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EXPERT CONSULTATION ON THE USE OF IMPROVED AGRICULTURAL  
TECHNOLOGY BY FARMERS IN THE RAINFED AREAS OF MONSOON ASIA

Sponsored by FAO/UNDP in cooperation with Government of Malaysia  
Kuala Lumpur, 8 - 13 December, 1974

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SOIL SUITABILITY AND LAND USE CLASSIFICATION  
AS A MEANS OF IMPROVING TECHNOLOGY  
FOOD CROP PRODUCTION

by

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INTERNATIONAL EXPERT CONSULTATION ON THE USE OF IMPROVED  
TECHNOLOGY FOR FOOD PRODUCTION IN RAINFED AREAS  
OF TROPICAL ASIA

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SOIL SUITABILITY AND LAND USE CLASSIFICATION AS A MEANS  
OF IMPROVING TECHNOLOGY FOR FOOD CROP PRODUCTION

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

# SOIL SUITABILITY AND LAND USE CLASSIFICATION AS A MEANS OF IMPROVING TECHNOLOGY FOR FOOD CROP PRODUCTION

## Summary

Soil suitability classification provides a consistent method for evaluating soils for food crop production. This system of evaluation also provides a permanent record of areas suitable for such enterprise. For Peninsular Malaysia there are large tracts of dry-land soils which can be cultivated with food crops under a rainfed basis. Substantial acreages have already been utilized for the cultivation of rubber, oil palm and coconuts; possible areas exist under forest and scrubland. There is also a possibility of utilizing peat soils for food crop production as experimental trials indicate that the cultivation of maize, tapioca, soyabean, sorghum, vegetables and sweet potato are very promising. Further possible sources of land for food crop production are in existing single-cropping paddy areas where food crop production can be practised during the off-season and in high level terraces where flooding occurs only infrequently.

## I. Introduction

1. The cultivation of foodcrops in Peninsular Malaysia, with the exception of sugarcane, is carried out mainly by smallholders. Choice of land for cultivation is usually on a trial-and-error basis. Yield results from such lack of proper soil selection are therefore expectedly variable.

2. It is, however, possible to select, with a greater measure of confidence, soils that are suitable for food crop production. Criteria for selection, based on soil properties recorded by soil surveyors and from laboratory analysis, are not only more consistent but are also useful in correlating similar soils from different regions. Definition of the criteria for selection of soils suitable for food crop cultivation is an objective which has been pursued by the Department of Agriculture, Peninsular Malaysia, since the launching of its programme of systematic soil survey in 1957.

3. The soil suitability classification that is presented in this paper is based on a more comprehensive classification<sup>(11)</sup>. Basically this system of soil suitability classification is similar in approach to the system used by the United States Department of Agriculture<sup>(6)</sup>. It differs from the U.S.D.A. system in its comprehensiveness since it not only takes into account arable farming but also the cultivation of tree crops such as the sago palm.

A. Factors Limiting Crop Growth

4. The major food crops grown in rainfed areas in Peninsular Malaysia are sugarcane, maize, tapioca, soyabean, sorghum, groundnut, dryland rice, sago, vegetables and sweet potato. Assessment of soil suitability for these crops can be adequately made on the basis of nine soil properties; these are indicated in Table 1.

5. Subdivision of the nine crop growth limiting factors (the tenth - disturbed land - being non-agricultural land is not a soil property) makes it possible to separate soils according to the extent their inherent properties limit the growth of plants. Thus, very serious limitations are those properties which not only retard the growth of crops but may even totally inhibit crop production; among these the more obvious ones are shallow and/or extremely stony soils and those with toxic levels of certain elements such as nickel, boron and sulphur. Soils on steep slopes may not appear to be unsuitable for crop cultivation until clearing of the natural vegetation results in accelerated erosion. Serious limitations are not detrimental to all crops; while some of the more sensitive crops may not survive such conditions, others may even thrive in them, e.g. sago palm under wet conditions. Moderate limitations affect a limited range of crops which may be very sensitive to some soil conditions; for most crops these limitations can be surmounted by proper management. Minor limitations affect a selected number of crops and these effects are more in the form of a lowering of yields rather than of crop survival.

TABLE 1 LIMITATIONS TO CROP GROWTH

SYMBOL	TYPE	VERY SEVERE	SEVERE	MODERATE	MINOR
a	DEPTH TO ACID SULPHATE LAYER	-	0-25 cm from the surface (0-10 inches)	> 25-50 cm from the surface (10-20 inches)	> 50-100 cm from the surface (20-40 inches)
c	DEPTH TO COMPACTED LAYER	0-25 cm from the surface (0-10 inches)	> 25-50 cm from the surface (10-20 inches) Excessively drained	> 50-75 cm from the surface (20-30 inches) Somewhat excessively drained	> 75-100 cm from the surface (30-40 inches)
D	DRAINAGE	-	Excessively drained	Imperfectly drained	Imperfectly well drained
d		> 20° slopes for more erodible soils	Very poorly to poorly drained	> 6°-11° slopes for more erodible soils	2°-6° slopes for more erodible soils
E	ERODIBILITY	> 35° slopes for less erodible soils	> 12°-20° slopes for more erodible soils	> 12°-20° slopes for less erodible soils	2°-12° slopes for less erodible soils
e		Toxicity caused by extremely high amounts of certain elements	-	-	-
N	NUTRIENT IMBALANCE	-	Low nutrient retaining capacity with or without acute nutrient deficiencies	Acute nutrient deficiencies	-
n		> 125 cm plus severe year-round precipitation	> 125 cm thick from the surface	> 50-125 cm thick from the surface	25-50 cm thick from the surface
O	ORGANIC HORIZON THICKNESS	> 75% with 0-25 cm stone-free soil	> 50-75% with 0-25 cm stone-free soil	> 25-50% with 0-25 cm stone-free soil	10-25% with 0-15 cm stone-free soil
R	% STONINESS TO 100 cm DEPTH	-	-	> 50-75% with 15-50 cm stone-free soil	15-50% with 25-50 cm stone-free soil
r		-	Strongly saline	Modestly saline	Very slightly saline
s	SALINITY	-	Coarse textured and structureless	Coarse textured and weakly structured	-
T	TEXTURE AND STRUCTURE	-	Fine textured and structureless	Fine textured and weakly structured or strongly coarse structured	-
t		Land disturbed by urbanization (u) and mining (m)	-	-	-
H	HUMAN	-	-	-	-

\* In general the drainage change in deep coarse at 15° instead of 20°.

