Soil Constraints on Sustainable Plant Production in Malaysia

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ABSTRACT

Tin-tailings, bris, peat, acid sulphate and steepland soils are considered unsuitable for agriculture unless they are properly reclaimed and subsequently ameliorated. Tin-tailings and bris soils are sand-textured. Both soils are infertile, intensely leached, have low water-holding capacity and high surface temperature. Their productivity could be enhanced by incorporation of organic matter. Peat soils are constrained by low acidity, nutrient deficiency, low soil-bearing capacity, woody composition and poor drainage. They are also susceptible to burning and shrinkage. Selection of suitable crops and appropriate land reclamation procedures, especially compaction and water table control are necessary for successful production. The limitations of acid sulphate soils include low pH, Al toxicity, and nutrient imbalance. The soils are prone to the adverse effect of excessive drainage. With proper water table control, dryland crops can be grown successfully. However, these problems are less severe under bouble cropping of wetland rice. In steeplands, the problems encountered are topsoil erosion, structure degradation, and non-sustainability. With the choice of suitable tree crops, adoption of proper conservation measures and farming systems, these soils could be cultivated. Moreover the cooler climate in steep highlands enables the cultivation of subtropical crops. The marginal steeplands should be best kept under forest.

Introduction

Malaysia has a total land area of approximately 33 million hectares. About 13 million hectares are situated in West Malaysia, and the rest in East Malaysia. About 50% (7 million hectares) of the land in West Malaysia is considered unsuitable for agriculture (Mohd Tamin *et al.,* 1982) and the percentage of unsuitable land in East Malaysia is even higher. These soils are usually referred to as problem soils and consist of several groups as indicated in Table 1.

Since Malaysia is an agro-based country, most of its productive soils have been utilized for agriculture. Hence, there is an increasing need to use the problem soils for cropping. This paper examines some of the management aspects of the major problem soils and their prospects for agricultural development.

Bris and tin-tailing soils

Availability, usage and constraints

Bris soils are a complex of soils developed on the sandy coastal ridges. They occur as a narrow belt varying in width between 0.2 and 8 km from the coastline and they are mostly

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Table 1 Extent of problem soils in Malaysia

Soil group	West Malaysia		East Malaysia*	
	Acreage (ha)	%	Acreage (ha)	%
Deep peat (>2m)	598,790	8.2	1,552,000	7.8
Tin-tailings	200,000	2.8	—	—
Bris	164,464	2.3	40,400	0.2
Acid sulphate and potential acid sulphate soils	356,880	4.9	n. a	—
Stony soils and steepland	5,614,510	77.3	10,249,000	51.2
Saline soils	325,910	4.5	n. a	—
Total	7,260.554	100.0	—	—

n. a=not available

Entisols and Spodosols. Tin-tailings are heterogeneous soils resulting from waste deposits of mining activities. They have no profile development and are classified as Entisols.

The texture of the bris tin-tailing soils is sand. Therefore some of their properties are rather similar (Table 2). However, tin-tailing soils have a winder range of pH because some of the original tin mining areas consisted of peat, acid sulphate, or were underlain by limestone.

Table 2 Some physical and chemical properties of bris and tin tailing soils

Soil properties	Bris	Tin-Tailings
Saturated hydraulic conductivity (cm/hr)	100—250	53—150
Water retention 1/3 bar g w/w)	3.2—6.0	1.6—6.5
Bulk density (gm/cc)	1.3—1.4	1.4—1.5
Sand (%)	93—98	90—96
Silt (%)	2 — 4	1 — 5
Clay (%)	0 — 3	3 — 5
Total pore space (%)	42—53	43—50
Cation exchange capacity (meq/100g)	1.0—10.5	2.0—11.5
Soil pH H_2O (1 : 2.5)	4.5—5.5	3.5—8.0
Organic matter (%)	0.2—2.0	0.3—1.5
Base saturation (%)	3 —20	5 —30
Total N (%)	0.01—0.04	0.02—0.05

Due to the sand texture these soils are infertile, have a low water-holding capacity, and are subjected to high leaching. They are also subjected to high soil temperatures which could reach more than 40°C at the surface, thereby inhibiting germination and retarding crop growth. During the prolonged dry months the conditions of these soils are similar to those in the semi-arid regions. During the wet season, some of the bris soils are completely inundated. Thus, infrastructural drainage is relevant in flood-prone areas. In addition, successful agriculture on these sandy soils also requires the improvement of agricultural technology with specific emphasis on soil management.

