

BRIS Soil Suitability Assessment on Sweet Potato in Merang- Terengganu Region of Malaysia

Usman M. Ishaq[1,2*], Babagana Umara[2] ,H.M. Edi Armanto[1,3], M.A. Adzemi[1]
1.Department of Agrotechnology, Faculty of Agrotechnology and Food Science (FASM) UMT - 21030 Terengganu – Malaysia
2.Department of Agricultural Engineering Technology, Ramat Polytechnic, pmb 1070. Maiduguri Borno State, Nigeria
3.Faculty of Agriculture, Sriwijaya University, 30662 South Sumatra, Indonesia
* E-mail: tkbusman@yahoo.com

Abstract
The research objectives focus on the evaluation of the physical properties of BRIS soil; to investigate the limiting factors for sweet potato crop; also to create the awareness of the farmers as to the fertility and soil characteristics for better sweet potato production and the effort to increase sweet potato crop production. Soil fertility status of soil series are classified as very low to low, except Base Saturation because the soils are strongly influenced by sea movement. Soil fertility status of soil series are classified as very low to low, except Base Saturation because the soils are strongly influenced by sea movement. However, Baging and Rhu Tapai soil suitability in terms of nutrient where mostly M/nU/d, with SU at the slope; for Rudua and Jambu they are mostly S with no trace of some soil criteria. However the needed efforts required in improving the soil capability from actual to potential soil suitability for sweet potato cultivation can be seen in the agronomic requirement table above. Hence, cover the soils with mulch, make sprinkle irrigation, make dam for water holding and retention, give and maintain organic matters in the soils and do not burn biomass, fertilize soils with NPK and organic fertilizers.
Keywords: Suitability, assessment, Bris soil series, Soil Profile, Terengganu

INTRODUCTION

The benefit of input in all ramifications is to enhance a specific product (soil) with a great preference of outcome which will be of important requisites in the development of agricultural product. The suitability evaluation of soil is usually determined by the robust success of produce cultivated in the study area. Undoubtedly, the assessment has often been used in reference to the term evaluation and attributes to the summery of a particular situation, thereby contributing to adequate experimental or analytical information about the soil. However, the basis criterion for a particular crop suitability classification is mainly aimed on the soil physical properties. Thus, in view of many constraints that are very common in the field of soil science, the study has continued to emulate the basis of soil science experts in the system, in order to produce a comprehensive soil classification.

However, BRIS soil is a problematic soil and as such should be handle traditionally in terms of the physical capability classification, knowing very well the constraints like, limited ability to support crop growth, poorly structured, low water retention, this is as a results of excessive accumulation of sediments and sand from undulating sea during the monsoon seasons that carries along coarse sand particles. Therefore, BRIS (Beach Ridges Interspersed with Swales) soils in Peninsular Malaysia are mostly found near the coastal area in Terengganu with area of 67,582.61 ha, in Pahang around 36,017.17 ha, and in Kelantan about 17,806.20 ha (Armanto et al., 2013).Therefore, the main objective of this article is to evaluate the physical properties of BRIS soil and the effort to increase of maize crop production.

METHODOLOGY

Geography of Study Area

The research sites consist of four selected location in the East coast area of Terengganu, Malaysia and the study was conducted from March to December 2013. The study area lies at the elevations in a range between 0-5 m a.s.l (m above sea level).The slope steepness is 0-3 % with a mean value around 2%. It is located at 05^0 12'20 north and 103^0 12'21 east, with temperature of 29^0c, the vegetation of the area is mostly grasses and shrubs. Some of the selected locations have soil parent materials of sand sediment by using geological maps with 1:50,000 scale. Most of soils are classified as BRIS soils (Entisol and Spodosols). Landsat images help to characterize the boundaries of three locations. The topographic characteristics included slope while the soil properties included soil texture, depth, salinity, and drainage and carbon materials.

Also, soil properties such as Cation Exchange Capacity (CEC), organic matter (%OM) and pH were considered in terms of soil fertility (Sys et al., 1991). A soil profile pit was opened in each land unit, four profile pits in total, and described using soil description guideline (FAO, 1990). Soil classification was made based on FAO (1998).

