SOILS, LAND USE AND SOCIETY

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by

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The title of this inaugural lecture must surely suggest to many of you that I am attempting this evening to bite off more than I can chew. I must therefore warn you, that all I shall attempt is to touch briefly on the three components which form the basis of my talk. I hope that by the end of this lecture a canvas will emerge to show the possible directions in which society in Malaysia may be influenced by the parameters of land use, as I see it.

The discovery of the relationship between seed and soil set in motion profound changes that brought rapidly in their wake, that which may be loosely termed, — the joys and miseries of civilisation.

It is now my purpose to scan the early period of Man's adventures on this spaceship 'Earth' and to discuss the kinds of changes and stresses that have affected the quality of human life, dependent at first entirely on natural ecosystems, and that resulting, subsequently, in the beginnings of this planned and directed interaction of seed with soil.

In order the better to appreciate the relationship and links of soil with land use and land use with man, I shall take the advice to Alice given by the King of Hearts,* and 'begin at the beginning'.

About 350 million years ago, in the era described by geologists as the Silurian period, the first plants began to colonise land from their evolutionary beginnings in the seas. With the appearance of plant life on land, the initiation of the process of soil formation in the strict sense of the word was first triggered. The effect of vegetation on soil and soil on vegetation set in motion the beginnings of nutrient cycles and hence nutrient cycling, thus ushering in the concepts of equilibria

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* In Alice In Wonderland.

and equilibrium levels between the soil/plant ecosystems, all in tune with the relevant climatic regimes of the world throughout subsequent periods.

It is true that rock debris and weathering products existed since the dawn of time on this planet, the first rocks disintegrating to produce something very much like the moon dust described by the two astronauts when they first set foot on the surface of the moon; yet it lacked the all important living and dynamic phase, critical to the development of natural ecosystems as we know them. The conversion of this inert material from the incorporation of organic debris through a sequential succession of plant life made it possible for the new living soil to support increasingly complex forms, culminating in the towering trees of the tropical and temperate forests.

"A clod of earth seems at first sight to be the embodiment of the stillness of death" writes Sir John Russell, "yet it is now known to be highly complex in structure, inhabited by prodigious numbers of living organisms inconceivably minute, leading lives of which we can only form the haziest conception, yet somehow linked up with our lives, in that they produce the food of plants which constitute our food, and remove from the soil, substances that would be harmful to us." In one of the earliest books on the soil called 'Terra', J. Evelyn in 1675 reckoned that the theorists of his day computed "no fewer than one hundred and seventy nine million, one thousand and sixty sorts of earths". There is little merit in arguing this question; suffice it to say that a great range of soils exist with varying physical, chemical and microbial properties. This is not surprising when we consider that soil is formed by the action of climate on the aggregation of a mineral matrix represented by a range of rock types, modified by landforms and vegetation, and also by what the French call, – the "insults of time"! Many equations have been developed to describe this process but the simplest one is that soil is a function of the intensity of effective leaching of parent material, over the passage of time.

$$S = f\,(l, pm, t)$$

Different kinds of rocks break down into particles of varying size from sand to clay, to form the mineral matrix or skeleton of the soil on which the biological processes of organic matter development and transformation are carried on. We are concerned here not just with the mineral skeleton of the soil in all its architectural grandeur, but also with the relevant aspects of anchorage and aeration, water release and the continuing supply of nutrients – all properties that contribute to support and regulate the kinds of plant and animal life. Be it sand or clay, shallow or deep, red or grey, the soil is the link between the rock core of the earth and the living things on its surface. The continuous distribution of soils at the earth's surface and their conspicuous regional differences at all scales, from the continent to the hillslope, makes soil one of the most intrinsically geographical phenomena. In soil mapping one sees, for example, the clearest contemporary expression of the essential unit of study in classical geography, namely 'the natural region'. Equally important in the study of man-land interrelationships, the ground trodden under foot is of immediate concern. In geographical regions where a marked dry season occurs, in low rainfall areas, or in periods of water stress, the nature of the soil, particularly its moisture holding and release properties, become central factors in determining the patterns of plant communities that form the vegetational climax. The development therefore of natural ecosystems, whether forest, grassland or swamp, has thus been governed both by climate as well as the properties of soil determining its capacity to support the type of natural food chains, which have evolved over very long periods. E.J.H. Corner, perhaps the greatest botanist of our time, describes the plant community as one "intercepting not only the passage of light but also the flow of water, absorbing sunlight, making sugar and exploiting this success to evolve and pervade the environment to the utmost possibility by reproducing excessively in forms that inherit its increasing powers and in the shadow of its reality, we (mankind) were brought forth".