## B. Soil Suitability Classes

6. Soils are grouped into suitability classes according to the severity of crop growth limitations currently occurring in them. For agricultural purposes a grouping into five suitability classes has been found to be sufficient.

7. Class 1 soils are those with no limitation or only minor limitations to crop growth. These soils are therefore suitable for the widest range of crops. They can be profitably cultivated with a moderate level of management i.e. a management which will conserve a soil while the latter is cultivated; include fertilizer application as a routine practice; construct and maintain necessary minor drains for water control if necessary; and carry out tillage operations. Class 1 soils occur on flat to rolling terrain (0-12°). They have good water-holding and nutrient-retaining capacities and are well suited to continuous cropping on a sustained yield basis.

8. Class 2 soils include those with moderate limitations to crop growth. They are suitable for a narrower range of crops than those of class 1. Management practices for these soils may include erosion control measures such as contouring, minor drainage and irrigation works, or improvements resulting in better tilth.

9. Class 3 soils are those with at least one serious limitation and possibly one or more moderate limitations to crop growth. As such they are restricted to a narrower range of crops. Their proper utilization

may include erosion control measures, an intensive fertilizer programme and/or drainage and irrigation works involving moderate expense.

10. Class 4 soils have more than one serious limitation to crop growth. They are therefore suitable for a very narrow range of crops. Moreover, major conservation or amelioration measures are necessary before they can be cultivated on a long term basis.

11. Class 5 soils possess at least one very serious limitation to crop growth. In their present condition they are least suitable for crop growth. Amelioration and/or conservation measures would be too prohibitive for normal agriculture. Where they are not built over for urban development or excavated for mining and quarrying purposes they are best allowed to continue under primary or regenerating forest.

#### C. Soil Suitability Subclasses

12. Soil suitability subclasses are subdivisions within suitability classes. They are formed on the basis of the kinds of limitation affecting crop growth. While suitability classes are broad groupings, the subclasses are more specific. On the basis of subclasses it would be possible to make recommendations on specific crops and management practices. Thus the formation and inclusion of subclasses in soil suitability maps will give potential users of such maps a better guide regarding the choice of crops and the management practices which may be needed for long term cultivation of land.

13. As there are altogether ten different types of limitations to crop growth in Peninsular Malaysia, subdivision of suitability classes into subclasses is accordingly based on these. They are listed below with respective letter symbols which will indicate on soil suitability maps the kinds of limitation possessed by different mapping units. The tenth (disturbed land) although not a limitation in the sense of the other nine, is included because all land that is presently being mined or is under urban development is not available for agriculture and therefore cannot be considered for crop growth in the present scheme; but as they constitute a form of land use they would appear on soil maps and accordingly their suitability classification for crop growth would have to be indicated.

14. Each soil limitation will therefore be indicated by its respective letter symbol as shown below :-

Symbol		Limitation
a	=	acid sulphate layer
c	=	depth to compacted layer
D or d	=	drainage
E or e	=	erodibility
H	=	disturbed land
N or n	=	nutrient imbalance
o	=	organic horizon
R or r	=	stoniness
s	=	salinity
T or t	=	texture and structure

i. Acid Sulphate Layer (a)

15. A considerable acreage of marine alluvial soils in Peninsular Malaysia are highly acid due to the presence of excessive quantities of oxidisable sulphur compounds. These sulphur compounds are produced by the microbiological reduction of sulphur derived from sea water. When the soil is drained, oxidation of the sulphur compounds to sulphate takes place <sup>(2)</sup>. Hydrolysis of the sulphate in water produces an acid condition in the soil. Drainage of a sulphate-containing soil usually results in severe deterioration of the condition of the soil so that very many years of continued aeration and leaching must elapse before the soil can become suitable for general cultivation.

16. The acid sulphate condition of a soil can be determined in the laboratory. Two measurements are made, the pH of the air dried soil in a water culture and the water soluble sulphur content as sulphate. Soils with pH readings of 3.5 or lower and sulphate concentrations of more than 0.1% inhibit the growth of cultivated crops.

17. As the acid sulphate condition of a soil is influenced by the permanent ground water table, this condition occurs in affected soils as a definite layer within the profile. Utilization of acid sulphate soils involves proper drainage control and application of lime. Both of these are now standard recommendations for crop cultivation on acid sulphate soils; gradual lowering of minor drainage channels will remove excess sulphides and, at the same time, prevent the formation of sulphates; application of lime will neutralize the acidity of the soil and so condition it for initial cultivation of shallow-rooting crops.

