7 CHAPTER

Land Characteristics Influencing the Growth and Performance of Oil Palms Planted on Organic Soils

Introduction

The data generated during the soil survey provides the physical and chemical characteristics of the soils mapped in an area. To put the field survey in more practical terms this soil information needs to be interpreted with respect to the use under consideration. This is done by determining the suitability of the soil mapping units for the crop or crops under consideration for planting. Thus the suitability interpretations are predictions of performance and not necessarily the final recommendations for the use of the land. The optimal use of the land involves further considerations of, for example, environmental, social, economic, preference of the owner and access to markets. By virtue of being Government Agencies, the Departments of Agriculture need to determine the suitability of the land for a wide range of crops. The plantations or the private sector normally pre-determines the crop to be evaluated for planting on a piece of land.

Currently two systems of soil suitability classification are used in Malaysia by the Departments of Agriculture. In Peninsular Malaysia, the *'Soil-Crop Suitability Classification for Peninsular Malaysia'* (Wong, 1986) is used while in Sarawak, the *'Sarawak Land Capability Classification and Evaluation for Agricultural Crops'* (Maas *et al.*, 1979) is used. Sabah does not have a published system. In spite of the different terminologies both the Peninsular and Sarawak systems are quite similar. Both systems, identify the limitations a soil map unit has for crop growth. The crops are grouped into crop groups and the soil criteria for optimum growth of the various crop groups outlined. The evaluation of the suitability or capability of the soil for growth of each crop group is determined by comparing the limitations the soil possesses with soil criteria for optimum crop growth.

A soil which is capable of supporting a wider range of crops is considered to be a better soil than another soil which is only capable of supporting a smaller range of crops. The main difference between the two systems lies in how the organic soils are evaluated. In Wong's (1986) system the mineral and organic soils are evaluated together while in the Sarawak system the organic soils are evaluated separately from the mineral soils.

The objective of this Chapter is to review both these soil evaluation systems and in particular how the organic soils are treated. The Chapter outlines the organic soil characteristics which influence the suitability and management of these soils. The chapter also proposes the criteria to be used for the evaluation of oil palm, when planted on organic soils.

Soil-Crop Suitability Classification for Peninsular Malaysia

A detailed evaluation of soil suitability for different crops in Penisular Malaysia was done by Wong (1986) and this is taken into consideration below.

The classification system

A total of ten limitations *(Table 7.1)* affecting crop growth are used in the classification system. These factors are further evaluated using the degree to which they limit the growth of crops. Four degrees of limitations are used:-

a) ***Very serious limitations***
May seriously retard or totally inhibit use of the soil for crop growth.

b) ***Serious limitations***
Not detrimental to all crops. Some sensitive crops may not survive.

c) ***Moderate limitations***
Affect a limited range of crops. Such limitations can be overcome by proper management.

d) ***Minor limitations***
Affect only a selected number of crops. Effect is more on yields than crop survival.

The soils are grouped into five suitability classes according to the severity of crop growth limitations occurring in them.

Class 1 : Soils with no limitation or only minor limitations to crop growth.

Class 2 : Soils with moderate limitations to crop growth.

Class 3 : Soils with one serious limitation to crop growth.

Class 4 : Soils with more than one serious limitation to crop growth.

Class 5 : Soils with at least one very serious limitation to crop growth.

The soil suitability subclasses are subdivisions within the suitability classes based on the kinds of limitations affecting crop growth which are present. These would assist in making recommendations for specific crops and identify the major limitations present in the soil.

Evaluation procedure

The characteristics of the soil mapping units *(Table 7.2)* are compared to the Table of Soil Limitations *(Table 7.1)* and the nature and degree of the limitations present are noted. Depending on the number and degree of limitations, the soil suitability class and subclass are recorded *(Table 7.3)*. The suitability or otherwise of the 26 crop groups is then evaluated by comparing the limitations the soil mapping unit possesses *(Table 7.3)* with the Soil Criteria for Optimum Crop Growth. By doing this each soil mapping unit is considered to be suitable, marginal or unsuitable for each of the 26 crop groups *(Table 7.4)*.

TABLE 7.1. LIMITATIONS TO CROP GROWTH (Wong, 1986)

Symbol	Type of limitation	Degree of limitation			
		Very serious	Serious	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)	> 50–75 cm from the surface (20–30 inches)	> 75–100 cm from the surface (30–40 inches)
D	Drainage	–	Excessively drained	Somewhat excessively drained	–
d			Very poorly to poorly drained	Imperfectly drained	Moderately well drained
E	Erodibility	> 25° slopes for more erodable soils	> 12°–25° slopes for more erodable soils	> 6°–12° slopes for more erodable soils	2°–6° slopes for more erodable soils
e		> 35° slopes for less erodable soils	> 25°–35° slopes for less erodable soils	> 12°–20° slopes for less erodable soils	2°–12° slopes for less erodable soils
N	Nutrient imbalance	Toxicity caused by extremely high contents of certain elements	–	–	–
n		–	Low nutrient retaining capacity with or without acute nutrient deficiencies	Acute nutrient deficiencies	–
o	Organic horizon thickness	> 125 cm plus other unfavourable properties	> 125 cm thick from the surface	> 50–125 cm thick from the surface	25–50 cm thick from the surface
R	% Stoniness to 100 cm depth	> 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 0–25 cm stone-free soil
r		–	–	> 50–75% with 25–50 cm stone-free soil	25–50% with 25–50 cm stone-free soil
s	Salinity	–	Strongly saline	Moderately saline	Very slightly saline
T	Texture and Structure	–	Coarse textured and structureless	Coarse textured and weakly structured	–
t		–	Fine textured and structureless	Fine textured and weakly structured or strongly coarse structured	–
H	Human	Land disturbed by urbanization (u) and mining (m)	–	–	–

TABLE 7.2. EXAMPLE OF SOIL CHARACTERISTICS OF THE MAPPING UNITS IN A STUDY AREA

Limitation		Soil characteristic of the mapping units				
Symbol	**Type**	**Kms/3**	**Kms/4**	**Tsi/3**	**Tsi/4**	**Kuh/4**
a	Depth to acid sulphate layer	Not limiting	Not limiting	Not limiting	Not limiting	Not limiting
c	Depth to compacted layer	Not limiting	Not limiting	Not limiting	Not limiting	Not limiting
D	Drainage	–	–	–	–	–
d		Moderately well	Moderately well	Well	Well	Moderately well
E	Erodibility	–	–	6-12	12-20	–
e		6-12	12-20	–	–	12-20
N	Nutrient imbalance	–	–	–	–	–
n		Not limiting	Not limiting	Not limiting	Not limiting	Not limiting
o	Organic horizon thickness	Not limiting	Not limiting	Not limiting	Not limiting	Not limiting
R	% Stoniness to 100 cm depth	–	–	–	–	–
r		70 cm	70 cm	70 cm	70 cm	40 cm
s	Salinity	Non saline	Non saline	Non saline	Non saline	Non saline
T	Texture and Structure	–	–	–	–	–
t		fsc	fsc	fscl	fscl	fsc
H	Human disturbance	–	–	–	–	–