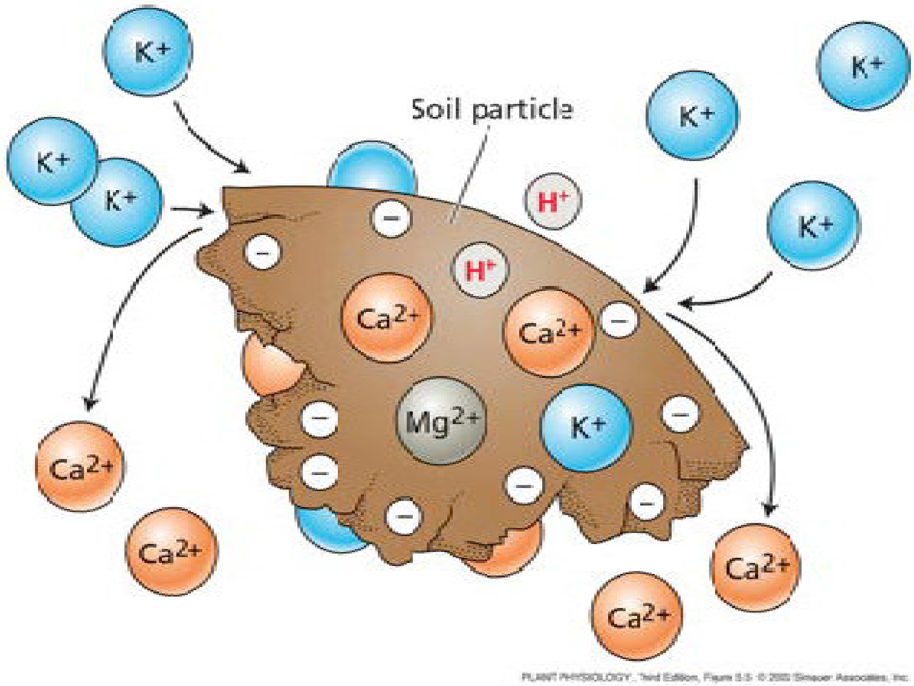

Figure 1: CEC of soil regulates the nutrient absorption in sandy soil

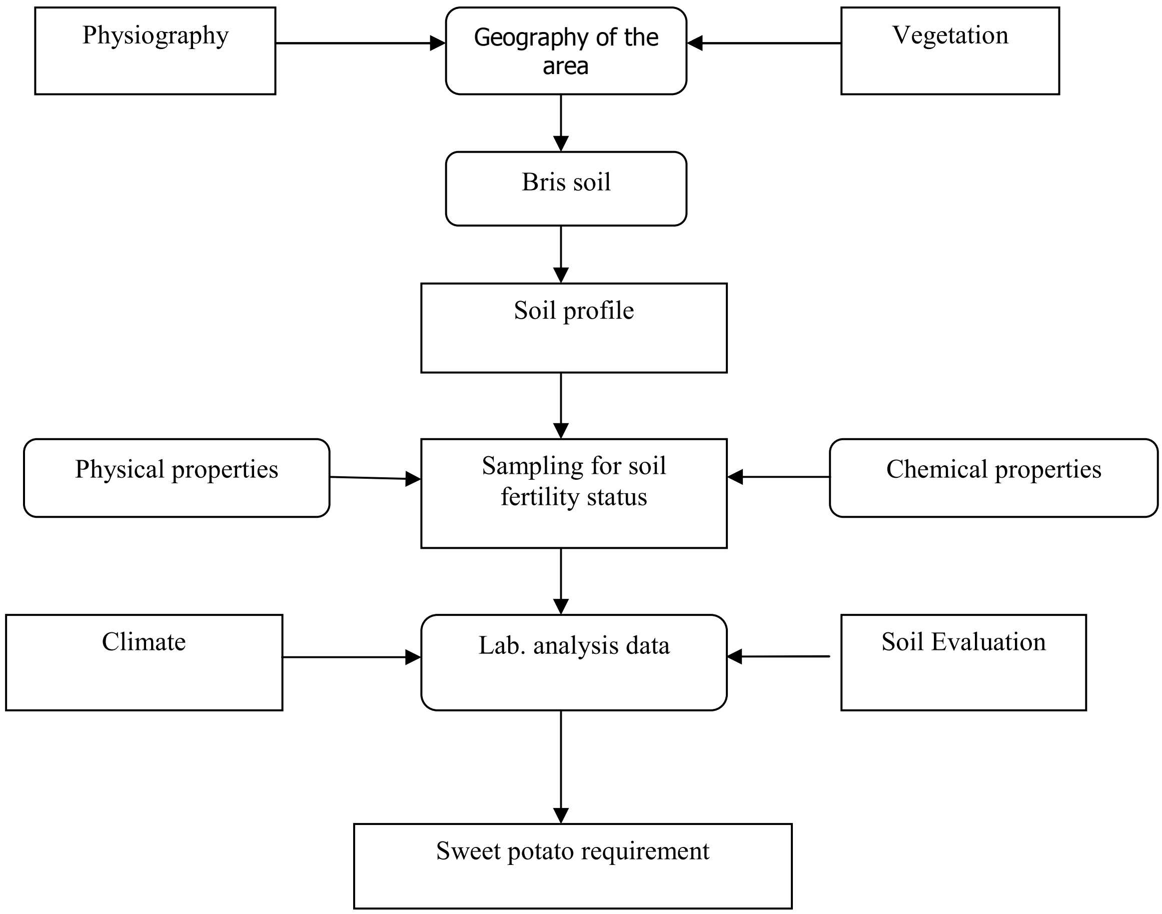

Figure 2: Flowchart for land evaluation.

RESULTS AND DISCUSSIONS

physiography of the study area

The physiographic group of the soil, the subgroup, the soil characteristics, and the land uses of the study area are tabulated in Table 1 and soil map is depicted in figure 3. Whereas the explanation of the soil map legend is included in the soil sample analyses result for each soil mapping unit as represented in table 1 below.

As the work progresses in the study area, the land uses in the locations of alluvial deposit and that of the marine were bushes, shrubs, tree crops, upland crop, plantations of tree crops like oil palm, etc. also in some areas are settlements, home garden. While the peat bog area were mainly dominated with features like oil palm plantation, tree crops, smallholder crop farming, settlements, swampy peat forest, swampy bushes and shrubs, some swampy area are covered with forest, shrubs and bushes as well as rice farm.

Table 1. Physiographical groups, soil subgroups, soil characteristics and land uses of Merang study area.

Physiographic group	Subgroup of Physiography	Soil	Soil characteristic	Land use
