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CONSERVATION IN

MALAYSIA

PART I CLIMATE

PART II SOIL

PART III } AGRICULTURE

PART IV }

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ANNOUNCING A NEW MONTHLY SERIES:

CONSERVATION IN MALAYSIA

by

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Dr Wycherley's monograph,* sub-titled *A Manual on the Conservation of Malaysia's Renewable Natural Resources* was the subject of a review in our August 1971 issue.

Through the kindness of the author and the special permission of his publishers, we are pleased to announce the monthly serialisation in *The Planter* of the complete Manual, beginning this month.

The main sections are entitled Climate, Soil, Agriculture, Biological Communities, Threatened Species, National Parks and Nature Reserves, and Conclusions. The text has been specially re-edited by the author.

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Introduction

Botanists recognise phytogeographic regions, each of which has a characteristic floristic composition, that is, places within a region have many native plants in common, but outside the region many of the native plants are different even if some are found both within the region and in the surrounding area. The Malasian phytogeographic region includes the Malay peninsular south of the Isthmus of Kra, Borneo, the Philippines, the Indonesian islands and New Guinea.

South East Asia is a geographical and political concept comprising not only the Malay peninsular and archipelago outline above, but also the mainland countries of Burma, Thailand, Cambodia, Laos and Vietnam. Sometimes the island of Sri Lanka is included also.

Geographically these countries lie in the equatorial or humid tropic zone between Central Asia and Australia. Politically and economically they are among the developing nations. Nevertheless there is great diversity. Therefore when discussing any problem in South East Asia or the Malasian region, there are broadly two alternatives open, either to treat the whole area in a superficial manner or to deal with one country in greater detail. The latter course has been chosen here.

Malaysia is central to South East Asia as a whole and is typical of the Western sub-region of Malasia. It is a rapidly developing country, opening up its natural resources and making great strides in education and social welfare. It has been selected as an example to discuss conservation problems in South East Asia.

Malaysia is divided by the South China Sea into peninsular West Malaysia, which is the furthestmost tip of the Asian mainland, and East Malaysia comprising the two States of Sarawak and Sabah on the northern shore of the island of Borneo. West Malaysia consists of the States of Malaya, which formed previously the Federation of Malaya, and it is more convenient to refer to West Malaysia as Malaya in a largely geographical account of this nature.

Therefore the following usage has been adopted in this account. Malaysia refers to both East and West Malaysia, for instance the east coast of Malaysia means both the east coast of Sabah and the east coast of Malaya (climatically they have much in common). East Malaysia refers to both Sabah and Sarawak. West Malaysia is sometimes referred to as such but more frequently it is simply called Malaya, especially when it is necessary to specify some part, for example the West Malayan Rainfall Region.

Climate

Our planet, Earth, receives radiant energy from the Sun. This is the light which enables us to see by day and the energy which plants convert by photosynthesis into food and fuel. The Earth's surface and atmosphere are warmed by absorption of solar radiation. Energy is lost again and local cooling occurs due to radiation of heat back into space and by such processes as evaporation of water.

The Earth traces an elliptical path around the Sun. The distance between Earth and Sun is least in late December and the total solar radiation intercepted by the planet each day is then at a maximum. Six months later the distance is greatest and the energy intercepted is about 7% less. This variation exaggerates slightly some seasonal differences in the Southern Hemisphere relative to those in the Northern Hemisphere, but this is trivial compared with the differences due to the greater proportion of land in the Northern Hemisphere or the other effects of the Earth's motion. The alternation of night and day results from the Earth spinning about its axis, which is inclined at about 23° from the vertical to the plane of the Earth's rotation about the Sun. Owing to this inclination the Northern and Southern Hemispheres are alternately tilted towards and away from the Sun in their respective summer and winter seasons.

The possible maximum intensity of radiation declines as the angle of the Sun's rays departs from the vertical, whether due to time of day or to change in latitude. These factors work together so that at the equator day and night are equal in length throughout the year and there is relatively little variation in the radiation reaching the atmosphere during different months of the year. Most of the seasonal variation in sunshine recorded at ground level near the equator is due to cloudiness and other atmospheric effects.

The greater the latitude the less total solar radiation received during the year and the greater the seasonal variation in its distribution throughout the year, both in the hours of daylight and its intensity. This greater variation beyond the equatorial region than within it, is an interesting contrast in itself, furthermore large seasonal changes outside the Tropics are a major factor in generating the monsoons which are important rain-bearing winds in South East Asia. During the winter months the oceans and in particular the land masses lose heat, the air above them cools and becomes denser, barometric pressure rises and the air flows outward, these winds acquire a circular motion such that they are easterlies as they approach the equator. If they cross the equator they are deflected to become westerlies.

The weather at a given time and place may be defined as the sum of the ambient physical conditions or the meteorological aspects of the environment. The climate of a place is an appreciation of the weather throughout the year. Some of the components of Malaysia's equatorial climate are significant natural resources in themselves, which arise from the motion of our planet about the source of solar radiation and the effect of this upon distant parts where the winds and rain arise. These are beyond the control of mankind, which is perhaps as well at this stage of human development.

Sunshine

Hitherto meteorological stations throughout Malaysia have recorded the hours of bright sunshine and from these may be calculated the intensity of solar radiation in calories per square centimetre per day. More recently some stations have installed solarimeters which measure the incoming radiation. The few direct measurements available enable the values for energy calculated from the hours of bright sunshine to be corrected appropriately.

In Malaysia sunshine increases with distance northward from the equator and decreases with distance from the coast and with altitude above sea level. The approximate increase for each degree of latitude is one third of an hour of bright sunshine per day or 11 cal/sq. cm/day. The decline for every ten miles inland in the lowlands is about 8 minutes of bright sunshine or 4 cal/sq. cm/day. The annual means of twenty one stations in the lowlands of Malaysia (based on five years records) were 6.5 hours bright sunshine per day and an estimated 435 cal/sq. cm./day. The lowest annual means were at Kuching: 5.1 hrs and 390 cal. The highest were at Labuan: 7.4 hrs and 460 cal. These are quite high values compared with other parts of the world.

There is a trend of increasing yield of rubber trees from south to north in Malaya, which may be accounted for by the similar variation in solar radiation in conjunction with other factors. The growth of green plants is dependent on photosynthesis, which requires light energy, and there is a correlation between intensity of solar radiation and yield in many crops. Abundant sunshine is a natural asset, but tempered with the disadvantage that the rate of evaporation from soil, plants or open water such as fish-ponds, padi-fields and reservoirs is largely controlled by the intensity of solar radiation. The rate of evaporation is accordingly high in this region. The maximum benefit in crop yields from plentiful solar energy, whose intensity we cannot control, depends upon the availability of water, a resource whose use can be wisely planned to compensate for evaporation. The energy involved in evaporation is at least sixty and often one hundred or more times that stored by concurrent photosynthesis.

At most places in Malaysia the hours of bright sunshine per day and the estimated intensity of solar radiation follow a similar pattern of variation throughout the year. There is a cycle from a trough of low values somewhere in the period October to January rising to peak sunshine in February to April; the cycle is about two months earlier on the west coast of Malaya than on the east coasts of Malaya and Sabah. The west coast of Sabah is intermediate between these. Western Sarawak is rather exceptional, although the trough is in January, the peak is delayed until July, although fairly high values occur in April and May. There is a tendency in South Malaya towards a minor rise in August or September.

Temperature

The air temperature in the shade is lowest about dawn and rises to a maximum in the early afternoon usually between noon and 3 p.m. The mean temperature can be calculated by adding the minimum and maximum temperatures and dividing

by two or determined by continuous recording throughout the twenty-four hours, and determining the average. The former gives values about 0.6°C (1.1°F) higher than the latter in Malaysia.

If a wide range is examined, for example throughout the whole world, the annual mean temperature is correlated with the annual mean solar radiation or more correctly with the radiation balance. The highest annual mean temperatures in the old world are recorded about latitude 10°N instead of at the equator. The annual mean temperature in the lowlands of Malaysia might be expected to show an increasing trend from south to north in view of this general global pattern and the similar trend of increasing solar radiation from south to north. However, the relationship between the annual means of temperature and radiation is not marked in Malaysia and the tendency towards a south-north trend in mean temperature is obscured by strong local modifying influences. Examples of these are the stabilising effect of winds from off the sea, whose temperature is almost constant at 27°C (80°F), and the disturbing effects of air movements down the sides of the mountain ranges and atmospheric convection currents.

The west coast of Malaya is warmer than the east coast. There is insufficient data at present to generalise concerning Sabah and Sarawak. The highest annual mean temperatures of about 27.3°C (81.9°F) have been recorded inland in the lowlands of Malaya's west coast and on the island of Labuan off the west coast of Borneo. The temperature declines with elevation by approximately $6^{\circ}\text{C}/1000\text{m}$ or $3^{\circ}\text{F}/1000\text{ft}$. The lowest temperatures are recorded at the hill stations.

The monthly mean temperature follows a cycle throughout the year similar to that of sunshine, although the temperature peak is on the average two months behind the peak sunshine in Malaysia. The trough in the temperature curve is on the average less than half a month behind the lowest solar radiation at any place. The sunshine curve is symmetrical at Kuching only of the Malaysian stations examined and there the mean temperature curve is in phase with the sunshine curve. At most places in Malaysia the highest mean temperature is in May and the minimum occurs during the period November to January.

The difference between the lowest and the highest monthly mean temperature is between 0.7 and 2.4°C (1.2 and 4.3°F), in Malaysia. There is most variation on some parts of the east coast which are exposed fully to the north east monsoon and at certain central inland stations, but it is least along sheltered coasts. This limited variation indicates how small seasonal differences are in an equatorial climate. This may be contrasted with the difference between the minimum and maximum temperatures during the 24 hours, which is called the diurnal range. The annual mean diurnal temperature range varies between 5.2 and 11.2°C (9.4 and 20.1°F).

The diurnal temperature range is closely correlated with the concurrent sunshine at any place. When conditions favour strong solar radiation inward during the day, there is probably high reverse radiation outward at night. Thus the daily warming and cooling is more pronounced during sunny periods and the temperature accordingly fluctuates more markedly. This accounts for the variation in diurnal temperature range throughout the year at each place; however the variation from

place to place is not related to the mean solar radiation. The annual mean diurnal range is usually least close to the coast and the stabilising influence of the sea. Variation increases with distance inland in the lowlands, although some of the cooler hill stations are less variable.

The maximum temperature attained by day follows more closely the sunshine cycle through the year. The peaks and troughs in the maximum temperature lag on the average about one month behind those for sunshine. Since strong radiation induces greater diurnal temperature changes, the minimum to which the temperature falls each night before dawn does not mount as rapidly as the maximum day temperatures during the period of increasing solar radiation. The minimum or dawn temperature curve lags about a month behind that for the maximum or noon temperature. In most of Malaysia the peak and trough for sunshine occur respectively in March and November—December; those for maximum day temperatures are in April and December, those for minimum or dawn temperatures are in May and December-January, and those for the mean temperatures are in May and December.

Hot afternoons are usually too warm for comfortable work, whereas in the cool hours before sunrise some covering is necessary to prevent chilling of the inactive sleepers. It has recently been suggested that the effective temperature, which takes into account air movement and relative humidity as well as the air temperature, is a good index of comfort. The effective temperature is usually lowest at dawn, rises to a peak at noon or shortly afterwards and then falls to a low value by about an hour after sunset which is followed by a minor rise during the night before dropping to the minimum again before dawn. The mean effective temperature shows a similar pattern of variation throughout the year at most places in Malaysia, usually it is lowest in January and highest in May. The effective temperature declines with altitude and the hill stations are too chilly unless warm clothing is worn. In the lowlands the average effective temperature increases with distance from the coast, which is in accord with experience that small hills exposed to sea breezes are pleasantly cool and comfortable sites.

Relative Humidity

Except for the unstable condition known as super-saturation, the air can only contain a certain amount of moisture. This quantity of water vapour increases with temperature. Excess water condenses as dew or mist especially when the temperature falls. The relative humidity is the amount of water present expressed as a percentage of that which would saturate the air for the ambient temperature, *i.e.* the relative humidity of saturated air is 100%.

The relative humidity usually attains a high value close to saturation after sundown and maintains this during the night, reaching a maximum just before dawn. The average maximum relative humidity of the air varies from 94 to virtually 100% in Malaysia. There is a tendency for the average maximum to be greater at places where there is a greater diurnal range in temperature.

As the air is warmed after sunrise so the relative humidity drops to reach a minimum at the hottest time of day. The drop in humidity is closely related to the amount of the temperature rise, that is the diurnal temperature range, both from place to place in Malaysia and from month to month throughout the year. Often the fall in humidity during the day is approximately equal to that predicted from warming saturated air at the minimum night temperature to the maximum day temperature. However, usually the minimum relative humidity is higher than this predicted value because of evaporation of moisture from soil and water and transpiration of plants. Also rain temporarily increases the humidity preventing a fall to the predicted minimum. In the Malaysian region the relative humidity falls lower than the minimum predicted from the diurnal temperature range rather infrequently during dry spells, when reserves of moisture for evaporation have been reduced.

If the relative humidity over the 24 hours is averaged, the mean relative humidity is obtained, which is intermediate between saturation and the minimum attained by day. During rainy seasons the average humidity tends to rise. In the lowlands the monthly mean minimum relative humidity ranges from 45 to 85%, the annual mean minimum relative humidity falls within a narrower bracket of 60 to 75%. The average relative humidity has a range in monthly means of 70-90% and the bracket for annual means is 80-88%. The corresponding figures at hill stations are all higher. The intermediate hill stations in the cloud belt at about 4 000 ft are the dampest.

The humidity is higher in the shade of forest trees and many delicate plants and animals cannot stand desiccation. Most mosses and ferns are confined to forest conditions or to the cloudy hills. Examples of such habitats must be preserved if the full range of plant life is to survive. There are more immediate applied reasons for studying variations in relative humidity and associated phenomena. Parasitic fungi are often susceptible to dry conditions, especially during their stages of dispersal and invasion of new hosts. Many require critical minimum periods of near saturation or even actual dew formation in order to infect a plant. In some crops it is possible to apply plant protective measures at the most opportune moment to prevent disease by predicting through meteorological observation when the fungus would otherwise attack.

Dew and Mist

As moist air cools, its relative humidity rises until it reaches saturation; if further cooling takes place there will be excess water in the air. If the excess remains in the vapour state, the air is supersaturated, but this is an unstable and therefore usually a temporary condition. The excess moisture condenses into water droplets. Condensation on soil, plant or other surfaces is called dew. Condensation as fine suspended droplets is called mist, which forms more readily if there are fine particles of dust or similar nuclei for condensation floating in the air. Dew is probably more common than mist, partly because mist formation may be retarded for lack of nuclei, but mainly because solid bodies radiate heat more rapidly so the air in contact with them is cooled more.

Dew formation is not regularly recorded at most meteorological stations in Malaysia, but some data on mist have been collected because of its important effect on visibility for navigation of aircraft and shipping.

The number of times mist is recorded during the year is greater in places where the average maximum relative humidity is higher, which is not unexpected. Mist is most common in places where the relative humidity does not fall by day as much as predicted by the temperature range, or in other words where rain and evaporation increase the moisture content of the air so that it is over-saturated at night temperatures.

Mist-free places are known on both east and west coasts of Malaysia and even one place inland, namely Ipoh. Despite these exceptional places, there is a general pattern of fewest mist days on the west coasts, twice to three times as many on the corresponding east coasts, and about ten times as many inland as near the coast. Mistiness increases as the hills are ascended to the cloud belt, above which on the highest hills there is some decline in the number of mist days.

Correlations between the number of mist days per month and the corresponding monthly mean maximum relative humidity, and with the excess humidity above that predicted from the monthly mean diurnal temperature range, are found in several places, but not at all the stations investigated.

The distribution of mist days throughout the year is rather erratic and it is not possible to give any simple generalisation. Dew formation is probably under similar conditions as mist but more frequent. The amount of dew precipitated is not known, but it is probably trivial compared with the large amounts of water needed to meet the demands of evaporation and transpiration.

Evaporation

The change of state of liquid water to water vapour is called evaporation. This change requires a considerable amount of heat energy, about six times as much energy as that required to raise the temperature from freezing point to boiling point without change of state at atmospheric pressure. Whenever water is in contact with air which is not saturated, evaporation will take place provided there is adequate energy available. There is abundant solar radiation in a tropical climate, the warmth of the sunshine is self evident, and the air is not saturated by day as the relative humidity figures demonstrate. Thus from every water surface, whether a lake, damp soil or the tissues of a plant, evaporation takes place.

Land plants must obtain carbon dioxide from the air in order to make carbohydrates by photosynthesis, therefore they must expose tissues to the air during periods of sunshine in order to assimilate, metabolise and grow. It follows that inevitably they must lose water from these exposed tissues by evaporation or transpiration as it is called in plants, even if the dissolved substances in plant juices reduce the rate of evaporation. Some plants have devices such as closure of the leaf pores to prevent loss of water under severe conditions, but this reduces carbon dioxide supply and photosynthesis. The utilisation of the light energy abundant

in the tropics to make plant products, including timber and the food of man, animals and the plants themselves, depends on provision of adequate water to balance the losses by transpiration. This is especially true of most crop plants, which have a high water demand, and in particular of wet padi because water evaporates from the rice fields as well as transpiring from the plants. One or more (often several) tons of water are required to enable one pound of food, timber, clothing, industrial or agricultural produce to be obtained.

The rate of evaporation from free water surfaces such as reservoirs has been determined under various conditions. This has been correlated with the losses from pans of specified construction, which provide a convenient means of routine meteorological observation. Such results have been related to other meteorological phenomena such as solar radiation, temperature, relative humidity or saturation deficit, and wind speed, thus it is possible to calculate the potential evaporation from such meteorological records where direct observations on evaporation are not available. Evaporation is very closely correlated with the solar radiation balance, in general the longer the hours of bright sunshine are in Malaysia the greater is the potential evaporation. Evaporation is also correlated with the saturation deficit, (the deficit in water vapour pressure required to saturate the air). Wind movements enhance evaporation by circulating the air.

The rate of transpiration by various crop plants has been investigated. It is found that a complete cover of vegetation with several leafy layers such as a forest can transpire as much water as would evaporate from a free water surface such as a lake of the same area. Mature rubber trees and oil palms probably transpire as much as the theoretical maximum potential evaporation and similar amounts evaporate from padi fields. The actual evaporation is limited by the water available and during periods of drought is less than the potential.

There are relatively few records of evaporation from reservoirs, pans or catchment area studies in Malaysia. These have been supplemented by calculations from other meteorological data. Calculated values may not appear as reliable as actual observations, but since minor variations in the technique of operating evaporation pans can cause considerable differences, and there is nonetheless reasonable agreement between the calculations and observations, all these results can be pooled to give a fair estimate of the degree of potential evaporation.

Evaporation is expressed in the same way as precipitation as the depth of water in inches per month or millimetres per day. The range in observed values is from 3.5 to 7.7 in. per month (2.9 to 6.5 mm per day) and the range in annual means from 51 to 78 in. per year (3.6 to 5.5 mm per day) at various places. Calculated monthly values range from 4.0 to 7.8 in. per month (3.4 to 6.6 mm per day) and calculated annual means vary at different locations from 62 to 79 in. per year (4.3 to 5.5 mm per day). These are relatively large figures compared with the precipitation; indeed pilot catchment studies indicate that from one half to two thirds of the actual rainfall is evaporated (including transpiration), and never reaches rivers, reservoirs or the sea.

Evaporation declines with distance inland, roughly one tenth of an inch per month for every ten miles inland (or 0.1 mm per day for every twelve miles). Evaporation also declines with elevation. This distribution reflects the variation in solar radiation, which also strongly influences the seasonal variation in the rate of evaporation. On the west coast of Malaya the rate of evaporation is greatest in February and is usually still high in March; on the west coast of Sabah the maximum is in March or April. On the west coasts of both Malaya and Sabah the minimum is mainly in November, although at some places it is October or December. On the east coasts of Malaysia the peaks and troughs are generally a month or two later; the maxima are spread from February to April (especially the latter), whereas evaporation is least in December with low values in November and January.

There is a rough inverse correlation between rainfall and evaporation at most places in Malaysia, and the periods of maximum evaporation mentioned above are nearly all times of low precipitation. Thus when water is needed most, it is least available. The water storage capacity of the soil is likely to be exhausted during dry spells of two or more months.