TABLE 7.3. EXAMPLE OF SUITABILITY SUB-CLASSES OF THE SOIL MAPPING UNITS IN A STUDY AREA

Limitation		Degree of limitation of the soil mapping units				
Symbol	**Type**	**Kms/3**	**Kms/4**	**Tsi/3**	**Tsi/4**	**Kuh/4**
a	Depth to acid sulfate layer (cm)	Not limiting	Not limiting	Not limiting	Not limiting	Not limiting
c	Depth to compact layer (cm)	Not limiting	Not limiting	Not limiting	Not limiting	Not limiting
D	Drainage	–	–	–	–	–
d		Not limiting	Not limiting	Not limiting	Not limiting	Not limiting
E	Erodibility	–	–	Moderate	Serious	–
e		Moderate	Serious	–	–	Serious
N	Nutrient imbalance	–	–	–	–	–
n		Not limiting	Not limiting	Not limiting	Not limiting	Not limiting
o	Organic horizon thickness	Not limiting	Not limiting	Not limiting	Not limiting	Not limiting
R	% Stoniness to 100 cm depth	–	–	Minor	Minor	–
r		Minor	Minor	–	–	Moderate
s	Salinity	Not limiting	Not limiting	Not limiting	Not limiting	Not limiting
T	Texture and Structure	–	–	–	–	–
t		Moderate	Moderate	Moderate	Moderate	Serious
H	Human disturbance	–	–	–	–	–
Soil Suitability Subclass	Current	2et	3e(t)	2Et	3E(t)	4et
	Potential	2et	3e(t)	2Et	3E(t)	4et

Note: Kms = Kumansi Series
Tsi = Talisai Series
Kuh = Kuah Series
3 = rolling (12-24% slopes) terrain
4 = hilly (24-38% slopes) terrain

TABLE 7.4. EXAMPLE OF CROP SUITABILITY EVALUATION OF THE SOILS IN A STUDY AREA

Crop group		Potential suitability of the soil map units				
No.	Name	Kms/3	Kms/4	Tsi/3	Tsi/4	Kuh/4
1.	Durian	S	M	S	M	M
2.	Coconut	S	M	S	M	M
3.	Oil Palm	M	M	M	M	M
4.	Cocoa	M	M	M	M	M
5.	Rubber	M	M	M	M	M
6.	Sago	U	U	U	U	U
7.	Starfruit	M	M	M	M	U
8.	Banana	M	M	M	M	M
9.	Cashewnut	M	M	M	M	M
10.	Coffee	M	M	M	M	M
11.	Tea	M	M	M	M	U
12.	Clove	M	M	M	M	U
13.	Papaya	M	M	M	M	U
14.	Tobacco	S	M	S	M	U
15.	Citrus	M	M	M	M	U
16.	Ginger	M	U	M	U	U
17.	Sugarcane	M	U	M	U	U
18.	Tapioca	M	U	M	U	U
19.	Sorghum	M	M	M	M	M
20.	Pepper	M	U	M	U	U
21.	Pineapple	M	M	M	M	M
22.	Groundnut	M	U	M	U	U
23.	Vegetables	M	M	M	M	M
24.	Wetland Rice	U	U	U	U	U
25.	Fodder Grass	M	U	M	U	U
26.	Pasture	S	M	S	M	M

Note: Kms = Kumansi Series; Tsi = Talisai Series; Kuh = Kuah Series
3 = rolling (12-24% slopes) terrain; 4 = hilly (24-38% slopes) terrain
S = Suitable; M = Marginal

In the *Soil-Crop Suitability Classification for Peninsular Malaysia* (Wong, 1986) only 5 of the 10 soil limiting factors considered can directly or indirectly be applied to organic soils. The five factors are: depth to acid sulfate layer (a), drainage (D/d), nutrient imbalance (N/n), organic horizon thickness (o) and salinity (s). However at that time not much organic soil series were mapped and these organic soils were only mapped using depth and drainage. Thus only 9 soil suitability subclasses as follows were recognized for the organic soils:

2d(o), 2do, 3D, 3D(o), 3d, 3d(o), 3o(d), 4Do, 4do

The suitability of these 9 subclasses for the 26 crop groups as summarised by Wong (1986) is given in *Table 7.5*.

TABLE 7.5. CROP/SOIL SUITABILITY EVALUATION OF THE ORGANIC SOIL SUITABILITY CLASSES (Wong, 1986)

Soil suitability subclass	Crop group / Limitation and degree	1 Durian	2 Coconut	3 Oil Palm	4 Cocoa	5 Rubber	6 Sago	7 Belimbing	8 Banana	9 Cashew	10 Coffee	11 Tea	12 Clove	13 Papaya	14 Tobacco	15 Citrus	16 Ginger	17 Sugarcane	18 Maize	19 Sorghum	20 Pepper	21 Pineapple	22 Ground nut	23 Vegetable	24 Wetland rice	25 Fodder grass	26 Pasture
2d(o)	Drainage – moderate Thickness – minor	U/(o)	U/(o)	S	U/(o)	U/(o)	M/d	U/(o)	U/(o)	U/(o)	M/(o)	U/(o)	U/(o)	U/d(o)	U/(o)	U/(o)	U/d	M/(o)	S	S	U/(o)	S	U/(o)	S	U/(o)	S	U/(o)
2do	Drainage and thickness – moderate	U/o	U/o	M/o	U/o	U/o	M/d	U/o	U/o	U/o	U/o	U/o	U/o	U/o	U/o	U/o	U/o	U/o	S	S	U/o	S	U/o	S	U/o	S	U/o
3D	Drainage – serious	U/D	M/D	U/D	U/D	U/D	U/D	U/D	U/D	M/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	M/D	U/D	U/D	U/D
3D(o)	Drainage – serious Thickness – moderate	U/D(o)	U/D(o)	U/D	U/D(o)	U/D(o)	U/D	U/D(o)	U/D(o)	U/(o)	U/D(o)	U/D(o)	U/D(o)	U/D(o)	U/D(o)	U/D(o)	U/D	U/D(o)	U/D	U/D	U/D(o)	U/D	U/D(o)	M/D	U/D(o)	U/D	U/D(o)
3d	Drainage – serious	U/d	M/d	M/d	U/d	U/d	S	U/d	U/d	U/d	U/d	U/d	U/d	U/d	U/d	U/d	U/d	U/d	U/d	U/d	U/d	U/d	U/d	M/d	S	S	U/d
3d(o)	Drainage – serious Thickness – moderate	U/d(o)	U/o	U/d(o)	U/d(o)	U/d(o)	S	U/d(o)	U/d(o)	U/d(o)	U/d(o)	U/d(o)	U/d(o)	U/d(o)	U/d(o)	U/d(o)	U/d	U/d(o)	U/d	U/d	U/d(o)	U/d	U/d(o)	M/d	U/(o)	S	U/d(o)
3o(d)	Thickness – serious Drainage – moderate	U/o	U/o	M/o	U/o	U/o	M/(d)	U/o	U/o	U/o	U/o	U/o	U/o	U/a(d)	U/o	U/o	U/(d)	U/o	S	S	U/o	S	U/o	S	U/o	S	U/O
4Do	Drainage and Thickness – serious	U/Do	U/o	U/Do	U/Do	U/Do	U/D	U/Do	U/Do	U/o	U/Do	U/Do	U/Do	U/Do	U/Do	U/Do	U/D	U/Do	U/D	U/D	U/Do	U/D	U/Do	M/D	U/Do	U/D	U/Do
4do	Drainage and Thickness – serious	U/do	U/o	U/o	U/do	U/do	S	U/do	U/do	U/do	U/do	U/do	U/do	U/do	U/do	U/do	U/d	U/do	U/d	U/d	U/do	U/d	U/do	M/d	U/o	S	U/do