The history of Man's biological evolution and the controversies of the pathways, lineage and time frames are irrelevant to this discussion. We need only to take up the threads of this history at the point where it can be said with a fair degree of certainty that until about 20,000 years ago, Man, in all the parts of the world that he had reached, was a forager and hunter and in this regard the appearance of Man as a creature of the climax left the balance of input and output – i.e. photosynthesis and respiration undisturbed. Nowhere was the population large but over the earth as a whole, Deevey (1960) gives the figure of 5 million with a man land ratio of 1 person per 10 sq. miles of land, a value about ten times less than the known carrying capacity of forests. From early times men appeared to have been living together in small mobile groups and united by ties of kinship. They had, through the ages, learned to accept taboos or man-made laws as being necessary for group survival. The integration of material, mental and ethical progress, which was effected continuously over a period of time so lengthy that we can hardly comprehend it, assisted palaeolithic man to remain as poised and balanced as the animals he hunted. During the last glaciation, somewhere between 20,000 and 13,000 years ago, game was so easily obtained in favoured regions that the hunters had the economic security and leisure necessary to build up artistic schools that produced animal paintings or carvings hardly to be surpassed in their inspired naturalism. I refer to the Magdelenian drawings of the pre-historic painters who created those magnificently living beasts. But as the glacial period drew near its end, the forests began to cover what had once been open grassland. Dependent as they were on natural forest supplies, the later palaeolithic cultures collapsed with the passing of the great herds and were replaced by forest cultures with a lower standard of living. The amount of food that could be gathered and the game available were basically a function of the productivity of the natural ecosystems which were again subject to transformation as a result mainly of climatic changes. Men hunting and gathering food were held in balance with soil fertility, subject to the checks, which keep all members of the ecosystem in equilibrium.

A happy conjunction of natural and human events created agriculture in the 'Fertile Crescent' of the Middle East about 10,000 years ago. We do not know where farming first arose nor even whether this was discovered only once, or several times in different places. There would be nothing extraordinary in the same accidents, exploited by an identical opportunism, occurring at widely separated points in similar conditions of soil and climate. The assurance of food supplies and the more settled way of life resulting from these discoveries in the hills around the 'Fertile Crescent' and at slightly later times in the Indus Valley, in China, in Central America, in the Andes and in S.E. Asia, led to an increase in population and the establishment of village communities and organised society.

This first great acceleration in material progress has been called the Neolithic Revolution and it unquestionably had a deeper effect on the everyday life of men and women than any other episode in history before the Industrial Revolution. As far as we can judge, all the advances described — the invention of mixed farming and the new crafts — had been made within a few millenia, somewhere between 7,000 B.C. and 4,000 B.C., a very brief span when set against the vast, uneventful stretches of Paleolithic time. By 3,000 B.C. many highly organised cities were flourishing in the alluvial plains of the Tigris and Euphrates and in the Nile Valley. It was at this stage of Man's history that the nature of soils strongly affected his progress, for the full benefits of the Neolithic Revolution were denied to those unable to alleviate their soil problems. Besides a suitable climate for the growing of his plants Man needed a soil that was friable, one easily worked with his primitive tools – with adequate soil moisture and a method of maintaining its fertility. The stability in soil fertility enabled continuous cropping for many generations giving rise to food surpluses which led in turn to trade and commerce and the building of cities.

Civilization spread from the irrigated valleys to other areas but these other areas, unlike the strip floodplains, which were continually being refertilised by annual additions of alluvial mud on the surface, were soon exhausted through deforestation and overgrazing. When this happened, the people moved away to new frontiers where the process was repeated again and again. When history is stripped down to its essential fundamentals, it would appear that this forms the basic pattern for the rise, growth and decline of past empires and civilisations. The fundamental cause of the decline in most areas was deterioration of the natural resource base. Even when cities were destroyed by wars and conquering hordes, these were usually rebuilt so long as the soil and other resources remained. Within a few thousand years the neolithic way of life spread over the greater part of the world and was profoundly influenced by the soils that it encountered and in turn it marked its progress by the changes that it produced in the soil. Between 3,000 and 1,000 B.C. ancient civilisations were flourishing in Egypt and also where similar soil conditions prevailed as in Mesopotamia, the Indus valley and the plains of the Hwang Ho. All were based on recent alluvial soils with agricultural production augmented by irrigation.