In some places such as Sitiawan the annual precipitation barely balances the annual evaporation, whereas at the other end of the scale Kuching almost invariably has an excess of rain over evaporation. There are many intermediate conditions in which water stress is likely during certain seasons. Such measures to increase food production as double cropping of padi in areas which have only one major wet season, or vegetable growing and cattle grazing throughout the year even where there are two rainy seasons, depend on water being available all the year round. Health and comfort in village and city demand adequate clean water at all times. Simple processing units such as estate or smallholders rubber factories have considerable water requirements and the increasing number of industrial complexes being developed in Malaysia will magnify these. In many countries urban and industrial development is limited by the availability of water, even when used water is treated and re-used repeatedly. The hydro-electric schemes are sited where there is plentiful water, but its release throughout the year requires conservation and control.

The fate of rain after it has fallen, and what measures may be taken to conserve water, will be discussed in greater detail below. Agricultural industrial and social improvements in Malaysia demand more water throughout the year, which implies water conservation at every level, locally and in the distant catchments, in the management of each farm and plantation as well as in the big irrigation and water supply schemes.

Wind

The wind has two components of importance, its speed and its direction. The Doldrums form a relatively windless zone near the equator between the trade winds and monsoons, and shift their latitude as the earth makes its annual orbit round the sun. For most of the year Malaysia lies in the Doldrums and average wind speeds are low. The mean velocity of the wind increases with elevation, but no

records are available from Malaysia's highest mountains. At Cameron Highlands (5153 ft or 1561 m elevation) the average wind speed for the year is about 6.3 mph (2.8 m/s), gusts of 40 mph occur on about 14 days during the year and gusts above 30 mph on nearly 60 days each year. These figures are approached or equalled at Kuala Pahang and Mersing, which are much exposed to the South China Sea, and at Bukit Jeram and Malacca which receive the full force of the 'Sumatra' squalls across the Straits of Malacca. The average wind speed falls along the more protected coasts and is least in sheltered places inland, for instance at Kuala Lipis the monthly average fluctuates little from 1.3 mph (0.6 m/s). There is little seasonal variation at such windier places as Butterworth and Kota Kinabalu, both have annual means of 3.9 mph (1.75 m/s), or Bukit Jeram 5.2 mph (2.3 m/s), all on the respective west coasts. Although Labuan and Malacca on west coasts show considerable variation, the greatest seasonal fluctuations in wind speed occur on the east coasts in the contrast between their Doldrums period and the full force of the North East Monsoon, for example at Mersing the May and January means are 4.0 and 9.4 mph (1.8 and 4.2 m/s).

The non-directional effects of wind are to dispel mist, to somewhat increase the rate of evaporation, to markedly depress the effective temperature, that is to give a more cool or chill sensation, and to cause structural damage to some crops such as banana and rubber trees at the higher velocities. Probably because of the comparatively low velocities obtaining at most places during most seasons, much of the plant and animal life in Malaysia seems to be poorly adapted to withstand exceptionally high wind gusts or exposure to wind. In 1883 large areas of forest in Kelantan and Trengganu were devastated by a hurricane and forest suffered severe damage in Malacca during a storm in 1917. Multiple wind throw patches have been observed recently in Central Pahang. Where left alone, these forests have slowly regenerated. There are indications that some animals, especially primates, suffer if chilled by exposure to abnormally low effective temperatures, in contrast to cattle, in particular water buffalos, which have poor heat tolerance. Provision of an adequate cushioning boundary and enough space for animals to find suitable cover may necessitate larger reserves of the appropriate habitat for the survival of some animals than food supply alone would dictate.

Monsoons

The monsoons are the major rain-bearing winds, which persist for some months each year and determine the overall climatological pattern of South East Asia. The outflow of air as the vast Asian land mass cools in winter generates the North East Monsoon which crosses the South China Sea to reach Malaysia's east coasts from October in the north, striking progressively later further south. The North East Monsoon blows strongly through November into January, slackens a little in February and stills about the equinox after a final upsurge. Heavy rainfall is experienced in all parts exposed to this monsoon and also in the boundary zone where it peters out against the Doldrums lying about the equator.

The other major monsoon is the South West as it is known in Sumatra, northern Malaya and Sabah, or South or South East in much of Sarawak and

Southern Malaya. Commencing in May the southerly monsoon continues until August, bringing rain to the west coast of Sabah, but only to parts of the Malayan west coast owing to screening in places by Sumatra.

The reverse exposure of the east and west coasts to these Monsoons, especially the east coasts lying open to the powerful North East monsoon, is largely responsible for the difference of up to two months in the sunshine, temperature and dependent meteorological cycles on the opposite coasts. The major differences in the seasonal distribution of rainfall are largely, but not entirely, due to the monsoons.

The transitional periods occur between monsoons about the equinoxes and for some weeks later. The first transitional period is late March, April and part of May. The second starts in September and continues until November.

Apart from the monsoons, which are persistent prevailing winds, there are more local and frequently changing phenomena. The 'sea' and 'land' breezes experienced on the coasts are due to the differential warming and cooling of sea and land, 'sea' breezes blow from sea to land by day and the 'land' breezes in the reverse direction at night. Day squalls arise on the east coasts and night squalls strike the west coasts, especially across the southern Malacca Straits as 'Sumatras'. Advection currents associated with convection currents, thunderstorms and instability rain are common during the afternoons during the equinoctial transition periods between monsoons in the inland districts. Cold air rolls down off the mountain ranges to raise an evening breeze in foothill areas.

Types of Rainfall

When the wind crosses the sea it gathers moisture and if the air is forced to rise by mountains, the cooling causes precipitation of rain. This is called *orographic* rain from *oros* the Greek for a mountain. In Malaysia the small rise on crossing a low coastline is enough to precipitate heavy rain from the air laden with moisture after passing over the warm seas. Hence the heavy rain in districts exposed to the monsoons. Even so the rainfall increases over the foothills and mountains further inland from the coast.

Boundary rain occurs where two air streams converge and force each other upward, as over Malacca during the South West Monsoon period. Boundary rain also occurs when a moisture laden wind presses against a relatively static body of air, for example over Western Sarawak when the North East Monsoon plays itself out against the Doldrums then resting about and below the equator. Thus boundary rain is largely associated with the strong monsoon winds, although the mechanism of precipitation is somewhat different from the orographic.

Instability rain is the commonest form in many parts of Malaysia during much of the year. The sun heats up the land and convection currents rise, which eventually force up rain-bearing clouds into colder air where precipitation occurs. Convection currents arise from relatively warm places and the ground is cooled where the rain falls, thus a mosaic of temperature and pressure changes occur which are rapidly brought into equilibrium by fairly strong local wind and rain storms. Such rain is

most common during the transition periods between monsoons just after the equinoxes.

Seasonal Distribution of Rain and Rainfall Regions

The country may be divided up into regions, each with a characteristic seasonal pattern of rainfall distribution. East Malaya and East Sabah are similar in receiving heavy rain during the North East Monsoon and light to moderate rain during the rest of the year. Western Sarawak also receives most rain during the North East Monsoon, but rainfall is quite heavy throughout the rest of the year too.

North West Malaya from Kulim northward and the West Coast of Sabah agree in having low rainfall during the North East Monsoon; both are protected by mountain ranges to their east. Rain falls during the transitions and South West Monsoon in varying amounts. A rather small area around Malacca also has its lowest rainfall during the North East Monsoon, the dry spell sometimes extending almost until the South West Monsoon begins.

The greater part of Malaya lies in the West Malaya rainfall region with heavy rain during the latter parts of both transition periods and fair amounts during the beginning of the North East Monsoon. The remainder of Sarawak or the Central Region has a somewhat similar pattern, although the rainfall is high during the rest of the year compared with other places.

The Interior and South East Regions of Sabah are areas of relatively low rainfall and little seasonal variation compared with the rest of Malaysia. They are distinguished from each other by the Interior usually having somewhat more rain after the first equinox than during the second transition period, whereas in the South East the latter period has the most rain. The usual annual rainfall in the Interior, which is a plateau surrounded by mountains is 60-75 in. (4.2-5.5 mm/day) and in the South East at the upper limit of this range.

Such relatively low annual rainfall in the bracket 70-80 in. (4.9-5.6 mm/day) is known in Malaya on the west coast around Kuala Selangor and Sitiawan and inland also in the West Malaya Rainfall Region round Kuala Pilah and Lenggong. Although dry spells are quite frequent in these areas of low annual rainfall, the most severe dry spells are experienced in the North West Region of Malaya, at Kangar for instance there is no rain at all during January about one year in eight. Dry spells in Malaysia are much less severe and far shorter than conditions prevailing in the arid regions of the world where there may be hardly any rain at all for years.

The whole of Sarawak has consistently heavy rainfall; with only a few local exceptions the annual means are over 120 in. (8.4 mm/day) and the annual rainfall is over 150 in. (10.5 mm/day) for more than half the records. The rainfall at Matang usually exceeds 170 in. per annum (12 mm/day). South West Sabah around Beaufort also has high annual rainfall about 150 in. (10.5 mm/day). There is another area of fairly high annual rainfall (120 in./year or 8.4 mm/day) on the East Coast of Sabah around Beluran and Sandakan.

In Malaya the east coast is somewhat wetter than the west coast owing to the greater exposure to the North East Monsoon. Rainfall increases further inland on ascending into the hills. The annual rainfall throughout the East Malaya Rainfall Region is in excess of 100 in. (7 mm/day) and in the hills of the East Range, especially on the seaward side, rises to 160 in. (11.2 mm/day). Along the western coast of Malaya the annual rainfall is below 100 in. (7 mm/day) and markedly less in places, but increasing inland so that the hills have as high a rainfall as those on the east coast. The Larut hills in the neighbourhood of Taiping receive average annual rainfall up to 230 in. (16.2 mm/day).

Intensity of Rainfall

The most intense rainstorm recorded in Malaya was 2 in. (51 mm) in 15 mins at Kuala Lumpur; this was an extreme example of the relatively brief but heavy precipitation commonly occurring as instability rain. In places exposed to the monsoons, especially the East Coasts during the North East Monsoon, rain may continue for five days at an average intensity of about 0.1 in./hour (61 mm/day) or 12 in. total (305 mm).

On the East Coast of Malaya precipitation in excess of 32 in. (810 mm) may be expected during November or December about once every three to five years. Once every ten years more than 10 in. (254 mm) may be expected to fall within 24 hours at East Coast Stations, indeed in places once every five years. This precipitation is most heavy on the seaward side of the East Mountain Range and the run-off must make its way across a relatively narrow (upto 30 miles wide) but almost flat coastal plain. The greatest precipitation within 24 hours was 24.0 in. (610 mm) near Kuantan. Heavier downpours of such durations are believed possible.

In the Matang hill area near Kuching in Sarawak, the precipitation in January exceeds 32 in. (810 mm) one year in two and exceeds 64 in. (1 620 mm) once every fifteen years. At Kuching itself more than once in every four years the rainfall exceeds 32 in. and exceeds 64 in. once every thirty. Therefore it is hardly surprising that floods occur periodically; it is surprising that they are not more frequent or disastrous.

The landscape is moulded by the environment and after a period of centuries becomes stabilised and adjusted to the average physical conditions. This is largely a living process in which the natural vegetation plays a dominant role. Such a natural landscape can absorb the shocks of all except the most extreme storms of wind and rain. Even when some catastrophe strikes the worst wounds are soon healed although some signs of disturbance can still be seen. When a landscape has been modified by human activity, felling, clearing, burning, over-grazing, cultivation or subsequent abandonment, it may lose both its capacity to withstand extreme conditions and the resilience to recover.

Floods

During January and February 1963 more than twice the usual precipitation was experienced throughout East Malaysia, as much as 147 in. (3 740 mm) fell at

Semantan in Sarawak. Deep floods were widespread. The years of serious floods in Malaya were 1897, 1926/7, 1966/7 and 1970/1. The assessment of the most recent floods is still in progress, but there is some circumstantial evidence, such as the maximum height the river reached at Kuala Kangsar and how rapidly the waters rose, that successive floods have been more dangerous and damaging. If so, this could be related to neglect of soil, water and river bank conservation measures, and to the increasing areas which have been disturbed by human activity. As the country develops, more public works and private property are at risk, therefore protection becomes an increasingly important investment as insurance.

The silting up of the lower reaches of the Kinta River, a tributary of the Perak River, as a result of tin mining further up the Kinta Valley, has caused frequent flooding in both the lower and middle reaches about Teluk Anson and Ipoh. Heavy rain is unable to escape rapidly to the sea because the river bed has been raised by silt and so the waters readily over-flow the banks and flood the country-side. The Batang Padang River in the same area became silted from mines near Tapah; the river changed its course and flooded large areas, converting them into inaccessible swamps until reclaimed by the Manik River irrigation scheme. The inability of flat alluvial plains and of steep hill slopes to cope with the heavy downpours after human interference with the landscape, has been tragically demonstrated when a mining dam broke at Cheras in 1963 and a massive landslide occurred at Ringlet, Cameron Highlands, in 1961.

Periodically intense or prolonged downpours will occur; these cannot be prevented at present, but the results can be ameliorated by good land use, soil and water conservation. Over-exploitation of the land and neglect of conservation measures have led to loss of life, property and land.

The Hydrological Cycle

In the preceding sections rainfall and evaporation have been described and mention made of flooding resulting from impeded river flow. These are all aspects of the hydrological cycle, which is an account of how water, an essential for life, circulates on our planet. The rain falls on land and sea and returns to the atmosphere by evaporation. Only the fate of rain falling on the land will be considered here. Minor forms of precipitation such as dew and hail follow a similar course.

Rain may fall directly onto the soil surface or be intercepted by plants. Intercepted water may be absorbed by the plant, usually to be almost immediately evaporated by transpiration in this climate, or it may drip off the foliage or trickle down the stems to the ground. Raindrops vary in size according to the manner of their formation and the degree of saturation of the atmosphere they have travelled through; in Malaysia's humid conditions raindrops are often rather large. The diameter may be 0.5 to 3 mm which would hit the surface at a speed of 9 to 20 mph (4 to 9 m/sec) respectively. The actual energy involved depends on various factors, but many thousands of droplets fall on a square yard or metre of land during an hour of quite light rain. This energy must be absorbed in some way. If the rain strikes a bare soil surface, much of the energy will be used in dislodging

particles, weathering and eroding the soil. With a cover of vegetation the force of the rain displaces and even damages the foliage, although the resilient nature of the leaves and branches can tolerate much damage, and moreover the plants can replace damaged leaves.

When precipitation reaches the soil surface, whether directly or after interception by vegetation, it may either infiltrate into the soil or run off over the surface. If the soil is already saturated with water, the rain cannot infiltrate but must run off. The rate at which rain infiltrates the soil depends on physical conditions at and near the soil surface, on the degree to which the soil is already saturated and how freely water can drain away. The water which infiltrates replenishes the soil water reserves available to plants, and that which infiltrates in excess of immediate requirements and of the soil water storage capacity percolates through the soil until it appears in streams or is impounded in deep underground water reserves. Percolation into streams and hence gathering of the water into lakes and rivers, which eventually discharge into the sea, is more usual in Malaysia. Deep water reserves, such as are tapped by artesian wells in other countries, are comparatively rare in this country.

The water which runs off directly over the soil surface after reaching the ground also makes its way into streams, lakes, rivers and the sea. However, this direct surface run-off causes erosion and carries off soil material into the streams and rivers to an extent determined by the topography of the land, soil characteristics and the degree of interference with natural conditions. If there is a cover of vegetation rapid run-off is impeded, the eroding effects are reduced and some of the particles are deposited again on the surface, mixed with plant material and not lost to the soil. Vegetation affects the balance between infiltration and surface run-off in various ways. The plant litter on the soil surface forms a filter which removes fine debris and prevents it from clogging the narrow channels through the soil, organic matter improves soil structure so keeping these channels open. The transpiration demands of the plants often bring the soil water content below saturation, but in turn the humus or organic matter added by the vegetation to the soil increases its water storage capacity. Although transpiration may reduce the amount of water reaching streams, vegetation controls loss of soil by erosion and keeps the water free from an over-burden of silt. Streams laden with silt lead to flooding down river as described in an earlier section, or if the silt is trapped in reservoirs for hydro-electric power, urban water or irrigation supplies, the life of these expensive installations is severely curtailed.

If more water is obtained in the streams and rivers by destruction of the surrounding vegetation, not only is this water dirty, needing costly treatment to render it usable, but its release is erratic, following closely the original pattern of rainfall, drought and storm. Vegetation enables the catchment area to act like a sponge taking up water and releasing it more slowly, smoothing the extremes of discharge rate. This was demonstrated by preliminary studies in central South Johore. The flow of water in the streams during dry periods was lower the greater the proportion of the catchment that had been cleared of forest.

The limited investigations made so far suggest that when rubber trees have established a complete canopy, the rate of run-off differs little from that for similar

areas with natural forest, provided the steeper slopes have been terraced. The proportion of precipitation (a) which runs off directly over the surface and (b) which eventually contributes to stream flow, including immediate run-off, can be determined by prolonged careful measurements in catchment areas. Few such studies have yet been made in Malaysia, but considering these results in conjunction with the measured or calculated evaporation, the following estimates may be made.

In low rainfall areas such as parts of the Selangor and Perak coast and the sheltered inland part of Negri Sembilan, the interior and south east of Sabah, there is probably very little run off or local contribution to stream flow, because evaporation accounts for most of the precipitation; these areas can be irrigated by rivers which rise in mountains elsewhere.

In intermediate conditions of 90-100 in. (230-250 mm) rainfall per annum fairly equitably distributed, about one third to one half probably reaches the rivers from catchment areas with continuous tree cover. Perhaps one tenth of the rainfall contributes to direct surface run off.

In regions of seasonal rainfall, especially monsoons, the soil in the affected areas will soon be saturated during the rains and in these months 75-90% will run off directly into streams. During the rest of the year conditions will approximate to one of the previous categories.

At continuously wet places such as Kuching at least half the precipitation almost certainly runs off directly during all seasons.

The hydrological cycle is completed by evaporation of water back to the atmosphere. This may be by transpiration of plants growing in the area where the rain fell, or which received the water by rivers or irrigation streams. Water may evaporate directly from the soil, but this is usually relatively little, more is lost from extensive water surfaces such as lakes, reservoirs, rice fields and finally the sea itself.

Water and River Conservation

Several measures to conserve water have already been indicated, moreover soil and water conservation are very closely related, yet these aspects are so important that repetition of some of the foregoing here and under soil conservation needs no apology. At the national level the upper and steeper slopes of the hills should be kept under protective forest, whether they are catchment areas for public utilities or the headwaters of rivers, so that large fluctuations in flow are dampened and burdening of the water with silt is prevented, thereby reducing risk of floods and low water alternating downstream. Excessively low water prevents navigation, often depletes stocking with fish and leaves no surplus for irrigation. The hills are not the only source of water or of silt in the rivers, which are fed by the surrounding land along their course to the sea. The river banks themselves are constantly being eroded and the resultant silt deposited in slack water on bends (meanders) and further downstream especially in estuarine flats, which slowly claim land from the sea. Thus some erosion is inevitable and can serve a useful purpose provided it is

under control. If the river is alternately in spate, when the scouring by the torrent and its over-burden will be greatest, and then in low water when the banks will dry out and crack, there will be a rapid breakdown of the banks. Therefore the first measure towards protection of the river banks is to promote a stable water regime by maintaining the catchment under forest.

There is no doubt that the benefits of a vegetational cover in the catchment areas far outweigh any disadvantages under Malaysian conditions or indeed in most regions of the world. The deleterious effects of exposed or disturbed soil can be disastrous, both by losing soil by erosion and by depositing it where it is not wanted either in reservoirs or in rivers where it may cause flooding. It is unwise to clear large contiguous areas on the upper steeper hill slopes, since calamity may strike during the comparatively short periods before the cultivated crops can cover the soil. Short rotation crops which expose the soil repeatedly are particularly undesirable. Undisturbed natural forest is the best protection in these areas and it is planned to retain about one fifth of Malaya's land area, namely that above 1 000 ft a.m.s.l. (approximately 300 m), as protective forest for this purpose. This resolution should not be weakened, and it seems desirable to observe the stricter rule not to alienate for agriculture land above the 'steep land line', a relatively distinct contour where a marked inflection in the slope of most Malayan hills occurs, although its elevation varies from 150 ft (45 m) in Kedah to 750 ft (225 m) in North Pahang.

The fertile valley bottoms and flat coastal strips are those most suited to intensive market gardening, padi production and other crops requiring regular cultivation of the soil. These must be protected from flooding by wise management of the catchments areas above, which can also provide water for irrigation in those areas where dry spells are likely. In the intermediate areas tree and palm plantations are probably best.