Alluvial (fine to coarse soil)	Alluvial plain (transition zone)	isohyperthermic, typic, siliceous, quartzipsamments, psammaquents	Fine – coarse, slightly acidic, very deep.	Rice, ponds, coastal ponds, coconut, swamps.
	Flood plain	Endoaquepts Endoaquents Udifluvents	Deep - very deep, Slightly Acid-neutral Slightly coarse-fine	Rice fields shrubs/ bushes
	River terraces	Sandy, siliceous, isohyperthermic, arenic, alorthods Udifluvents	Deep-very deep, Acidic- neutral, slightly fine-fine	Rice field, upland agricultural farming
Marine (fine to coarse soil)	Beach ridges and swales	isohyperthemic Cryaquods, udipsamments	Deep-Very deep, neutral, coarse (top soil slightly coarse-peaty)	Sparsely coconut, shrubs (casuarinas equisetifolia etc) /bush, settlements,
	Palustarine terrain	Placorthods, Alorthods, Arenic Alorthods Aquic Duricryods	Very deep, neutral, slightly coarse-fine	forest, swampy forest, shrubs/ bush, grass vegetation, mangrove
	Coastal plain	Udispsamment, endoaquepts, eutruquept	Very deep, neutral, slightly coarse-slightly fine	coastal ponds, ponds, rice field, settlement, shrubs/bushes
	Marine tarraces	Dystrudepts, eutrudepts, endoaquepts	Deep-Very deep, acid-neutral, slightly fine	upland agricultural land,
Peat bog (organic matter)	Oligotrophic, peat dome	Haplosaprists, haplohemists	Saprists- hamists > 2m	food crops (vegetables), tree crops, forest, swampy bushs

source: from field observation, laboratory analyses and adoption of Wahyunto et al.