Management and prospect

With adequate fertilizer and proper soil and water management, many crops, especially those that can tolerate drought can be used for the cultivation of coconut, cashew, tobacco, watermelon, passion fruit, citrus, carambola, guava and a variety of vegetables. Their productivity could be improved when the soil constraints mentioned previously are collectively reduced. For instance, irrigation and mulching were found to be effective in minimizing the rapid evaporation as well as lowering the soil temperature. Application of manures/wastes and composts is effective in overcoming the low water-holding capacity and high infiltration rates of the soils. In addition, they also provide plant nutrients. However, since these nutrients are not sufficient, additional and frequent application of fertilizers is necessary to maintain good crop conditions . The irregular topography of tin-tailings affects the crop growth, and land levelling is a suitable solution prior to planting.

Although much research has been carried out on tin-tailing soils, application for land reclamation is still lacking (Lim, *et al.,* 1981). On the contrary, in bris soils, sufficient technology has been generated to support the production of high-value crops such as tobacco, It was found that with 6% (7 kg/m_2) of Palm Oil Mill Sludge (POMS) applied, the yield of tobacco doubled to about 2,000kg/ha (Abdullah *et al.,* 198).

Similarly POMS was used together with Oil Palm Empty Fruit Bunch (EFB) in sand tailing areas for fruit tree cultivation. It was found that with 6% (w/w) of POMS and EFB application, carambola (B10) gave the highest yield compared with the most prevalently used organic manure treatment such as chicken dung (Table 3). Thus, organic matter amendments, especially POMS and EFB have been effective in sandy soils.

Table 3 Effect of organic amendments on the fruit yield of carambola (B10)

Organic amendments	Yield	
	No. of fruits/tree	Weight of fruit/ha
1 . POMS+EFB	99	4.93
2 . Chicken dung	68	3.49
3 . Control (NPK)	42	1.91
LSD 5% (1 VS 2)	22	1.01
LSD 5% (1 VS 3)	34	1.60

Peat

Availability, usage and constraints

Only 32% and 1% of peat soils in West and East Malaysia respectively have been developed for agriculture and the remaining areas are under forest cover. The slow rate of development of peat areas reflects the many problems posed for successful agriculture. Aquatic plants like sago which adapt well and pose less problems, could give sustained economic returns. Some non-aquatic plants like pineapple adapt well to low acid and low fertility conditions. Other dryland crops that are grown include oil palm, banana (*Musas*spp.), coffee, maize (*Zea mays*), and vegetables. Rubber cultivation has been attempted but the acreage decreased as numerous problems occurred (Mohd. Noor *et al.,* 1989).

Selection of suitable crops is a major criterion to ensure successful agriculture on peat. Even for the adaptable aquatic crops, many soil constraints are encountered, including high percentage of tree trunk, micro- and macronutrient deficiency, and poor soil support for machine mobility. For non-aquatic plants additional soil constraints include poor soil drainage, soil shrinkage, poor plant anchorage, and susceptibility to flooding.

Drainage is a prerequisite for agricultural development of dryland crops. It is often difficult to be implemented as peat areas are low lying, and easily flooded. Construction and maintenance of drains are fairly expensive (Yim *et al.,* 1984). Upon drainage peat soil undergoes shrinkage and subsidence due to consolidation and oxidation. The subsidence rate can be as high as 0.3-0.9 m after the initial drainage, and after three years it stabilizes to about 2.8-3.6 cm/year (Sharif *et al.,* 1986). With excessive drainage, peat can undergo irreversible drying and will not wet easily. Thus, reclaimed peat areas are also susceptible to burning which could seriously damage crops.