Strips of natural vegetation should be retained on river banks, so that the roots will bind the soil. In most states of Malaya there is legislation to this effect, but it is hardly ever observed or enforced. A fringe of trees along the river banks would help to prevent logs left after felling the forest from being lifted up and swept away by flood waters. Occasional floods are inevitable, but far more damage is done to public works such as bridges, when a great weight of timber crushes against their piers and then lifts beneath the spans on the rising water or forces water downward to scour away the river bed from the foundations because it cannot penetrate or overflow the barrier of matted vegetation. Much damage of this nature might have been spared during the recent floods, if this legislation had been observed in large-scale land clearing operations. The Drainage and Irrigation Department endeavours to prevent this damage by the construction of artificial control measures and the re-establishment of natural or other suitable vegetation along the banks.

The law forbids mines specifically from dumping excessive silt in the rivers, and more obscurely prohibits any pollution of waterways. Organic matter from soil, factory or domestic wastes uses up the oxygen in the water so that fish are suffocated and bacteria may proliferate. Miners have found ways of evading the silt clauses and many others are ignorant of the law or disregard it.

In the cultivated undulating lowlands the object is to retain as much soil on the land and to store as much water in the soil as possible without actual water logging. As always a vegetational cover plays a useful role by breaking the force of the rain and adding to the organic matter in the soil. Tree, palm and other permanent or long rotation crops provide good cover and expose the soil least. Even so since there are several years before rubber trees or oil palms cover the whole ground area, it is good practice to plant a 'cover crop' of creeping legumes or to manage the weeds or grasses between the rows of trees as a protective cover. On the steeper slopes the rows of trees should follow the contours and be prepared as terraces with marginal bunds. The rows are usually ten yards or metres apart, so this is the maximum distance rain water trickles before reaching a terrace, where it can soak into the soil. Thus swift flowing streams, which would erode the soil and run the water off the land too quickly, do not develop. Sometimes additional contour ditches or silt pits are necessary.

Weeds in the rows compete with the trees and it is customary to control these. In the past this was done by hoeing with a changkol and the cultivation of the soil was supposed to reduce evaporation from the soil and increase infiltration. More recent investigations suggest that puddling of the soil and clogging of its interstices may result from the pulverising of soil by the action of such tillage and exposure to the sun and rain. It is probably better to control weeds by spraying with herbicides. The weeds or cover plants between the rows transpire water and in this compete with the tree crop for water. This can be reduced by spraying or slashing back the weeds or covers before an anticipated dry spell, their debris will still afford some protection and organic matter, but because it is beneficial in other ways the vegetational cover should not be eradicated permanently.

On flat land the main measures for water conservation are to preserve the soil surface in a condition favourable for infiltration, and to improve the soil structure and water storage capacity. These are enhanced by plants whether crops or covers. Competitive transpiration by weeds should be reduced either by intensive cultivation of the crop itself to provide the cover of vegetation, or by keeping the weeds or covers under control when for example a tree crop is still young.

The Climate as a Resource

Apart from the soil and its nutrients, plants require warmth, rain and sunshine to grow. The lowlands of Malaysia are never too cool for crop production. The amount of sunshine varies from adequate to abundant. Water is needed in order to take advantage of abundant sunshine. The average amount of rainfall varies from just enough to balance evaporation in some places to a great excess in the hills. There is also variation throughout the year such that excess at one time may not compensate for seasonal deficit. The key to the use of Malaysia's climatic resources is to provide water where it is needed from the surplus elsewhere at other times; moreover the measures to provide for this are closely related to those for flood prevention. In a country where heavy downpours are a recurrent feature, uncontrolled excess rain can soon prove the source of disastrous floods. Whether or not it proves feasible to precipitate monsoon rains over the seas before they reach Malaysian

shores, this will not prevent intense storms of accident rain arising from convection currents inland. The coordination of water conservation and flood prevention is an obvious necessity and considerable advances have already been made by the Drainage and Irrigation Department in Malaysia. Even so serious floods involving loss of life and property in recent years show that there is no reason for complacency. Land and other development schemes may result in forest clearance and earth moving activity for various constructions from almost the headwaters to the mouths of the rivers. Under these conditions one of the periodically recurrent heavy storms can do immense damage, unless conservation measures are constantly being applied.

The coordination of conservation practices adapted to hill and plain, results in the managed landscape or planned land system. Some of the most valuable agriculturally are those in which a flat or undulating coastal plain or interior plateau of fertile soil receives abundant solar radiation but only seasonally adequate rainfall and is able to make up this deficit by irrigation from protected catchments in the hinterland. The course of the water from catchment to the sea must be gentle and controlled; often it can serve as a public utility on the way. If this type of landscape is mismanaged, its resources are not only wasted but disaster is almost inevitable throughout the whole.

Another landscape common in Malaysia has excessive precipitation throughout from coast to mountain. This cannot cope with even greater flows in the plain, where soils are often less fertile in these cases owing to peat formation. These swampy lowlands, as in Sarawak, may be more suited to continued forestry and the introduction of industrial developments requiring large amounts of water and raw forest products, for example pulp and paper manufacture.

In such planned landscapes, where both large areas and protective strips—for example along river banks—are maintained under appropriate vegetation there will be room for wild life and recreation to meet the needs of the aesthetic conservationist as well as the applied conservator; the country will continue to display a fresh and beautiful countenance while exploiting its economic, including climatic resources.

(Next month: SOIL)

Conservation in Malaysia

P. R. WYCHERLEY

PART TWO — SOIL

Solar energy becomes human food energy by two main pathways, and in following these the energy carriers in our food become associated with the other essentials such as amino-acids, vitamins and mineral salts. One pathway is by water in ponds, rivers, lakes or the sea. Water-plants, often microscopic in size, trap solar energy and become the food of fish, which in turn are eaten by mankind. There are variants of this foodchain, for example invertebrate animals including shellfish may form an alternative or additional link as carrion feeders, or in different parts of the world whales or wildfowl may form the last link before man. Important as this water pathway is, especially to provide protein, by far the greatest proportion of human food is obtained by the soil pathway.

Plants root in the soil and obtain water and nutrients from this medium while assimilating carbon dioxide from the air and energy from the sun. Whether we consume these plants directly or animals form an intermediate link in the foodchain, the soil is as essential as our crops which grow in it or our grazing stock. The water pathway may be blocked for such reasons as low nutrient content or excessive salinity or drying out, yet it is a simple medium compared with the soil and research may find relatively easy ways of removing such blockages as occur. The soil is slow to form and is not replaced as rapidly as it can be lost by erosion, misuse or neglect. Its composition and the balance of nutrients are relatively delicate and dependent on living processes.

Soil Function

Plants obtain most of their water from the soil, which as described previously they require to transpire when tissues are exposed to the air in order to assimilate carbon dioxide for photosynthesis. The movement of water from the soil into the plant carries with it dissolved substances which are also essential nutrients for the plants and the animals which feed on them. The nutrient required in greatest quantity is nitrogen, a constituent of aminoacids, and the derived proteins and nucleic acids the substances most characteristic of living organisms. The fertility of the soil, that is its capacity to bear crops, is often dependent on the availability of nitrogen. Phosphorus, potassium, magnesium and calcium are also needed in fairly large quantities; sulphur and iron are used to a lesser degree and others such as boron, manganese, molybdenum, zinc and copper are required in much smaller amounts. It is also possible for some substances, especially common salt from the sea, to be present in too great a quantity and so prevent the growth of crop plants. Other toxic substances such as mine wastes containing arsenic cause local problems in Malaya; manganese toxicity is suspected in some Malaysian soils.

Plants can only take up nutrients from the soil in solution. The solubility of salts and hence their availability in the correct proportions is greatly influenced by the degree of acidity or alkalinity of the soil, which is measured on the pH scale

(pH 7.0 indicates neutrality, lower values acidity, higher alkalinity). Most Malaysian soils are rather acid. The uptake of salts from the soil is not an entirely passive process, oxygen is needed for respiration to generate the necessary energy to take up some ions against the electrical potentials and concentration gradients. Some plants which live in swamps have developed root tissues with many air spaces which can allow exchange of gases between cells in the plant roots and the air. Most common crop plants do not have such extensive development of internal air spaces and as a result cannot stand stagnant water-logged conditions. Air spaces in the soil are necessary for these plants. Respiration by plant is not the only demand for air in the soil. Many processes in the circulation and release of plant nutrients, especially nitrogen, also require air for respiration by soil micro-organisms. The fixation of atmospheric nitrogen by bacteria, either free living in the soil or in association with the roots of plants, especially many legumes, requires penetration into the soil of both nitrogen and oxygen. The legume-bacteria association is most important in agriculture. Thus a fertile soil is not a solid mass, but has a structure permeated by fine air and water passages.

The development of a good soil structure takes time. Mineral particles are obtained by the breakdown of the parent materials. The channels between the particles are made by plant roots and soil animals, and by the formation of aggregates. The mineral particles are stuck together by colloidal material, sometimes clay colloids and often organic colloids derived from humus, leaving pores between these aggregates. These colloids or jelly like substances in the soil have other important properties in water and nutrient storage. The nutrient ions or salts would easily be leached away from the soil and lost through the constant washing by the high rate of rainfall in the region, were it not for the clay and the organic content of the soil. A fertile soil is a complicated product of physical, chemical and living processes.

Soil Formation

Soils can be grouped into two main classes, the *sedentary* soils formed on site from the underlying rocks and the *alluvial* soils formed from the materials transported from elsewhere by water and deposited on the site from rivers, lakes or the sea. The *colluvial* soils are an intermediate group, which form on the lower slopes of hills from material washed down by the surface run off of rain water from the upper slopes. There is another intermediate group of old alluvia, whose material was transported so long ago that they have continued to develop at their new locations during a period of geological time similar to that taken for some sedentary soils to form. Soils are classified into series, each of which is characterised by its parent material and profile, that is the relative thickness, colour, texture and structure of each layer or horizon in a vertical section. The series are grouped in families, great soil groups and orders in a similar manner to the classification of living species. Soil formation starts with the breakdown of the parent rock into particles, their subsequent weathering and/or transport. It continues with further physical and chemical changes occasioned mainly by the climate including the availability of water, but affected also by the vegetation it can support at each successive stage.

In the regions where there is a very wide diurnal or seasonal temperature range, in particular if freezing and thawing are common, physical forces play a major role in weathering the parent material. In Malaysia's equitable, warm humid climate physical action is less important compared with chemical effects, in particular solution in and deposition from tepid water. Water percolating through the soil continues weathering to a great depth. Substances are dissolved in the water from the top soil and carried downward and either leached away completely and lost in waters draining from the area, or deposited again lower down the profile. The substances available in the topsoil and the chemical properties of the soil water are affected by the presence and nature of vegetation and its litter. Roots penetrate the soil and alter its physical structure, also deep roots bring up nutrients from lower levels and reverse the downward leaching process. Natural vegetation aids soil formation, so do agricultural crops provided there is compensation for the nutrients lost from the site at harvest and reduction of the risk of soil erosion by exposure. These losses and risks are much greater with short term crops like cereals or tapioca than with tree and palm crops.

Topography and Time

Topography and parent material are other important factors in soil formation on which the climate (warm water) and vegetation act. The length of time they can operate depends much on the topography. Steep slopes are always losing materials so that deep profiles are unable to develop. Indeed it is only their cover of vegetation which saves the soils on the steeper land from being lost altogether. The material lost from the steep slopes is deposited in the flatter or low-lying areas. Deep profiles may develop on gently undulating land if they remain undisturbed for long periods. Peat formation may occur in the wetter low-lying areas of high acidity, the depth reflecting the period of accumulation.

Parent Materials

The parent materials, rocks or geological formations are classified primarily by the way they were formed, namely sedimentary, igneous and metamorphic rocks, and by their age, which are reflected in their chemical and crystalline composition. The *sedimentary* rocks were deposited as alluvia, sand and gravel (sandstones and conglomerates), clay silt (shale), coral, shell (limestone) from water and subsequently compressed. The *igneous* rocks solidified from molten lava in the heart of the earth, granite being the most common example throughout Malaysia. The pressure and heat of the intrusion of the igneous rocks have changed some sedimentary rocks, examples of such *metamorphic* rocks are quartzite from sandstone or schist from shale, much of the limestone in Malaya has been metamorphosed to marble. Igneous rocks may be metamorphosed by a subsequent intrusion, for example the formation of gneiss from granite.

There are some tracts of basic volcanic material, andersite and basalt mainly in parts of Pahang and Sabah, which yield deep fertile clay-loam soils with a good crumb structure. The shales usually yield clay, clay loam or silty soils with a wide range of fertility. Quartzite yields rather sandy loams, which are shallow and of poor fertility on steep slopes, but fair soils are derived in undulating lowland terrain.

Granite weathers deeply producing a well drained soil with a good balance of clay and sand, which stores water and nutrients in depth. The distant parent material contributes to the properties of alluvial soils and the nature of the body of water from which they are deposited exerts an influence too. Sandy river alluvia are often infertile, but marine or coastal clay alluvia are usually richly fertile.

Soil Fertility

Different crops are adapted to different types of soil. Their performance on a suitable soil depends on other environmental factors and husbandry methods such as application of fertilisers. The principles of conservation require that land should be utilised with respect to these soil and other factors in the best way to provide food, materials for clothing, shelter and fuel for mankind, and also recreational amenities. Reserves of wild plant and animal life contribute to man's aesthetic needs and may be considered to be recreational amenities. However, wild plants and animals impinge on agriculture not only as weeds and pests, but as genetic reserves for breeding improved crop plants and as reservoirs of the natural agents which control pests. Timber production under the managed natural regeneration system so well developed in and adapted to this country is an obvious contribution of wild plants to rural economy. The major soil types in Malaysia are reviewed below with respect to their fertility, suitability for conventional agriculture or conservation under more natural conditions.

Recent Coastal Alluvia

The more sheltered coasts of West Malaya and of Sarawak have extensive mangrove forests still tidal and in process of being won from the sea by the advance of the mangrove. Conventional agriculture is impossible here. Very extensive dykes or bunds would be necessary to keep the salt water out, drainage would also present many problems. The rate of natural advance seems quite rapid. Shell fisheries have been developed in places and the burrowing prawns aid in the aeration and colonisation process. Eventually the land furthest from the sea becomes sufficiently elevated for fuller utilisation and reclamation, meanwhile very profitable crops of poles and wood for conversion to charcoal can be obtained on a rotational system. This seems the best use of these young soils, which also provide a protective coastal fringe.

Coastal Alluvia

These are the geologically recent soils deposited along the coasts during the last 25 000 years. In general those on the more sheltered coasts contain finer clay and are more fertile. Many of the finer particles were probably first suspended in sea water, where they absorbed various nutrients and were then precipitated when the sea water met less dense fresher water draining from the land. On the exposed coasts coarser sandy material is thrown up by the rough seas, except where erosion rather than accretion is in progress. Other river borne material is dropped when the force of the stream is slowed by running into the sea, either on the banks of the estuaries or in sand bars. The debris of sea and river life, shells and plant material, is also found scattered or in discrete deposits in the alluvium.

Thus the coastal alluvia are very variable in their physical and chemical properties, and the degree to which they become built up and elevated to be drained naturally, or that they may be drained artificially. Harmful sea salt is leached out by rain and carried away where drainage is successful and subsequent inundations are prevented. The drainage and aeration must be adequate to prevent water-logging and the formation of harmful sulphides. The coastal clays are among the most fertile soils if these conditions can be satisfied, although irrigation with water of low salt content is often necessary for padi cultivation throughout the year to balance the high rate of evaporation. It is dangerous however to keep some of these soils water-logged by excessive irrigation throughout the year, when sulphides may accumulate. In these cases a crop with a lesser water demand should be included in the rotation between rice crops, so that there is opportunity for air to penetrate and oxidise the sulphides. In turn it may be necessary to leach out or neutralise sulphuric acid. These soils should be reserved for the most productive agriculture. However, large areas have been lost or their management by drainage and irrigation made much more difficult and costly owing to flooding, which has its origin in erosion upstream as described earlier.

Swamps

Where lagoons have become isolated behind the various coastal alluvial deposits, and sometimes in flat river valleys, a permanent water logged swamp forms. The litter of the plants does not decay rapidly owing to the lack of aeration in the wet soil and plant debris accumulates as peat. At first the swamp receives most of its water from rivers and occasional tidal inundations from the sea, both these may bring some mineral detritus, even if the general conditions are brackish. In areas where the precipitation does not greatly exceed the evaporation, the peat does not become raised much above the water table determined by the sea and rivers. In regions where the rainfall is very heavy, peat continues to accumulate until the swamp surface is raised above the level of other sources of water. Rain-water contains few dissolved plant nutrients compared with those brought in by other sources of water. Any nutrients released by the decay of the peat tend to be leached away by the rain water as it drains off, but much of the peat continues to accumulate.

There are large areas of swamp forest in south east Malaya and even more extensive areas in Sarawak. Their soils are very low in fertility, because all the nutrients are locked up in the organic matter and applied fertilisers are easily leached away. Artificial drainage causes some drying and shrinkage of the peat, but reclamation by such means is a long and costly process. If the peat was removed or destroyed, the clays beneath might prove fertile. However, drainage would remain an important and difficult factor, because the land level would have been reduced to the normal water table or lower, and not only would bunds be needed to keep flood waters out, but pumping might be necessary to get rid of the excessive rain water. Until such massive engineering works can be afforded or pressure on lands is so severe, it would seem the most profitable land use to discover means of managing the extensive tracts of swamp forest to yield the maximum forest products and to retain some as game reserves. Vegetables may be grown by intensive methods, but the market available within the range of economic transport is often

limited so that this land use is local only in most cases. The market for pineapples, also grown on these soils, is saturated at present. Thus forestry remains the most promising large scale usage.

Valley Alluvia

Weathering occurs naturally in the hills and where the rivers are slowed down on entering the coastal plain, part of the burden carried by the streams is deposited as river valley alluvium, since the coarsest material is usually deposited first, rather sandy strongly leached soils of low fertility often result. The finer material giving rise to clay and loam alluvial soils is usually carried into the lower reaches, the estuaries and flood plains, where fertile soils may be deposited over a period of time, the risks involved where this process gets out of control due to excessive soil getting into the rivers have already been described.

Older Alluvia

During earlier geological periods river, flood plain and coastal alluvia were deposited in terraces ranging from 20–270 ft (6–80 m) above the present level of the sea. These terraces are interesting indicators of the geological history of South East Asia, whether they correspond to the then levels of the sea as supposed by some, or to extensive lakes. Prolonged leaching of these soils has reduced their fertility. The forest on these impoverished soils is not very valuable in preferred timber species. Fertilisation and cultivation of the less demanding tree crops such as rubber is often difficult owing to multiple deficiencies of both major and trace nutrients, although there are a few isolated cases of very good yields from oil palms on these soils. If abandoned after unsuccessful cultivation, waste lands of lallang and poor scrub are likely to predominate. It would seem wise to expand the cultivated area cautiously taking careful note of past experience.

Shallow Soils of Steep Land

On steep hill and mountain slopes erosion of parent material, especially of sedimentary rocks, is most rapid and the situation is the reverse of that which obtains where alluvium is being deposited. These young soils are shallow and easily lost if their vegetational cover is removed. Twenty times as much soil is lost from the tea and vegetable gardens as that from forest in the Cameron Highlands of Malaya, although the gardens are terraced and the forest is not. These are soils which from their situation should remain for the greater part under protective forest.

Lateritic Soils

In the humid tropics the constant washing of the soil by rain can have various effects. Laterisation occurs when the silicates are washed out, but the remaining sesquioxides of aluminium and iron accumulate and impart a deep red colour to the soil. The formation of hard concretions is the most typical aspect of this process. There is usually a rather shallow soil covering the hard layers of laterite nodules, which are easily exposed by erosion. These soils are difficult to work, the fertility is moderate at best but often low. The main problem is poor root penetration and thus limited utilisation of the nutrients. The hardier tree and palm crops are

perhaps the most suitable usage, although shallow rooted crops can sometimes be grown if the lateritic layer is not too near the surface.

Podzols

Podzolisation is sometimes considered to be the reverse of laterisation. In a podzol a shallow peaty topsoil covers a depth of bleached sandy material extending downward and beneath it is a dark stained layer. The sand is almost pure silica except for a few plant remains on or near the surface. The iron and other materials washed down are concentrated in the dark usually red layer, which may be a hard impenetrable pan. In Malaysia some of these heavily leached podzol profiles are deep (3 ft or 1 m. or more), they form on old raised beach terraces, as for instance on the East Coast of Malaya or in parts of Sarawak where at least some of the kerangas areas are of this nature.