18. The presence of the acid sulphate layer within the first 25 cm of the surface constitutes a serious limitation as the soil can only be considered for shallow-rooting crops. At depths between 25 cm and 50 cm, the cultivation of medium-rooting crops is possible, thus making the limitation a moderate one. When the acid sulphate layer is at 50 cm to 100 cm depth tree crop cultivation would be feasible so that the limitation can be considered to be minor only.

ii. Depth to Compacted Layer (c)

19. Massive thick laterite, densely packed concretions, unweathered rock, pans and very firm or compacted subsoil layers are serious impediments to root ramification. Root crops such as tapioca, yams and sweet potatoes are affected by shallow soils and although arable farming can be practiced on such soils, special management techniques e.g. ridging, have to be applied if proper growth of the crops is to be expected. Often other detrimental effects are associated with such soils; these could be low waterholding capacity and inadequate nutrient retention.

iii. Drainage (D or d)

20. The drainage status of a soil does not affect all plants in the same way. While wetland crops such as padi and sago palm thrive under very wet conditions all dryland crops may not survive under these conditions. As most crops are inhibited in growth with increasing soil wetness or dryness the drainage classes of the U.S.D.A. Soil Survey Manual have been adopted in this suitability classification.

21. Accordingly very poor drainage occurs when water is removed from the soil so slowly that the water table remains at or on the surface the greater part of the time. Poor drainage occurs when water is removed so slowly that the soil remains wet for a large part of the time; the water table is commonly at or near the surface during a considerable part of the year. Poorly drained conditions are due to a high water table, to a slowly permeable layer within the profile, to seepage, or to some combination of these conditions. Among the marine coastal clay soils a very poorly drained soil is characterised by a uniform greenish grey colour throughout the profile. Very poorly drained coastal sands and podzolic soils have dark-grey or black surfaces and are light grey, with or without mottling in the deeper parts of the profile. Poorly drained soils of marine clay origin have brownish grey to greyish brown profiles with or without mottles. Among the podzolic soils, poorly drained soils may be light grey from the surface downwards with or without mottlings. Very poorly and poorly drained conditions are serious limitations to the cultivation of all dryland crops, the only crops which can grow under such conditions being wet paddy and the sago palm.

22. Imperfect drainage has been defined as the condition when "water is removed from the soil slowly enough to keep it wet for significant periods but not all the time. Imperfectly drained soils commonly have a slowly permeable layer within the profile, a high water table, additions through seepage, or a combination of these conditions"<sup>(9)</sup>. Soils with imperfect drainage

are characterised by the presence of mottles in the A, B and C horizons. This is a moderate limitation to crop growth as it only affects crops which are very sensitive to high moisture conditions.

23. In a moderately well drained soil water is removed somewhat slowly, so that the profile is wet for a small but significant part of the time. Moderately well drained soils commonly have a slowly permeable layer within or immediately beneath the solum, a relatively high water table, additions of water through seepage or some combination of these conditions. Moderately well drained soils have uniform colours in the A and upper B horizons, with mottling in the lower B and C horizons.

24. On the other hand, excessive and somewhat excessive drainage affect crop growth through the possible lack of moisture supply. Excessive drainage occurs when water is removed from the soil very rapidly. The soil is very porous and usually has a very high sand content. Enough precipitation is commonly lost from these soils to make them unsuitable for ordinary crop production. Excessive drainage would therefore constitute a serious limitation to crop growth on a sustained yield basis.

25. In somewhat excessively drained soils water is removed from the soil rapidly. Such soils may be predominantly sandy but would have a small percentage of clay or silt to retain moisture for some time. Among some of the soils developed from high ferro-magnesian mineral-containing rocks, structural development is very stable so that porosity between the stable soil peds is

high; the result of this high porosity is that drainage becomes somewhat excessive. Although the clay in the soil retains a high proportion of the moisture from precipitation as much as 40% of this moisture may be unavailable for crop growth<sup>(8)</sup>.

26. The symbol 'D' is used to indicate excessive drainage while 'd' represents poor drainage conditions.

#### iv. Erodibility (E or e)

27. The severity of erosion by water in this country where heavy thunderstorms, frequently with rainfall intensities of 4 to 6 inches per hour<sup>(3)</sup>, is not only influenced by gradient but also by the stability of the surface soil. The resistance of a soil to physical breakdown is a function of aggregate stability which in turn is dependent on texture and grade of structure. Excluding soils which have been cemented together by soil-cementing agents, field observations indicate that soils with surface textures of clay loam, silty clay loam, silty clay and clay have more durable structural aggregates; these are soils with clay contents exceeding 27% and sand contents less than 45%. As indicated in Fig. 1, these are the less erodable soils which are indicated by the symbol 'e'. The more erodable soils, denoted by the symbol 'E' are those in which surface textures consist of less than 27% clay and more than 45% sand; such soils are included in the texture classes of sand clay, sandy clay loam, sandy loam, loamy sand, loam, silt loam and silt.

