first choice for agricultural use should be a sapric peat, preferable of topogenous origin, with a depth of around 150.

**The ecological value of lowland peatlands**

Whatever the purpose of use peatland is, its natural functions must not be disturbed, the more so destroyed. Lowland peatlands play specific, definite roles in the environment. These are:

1. Hydrology, through regulating groundwater recharge and discharge, and controlling flood
2. Sanitation, through the retention of sediment, contaminants, and toxicants
3. Heritage, through preserving biological diversity, wildlife resources and uniqueness to culture
4. Protection, through carbon sequestering
5. Production, through the retention of nutrients, generating valuable forest and agricultural resources, and water supply.

(modified from Dugan, 1990; Maltby & Immirzi, 1991)

The total area of peatland in Indonesia is estimated at 17 million hectares (Soepraptohardjo & Driessen, 1976). Added to it the peatlands of Malaysia, Thailand and Vietnam, Southeast Asia has perhaps the most massive area of tropical peatland. It comprises an extent of probably close to 25 million hectares with an average depth of may be 6 meters. The regional environment influence of such enormous peat mass cannot be ignored. Any matter which has any connection with peatland becomes important.
One of the most far reaching effects of peatland is on the regional hydrology. It acts as a surface collector of water, building a potentially huge water storage. The water balance in peatland may be written in a simple equation as follows:

\[
\text{INFLOW + PRECIPITATION} = \frac{\text{OUTFLOW + EVAPORATION}}{\text{gain}} + \text{RETENTION}\]  

From the point of its hydrological role, peat is differentiated into three types, which according to the classification of Moore & Bellamy (1974) are called primary, secondary, and tertiary peat. Primary peat is a normal topogenous peat, formed in a water body contained in a basin or depression. This type of peat has no significance in retaining water as even without any peat the basin will retain water. In fact, the peat reduces the water storage capacity of the basin as it takes up a part of the basin volume. Secondary peat is the upper part of a thick topogenous peat. It is peat that grows above primary peat beyond the physical boundaries of the basin. This type of peat adds to the water retention capacity of the landscape. Tertiary peat is ombrogenous peat as it is formed above the accumulated rain water on the land surface. It retains water by capillary forces, eventually forming a perched water table. This type of peat is the most significant water retaining structure in peatland.

The water balance equation, if applied to primary peat, postulates that outflow is small as water is confined to the basin, and evaporation is restricted as water is adsorbed by the organic matter particles. Thus, although primary peat reduces the water storage capacity of basins, it conserves the water stored in the basin.

Peat has a high water retention capacity because of its high organic matter content of over 70%w and high porosity of over 85%v. The porosity of peat is related to its degree of decomposition. As inferred previously, a more decomposed peat is more compact, thus has lower porosity and consequently has less water retention capacity. The bulk density of peat ranges from around 0.1 in fibric peat to around 0.2 in sapric peat. The maximum water holding capacity of fibric peat ranges from 850%w to sometimes more than 3,000%w, hemic peat is 450-850%w and sapric peat is less than 450%w (Notohadiprawiro, 1985).

Assuming a fibric peat to have a bulk density of 0.1 and a maximum water holding capacity of 900%w, and sapric peat to have a bulk density of 0.2 and a maximum water holding capacity of 400%w, then the water retention capacity of each cubic meter of peat will be:
fibric: $0.1 \times 1 \times 900/100 = 0.9$ t or $0.9$ m$^3$ which is equivalent to 900 mm for each meter thickness

sapric: $0.2 \times 1 \times 400/100 = 0.8$ t or $0.8$ m$^3$ which is equivalent to 800 mm for each meter thickness

An average value of 850 mm may be assumed as the water retention capacity of tropical peat.

Assuming that 50 percent of the total peat in Indonesia is ombrogenous peat and thick topogenous peat, which may not be an unlikely truth, the total water per meter layer of peat will be:

$$8.5 \times 10^6 \times 10^4 \text{ m}^2 \times 0.85 \text{ m} = 7.2 \times 10^{10} \text{ m}^3$$

Just for comparison, all 53 reservoirs which had been built in Indonesia since 1914 until 1992 have a total water storage capacity of $9.2 \times 10^9$ m$^3$ (National Research Council Group II, 1994). It took 80 years to provide water only one-tenth of the natural water storage furnished by a one meter thick peat. It is not unusual, for instance in West and Central Kalimantan, to find peat of 6 meters thick or more.

