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Soil Suitability Classification Systems For Hevea brasiliensis *Cultivation*

F.K. YEW* AND H.Y. CHAN*

Four systems of soil suitability classification for Hevea brasiliensis, *viz, Soil Suitability Classification System for Rubber, Soil Suitability Technical Grouping System for Rubber, Soil Suitability Evaluation System for Rubber using Land Characteristics, and Soil Suitability Evaluation System for Rubber using Land Qualities, were tested for thirteen common soils in Peninsular Malaysia. The first system is non-parametric and simple to use but lacks precise definitions of criteria, which leads to much subjectivity in usage. The others are more precise in their definitions of criteria and also parametric in approach. The second system is an additive system while the last two are multiplicative systems. Among the parametric systems, the multiplicative systems are superior in soil classification and yield prediction.*

All the systems correctly classify the very suitable and the unsuitable soils for rubber. However, they have different abilities to classify soils which have suitabilities between these two levels. The last system, which uses land qualities as diagnostic criteria, was found to be the best system as it predicted soil suitability better than the others.

Soil suitability evaluation is the process of assessing the suitability of the soil for a specific use. Such an assessment can be obtained from the interpretation of soil survey information. For *Hevea*, the earliest attempt of such an assessment was a system proposed by Hamilton[1] in 1936 where six soil properties were used to evaluate the fertility of a soil and these were related to performance. Except for texture, the other five attributes used in the system were chemical indices of soil nutrient status.

In 1972, Chan and Pushparajah[2] developed a system known as the *Soil Suitability Classification System for Rubber*. This system was based on the number and type of soil attributes imposing limitations to rubber cultivation. Later on, parametric systems were tried such as the *Soil Suitability Technical Grouping System for Rubber*[3] in 1975 using the addition method and *Soil Suitability Evaluation System for Rubber using Land Characteristics*[4] and *Soil Suitability Evaluation System for Rubber using Land Qualities*[4]. The last two were multiplicative systems and were developed in 1982.

The four systems of evaluating soil suitability proposed to-date for rubber utilise different concepts, principles and approaches. An attempt is made here to compare the merits and demerits of these systems to grade soils for rubber cultivation.

MATERIALS AND METHODS

Thirteen common soils in Peninsular Malaysia (*Table 1*) were used for the study. The soils were chosen as they cover a wide spectrum of morphological, physical

*Rubber Research Institute of Malaysia, P.O. Box 10150, 50908 Kuala Lumpur, Malaysia

and chemical properties commonly found in soils under rubber in Peninsular Malaysia. Their main properties are shown in *Table 2*, and have been condensed from complete soil profile descriptions and characterisation[4].

The soils were classified according to the four systems:

- System 1. Soil Suitability Classification System for Rubber[2]
- System 2. Soil Suitability Technical Grouping System for Rubber[3]
- System 3. Soil Suitability Evaluation System for Rubber using Land Characteristics[4]
- System 4. Soil Suitability Evaluation System for Rubber using Land Qualities[4]

In *System 1*, the soil criteria are categorised into nil, minor, serious and very serious limitations to rubber cultivation. Based on these, soils are placed into five soil suitability classes as follows:

- Class I. Soils with no limitations to rubber cultivation
- Class II. Soils with one or more minor limitations to rubber cultivation
- Class III. Soils with at least one serious limitation to rubber cultivation
- Class IV. Soils with more than one serious limitation to rubber cultivation
- Class V. Soils with at least one very serious limitation to rubber cultivation.

In *System 2*, sixteen soil and landscape criteria are graded as having nil, minor, serious or very serious limitations to rubber cultivation. The criteria are rock out-crop, effective soil depth, texture, consistency, structure, internal drainage, peat characteristic, acid sulphate characteristic, moisture retention, permeability, erodibility, pH, levels of N, P, K and Mg, terrain, susceptibility to flooding and stagnation of water at the soil surface.