Mesopotamia has probably contributed more to the advancement of civilization than any other area of like size in the world. It was the favourable environment for early man that made this region significant, yet the chief resources were the fertile valley lands and the waters of the Tigris and Euphrates rivers which constituted, in the main, the natural wealth that made Mesopotamia the cradle of civilisation. The valley land of these two rivers stretching between present day Baghdad and the Shatt-al-Arab are fertile. Even more important than fertility however were the almost level topography and the low rainfall, giving are now threatened. They may well be effective for a few generations but their life time, compared to the 7,000 years of non reservoir irrigation in Egypt, will be very short; — that is, if present land use practices in the headwaters are continued.

These early civilisations illustrate well not only the importance of natural soil conditions but also the power of society to raise the productivity of the soil by devising such additional methods of meeting crop requirements as the use of the plough, irrigation and crop rotation. This power is also exemplified by the much later 'neolithic' civilisations of Peru where great stone terraces kept the erodible soil in place, where irrigation canals were built to bring water long distances, where the soils were fertilised with guano, and where the birds that produced the guano were protected by statute, and the visiting of the islands where they nested was prohibited during the breeding season.

The decline of these civilisations was accompanied by lack of continued improvement of soil fertility to meet the needs of the expanding population — due either to invaders who allowed the carefully built-up systems to fall into disrepair, or to the failure of the community itself to develop and adopt new techniques as they became necessary.

The natural grasslands of the world, on the other hand, favoured a pastoral use based on domestic animals rather than crops. These natural grasslands, popularly referred to as steppes and prairies situated in semi-humid areas between the wetter forest lands and the dry deserts were mostly on fertile and friable soils such as the Chernozems and Chestnut soils. Here were soils that could have supported strong early civilisations but although some civilisations did develop on hilly terrain in such places as Asia Minor and Palestine and had counterparts in Mexico and Peru, they do not appear to have developed on the broad plains. Large areas of these soils occurred in Europe, Asia, Africa, and the Americas, and their natural fertility remained to be exploited in recent times.

The inhabitants, basing their economy on domestic animals, were nomads following the animals and their grazing. Cropping was subsidiary, and some tribes hardly practised it at all. These people were nearest in their way of life to the late palaeolithic hunters and indeed in North America it was hunting of the wild bison herds that was combined with subsidiary cropping.

These nomadic peoples demanded little of the soil and gave nothing back. They did, however, affect history profoundly because of the critical nature of the environment of the drier soils. In moist cycles when the natural pastures were most productive, they and their herds multiplied explosively. In dry cycles, they were forced to migrate, displacing other peoples successively until the impact was felt from ocean to ocean.

About 2,000 B.C., when neolithic culture was becoming widespread in Western Europe, on soils which grade from brown earths, to grey-brown podsolic soils and podsols, reflecting increased leaching and poorer nutrient status all under a temperate regime, the area was covered largely with forest, mainly deciduous to the south and pine to the north, although the boundaries were not static and changed with fluctuations of climate. Under the deciduous forests, the soils were moist and friable enough for agriculture but, owing to the leaching regime under heavy rainfall they were mostly low in plant nutrients; there was no natural mechanism for renewing the fertility as in the accumulating soils from alluvium. After an area of forest had been burnt, reasonable crops could be produced; but, when the fertilising effect of the ashes was exhausted, crop yields diminished and a new area had to be brought in – a system known as "swidden agriculture" or "shifting cultivation". Thus was ushered into Western Europe an era of forest destruction and soil exhaustion – a process that was speeded up with the coming of the iron age. A method of permanent mixed farming based on the interdependence of animals and crops was later evolved, the dung of the cattle being used to re-fertilise the soils used for crops.

Although the introduction of the plough, supplementary feeding of animals, crop rotation, and the fallow, and the gradual evolution and introduction of lower fertility-demanding crops, such as rye and oats, enabled production to be carried on, the soil as a whole tended to become impoverished; and it was not until the industrial revolution that this process was rectified. Here was no sound basis for an early civilisation, such as existed in Egypt.