In parts of Sabah there are red-yellow soils classified as podzolic by some soil scientists and as latosols by others; these are fair agricultural land if fertilised adequately. The typical grey podzols require heavy manuring, preferably with organic matter, and possibly irrigation to produce agricultural crops of value; if abandoned these heavily leached podzols revert to poor scrub. The natural vegetation is poor, in places careful management can give crops of poles and firewood; the deep roots of these trees bring up nutrients from the lower depths and counteract the leaching process to a limited extent. Part of the Bako National Park in Sarawak includes podzols. Owing to the infertile soil, many interesting insectivorous and other peculiar plants are found, and even if the stocking with wild animals is not high, it is adequate to justify preservation as totally protected nature reserve and to provide recreational amenities. Shallow rooted coconut palms occupy much of the podzols of East Malaya, the crops are poor and do not repay the heavy fertilisation necessary to effect any improvement; this mistaken land use should not be repeated.

Pure silica sand for making high quality optical glass has been obtained by dragline (opencast) mining from podzols of raised beaches in Penggerang Peninsula of Johore. This is not a renewable resource until geological time elapses. Extraction is justifiable, where the forest has been cleared and the subsequent cultivation abandoned to lallang. The few relics of forest on these soils as at Padang Mulud are worthy of conservation.

Latosols

These are yellow, red or brown soils of usually deep profile, which have been subject to prolonged weathering and intensive leaching by rain water on site; they are primarily sedentary soils, although some of the colluvial and older alluvium soils also may be regarded as latosols which have developed since their ancient deposition. With the exception of disturbed soils, some older alluvia and the young shallow examples in the mountains, the latosols as a group are of suitable physical structure for most crops, but their nutrient content is variable. Some of the widespread latosols derived from granite owe their fertility more to their friable structure enhancing drainage and water storage than to the amount of available nutrients.

the latter being low. These soils allow the roots of tree and palm crops to penetrate deep and tap the nutrients from a large volume of soil, also the free percolation of water enables weathering and release of bound nutrients, especially potash, to continue deep in the profile.

In some latosols nodules of laterite occur. The most fertile latosols are those rich in nutrients, well weathered and yet retaining a good crumb structure to a great depth, the best known of these are derived from effusive volcanic rocks. In Malaya, these are known near Kuantan and Temerloh in Pahang and also in Johore. In Sabah they occur in the South East near Tawau and Darvel Bay. Owing to their richness and the easy infiltration of water through the crumb structure, it is sometimes thought that these soils need no management. In fact they respond better than any other soils to good husbandry. Since they are so valuable an asset, it is most important to use these soils for the most beneficial food production and to protect them by careful treatment.

The latosols, with their wide range in fertility and structure, provide much of the agricultural land and the poorer amongst them support good forest. They are the product of weathering on site for a long period. The soil is still in place in a more or less natural profile, even if the degree of humic penetration in the topsoil has altered under cultivation, unless eroded by exposure and bad management. It does not follow that because latosols are widespread that these soils are sufficiently robust to withstand all abuse. Whenever in nature there is opportunity for contrasting processes to operate, such as where soil formation by weathering on site may pass over into erosion from the site, then it is a warning that careful management is necessary to preserve the balance or to control the rate of soil loss.

Disturbed Soils

Dredging and hydraulic mining for tin is widespread in Malaya. In the process of extracting the tin ore, the soil is washed and loses most of the soluble nutrients. The soil profile is drastically altered, top soil is buried, deep layers of infertile, free draining sand cover vast tracts. In the slimed areas the clay which has been saved cakes and cracks, so that it is easily drained through the cracks but the hard surface between is not readily penetrated by roots and colonised by plants in these locally arid conditions. Natural colonisation is slow; there are many areas fifty or more years old with but a scanty fire prone regeneration of scrub. Rehabilitation by planting trees, such as pines for pulp production, has met with only limited success owing to the low fertility and fire hazards. As for agriculture only intensive methods using large amounts of organic manure are possible on a strictly limited local scale.

This is all the more sad because the 200 000 acres (80 000 ha.) of badly degraded tin tailings represent much which was originally among the best agricultural land in Malaya. The profits of tin mining when prices are high and the revenue earned by government through taxation make it unlikely that alienation for mining would ever cease, apart from the large number of prospecting and mining leases already given. The following measures might help to ameliorate the worst effects and make rehabilitation easier.

Areas are worked piecemeal at present, rich deposits when the price is low, the poorer only when there is a premium. Old fashioned methods could not reach all the tin in some fields, which are now accessible to modern workings and will be mined again. Several different companies may hold adjacent leases and each works at its own rate according to its own methods and resources. If complete and co-ordinated working of a particular area could be introduced, resettled soil need not be disturbed afresh by re-mining or flooding or changes in drainage by adjacent activities at a later date. Sliming in banded pools with the clay spread on top is a promising method. Coordinated planning to remove limestone and dolomite, which are exposed by hydraulic mining for tin, would make rock available for constructional purposes and for magnesium fertiliser preparation, as is already done on a limited scale to obtain marble and for cement and lime manufacture. This would do no more harm to the landscape than tin mining already inflicts and would make additional spoil areas available, although at the cost of some pumping. The main object would be to relieve the pressure on the rare limestone outcrops for these materials by overall conservation planning.

Limestone

Nearly all the limestone exposed above ground level in Malaysia is in the form of precipitously rising hills or karst towers. The limestone hills are isolated islands, survivors of much more extensive formations in the past. Limestone consists of calcium carbonate, there may be various proportions of magnesium carbonate from nil to equal amounts of calcium and magnesium in the double carbonate or dolomite. These carbonates dissolve in water containing carbon dioxide, a little of which is taken up by rain passing through the atmosphere, as well as in other acids produced by the decomposition of debris from plants growing on the surface. Many drainage channels are formed through the rock. The strong drainage is one of the factors determining the vegetation able to grow on limestone.

The limestone hills present a mosaic of different habitats. There are the steep dry cliffs and pinnacles with hardly any soil except in a few crevices. The top is broken into ridges and valleys, damp hollows alternate with dry ridges. The soil is shallow in most places, because the limestone leaves few residues after dissolving away, occasionally iron oxides accumulate (sometimes as valuable haematite ore), or a peat of fibrous plant remains may form because the dry conditions and low nitrogen status does not encourage rotting. Spontaneous fires sometimes break out, quite frequently on Gunong Api (Fire Mountain) in Sarawak. Their topography alone makes them unsuitable for agriculture. There is no agricultural pressure for these limestone hills, but their specialised vegetation and the rare fauna of cliff and caves are threatened by quarrying. Often the dry vegetation is burnt off by fires started accidentally or purposefully by mineral prospectors.

Because of their value to science, interest for tourists and unique contribution to characteristic landscapes, the best use of the limestone hills is to conserve them.

Soil Survey

Soils in Malaysia were first described by examination of profiles in agricultural land, where the penetration of humic substances was often deeper than under

undisturbed natural forest. Even so the period of cultivation in Malaysia has hardly ever been so long that the relationship is obscured between soils recognised in agriculture at the series level and the soil developed from the same parent material under similar climatic and topographical conditions but still covered by forest. Therefore soil surveys are conducted by visual, physical and chemical examination of soil profiles or of samples from pits dug at selected points in both cultivated and undisturbed land. The soil series or broader units of classification are identified and plotted on maps. The experience with these soil types in agricultural practice enables their inherent suitability for certain crops with or without artificial aids such as drainage or manuring to be assessed. A soil survey throughout the country is one of the steps towards classifying the suitability of different areas for various crops or indicating those parts more wisely left under forest.

Land Capability Classification

Although soil fertility is one of the important factors in deciding the most suitable use for a piece of land in the nation's economy, others must be taken into account. Climate and topography influence the soil, but they have independent effects also. Some crops thrive in a markedly seasonal climate, whereas others are adapted to equitable conditions throughout the year. Erosion control measures on very steep land or drainage of low lying areas may be impracticable or too expensive. The position of the water economy must be determined, whether the area is catchment which should be protected, or in need of irrigation and, if so, whether adequate water is available. Abundantly rich mineral deposits take priority in exploitation.

Reconnaissance soil surveys had covered more than 20% of Sarawak, 30% of Sabah and all of West Malaysia by 1968. The climatic conditions are known in broad outline throughout the lowlands at least, although more detail is needed concerning radiation and hydrology. Topography and current land use are mapped by aerial photographic survey supported by ground investigation. Geological surveys and mineral prospecting locate these resources. All this information is entered on maps and collated for Land Capability Classification as it is called in Malaya; surveys similar in method and object are conducted under other names elsewhere. The purpose is to recommend the best land use for any area.

Such surveys grew first from the need to be able to alienate the land of most promise for success in agricultural development to the landless settlers, who otherwise would try to satisfy their hunger for land by squatting on land more suited to other uses or by shifting cultivation in protected forests or catchments and so damage the national economy. It has always been appreciated that some non-agricultural uses such as working rich mineral deposits must take high priority for the capital they attract, the employment created and the foreign exchange earned. Water power is also a valuable asset, water supply is necessary for irrigation, urban and industrial development. Since exploitation of these non-agricultural resources depends on good conservation practice in the catchments and channels of safe water movement, the outcome of a well organised comprehensive survey and the wise implementation of its recommendations is not antagonistic to appropriate nature protection projects. The surveyors and planners not only mark some areas as unsuitable for agriculture and recommend retention as forest, game reserve or

recreational amenity, but indicate further where misused land should be converted back to these purposes.

Soil Erosion

The Land Capability Classification attaches great importance to the topography of the land, that is the steepness of any slope, because this is a major factor in predisposing the soil to erosion. It is not intended to cultivate land with a steeper slope than 20° (about 1 in 3). The 'steep land line' is detected on topographic maps of Malaya as the level where the contours change from widely to closely spaced and indicates the boundary between the lower slopes less than $20\text{--}25^\circ$ and steeper above. Most of the land of 500 ft (170 m) elevation or more is above the steep land line in Malaya, that is about 40% of the surface of the peninsula. These upper steep slopes should be retained under protective forest.

In the arid and semi-arid regions of the world the scouring action of wind blown particles is a major cause of soil erosion, but this is of minor consequences in Malaysia, where water is the principal agent. Coastal erosion may occur after interference with the protective mangrove swamps, sandy foreshores and coral reefs; these are special cases of water erosion by the sea and the concurrent inundation of agricultural land by salt water does equally serious damage. Most soil erosion in Malaysia arises from the action of rain falling on sloping land and the subsequent movements of the water. The amount of erosion depends on the degree and length of slope, the quantity and force of the rain, the presence or absence of vegetation, the properties of the soil and any artificial measures taken such as terracing or silt pitting to reduce the length of uninterrupted slope.

Splash Erosion

The energy of a falling raindrop, or of repeated raindrop blows, may detach a soil particle from the soil surface. When this or other detached particles are struck by further rain, they are flung up into the air and—if the surface slopes—on the average each particle will fall back a little further downhill. The effect of heavy rain on exposed soil is often insidious, thousands of tiny particles each move a short distance downward during every storm. The cumulative result is that a whole sheet of top soil moves down the slope. The value of vegetation in breaking the force of the rain is evident. The litter serves this purpose also and is often too big to be as easily dislodged as mineral particles, moreover the organic matter helps to stick the soil particles together and modify the soil surface so that the rain water is rapidly absorbed instead of bouncing back. The encouragement of infiltration instead of run-off is important in preventing the next type of erosion too.

Channel Erosion

Rill, gully, stream and river erosion are varying degrees of channel erosion from the first incipient stages in the field. All arise from water which runs off over the soil surface and gathers together into progressively larger channels following the path of least resistance, which at first may be any slight depression avoiding rocks and other obstructions. As the quantity of water and speed of flow increase so the

channel is scoured deeper and wider until adjoining gulleys coalesce and the original surface is lost.

The severity of channel erosion depends on the intensity of rainfall, the proportion which runs off, and the steepness and length of the slope. These factors determine the amount of water and the speed it attains. Vegetation and its litter affect the surface soil and hence the balance between infiltration and run-off, although this is less important in channel erosion most common during intense rainfall than in splash erosion equally serious during prolonged light rain. Plough furrows and planting rows are agricultural artifacts which provide primary channels for run off; if they run up and down hill, they will concentrate water movement in streams of the maximum velocity. Contour ploughing and terraced planting rows interrupt the rush of water downhill.

Landslips and Slides

Landslips are small landslides; both are most common where clay soils overlie impervious rock strata on steep slopes. Clay is colloidal and can hold great quantities of water, which increase its weight and lubricate the interface between the soil and underlying rock, so that the soil eventually slips and slides downhill. The risk of landslide is increased by undercutting, either deliberately in road construction or accidentally by stream erosion at the foot of the slope. The role of vegetation appears at first to be uncertain, whether beneficial or otherwise, if it increases infiltration and the water loading of the soil. However, the vegetation also transpires water so that the clay is partially dried out and tree roots improve drainage. Plants differ in their effects and the balance between these processes. Artificial drainage may assist. Early detection of areas liable to landslide enables roads and dwellings to be sited safely elsewhere, or where that is impossible for the banks to be sculptured to reduce the hazard.

Biotic Erosion

Except for man himself, animals cause little direct erosion in Malaysia. In other countries they do on a moderate scale. Burrowing animals undermine banks or eat the roots of plants. This activity or more commonly over-grazing and barking of trees may alter the vegetation and its stabilising influence on the soil. Cattle may puddle the soil and upset infiltration, or their weight cause landslips; however, this is not serious in Malaysia because there is still very light stocking with cattle in most places.

Erosion Control

The old proverbs 'Prevention is better than cure' or 'It is no good shutting the stable door after the horse has bolted' are most appropriate in discussions of erosion control. It is sometimes possible to restore land, if erosion has not gone too far, but this is an expensive procedure relative to the value of the crops which can be taken from such impoverished and rehabilitated soil. Good conservation agriculture is practised in many cases throughout Malaysia, especially in the old established and well capitalised plantations which learnt their mistakes during the early days

of clean weeding. However, erosion control should be universal, not just observed by a majority only, otherwise the spoilers of the soil will constantly look for new land elsewhere and erode away the nation's capital resources. Many of the principles and practices of erosion control have been indicated already in explaining how erosion comes about.

The first golden rule is to have an adequate cover of vegetation to prevent exposure of the soil to sun and rain. Where the spontaneous growth or agricultural crop provides incomplete protection, cover plants should be established in the bare spaces. Legumes are favoured in agriculture, because they can improve the nitrogen status of the soil as well. Roadsides and urban open spaces are usually put to grass. A common mistake is to try to get plants to grow on the infertile newly exposed subsoil of recently mechanically cleared sites. This can be overcome by preparing a seed bed and manuring. Another mistake is to mow grass too low or to let it be overgrazed. This restricts the root growth too, so that the grass is susceptible to drought and the short tops wither away to unsightly wisps insufficient to protect the soil when the rains return. Run-off may be rapid if the soil is baked and puddled. Fertilisation and moderate cutting give quicker establishment, add more organic matter to the soil and so increase its water retaining and soil binding power, as well as giving a more pleasant appearance. Crop residues should be returned to the soil as far as possible, instead of being burnt as is often the case at present. Crop residues are sometimes grazed by animals or fed to them, in which case the farmyard manure should be returned to the soil.

The next important rule is to follow the contours whether this be ploughing or preparing planting rows along terraces. Contour bunds and silt pits provide an alternative where the land is not so steep as to justify terraces or form an additional measure on very steep land or under mature rubber which has shaded out the ground covers. Sometimes in estates whose field plantings are well laid out, these bunds and pits are forgotten in nurseries because a nursery is regarded as only temporary; nevertheless the need for soil and especially water conservation is all the more in nurseries because they are intensive agriculture, even if it is of short duration. Terraces should slope back into the hill to assist soil water accumulation. Even so provision must be made to carry off any large excess of water safely by gently graded drains with sodded banks. It is often desirable to leave the larger streams surrounded with the original vegetation. Concrete lined drains and silt traps are useful permanent installations in places where occasional flash floods are inevitable. Sometimes a drain or silt pit to protect the upper boundary of a plantation is forgotten and water pours in from behind breaching the upper terraces.

Soil Conservation

True soil conservation as the best use of the land and water resources goes beyond erosion prevention and control. Firstly land mapping and planning can ensure that the right sort of development is undertaken on the land which can sustain it, and that wrong developments are corrected by reforestation. There are social aspects too. Squatters, who have no legal title to the land they occupy, are careless in its use. Cultivators, who are given only short term tenures such as

annual leases or who have uneconomically small holdings, will not bother or cannot afford to invest their small capital in effecting improvements to preserve its fertility. Alienation and alignment of holdings must be planned in units for soil and water use. The Malaysian government is taking steps to prevent illegal occupation, fragmentation of holdings and short insecure tenures in future schemes, but there is still much misuse of land attributable to inherited problems of customs, ownership titles or the lack of them.

Although soil conservation is largely a problem of land use planning, agricultural and forestry, public works such as roads and open spaces are important too. The engineer's first problem is to prevent flooding, subsidence and blockage by landslips of the highways and airfields. However, the effects of rapid run-off and surface erosion over tarmac and short grass on the areas receiving this water and its overburden may be neglected. Sediment traps in the major outlets are often a useful intermediary barrier to break stream flow and deposit soil particles where they can do no harm. Indeed sand caught in these traps can usually be sold as building material.

The Malay expression *tanah ayer kita*, literally 'soil and water of ours', to describe the land of the country has a deeper meaning. Soil and water are among the most significant natural resources. Water enables solar energy to be used to the full, it must be safely channelled, it can be stored in reservoirs and improved soils, it is replenished. The soil is the basis of the greater proportion of food production, it can be protected and improved, it can be neglected and eroded, but if lost it cannot be replenished in a commensurate period.

(Next month: AGRICULTURE)

Conservation in Malaysia

P. R. WYCHERLEY

PART THREE — AGRICULTURE (I)

The literal meaning of agriculture is to till the fields. The development of settled agriculture has been the precursor of modern civilisation. Early man gathered wild plant produce such as fruits and roots. He collected also simple animal foods, eggs, insects and honey, much as many of the wild primates (monkeys and apes) do today. Later man became a hunter and a fisherman as well as a gatherer.

Another early stage seems to have been the partial domestication of cattle, sheep and goats in herds and flocks which were grazed in natural rough pastures for their milk, meat and skins. This may have evolved from keeping animals captured alive as a living larder. Working animals including dogs may have been adopted by man in a similar way during the hunting phase. Pets may have evolved in the same way, although in more advanced cultures they may have originated from animals kept for religious purposes, divination, sacrifice or as incarnate deities.

Most of the early graziers were nomads, travelling great distances to find adequate fodder and water for their flocks. They had to travel partly because they lived in the more arid regions where natural grasslands occur and water is scarce, and partly because they kept excessively large herds as indicative of wealth and allowed these to exhaust local resources before moving on, which in turn was due to the need to concentrate the herds for protection. The natural vegetation and terrain of south-east Asia has not been suitable for the development of this phase of migrant shepherds and herdsmen, which has been poorly represented in Malaysia. In other parts of this region the grasslands left by abandonment of shifting cultivation have been grazed, but this has not been on so great a scale in south-east Asia as in Africa, where large areas were kept under grass by fire and numerous cattle.

The deliberate planting of crops for subsequent harvest as distinct from reliance on collection from self-sown wild plants was the great step towards agriculture as we know it. Some believe that the first crops were vegetatively reproduced plants such as bananas and roots or tubers, because these are most easily grown by division of existing plants. According to this view crops raised from seed came later, because the idea of saving seed and sowing it is more complicated. The saving of seed for sowing next season may have evolved from storage of seed as a reserve of food in a manner roughly parallel to the evolution of flocks from living larders. These first plantings were probably on recent alluvial deposits by rivers, or on soil exposed by windfalls, landslips or fire caused by lightning.

The next phase was to destroy the natural vegetation in order to plant crops. This required tools and the use of fire. Unless storage preceded cultivation, methods of storing seasonal crops had to be devised. A similar development was to supplement the grazing of livestock with fodder fetched from elsewhere or stored in some way especially during the adverse season in the cold or arid regions. These animals

kept in stalls and paddocks could be slaughtered when food was scarce. The pressures towards these developments have been less in the humid tropics than in other climatic zones.