TABLE 1 SOILS USED FOR THE STUDY

Soil	Parent material	Soil taxonomy (sub-group level)	FAO
Linau	Marine alluvium	Typic Sulfaquent	Thionic Fluvisol saline phase
Briah	Mixed riverine/ marine alluvium	Typic Fluvaquent	Dystric Fluvisol
Chat	Argillaceous shale	Typic Kanhapludult	Ferric Acrisol
Durian	Argillaceous shale	Typic Kanhapludult	Ferric Acrisol
Serdang	Sandstone	Typic Kandiudult	Dystric Nitosol
Rengam	Granite	Typic Kandiudult	Dystric Nitosol
Harimau	Older alluvium	Typic Kandiudult	Dystric Nitosol
Kuantan	Basalt	Typic Hapludox	Orthic Ferralsol
Munchong	Argillaceous shale	Typic Hapludox	Xanthic Ferralsol
Segamat	Andesite	Rhodic Hapludox	Rhodic Ferralsol
Malacca	Argillaceous shale	Petroferric Hapludox	Xanthic Ferralsol petric phase
Holyrood	Riverine alluvium	Xanthic Hapludox	Xanthic Ferralsol
Peat	Organic material	Hydric Troposaprist	Dystric Histosol

TABLE 2. MAIN PROPERTIES OF THE SOILS STUDIED

Soil	Horizon development 0-150 cm	Water table at depth (cm)	Soil colour at 50-100 cm	Texture at 50-100 cm	Moist consistency	Common soil structure	Slope (%)	Fertility[a]	Soil pH[b] at 50-100 cm
Linau	A (B) Cg	50	2.5Y3/2	SiCl	Firm	mod. coarse SBK	1-2	H(N,K)	2.9
Briah	A (B) Cg	160	7.5YR6/2	SiC	Firm	v st. coarse ABK	1-2	H(K,Mg)	4.1
Chat	A Bt C	> 160	10YR6/6	C	Firm	mod. st coarse SBK	16-24	H(K, Mg)	4.6
Durian	A Bt C	> 160	10YR7/4 & 7.5YR6/6	SiC	Firm	strong v. coarse SBK	9	H(K)	4.1
Serdang	A Bt	> 160	7.5YR5/8	SCL	Very friable	mod. med. SBK	25	L	4.6
Rengam	A Bt	> 160	10YR7/8	C	Friable	mod. st coarse SBK	4-7	L	4.8
Harimau	A Bt	> 160	10YR6/6	SCL	Friable	mod. med. SBK	9	L	4.6
Kuantan	A Box	> 160	7.5YR4/4	C	Friable	mod. med. SBK	2-3	H(P)	4.7
Munchong	A Box	> 160	7.5YR5/6	C	Friable	mod. med. SBK	4	M(P)	5.2
Segamat	A Box	> 160	2.5YR3/6	C	Friable	weak med. SBK	3-8	H(P)	4.7
Malacca	A Bcn	> 160	7.5YR6/6	C with 50% laterites	nd	nd	15	L	5.0
Holyrood	A B	> 160	7.5YR7/8	Coarse SCL	Friable	weak coarse SBK	1-2	L	4.7
Peat	Oa	120	2.5YR2.5/4	Sapric	nd	mod. fine crumbs	1-3	VH(N,Mg)	3.2

Si = silt, C = clay, L = loam, S = sand, nd = not determined, mod = moderate, v = very, st = strong, SBK = sub-angular blocky, ABK = angular blocky, med = medium

[a] All soils are low (L) in nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) status unless otherwise stated. H = high; M = medium

[b] pH in 1:1 water

The method adds up the scores for the sixteen criteria (scores being 5 points for a desirable feature, 4 for a minor limitation, 2 for a serious limitation and 1 for a very serious limitation). The total scores are converted to percentage values. Such values are then used to group the soils into five soil suitability classes which are defined in the first system.

System 3 evaluates the soils according to land characteristics[5] *viz.* slope, drainage, flooding, texture/structure, surface and sub-surface stoniness, soil depth, weathering stage and organic carbon content. These criteria are graded into non-limiting, slight, moderate, severe and very severe limitations; a sliding scale of scores ranging from 100 (non-limiting) to 0 (very severe) as defined by Sys[6] is used.

The scores are multiplied by depth correction indices as shown in *Table 3* to give relative importance to the top soil horizons.

The soil index value is obtained by a multiplication system thus:

$$\text{Soil index} = \frac{A_1 \times A_2 \times A_3 \times \ldots\ldots\ldots A_n}{10^{2n-2}}$$

where A_1, A_2, A_3, ... A_n are ratings for the various diagnostic criteria after depth correction.