BRIS Soil Series

Based on drainage classes and absence/inabsence of spodic horizon depths, BRIS soils can be divided into four soil series, i.e. Baging, Rhu Tapai, Rudua and Jambu.

Baging Series. Baging is located nearest and running parallel to the shoreline on the first terraces (R1) and belongs to the youngest among the three other soil series. The topography of the area was almost flat which probably due to agricultural activities with elevation around 50-120 cm above sea level. Baging series do not show horizon differentiation and are classified as Entisols (Sandy, siliceous, isohyperthermic, Typic Quartzipsamments). Baging series are somewhat excessive drained **meaning that water** is removed from the soil rapidly. Internal free water occurrence commonly is very rare or very deep. The soils are commonly coarse-textured and have high saturated hydraulic conductivity. The water table was < 130 cm depth (during the dry months). Spodic horizons are not found till depth of > 130 cm (Armanto et al 2013).

Rhu Tapai Series. Rhu Tapai Series are commonly located on the second terraces (R_2) in the distance away (> 500 m) from the first terraces and classified as Spodosols (Sandy, siliceous, isohyperthermic, Arenic Alorthods). Rhu Tapai series are moderately well drained. It **means that w**ater is removed from the soil somewhat slowly during some periods of the year. Internal free water occurrence is moderately deep and transitory through permanent. The soils are wet for only a short time within the rooting depth during the growing season, but long enough that most mesophytic crops are affected. They commonly have a moderately low or lower saturated hydraulic conductivity in a layer within the upper 1 m and periodically receive high rainfall. Spodic horizon occurs at < 50 cm depth.

Rudua Series. Rudua series are somewhat e**xcessively drained.** Water is removed very rapidly. The occurrence of internal free water commonly is very rare or very deep (> 50 cm). Free of mottling was related to wetness. The soils are commonly coarse-textured and have very high hydraulic conductivity. Processes of eluviations, illuviation and podzolization are commonly caused by the excessive drainage conditions. Therefore spodic horizon is translocated down to a lower depth compared to that of Rhu Tapai series; in the Rudua series spodic horizon occurs at 50-100 cm depth. The Rudua series are more leached comparing to Rhu Tapai. Both soils are classified as Spodosols (Sandy, siliceous, isohyperthermic, Arenic Alorthods).

Jambu Series. Jambu Series are sited on the oldest among the terraces (R3) and located farthest away from the coastline. Spodic horizon in the soil was found at depths of > 120 cm. The strongly bleached elluvial horizon is very thick. The Jambu series are classified also as Spodosols (Sandy, siliceous, isohyperthermic, Arenic Alorthods). The terraces containing Jambu Series could have been leveled flat (to a lower elevation) as a result of sand mining or agricultural activities (land leveling). Sometimes it was done in good faith, trying to make this ridge conform to the surrounding landscape for practical agricultural production. As such the spodic horizon in this area was observed to be less than 120 cm below the surface and thus no longer considered as Jambu Series as defined by the Malaysian System of Soil Classification. Jambu Series were commonly found in an undisturbed location (Armanto et al 2013).

Base on the Soil Taxonomy (Soil Survey Staff 2003), the soil in the study area dominantly Entisols and Spodosols orders. Entisols at the location of study are still young and they are situated by the saturated water environment. They lack the presence of diagnostic horizons within a specific depth in their profile. Spodosols soil is commonly found in cool, moist, humid, or perhumid environments. They can also be found in hot humid tropical regions etc. Surface litter composed of debris, breaks down in the presence of water to form a weak organic acid. Acidic soil water removes base ions in solution to create an acidic soil. Easily dissolved materials are leached from surface layers leaving behind the most resistant material like quartz creating an ashy-grey, near-surface layer. Layers at depth are stained with iron and aluminum oxides.