The 19th century western expansion in North America was carried out by men equipped to carry soil exploitation to its limits. The American pioneer peasants faced with a choice between parkland, forest and steppe, swarmed towards the latter for it offered few natural obstacles to the plough. The case of the soil of Oklahoma is of especial interest because it affords an example of this exploitation of soil by men reaching a mortal stage of virulence within a very short period.

Forty million acres of virgin soil in a rainfall region of only 10 in. per year were ploughed and cropped continuously. A combination of continuous monocropping and drought in successive years, had its inevitable result. Less than 35 years after the settlement in Oklahoma, a strange dark cloud hung over the city of New York and all the coast north and south of it. The cloud was dust and the dust was the top soil of the midwest including vast areas of Oklahoma on its way to be lost. Steinbeck in his "The Grapes of Wrath" describes eloquently the death of this soil, of this delicate natural grassland which maintained the stability of its ecosystem during thousands of years in such arid conditions, when he wrote: "In the roads when the teams moved, where the wheels milled the ground and the hooves of the horses beat the ground, the dirt crust broke and the dust formed. Every moving thing lifted the dust into the air; a walking man lifted a thin layer as high as his waist and a wagon lifted the dust as high as the fence tops and an automobile boiled a cloud behind it. The dust was long in settling back".

Innumerable examples of land abuse abound throughout history in many parts of the world. Erosion by water as a result of deforestation particularly in catchment areas has caused an increased frequency of floods, both in the past and in recent years. The Hwang Ho in China is referred to as the "Yellow Sorrow" not only because of the yellow coloured sediments formed by the erosion of loess soils that the river carries but also because of the misery it brings to that portion of humanity on which it directs its fury. At the beginning of the third of his Four Quartets, T.S. Eliot went a long way towards expressing the relationship between man and his environment in the following passage.

"I do not know much about gods but I think that the river
Is a strong brown god — sullen, untamed and intractable,
Patient to some degree, at first recognised as a frontier,
Useful, untrustworthy, as a conveyor of commerce;
Then only a problem confronting the builder of bridges.
The problem once solved the brown god is almost forgotten.
By the dwellers in cities — ever, however, implacable,
Keeping his seasons and rages, destroyer, reminder
Of what men choose to forget. Unhonoured, unpropitiated
By worshippers of the machine but waiting, watching and
waiting. . . . ."

The river represents a natural order which precedes and transcends both Man as a species and Man as a society. This natural order by which living organisms, including Man, are bound to each other and to their environments is essential to the existence of all the species on Earth.

We see from Man's early and recent history that only irrigation systems, with appropriate watershed management, appear to have been able to shape land and water development on a logical basis. In cases where an overall discipline was imposed we note societies' great powers of survival. All the past evidence appears to indicate a particularly close relationship between the flourishing of irrigation agriculture and the existence of a stable and vigorous central Government. The large scale irrigation farming in Mesopotamia and the centuries of prosperous irrigation elsewhere all ended in destruction through inability to maintain the essential discipline.