The structure of the soil suitability classification system follows that suggested by FAO[7]. It differs from the FAO system in that the parametric approach is combined within the system:

TABLE 3 DEPTH CORRECTION INDICES

Soil depth (cm)	Depth correction index
0 – 25	× 3.40
26 – 50	× 1.40
51 75	× 0.36
76 – 100	× 0.32
101 – 125	× 0.28
126 – 150	× 0.24

Order S. Suitable.
Soil units with no, slight or moderate limitations and no more than two severe limitations that, however, do not exclude the use of the soil. The soil index is more than 25.

Class S1. Highly suitable.
Soil units with no or only slight limitations which, in combination, give soil index values ranging from 75 to 100.

Class S2. Moderately suitable.
Soil units with slight or moderate limitations which, in combination, give soil index values ranging from 50 to 74.

Class S3. Marginally suitable.
Soils units with moderate limitations which, in combination, give soil index values ranging from 25 to 49.

Order N. Not suitable.
Soil units with more than two severe limitations or with at least one very severe limitation that exclude the use of the land. The soil index is normally 24 or less.

Class N1. Currently not suitable.
Soil units with severe or very severe limitations which may be overcome in time but which cannot be corrected with existing knowledge at currently acceptable cost.

Class N2. Permanently not suitable.
Soil units having limitations which appear so severe as to preclude any possible use of the soil in the given manner.

The kinds of limitations are reflected in the soil suitability sub-classes. As an example, a moderately suitable soil with limitations associated with soil erosion is designated as S2e.

System 4 is a soil evaluation system based on the use of land qualities[7] *viz.* available foot-hold for roots, available nutrients, favourable soil pH, absence of salinity, availability of oxygen, availability of water, soil erosion hazard, accessibility/trafficability, flooding hazard and workability/planting operation facilities as a function of rock out-crops. The parametric approach and structure of this system is the same as in *System 3.*

The soil suitability classes obtained by the four systems were then compared to yield performance[8] of rubber obtained from site-specific field studies.

RESULTS AND DISCUSSION

Differences between Classification Systems

Soils can be grouped into five Soil Productivity Classes[2] which have also been called Soil Suitability Classes[9] using *System 1.* Chan and Pushparajah[2] did not distinguish between actual and potential soil suitabilities in their system; actual soil suitability being the soil suitability for a specified use in its present condition, without any soil improvements while its potential suitability is the soil suitability after the specified soil improvements have been made. Experience in using the system indicates that the use of the potential suitability for classifying the soils under this system is more appropriate; its suitability takes into account that soils of low fertility can be corrected by discriminatory fertiliser usage[10]. Terracing, soil erosion control and drainage of excessive water in water-logged areas are also carried out when necessary.

With reference to the potential suitability, the *Class I* soils are Rengam, Harimau, Kuantan, Munchong and Segamat series. The *Class III* soils are Chat, Serdang, Malacca and Holyrood series. The *Class IV* soils are Durian, Linau and Briah while the *Class V* soil is Peat. No *Class II* soils are encountered in this study. *Table 4* also shows the actual suitability of the soils.

System 1 lacks precise definitions for the diagnostic criteria, leading to much subjectivity in interpretation. As an example, sub-optimal soil nutrient status as reflected by low contents of N, P, K and Mg is considered to be a minor limitation while a very poor soil nutrient status is a very serious limitation. It is not clear whether the low nutrient status of *System 1* is synonymous to that defined by Guha and Yeow[11]. This vague definition also lends subjectivity in placing soils in the different soil suitability classes when they have different combinations of nutrient status e.g. Rengam series which has very low K and Mg status and is low in N and P.

The *Soil Suitability Technical Grouping System (System 2)* is an additive system giving equal weightage to all the sixteen parameters used. This is a more objective method of soil suitability evaluation compared to the first system. The classification of the soils using this method generally conforms to similar soils evaluated by Chan *et al*[3]. The only differences are seen in the classification of Briah series (*Classes III, Va*), Segamat (*Classes IIa, Ib*) and Malacca (*Classes III, IV*) as shown in *Table 5.*

Some vagueness in definition of criteria is noted. As an example, the limitation levels for the criterion of pH can be improved since *System 2* considers only pH values from 4.3 to 6.0. This gives rise to difficulty in classifying soils with sulphuric horizons e.g. Sulfaquent (Linau series) with an average soil pH of 3.2.

Similarly, the placement of soils according to their contents of sand, silt and clay fractions rather than soil textural classes also poses problems for the classification of Durian series which has 50%-70% clay (minor limitation), while its silt + clay content is 70%-90% (serious limitation). The texture criterion can be better defined, without causing ambiguity, by referring to soil textural classes.