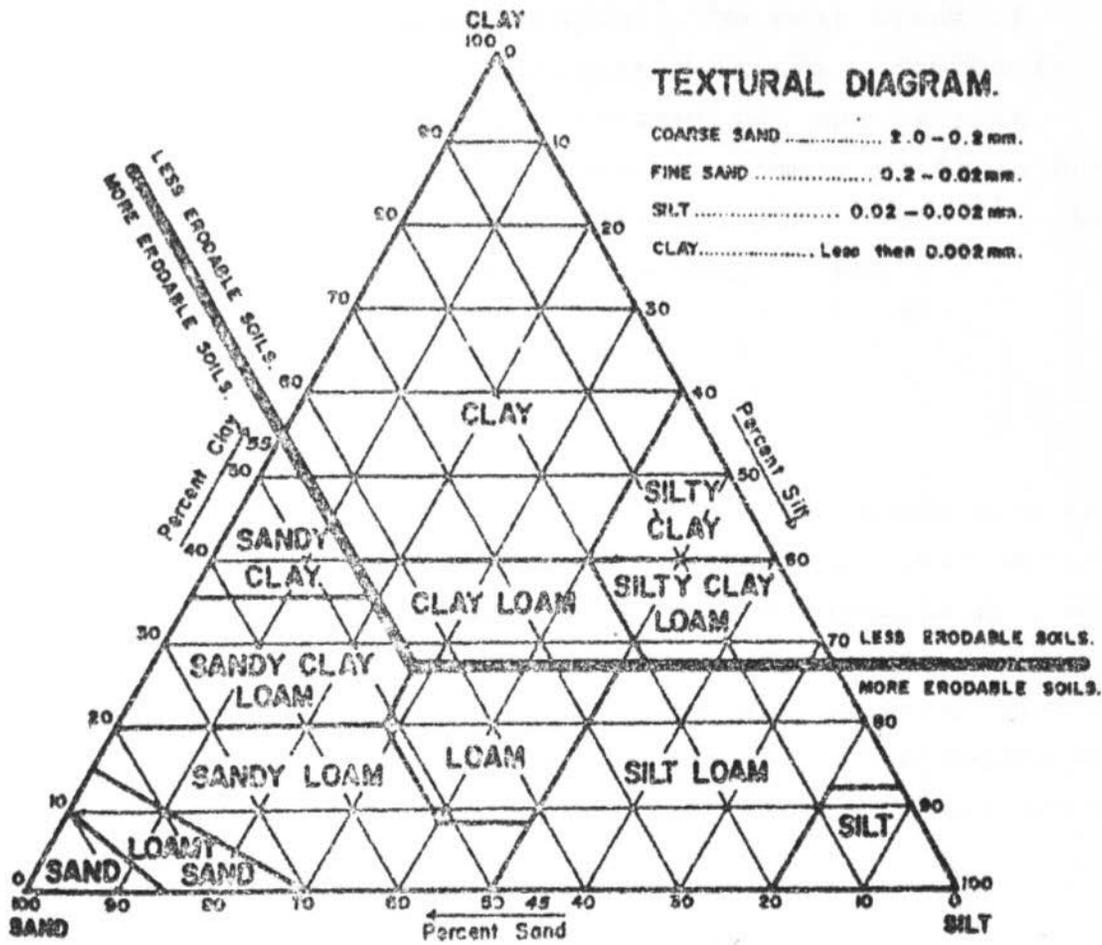


FIG. 1. TEXTURE DIAGRAM SHOWING THE SURFACE TEXTURES OF THE MORE ERODABLE AND LESS ERODABLE SOILS.

28. The slope parameters for this classification are based on observations made in the field and on measurements made on contour maps by soil surveyors in Peninsular Malaysia. In East Malaysia and, to a lesser extent, Peninsular Malaysia, gradients of  $35^{\circ}$  mark the upper limit of very steep slopes. The next break of slope occurs at  $20^{\circ}$  in Peninsular Malaysia. Similarly, the hilly terrain slopes are between  $20^{\circ}$  and  $12^{\circ}$ ; in rolling terrain  $12^{\circ}$  to  $6^{\circ}$  slopes are common while in undulating terrain the slopes range between  $6^{\circ}$  and  $2^{\circ}$ . On the plains slopes are commonly between  $2^{\circ}$  and  $0^{\circ}$ .

#### v. Disturbed Land (H)

29. Land that has been disturbed by human activity, particularly by mining and urbanization, is least suitable for crop cultivation in its present condition. When such land has been allowed to return to its native condition it can then be considered for agricultural development; its suitability classification will then depend on the properties it has developed as a result of the change in land use.

#### vi. Nutrient Imbalance (N or n)

30. Although the majority of soils in Peninsular Malaysia are considerably leached, this fact does not prevent them from being utilized for crop cultivation since fertilizer application is a standard practice for commercial agriculture. Nevertheless, a soil with acute nutrient deficiencies needs better management than one without such problems, so that the former cannot be raised to a status equal to that of the latter, all other

conditions being equal. Acute nutrient deficiencies, which include not only major but trace elements as well, are therefore moderate limitations to crop growth. A more serious condition is when a soil has not only nutrient deficiencies but also an extremely low nutrient-retaining capacity. This applies particularly to the sandysoils on the coast. A limitation of this nature is serious as fertilizer application will not correct it.

31. A more serious limitation is the presence of excessive quantities of some elements such as nickel, boron and sulphur which are needed by plants in minute quantities only. Fertilizer application alone will not correct such excesses easily. Continuous applications of chemicals and years of continuous leaching may be necessary before the toxicity can be brought under control.

32. The presence of toxic levels of plant nutrients is indicated by the symbol "N" while deficiency levels are denoted by "n".

#### vii. Organic Horizon (O)

33. Organic or bog soils in Peninsular Malaysia with the exception of minor occurrences in highland areas, are associated with bottom lands which are usually waterlogged. They vary in organic matter content from true peats to organic clays and mucks. A true peat consists of incompletely decomposed organic debris which, on being ignited at 800°C, registers a loss in weight of more than 65%. Much is organic material which has decayed to such an extent that plant remains are well

broken down; on ignition its loss in weight is between 35% and 65%. Organic clay is clay in which there is a substantial proportion of decayed organic matter; its loss in weight on ignition is between 25% and 35%. High acidity is frequently associated with such soils the presence of humic acids being the major cause.

34. Because of their high porosity the permeability of peats is very rapid. Very frequently, in deep peats, large logs occur which impede tillage operations. The maintenance of a correct water table level is critical in the proper utilization of peats - over-draining produces very rapid initial shrinkage followed by irreversible drying and oxidation of the organic matter at the surface while lack of draining results in waterlogging and inhibition of root development. With proper draining, however, the cultivation of shallow-rooting crops is a feasible proposition and it has been shown that pineapple cultivation is very successful under such conditions. Muck and organic clays, because they have higher mineral matter content, more thoroughly decomposed organic matter and are shallower, do not limit the cultivation of most crops except where the drainage is poor or where the underlying clay is strongly sulphurous.