From this transect of human experience through space and time let us now examine Land Use in Malaysia from both past and present perspectives to arrive at possible indications to the direction in which forms of Land Use in Malaysia should be encouraged. While mainland S.E. Asia was one of the earliest pre-historic centres of agriculture, the Malay Peninsula and Northern Borneo were amongst the last areas in the region to be populated by agricultural peoples. Malaysia from more recent times up to the colonial period, presents a picture of Land Use in total harmony with the environment. The river systems which played a major part in the life of the peoples were unaffected by their activities whether at the upper reaches (ulu) midstream or down stream at the river mouths (kuala) where most of the human settlements were developed. During the colonial period in the late 18th and 19th centuries there were large areas relatively unpopulated and these were attractive where accessible from the coast to European capitalists for the growing of tree crops especially rubber. By 1922 rubber occupied one and a quarter million acres representing over 50 per cent of the then world's area under this crop. Although this figure represents nearly a quarter of the total rubber acreage in modern 1980 Malaysia, techniques of converting the Dipterocarp forests to rubber forests, and the scale of jungle clearing carried out in this period was of a lower magnitude in terms of disturbance to the environment. After independence in 1957 rapid agricultural development took place under the aegis of the Federal Land Development Authority. Malaysia's performance in Agricultural development has been strikingly impressive. The effects of the Agricultural Development Plans of the Government are evident in the large increases of agricultural cropped land as indicated by the Land Use surveys carried out in 1966 and 1974. Although, Malaysia has still more than half of her total land area under natural forest, log extraction is currently carried out at a rate which is beyond the capability of the forest to regenerate itself both in Peninsular Malaysia and Sabah. Only in Sarawak is the current extraction rate in conformity with the regeneration rate of the forest. In 1977, a national forestry policy, which has now designated 12.6 million acres of forest land in Peninsular Malaysia as Permanent Forest was adopted. Although the stated aims of the National Forest Policy are to enable forest management, reforestation and rehabilitation to be undertaken more effectively and to maintain the production capacity of the forest there is considerable doubt if this extent of permanent forest cover will safeguard the environmental stability with respect to soil and water resources in the country. The Government's most significant achievement is undoubtedly that of the Federal Land Development Authority in land settlement. Progress in land development achieved through various programmes and conducted by a multifarious set of Government agencies at Federal and State levels over the past 2½ decades or so, has been remarkable, both in physical and programmatic terms. In view of the substantial increase in the demand outlook for rubber, the immediate problem we face is to ensure adequate supplies of natural rubber to be maintained at a rate so as to prevent a serious disequilibrium developing as a result of significant shortfalls in supply. Malaysia's current strategy of increasing rubber production is both to increase land areas (through new frontier development) as well as to increase smallholder output from existing areas. A forecast of world demand of about 7 million tons of natural rubber in 1985 would suggest that considerable effort is needed to increase the supply. The dilemma we face is the question of how much more of the new land frontier we should consume for rubber against the decrease of our natural Dipterocarp forests. The reworking and upgrading of already settled and developed areas is more significant both from the point of view of its impact on the lives of the inhabitants as well as for maintaining the water resources in the country. It should be pointed out that after nearly two and a half decades, only about 64,000 families have been settled through FELDA's frontier development as against over half a million existing rubber small holders, stressing therefore the priority of focussing attention on areas already settled.

At the critical interface in the hydrological cycle, where precipitation or rainfall meets the soil, water is absorbed and the proportion not absorbed runs off the surface. Whether rainfall takes a beneficial or destructive route is determined largely by the canopy of the forest cover and the properties of the surface as well as the subsurface horizons of the soil, especially its infiltration and permeability characteristics which are in turn governed by the geometry of the pore spaces within the soil body or soil pedons. Tropical climates of water excess at high temperature, which we experience, favour the development of tall dense forests which collect and hold a precarious supply of nutrients. Also these forests represent a key intermediary between the soil and the large volume of water regularly cycling through or being stored in the ecosystem. Removal of the forests upsets the local cycling of water through the ecosystem resulting in marked changes in runoff. Differences in land use show significant differences in the runoff component in the water balance and storm rainfall runoff.

There is therefore now an urgent need requiring careful re-evaluation of the current strategy involving both kinds of crop (rubber vs oilpalm) and the rate at which new frontier development is taking place on these zonal soils of the humid tropics i.e. sedentary soils involving both the ultisols and oxisols which currently carry our forest cover. FELDA's and other agencies' programmes for the future should be confined to rubber on these upland soils, but the pace at which new areas are being opened up should be slowed down considerably until such time as improved systems and techniques of land clearing involving detailed specifications to minimise effects of runoff and sediment loss through systems of mosaic clearing, whereby isolated hillocks and stream edges are left untouched are developed. More effective nutrient cycling and lower levels of nutrient removal from latex also favours rubber over oil palm in addition to the more effective protective canopy that a rubber forest develops. Rubber forests as a source of timber and fuel wood for the future is another spin off from such a policy.

Oil palm development should really be confined to the richer alluvial soils and areas which have already been converted from jungle. Estimates of idle land in Peninsular Malaysia have been variously given as being of the order of 2 million acres. Depending on the proximity of palm oil mills these areas could be seriously considered for palm oil development.

The conversion of tropical rainforest to pastures on the other hand for the grazing animal in Malaysia has no justification whatsoever, both from economic as well as environmental considerations. It should also be pointed out that nowhere in the humid tropics does one find grassland communities as ecological climaxes which are in tune with the climatic and edaphic conditions of the environment. Everywhere the tropical grasslands are stages in ecological regression below various types of forest. It is therefore a matter of regret that it should be recorded that both the World Bank and the Division of Tropical Pastures CSIRO (Australia) have indirectly appeared to support what is to me and to many colleagues in this University an incredible act of irresponsibility, defying every known principle of the agro-ecosystem on landforms subject to high intensity rainfall as we experience in Malaysia. Fortunately the areas involved have not been large and the damage can be contained if there is to be no further expansion from further removal of existing forest cover.

