Twenty-five Years Experience in Peatland Development for Agriculture in Indonesia

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Introduction

Tropical peat was first discovered by Kooders in 1895 in a swamp forest on the east coast of Sumatra. The extent was estimated then at almost one-fifth of the total area of Sumatra. Subsequent explorations revealed vast areas of thick peat on the western and southern coastal plains of Kalimantan and on the southern coastal plain of Irian Jaya. The peatlands of Indonesia together with those of the coastal plains of Malaysia make up the largest area of peat in the tropical zone (Polak, 1950).

The presence of deep peat in the tropics disproves the long accepted theory that peat forms in a low temperature environment and occurs only in temperate and cold climates. Temperature is not the sole factor controlling peat formation and it can accumulate also in high temperature regimes in places where oxygen is deficient, where waterlogged conditions prevail over a long period of time and the underlying substratum is low in nutrients (Siefferman et al., 1988). Tropical peat, which is formed from rainforest trees, contains higher lignin and nitrogen and lower ash, carbohydrate and water soluble protein than temperate peat; the organic matter is less biodegradable leading to a more rapid accumulation of peat.

Since tropical peat is always associated with permanently waterlogged conditions, it had been postulated that only topogenous peat could exist in the tropics. According to the climate theory of peat formation in the temperate zone ombrogenous peat in the tropics would be restricted to high altitudes where Sphagnum moss may be found. In fact, large areas 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, especially trees (Polak, 1950).
The use of peatland for agriculture in Indonesia

The prerequisites of oxygen scarcity and nutrient deficiency in peat formation imply that the lowering of groundwater to improve aeration in the rooting zone will induce shrinkage and subsidence of the peat; the addition of fertilizers and/or lime will accelerate peat decomposition. Whilst cultivation leads to the degradation of tropical peatlands their agricultural potential, especially for lowland rice, cannot be ignored. The points in favour of peatland cultivation are:

1. The water required is already there naturally, so that expensive irrigation programs are not required;
2. The immensity of these areas (million of hectares) makes them an important national asset;
3. They can be developed by the simple, traditional channeling systems of the Banjarese and Buginese, lending them easily to small farming enterprises.

The two opposing views of peatlands use, one for preservation and the other for development, have complicated the formulation of peat land use policies for a long time. Whatever the decision may be, it should address the entire tidal swamp land system\(^1\) since most Indonesian peatlands occur in coastal areas where they constitute a subsystem of the tidal swamp lands although their distribution pattern is not clearly defined. It is impossible, therefore, to manage peatlands in isolation from the remainder of the tidal swamp land.

Tidal swamp land development began at the beginning of the twentieth century when Indonesia faced a rice shortage during and just after World War I. The first areas to be converted were the coastal swamp lands of Kalimantan where the Banjarese had already succeeded in producing rice using their traditional water control system of "sawah bayar". This initiated a comprehensive exploration of the coastal plain of southern Kalimantan, with the objective of finding out more about the bayar system and its soil requirements. These were co-ordinated with the transmigration of Javanese and Madurese people to other islands (van der Voort, 1951; van Mijk, 1951). In the 1960s Indonesia was confronted again by a shortage of rice, this time more serious, and became the world's largest importer. Various lowland rice intensification programs on Java had failed because of the

\(^1\) Low altitude coastal and sub-coastal wetlands, influenced by flooding from the interior and ponded up by tidal movements from the sea
limited availability of land with adequate irrigation facilities. Once again the tidal swamps were looked to for a ready solution. This time the source of inspiration for the development was the traditional technique of the Buginese, but using a systematic, soil science approach, and involving large areas of Sumatra, Kalimantan and Irian Jaya. This became a national program of the highest priority, starting in 1968 until 1983 and continuing in some selected areas to the present day. The program was also carried out in association with transmigration settlement of farmers, experienced in the cultivation of lowland rice, onto the newly developed land.

These two development efforts, although entirely different in political situation, one under colonial rule and the other under a national government, show two striking similarities:

1. The act was motivated by food shortage and followed the example of a traditional agricultural system.
2. The objective was regional development combining increasing agricultural production with population redistribution.

In a further development, the improved Buginese traditional system of water control was coupled with the Javanese traditional system of water management known as the 'surjan system'. The former controls water at a zonal scale, while the latter manages water at a field scale. The result was astonishing since not only rice could be grown, but also palawija (secondary crops), vegetables and perennial crops, including fruit trees, coconut, coffee, and cloves.

The agricultural value of lowland peatland

The inherent conditions of lowland peatland that directly constrain agricultural development (Soepraptodihardjo & Driessen, 1976; Notohadiprawiro, 1987) 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
1. 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.