The domestication of animals by Malaysian aborigines has been limited largely to dogs, but some animals caught alive have been kept as pets, there is even a record of aborigines keeping a pet sambar deer. Fishing has always been an important part of the Malay economy and the coconut seems to have been adapted early as a crop from the self-sown palms of the sea-shore. Malaya has been ideally situated to obtain crops from other parts of Asia, from Africa and eventually America by the successive Arab, Portuguese, Dutch and British traders, navigators, settlers and colonisers.

Shifting cultivation

One of the more primitive types of agriculture in the tropics, shifting cultivation, is still practiced by aborigines in Malaya and by other indigenous peoples in East Malaysia. Although there are archaeological indications from different parts of the world and many current anthropological observations that shifting cultivation has been widespread throughout the tropics from the Stone Age onwards, it is largely conjecture as to what extent the methods have changed.

It is often assumed that the way of life of the aborigines has remained unaltered until the impact of the twentieth century, whose penetration by such agencies as the transistor radio can be traced and assessed. However, there is evidence that the Temiar of North Malaya did not begin to acquire hill padi from the Malays until as recently as 60 years ago before any disturbances from technicolgical civilisation reached them. Previously millet (*Setaria italica*) was the main cereal crop of the Temiar and still is in their more remote clearings. Millet has been cultivated in east Asia for at least 4 500 years. *Sorghum vulgare* of Old World—probably African—origin is grown by aborigines to a limited extent; it is uncertain when it first reached them. The Temiar grow chillies, tapioca and maize also; they seem to have adopted these crops before accepting padi. They can only have acquired these three crops during the last 400 years because these plants are American in origin and were unknown in the Old World until Columbus discovered the New. Thus, if for no other reason than the acquisition of new crops, we know that there have been some changes, but when, their magnitude and rate are difficult to judge.

Temiar millet system

Probably the shifting cultivation based on millet as the main crop practised by the more isolated Temiar is typical of the ancient methods of many of the aboriginal peoples in the region. The Temiar hunt and fish also, which provides most of the protein in their diet. The people of the family or clan group living in each longhouse or village fell an area of nearby primary or old secondary forest and burn the trash. On sloping land simple terraces are sometimes made by lining the larger partially burnt logs along the contours, so that some of the silt and ash collects above them as seed beds. The millet is planted in holes dibbled with a pointed stick and usually

only one crop is taken. Afterwards the area is abandoned to invading secondary forest; or perhaps bananas, whose wild relatives are secondary jungle species, are planted to give one crop which is not very carefully weeded until the forest is allowed to take over. Other vegetables are grown near their dwellings and the occasional fruits of the jungle are gathered on hunting trips.

The abandonment to secondary forest is the equivalent of turning a field over to fallow. It is allowing a period during which the soil fertility is restored by a covering of forest, even if it is secondary forest different from the primary jungle, soil reserves are not severely depleted, the invasion of tree species is rapid, and as but no crops are sown, grown or harvested. If only one crop of millet is taken, the soil reserves are not severely depleted, the invasion of tree species is rapid, and as far as it is possible to judge, fertility is completely restored in a period perhaps as short as 10 years, when the cycle may be repeated.

While the human population density is low, it is possible for an adequate number of clearings or fields, each with its long fallow relative to the cropping period, to be used in turn in the district surrounding the settlement, without any serious deterioration in the soil. However, sometimes soil fertility does become noticeably less and the aborigines move, perhaps only a few miles, and set up in a new area, but by the time they need to move again, the longer fallow has probably restored the soil at the first location. The result is a matrix of undisturbed virgin forest with many islands in all stages of felling, cultivation and fallow. The cultivation is shifting in the sense that it moves from field to field and occasionally the village centre moves too, but from generation to generation the same tribal lands are occupied, the soil fertility and the forest hunting reserves are maintained. The preservation of ancient varieties of only partially domesticated crop plots, such as unselected millet and bananas, is a useful service to plant breeding.

Severer systems

When the Temiar adopted dry padi, they often grew two crops instead of only the one usual with millet. Planting up the more thoroughly cleaned and weeded land afterwards with tapioca, which is a demanding crop unless heavily fertilised, continues the process of soil exhaustion. The result is a strong tendency for the grass *lallang* (*Imperata cylindrica*) or at higher elevations bamboos (*Gigantochloa*, etc.) to take over and to prevent forest regeneration indefinitely when the clearing is abandoned. Soil fertility deteriorates under *lallang* and does not seem to be restored under bamboo, a thicket of which is very difficult to clear in any case. Fires in *lallang* or bamboo retard further forest regeneration and encourage leaching of nutrients from the soil.

The use of the hoe, or *changkol* as it is known locally, in place of the dibble stick may cause more soil disturbance and hence more erosion on sloping land. Irrespective of this, the main factors in turning the course of regeneration from secondary forest to grass or bamboo after abandonment to fallow, are the increase in the period of cultivation and the decrease in the duration of the preceding fallow.

Other undesirable features, which usually occur in conjunction with those already mentioned, are the clearing of steeper slopes and of contiguous clearings with inadequate adjacent forest to assist in regeneration or to provide boundary belts to check the spread of fire or massive sheet and gully erosion. Various influences cause these changes leading to permanent destruction of the forest and its replacement by undesirable 'biotic' or 'fire' climax vegetation, soil erosion and loss of fertility, unless made good by the use of fertilisers and the methods of settled agriculture.

Usually these pressures and changes are blamed on increasing population density, whether this is due to squatters invading an area or to natural increase (population explosion), the resultant land shortage causes cultivation to continue too long with inadequate fallow in adjacent clearings. However, other reasons should not be forgotten. Resistance to shifting when necessary may arise, because one centre is well situated for access by traders, who purchase jungle produce for each which enables the aborigines to buy sophisticated tools, firearms and radios, and by various official agencies bringing education, medical facilities and social welfare. These outside contacts may be very attractive and break up the traditional pattern with its respect for the tribal forest heritage. Eventually the system may be reduced to one of the thoughtless over-exploitation as practiced by many who had no stake in the country in the past.

Chinese gambier system

This is an example of one of the crudest and most devastating forms of shifting cultivation. *Uncaria gambir* is a shrubby climber of the Coffee family, whose fresh leaves, when boiled, yield gambier used in the dyeing and tanning industry. During the first half of the nineteenth century it was planted extensively in Singapore and later in South Johore by the Chinese. The method was to crop each clearing exhaustively first with gambier and then with tapioca until it yielded too little to be worth harvesting, *lallang* almost invariably invading afterwards. The depredations of the nearby forest for firewood to boil the gambier were equally severe. As each area was ruined, the cultivators moved on further to repeat the process. Often they had no title to the land and certainly made no efforts to restore it. The sole object was the maximum profit for the minimum outlay. The effect of this on the soil in these areas has been long felt.

A similar situation arose in some areas occupied by squatters during the Second World War for the cultivation of subsistence food crops. The lack of fertilisers largely forced them into this irresponsible treatment of the land, accentuated by the knowledge that they had no title to the land, which was neither their heritage nor to be patrimony of their children.

These extreme examples should not lead to condemnation of all shifting cultivation. Nevertheless the pressures on the benign primitive system are increasing and it is doubtful if it can survive long. In some cases settled agriculture must be introduced immediately, especially where shifting cultivation is not the traditional life of the people. In others the shifting cultivators may survive with varying degrees

of success for a few generations more, until probably sooner rather than later, the essential forest fallow cannot be secured, and the land will have to be rehabilitated from *lallang* or bamboo for settled agriculture or for productive or protective forestry, perhaps at great national expense.

Where the aboriginal shifting cultivators find themselves alongside land development schemes, successfully using the methods of settled agriculture, the aborigines may copy these methods, much as they have borrowed crops in the past, and settle down to make the best use of their lands under the changed conditions of population pressure. Wise advisers may assist them to do this without complete disruption of their social system and culture. Government planners may reserve the rights to hunt and fish by their traditional methods in adjacent forest to the aborigines. The fatal susceptibility of the aborigines to diseases such as measles, chicken pox and mumps, which are regarded as normal childhood complaints among the town dwelling races, and other social factors make the adjustment of the aborigines' way of life to the modern world very difficult. Equally to try to preserve them as fossil cultures in distant reservations may deny them self-determination, political development, education and material advantages, which are regarded by many as the rights of man. Who shall decide to what intellectual and physical benefits and risks any others shall be exposed to or preserved from contact? Conservation of natural resources brings conflict with the aspirations of people, whether it be the hungry majority in the world or the cultural minorities.

Settled agriculture and civilisation

Civilisation is derived from a word meaning to do with cities. Whatever we mean by civilisation, for instance government by law, political and social development, the practice of the arts and sciences, the communication of ideas or even the waging of modern warfare, has required fixed centres. In these people can congregate, facilities such as machinery and records can accumulate, and at least some of the people are not totally occupied in food collection or cultivation so that they have time to invent new things and pass on this information by education of their children and neighbours.

The villages of the gatherers, hunters and fisherfolk could be fixed in location, but these occupations were so time-consuming that little was left over for progress towards civilisation. Also since they could easily exhaust food supplies within a convenient distance from their village, there were limits to the size of the villages sustained in these ways.

The nomadic graziers undoubtedly had more time for spiritual and cultural contemplation with the consequent emergence of religious thinkers, poets, musicians using simple instruments, and story tellers. However, their constant movement virtually limited the records they could carry to oral tradition; similarly advances in building or mechanical aids were either impossible or greatly hampered. It has been argued that these cultures before civilisation were better adapted to their environment than those since, but for the vast majority of the world's population there is no way to return.

Shifting cultivation in the more fertile areas may have sustained some centres of civilisation, especially where a military caste or a religious priesthood could command as tribute any excess produced by the surrounding cultivators. The Egyptian civilisation was supported by the seasonal agriculture of the Nile delta based on the annual flooding and deposition of alluvial silt, but this was not shifting cultivation in the sense used here. Eventually the modern civilisations of the temperate and mediterranean regions were the product of settled agriculture spurred on by the need to provide for the adverse cold or dry seasons.

The development of settled agriculture has a long history and many variations in different parts of the world, which cannot be recounted here. Settled agriculture is the source of most human food today and thus is still the mainspring as well as the origin of civilisation as we know it. In as far as a conservationist is an advanced or civilised person, he is the product of agriculture and dependent on it. Efficiency in agriculture is essential to feed the hungry millions of humanity in the world today, especially if there is to be any room left over for nature conservation.

Efficient agriculture is a process of continual use and renewal of natural resources, it is conservation in its highest form. Agriculture and nature conservation are interdependent at every level, not only in the obvious need to manage the soil and water resources wisely, but in various ecological relationships.

Human needs

Agriculture gave us civilisation, but disease limited human population until civilisation produced medicine, public hygiene and sanitation. The result of the latter has been the well known population explosion. Soon (perhaps already) there may be alive on Earth more people than have ever lived to reach maturity and died in the past. This increase in human population has created a colossal demand for food. More than half the people in the world are hungry and under-nourished. All food comes from use of natural resources and most of the extra food required must come from agriculture. Adequate food supply may help to relieve tensions between nations jealous of each other's natural resources.

Admittedly bad distribution of the world's present food production aggravates this problem. The world has been close to meeting its total food requirements in recent years, but bad distribution has made the rich countries richer and the poor nations poorer keeping many ill-fed. The increasing population makes ever greater demands. Unless the increase in world population is arrested, the problem will never be solved except by the collapse of humanity owing to famine, pestilence or self-extinction by war.

Agricultural food production can be increased in two ways. Firstly expansion of the area cultivated, which means the destruction of more natural vegetation in most cases, although land reclamation and in particular rehabilitation of abandoned areas should not be forgotten. Secondly improving the efficiency of agriculture which has been achieved by breeding and selection of more productive plants and animals, by the use of fertilisers and by the control of pests, diseases and weeds.

The pesticide revolution

Approximately the last 30 years have seen a major revolution in the control of the destroyers of or competitors with crops by means of powerful synthetic chemicals. Moreover insecticides are widely used not only for agricultural purposes, but to eradicate the vectors of human disease, e.g. malarial mosquitoes. All of these chemicals kill something and present hazards to their users, the consumers of the crops and to wildlife. Man, his animals and the natural environment are all in some measure at risk. Incorrect use of dangerous chemicals may poison food and defeat the object of increased production, but there are more subtle ways in which pesticides may make agricultural efficiency more difficult to achieve in future.

Whether wildlife is directly threatened by destruction of the natural habitat for agricultural alienation or is indirectly endangered by the effects of chemical usage spreading beyond the area of application and persisting for long periods, our civilisation is also susceptible to damage. Firstly because the wild flora and fauna are the genetic reserves for improvements in agriculture by breeding and selection of higher yielding and disease resistant plants and animals. Without wildlife these benefits may be curtailed in future. Secondly the chemicals sometimes cease to be effective owing to the appearance and multiplication of resistant pests when recourse must be made to biological control, for which wildlife again provides the reservoir.

Naturally occurring chemicals, especially in plants and micro-organisms, are employed as drugs, antibiotics, insecticides, and as industrial raw materials such as rubber or as the pattern for chemists seeking synthetic substitutes. We cannot afford to lose what may be the patterns for many valuable chemicals as yet undiscovered. Several important enzymatic processes depend on micro-organisms, for example the conversion of carbohydrates and inorganic nitrogen to protein by *Torula* yeasts, which has recently attracted attention for its potential in reducing protein deficiency, which is the greatest growing need in man's diet on a world scale. There are more to be discovered if an adequate range of natural habitats is preserved, in which genetic diversity is not only maintained but continues to evolve.

The revolution in pesticides and alternative methods of controlling pests have stimulated great interest in recent years as the effects of the new agents to kill weeds, disease organisms, insects and rodents have become better known. Some examples of each will be considered.

Aboricides

These are the tree-killers used in both forestry and plantation agriculture. Trees of no commercial value are poisoned in forests regenerating after extraction of timber to leave more space for the growth of the valuable timber species, and so to improve progressively the value of productive forest. This treatment of regenerating forest has been criticised, because quite often the first trees to fill the gaps caused by poisoning are not the most desirable timber trees of the primary forest but species typical of secondary growth. Thus the poisoning treatment may defeat its intended purpose. However, these methods have not yet been tried out for a sufficiently long time to discover whether or not the proportion of favoured timber species is increased

in the final stocking of emergent trees, which eventually over-grow the secondary species; further it is not known if treatment extends or curtails the period of temporary domination by secondary species. Experiments in forestry must continue for a whole regeneration cycle, which is longer than a man's working life. Also it is necessary to maintain virgin jungle reserves untouched, neither felled nor treated, as controls to enable future generations of foresters to compare the results of treatment with the original forest, which is so complex in the tropics that no description would be adequate. The oldest treated areas should also be conserved, because these are the most informative experiments for the long-term planning of natural regeneration forestry methods and for basic studies of productivity.

Sodium arsenite is still the most commonly used tree-killer in forestry. Its salty taste is much liked by many animals, especially large herbivores which commonly use naturally occurring salt licks. Elephants have been fatally poisoned and died in agony from consuming sodium arsenite carelessly disposed of in the forest. Even burying empty tins containing residues is not always enough to prevent wild animals obtaining the sodium arsenite, which is so attractive to them. 2,4,5-T, widely used to kill old rubber trees in Malaysia, is not a satisfactory poison for jungle trees. Nevertheless it is hoped that continued trials will find an alternative to sodium arsenite of lower toxicity to mammals, both wild animals and the human labourers who apply it, perhaps one of those mentioned below for rubber.

Replanting

When replanting rubber plantations the old trees must be destroyed and new trees (or palms) replanted in their place. One way of getting rid of the old trees is simply to poison them and leave them to rot and fall down. This is relatively cheap and needs little capital outlay in equipment. The organic matter of the old trees (equivalent to the amount of timber produced in 5 years at the maximum rate of growth) remains on the site to enrich the soil. Better growth of the following crop has been demonstrated in some experiments where the old timber has been left on site instead of being burnt or carried away for fuel. However, if the old trees are just left to fall down, considerable damage is done to the young new plants and there is risk of injury to people working in the area. Therefore it is necessary to fell the poisoned trees while it is still safe to do so and push them over between the rows of young plants. Thus the cost of felling is re-introduced as well as the inconvenience of less easy operation in the field due to the piles of debris between the rows. Tree-poisoning might have been abandoned, but it was discovered meanwhile that the incidence of root diseases in the new stand of trees is reduced by poisoning the old trees or their stumps, the latter being somewhat less effective.

The root diseases of rubber trees are caused by parasitic fungi which encircle the roots and stem base of the trees and cut off the vascular supply between root and shoot, so killing the tree. These fungi are able to live as saprophytes, that is on the material of dead plants, as well as being parasites of living trees. Poisoning and killing the old tree does not kill the fungal parasites or prevent them from living as saprophytes on the old stump. Killing the old stump does allow it to be invaded by many more fungi which are true or obligate saprophytes only able to live on

dead material, but unable to infect living tissues, which are the preserve of the parasites. These invading saprophytes compete with the root disease parasites, so that the latter do not expand to occupy the whole stump. These saprophytes and some boring insects unable to attack healthy trees speed the rotting away of the stumps, so that the sources of infection in the new stand have disappeared by the time the roots of the new trees have grown out and might otherwise come into contact with infective material.

Earlier, sodium arsenite was the usual poison for rubber trees. When 2,4,5-T (2,4,5-trichloro-phenoxy-acetic acid and its butyl ester) was introduced as a weed and tree killer, it was found that it stimulated old rubber trees to give an extra flow of latex before dying, which paid for the operation. Although perhaps not quite so effective as sodium arsenite according to some investigators, the advent of 2,4,5-T put a reasonably effective tree killer in the hands of smallholders, whose families should not be exposed to the hazards of sodium arsenite. Recently 4-amino, 3, 5, 6-trichloro-picolinic acid and its derivatives applied by a tree injector have been found to combine very effective killing of old rubber trees with very low toxicity and risk to humans, domesticated and wild animals.

Cacodylic (dimethylarsinic) acid is another promising tree killer. Although an arsenical compound, it is almost non-poisonous to mammals. The inorganic arsenic compounds such as sodium arsenite and lead arsenate are very dangerously poisonous, but many organic arsenicals are of about the same toxicity as aspirin. These are worthy of trial in plantation agriculture and forestry. They probably will not have any yield stimulatory effect on dying rubber trees. They and other tree killers have a possible use of growing importance even if of little consequence hitherto. The value of rubber timber for pulping is reduced by contamination of the wood with latex flowing out from the bark on cutting the trees. If the trees are killed first no latex flows on felling. This may make removed of the bark more difficult, unless the operations are well timed.

The use of tree killers in plantation agriculture helps in reducing root disease incidence, enables the organic matter to be conserved on site or old rubber wood to be removed in a form suitable for pulping. The value of tree killing in forestry is perhaps open to debate, but the risks to wildlife can be greatly reduced or eliminated by finding effective, less toxic alternatives to sodium arsenite, and the prospects of finding these are good.

Herbicides

Weeds are plants growing where they are not wanted, in particular those which by doing so compete with crop plants and reduce the yield of the latter, or in the case of plantation tree and palm crops slow down their growth and delay the time of harvest. A wide range of plants may be classified as weeds, including herbs, shrubs and trees. The name 'herbicide' suggests that only soft or herbaceous weeds are the target, but the difference between arboricides and herbicides is more in the mode of application. Arboricides are applied to individual trees, whereas herbicides are sprayed over vegetation to kill both herbs and shrubs. 2,4,5-T for example is

used in different formulations as both an arboricide and a herbicide. Weedicide and weed-killer are alternative names for herbicide.

Sodium arsenite has been used as a general purpose weedkiller for over 60 years in Malaya. Its use has been restricted by law to places where there are safe storage facilities, the labour are regularly medically examined and the areas sprayed are indicated by danger notices. Despite these and other requirements concerning containers and admixture of a dye, there have been cases of accidental poisoning (not always fatal) of humans and many cattle have died after eating sprayed herbage, whose flavour is attractive to them. A ban on the use of sodium arsenite for weed killing throughout Malaysia was proposed but postponed repeatedly.

The main advantages of sodium arsenite are its cheapness and that it kills the green parts of most plants on contact. Some plants, especially the beneficial creeping legumes sown as cover plants are very sensitive to sodium arsenite spray including accidental drift. Other plants, especially the coarse grasses and ferns, have to be sprayed repeatedly to destroy the green parts several times before the storage organs are exhausted and the plants are finally killed. Thus the use of sodium arsenite was self-perpetuating in that some less desirable types of ground cover became better established than those wanted but suppressed.