As the Malaysian peat is woody and fibrous in nature, it has a high pore volume. Its average bulk density ranges mostly between about 0.1 to 0.2gm/cm^3 (Ismail, 1984), and the cohesion is less than 0.1kgf/cm^2 (Ooi, 1982). Its woody nature and softness restrict machine mobility and top-heavy tree crops such as oil palm tend to lodge due to poor root anchorage on soft soils.

The mineral content of Malaysian peat soils is also variable. In the West coast, about 70% of the soils contain less than 10% ash whereas in the East coast about 40%. Peat soils are also acidic, with pH_W values between 3.0 to 4.5. They are also known to be deficient in

Table 4 Yield of various crops grown on peat soils

Crop (common name)	Variety	Yield (ton/ha)
Pineapple	Sarawak	50—60$^+$
	Singapore—	40—48$^+$
Banana	Spanish	7—10$^+$
Papaya	Berangan	20—30$^+$
Tapioca	Black twig	49*
Sweet potato	Large white	24*
Cucumber		19—30$^+$
Groundnut	V13	2.2^{++}
Maize	Suwan－1	7.5$_-$
Sorghum	E 178	2.5^{++}
Mulberry	Local	7.5
Pasture	Napier	24.7°
Coffee	Liberica	6－13$^+$
Chilli	MC5	10－16$^+$
Cabbage	KK	14－22**
Tomato	Local	20－30$^+$
Brinjal	Local	18$^+$
Chinese-mustard	Large flower	46
Shallot	FillippinesII	7
Rubber	Local	0.45/yr
Oil palm	Dxp	20－25ffb
Sago	Local	17 (dry starch)

$^+$ fresh fruit, * fresh tuber, $^{++}$ dry grain,
$^-$ fresh cob, $^{\circ}$dry grass, ** head.

micronutrients particularly Cu, Zn, Fe and B (Ng and Tan, 1974). Preliminary studies by MARDI show that there is a fairly high microelement adsorption in peat soil.

Technology generation and future prospects

The yield of crops grown on peat is shown in Table 4. Successful agriculture on peat commences with the selection of suitable crops, and appropriate land reclamation procedures. Several agronomic practices have been developed for dryland crops, including compacting the soils by running heavy machines several times over the planting rows before tree crops are planted (Gurmit, 1989). In areas where there is a short dry season, water table control in drains is essential to store soil water. Crops grown under such conditions have access to more soil water as compared to those grown on some upland mineral soils.

Drainage in peat areas is designed to enable the discharge of flood waters within the period required by the crops, and for oil palm it takes about 7 days. At the same time controlled gates are required so that the soils are not overdrained. To overcome the effect of soil subsidence, an innovative practice has been developed by planting oil palm seedlings in a planting hole dug within a larger hole.

Acid sulphate soils

Availability, usage and constraints

A considerable acreage of acid sulphate and potential acid sulphate soils in the coastal plains of Malaysia contains appreciable quantities of the mineral pyrite F_eS_2). The limitations of such soils for agriculture in Malaysia are well-documented. These include very low pH, Al toxicity, nutrient deficiency, susceptibility to flooding, and the adverse effect of excessive drainage.

In the past, large areas of acid sulphate soils in West Malaysia were overdrained which lowered the water table below the zone of pyrite accumulation, causing the pyrite to oxidize and soils to become very acidic (pH of 2.6-3.4). Joseph and Nuruddin (1975) monitored the changes in pH in a 50,000 acre area in West Johore. They observed that after drainage, in about 30,000 acres of the soils at 12-18 inch depth, the pH dropped to 2.6-3.4. Such a low pH was not observed prior to draining. It was observed that the yield of coconut in this area had dropped compared to the undrained areas. At the same time the quality of the nuts also deteriorated.