Note: D = Drained (well)
d = not drained (poor)

Sarawak Land Capability Classification and Evaluation for Agricultural Crops

Limitations and their severities

A total of 15 different soil limitations or attributes were identified in this classification by Mass *et el.* (1979). Of these attributes 12 are used for mineral soils *(Table 7.6a)* while 8 are used for organic soils *(Table 7.6b)*. These are separated into 5 degrees of limitations as follows:-

(a) None : No crop restrictions attributable to soil, water or terrain criteria.

(b) Minor : Limitations that reduce the productivity of only a few specific crops or that can be easily corrected by proper management.

(c) Moderate : Soil, water and terrain limitations that restrict the range crops of require moderate conservation practices.

(d) Severe : Soil, water and terrain limitations that will seriously inhibit or even preclude the growing of some crops but which may be well suited to others.

(e) Very serious : Soil and terrain limitations that will not only hinder but may totally inhibit the use of this land for crop production.

Both the mineral and organic soils are then grouped into Capability Classes according to the increasing severity and number of limitations affecting crop production. In the case of organic soils the prefix 'O' is added to the class.

Capability classes for mineral soils

Generally five classes of capability are considered for mineral soils. These are:-

Class 1 : Land with no limitation or only one minor limitation to crop growth.

Class 2 : Land with two or three minor limitations or one moderate limitation that restricts the range of crops and/or requires moderate drainage or some conservation practices.

Class 3 : Land with two or three moderate limitations or one serious limitation that restricts the range of crops, the degree of possible mechanization, or requires special conservation practices.

Class 4 : Land with several moderate or two or three serious limitations that severely restrict the range of crops or require special conservation practices or both.

Class 5 : Land with such severe limitations that with a few limited exceptions precludes the use of the area for agriculture.

TABLE 7.6A. LIMITATIONS TO CROP SUITABILITY ON MINERAL SOILS (Maas *et al.*, 1979)

Symbol	Type of limitation	Degree of limitation				
		None	Minor	Moderate	Serious	Very serious
a	Depth to sulphidic layer (cm)	>100	75-100	50-75	<50	–
c	Depth to massive clay (cm)	>75	50-75	25-50	<25	–
d	Soil depth to impervious layer or 50% rock fragments (cm)	>100	75-100	50-75	25-50	<25
e	Erosion hazard	none	low	medium	high	very high
f	Fertility	medium	–	low fertility low retention	acute deficiency, very low retention	–
i	Inundation hazard (frequency & duration)	none	infrequent, short	frequent, short	infrequent, long	frequent and long or submerged
m	Moisture-holding capacity	high (loam to clay)	–	medium (sandy loams)	low (fine and medium sands)	very low (coarse sand)
o	Depth of organic layer (cm)	<25	–	25-50	–	–
r	Stoniness (% rock fragments or stone within top 25 cm)	<0.1	0.1-3	3-15	15-50	>50
s	Salinity of groundwater (μmhos/cm)	<1,000	–	–	1,000-4,000	>4,000
t	Slope (topography)	0-6°	6-12°	12-25°	25-33°	>33°
w	Wetness	well drained	moderately well drained	imperfectly drained	poor to very poorly drained	–

TABLE 7.6B. LIMITATIONS TO CROP SUITABILITY ON ORGANIC SOILS (Maas *et al.*, 1979)

Symbol	Type of limitation		Degree of limitation				
			None	Minor	Moderate	Serious	Very serious
a	Depth to sulphidic layer*1 (cm)		>100	75-100	50-75	–	–
f	Fertility of the organic layer		medium (loamy*2 muck)	–	–	very low (peat or sandy muck)	–
g	Depth to groundwater-table (cm)	natural	–	–	30-60	0-30	–
		drained	60-100	–	30-60	>100	–
h	Degree of humification		hemic-sapric	–	–	fibric	–
i	Inundation hazard (frequency & duration)		none	infrequent, short	frequent, short	infrequent, long	frequent and long or submerged
n	Nature (texture) of mineral subsoil at 50-100 cm		fine loamy to clayey	–	–	sandy to coarse loamy	–
o	Depth of organic layer (cm)		–	–	50-100	>100	–
s	Salinity of groundwater (μmhos/cm)		<1,000	–	–	1,000-4,000	>4,000

*1 Depth after reclamation; allow 25 cm more for subsidence of virgin organic soils.
*2 the clay content of mineral component must be greater than 18%.

Capability classes for organic soils

The organic soils are rated on the same capability scale for crop production as the mineral soils but labeled with the prefix 'O' because their management requirements are quite different and much more exacting. Currently this method rates most of the peat soils in Sarawak as unsuitable for agriculture (Class 05) and even the better ones as only marginally suitable (Class 04). It should be noted that after drainage and reclamation most of these soils would be improved by one unit in their class ratings. However, the feasibility of drainage has not been determined and its certainty should not be assumed.

Class 05 : Land consisting of peat greater than 100 cm or shallow peat over sand. Land with four or more serious limitations.

Class 04 : Land suitable without drainage for only sago and rice. Land with two or three serious limitations.

Class 03 and 02 : These are good soils for wetland rice or sago and dry season crops such as vegetables, maize and soyabeans. They have one serious limitation when undrained but when drained they may have two or three moderate limitations or one serious limitation.

The number and severity of limitations for each capability class is summarised in *Table 7.7.*

Table 7.7. Number and Severity of Limitations for Each Capability Class (Maas *et al.*, 1979)

Class	Number of limitations			
	Minor	Moderate	Serious	Very serious
1 or 01	0-1	0	0	0
2 or 02	2-3	1 or its equivalent	1 or its equivalent	0
3 or 03	≥4	2-3 or their equivalent	1 or its equivalent	0
4 or 04	–	4	2-3 or their equivalent	0
5 or 05	–	–	≥4	≥1

Land capability subclasses

The land capability subclasses are sub-divisions within the capability classes. They are based on the kinds of limitations and the degree that these limitations have in the soil/land.