One area in which Malaysia's development programme has gone sour, although the full implications of this have not generally been grasped is in the conversion of the mangrove ecosystem and former mangrove areas now further degraded by more intensified systems of drainage. It is quite a common experience that when a coastal area is drained the soil rapidly becomes very acid, and crop growth suffers severely as a result. The acidification is well illustrated by maps of the Parit Jawa area of Johore produced for 1960/61 and 1973 which record the acidity of the soil (pH) before and after existing drainage canals were improved and new canals constructed (Joseph and Nuruddin bin Maarof, 1975). The information given in the maps shows that the effect of draining has been to increase the acidity of the soil from the surface down to 36 inches below. The overall effect has been an extension of the acid area, spreading from inland towards the sea.

Many similar instances can be quoted from Peninsular Malaysia and elsewhere in the tropical world. The reason for this acidification is the presence of pyrite in the undrained soil. Pyrite is an iron disulphide FeS_2, that typically is formed in coastal swamps where the deposit is anaerobic, and where the sea provides a source of sulphate. Under anaerobic soil conditions, sulphate is reduced microbiologically to sulphide which reacts with iron compounds in the soil to form the black monosulphide FeS, which subsequently reacts to form FeS_2 (pyrite) in which form quite large amounts of sulphide can be accumulated. Pyrite is quite stable so long as the soil remains waterlogged, but it oxidises to form sulphuric acid once water is removed and air can enter the soil mass. This oxidation process is part chemical and part microbial. In the oxidised or partially oxidised state such soils are known as acid sulphate soils and in the original unoxidised state as potential acid sulphate soils. The overall process following drainage of soil material containing pyrite or other sulphide material comprises the following chemical reactions:

$$FeS_2 \xrightarrow[H_2O]{O_2} Fe^{2+} + SO_4{}^{2-} \quad \ldots \ (1)$$

$$Fe^{2+} \xrightarrow{O_2} Fe^{3+} \quad \ldots \ (2)$$

$$FeS_2 + Fe^{3+} \longrightarrow 2Fe^{2+} + (S_0 \ldots SO_4{}^{2-}) \quad \ldots \ (3)$$

Reaction (3) is mainly responsible for the oxidation but unless the oxidation of ferrous iron (Fe^{2+}) by reaction (2) keeps pace with its formation by reaction (3), the overall process will slow down – in other words reaction (2) determines the rate of the overall process. Reaction (1) is moderately fast (measured in days). Reaction (3) is very fast (measured in hours); however at the low pH values with which we are concerned, the atmospheric oxidation of Fe^{2+}, i.e. reaction (2), is much too slow to account for the observed rate of the overall oxidation process. This was resolved in 1947 when a hitherto unknown bacterium was discovered by Colmer and Hinkle in acid mine water that obtained the energy required for its growth by catalysing the oxidation of Fe^{2+} to Fe^{3+} at low pH, thereby causing a very great increase in the rate at which pyrite is oxidised. This bacterium was named *Thiobacillus ferroxidans* and micro organisms with the same property of promoting the oxidation of Fe^{2+} and hence of pyrite have been found in samples of acid sulphate soil from Peninsular Malaysia (Bloomfield, 1972). *T. ferroxidans* does not grow at pH values greater than 3.5 to 4.0 so that it is not until the chemical oxidation of pyrite has proceeded far enough for the pH of the soil to have fallen to within this range that the rapid microbial process can start. This explains why techniques used previously to ascertain the presence of acid sulphate conditions were generally unsatisfactory. Measuring acidity of oven dry soil samples did not reflect 'potential acidity of the soil' which now can only be ascertained by soil incubation techniques.