Soil profile

Soils in their natural characteristics can vary significantly, thus the sizes and form of the particles that contribute to the soil are explained more on the characteristics:

- Clay size: less than 0.002mm
- Silt size : 0.002-0.05mm
- Sand size: 0.05-2mm
- Stones size: larger than 2mm in size

The dominating particle size and shapes in some cases gives soil its characteristics and due to the tiny clay particles having a large surface area for a given volume of clay they dominate the rest of the particles, for instance:

- More often, soils with clay particles have over 25 percent clay. Also known as heavy soils, these can be potentially rich as they have nutrients bound to the clay minerals in the soil. However they also rich in holding a high proportion of water due to the attraction in capillary of the tiny spaces between the much clay particles. They also have the ability to drain slowly and take longer to warm up in spring than sandy soils. Clay soils are easily compacted when trodden and they become very hard in sunny period as result in the influx of radiation, often with indication of cracking noticeably. Soils of these nature often test the limits of the farmer to, thus when administered properly with cultivation and it is very much rewarding to work with.
- However sandy soils on the other hand have high sand and little proportion of clay. Which

is also known as light soils, these soils drain quickly in the present of rain or watering, and they are easily workable and cultivated. They get warm up easily and quickly during spring than clay soils. However on the downside, they dry up quickly and are weak in plant nutrients, which are quickly washed away by rain and they are often very acidic as a result of humus activities. They are mostly found at the top soil profile.

- Silt soils, these comprised mainly of intermediate sized particles, they can be fertile depending on the vegetation and topography of the area and they are fairly well drained and hold more moisture than sandy soils, but they are easily compacted due to the structure they retain.
- Loamy soils, they comprised mainly of a mixture of clay, sand and silt that limit the extremes of clay or sandy soils and are fertile, they are well-drained and easily worked. However they can be clay-loam or sandy-loam depending on their predominant composition and cultivation characteristics.
- Hence, in the case of peat soils they are mainly organic matter and are usually very fertile and hold much moisture characteristic. They are seldom found in vegetated area. However sweet potatoes grow very well in sandy or sandy loam due to the characteristics formation of the soil.

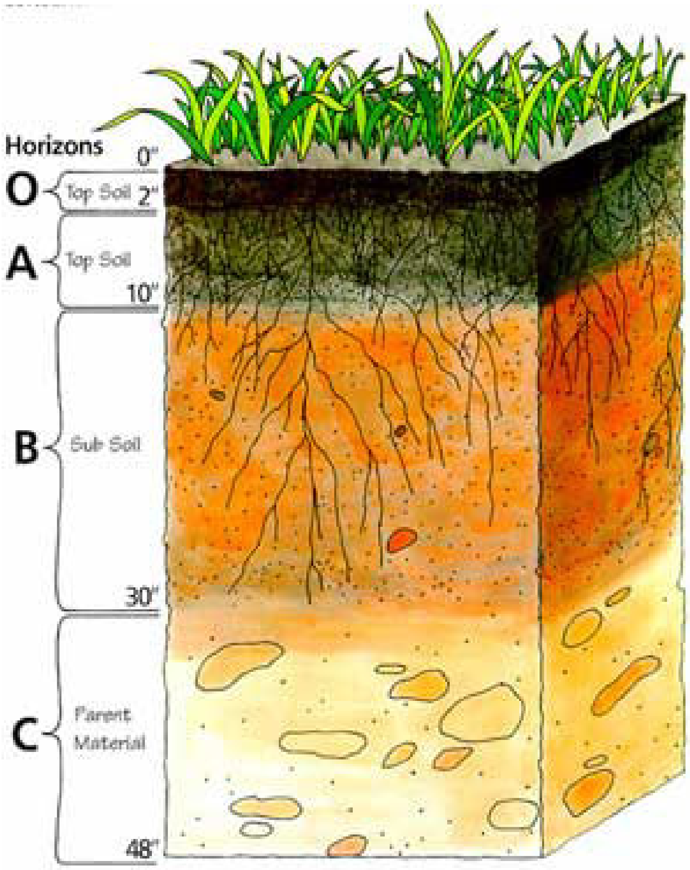

figure 3: A comprehensive soil profile

Physical properties

The physical and chemical properties of (P4) are more or less deficient as par their content in all ramifications for crop growth; hence the available P is better in terms of crop growth, where as the exchangeable bases are low and as well the N total and the organic C. However, the Baging soil indication of light yellowish to brown color does not give a clear detection of iron in the soil profile. Therefore, a soil administration is advised in order to increase crop production suitability (Usman et al 2013).