This system also shows that if a parametric approach is combined with a non-parametric approach in a single system, this may lead to conflicts in classification. As an example, soils with serious limitations of low nutrient status e.g. Harimau, Kuantan, Munchong and Segamat series should be classified as *Class III* soils. However, if the soil scores are used they are classified as *Classes I* and *II* soils.

The soil suitability classes given in *Table 4* are based on the soil scores. The *Class I* soils are Rengam, Kuantan and Munchong. Segamat, Chat and Harimau series are *Class II* soils while Briah,

TABLE 4. SOIL SUITABILITY CLASSES OF SOILS FOR RUBBER AND SOIL LIMITATIONS USING SYSTEM 1

Soil	Soil suitability class			Limitations
	Actual	Potential	Potential[a]	
Linau	IV	IV	V	Permanent water table at 20-50 cm from surface (s) poor structure. massive (s)
Briah	IV	IV	V	Strong compaction (s) poor structure. massive (s)
Chat	III	III	–	Moderately well drained, mottles at 64-126 cm (m) slope 16%-24% (s)
Durian	IV	IV	IV	Strong compaction (s) susceptible to moisture stress (s)
Serdang	IV	III	II	Slopes 25% (s) very low N and P status (s)
Rengam	II	I	I	Very low K and Mg status, but low in N and P (m)
Harimau	II	I	I	Susceptible to soil erosion (m)
Kuantan	II	I	I	Susceptible to soil erosion (m) low N, K but very high P and just below medium Mg(?)
Munchong	II	I	I	Susceptible to soil erosion (m) low N, K and Mg, medium P(?)
Segamat	II	I	I	Susceptible to soil erosion (m) low N and K; just below Mg and high P (?)
Malacca	III	III	IV	Susceptible to moisture stress (s) low K, Mg, just below medium N, medium P(?)
Holyrood	III	III	III	Susceptible to moisture stress (s) low N, P, K, Mg (m)
Peat	V	V	V	Acid peat layer > 20 cm thick at or near surface (vs)

[a] Similar soils as classified by Chan and Pushparajah[2]
– Not studied
m Moderate limitation
s Serious limitation
vs Very serious limitation
? Subjectivity in classification

TABLE 5 SOIL SUITABILITY CLASSES OF SOILS FOR RUBBER AND SOIL LIMITATIONS USING SYSTEM 2

Soil	Soil score (%)	Soil suitability class	Soil suitability class[a]	Limitations	
Linau	60	Vb	Vc	Very serious Serious	floods after light downpour – water stagnates for > 3 days – poor internal drainage – low pH – shallow effective depth > 70%-90% silt + clay extremely sticky wet consistency – very slow permeability
Briah	79	III	Va	Serious	– strong coarse sub-angular blocky – imperfectly drained slow permeability floods after heavy rain – water stagnates
Chat	89	IIa	[b]	Serious	– low nutrient status
Durian	75	IVa	IVa	Very serious Serious	– strong very coarse sub-angular blocky – very firm consistency – > 70%-90% silt + clay – low nutrient status – slow permeability
Serdang	80	III	III	Serious	– low nutrient status – rapid permeability – terrain 25% – > 70%-90% sand
Rengam	91	Ib	Ib	Serious	– low nutrient status
Harimau	89	IIa	Ib	Serious	– low nutrient status
Kuantan	91	Ib	Ib	Serious	– low nutrient status
Munchong	93	Ib	Ib	Serious	– low nutrient status
Segamat	90	IIa	Ib	Serious	– low nutrient status
Malacca	80	III	IV	Very serious Serious	< 25 cm effective soil depth – more laterite stones than fine earth, poor structure – low nutrient status
Holyrood	79	III	III	Serious	– > 70%-90% sand – low nutrient status – somewhat excessively drained – rapid permeability – poor moisture retention
Peat	54	Vc	Vd	Very serious	– acid peat layer < 25 cm from surface and 50–100 cm thick

[a] Similar soil series as classified by Chan *et al*[3]

[b] Soil not encountered and classified by Chan *et al*[3]