Drajad, et al., (1986) reported an average subsidence rate of 0.36 cm month\(^{-1}\) in a sapric peat deposit 45-63 cm thick at Barombai (South Kalimantan) 12-21 months after hydroreclamation. At Talio (Central Kalimantan) the rate of subsidence in 180-240 cm thick sapric peat was 0.78 cm month\(^{-1}\), whereas in a hemic-sapric peat, 179-236 cm thick, it was 0.9 cm month\(^{-1}\). It appears that the rate of subsidence is slower the thinner and/or more decomposed the peat, a feature that has also been reported from Sumatra (Haridjaja & Herudjito, 1979). This may be related to the greater stability of thinner and more decomposed peats which may be more suitable for agriculture.

Pore size distribution, determined by storage and delivery of nutrients and water improves at higher levels of decomposition. Compaction can improve pore size distribution (Setiawan, 1991) although, for fibric and hemic peats, the improvement was not as good as in an uncompacted sapric peat. Compaction may be applied to peat to control nutrient leaching, enlarge the effective rooting volume and improve the soil moisture regime and may compensate for the effects of drainage. More advanced decomposition increases the nutrient status of peat.

Field observations indicate that most fibric peats are more than 200 cm deep, hemic peats 150 to 200 cm and sapric peats less than 100 cm; the critical limit of peat thickness for agriculture is 150 cm (Notohadiprawiro, 1986). The Agricultural Department of Sarawak, Malaysia, has set the critical limit at 100 cm, although some local farmers still obtain good yields on peat of more than 200 cm thick (Geurts & Andriesse, 1986). For lowland rice the best thickness range is 30-60 cm (Leiwakabessy & Wahjudin, 1979).
Because peatlands are waterlogged, the crop best adapted to that condition is lowland rice which can also tolerate acid conditions as low as pH 4 and can withstand salinity. In peatlands where the pH declines following drainage, or still give good yields. Rice growing on peatland, however, can suffer from Cu deficiency, causing empty grains, especially on deep peat. Symptoms may gradually disappear as the peat matures.

Experiments using local varieties of cassava and improved varieties of corn on peatland in Barambai, South Kalimantan; cassava yielded an average of 16.6 t ha\(^{-1}\) compared to 8-10 t ha\(^{-1}\) by farmers in upland fields and the national average of 9.5 t ha\(^{-1}\) (Sihombing & Sebayang, 1986; Brotonegoro, et al., 1986). Applying fertilizers, at a rate of N 90, P 45 and K 30 kg ha\(^{-1}\), and 2 t ha\(^{-1}\) of lime, improved the yield of the corn variety Harapan to 1.6 t ha\(^{-1}\); the average national yield is 1.76 t ha\(^{-1}\) (Basa, et al., 1986).

Observations on peatlands at 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, peat of 3-4 m depth can still be made productive for soybean (0.7-1.1 t ha\(^{-1}\)) (Taher & Zaini, 1989). The national average yields of soybean is 0.85 t ha\(^{-1}\) (Brotonegoro et al., 1986; Harnoto & Yurida, 1986). In the same area water management played an important role in determining peanut yield, and good harvests were obtained on thick peat (0.9-1.7 t ha\(^{-1}\)) (Taher & Zaini, 1989). The average national yield of peanut is 0.98 t ha\(^{-1}\) (Brotonegoro et al., 1986; Sutarto et al., 1986).

Comparison of the yield various crops on peatland with the national average suggests there is a good prospect of using shallow peatland for growing food crops. With effective water management to maintain the groundwater level at a depth of about 60 cm, pH control, fertilizer addition and adapted crop varieties, perhaps in combination with the surjan system, peatland can be developed into productive farmland. Employing well adapted crops or varieties pH need not be strictly controlled and there is no need for liming; lime may be added only to supply Ca and Mg. The addition of rock phosphate is sufficient to control pH while, at the same time, providing P (Suryanto, 1992). The application of peat ash or wood ash is much better than lime since these not only ameliorate pH, but also increase nutrient uptake considerably, notably of P and K (Suryanto & Lambert, 1992). Irrigation with brackish water is recommended since this had a fertilization effect on coconut plantations in Riau, Sumatra (Notohadiprawiro & Maas, 1991).
Little attention has been paid to peatland use for horticulture, as most of the efforts and available funds have been allocated to using peatland for the growth of staple food crops, especially rice although growing vegetables on lowland peatland is a common practice, particularly among the Chinese farmers in West Kalimantan. The water management requirement is quite simple since the level needs to be lowered only 30-45 cm. Chilli can produce yield 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 (Leong, 1992).

The ecological value of lowland peatlands

Whatever the purpose of using a peatland may be, its natural functions must not be disturbed, never mind destroyed. Lowland peatlands play definite, specific roles in the environment (modified from Dugan, 1990; Maltby & Immirzi, 1992) including:

1. Hydrological: through regulation of groundwater recharge and discharge and surface flooding;
2. Sanitation: through the retention of sediment, contaminants, and toxicants;
3. Heritage: through preserving maintenance of biodiversity, wildlife resources and cultural uniqueness;
4. Protection: through carbon sequestration and storage;
5. Production: through the retention of nutrients, generating valuable forest and agricultural resources, and providing a constant water supply.