Crop groups

For the mineral and organic soils, 20 crop groups are considered. The soil and physical limits for the satisfactory crop growth on organic soils is given in *Table 7.8.*

Since this Capability Classification to-date, has only been applied to the reconnaissance soil maps where the organic soil definitions were not precise, only 8 Organic Land Capability Sub-Classes have been identified. The evaluation of these subclasses for the suitability for the 20 crop groups is given in *Table 7.9.*

Land Evaluation for Oil Palm

It is obvious from the above review that current systems of Land/Soil Suitability Classification used both in Peninsular Malaysia (Wong, 1986) and Sarawak (Maas *et al.*, 1979) did not adequately evaluate the suitability of organic soils for the following reasons:

- soil map units in reconnaissance soil maps did not characterize organic soils adequately.
- these systems looked at the range of crops rather than specific crops.
- criteria used to evaluate organic soils were inadequate.

Hence there is a need to improve and develop a new classification system. This is particularly true in the case of commercial plantation crops such as oil palm, rubber, cocoa and coconut. Thus Paramananthan (1987b) developed a Land Evaluation Classification specifically for these four crops to meet the demands of the plantation industry where better evaluation and management levels were possible. This was subsequently updated (Paramananthan, 2003).

Paramananthan (1987b) adopted the FAO's *'Framework for Land Evaluation'* (FAO, 1976) and developed tables for the evaluation of common plantation crops – oil palm, rubber, cocoa and coconut. One of the advantages of using the FAO's Framework is that each evaluation criteria can be modified to suit the land utilization type. Thus 'Oil palm under estate-level management' or 'Oil palm under smallholders' can have different evaluation tables. Estates are able to manage problem soils such as acid sulfate, sandy and peat better than smallholders. Thus, the presence for example, of an acid sulfate layer below 50 cm depth can be a minor or moderate limitation for estates while it can be a serious limitation for smallholders who may not have the capacity to manage watertables adequately. The updated version of (Paramananthan, 2003) is reproduced in *Table 7.10.*

With increasing detailed information produced in the semi-detailed and detailed soil maps being produced today, especially for organic soils, there is a need to develop a revised land suitability evaluation system specifically for organic soils particularly to evaluate the common plants/crops – oil palm, acacia, rubber and sago being planted on these soils. It is obvious that the land characteristics of organic soils are quite different from those of mineral soils.

Land Characteristics Influencing the Growth of Oil Palms Planted on Organic Soils

A number of land characteristics influence the cultivation and growth of oil palm cultivated on organic soils. Some of these characteristics directly influence the growth and, hence, the yield of oil palms while others increase the cost and difficulties faced in the establishment of oil palms. Ten land characteristics have been identified as influencing the growth of oil palm on peatlands. These ten characteristics and the degree to which these affect the growth of oil palm are summarised in *Table 7.11* (Paramananthan and Wahid Omar, 2010; Paramananthan, 2013a) and discussed in the following.

TABLE 7.8. SOIL AND OTHER PHYSICAL LIMITS FOR SATISFACTORY CROP GROWTH ON ORGANIC SOILS*[1] (Maas *et al.*, 1979)

	Crop group	Crop	Depth of watertable (cm)	Degree of decomposition	Thickness or organic layer (cm)	Fertility of organic layer and nature of mineral subsoil	Depth to sulphidic layer (cm)	Salinity of groundwater (µm hos/cm)	Flooding (not submerged)
ANNUAL	1	Wetland rice	Near surface	Fibric	<100; n.r. if loamy muck*[2]	Medium if subsoil sandy and n.r. if subsoil fine loam to clay	>50	<2,000; 2,000-4,000 for tolerant cultivars	Frequent, long
	2	Upland rice	Near surface	Fibric	<100; n.r. if loamy muck*[2]	Medium if subsoil sandy and n.r. if subsoil fine loamy to clay	>50	<2,000; 2,000-4,000 for tolerant cultivars	Frequent, long
	3	Maize, sorghum	60-100	Hemic-sapric	<100	n.r. (i.e. no restriction)	(>50) 75	<1,000	None
	4	Vegetables, chilli, soyabean, tobacco	30-60	Hemic-sapric	n.r.	n.r.	(>50) 75	<1,000	None
	5	Ginger, groundnut, sweet potato, tapioca, yam	60-100	Hemic-sapric	n.r.	n.r.	>75	<1,000	None
PERENNIALS	7	Banana	60-100	Hemic-sapric	<100	Medium if subsoil sandy and n.r. if subsoil fine loam to clay	(>75) 100	<1,000	Frequent, short (infrequent, long)
	8	Passion fruit, sugar cane	60-100	Hemic-sapric	n.r.	n.r.	(>75) 100	<1,000	Infrequent, short
	9	Fodder crops, lemon grass	30-60	Hemic-sapric	n.r.	n.r.	>75	<1,000 for lemon grass variable for fodder crops	Infrequent, short
	10	Forage crops*[3]	30-60	Hemic-sapric	n.r.	n.r.	>50	Variable	Short; infrequent to frequent depending on species
	11	Pineapple	60-100	Hemic-sapric	n.r.	n.r.	>50	<1,000	None

PERENNIALS	12	Cocoa	60-100	Hemic-sapric	<100	n.r. but subsoils must be fine loam to clay	>100	<1,000	Frequent, short
	13	Oil palm	60-100	Hemic-sapric	n.r.	n.r. but subsoil within 1 m must be fine loam to clay	>75	<1,000	Frequent, short
	14	Pepper, papaya	Not suitable						
	15	Annatto, coffee, mulberry	60-100	Hemic-sapric	n.r.	n.r. but subsoil within 1 m must be fine loam to clay	>75	<1,000	Infrequent, short
	16	Citrus, clove, durian, guava, mango, nutmeg, rambutan	60-100	Hemic-sapric	<100	n.r. but subsoil must be fine loam to clay	>100	<1,000	*4
	17	Coconut	60-100	Hemic-sapric	<100; n.r. for dwarf coconut	n.r.	>75	<4,000	Frequent, short
	18	Cashew	60-100	Hemic-sapric	<100	n.r.	>75	<1,000	Infrequent, short
	19	Sago (metroxylon spp.)	n.r.	n.r.	n.r.	n.r.	>75 (n.r. if permanently wet)	<4,000	Frequent, long
	20	Rubber, illipenut	60-100	Hemic-sapric	<100	n.r. but subsoil must be fine loam to clay	>75	<1,000	Frequent, short

Note:

*1 Parenthesis denotes the limits under the conditions of small-holder and subsistence farming. Requirements of water melon (Group 6) and pepper (Group 14) are not certain and are therefore not indicated.

*2 The clay content of the mineral component must be 18% (Soil Survey Staff, 1975).