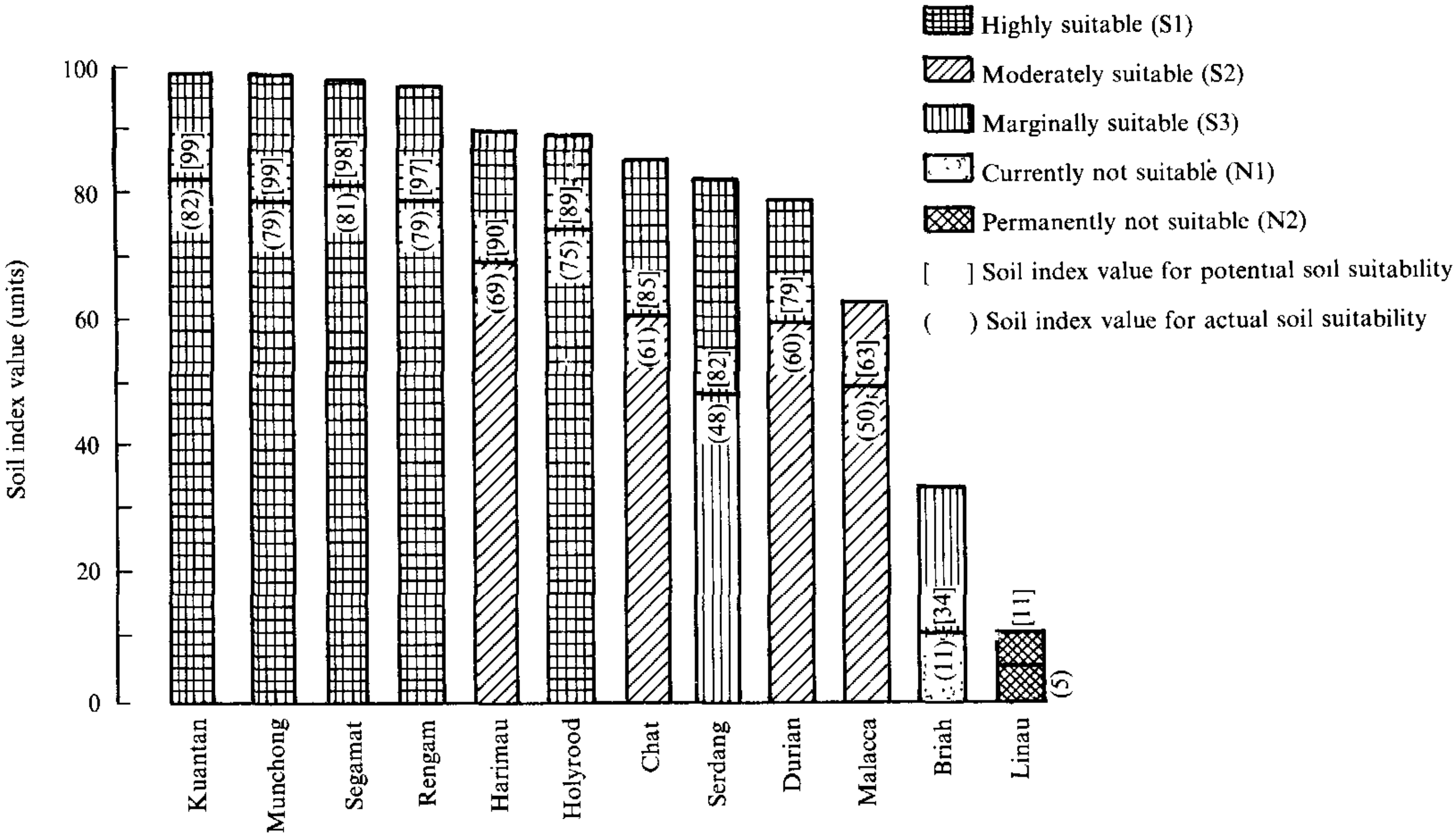

Figure 1. Actual and potential suitability of soils classified by land characteristics.