The total area of peatland in Indonesia has been estimated at 17 Mha (Soepraptohardjo & Driessen, 1976). Together with the peatlands of Malaysia, Thailand and Vietnam, Southeast Asia has the largest area of tropical peatland in the world, comprising close to 25 Mha with approximate average depth of 6 m. The regional and global environment influence of this enormous peat mass cannot be ignored.

Peatland has a major effect upon 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:

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

Peat has a high water retention capacity because of its high organic matter content of more than 70% (weight) and high porosity of over 85% (volume). The porosity of peat is related...
to its degree of decomposition; a well decomposed peat is more compact, and has a lower porosity and water retention capacity, than less decomposed peat. The bulk density of peat ranges from 0.1 in fibric peat to 0.2 in sapric peat. The maximum water holding capacity of fibric peat ranges from 850-3,000% (weight); the water holding capacity of hemic peat is 450-850% and sapric peat is less than 450% (Notohadiprawiro, 1985). Assuming that fibric peat has a bulk density of 0.1 and a maximum water holding capacity of 900%, and sapric peat to have a bulk density of 0.2 and a maximum water holding capacity of 400%, then the water retention capacity of each peat type per cubic meter will be:

fibric: $0.1 \times 1 \times 900/100 = 0.9$ t or $0.9$ m$^3$ (equivalent to $900$ mm m$^{-1}$)

sapric: $0.2 \times 1 \times 400/100 = 0.8$ t or $0.8$ m$^3$ (equivalent to $900$ mm m$^{-1}$)

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

Assuming that 50% of the total peat in Indonesia is either ombrogenous peat combined water storage capacity per meter layer of peat will be:

$$8.5 \times 10^6 \times 10^4$ m$^2$ $\times 0.85$ m $= 7.2 \times 10^9$ m$^3$

In comparison, the 53 reservoirs built in Indonesia from 1914 to 1992 have a combined water storage capacity of $9.2 \times 10^9$ m$^3$ (National Research Council Group II, 1994); it took 80 years to provide one-tenth of the natural water storage in one meter thickness of peat.

Peatlands play an important role in carbon storage and carbon flux. Peat contributes substantially to the sequestration of carbon from the atmosphere. Measurements carried out on peat in Pontianak (West Kalimantan) and Barambai (South Kalimantan) showed that peat less than 3,000 years old had an average growth rate of $1.6 \times 10^3$ kg ha$^{-1}$ y$^{-1}$ (Notohadiprawiro, 1981); older peat of more than 4,000 years BP in Sarawak had an average growth rate $19.8 \times 10^3$ kg ha$^{-1}$ y$^{-1}$ (Pons, 1974). These data suggest that older peats accumulated 12 times faster than younger peat implying that during the last 3,000 years peat formation has slowed down, probably in response to natural changes in the environment. Assuming an organic matter content in peat of 80% and a carbon content in the organic matter of 58%, the rate of carbon sequestration in young peat was:

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

For a peat bulk density of 0.15, the amount of carbon 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$ t m$^{-1}$ ha$^{-1}$
Carbon release as a result of deforestation and shifting cultivation in the tropics is $14 \times 10^4$ kg ha$^{-1}$ y$^{-1}$ (Bouwman & Sombroek, 1990). The emission of carbon per year from each hectare caused by deforestation and shifting cultivation could be compensated by the annual sequestration of the carbon in 190 ha of peat. By introducing good forest management and substituting conservation farming for shifting cultivation, fewer 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 is estimated to be 900,000 ha (Kretosastro, 1990). There are lessons to be learned from the effects of exploitation; few development projects have been completely satisfactory and some have been detrimental. Adverse impacts include increased sea water intrusion, accelerated, uneven subsidence, hydrological disturbance, development of extreme acidity and hydrophobicity in peat upon drainage and the production of peat dust particles as a result of desiccation. Crops, especially trees may exhibit distorted growth and instability. If these detrimental consequences are taken into account the development of tropical peatlands for production and sustainability may be achieved if the following guidelines are followed:

1. Ombrogenous and deep topogenous peatland are unsuitable for agriculture and should be excluded from development and preserved intact to protect and maintain important environmental functions.

2. Agricultural and intensive forest production should be restricted to sapric, thin to medium topogenous peat, employing good conservation practices, including shallow drainage, surjan culture, adapted crops and varieties, lime as Ca and Mg fertilizer, not for pH correction; pH correction using peat ash or wood ash which also improve nutrient uptake, or rock phosphate to combine P supply with pH correction and timber production by selected cutting, not clear felling.

The proper execution of holistic approach to peatland development requires a positive, integrated land use policy supported by well organized and adequately resourced enforcement institutions, policies and practices. In order to gain the maximum benefit from peatlands without damaging the functioning of the resource, planning zoning is essential. The first choice for agricultural use should be topogenous sapric peat less than 150 cm thick.
References