Joseph *et al.* (1976) conducted a study to detect the presence of potential acid sulphate soils on a 250,000 acre area in West Johore. They found that about 50% of the area consisted of potential acid sulphate soils with a pH of 2.6-3.4 within a 12-18 inch depth. They stressed that the area should not be overdrained. Shallow drainage and water table control should be practiced in the area. The latter approach could increase the yield of crops like oil palm and coconut.

The distribution of pyrite in soils is usually sporadic, both vertically and horizontally. Thus, acid sulphate soils often occur as patches in association with other fertile soils. This poses practical problems during land reclamation i. e. while draining the soils, some areas are unavoidably subjected to overdraining.

Development of improved agriculture

Acid sulphate soils pose less problems when used for aquatic plants like rice. However, when they are used for dryland crops that require drainage, the acidity problem becomes severe. Production of wetland rice on about 25,000 ha of acid sulphate soils in the MADA scheme has been found to increase with time. In the early years when single cropping was practiced the yield of rice was below 2t/ha, and after double cropping was practiced for more than 20 years a yield of 3-4t/ha could be achieved. The increase in yield was due to the prevention of sulphidic properties generated under flooded conditions.

For the cultivation of potential acid sulphate soils for dryland crops, the most appropriate strategy is to prevent them from drying out. When the pyritic subsoil is kept waterlogged, the pH of the surface soils can be corrected with less difficulty. Some smallholders in areas with acid sulphate soils in West Johore maintain the water table or about 40 cm from the surface by allowing sea water to enter the drainage channels at high tide. The coconut in these areas produced 70% more nuts compared to the bunded areas. Zahari *et al.* (1982A) showed that with controlled water table the coconut yield increased from 2350 nut/ac/year at the onset of the experiment to 2858 nuts after four years. Contradictory results however have been reported for cocoa. Zahari *et al.* (1989) found that cocoa yield was highest under freely drained conditions, and least under water table control.

Rubber does not grow well on acid sulphate soils. In West Johore, its yield is about 500 kg/ha/year which is about half of that obtained in non-acid sulphate areas. Oil palm survives relatively well on acid sulphate soils. However in the absence of ameliorative measures the yield (fresh fruit bunches) is less than 5 t/ha/yr. With fertilization and proper maintenance of the water table the yield could reach 18 t/ha/year.

Vegetable farmers on acid sulphate soils in Malacca and Johore make ridges on the non-pyritic top soils and flood the rest of the field with fresh water. With regular liming and appropriate fertilizer application, the yields for this area are very satisfactory.

Steeplands

Availability, usage and constraints

One of the major constraints associated with soils in sloping areas is erodibility. The topography and intensive tropical rainfall cause problems such as topsoil erosion, soil

Table 5 Role of plant cover in erosion control (After Ghulam and Wong, 1987)

Plant cover	Soil erosion (kg/ha)		
	Vegetated area	Bare area	%
Mucuna	544	16,224	3
Asystasia	629	11,102	6
Indigofera	1,198	8,286	14
Mixed grasses	2,232	14,810	15

structure degradation, excessive runoff, deposition and siltation. Ghulam and Wong (1987) showed that erosion in areas with steep slopes is affected by the slope gradient and land use. It was shown that erosion from areas with good plant cover varied from 3% to 15% of the erosion from adjacent bare areas with similar slopes (Table 5).

The phenomenon of soil erosion in important in Malaysia due to the high occurrence of steepland. In West Malaysia, 42% of the land surface has slopes with on inclination greater tian 20°. In Sarawak mountainous upland (>33°) occupies 70% of the area (Hatch and Tie, 1979) while in Sabah, 22% of the land surface consisted of 'steepland' (>20°) (Webb, 1973). When the native vegetation from these areas is cleared for development, soil erosion and associated problems will be experienced if soil conservation measures are not implemented.