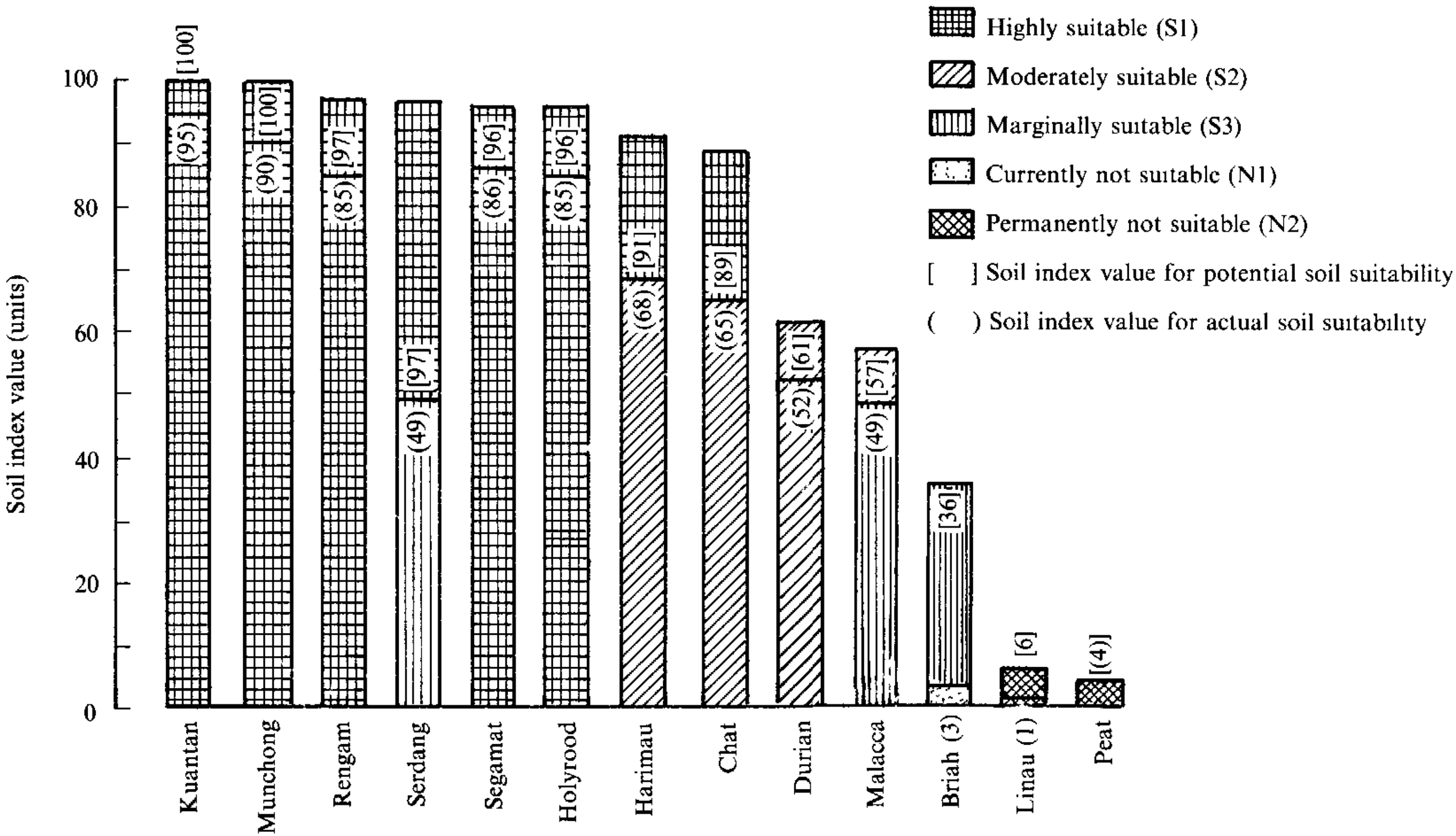

Figure 2. Actual and potential suitability of soils classified by land qualities

Serdang, Malacca and Holyrood series are *Class III* soils. A *Class IV* soil is Durian series while Peat and Linau series are *Class V* soils.

Use of *System 3* indicates that all the soils are highly suitable for rubber cultivation, with the exception of Harimau, Chat, Durian and Malacca series which are moderately suitable (*Figure 1*). Serdang series is marginally suitable. Briah series is currently not suitable while Linau series is permanently not suitable for rubber cultivation. Peat cannot be evaluated by the criteria which were developed for evaluating mineral soils.

As for potential suitability, all the soils are highly suitable except Malacca series which is moderately suitable. Briah series is marginally suitable while Linau series is permanently unsuitable for rubber cultivation.

The actual and potential suitabilities of the soils calculated using *System 4* are shown in *Figure 2*. With regards to the potential suitability, all the soils are highly suitable for rubber cultivation, except Durian and Malacca series which are moderately suitable while Briah series is marginally suitable. Both Linau series and Peat are permanently not suitable for rubber cultivation.