*3 Forage Crops – Although pasture grasses can be grown under the conditions stipulated, the trafficability of animals is uncertain. It is noted that lighter animals like goats may not pose a problem and that the trafficability is probably better where the mineral content is higher.

*4 Frequent, short for clove, nutmeg and rambutan and infrequent, long for citrus, durian, guava and mango.

n.r. no restriction

TABLE 7.9. LAND AND CROP SUITABILITY EVALUATION FOR ORGANIC SOILS (Maas *et al.*, 1979)

Organic landcability subclass \ Crop group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Wetland rice	Upland rice	Maize, Sorghum	Soyabean, Vegetables	Groundnut, Tapioca	Water melon	Banana	Sugar cane	Fodder crops	Forage crops	Pineapple	Cocoa	Oil palm	Pepper	Coffee	Fruit trees	Coconut	Cashew	Sago	Rubber
O3g	S	S	C4	C4	U	U	U	U	C4	C4	C4	U	U	U	U	U	U	U	S	U
O4ga	M	C5M	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	S	U
O4gf	M	M	C4M	C4M	U	U	U	U	C4	C4	C4	U	U	U	U	U	U	U	S	U
O4gs	C3	C3	C4	C4	U	U	U	U	C4	C4	C4	U	U	U	U	U	U	U	S	U
O5gn	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	M	U
O4go	M	M	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	S	U
O5go	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	M	U
O5gs	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U

Note: C3 - tolerant or suitable cultivars
C4 - slightly improved drainage
C5 - permanently saturated condition

TABLE 7.10. EVALUATION OF LAND CHARACTERISTICS FOR OIL PALM (Estate Level Management)

Characteristic	Degree of limitation				
	Not limiting S1	Minor S2	Moderate S3	Serious N1	Very serious N2
Climate					
Annual rainfall (mm)	+ 2000	1,700-2,000	1,450-1,700	1,250-1,450	– 1,250
Dry season (months)		1	1-2	2-3	+ 3
Mean annual max. temp. (°C)	+ 29	27-29	24-27	22-24	– 22
Mean annual min. temp. (°C)	+ 20	18-20	16-18	14-16	– 14
Mean annual temp. (°C)	+ 25	22-25	20-22	18-20	– 18
Topography					
Slope (%)	0-12	12-23	23-38	38-50	+50
Wetness					
Drainage Class	Moderate to imperfect	Well and somewhat excessive	Poor (aeric) (easily drained)	Poor (typic) difficult to drain	Very Poor
Flooding	Not Flooded	Not Flooded	Minor	Moderate	Severe
Physical soil conditions					
Texture/structure	Cs, SC,CL, SiCs, SiCl	Co, L, SCo	SCL, Cm	SL, LSf	LSco, S
Depth (cm)	100 +	75-100	50-75	25-50	– 25
Depth to top of sulfuric horizon (cm)	100 +	75-100	50-75	25-50	– 25
Thickness of Peat (cm)	– 50	50-150	150-300	300 +	–
Soil fertility conditions					
Weathering stage (effective CEC)	+ 16	– 16	–	–	–
Base saturation (%) A horizon	+ 35	20-35	– 20	–	–
Organic carbon (%) A horizon	+ 1.5	– 1.5	–	–	–
Salinity (dS/m) (50 cm)	0-1	1-2	2-3	3-4	4 +

Source: Paramananthan, 2003 (updated)

TABLE 7.11. EVALUATION OF ORGANIC SOIL CHARACTERISTICS FOR OIL PALM (ESTATE LEVEL MANAGEMENT) – ORGANIC SOILS (Paramananthan and Wahid Omar, 2010; Paramananthan, 2013a)

Characteristic	Degree of limitation	Characteristic	Characteristic	Degree of limitation	Characteristic	Degree of limitation
CLIMATE (c)						
Total annual rainfall (mm)	2,000-3,000	3,000-3,500 1,500-2,000	3,500-4,000 1,000-1,500	4,000-5,000 750-1,500	≥ 5,000 ≤ 750	High rainfall – flooding/hampers field operation Low rainfall – increases susceptibility to fires
Dry season (months)	≤ 1	1-2	2-3	3-4	≥ 4	Long dry period susceptibility to fires
Mean annual temperature (°C)	≥ 25	22-25	20-22	18-20	≤ 18	Low temperature – long gestation period, poor flowering, low bunch weight
WETNESS						
Depth to ground watertable (cm) (g)	50-60	60-80 40-50	80-100 30-40	≥ 100 20-30	≤ 20	Depth of watertable may affect GHG emissions and subsidence
Drainability (dr)	Drained	Easy	Moderate	Difficult	Very difficult	Determines life of plantation
PHYSICAL SOIL CONDITIONS						
Depth/Thickness of organic materials (cm) (d)	≤ 100	100-150	150-300	≥300	–	Increased potential for shrinkage of peat and leaning of palms
Surface woodiness (%) (s)	≤ 10	10-30	30-40	40-50	≥ 50	Stumps of *Shorea albida* common in PC3-4 – increased cost of land clearing and stacking. Surface wood common in PC2-4
Surface wood litter (%) (l)	≤ 25	25-50	≥ 50	–	–	
Organic soil material class (m)	te/or, sa/te, sa/he	sa/fi, he, he/fi, te/wd/wu, sa/wd/wu	fi, he/wd/wu	fi/ wd/wu	wd/wu	te = terric, or = organic, sa = sapric, he = hemic, fi = fibric, wd = wood decomposed, wu = wood undecomposed
Depth to buried wood layer (cm) (b)	≥ 100	75-100	50-75	25-50	<25	Occurrence of wood within 100 cm.
Nature of buried wood (100 cm) (h)	No wood	Decomposed	Undecomposed	–	–	No wood, decomposed or undecomposed.
Nature of mineral substratum (t)	Clay	Clay, sulfidic	Sandy clay, sand	Sand sulfidic	–	Sand, clay, sulfidic
CHEMICAL SOIL CONDITIONS (f)						
Fertility status (CEC)	>24	12-24	≤ 12	–	–	Surface 50 cm
Salinity (50 cm) (dS/m)	≤ 1	1-2	2-3	3-4	≥ 4	Surface 50 cm

KEY:

c = climate
w = wetness
d = depth/thickness of organic layer
f = fertility status
g = depth to groundwatertable
dr = drainability
h = nature of buried wood

l = surface wood litter
m = organic soil material class
b = depth to buried wood layer
t = nature of mineral substratum
s = surface woodiness

te = terric (mineral layer)
sa = sapric
he = hemic
fi = fibric
or = *organic (unclassified)*
wd = *wood decomposed*
wu = *wood undecomposed*

Climate

The climate of an area to a large extent determines the suitability of the area for the cultivation of oil palm. Three elements of the climate namely, total annual rainfall, the length of the dry season and the mean annual temperature determine the suitability of peatlands for the cultivation of oil palm. It is important to remember that climate is one factor that is difficult, if not almost impossible, to correct and thus constitutes one of the overriding characteristic that determines the suitability of the land.