The overall effect then of draining wet soil containing pyrite is the lowering of the water table which results in aeration of the soil which then leads to oxidation of pyrite and acidification. In considering methods of ameliorating acid sulphate soils, what often seems to have been overlooked is that whereas pyrite that has already oxidised is the cause of the present poor condition of the soil, the residual unoxidised pyrite is a source of continuing acidification and it is therefore quite unrealistic to embark on an attempt at reclamation by leaching and liming when only the sulphate content has been considered. Oxidative leaching will eventually cause all the pyrite to be oxidised and the oxidation products to be leached from the soil but the process will take very many years (about 50 years in areas affected in West Johore) and the problem of dealing with a soil that is very acid and saturated with aluminium down to the depth of the drains would then remain. Apart from the excessive amounts of lime that would be required (in the order of hundreds of tonnes/ha) the virtual impossibility of liming to the required depth, as has been advocated in some quarters, makes the proposal quite unrealistic. The formation of yellow incrustations of jarosite on exposed surfaces of acid sulphate soils is a familiar occurrence in Malaysia. This and other basic sulphates that are formed are sparingly soluble in water and their formation tends to inhibit further the leaching of sulphate from the soil. In the West Johore Development Area, it has been shown (Joseph et al, 1976) that nearly a quarter million acres, of both phases of this project financed by the World Bank covering almost all the alluvial soil consist of potential acid sulphate soils, with pyrite fairly close to the surface. I believe that the effect of the current intensification of drainage in this area has not yet run its full course and we can expect marked and dramatic decreases in yield from the areas as a result of the intensification of acidity that will follow. Unless the water table is now raised by allowing sea water in the canals and drains and holding it through the construction of gates and the use of pumps, further deterioration can be expected. This will increase further the cost of the project (originally estimated at over 200 million ringgit) and it would appear that the whole exercise in Johor Barat, in my view, was a very expensive exercise in futility. In Kedah, the Ban Merbok Scheme is another example of abuse of such an ecosystem. We hope that all the remaining mangrove areas will be left untouched. There is absolutely no question of compromise between development needs and conservation in this ecosystem. The drainage of potential acid sulphate soils leads to disaster.

There is therefore now an urgent need for a reorientation of focus for soil survey activities in Malaysia to delineate areas of potential acid sulphate soils from non acid sulphate areas. In the past 25 years soil survey activities have been concentrated on the sedentary, or upland, low activity kaolinitic clayey and sesquioxide rich oxisols and ultisols where the optimum form of land use is forestry, be it natural forests or rubber forests. The areas of depositional topography, on the other hand, namely the marine and inland alluvia, peaty and swamp areas, which have considerable potential for food crops and aquaculture, have been neglected.

Soil survey activities should be closely integrated with agronomic and crop research and therefore these activities should be placed under the same authority for greater effectiveness of effort towards rationalising land use in Malaysia.

An important edaphic zone that could be utilised is peat, covering about 6 million acres, representing an edaphic environment of considerable potential yet untapped for intensive agriculture in Malaysia. This medium has the advantage of high nutrient holding capacity (cation exchange capacity in the rooting volume is extremely high) a zero erosion risk, insignificant phosphate fixation (extremely high on the sedentary soils) and of particular relevance is the very low nutrient leaching losses even after heavy intensive fertilization with nitrogenous and potassium fertilisers. Yields of 50 tonnes/ha of tapioca tuber consistently reported on peat could make this the third most important crop in Malaysia, in the years ahead. Alcohol from tapioca on peat could provide Malaysia with an important source of a renewable form of energy and steps should be taken to develop this industry. The development of peat, however, calls for very special techniques of both careful drainage and land clearing which will involve large capital costs. A Peat Development Authority financed by petrodollars would be a logical approach to plan for the future of this important, renewable energy source.