35. In their natural condition even shallow peats possess a serious limitation to crop growth, namely, very poor drainage. When drained, however, progressive shrinkage occurs in them so that the main limitation is the cultivation of permanent tree crops the roots of which may be exposed in time when the peat has shrunk substantially. While a peat thickness of 25-50 cm may be a minor limitation, thicknesses of 50-125 cm constitute a moderate

limitation since the choice of crops is limited to those below tree size. Peat thicknesses greater than 125 cm constitute a serious limitation and in cases where other unfavourable properties, such as excessive amounts of tree trunks, occur, the severity of the limitation would be considered as very serious.

vii. Stoniness (R or r)

36. This limitation includes rocks, stones and concretions of varying sizes ranging from boulders to gravels occurring as loosely dispersed particles or densely packed masses within the soil and/or on its surface. Thus a compacted layer in a soil may consist of two limitations if the material composing the compacted layer is made up of indurated particles such as rocks, stones and lateritic concretions; standard tillage operations may break up the indurated layer but are not likely to remove the constituent indurated particles.

37. Instead of considering only the surface area of land occupied by rocks, stones or concretions, the whole volume of a soil down to 100 cm depth is taken into account; in this way the impediment to crop growth posed by rocks, stones and concretions throughout the soil is taken into consideration. While rocks on the surface can reduce the effective area for crop cultivation, those within the soil not only have the same effect but can also impede proper root ramification besides reducing the effective soil volume for moisture and nutrient retention. Yields of root crops such as tapioca (cassava), yams and sweet potatoes are drastically reduced. As stones can occur dispersed throughout the soil profile or concentrated within definite layers

it is necessary to differentiate between these two forms of occurrence. Where the stones occur downwards from the first 25 cm of the surface this would be a more serious limitation than if they occurred further down from the surface, that is, the thickness of stone-free soil on the surface is an important factor to be considered. Thus for the same percentage of stones within a soil the presence of more than 50 cm of stone-free soil would constitute a less severe limitation to crop growth than one with less than 25 cm of such topsoil.

#### ix. Salinity (s)

38. Salinity is associated with fine-textured marine alluvium inundated by sea water. A salinity classification which has been found to be satisfactory by the U.S. Salinity Laboratory <sup>(10)</sup> for appraising soil salinity in relation to plant growth has been adopted for conditions in Peninsular Malaysia and is indicated in Table 2 below :-

Table 2. Salinity Scale

Conductivity of saturation extract of soil (millimhos/cm at 25°C)				
0	2	4	8	16
Non Saline	Very slightly saline	Moderately saline	Strongly saline	Very strongly saline
Salinity effects mostly negligible	Yields of very sensitive crops may be restricted	Yields of many crops restricted	Only tolerant crops yield satisfactorily	Only a few very tolerant crops yield satisfactorily

39. Results of a soil investigation in the proposed Sungai Sarawak Padi Scheme Area<sup>(1)</sup> indicate that salinity is not uniform throughout any one area. In general, however, the type of natural vegetation can be taken as an indication of the frequency of tidal flooding of a soil; mangrove, characterized by *Rhizophora* species occupy sites daily subjected to two tidal floods. The soils in such sites would be strongly to very strongly saline. Where the mangrove vegetation consists of species of *Avicennia* and *Sonneratia* flooding by saline water is less frequent; the soils in such sites can be expected to have conductivity readings of up to 8 millimhos/cm at 25°C, which would be within the moderately saline range. Often moderately saline sites can be identified by the presence of a mixture of mangrove and nipah palm (*Nipah fruticans*). On sites where the nipah palm is predominant flooding by saline water is even less frequent so that the soils are only very slightly saline. Where the nibong palm (*Oncosperma filamentosa*) is predominant flooding by saline water is of very occasional occurrence so that the soils are usually non-saline.

#### x. Texture and Structure (T or t)

40. Texture and structure are considered together because in combination they influence the workability, aeration, drainage, root penetrability and water-releasing capacity of the soil. Poor structural development occurs in sands and clays as well as soils of intermediate textures. While poor structures may occur in soils of both extremes of textures their effect on crop growth are dissimilar. A structureless sand may not be suitable for wet paddy cultivation because of its rapid permeability but a massive clay would be very suitable.

41. Lack of structure in sands and organic soils constitutes a serious limitation to crop growth as it deprives the soil of an essential property - that of anchorage. Besides this the absence of structural development makes tillage operations impossible. In the sands moisture conservation is at a minimum so that the wilting point is rapidly reached as soon as drought conditions prevail. In the organic soils, although moisture can be retained for a longer period, irreversible drying can pose serious problems to practical farming.

42. Massive clays, on the other hand, do not allow for proper aeration or easy permeability of excess water. They are also difficult to till, forming large clods instead of the fine ones required for crop cultivation.

43. Weak structural development in both heavy and light textured soils, although an improvement on the lack of structural development, also constitutes a limitation to crop growth. In this case it is only a moderate limitation.

44. Among the heavy textured soils, strongly developed coarse blocky structures also affect the workability, root penetrability and water-releasing capacity of the soil. Because of the high clay (and at times, silt) content in these soils, tillage operations have to be timed carefully; when the soil is too moist it is plastic and sticky so that tillage operations tend to cement the large clods together into a structureless mass. When it is too dry the clods are almost as hard as rocks and just as difficult to break up. Plant roots do not penetrate the large clods with ease but are more often than not concentrated on the outer surfaces within the cracks separating the clods.

45. For the suitability classification soils are grouped into five textural classes<sup>(9)</sup> as indicated in Table 3.