Total annual rainfall

Oil palm requires an adequate amount of moisture for its growth. Most peatlands are formed in areas with good rainfall and high watertables and thus rainfall in most cases is adequate. However excessive rainfall in peatlands often results in a high watertable and even flooding which then hampers field operations. Further, excessive rainfall restricts the time available for fertilizer applications and if the rainfall occurs immediately after the fertilizer/agriculture chemicals have been applied can result in these being washed into the canals and out of the estate. Peatlands which are flooded give rise to methane emissions and can contribute to global warming. Low rainfall on the other hand causes moisture stress, low availability of applied nutrients and can make the peatlands susceptible to fires.

Dry season

Any month with a monthly rainfall of less than 100 mm is considered to be a dry month. Prolonged dry periods can result in 'irreversible drying' of the surface layers in the peatlands making these surface layers lose their ability to absorb moisture. Prolonged dry periods increase the susceptibility of the peatland to fires which not only result in haze, health and environmental problems but also increase greenhouse gas emissions – particularly carbon dioxide. The growth of oil palms will also be affected by prolonged dry periods. The increase in number of unopened spears, reduction in female inflorescences and increase in pollen sterility are just some of the effects.

Mean annual temperature

In the tropical lowlands temperatures are usually above 22° and not really a problem for oil palm cultivation. However in the Sub-Tropics or at higher altitudes the mean annual temperature and in particular the night temperatures can be low. Low temperature will increase the immature period in palm oil. At high altitudes in the Tropics, the cloud cover and hence the sunshine hours are reduced thereby reducing photosynthesis resulting in lower yields. Thus it is not recommended to plant oil palms above 400 m (1,200 feet) elevation in the Tropics.

Wetness

Most peatlands in their natural state are underwater for prolonged periods of the year. They are thus often flooded. However during prolonged droughts, watertables can be 100 cm below surface. Thus in their waterlogged period, tropical lowland peats produce methane (CH_4) while in the dry periods they produce carbon dioxide (CO_2). Both of these gases are greenhouse gases (GHG) which contribute to global warming. Of the two methane is 23 times more detrimental compared to carbon dioxide.

It is obvious therefore that most tropical peatlands due to their prolonged flooded conditions are not suitable for most crops – especially perennial crops. In order to utilize these areas controlled drainage is a prerequisite. In the past, large drainage canals with little or no control structures were used to drain these swamps resulting in severe subsidence, irreversible drying and decomposition and increase of GHG emissions. Today controlled drainage is the key to the utilization of the Tropical Lowland Peats. Two characteristics determine the suitability of these areas – depth of the controlled ground watertable and the drainability of the swamp as a whole. Wherever possible the whole peat profile above the watertable should remain moist i.e. most of the pores should have sufficient moisture to minimize GHG emissions.

Depth of the ground watertable

It is obvious that controlled drainage is the key to the development and utilization of tropical Lowland Peats. The depth of the ground watertable is controlled by the use of a series of primary, secondary and tertiary drains of different dimensions and with the use of control structures such as weirs, control gates etc. The ideal depth to which the watertable is to be maintained is 50-60 cm below the surface. Too high a watertable is detrimental to most crops. Too low a watertable results in over drainage, irreversible drying of the surface and increased subsidence and decomposition and GHG emissions. Most large tropical lowland peat swamps are dome-shaped and hence require a complex drainage system. The system used in a particular area is dependent on the hydrological characteristics of the individual swamps.

Drainability

Most tropical lowland peats have a dome above ground or inverted saucer-shape surface morphology. However the base of the organic deposits is basin-shaped overlying the underlying mineral substratum giving the organic deposit a disc-shape (*Figure 7.1*, Tie and Melling, 1999). A particular peat swamp can be easily drained or can be difficult to drain. Due to the dome shape the surface of most swamps is higher than the local river level and thus can be drained. This is however not always the case where due to high tides or heavy rains the water level in the rivers can be high, making drainage difficult. Subsidence and compaction of the peat due to prolonged cultivation can also result in the peat surface becoming lower than the local river level resulting in backflow into the swamps. In such cases, control structures and pumping may be required to maintain the successful cultivation of crops. Pumping can be expensive.

Physical soil conditions

Physical soil conditions affect the growth of crops. Seven physical soil characteristics are recognized in organic soils that affect the growth and yield of crops to some degree. Some of these limitations can be readily corrected while others are more difficult. Some of these limitations increase the cost of development. These seven physical conditions are discussed below and their degrees of severity given in *Table 7.11*.

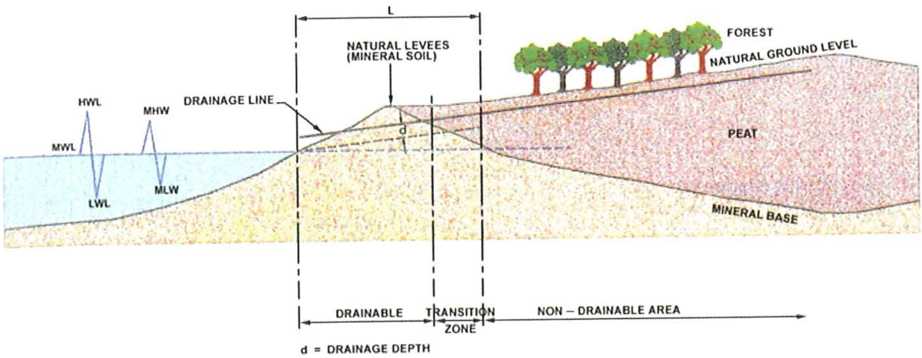

Figure 7.1. *The drainability concept* (after Tie and Melling, 1999)

Depth/Thickness of organic soil materials

The depth or thickness of organic soil materials refers to the depth of organic soil materials from the organic soil surface to the underlying mineral substratum. In the current definition of organic soils, a soil must have more than 50 cm thickness of organic soil materials within the upper 100 cm of the soil. Thus, a soil with e.g. 40 cm terric (mineral) soil material overlying a thick organic deposit will be an organic soil but in the evaluation of the soil for crops the upper 40 cm of mineral soil can support most crops and thus be better evaluated with mineral soils. The depth classes used for organic soils are very shallow [<50 cm – organic phase of mineral soils (0-25 cm) of mineral soils and:- histic (25-50 cm) epipedon]; shallow (50-100 cm); moderately deep (100-150 cm); deep (150-300 cm) and very deep (>300 cm).

Deep peats have a greater potential for shrinkage resulting in leaning palms on drainage. This results in difficulty of harvesting as the adjacent palms can lean in different directions. In extreme cases the palms can topple over. In spite of these problems, oil palms have been planted successfully on very deep peats (>3 m) suggesting that depth of the organic deposit is not a very severe limitation to most perennial crops including oil palms. This limitation however increases the harvesting cost.