The multiplicative method used in the third and fourth systems is an improvement over the additive method used in the second system since the multiplication procedure permits a certain interaction between factors and the operation of the 'law of the minimum'[12]. However, its usage is more laborious than the additive method.

TABLE 6. SOILS CLASSIFIED BY DIFFERENT SYSTEMS AND THEIR RELATIONSHIP TO YIELD

Soil	System				Yield (units)
	1[a]	2	3[a]	4[a]	
Rengam	I	I	S1	S1	1.00
Harimau	I	II	S1	S1	1.00
Kuantan	I	I	S1	S1	1.00
Munchong	I	I	S1	S1	1.00
Segamat	I	II	S1	S1	1.00
Chat	III	II	S1	S1	1.00
Serdang	III	III	S1	S1	1.00
Holyrood	III	III	S1	S1	1.00
Malacca	III	III	S2s	S2d	0.87
Durian	IV	IV	S1	S2ds	0.77
Briah	IV	III	S3w	S3wd	0.50–0.75
Linau	IV	V	N2ws	N2wz	<0.5
Peat	V	V	–	N2da	<0.5

[a] Potential suitability
– Not evaluated
Suffixes denote soil limitations

a = soil acidity conditions
d = availability of foothold for roots
e = soil erosion hazard
w = wetness
s = physical soil conditions
w = availability of oxygen
z = salinity

Land qualities are complex land attributes and their evaluations are usually more complicated. Several criteria are commonly used to evaluate one land quality. As an example, long and detailed calculations are required to assess just one criterion of 'availability of water to rubber' using the Doorenbos and Pruitt[13] method by considering crop-water requirements, precipitation, available water-holding capacity of the soil in the root zone, and contribution from the ground-water. Hence, more data collection is required for *System 4* than for the other three systems, which is a disadvantage for using it.

Efficacy of the Systems and Rubber Yield Relationship

Rengam, Harimau, Kuantan, Munchong and Segamat series are considered to be very suitable (SI, I and II) soils for rubber cultivation by all the four methods as seen in *Table 6*. The unsuitable soils for rubber, namely Peat and Linau series, are correctly classified by all the four methods with the exception of *System 3* which is unable to classify non-mineral soils. The soils that are classified quite differently by the four systems are: Chat series (III, II, S1, SI), Serdang and Holyrood series (III, III, S1, SI), Durian series (IV, IV, S1, S2) and Briah series (IV, III, S3, S3).

Based on site-specific field studies, rubber yields[8] on Chat, Serdang, Rengam, Segamat and Holyrood series (in moist regions) were found to be high as shown in *Table 5*. *Systems 3* and *4* rated these soils as highly suitable soils for rubber while *System 1* under-estimated the productivity of Chat, Serdang and Holyrood series. The productivity of the last two soils were also under-estimated by *System 2*.

The rubber yields on Durian series were found to be 77% that obtained on the highly suitable (S1) soils. Both *Systems 1* and *2* classified it as a *Class IV* soil and hence, had under-estimated the productivity of the soil while *System 3* over-estimated it.

Yields on Briah series were average and the soil was rated as a marginal soil (*Class S3*) by *Systems 3* and *4*, *Class III* by *System 2* and *Class IV* by *System 1*; *indication of an under-rating by System 1.*

The decreasing ability of the classification systems to predict rubber yield performance arranged from left to right was *System 4*, *System 3*, *System 2* and *System 1*. Regression analysis for the soil indices obtained by the three parametric systems *viz*. *System 2* (*Table 5*), *System 3* (*Figure 1*) and *System 4* (*Figure 2*) with yield (*Table 6*) confirmed that the highest correlation was obtained for *System 4* followed by *Systems 3* and *2* as shown in *Table 7*. Significant correlations between rubber yields in the field and soil indices had also been reported earlier for *Systems 2*[14], *3*[4] and *4*[4].

TABLE 7. RELATIONSHIP BETWEEN SOIL INDICES AND YIELD OF RUBBER

System	Correlation coefficient (r)	Yield equation index
2	0.891	$Y = 1.462X - 31.38^{***}$ (0.2251)
3	0.946	$Y = 0.586X + 44.54^{***}$ (0.0637)
4	0.986	$Y = 0.551X + 47.26^{***}$ (0.0283)

Y = yield units
X = soil index value
*** = Significant at $P < 0.001$
Potential soil index values are used in *Systems 3* and *4*.