Table 3. Soil Textural Classes

CLASS	BASIC SOIL TEXTURAL CLASS NAME
Coarse-textured soils	Sands Loamy sands
Moderately coarse-textured soils	Sandy loam Fine sandy loam
Medium-textured soils	Very fine sandy loam Loam Silt loam Silt
Moderately fine-textured soils	Clay loam Sandy clay loam Silty clay loam
Fine-textured soils	Sandy clay Silty clay Clay

46. Coarse-textured soils, unless coalesced by cementing agents such as ferric oxides and hydroxides, normally have weak structural development and, as such, are poor anchoring mediums for large plants. As they tend to drain rapidly, they are more likely to be deficient in moisture during drought periods; moreover, such soils, which include beach sands, also tend to have low nutrient-retaining capacities so that their continued use may well

involve a high frequency of fertilizer application. Lack of structural development in such soils therefore constitutes a serious limitation to crop growth on a sustained yield basis.

47. Among the moderately coarse-textured, medium-textured and moderately fine-textured soils, texture alone may not be a limiting factor for crop growth. In combination with weak structural development, however, these soils will tend to break down easily with cultivation resulting mainly in poor drainage and aeration. For crop growth on a continuing basis weak structures in such soils are therefore only minor limitations.

48. Fine-textured soils, when not subjected to floods and possess well developed structures, are usually free draining and well aerated so that together with a relatively high water-holding capacity these soils are eminently suitable for a wide range of crops. On the other hand, when similar soils have poorly developed structures, particularly massive structures, this feature is usually associated with poor to very poor drainage conditions; anaerobic conditions may prevail under such situations leading to retardation or inhibition of root development in most crop plants. While poor drainage can be caused by other factors the workability of a poorly structured fine-textured soil is a direct consequence of the combined factors of texture and structure. The combination of massive structure and fine-texture therefore constitutes a serious limitation to crop growth.

49. When a strong blocky structure has developed in a fine-textured soil root development is less hampered. Although the available soil volume for root development may still be limited because of the difficulty of root penetration into the large structural units, the presence of structural faces within the soil is a distinct improvement on the massive structure. Consequently a strong coarse structure constitutes a moderate limitation to crop growth on a sustained yield basis.

50. Coarse-textured, moderately coarse-textured and medium-textured soils are indicated by the symbol "T" while the moderately fine-textured and fine-textured soils are denoted by "t".

### III. Land Use Classification

51. The use of the soil series as the basic mapping unit in Peninsular Malaysia has facilitated the setting up of the soil suitability classification. Examination of the 127 established soil series indicates the existence of certain combinations of crop growth limitations; these are shown in Table 5. Correlation between the criteria for optimum crop growth (Table 4) and each soil suitability class results in the suitability classification of each combination of soil limitations for each of the seven groups of food crops shown in Table 5.

52. The classification also takes into consideration soil properties which are of marginal suitability for crop growth. Table 5 therefore shows not only the sub-

Table 5. Soil/Crop Suitability Classification

SOIL SUITABILITY CLASSES	CROP SUITABILITY							CROP SUITABILITY							CROP SUITABILITY							
	Sugarcane	Maize, tapioca and soyabean	Sorghum	Groundnut	Dry-land Padi	Sago	Vegetables and sweet potato	Sugarcane	Maize, tapioca and soyabean	Sorghum	Groundnut	Dry-land Padi	Sago	Vegetables and sweet potato	Sugarcane	Maize, tapioca and soyabean	Sorghum	Groundnut	Dry-land Padi	Sago	Vegetables and sweet potato	
<b>Class 1.</b>																						
1	S <sub>x</sub>	S	S	S	S	U <sup>+</sup>	S	2dn(o)	M	S	S	U	U	M	3e(Er)	M	M	M	M	M	U	M
1ce	S	S	S	S	S	M	S	2dno	U	S	S	U	U	M	3c(r)	M	M	M	S	S	U	S
1d	S	S	S	S	S	S	S	2dr	M	M	M	S	S	S	3c(rT)	M	M	M	S	S	U	S
1E	S	S	S	S	S	U <sup>+</sup>	S	2dr(e)	M	M	M	S	M	S	3c(t)	M	M	M	S	S	U	S
1e	S	S	S	S	S	U <sup>+</sup>	S	2dT	S	S	S	S	S	S	3D(n)	U	U	U	U	U	U	U
<b>Class 2.</b>								2dt	S	S	S	S	S	S	3D(no)	U	U	U	U	U	U	U
2adt	M	M	M	M	S	S	S	2dt(a)	S	S	S	S	S	M	3D(T)	U	U	U	U	U	U	U
2cd	S	S	S	S	S	S	S	2dt(E)	S	S	S	S	S	M	3D(t)	U	U	U	U	U	U	U
2cdet	U	U	M	U	M	M	M	2E	M	M	M	M	M	U	3d(st)	U	U	U	U	U	U	U
2c(de)	S	S	S	S	S	U <sup>+</sup>	S	2ErT	M	M	M	M	M	U	3d(n)	U	U	U	U	U	U	U
2cdt	S	S	S	S	S	U <sup>+</sup>	S	2ET	M	M	M	M	M	U	3d(no)	U	U	U	U	U	U	U
2c(e)	S	S	S	S	S	U <sup>+</sup>	S	2Et	M	M	M	M	M	U	3d(T)	U	U	U	U	U	U	U
2ce	U	U	M	U	M	M	M	2e	U	U	U	U	U	U	3d(t)	U	U	U	U	U	U	U
2cs(d)	U	U	M	U	M	M	M	2et	U	U	U	U	U	U	3dt(e)	U	U	U	U	U	U	U
2ceR	U	U	M	U	M	M	M	2t(e)	M	M	M	S	S	S	3E	M	M	M	M	M	M	M
2cE	M	M	M	M	S	U	M	2tT(E)	M	M	M	S	S	S	3E(cT)	M	M	M	M	M	M	M
2cET	M	M	M	M	S	U	M	2T(S)	S	S	S	S	S	S	3E(T)	M	M	M	M	M	M	M
2cR	U	U	M	U	M	M	M	2t	S	S	S	S	S	S	3E(t)	M	M	M	M	M	M	M
2D(e)	M	M	M	M	M	U	M	2t(d)	S	S	S	S	S	S	3e	U	U	U	U	U	U	U
2De	U	U	M	U	M	M	M	2t(E)	S	S	S	S	S	S	3n(DT)	U	U	U	U	U	U	U
2DEnT	M	M	M	M	M	U	M	2t(e)	S	S	S	S	S	S	3n(DET)	U	U	U	U	U	U	U
2DnT	M	M	M	M	M	U	M	3c	M	M	M	S	S	S	3n(t)	U	U	U	U	U	U	U
2DT	M	M	M	M	M	U	M	3c(d)	M	M	M	S	S	S	3o(dn)	U	U	U	U	U	U	U
2Dt	M	M	M	M	M	U	M	3c(det)	U	U	U	U	U	U	3R	U	U	U	U	U	U	U
2Dt(e)	M	M	M	M	M	U	M	3c(3Et)	M	M	M	U	U	U	3R(ca)	U	U	U	U	U	U	U
2d	S	S	S	S	S	U	S	3c(dt)	M	M	M	S	S	S	3R(E)	U	U	U	U	U	U	U
2d(Er)	S	S	S	S	S	U	S	3c(e)	U	U	U	U	U	U	3R(e)	U	U	U	U	U	U	U
2d(e)	S	S	S	S	S	U	S	3c(er)	U	U	U	U	U	U								
2d(r)	S	S	S	S	S	U	S															
2de	U	U	M	U	M	M	M															