Surface woodiness

Forest trees in many peat domes, especially those dominated by Alan Batu/Alan Bunga *(Shorea albida),* have large tree trunks and large long buttress roots. Consequently after logging these large stumps are left standing on the ground surface. These stumps are similar to rock outcrops in mineral soils. The presence of these stumps can hinder the lining of palms during planting and result in a lower stand per hectare. Palms planted close to these stumps are often stunted due to the presence of wood close to the roots. One solution is to destump at least along the planting row but this is not only costly but also results in depressions where the stumps used to stand resulting in the need for land leveling before compaction prior to planting. These remedial measures increase the overall cost of production.

Surface wood litter

In the Alan Batu and Alan Bunga Forests where *Shorea albida* forest species dominate, large amounts of branches and twigs litter the soil surface. This is similar to the presence of surface stones and gravels in mineral soils. Such surface wood litter can hamper field operations such as compaction as they are just pushed into the soil only to be exposed later. The common practice is to clear the planting line of this litter by pushing them onto the stack row. This is also an additional cost.

Organic soil material class

This land characteristic refers to the type of organic or mineral soil materials that make-up the upper 100 cm [surface tier (0-50 cm) and subsurface tier (50-100 cm)]. This characteristic is similar to the particle-size class used in mineral soils. The particle-size classes used in organic soils are shown in *Figure 7.2.*

Depth to buried wood layer

Buried wood, often in the size of logs, occur in the deep organic soils. These pieces of wood may be decomposed or undecomposed. The presence of such wood hampers drain construction and, if the wood is undecomposed, costly chainsaw operations are required to cut the wood. The presence of buried wood often also results in termite activity which subsequently attack the palms. Palms planted over buried wood are often stunted (Mathews and Clarence, 2004) and may die.

Nature of buried wood

The buried wood may be decomposed or undecomposed. Undecomposed wood presents a bigger problem compared to decomposed wood especially during drain construction.

Nature of mineral substratum

The nature of the mineral substratum, particularly in the shallow organic soils, influences the fertility status and hence palm growth.

Soil chemical conditions

Most tropical organic soils are of low fertility status and are very acidic unless they are underlain by calcareous materials. Where the organic soils are shallow or moderately deep and occur near the coast their fertility status can be better and this is reflected in higher cation exchange capacity and exchangeable cations. However the influence of sea-water increases the salinity and this can be detrimental to many crops. The fertility status of the organic soils is best determined in the surface tier (0-50 cm). The fertility status of the soil unlike its physical soil condition can be readily modified by the use of fertilizers and other cultural practices.

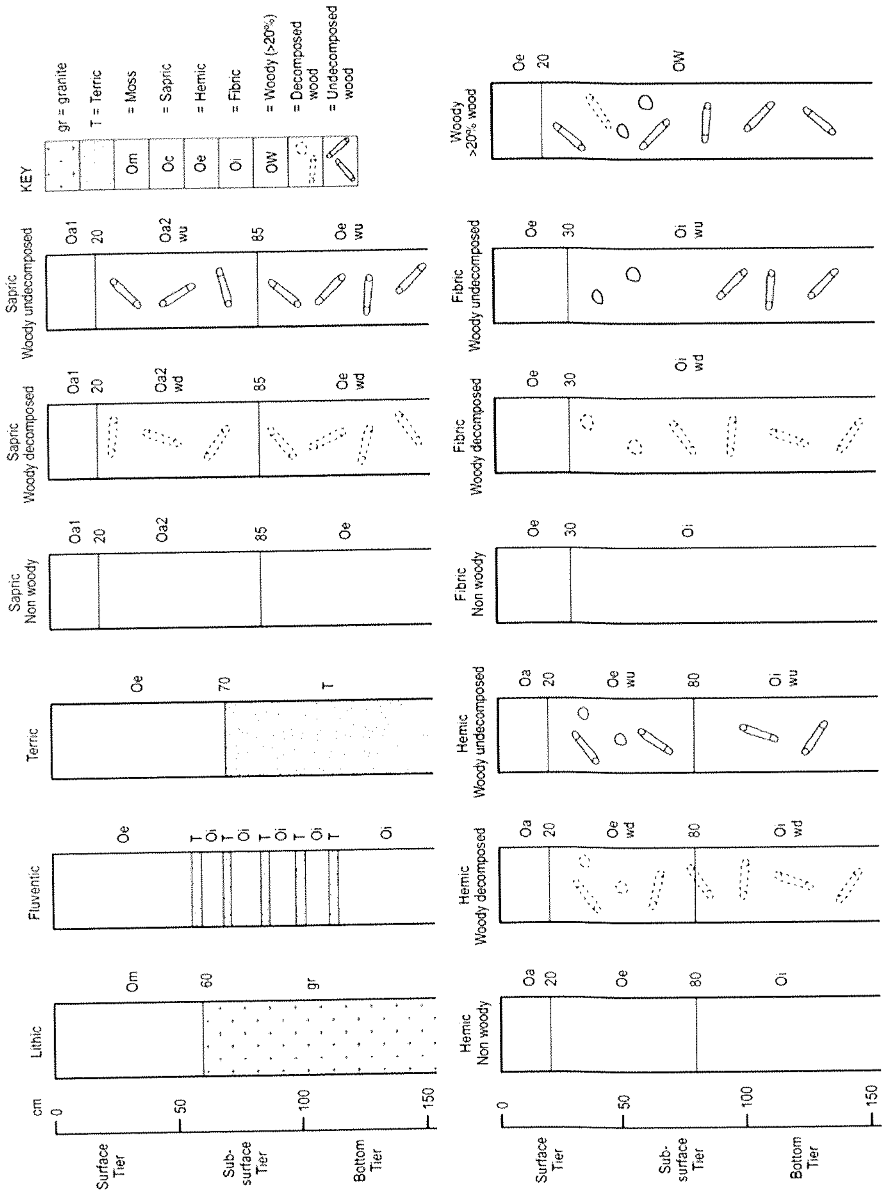

Figure 7.2. Soil morphology classes for organic soils

Land Suitability Evaluation Procedure for Organic Soils

Classification system

The land/soil suitability classification system utilized corresponds to that of FAO (1976). The framework in this system consists of three hierarchal categories: orders, classes and subclasses.

At the highest level two orders are used and defined as follows:

- **Suitable (S)** : Land on which sustained use for the defined purpose and manner is expected to yield benefits that will justify recurrent inputs without unacceptable risk of damage to the resource base.
- **Unsuitable (N):** Land having qualities that appear to preclude its sustained use for the defined purpose and manner.

The classes reflect degrees of suitability within the above orders. Three classes are recognized under the suitable Order and two classes under the Unsuitable Order. An outline of the suitability classification system is presented in *Table 7.12*.