Another important environmental effect of peatland is on carbon dioxide emission to the atmosphere. Peat contributes substantially to the sequestering of carbon. Measurements done by Notohadiprawiro (1981) on peat in Pontianak (West Kalimantan) and Barambai (South Kalimantan) obtained in peat of younger than 3,000 years BP an average growth rate of $1.6 \times 10^3$ kg ha$^{-1}$ y$^{-1}$. In older peat of more than 4,000 years BP in Sarawak, Pons (1974) reported an average growth rate $19.8 \times 10^3$ kg ha$^{-1}$ y$^{-1}$. Thus older peats grew 12 times faster than younger ones. It seems that during the last 3,000 years peat formation had slowed down, probably due to natural changes in the environment.

Taking for an organic matter content in peat of 80% and a C content in the organic matter of 58%, the rate of C sequestering in young peat can be estimated at

$$0.81 \times 0.58 \times 1.6 \times 10^3 = 7.4 \times 10^2 \text{ kg ha}^{-1} \text{ y}^{-1}$$

Henceforth, taking for a peat bulk density of 0.15, C sequestered in each meter layer of one hectare of peat can be estimated at:

$$0.81 \times 0.58 \times 0.15 \times 10^4 = 7 \times 10^2 \text{ tons m}^{-1} \text{ ha}^{-1}$$

Carbon (C) release from deforestation and shifting cultivation in the tropics is $14 \times 10^4$ kg ha$^{-1}$ y$^{-1}$ (Bouwman & Sombroek, 1990). By simple accounting, the emission of C per year from each hectare deforestation and shifting cultivation can be compensated by the sequestering of C per year by 190 ha of peat. By introducing good forest management
and farming system to substitute conservation farming for shifting cultivation, less hectares of peat would be needed for compensation.

**Peatland use**

The total area of tidal swamp land, including lowland peatland, that has been cleared for farming may be guesstimated at 900,000 ha (rationalized from related figures presented by Kretosastro, 1990). It is large area indeed for such a delicate ecosystem like tidal swamp, particularly lowland peatlands. Many lessons can be learned from the outcomes, not all of them are satisfactory, some of them even detrimental. The detrimental impacts include increased intrusion of sea water, accelerated, uneven subsidence causing hydrological disturbances, development of extreme acidity upon drainage due to the oxidation of sulphidic substances into sulphuric acid, evolution of hydrophobicity in peat due to excessive drying, changing peat into loose dust particles, and the slanted growth of trees.

Peatland is a fragile ecosystem. Its existence is strongly determined by the regional hydrology. By applying appropriate technology, however, the prospect of peatland for agriculture is good. But since peatland development should be planned carefully. Dugan (1990) has listed the major causes of peatland degradation and loss which are drainage for agriculture, forestry, and mosquito control, and mining for peat (for fuel). Others which according to Dugan are not major causes of loss are subsidence, drought, and erosion.

The development of peatland for productivity and sustainability may be designed as follows:

1. Peatlands of ombrogenous and thick topogenous peat should be put aside and their whole ecosystem preserved for environmental functions. As a matter a fact, those peats are not suitable for agricultural use.

2. Agricultural and forest production should be restricted to sapric, thin to medium topogenous peat, carried out with good conservation practice, which constitute of the following:
   a. Shallow drainage
   b. Surjan culture
   c. Adapted crops and varieties
   d. Lime as Ca and Mg fertilizer, not for pH correction
e. pH correction is better done with peat ash or wood ash which adds to better nutrient uptake, or with rock phosphate to combine P supply with pH correction

f. Timber production by selected cutting, not by clean cutting.

The proposed holistic approach to peatland development requires for proper execution a strong, well rationalized land use policy, backed up by well organized enforcement institutions.

References


Appendix

For fair comparison the figures of the average national yield of the various food crops presented in the text were taken from about the same period as that of the recorded yields from peatlands. According to the Biro Pusat Statistik (Central Bureau of Statistics), the average figures for the period of 1990-1993 in tons per hectare are as follows:

<table>
<thead>
<tr>
<th>Food Crop</th>
<th>Java &amp; Madura average</th>
<th>National Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowland rice</td>
<td>5.3</td>
<td>4.6</td>
</tr>
<tr>
<td>Corn</td>
<td>2.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Soybean</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Peanut</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Cassava</td>
<td>12.6</td>
<td>12.2</td>
</tr>
</tbody>
</table>