Hormone weedkillers

The hormone or auxin type herbicides, so called because the active ingredients are synthetic plant growth substances, for example 2,4-D (2,4 dichloro-phenixy-acetic acid) and 2,4,5-T, are very selective in their action, killing most dicotyledons (broad-leaved plants) leaving grasses and many other monocotyledons hardly affected. Thus if used alone, the suppression of legumes and dominance of coarse grasses among ground covers is even more pronounced with these than with sodium arsenite. Many cultural practices and natural hazards such as fire encourage coarse grasses, whose control has been the object of widespread research.

During recent years new herbicides or new formulations or methods of applying existing weed killers have been sought with the following objects in view. Firstly to provide a general purpose herbicide as cheap as sodium arsenite but less hazardous, this has now been practically achieved. Secondly to provide a range of herbicide with specific selective properties, for instance to eradicate coarse grasses with less effect on legumes or to eliminate individual broad-leaved weeds such as *Mikania* from among leguminous covers. Sometimes another weed or population of weeds different from those there before arises in the place of weeds sprayed out. A sequence of different herbicides appropriate to the weed population obtaining at each stage of the cycle may be necessary. This is not necessarily undesirable so long as the problem is recognised, otherwise there may be great wastage on repeating applications which are no longer suitable for the changed conditions, meanwhile some weeds unaffected by the herbicide used may become established and predominant in the planting. This means that the planter must be able to recognise the weeds and act accordingly. Some herbicides are more effective when mixed than applying the same amounts separately, whereas others are incompatible with each

other. Wetting agents and new equipment such as nozzles giving very fine droplets have contributed to the efficiency of herbicide usage.

The chemicals used for these purposes in Malaysia today are generally of reduced hazard to animal life. Sodium chlorate is a general contact herbicide; its main disadvantage is that it makes the debris of the sprayed vegetation very inflammable if it dries out; however, that is perhaps less of a risk in the humid tropics and calcium chloride which attracts moisture is sometimes mixed with sodium chlorate to reduce the fire hazard further. At the rates used in Malaysia there does not seem to be any build up of sodium chlorate in the soil; probably the warm moist conditions aid rapid breakdown.

Recently there have been adverse reports on 2,4,5-T arising from experiments with relatively large doses on pregnant mice. 2,4,5-T has been used for nearly 20 years and the risks to humans do not seem to have been substantiated where this herbicide has been applied as recommended. Nevertheless constant reappraisal and the prevention of careless use due to familiarity are always necessary.

New herbicides

The organic arsenicals MSMA and DSMA, monosodium and disodium methyl arsenates, are general contact herbicides, which like most organic compounds of arsenic are almost harmless to animals even in a concentrated form. Paraquat is another general herbicide which dries out the plant tissues sprayed. Pure paraquat is quite poisonous, but many preparations on the market are diluted in unpalatable carriers, so that even deliberate ingestion of a lethal amount is difficult and unlikely. Even so there is legislation to provide for suitable containers and warning labels, in particular to reduce risks of dermatitis due to careless handling. When further diluted to the concentration sprayed there is virtually no risk to animals either by inhaling the spray, by contact or by eating the sprayed herbage; vast quantities—too much for even an elephant—would have to be consumed to reach a toxic level. Moreover paraquat breaks down rapidly in the soil.

Although the above are classified as general herbicides because they kill a wide range of plants; none of them kills all plants; there are certain species resistant to one or other. When resistant species are present; it is necessary to use mixtures or sequence of two or more herbicides, often one general and one specific to control the particular troublesome plant.

2,4-D and 2,4,5-T have already been mentioned, the amine of the former is currently used in a new formulation instead of the salts and esters in the older preparations. These are selective in that dicotyledons (broad leaved plants) are much more susceptible to them than most monocotyledons. The cereals are among the more resistant monocotyledons and 2,4-D preparations have been much used to clear away broad-leaved weeds, although other monocotyledons such as sedges may subsequently become more common in rice fields. Drift of herbicides of this type may do damage outside the area of application. Usually drift is controlled as far as possible in plantation agriculture because sown legumes, rubber trees and

even oil palms are susceptible in some measure, so that care is taken to direct these herbicides to the weeds only.

The most commonly used coarse grass killer nowadays is dalapon (2,2-dichloropropionic acid and its salts). It is not dangerous to wild life and breaks down fairly rapidly in the soil. Amitrol is used against some grasses unaffected by dalapon.

Significance of herbicides in plantations

Plantation agriculture of tree and palm crops covers several million acres in Malaysia and is certainly in aggregate the largest single user of herbicides in the country. Now that a ban on the acknowledgedly dangerous sodium arsenite as a weed killer has been proposed, the role of the other less hazardous chemicals in wildlife and natural resource conservation may be assessed.

In the early days clean weeding was practiced. This led to severe erosion on slopes and to reduced organic content and water holding capacity of the soil in all areas. During the next phase there were two rival schools concerning the ground cover between the weeded planting rows; those advocating sown leguminous covers and those who favoured natural shrubs, that is a secondary jungle-like growth kept under control by periodic slashing. All grasses were considered to be harmful.

Recent experimental work has confirmed the beneficial effects of many legumes. Natural shrub covers have been shown to be very competitive unless regularly slashed manually, which is expensive, or sprayed periodically with herbicides to check their growth, which leads to their eventual displacement by other ground covers. These recent experiments have shown that *Eupatorium*, *Mikania* and *Passiflora* for example have an adverse effect on tree growth. On the other hand the grasses display a wide range of effects from severely depressive (*lallang* and other coarse grasses) to beneficial results little different from those of legumes (*Ottlochloa* and light grasses). However, a disadvantage of even the more benign grasses is that they easily invade the planting row, where they compete for applied fertilisers and may induce penetration of the tree collar by root disease fungi owing to provision of ideal incubation conditions.

During the early stages at least, clean weeding of the planting rows is desirable for ease of working, and to reduce competition by weeds for applied fertilisers and water. Later when harvesters must work in the area, ease of access is again important. Therefore experiment and experience have shown that for efficient working, maximum growth and product, the planter needs to keep the planting rows clean-weeded. In the areas between the rows, either a cover of sown legumes or perhaps light grasses should be maintained or, if a cover of less beneficial growths is allowed to arise spontaneously it should be controlled regularly.

Weeds have always been eradicated from certain areas. When manual labour is cheap, this can be done by hand pulling or by hoeing with a *changkol*, which involves soil disturbance, often removes plant debris from where it could provide a mulch, and digs hollows about the trees which later become waterlogged. When

herbicides are used the debris is left to rot as a mulch on site improving the soil organic content without soil disturbance, which is preferred soil husbandry.

Floral changes

The flora of the plantations is becoming progressively poorer in the number of species present. The oldest plantations are separated in distance by other plantations and in time by two or more generations of crop plants from the original forest. There is no adjacent forest to replenish the stocking of the native flora and fewer species survive each successive replanting. Herbicides—like any other weeding operation—are probably accelerating this process. The sowing of desirable leguminous cover plants to fill the space of displaced weeds is good agricultural practice but also impoverishes the flora. The selective action of some modern herbicides gives rise to a rotation of weed populations and the need to use a sequence of herbicides, this gives some variation in the ground cover and may prevent excessive accumulation of any one herbicide in the soil.

If weeding is accepted as part of agriculture, it is doubtful if the introduction of modern herbicides has done more than accelerate certain changes in the floristic composition, which were taking place in any case. Herbicides are probably an improvement on the old manual methods, which are now too costly for economic operation, by reducing soil disturbance and so conserving soil and moisture.

The changing ground flora may be affecting the wildlife of the plantations, which is sparse in rubber but rather richer in oil palm, by encouraging birds which eat grass seed at the expense of those taking the fruit of secondary jungle trees like figs, although far too little is known about this. There is no evidence to date that the modern herbicides of low mammalian toxicity have been responsible for poisoning any wildlife or seriously affecting the flora or fauna, including fish, of streams and rivers draining the plantations. Micro-organisms in the soil are responsible for breaking down the organic herbicides and rendering them inactive. Therefore one might expect changes in the soil fauna and flora, certain groups becoming more abundant and others, perhaps those responsible for important processes in the soil, being depressed in their activity. So far there is little evidence of this and certainly no signs of bad effects attributed to this cause. There is urgent need to investigate these possible remote, residual or delayed actions, otherwise some unsuspected side effect may grow rapidly to serious dimensions. Nevertheless these have not yet been demonstrated, even if they have not been looked for on an adequate scale, and on balance modern herbicides are beneficial in plantation agriculture including its conservation aspects.

Blanket use of herbicides

During emergency police actions or in wartime, herbicides have been sprayed on roadside scrub and on to forest from the air to reduce the cover available to the enemy. Foodcrops have been sprayed from the air to deny the enemy sustenance. Herbicides such as 2,4,5-T have been employed most commonly. These operations have often been carried out without respect to cost or critical minimal rates to achieve effect. As a result there has been drift over long distances and there have been long-

lasting residual effects and a predominance of coarse grasses in the regeneration. These instances cannot be quoted fairly as examples of the results of herbicide usage.

Secondary and derivative habitats are exploited by the grasses, a highly evolved group among the monocotyledons, which as a whole are believed by many to be more advanced than the woody and broad-leaved plants of the dicotyledons. If so, human activity such as destruction of forests, grazing of cattle, the indiscriminate use of fire and herbicides, may be aiding a larger evolutionary process of world domination by the grasses. The grasses, especially the cereals and the fodder grasses, are valuable to mankind, who in turn is helping the spread of the grasses. This may be regarded as an unconscious symbiosis (the living together of different species for their mutual benefit), or in fact one partner may be the tool of the other; if so, man does not seem to be in control of the situation.

This is speculative, but the large-scale clearing of forest by aerial spraying of arboricides and herbicides is now being tested. If the land is going to be cleared in any case, this may be as good a way as any. However, now that grass-killers are also available, it would be instructive to attempt on an experimental scale at least the eradication of sheet *lallang* or another grass climax by aerial spraying, followed by seeding with trees or legumes.

Fungicides

Fungi are plants unable to make their own food by photosynthesis and live either as parasites of living things and/or as saprophytes on dead plant material. Saprophytic fungi rot damp timber in buildings or fence posts, although in the tropics termites (white ants) are perhaps even more destructive. Timber is treated with chemicals to preserve it from insect and fungal attack. In normal circumstances there is little or no hazard to human or wild life.

Many diseases of plants are caused by fungal parasites. There are three main ways of combating fungal diseases: breeding and selection of resistant plants, cultural practices, and application of fungicides, which are chemicals which should kill the fungus without harm to the crop plant which is host to the parasite. Sometimes one method is adequate, whereas some diseases can only be brought under control by a combination of two or more. The economics of the relative cost of disease control and the value of the crop obtained must be carefully weighed. The soil-borne *Fusarium* fungi cause wilt diseases of many field crops, for instance the Panama disease of bananas; control might be achieved in some cases by soil sterilisation, but this is so expensive that usually recourse must be made to a resistant variety in the case of bananas, or introduction into the rotation of a completely different crop if no resistant varieties of the original crop are available. This gives time for the amount of infective material to decline.

The mildews, including Powdery Mildew which is one of the causes of secondary leaf-fall in rubber trees, attack only the young leaves in most cases. The germinating spores of mildew are easily washed off by heavy rain or by syringing the foliage, a method now confined largely to amateur growers of roses for show. Although dis-

placed by heavy rain, mildew requires high humidity and water as dew or mist for infection. The germinating spores are susceptible to drying out and also to sulphur dust. Fine sulphur is almost a specific pesticide for mildew among the fungi and for mites among the arthropods. Other forms of life are not affected by sulphur dusting and spraying at the usual rates.

Bordeaux mixture (of 2 parts copper sulphate, 1 part quick lime and 100 parts water) is one of the oldest, cheapest, most widely used and still one of the more effective fungicides for many stem and leaf diseases. The deposit, which dries on the sprayed parts is only marginally poisonous to most animals if ingested, in practice they would have to consume improbably large quantities of bark and foliage to come to any harm.

There is limited evidence from other countries, not Malaysia, that repeated, very heavy applications of Bordeaux mixture may build up concentrations of copper in the topsoil toxic to soil organisms. The other risk is to life in ponds, rivers and streams, especially to fish which take great volumes of water through their gills in order to obtain enough dissolved oxygen to respire and hence may concentrate soluble poisons in their blood, if large amounts of copper salts are carried off in drainage water. To a certain extent these risks are contrary, if the copper is accumulating in the soil, it is not available in solution in the drainage waters, and *vice versa*. The main point is that the rates of application in Malaysia are still relatively small and likely to remain so. Copper is an essential element for plant growth even if in trace quantities, for example a stand of old rubber trees contains about 4 lb of copper per acre. There must be some copper in the soil to support crop growth and cases of deficiency are known. Moderate additions by way of fungicides are beneficial in these cases and by no means harmful in others.

Modern fungicides

The quarternary ammonium compounds are detergent-type chemicals, whose main fungicidal application in Malaysia is to treat stem and panel diseases of rubber trees, and they are virtually harmless to all animal life; careless handling of the concentrate may cause trouble to those with sensitive skins, but this is no greater hazard than domestic washing powders. These detergent-type fungicides might find wider application or be more efficient if they were not so easily eroded by the rain; the incorporation of greases may be the answer. Tar and bitumen have their uses and by their nature are not hazardous.

The dithiocarbamate group of fungicides are used to control a number of leaf diseases and to prevent 'damping off' of young seedlings, in which the latter are attacked at or near ground level by moulds. These carbamates have various metal bases, such as iron or zinc, and most are only marginally toxic, for instance a man would have to eat a teacup-full of the most unappetising pure substance to come to grief. They are sprayed at such low rates as 2 lb of active ingredient per acre or 1/5th of one per cent concentration. There is no evidence of risk to wildlife by inhalation of drifting spray or ingestion of sprayed foliage or fruit at these concentrations, or of any build up in the soil.

The collar protectant to prevent penetration by white root disease of rubber is based on pentachloro-nitro-benzene, which has negligible toxicity for most animals. Pentachlorophenol on the other hand is much more dangerous, but this is mainly used to treat timber. Thiram also falls in an intermediate category for toxicity. Thibenzole, now used in oil palm nurseries, is also used to free sheep and cattle of worms by drenching them in its solution. It is a rather safer and more effective fungicide than thiram in some respects.

The most dangerous fungicides used in Malaysia until recently were the organic-mercurials, as little as one twentieth of an ounce of the pure substance could kill a man. If these were sprayed, damaging amounts might be inhaled if the operator did not wear a respirator and goggles, which are uncomfortable in the humid tropics and liable to be left off with serious consequences. These organic-mercurials were recommended to treat those panel diseases of rubber trees which did not respond to the detergent type fungicides. The organic-mercurials should be painted on, even so gloves should be worn, all contact with concentrate, solution and treated surfaces avoided, and even if gloves are worn the hands should be washed thoroughly before eating or smoking in case of accidental contact. Very little animal life, apart from humans, is liable to handle these chemicals or to come into contact with treated panels. The risk to wildlife is not great, but it is obviously desirable to replace such dangerous chemicals with safer materials. Captatol (in a formulation called Difolatan) is one of several new fungicides which seem to be satisfactory in this respect. In other countries the organic-mercurials have been used as seed dressings for cereals, often with serious consequences for birds, fish and possibly humans.

Cultural control of fungal diseases

The reduction of the incidence of root diseases in the new stand of rubber by poisoning the old trees has been discussed in the section on arboricides. The establishment of leguminous covers also helps to rot away old stumps which may be sources of infection before they can do any harm. Organic matter rots faster the lower the ratio of carbon to nitrogen; old stumps are rich in carbon and rot slowly, but this can be speeded by adding nitrogen. The favoured leguminous covers enrich the soil, or any stumps they scramble over, by symbiotic nitrogen fixation. The establishment of a creeping legume cover has been shown in experiment to reduce the incidence of root disease. This is the third beneficial effect of leguminous creeping covers mentioned in this manual: first the prevention of erosion, second soil enrichment and improved circulation of nutrients, now the reduction of root disease losses. Blessings do not come singly when natural processes are harnessed to good effect. In this and the following case curative fungicidal treatments have not been found, collar protectants are only preventive measures in rubber to reduce spread of the disease.

Basal Stem Rot of oil palms caused by *Ganoderma* is serious if old coconut palm trunks, the stems of wild palms or to some extent old oil palm stumps themselves are left lying around in new plantings or replantings of oil palm. Burying these sources of infection is the most economic way of dealing with this risk but burning instead of burying is more satisfactory; whereas neglect of these precautions usually leads to severe losses.

Slow growth due to overcrowding or inadequate fertilisation or irrigation of many crop plants predisposes them to infection. Excessive humidity due to overcrowding increases disease incidence in the nursery and panel diseases of rubber are prevalent if dense undergrowth is unchecked. Good cultural conditions help to cut down the fungicide bill considerably. Preventive cultural measures are often longer-lasting than curative treatments by spraying.

Genetic resistance

Few if any plants have been found resistant to the root diseases, whose containment is largely by cultural methods or plantation hygiene to reduce the contacts between the tree crop and sources of infection, assisted by treatment or destruction of cases when diagnosed. The situation among the leaf and stem diseases is very different.

Resistance to nearly every leaf disease has been found in some individual plants, which may be multiplied if vegetative propagation is possible. Some populations of plants have a larger proportion of resistants than others. Many crop plants have been bred and selected for yield over several generations without adequate attention to disease resistance. Thus when the disease builds up to serious proportions, it is often found that the highest yielding varieties are susceptible, but the resistant strains are low-yielding. Breeding and selection programmes are then necessary to combine the desirable features of high yield and good resistance. This may have to be done for more than one disease at a time.

Resistant high-yielding material is the simplest method of economic control of disease, the main difficulty is that it is a long-term programme in a world which urgently demands quick results. Sometimes the resistance of a selected variety breaks down; what actually happens in most cases is that a new strain of the disease has evolved which can attack the hitherto resistant selections. An interim measure possible in rubber is to bud-graft a resistant crown on to a susceptible but high-yielding trunk.

Resistance may have been lost in cultivated varieties or may break down. Almost invariably search among the wild plants of the same or closely related species of the crop will discover resistant—even if low-yielding—material, which can be taken into the programme. The discovery of new disease resistant strains is dependent on a supply of wild plants. It is quite impossible to collect and keep alive examples of every naturally-occurring variant in a series of huge botanical gardens. The only practicable way is to preserve examples of every known types of vegetation so that nature itself can be the genetic storekeeper. Malaysia is the centre of the range of the wild bananas, *Musa*, and several collecting expeditions to the forests and aboriginal *ladangs* have been arranged in recent years. The same argument applies to every crop and country. Apart from the native fruits, banana, durian, mangosteen, rambutan, jackfruits and relatives, Malaysia has provided important breeding material for the improvement of rice and sugarcane. The recent discovery of a new wild *Citrus* is important.*

* *Planter, Kuala Lumpur* 48: 90-92 (1972)

Another interim measure is to plot carefully the distribution of plant diseases, for instance *Oidium* or Powdery Mildew of rubber is more common in North Malaya and the Interior of Sabah, but *Gloeosporium* leaf disease is more common in south Malaya and south-west Sabah. Some reasonably high-yielding varieties are susceptible to one disease but resistant to the other and *vice versa*. These can be planted in the respectively appropriate areas, although there is some risk that the diseases may spread but this is likely to be rather slow.

With the exception of the organic-mercurial compounds, which can now be replaced for most uses in Malaysia, no fungicides used in Malaysia are very poisonous to animals. None are applied in dangerously large quantities. Cultural control measures are well appreciated, breeding and selection programmes to combine yield and resistance are in progress. The situation appears satisfactory provided there is constant improvement and no relaxation resulting in ground being lost. The cautionary remarks about the pesticide revolution may seem uncalled for, but the next group—the insecticides—should dispel any such illusion.

(Next month: *AGRICULTURE cont.*)

Conservation in Malaysia

P. R. WYCHERLEY

PART FOUR — AGRICULTURE (2)

Insecticides

Insects and other arthropods, such as mites and ticks, are harmful to mankind and his domesticated animals in three main ways, as pests of crops, thus competing for food, as parasites especially blood suckers and as vectors or carriers of diseases. Insects also destroy timber and *atap* thatching materials. Some insects and other arthropods such as spiders, scorpions and centipedes can inflict painful stings, which are seldom fatal except when someone is unfortunate enough to get multiple stings from wasps or hornets. Such venomous invertebrates or their nests are usually destroyed individually, they are not controlled by regular chemical applications and do not pose the kind of problem discussed here, which is the routine or extensive use of insecticides under rural conditions for agricultural or medical purposes.