Subclasses indicate specific limitations within the classes. A total of ten limitations are recognized and considered in the evaluation as follows:

c – climate

d – depth/thickness of organic layer

f – fertility status

g – depth to ground watertable/drainability

n – nature of buried wood

l – surface wood litter

m – organic soil material class

s – depth to buried wood layer

t – nature of mineral substratum

w – surface woodiness

Suitability assessment procedure

The individual land characteristics for each of the soil mapping units are summarised in *Table 7.13*. These qualities are in turn evaluated for oil palm. This rating is assigned to the land characteristics based on the criteria and class limits set out for oil palm planted on organic soils (*Table 7.11*, Paramananthan, 2013a).

An example of the evaluation assessment of the climate of a study area for oil palm is given in *Table 7.14*. The evaluation for each of the other land characteristics of the organic soil mapping units with respect to oil palm is presented in *Table 7.15*. For each soil mapping unit, an overall rating for oil palm cultivation is given at the bottom of the table.

In assigning an overall suitability rating to each soil mapping unit for a particular crop the lowest or worst suitability rating determines the overall rating. This is then summarised in *Table 7.16*.

TABLE 7.12. LAND SUITABILITY CLASSIFICATION SYSTEM

Order	Class	Definition
S Suitable	S1 Highly Suitable	Land having no significant limitations of the sustained application of the defined use.
	S2 Moderately Suitable	Land having limitations which in aggregate are moderately severe for sustained application of the defined use. Productivity will be significantly lower, and/or inputs will be significantly greater than the S1 Land.
	S3 Marginally Suitable	Land having limitations which in aggregate are severe for the sustained application of the defined use. Productivity will be so reduced and/or the required inputs will be so high that the use of this land will be only marginally justified.
N Unsuitable	N1 Currently Unsuitable	Land having qualities that appear to preclude its sustained use for the defined purpose and manner which can however be overcome.
	N2 Permanently Unsuitable	Land having qualities that are difficult if not too costly to overcome for sustained use for the defined purpose and manner.

TABLE 7.13. LAND CHARACTERISTICS OF THE ORGANIC SOIL MAP UNITS

Land characteristics	Soil map unit					
	Lgi/sh	Brm/md	Kba/md	Tel/d	Krp/vd	Gdg/vd
Depth to ground watertable (cm)	40	50	60	60	60	60
Drainability	drained	drained	drained	drained	drained	drained
Depth/Thickness of organic materials (cm)	50-100	100-150	100-150	150-300	300+	300+
Surface woodiness (%)	<10	<10	<10	10-30	10-30	10-30
Surface wood litter (%)	<25	<25	<25	25-50	25-50	25-50
Organic soil material class	sa	sa	sa	sa	sa	he
Depth to buried wood layer (cm)	100+	100+	75-100	75-100	75-100	75-100
Nature of buried wood to 100 cm depth	none	none	de	de	ud	de
Nature of mineral substratum	mc	ms	ms	ms	rc	rc
Fertility status (CEC)	low	low	low	low	low	low
Salinity (50 cm) (dS/m)	<1	<1	<1	<1	<1	<1

Key:
sa = sapric
he = hemic
fi = fibric
de = decomposed
ud = undecomposed
mcs = marine clay sulfidic
mc = marine clay
mss = marine sand sulfidic
ms = marine sand
rc = riverine clay

TABLE 7.14. AN EXAMPLE OF THE CLIMATIC EVALUATION OF A STUDY AREA (ORGANIC SOILS)

Characteristic	Climatic evaluation for				
	Oil palm	Acacia	Perennial crops	Annual crops	Sago palm
Annual rainfall	S1	S1	S1	S1	S1
Dry months (<100 mm)	S1	S1	S1	S1	S1
Mean annual temperature	S1	S1	S1	S1	S1
Overall climatic evaluation (Organic soils)	S1	S1	S1	S1	S1

Key : S1 = Highly Suitable
NOTE : Climatic data used — Taniku 1 & Taniku 2 Estates (mean 2001-2009)
Rainfall: 2,931 mm
Dry month (<100 mm): 0
Mean Annual temperature (°C): 29°C

TABLE 7.15. LAND SUITABILITY EVALUATION FOR OIL PALM – ORGANIC SOIL MAP UNITS

Characteristics	Suitability rating of soil map unit for oil palm					
	Lgi/sh	Brm/md	Kba/md	Tel/d	Krp/vd	Gdg/vd
Climate	S1	S1	S1	S1	S1	S1
Depth to ground watertable	S1	S1	S1	S1	S1	S1
Drainability	S1	S1	S1	S1	S1	S1
Thickness of organic materials	S1	S1	S1	S2	S3	S3
Surface woodiness	S1	S1	S1	S2	S2	S2
Surface wood litter	S1	S1	S1	S2	S2	S2
Organic soil material class	S1	S1	S1	S1	S1	S2
Depth to buried wood layer	S1	S1	S2	S2	S2	S2
Nature of buried wood	S1	S1	S2	S2	S3	S2
Nature of mineral substratum	S1	S1	S1	S3	S1	S1
Fertility status	S3	S3	S3	S3	S3	S3
Salinity	S1	S1	S1	S1	S1	S1
Overall rating:						
Current	S3f	S3f	S3f	S3f	S3dfh	S3df
Potential*	S2f	S2f	S2fh	S2f	S2dfh	S2fh

Suitability Class:

S1 = Highly Suitable
S2 = Moderately Suitable
S3 = Marginally Suitable
N1 = Currently Not Suitable
N2 = Permanently Not Suitable

Limitations:

c = climate
d = depth/thickness of organic layer
f = fertility status
g = depth to groundwatertable/drainability
n = nature of buried wood
l = surface wood litter
m= organic soil material class
s = depth to buried wood layer
t = nature of mineral substratum
w= surface woodiness

** Economics not considered.*

TABLE 7.14. AN EXAMPLE OF THE CLIMATIC EVALUATION OF A STUDY AREA (ORGANIC SOILS)

Soil map unit	Soil suitability subclass	
	Current	Potential*
Lgi/sh/1	S3f	S2f
Brm/md/1	S3f	S2f
Kba/md/1	S3f	S2fh
Tel/d/1	S3f	S2f
Krp/vd/1	S3dfh	S2dfh
Gdg/vd/1	S3df	S2fh

Suitability Class:

S1 = Highly Suitable
S2 = Moderately Suitable
S3 = Marginally Suitable
N1 = Currently Not Suitable
N2 = Permanently Not Suitable

Limitations:

c = climate
d = depth/thickness of organic layer
f = fertility status
g = depth to groundwatertable/drainability
n = nature of buried wood
l = surface wood litter
m= organic soil material class
s = depth to buried wood layer
t = nature of mineral substratum
w= surface woodiness

** Economics not considered.*

Conclusions

More work needs to be done on the suitability evaluation of organic soils. These predictions of suitability need to be tested against actual yields before the land evaluation tables proposed here can be finalized. As the management of oil palms planted on peat improve more updates may be required.