The natural vegetation in the study area and its surrounding is short shrub, grass (Zoysia matrala) and casuarina species (Casuarina equisetifolia). These low nutrients demanding plant species could have provided organic materials, but the humus is very acid and cannot produce soil humus especially in the topsoil, because this acidic humus is not able to support high biological activities in the BRIS soils.

The deposits of ridges (or terraces) consist of unconsolidated deposits of sand and gravel with some clay and silt.

These deposits are young Alluvium (Sub recent Alluvium) and belong to Holocene age (< 10,000 years). The young Alluvium is characterized by unweathered or slightly weathered clasts and soils developed from these deposits have depths of < 2 m.

Based on terrace locations and absence/inabsence of spodic horizon depths, thus the terraces found nearest to the coastal line is classified as the youngest age (R_1), while the middle terraces belong to the intermediate age (R_2); however the ridge farthest away from the coastal line is classified as the oldest age (R_3). The R_1 ridge is the youngest among the three and is located nearest and running parallel to the shoreline (Armanto et al 2013). During the field survey, soil series in the depression were not intensively studied because the common features of the landscapes were very dynamic and commonly they are not utilized for agriculture purposes, except for tourism and recreation. Catena of BRIS soils from East to West of Merang is given in Figure 2.

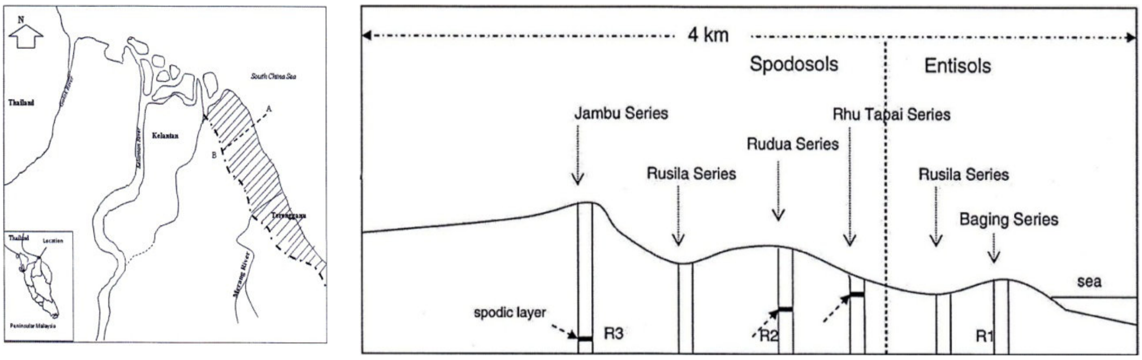

Figure 4: Catena of BRIS soils from East to West (R1, R2 and R3 represents the young, older and oldest terraces respectively, modified from Roslan et al., 2010)

Chemical properties and Sampling for Soil Fertility Status

All soil parameters are classified as very low to low, except Base Saturation because the soils are strongly influenced by sea movement. The soil reaction is closely related to some soil chemical properties, such as solubility H, organic matter content, the content of the bases, saturation-Al and so others. Soils with high hydrogen ion solubility and high organic acids, low bases content and high Al saturation generally reacted as an acidic to a very acidic soil. Instead, the soils have properties opposite to those above generally reacted neutral. The average value of pH H_2O and pH KCl are 4.3-5.1 and 4.0-4.6 respectively which indicated that the soil is generally classified as very acid to acid. The value of pH and CEC data was connected each other. This is also an indication that the oxidation of Fe and Al-free on these lands is rather high (Table 2).