An increasing drift of people into large urban concentrations is a feature common to Malaysia as well as in countries at all stages of economic development. Population growth compounded by the great increase in consumption of water per head by a modernising technological society will cause a vast increase in the rate of dam building in Malaysia. The life of a dam however will depend on the extent of protection or forest cover over the entire drainage basin that feeds the dam. We are concerned essentially with the water supply to sustain the population and with the optimum management of the land surface on which it falls and from which it must be collected. The combination of rising population, rising water consumption per head and rising volume of domestic and industrial water is outstripping the geographical resources of the environments of major cities. Irrigation needs for double cropping of padi and intensification of irrigated agriculture in the landforms of depositional topography would suggest that policies on water can no longer be divorced from forestry. Since agricultural ('frontier') development is at the cost of our forest resource, and since modern agriculture is so heavily dependent on fossil fuel subsidies, the question of energy can no longer be divorced from the total water resource the life of which is so intimately interwoven with our natural forests. Policies therefore on forestry, agriculture and fisheries, water and energy, have to be completely integrated and treated as a whole (holistically). In this connection it is essential that water Authorities or Boards be set up throughout the country to implement and monitor all activities for the major rivers and streams. The river basins of Malaysia should be governed by their own Water Authority, answerable to the Federal Government on all matters concerning forestry, agriculture, water and energy. No longer should land matters, especially forestry, be solely regarded as an individual state matter although in the past this sensitive issue has always been complicated by the question of state revenue. One possible way of overcoming this problem is through the payment of an annual subsidy or grant equivalent to the land area, immobilised for soil and water resource protection. The biological productivity of the land equivalent to for example, latex production that would have accrued from the area concerned would appear to me to be a fair compensation for the preservation of forests in key areas. The real culprits of land abuse in the major towns of Malaysia are the 'land developers' — the handiwork of their greed and avarice is abundantly evident in the new townships which are springing up everywhere. The need to maintain some balance of forested pockets, parks and playing fields within housing estates is essential and specifications controlling such activities need to be drawn. Floods are the most dynamic symptoms of land misuse, but not all floods are due entirely to man's mismanagement. Monsoon climates concentrate heavy rainfall into a few months and occasional random movements of converging airmasses cause unpredictable excesses of rainfall overloading the landscape with water, which it cannot cope with, thereby producing floods. In Malaysia, both from direct and indirect evidence, the frequency of floods points to the fact that what we now regularly experience both in Kuala Lumpur and in the country as a whole, is symptomatic of land misuse. The rivers and streams of Malaysia are beginning to carry enormous loads of silt and sediments and this is a direct consequence of indiscriminate felling in critical areas along stream channels and in some key watershed areas.

The transformation of the vegetation cover from forest to agriculture or for urbanisation affects, among other parameters, water storage and runoff and these are particularly significant in Malaysia. We should constantly remind ourselves that the most remarkable and fundamental feature of Malaysia is that most of the land surface is formed by valley slopes, presenting a vast zone of erosional relief and the need, therefore, to maintain a minimal level of primary forest cover is indisputable. The question is: what is this minimum level and how do we arrive at this level? The management of watersheds will be the ultimate limiting factor that will determine the carrying capacity and the quality of life of Malaysia's population, particularly in a world of diminishing fossil fuel reserves.

Research on the impact of land use on soil and water resources in Malaysia, and on the larger issues of land ownership and reform now being carried out by colleagues in the Department of Geography and by others in this University and elsewhere should provide some of the answers to the questions posed tonight as well as the prescription of strategies for agricultural development through the establishment of land balance sheets for land use both for national and regional purposes.

Finally to sum up, let me point out that two hundred generations of men and women have given us what is in our minds about soils and soil fertility – the arts and skills and the organised body of knowledge that we now call science. We know technically more about taking care of soils than our fathers and grandfathers did and yet we appear to have abused the land more than we have ever done in the history of this country. This abuse, however, has not been made, in Malaysia, by those men and women who actually till the soil, work with it and get from it its bounty, or in bad years, wrest from it its reluctant yield. The evidence in Malaysia is clear that this abuse is from exploitation motivated by excessive greed and profit and by our entirely inadequate system of ensuring controls in the abuse of the total resource environment. Unhappily too, some agencies have also been responsible for damage by misconceived conceptions of what 'Development' entails. The question is: will modern Malaysia begin to practise true and full conservation in time? Will our conservation efforts be like those of all the ancients – too little and too late? While we have not, fortunately, reached the critical 'point of no return', nevertheless Man in Malaysia must now take stock of his overall land resources and plan their use, not on pressing short term demands and emergencies that call for all out immediate production, but also 'discount' for future generations as well. If we do this, then succeeding generations will not look back upon our present administration of this great trust with amazement and disgust.

For all Malaysians wherever we live, soil, together with the vegetation it supports, is a basic treasure and we need to learn to appreciate its value and limitations. There is also an urgent and vital need to develop in our educational systems a greater sense of ethics and a radical modification to our present value system, which is becoming totally 'profit-oriented' particularly with regard to the question of the 'stewardship' of land. It is hoped that decisions on, and the implementation of, 'land use' in Malaysia will ensure the provision of a constantly improving land environment for the generations yet unborn, 'while they make their exits and their entrances' on this spaceship Earth as it moves in space and through time.

"Then shall the dust return to the Earth as it was and the spirit unto God who gave it".

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