Malaysia is fortunate that sleeping sickness and yellow fever do not occur here, although the mosquito which transmits yellow fever is common, which is why it is important that anyone suffering from yellow fever should be kept out of South-east Asia. Bubonic plague, carried by rats and transferred from them to humans by fleas, has troubled many countries at one time or another, it is still a terrible shadow which may fall across Asia. Typhus is transmitted by lice and ticks. Flies carry enteritis from faeces to food. Mosquitoes transmit the painful but seldom fatal dengue, the disfiguring and weakening filariasis or elephantiasis in East Malaya and the arbor viral encephalitis beginning to cause concern.

Although there was a heavier incidence of malaria during wartime conditions and occupation, it is difficult for many to realise the terrible effects of endemic and epidemic malaria 70 years ago on the Selangor coast. The victims were anaemic, the children were unable to concentrate on their lessons or enjoy their games, the men were unable to work hard and get a good living for their families, the women bore few children alive. The under-nourished died. In rural areas before malaria eradication began to take effect, an insidious intermediate condition prevailed which sapped the energy of the village people, who as a result were said to be lazy and their children stupid. Although the use of insecticides in malarial eradication campaigns has had undesirable side-effects in certain cases, it is essential to realise what a great benefit freedom from malaria is for the progress, health and happiness of the rural people.

It is difficult to get the maximum yields from certain short rotation crops without the use of insecticides, for instance from the protein rich soya bean or from maize, which is an important constituent in cattle and poultry feed, and so an indirect source of high grade protein. Owing to the short period of growth to harvest there is some risk of harmful residues being consumed by humans or the animal intermediaries under these conditions of intensive usage. Plantation crops on the other

hand present possible occasion for extensive usage and upset of conditions over a wide area.

The natural means of pest control and the various roles of insects as a whole must be reviewed before considering the action, benefits and risks of the various groups of insecticides. The effect, if any, of the vast majority of insects on human life is unknown. The harmful insects constitute a very small yet important minority among the group as a whole. There are perhaps somewhat more beneficial than harmful insects. Some insects pollinate fruit trees and many vegetables, especially the protein rich beans. Other insects provide the natural controls of pests, many are involved in processes of decay and re-circulation of nutrients. The two main types of biological control of pests effected by insects are through predation and parasitism.

Predators

These are the animals which prey on other animals, kill and eat them. Mosquito larvae are eaten by small fish and a wide range of freshwater invertebrates, this may not establish absolute control but it does reduce the number of larvae considerably. These natural predators are seldom able to operate in man-made mosquito breeding niches such as empty cans and jars. Adult flying mosquitoes are eaten by a wide variety of larger insects, spiders, birds, toads, lizards and bats, but again this is not absolute control.

Insect-eating birds consume both larvae, such as caterpillars, and adult insects in large quantities, especially when the rapidly growing nestlings must be fed. Many animals of different orders eat insects. Other insects are by no means the least important predators of pests. Among the better known in Malaysia are the Praying Mantis, which remains motionless until its prey wanders within its grasp, and the Ant-lion larvae which make traps in sandy soil. Others which do not move far in search of their prey are the larvae of the Hover-flies and Lacewings, also both larvae and adults of some Ladybirds and Thrips. One species of Ladybird and some Thrips are pests of crop plants, attempts at their control may kill off their beneficial cousins.

Dragonflies hunt down their prey on the wing, while various ants, beetles and assassin-bugs are predators on the ground. The wasps hunt other insects and spiders to feed to their young larvae. A few solitary wasps and all the social wasps and hornets carry food to their young larvae and feed them regularly. 'Social' means living together, these are the wasps and hornets which live in colonies and build large nests. The solitary wasps live alone (except for mating), and make a nest, stock it with caterpillars and similar live food, which has been paralysed by the wasp's sting, lay their eggs (sometimes directly on the host) and seal the nest. When the larvae emerge they feed on the living store of food. These are sometimes called parasitoids, because although the adults are hunters, they do not immediately kill their victims, which are parasitised by the larvae. As noted in the following section, parasitoids form a large proportion of insect parasites of insects in Malaysia.

Parasites

Insects, including mosquitoes, are subject to many diseases caused by other organisms, including bacteria, fungi and nematodes, which parasitise them. The majority of the insect parasites of other insects are laid as eggs in the eggs, larvae, pupae or nymphs of their hosts. The eggs of the parasites hatch and their larvae feed on their host until they eventually kill it, sometimes pupating within the pupa of the host. The adults are usually free-living and the females often roam far to find hosts for their eggs.

In Malaysia the scale insects and mealy bugs are often parasitised by small wasps. The grubs of cockchafers, which feed on the roots of many crop plants, are parasitised by digger wasps, which dig down into the soil to find the grubs, and by the maggots of parasitic flies emerging from eggs laid in the soil near the cockchafer grubs. Some other cases will be considered under the effects of contact insecticides.

Classification of insecticides

Insecticides may be classified by their mode of action. The stomach poisons are those which are ingested by biting insects as they consume the sprayed plants. Contact insecticides are those which penetrate the insect's body when it touches a solution, suspension or deposit of the poison. Systemic insecticides are absorbed by the plant so that sap sucking pests are poisoned. Fumigants are insecticides whose vapours kill the insects which breathe them, they are most effective in enclosed spaces such as stores, greenhouses, the soil or within enclosed leaf bases. Some insecticides have more than one kind of action.

Insecticides may be classified according to their chemical composition, or according to the pests they are intended to control, but these classifications often coincide with the mode of action classification. Other important considerations are the toxicity of insecticides to vertebrates, including fish, birds, mammals and man himself, and the persistence of this toxicity either on the plant or in the soil.

Inorganic insecticides

Most of these have been known for many years. Sulphur is used mainly against mites; it is not very effective, but since it has so little effect on other forms of life, it helps to tip the balance to bring the mites under natural control. Lime-sulphur has not been much used in Malaysia.

Termites used to be controlled by putting white arsenic in the runs and treating the attacked plants with dilute corrosive sublimate (mercuric chloride). These substances are both very toxic and dangerous. They are no longer used for this purpose.

Lead arsenate is a stomach poison of both insects and mammals, but it has relatively little contact effect. Lead arsenate is still the most satisfactory selective insecticide, when it is necessary to kill leaf-eating pests without harm to predators and parasites alighting on the foliage. Animals eating sprayed foliage or people handling it carelessly are in danger, stomach poison insecticides without contact effect but of low mammalian toxicity are much needed.

Fluorine and copper-based insecticides have been little used in Malaysia. Infrequently copper aceto-arsenite has been used in malarial control. Fluorine compounds are very hazardous. Some substances are on the borderline between the inorganic and organic compounds. The most dangerous is cyanide gas, but it is seldom used except for fumigation under strict control. At the other end of the scale soap and mineral oils, such as kerosene, are virtually harmless to vertebrates. Kerosene-soap emulsions suffocate scale insects, mealy bugs, lac insects and to a lesser extent aphids without any appreciable harm to beneficial insects. Often one round of spraying with emulsion will enable the natural enemies of these pests to re-establish control.

Oil has long been used spread in a thin film, one thousandth of an inch thick, over water to stop the breeding of anopheline mosquitoes, which transmit malaria. The females are discouraged from laying and the respiratory tubes of the larvae are unable to support them at the surface with lowered tension. Unfortunately this is a relatively expensive method where there is a fast flow of water. There is no definite evidence of damage to fish, birds or mammals from this practice, although it has been widespread for many years.

Vegetable extracts

Nicotine is a contact and stomach poison as well as a fumigant. It is not persistent but it is very dangerous to man and animals while its action lasts. It is not used much in Malaysia.

Rotenone is the active ingredient in the roots of *Derris elliptica* or *tuba* as it is called in Malay. The ground *tuba* root or derris powder stupefies fish if it is put into a river or pond and if the concentration is too great the fish are killed. Fishing by means of *tuba* is a royal prerogative in most Malay States. Despite the sensitivity of fish to derris, birds and animals have to consume very large quantities before they suffer any serious ill effects. Pure rotenone is much more poisonous, but the normal preparation of the ground root involves a manifold dilution factor.

Derris is a contact insecticide, but it does not persist. It is applied as a dust or as an emulsion. Repeated use on a plantation scale might harm beneficial insects and stupefy or kill fish in streams, although most of it would be broken down in the soil before reaching streams. Derris probably has a potential use on many short term crops, especially market garden vegetables, for which an insecticide of low persistence and toxicity to humans is needed. Unfortunately derris has been almost driven off the market by the synthetic insecticides. There is a case to re-investigate derris and perhaps to revive its cultivation in Malaysia, both to save foreign exchange and to provide this and other countries with a safe insecticide.

Pyrethrum is obtained from a plant in the Daisy or Sunflower Family. It is a relatively expensive material and cultivated in the rather drier tropics. A small amount knocks down or paralyzes flying insects, a slightly higher dose kills them. Pure pyrethrum is only marginally poisonous to man and warm-blooded animals, accidental poisoning is unlikely. It is not persistent, but breaks down in sunlight

or in contact with the air or soil. As with all contact insecticides there is some risk to beneficial insects, but if cheap enough it could have application in market gardening. Unfortunately due to the cost, more persistent synthetic insecticides such as DDT are often added to effect kill after knock down by the pyrethrum. The main usage of pyrethrum in Malaysia at present is in aerosols for domestic control of flies, mosquitoes and cockroaches.

The chlorinated hydrocarbons

The first of these was DDT, first used in Malaysia to deal with the vectors of human diseases, lice and mosquitoes after the war. It later found agricultural applications. The toxicity of DDT when eaten by mammals is moderate, about half an ounce or more would kill a man. It is much more persistent than the contact insecticides of vegetable origin discussed in the previous section. This persistence occurs on plants, in the soil and in animals.

DDT is still the preferred insecticide in the residual spraying campaign against malaria. A thin film of DDT is deposited on the inside walls of the village dwellings by spraying every 6 months. Most insects coming into contact with the DDT are killed. The number of anopheline mosquitoes in the area is not usually much reduced, but the life span of those coming into houses is shortened so that few of them have opportunity to first bite someone with malarial parasites in their blood, then to incubate and multiply these through the next phase in the parasite's life cycle and, finally, to infect a new human victim.

In conjunction with chemical therapy and prophylaxis by means of chloroquine and amodiaquine, these campaigns have over the years been successful. Strains of mosquitoes have developed resistance to DDT and it has been necessary to change the insecticide in such cases. Resistance has not developed as fast as might be expected, possibly owing to a large proportion of the breeding mosquitoes never coming into the sprayed dwellings and so giving a chance for selection in favour of resistance to operate, as is the case when an attempt is made to exterminate an insect population by exposing them all to insecticide. In malarial eradication campaigns the majority of mosquitoes which survive to breed are susceptible. Strains of mosquitoes and other insects have developed which are resistant to synthetic insecticides, but not to vegetable extracts like pyrethrum. Malarial parasites resistant to synthetic drugs such as chloroquine, but not to natural quinine, have arisen also.

Most flying insects alighting on the walls sprayed with DDT are killed, including those which parasitise the caterpillars living in *atap* roofs. As a result an *atap* roof thatched with palm fronds, which might be expected to last for 2 years, has holes eaten in it and begins to leak within 2 months of residual spraying of DDT. This was one of the first undesirable side effects noted.

DDT has been used to control a wide range of agricultural and horticultural pests. However, owing to its persistence it cannot be used on materials which will be consumed soon. There is no doubt that bagworms have appeared as a new pest on oil palms due to the use of DDT and similar insecticides. DDT was used against cockchafers in one case and almost immediately an infestation of bagworms appeared.

In another oil palm plantation the contact insecticide was added quite needlessly as a precautionary measure to a fungicide being sprayed for a different purpose, the bagworm infestation began and grew from that date. In an experiment a small area was deliberately sprayed with DDT and bagworms reached serious numbers in the sprayed area and the surrounding area, but fell off at some distance beyond. There is little doubt that the mobile females of the species which parasitise bagworms were killed in the sprayed area and their numbers reduced over a much wider area owing to their movements in and out of the sprayed area.

Since the first edition of this manual, there has been growing concern about the accumulation of DDT in the seas and its possible hazards on a worldwide scale. As far as possible the affluent countries are being encouraged to halt the further use of DDT, and to use instead methods or materials which have less persistent effects, although more expensive in themselves or because of the need for repeated application. However, DDT is still recognised as the most economic and effective insecticide for most malarial control programmes in developing countries.

BHC or *gamma* benzene hexachloride is another contact insecticide of this group. It has a limited use in malarial control. Many domestic formulations contain BHC. It is used often to kill soil-borne pests or others which strike close to ground level, both as a seed dressing or dusted along the drills. Although not so persistent as DDT, it often imparts taint to root and short rotation crops. Taint may survive the feeding of the products containing insecticide residues to poultry and appear in the eggs. This may serve as a reminder to the public that the chlorinated hydrocarbons are passed on from one animal to another, often concentrating in the fatty tissues. Quantities inadequate to cause taint are also transmitted and these may accumulate to harmful proportions somewhere in the food chain.

There is at least one case of BHC causing a minor pest of coconut palm to become very serious. *Artona* is a small moth, whose caterpillars feed on the undersides of the older coconut fronds giving them a scorched appearance. It is parasited heavily by a Tachinid fly and to a lesser degree by an ichneumon fly, also a Clerid beetle eats the pupae. If an outbreak is allowed to take its natural course, within about 3 months the tachinid has established control, the majority of the moth caterpillars being parasitised. However, when a few acres were sprayed with BHC to try to eradicate a small outbreak, the *Artona* spread rapidly until some hundreds of acres were out of bearing. Parasitism was at only a fifth of its normal level for some months. The mobile flies had been killed over a wide area and took a long time to recover.

Cyclodienes

The cyclodiene group includes aldrin, dieldrin, heptachlor and endrin. They are all persistent, even if not in their original form, for example aldrin is converted to dieldrin in the soil. They are all very poisonous, endrin is extremely dangerous, only one hundredth of an ounce could kill a man; the others would require about ten times as much. Birds are relatively more sensitive and fish even more so. As successive plants and animals in the food chain absorb the poison from the earlier link so it becomes more concentrated in their fatty tissues.

Dieldrin has been used in anti-malarial spraying, but its use is now confined to proven cases of resistance to DDT, because so many domestic animals and poultry died after absorbing dieldrin through the skin as well as ingesting it. Cats are particularly sensitive, perhaps because they rub themselves against walls and clean their coats by licking the fur so often, and were almost exterminated in some villages in Sabah when dieldrin was first used. Rodents increased when the cats were lost. Needless to say this damaged the image of the anti-malarial campaign. It has even been suggested in Africa that the end result might be an outbreak of plague or typhus.

The cyclodiene group, except for endrin because of its extreme hazard, are recommended for the both preventive and curative treatment of termite attack against rubber trees and other plantation crops. A diluted solution is poured round the bole of each tree. The soft bodied termites are particularly sensitive, although they seem to carry the insecticide to their nests before death, because the incidence of termites in the whole area often falls drastically. Such soil applications are sometimes made to control cockchafer. Apart from the natural controls of cockchafer, few of the flying predators and parasites of other pests are liable to alight on the small area of treated soil. The risks to birds and mammals are probably small. It is tempting to assume that because the termites are soft-bodied and sensitive, only they will be affected. Only a minority of termites are pests of the trees, the remainder being concerned with the reduction of plant debris and circulation of nutrients in the soil. Nobody really knows what effect this treatment has on the soil fauna. Until some observation indicates harm, this economic method of controlling termites is hard to deny, but there is need for investigation.

Several potent chlorinated hydrocarbon contact insecticides, including dieldrin and endrin, were sprayed regularly on the cocoa bushes in Sabah in order to control a wide variety of pests attacking the stems and leaves. It was decided to give natural control a chance and to stop spraying, within 1-2 years the Branch Borer caterpillar, one of the more serious pests, had disappeared following parasitism by ichneumon.

Spraying of these insecticides was therefore an unnecessary expense, because it was inadequate to control the pests and prevented the development of the eventually successful parasitism. Moreover, spraying or fogging these poisonous chemicals requires precautions such as respirators and goggles, which are unpleasant to wear in a tropical climate. In some cases alternative formulations or modes of application are possible.

Granular forms of these insecticides may be shaken out of disposable plastic dispensers, so that the hands do not come into contact with the granules. The volatility from the granules is only slight, so that there is no inhalation risk to workers in the open air. These granules can be shaken inside the cone of leaves of a maize plant, where their slow contact and fumigatory action keeps out stem borers. Another promising method is to shake the granules onto the ground under trees and palms infested with caterpillars. When healthy caterpillars drop to the ground to pupate, they come into contact with the granules and are killed, but the parasitised caterpillars and their parasites remain out of contact on the foliage. Eventually the

new generation of pests fails to emerge. This method can be used also to reduce the number of ants which farm mealybugs and aphids on the crops and drive away their natural enemies.

Birds are not very common in rubber plantations, but are plentiful in palm crops and gardens. Birds eat large numbers of insects, but are very susceptible to poisoning by accumulation of insecticides from the many pests they devour. Fish are also sensitive. Now that the dangers of these chemicals are known, it is desirable to use them only in ways which can do the least harm, otherwise birds and fish may be killed over a wide area as sometimes happens to the insects which are natural controls of pests.

Many hoped that these insecticides would be broken down very rapidly in the warm humid climate of Malaysia. Experiments have shown that the relatively small, dilute applications of chlorinated cyclodiene insecticides to control termites, retain their activity and effectiveness for up to 4 years on the sandier soils, for over 2 years on most soils and only in the case of peaty soils is there markedly reduced activity (not necessarily destruction) within 3 months. There are cases of snakes and birds of prey being killed or reduced in numbers and activity in areas where these insecticides have been used to poison rodents and other supposed mammalian pests. This example is discussed elsewhere, but the conclusion remains, namely that the widespread destruction of wildlife including migrant raptors (birds of prey which travel seasonally) far beyond the place of application and for long periods is possible under Malaysian conditions. There is abundant evidence of this from other countries, where there have been heavy losses of economically valuable birds in the chain of natural pest and rodent control and of fish, when these chemicals have been used indiscriminately or on a large scale. It is the small scale of usage and the very proper attention to methods of application by manufacturers, selling agencies and users, which have spared Malaysia the worst consequences to date, rather than any special advantage in the environment.

The organic phosphates

The organo-phosphorus insecticides have several different modes of action. The more poisonous are directly dangerous if inhaled, the more volatile have a fumigatory effect in enclosed places. They are all stomach poisons if the deposit is eaten. Most have an immediate contact effect, but this diminishes with time in many cases. The most interesting discovery is that some are systemic in their action, that is they are absorbed into the plant and translocated through it, insects sucking the sap are poisoned. The organic-phosphates break down quite rapidly, especially in the soil. Therefore they present virtually no residue problems if an adequate interval is allowed between spraying and harvest. Similarly there is rarely much build up in soil or rivers.

Parathion was one of the first organo-phosphorus insecticides on the market or to be employed in South-east Asia. It is very toxic at about the same level as endrin. It should only be applied by operators wearing full protective clothing, that is a complete waterproof covering, gloves, mask, goggles and respirator, which is quite

unbearable in the humid tropics. When human deaths occurred in South-east Asia owing to spraying parathion without adequate protection, because the latter was uncomfortable, the then government of Malaya banned the import of parathion and its use in this country. Unfortunately some neighbouring countries still allow parathion despite further loss of human life. Moreover parathion is smuggled into Malaysia and still used illegally and indiscriminately by some market gardeners.

Apart from exposing themselves and the public to terrible risks, these irresponsible users create very difficult problems for the cultivators of other crops and the agricultural entomologists who must advise them. Five years ago there was an outbreak of *Artona* moth on coconut palms, which grew to serious dimensions, meanwhile it was noted that the degree of parasitisation by the Tachinid flies was falling alarmingly; also nearby oil palm was attacked for the first time. The palm had not been sprayed with any insecticide, so that although there were close parallels with the case already described and attributed to BHC, it seemed that natural control had not broken down due to the use of insecticides. However, that was the probable explanation, because it was found that nearby plants of Ladies Fingers, whose fruit are usually bagged to keep away the flies, had been sprayed illegally with parathion, although the culprits did not wish to admit this until too late. The Tachinid fly parasitises both the *Artona* moth of palm and the leaf-rolling caterpillars of Ladies Fingers; it is very likely that the mobile Tachinid flies had visited the latter in search of caterpillars and so been killed over a wide area and prevented from laying their eggs on the *Artona* larvae. If the illegal use of parathion had not been discovered a completely misleading explanation of the breakdown in natural control of *Artona* might have been adopted with even worse results.