Class 4.

Class 5.

All class 5 soils are unsuitable.

+ Well drained and moderately well drained soils are unsuitable for sago palm cultivation.  
 x The symbols S = suitable; M = marginal; U = unsuitable.

Table 4. Soil Criteria for Optimum Crop Growth

Soil Criteria (marginal limits in parenthesis)

Crop	Slope	Drainage	Effective soil depth	Texture and structure	Salinity	Depth to Acid sulphate layer	Peat thickness	Stoniness	Nutrient imbalance
1. Sugarcane	0-6° (6°-12°)	Imperfect to well (somewhat excessive)	50 cm or more (25-50 cm)	Exclude structureless sands and clays (-)	2 mmhos or less in top 75 cm. (2 mmhos within 50-75 cm depth)	75 cm or more (50-75 cm)	25 cm or less (25-50 cm)	No restriction allowed within 50 cm depth. (Stones within 25-50 cm depth)	Exclude excessive trace elements or low nutrient-retaining capacity.
2. Maize, Topioca and Soya beans	"	"	"	"	2 mmhos or less in top 50 cm. (2 mmhos within 25-50 cm depth)	50 cm or more (25-50 cm)	Not limiting (-)	"	"
3. Sorghum	0-6° (6°-20°)	"	"	Exclude structureless sands (structureless sands)	4 mmhos or less in top 50 cm. (4 mmhos within 25-50 cm depth)	"	"	Up to 10% and uniformly distributed or present below 50 cm depth. (10-50% and/or below 25 cm depth)	"
4. Groundnut	0-6° (6°-12°)	"	25 cm or more (-)	Exclude structureless sands and clays (structureless sands)	"	"	No peat (-)	No restriction allowed within 25 cm depth. (Up to 25% if Uniformly distributed)	"
5. Dry-land Padi	0°-12° (12°-20°)	Imperfect to well (-)	25 cm or more (-)	Exclude structureless sands (-)	4 mmhos or less in top 25 cm. (-)	25 cm or more (-)	"	"	(acute nutrient deficiencies)
6. Sago	0°-6° (6°-12°)	Poor to very poor (Imperfect)	100 cm or more (50-100 cm)	Exclude loamy sands or coarser textures. (Loamy sands or coarser textures)	2 mmhos or less in top 100 cm. (2 mmhos within 75-100 cm depth)	100 cm or more (75-100 cm)	Not limiting (-)	Up to 25% and uniformly distributed or present below 75 cm depth. (25-75%)	(acute nutrient deficiencies)
7. Vegetables and Sweet potatoes	0°-6° (6°-20°)	Imperfect to well (Poor and somewhat excessive to excessive)	25 cm or more (-)	Exclude structureless sands and clays (Structureless sands and clays)	4 mmhos or less in top 50 cm. (4 mmhos within 25-50 cm depth)	50 cm or more (0-50 cm)	Not limiting (-)	No restriction allowed within 25 cm depth. (Up to 25% if uniformly distributed)	Exclude excessive trace elements (Low nutrient-retaining capacity and/or acute nutrient deficiencies)