Although the soil indices obtained by the three systems could predict yield, both multiplicative systems which employed depth correction techniques were superior to the addition method which did not employ depth correction i e *System 2*

System 4 was the only system that used land qualities for evaluation It was the best system and attributed to the fact that land qualities quantified soil features in direct relevance to plant requirements, e g oxygen availability, water availability, *etc* in the soil

CONCLUSIONS

Four methods of soil suitability classification system for rubber have been developed, namely the *Soil Suitability Classification System for Rubber* of 1972 *(System 1)*, *Soil Suitability Technical Grouping System for Rubber* of 1975 *(System 2)*, *Soil Suitability Evaluation System for Rubber using Land Characteristics* of 1982 *(System 3)* and *Soil Suitability Evaluation System for Rubber using Land Qualities* of 1982 *(System 4)*

The first system is non-parametric with a very simple structure based on the number and types in severity of limitations Because of its simplicity, it is the soil suitability classification system used for rubber today However, it lacks precise definitions of the criteria leading to much subjectivity in interpretation

The other systems are parametric, being additive in *System 2* or multiplicative in *Systems 3* and *4* They lead to more objectivity in interpretation Among them, the second system is simple to use but still lacks precise definitions of some of the criteria It rates soils on their actual suitabilities The multiplicative systems are laborious to use, the difficulty being aggravated by the introduction of depth correction indices for all the criteria employed They are superior to the addition method in soil classification and yield prediction

All the four methods can rate both the highly suitable (*Classes S1 I*) and unsuitable soils (*Classes N V*) for rubber correctly They vary in sensitivity to classify soils that fall between these two classes Among them, the fourth system, using land qualities, is favoured as it classifies soil suitability most correctly

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REFERENCES

1 HAMILTON, R A (1936) Notes on Tropical Soils with Special Reference to Malayan Soils for Rubber Cultivation *Rubb Res Inst Malaya*, **7**, 27

2 CHAN, H Y AND PUSHPARAJAH, E (1972) Productivity Potentials of *Hevea* on West Malaysian Soils *Proc Rubb Res Inst Malaysia Plrs Conf Kuala Lumpur* 97

3 CHAN, H Y , PUSHPARAJAH, E YEW, F K AND ZAINOL, E (1975) A Soil Suitability Technical Grouping System for *Hevea 3rd ASEAN Soil Conf Kuala Lumpur*, 277

4 YEW, F K (1982) Contribution towards the Development of a Land Evaluation System for *Hevea brasiliensis* Muell Arg Cultivation in Peninsular Malaysia D Sc Thesis submitted to State University of Ghent, Belgium

5 DENT, D AND YOUNG, A (1981) *Soil Survey and Land Evaluation* U K George Allen and Unwin

6 SYS, C. (1978) Evaluation of Land Limitations in the Humid Tropics *Pedologie*, **XXVIII, 3,** 307

7. FOOD AND AGRICULTURE ORGANISATION (1976) A Framework for Land Evaluation *Soils Bull No 32*

8. YEW, F K (1992) *Soil Suitability Evaluation for* Hevea brasiliensis *Cultivation using Land Qualities* Soil Science Conf of Malaysia 1992, Kuala Trengganu.

9 CHAN, H Y. (1974) *Soil Classification in Soils under* Hevea *and their Management in Peninsular Malaysia*, 57 Kuala Lumpur: Rubber Research Institute of Malaysia.

10 CHAN, H.Y (1971) Soil and Leaf Nutrient Surveys for Discriminatory Fertiliser Use in West Malaysian Rubber Holdings *Proc. RRIM Plrs' Conf 1971, Kuala Lumpur*, 201

11 GUHA, M M AND YEOW, K H (1966). Soil and Leaf Nutrient Status in Relation to Soil Type *Rubb Res. Inst Malaysia Plrs' Bull. No. 87*, 170.

12. RIQUIER, J AND SCHWAAR, D C. (1972) Parametric Approach to Evaluation of Soil Productivity *Proc. 2nd ASEAN Soil Conf. Bogor, Indonesia*, 1, 317.

13 DOORENBOS, J. AND PRUITT, W.O (1977) Guide for predicting Crop Water Requirements *Irrigation and Drainage Bull. No. 24*

14. CHAN, H Y. (1985) Classification, Genesis, Mapping and Rubber Productivity (*Hevea brasiliensis*) of Soils developed from Sedimentary Rocks in Peninsular Malaysia Ph. D Thesis submitted to University of Malaya, Kuala Lumpur