Although there has been no secrecy or illegal activity involved, planters have sometimes got their priorities wrong by using non-specific contact insecticides against comparatively minor pests of cover plants, which are an agricultural aid and not a crop in themselves. Spraying insecticides to control Ladybirds on creeping legume covers seems to have been responsible for the outbreaks in recent years of Short-horned Grasshoppers attacking both legumes and the rubber, which is not usually affected, owing to destruction of natural enemies. So an unimportant matter can develop into a serious situation.

Subsequently new organo-phosphorus insecticides have been discovered which are much less toxic to birds and mammals; for example malathion is practically harmless (except in certain rare cases of prior exposure to parathion), its smell and taste are unattractive. It is used in malarial control where the mosquitoes have become resistant to DDT, it is less dangerous and has fewer side effects than dieldrin, but malathion's lack of persistence is a disadvantage because more spraying rounds and higher costs result.

Trichlorphon is about twice as poisonous as malathion, but that is a hundred times less toxic than parathion. Its direct contact effect fades away quite soon, it is absorbed into the plant and translocated in the sap so that sucking insects are killed. This is called systemic action and is selective in that the sucking pests are at much greater risk than other insect visitors to the plants such as predators and

parasites. Trichlorphon was applied to cocoa in Sabah to tide over the gap between the use of non-selective contact insecticides of the chlorinated cyclodiene type and the re-establishment of full natural control. This was particularly useful in the case of bagworms, at first parasites were almost absent, but after the change to trichlorphon Tachinid flies returned to the area and eventually all spraying could be stopped.

Carbamate insecticides

The best known is carbyral, a naphthyl-methyl-carbamate, of moderate or marginal toxicity to warm blooded animals, it is of limited persistence. Carbyral controls a number of pests on which hitherto the persistent chlorinated cyclodiene insecticides were used.

Cultural control and environmental modification

Before the synthetic organic insecticides were invented, the range of natural and inorganic chemicals available was limited. Recourse had to be made to cultural methods in agriculture and modification of the environment for preventive medical purposes, of which malarial control was the best known example. The primary objective was to prevent anopheline mosquitoes from breeding and the secondary objective was to prevent contact between the mosquitoes and humans.

Denial of breeding places to the mosquitoes requires a knowledge of the local ecology. In many cases drainage to remove open stagnant water or to get the water in motion is advantageous. Badly constructed drains or contour silt pits and roads too close to the dwellings to be protected often result in new breeding places. Some mosquitoes can breed in moving water, but these are sun-loving species. Thus sometimes clearing the land and uncovering the streams may increase the number of dangerous mosquitoes, in these cases bushes and shade should be left along the stream-sides or the stream broken up into a series of pools by dams. A controlled degree of pollution with organic matter such as cut grass renders stagnant pools unsuitable for mosquito larvae.

The expert malariologist recognises the local conditions, including which types of mosquitoes are important, and adopts whichever methods are most suitable. It was perhaps because of this need for trained personnel and application to specific local conditions that natural control methods became unpopular when powerful insecticides were available. However, now that resistance to insecticides has arisen and to lesser extent, because they have inconvenient side effects which bring malarial eradication into understandable—even if misplaced—disrepute, the old methods are being reconsidered.

Mosquito nets and screens, or air-conditioning for the more sophisticated, are means of keeping mosquitoes from humans. Deviation of mosquitoes by alternative animal targets has been suggested, but this has little practical effect and some drawbacks, especially when other mosquitoes such as *Aedes* spread heartworm for example among dogs. The burning of incense coils is an old form of repellent.

Cultural methods in agriculture are varied. The growth of plants may be improved by fertilisation to help them get rid of minor pests such as Scale insects. Some advocate only natural manures for this purpose and consider that artificial fertilisers aggravate pest attack. That may have been true when unbalanced artificial fertilisers were given, but now much more is known about correct plant nutrition, and in any event there is not enough farmyard manure available.

Plantation sanitation prevents large pest populations from building up. Rhinoceros beetles are a serious pest of coconut and oil palms. The grubs breed in almost any debris, for instance old rubber stumps, palm logs or even sawdust. If these are distant from palms there is no risk, but in the vicinity of young palms especially, burning or deep burying of potential breeding material is essential. The growing of tall leguminous shrubs as covers is recommended also, because the Rhinoceros beetle does not fly strongly and its activity is restricted by such a barrier. Stem borers in maize are restrained by burning the trash after harvest. Crop rotation prevents the build up of pests in short lived crops. Different crops susceptible to different pests are planted in succession on the same ground, so that the pest population harboured in the soil after each crop will be without a suitable host to feed on during the next phase of the rotation. This is particularly important in sweet potatoes for example. Dust often kills off beneficial insects more than pests, therefore roads may be sealed against dust with advantage and needless tillage which pulverises the soil should be stopped.

Integrated methods

The integrated approach is to regard natural biological control, cultural and environmental methods, chemical insecticides and any novel means as partners, but not as exclusive alternative rivals. It is by no means a new approach, but it has been eclipsed in the quarter century during which the synthetic organic insecticides have been in the ascendancy. The disadvantages of the latter such as the development of resistant pests, the creation of new pests owing to the destruction of natural controls, the expense of repeated application, and the hazards in many cases to human and wildlife (all of which have been demonstrated on a small scale in Malaysia confirming what has happened on a large scale elsewhere) have led to a reappraisal.

If there were no natural or cultural controls the pests would have driven mankind from the face of the earth long ago. Nevertheless, the need to grow more food more quickly for more people than even before, makes it inevitable that man will create conditions of rapid crop growth ideal for an equally rapid build up of destructive pests before natural controls can catch up with the situation. The integrated approach starts with rotation of crops and plantation sanitation and other cultural methods to reduce the risk of rapid pest build up, but when this does occur complete eradication of the pest by chemical means is not attempted. An insecticide and mode of application are chosen which will have the maximum selective effect against the pest and least harm to its natural enemies. Usually the powerful contact insecticides, which temporarily wipe out a pest, have no such selective action. The

initially less powerful but more selective treatments can arrest a pest outbreak long enough to enable natural predators and parasites to reduce it to negligible proportions and so maintain a population of beneficial insects in the area.

Certain baits or traps may be used to increase the specificity. Several night flying moth pests and cockchafer adults are attracted to ultraviolet light. Light traps are set up during the breeding season in threatened areas. Some traps are designed so that insects flying in cannot get out or a non-volatile insecticide or oil kills them or immobilises them until they can be destroyed. Mosquitoes are attracted by carbon dioxide, warmth and humidity, traps are now being designed on this basis. Sex attractants are now sought for specific insects.

Other methods are under trial in different countries and may come to Malaysia later. Examples are the release of sterile males of the insect pests to reduce the number of fertile eggs laid. The bacterial and fungal diseases of insects should not be forgotten. *Bacillus thuringiensis* is the best known bacterial parasite of insects, which has been tried successfully as a spray against some pests. A fungus has been found on the migrant locust and another on the termite which attacks living trees. Some of these are quite specific in their attack and may be encouraged by cultural methods.

Malaysia has been fortunate in that the consequences of misusing insecticides have been realised before there has been any serious damage done. Agricultural and medical entomologists are alive to the need for integrated, specific control techniques. The understanding and cooperation of the public in the responsible use of insecticides at all levels and in all ways will help this object to be achieved, and also save individuals and their families from fatal hazards.

Rodenticides

Rodents such as rats can transmit dangerous diseases in urban areas, they consume large amounts of stored food and are serious pests in many crops. Rats do not evoke much sympathy from most people. However, when it is necessary to kill rats in or near human dwellings, man and domestic animals, especially pets such as dogs and cats, are at risk. Specific or selective poisons that will kill rodents or rats only are needed, which should be harmless to other mammals. True rodenticides of this type are unknown. Norbormide is perhaps the closest discovered yet, it is much more toxic to rats than to any other species, including mice. Some selective toxicity has been claimed for warfarin, but this is largely due to the baits used, which are more attractive to rats than to other mammals and are laid where they are more accessible to rats than to other mammals.

Nearly all other so-called rodenticides are poisons of equal toxicity to a wide range of birds and mammals including man. The best known examples are strychnine, fluoracetamide, barium carbonate, zinc phosphide, thallium sulphate, sodium arsenite and endrin, (the last was mentioned earlier as a very toxic insecticide). Any selective action depends entirely on the method of baiting, both materials and location. Of those mentioned zinc phosphide breaks down rapidly to phosgene gas, dangerous in confined places but not attractive to other animals. All the other poisons

mentioned in this paragraph are fairly stable and are hazardous to predators of semi-comatose primary victims or to scavengers of their corpses. Therefore discussion of the status and control of bird and mammal pests will consider alternatives to the use of poisons so dangerous to man and useful animals, both domesticated and wild.

Warm-blooded pests

The birds and mammals which damage cultivations may be considered in two groups, resident pests and temporary invaders from surrounding areas. The stocking of resident pests depends very much on the amount of food produced in the area. Although during the peak period of their growth, rubber trees increase in dry weight of timber at a rate among the highest recorded in any crop, the seasonal fall of seeds—seldom as much as 150 lbs per acre—is meagre fare for most of the larger animals. During the earlier phase the cover plants are also very high producers of vegetable matter, which may be grazed by herbivores, but the latter are usually kept out because of the damage they do to young trees and thus are relegated to the class of temporary invaders. Some rodents live in the covers and are pests of the trees. Seed-eating birds sometimes frequent the covers, but the rather poor avifauna in rubber plantations consists mainly of those eating insect pests of the covers and trees.

The resident mammal pests of rubber are mainly rats and related animals. Flying foxes, which are large bats, are very rarely troublesome in rubber. The natural controls of the rodents are snakes and birds of prey. Conditions in rubber plantations do not favour wild cats and other mammalian predators. When it is necessary to supplement natural control, traps of a selective design and specific poison baits may be used.

In oil palm the crop of fresh fruit bunches may be as much as 11 tons/acre/annum and the oil extraction may be as high as 22%, in addition there are considerable weights of foliage and stems in the palms and the covers. It is not surprising that quite heavy rat and squirrel infestations sometimes occur and that new pests have arisen, in particular wild parrots especially the long tailed parakeet have taken to consuming the fruit. At present shooting, trapping and selective poison baiting are attempted. There is an urgent need for research into the food chains and to encourage natural control by birds of prey, snakes and carnivores. The leopard cat, mongoose and other small carnivores control rodent populations in bamboo, secondary and primary forest, their possible role in oil palm plantations seems to have been neglected.

Judging by Malaysian experience with insect pests control measures must depend mainly on natural means with only temporary selective assistance from artificial methods and chemicals. In the humid tropics the climate is favourable to pest population growth throughout the year and traditional methods in the temperate regions of attacking vertebrate pests during the breeding season or when food is scarce in winter are less likely to succeed here.

Cocoa plantations are a relatively new venture in Malaysia. In Lower Perak cocoa is grown under coconut palms and rodent populations are again high, rats attack the cocoa and squirrels eat into young coconuts. In some areas musang or civet cats have been singled out for persecution by poisoning with endrin laid in banana baits. This is a risky procedure. There is evidence that excessive use of endrin in this way has led to birds of prey being killed and in the case of migrant raptors their loss may be felt elsewhere. In addition to this the campaign may be entirely misplaced; although catholic in their feeding habits, the civet cats and their relatives are carnivores and the young of rodents are a part of their diet. It is dubious how much of the damage done by mammals can be attributed to musang. This may be a case of trying to exterminate a relatively minor pest at the expense of upsetting all natural control including elimination of those which are in fact predators of real pests. These problems await proper investigation.

Padi is subject to bird attack during harvest, but if the padi areas are large enough, bird scaring can be made adequately efficient. In East Malaysia correct timing of padi planting and hence harvest reduces attack by migrant birds such as the Long-tailed Munia but in West Malaysia the main culprit is the White-headed Munia resident all the year round. Vegetable gardens have their share of rodents, often rats escaped from human dwellings and in turn domestic cats effect some control. Orchards are sometimes raided by flying foxes, squirrels and other fruit eaters, but these are not usually residents.

Cultivation's borders

In many developed western countries agricultural land, whether cultivated or grazed, planted woodlands and orchards, constitute the greater part; urban, industrial and mining areas are often large too and natural vegetation is reduced to fringe areas and isolated patches. Such a situation occurs in Java and the 'rice-bowl' of Thailand, but in most parts of South-East Asia extensive tracts of jungle remain yet. In Malaysia the forests still cover most of the land area despite the inroads of cultivation. In the long developed parts, such as Malacca, the jungle is restricted to a few outposts and beyond the boundary of cultivation there is often secondary forest or *lallang* where past cultivation has been abandoned. In the newly cleared areas agricultural development and primitive forest march side by side.

Inevitably wildlife crosses the boundary in places and feeds on crops or attacks livestock ranging from poultry upto cattle or even man himself. When this happens the animals are considered to be pests. However, before considering the relationships between man and invading wildlife seeking food after the destruction of the natural habitat, it is as well to repeat that many agricultural pests, especially rats, accompanied man or the extension of man-made *lallang* and bamboo dominated areas, they did not all come from the jungle. The most common pest in oil palm, *Rattus tiomanicus jalorensis* normally occurs in secondary forest; the second most frequent, *R. argentiventer* is naturally confined to grassland (*lallang*); both are of the *R. rattus* group, never found in deep forest.

Where large contiguous areas of plantations, whether estates or land development schemes, are bounded by forest, a barbed wire fence five feet (1.5m) high,

with wire netting for the bottom three feet (1m), will exclude the majority of deer, wild pig and porcupines. Hunting the larger deer, pigs and porcupines (the meat of which can be sold) using suitable heavy shot guns is a profitable additional control. Humane traps set within the margin of cultivation may be baited with vegetable food which is selectively attractive to the mammal pests. Porcupines seldom penetrate into the plantation more than 100 yards (100m) from the jungle. They can be caught in cage traps and then killed for fresh meat. Traps should be visited daily, because not only is it cruel to starve animals, but other porcupines will not enter a trap in which one of them has died. Porcupines are fond of salt meat. Poisoned baits are very dangerous, because of the risk to domestic animals and the hazard of secondary poisoning of predators and human scavengers. Various repellants work against deer, such as noise from banging scarers (operated by carbide) smell from foetid grease, or visual methods such as tinsel, aluminium paint bands, patterns of black and white dots. It is very dangerous to dig fall pits or set drop spears or sprung wire noose traps (the last mentioned are illegal) for two reasons. Firstly because the direct risk to humans is too great, even in or rather more so in the isolated places where these traps are usually laid. Secondly these traps are quite unselective and kill or maim useful animals as readily as pests.

The natural controls of pig and deer are mainly the larger cats, leopards or panthers, clouded leopards and tigers. These large cats are active animals and need plenty of food, a mother with cubs hunts over a large territory, as much as 50 square miles (13 000 hectares) is quoted for a tiger. Therefore the death or injury of a large cat so that it cannot hunt is likely to result in an increase in the unmolested population of wild pig over a wide territory. There is cumulative, convincing, well documented and circumstantial evidence that nearly every tiger or big cat which has turned man-eater or cattle-killer has been maimed by a steel wire snare, a shot gun wound or other man-inflicted injury. Several claws or whole paws may be lost or turn gangrenous so restricting the big cat's movements. No longer able to hunt, it must lie in wait until some unsuspecting domestic animal, a cow or goat, or a man, woman or child comes within easy range. Mankind earns just retribution for cruelty and ignorance of the natural balance, although innocent parties may suffer bereavement and the guilty escape.

There is evidence too, perhaps not so fully established as in the case of the big cats, that elephants which take to crop raiding are also victims of wounds inflicted by man's traps and firearms. An elephant with ulcerous sores on its ankle cannot support its great weight in comfort and travel long distances over its usual range. Usually it has been injured on the fringe of cultivation and there it remains, making raids into plantings of bananas, rubber and palms. Sometimes in old age an uninjured elephant may take to crop raiding, but this does not seem to be common perhaps because senile elephants normally succumb to natural causes. An ordinary fence will not keep out determined elephant, but electrified wires, with tension springs at intervals to prevent snapping by a sudden blow, supported on angle posts which are not easily pushed over, have been successful in some areas. The voltage should be adequate to shock, but not to kill, after a while the herd moves away. If a boundary is likely to remain static adjacent to jungle for a long time, an elephant belt can be felled beyond the ordinary fence against pig and deer. An elephant belt

consists of felling trees criss-cross, leaving the debris unburnt and allowing dense secondary jungle to grow up. Wild cattle sometimes enter plantations, these methods keep them out. Domestic cattle are kept out by fencing.

Monkeys, squirrels and flying foxes (large bats) can climb, jump or fly over fences. Locally they cause trouble. Monkeys are intelligent and often move away if some of their number are shot and the corpses hung up as a warning or psychological repellent. Elaborate cage traps defeat the monkey's ingenuity without risk to cats and are humane in operation if visited every morning. Squirrels are shot or trapped in fruit baited cages. Flying foxes can be deterred by nets and shooting. Smelly repellants can be used in many cases and it is probable that chemists will discover new nauseous but not noxious substances.

A well defined and fenced boundary with appropriate repellants just within the periphery does much to keep out mammalian invaders, who will in time adjust their stocking to suit the area of forest left to them without need to invade cultivation, especially if still subject to natural controls. The predators, such as large cats which hunt pigs and small cats which prey on rodents, are very easily depleted by indiscriminate trapping and poisoning. Traps should be regularly visited, humane and selective in action either by their construction or the nature of the bait. If poisoning seems to be the only solution, selective baits and methods and non-persistent poisons should be chosen as far as possible. Shooting reduces the numbers of some pests and is a deterrent to the more intelligent apart from being profitable and providing a means of taking a crop of meat (protein) from the jungle in the case of pig and deer. The boundary of cultivation can be managed, especially if the significance of natural balance, predation and stocking on the jungle side of the perimeter is understood, respected and protected. This is integrated pest control.

Artificial aids in agriculture

Agriculture from its definition to till the fields and from its history of converting natural vegetation is an artificial process, that is it is made by man. It is only natural in as far as man's dominance on the earth to the point of self destruction is a natural evolutionary process or divinely fore-ordained. Therefore unnatural or artificial practices and aids must be and have been introduced from prehistoric times to make agriculture more efficient. The rise of synthetic chemical pesticides and their impact on the Malaysian scene have been described in some detail. In other countries pesticide usage got out of control, especially where the consequences of non-selective action and persistence in soil and through the food chain were not understood. Quite rightly there has been a swing in public and scientific thinking, in some cases this counter reaction may have gone too far, where it has threatened to halt campaigns against the enfeebling diseases of mankind. Wherever thought is stimulated and research into specific and integrated control methods results, then this reaction has been beneficial. Man must examine his place in relationship with nature and work with instead of against natural processes.

Thirty years ago a writer on the benefits of chemistry to agriculture would have made little reference to pesticides. Artificial manures such as superphosphates and

in particular nitrogenous fertilisers made from atmospheric nitrogen would have commanded attention. The harvest of crops depletes soil nutrients, and the heavier the crop the greater the loss and more likely it is to exceed natural rates of replacement. The nutrients are not returned to the soil in many cases, for instance the waste from cities usually ends up in the sea. The provision of artificial fertilisers has been a great boon to agricultural food production.

Nevertheless there have been critics of artificial fertilisers. Many claim that lavish use of chemicals has led to lush growth prone to pest and disease attack, or led to deterioration in soil structure, although this is more often due to burning or removing plant debris from the site. Unhealthy growth may occur in some cases of excessive nitrogen application which depresses potash uptake. On the other hand if artificial fertilisers are given in the right amounts at suitable intervals and—equally important—in the right proportions of the different nutrients, the growth and health of the plants is improved. This implies that for each combination of soil type, crop species or variety and to a lesser extent climatic conditions, such as rainfall and solar radiation, there is an ideal combination of fertiliser composition, mode, rate and frequency of application. In the long run these are determined by fertiliser trials, but it takes many years to test every possibility. A less publicised revolution has been going on. Methods of analysing plant tissues, in particular leaves, have been improved in accuracy and automated for speed. These, in conjunction with better soil classification, enable the information gathered from one trial to be extended far more widely and accurately.

Synthetic plant hormones have been used to stimulate rooting and fruit set in a number of crops. There are signs that the next advance may be in the field of new discoveries and applications in the use of synthetic growth substances to control the growth, form and flowering of various crops.

The activities of the plant breeder are considered to be natural by some, since natural properties of the plant are used, although combined by controlled breeding. In other ways they are artificial. However, the genetic reserves, especially to provide disease resistance, are to be found in the wild. This brings us to consider the conservation of natural biological communities.

(Next month: BIOLOGICAL COMMUNITIES)