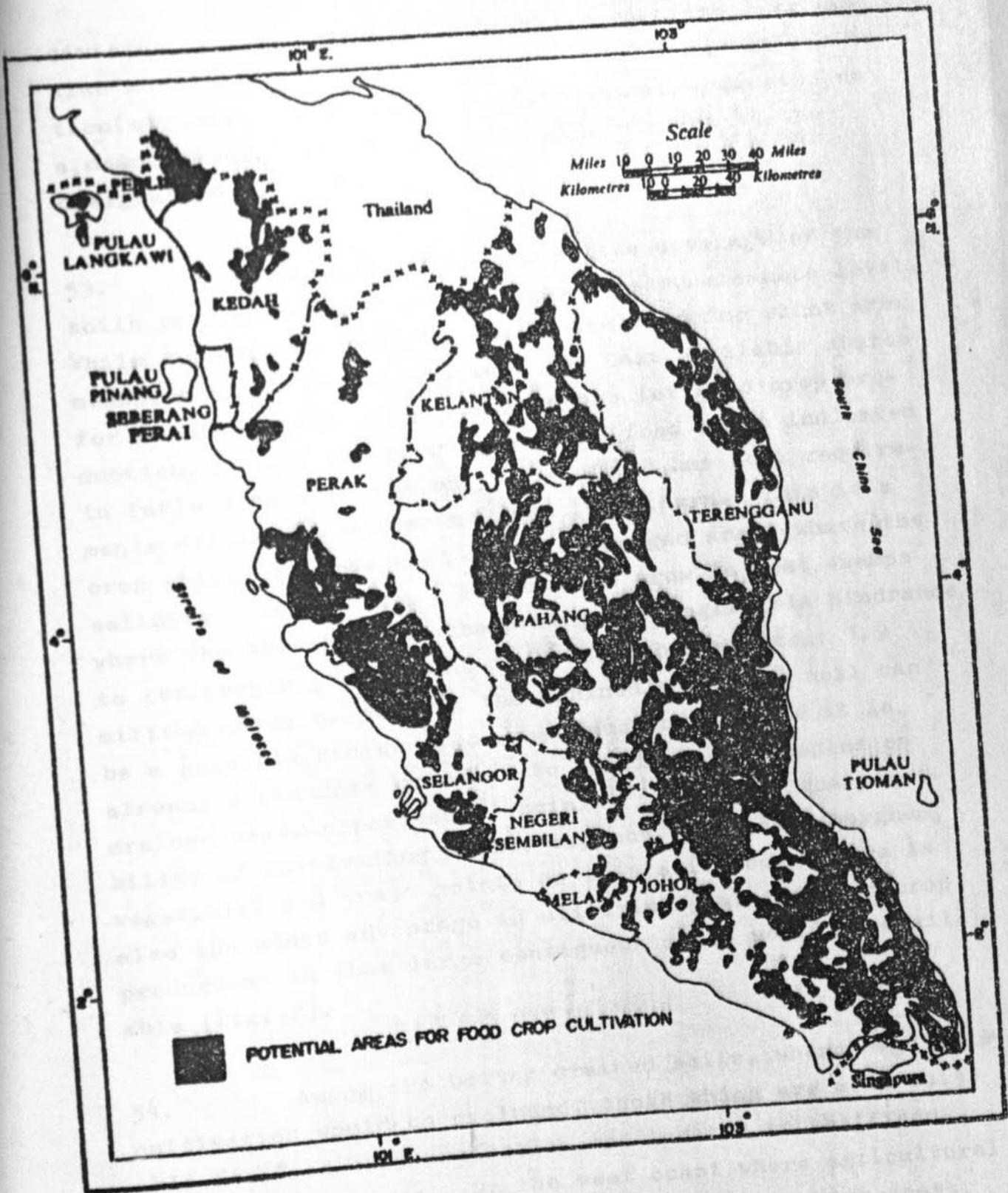


FIG. 2. POSSIBLE AREAS FOR IMMEDIATE FOOD CROP PRODUCTION.

division in terms of suitability and unsuitability but also marginal suitability. At the same time the limitation(s) influencing the classification is indicated as a denominator. The same method also applies to the designation of unsuitability.

53. To-date there is a complete coverage of the soils of Peninsular Malaysia at the reconnaissance level. While such mapping may be too generalised for exact area measurement it is nevertheless the best available source for identification of possible areas for food crop production. Among the seven groups of food crops indicated in Table 4 sago is the only crop which has soil requirements distinctly different from the others. This is a crop which can grow well in water-logged areas where the salinity level is low. It can also grow in peat swamps where the thickness of the peat is of negligible hindrance to its proper growth. As there are approximately 1.9 million acres of peat in the peninsula<sup>(7)</sup> this soil can be a possible source of sago production. While it is already a standard practice to cultivate pineapples on drained peat, experimental trials<sup>(5)</sup> indicate the possibility of cultivating maize, tapioca, soyabean, sorghum, vegetables and sweet potato on this soil too. There is also the added advantage in utilizing peat for food crop production in that large contiguous areas would be available (Fig. 2).

54. Among the better drained soils, where sago palm cultivation would be excluded, those which are most suitable for food crop production are located on the flood-plains and terraces. On the west coast where agricultural development has been more extensive than the east coast, such soils are generally not available in large contiguous

blocks. Marine alluvial and some riverine alluvial soils have been utilized for the double cropping of paddy or for coconut, oil palm and rubber cultivation. Only limited areas have been cultivated with food crops some on a catch cropping basis in single cropping paddy areas or in young coconut, oil palm and rubber holdings. Terrace soils have likewise been developed. In the northernmost state of Perlis terrace soils have been developed for sugarcane cultivation. The only extensive area of terrace soils on the west coast which is still to be exploited is in the southern part of the State of Perak; while the better drained sites have been opened for a sugarcane plantation and other smallholder cultivations, development of the major portion will involve major drainage works as there are peat swamps included in the area.

55. Most of the marine and riverine floodplain soils in the east coast have also been developed for paddy cultivation. Where single cropping of paddy has been practised tobacco cultivation forms the major off-season cropping enterprise instead of food crop production. While the floodplain soils generally tend to be flooded annually the terrace soils are only subject to unusually high floods. They are therefore more amenable to food crop production on a continuing basis. In the two northeastern states of Kelantan and Trengganu floodplain soils are closely associated with terrace soils. While wet paddy cultivation is practised on the floodplain soils, irregularity of water supply to the terrace areas has resulted in the latter areas being used for dry-land rice cultivation<sup>(4)</sup>. Such areas are also suitable for the cultivation of other dry-land food crops.

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