The problems of erosion and excessive runoff usually begin at the stage of land clearing. In land development projects, parcels of land as large as 2,000 ha are cleared at any one time, which exposes a large area of the surface soil to intensive rains and erosion. In most cases , heavy machines are used during land clearing which adversely affects the physical structure of soil, making it more vulnerable to erosion. Ghulam and Norhayati (1989) have shown that erosion of the original topsoil had reduced the infiltration capacity of land even after cocoa was planted and developed a closed canopy.

After clearing, soil conservation measures are not always implemented immediately. The plant cover takes time to be effective in controlling erosion because a complete coverage by leguminous cover crops requires at least 3 months after the seeds were swon.

Another contributing factor to soil erosion and sedimentation is the cultivation of crops which are unsuitable for steep slopes. Vegetables are being grown on steep slopes in Cameron Highlands, covering an area of about 2,000 ha. A reservoir in a hydro-electric scheme situated downstream suffers a severe sedimentation problem. In July, 1986, silt occupied about 1/3 of the total storage capacity of the reservoir and the life span was reduced by half. Similarly in areas where shifting cultivation is practiced, annual crops such as upland rice and maize are planted on steep slopes. The problem of soil erosion is compounded by the fact that the fallow period is rapidly decreasing, in some cases to less than three years (Sinajin, 1987).

Legislation in recognized as one of the tools in implementing soil and water conservation. However, there are several difficulties in the enforcement of legislation. Moreover there is a lack of manpower to ensure that the laws on land use are observed. The lack of enforcement of legislation is an important constraint associated with land use for agriculture.

Technology generation and future prospects

A large percentage of steepland in Malaysia occurs at high altitudes and is characterized by a subtropical climate. It could support crops that can not be grown in the lowlands. Despite the steepness, there are also areas where the soils are relatively deep. Both of these factors offer possibilities for crop cultivation in highlands.

The conversion of sloping land from forest to crop cultivation has to be studied and planned very carefully due to the fragility of the soils and the possible adverse effects on the environment. One of the most important tasks is to characterize the climate, soils and water resources in these areas in detail in order to obtain information on their limitations and potential for development. This would help in the identification of suitable areas for the various types of land use. At the same time, research on soil erosion and conservation is important and is being implemented, including research on the soil erosion processes on sloping land under tree crops and on physical models that can assist in conservation planning.

The sustainability of agriculture in sloping land is greatly influenced by land use. Studies on the determination of the most suitable tree crops, farming systems and soil conservation measures are necessary to avoid land degradation and environmental problems.

In view of the vast area of land still under forest in the interior of the country, there are good prospects for increasing soil productivity. However, any development need must be balanced by the prevention of soil erosion, excessive runoff, environmental problems and depletion of forest resources. Only tree crop farming which is environmentally suitable and sustainable should be allowed, and only land which can be adequately protected against soil erosion should be developed.

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Discussion

Toledo, J.M. (CIAT) : What is the relative importance of degraded *Imperata* grasslands and potential solution for Malaysia?

Answer : We kill the grass in using herbicides.

Khanna, S.S. (India) : What are the C,N,P ratios you wish to reach after proper decomposition and formulation of POMS used for manuring?

Answer : We do not have a complete analysis on such data yet.

Young, A. (ICRAF) : You mentioned that "Only properly organized and planned measures on these fragile steep slopes should be allowed". Are you in a position not to allow it and if so, how?

Answer : We can only exercise some measure of control.

Sekhon,G.S. (India) : You mentioned that clearance of forest land should be carried out carefully. Is it possible that forest land should not be cleared and that agriculture be intensified on crop land?

Answer : Yes it should be possible since we have to protect the forests.

Goh, K.M. (New Zealand) : I was impressed to see that you were able to grow crops on bris and tin-tailing soils using palm oil residues. Actually you are removing these residues from the farmers of the estates. Also how do they maintain organic matter in the plantations?

Answer : If they wish they can keep POMS and EFB. However they like to sell them (50M$/ton and for EFB, 1 to 5M$/ton). We also tend to replace chicken dung which costs 140 M$/ton with palm oil wastes.