In the BRIS soils, coarse sand and fine sand ratios may play an important role for present indices of parent material homogeneity. It seems that all soil profiles are developed from homogenous parent materials. The profile shows a relatively homogeneous content in all horizons. The indices of homogeneity that are the fine to coarse sand ratios throughout the profile may show the unique numbers-that the soils were formed from the same parent material. The ratio of silt to clay gives indices to weathering and soil development. This is based on the fact that the more weathered the soils are, the lower the silt contents. If the silt clay ratio is less than 0.15, the soils are classified as highly weathered. All BRIS soils give the figure of above 0.15 (1.91-12.45) that means the soils are relatively young.

Table 2. Laboratory analyses of BRIS topsoils (0-16 cm) and its Assessments [a]/

Laboratory analyses and its unit		Baging (no spodic)	Rhu Tapai [b]/ (< 45 cm)	Rudua [b]/ (> 50 cm)	Jambu [b]/ (> 98 cm)
Bulk density	kg/dm^3	1.38	1.30	1.27	1.43
Pore	%	48	47	42	53
pH H_2O (1:1)	-	4.7 (acid)	5.1 (acid)	4.3(very acid)	5.0 (acid)
pH KCl (1:1)	-	4.3 (very acid)	4.6 (acid)	4.0 (very acid)	4.0 (very acid)
C-organic	%	0.09 (very low)	0.78 (very low)	0.82 (very low)	0.83 (very low)
N-Total	%	0.01 (very low)	0.36 (middle)	0.09 (very low)	0.42 (middle)
P-Bray I	ppm	0.91 (very low)	10.40 (low)	12.78 (low)	2.40 (very low)
Na-dd [c]/	me/100g	0.01 (very low)	0.03 (very low)	0.02 (very low)	0.07 (very low)
K	me/100g	0.01 (very low)	0.02 (very low)	0.02 (very low)	0.05 (very low)
Ca	me/100g	0.05 (very low)	1.32 (very low)	0.03 (very low)	2.86 (low)
Mg	me/100g	0.11 (very low)	0.45 (low)	0.02 (very low)	0.65 (low)
CEC [d]/	me/100g	0.96 (very low)	2.12 (very low)	1.81 (very low)	4.52 (very low)
BS[e]/	%	68 (very high)	86 (very high)	75 (very high)	74 (very high)
Fe_2O_3	%	0.55	0.21	1.62	0.62
Texture class		Sand	Sand	Sand	Sand
Soil fractions					
Sand	%	98.21	96.50	95.56	98.64
Silt	%	1.54	2.30	4.11	1.04
Clay	%	0.25	1.20	0.33	0.32
Silt/clay ratio		6.16	1.91	12.45	3.25
WR[f]/					
0.33	bar, %	5.22	5.41	6.50	4.50
1.0	bar, %	3.33	3.92	4.10	3.93
15	bar, %	2.67	2.74	3.03	3.03

Explanation: [b]/ with Spodic Horizon, [c]/ dd: Exchangeable, [d]/ Cation Exchange Capacity, [e]/ Base Saturation, and [f]/ Water Retention

Source : [a]/ Data from Laboratory Analyses (2013) and Armanto et al 2013

Soil Evaluation for sweet potato Cultivation

The most important sweet potato growing environment is climate, physical conditions and soil fertility. According to Djaenudin et al, soil suitability for sweet potato is classified into S1 class (highly suitable), S2 (suitable), S3 (marginally suitable), and N (not suitable). The limiting factors for the development of sweet potato in Merang are explained as follows:

1) Soil temperature (t) that includes inhibiting factors, i.e. average temperature,
2) Water availability (w) that includes inhibiting factors, i.e. monthly rainfall and soil humidity,
3) Rooting medium (r) that includes inhibiting factors, namely soil drainage class, soil texture, coarse materials and rooting depth. Rooting depth is an indicator for effectively shallow depth of soils, especially in areas with high sand content and fast drainage,
4) Holding capacity of soil nutrients (n), which include inhibiting factor, i.e. Cation Exchange Capacity (CEC), Base Saturation (BS), soil pH, and organic C,
5) Poisoning (x), which include inhibiting factor, namely salinity and sulfidic materials (spodic horizons),
6) Erosion and abrasion hazard (e) that includes inhibiting factors, i.e. slope and erosion and abrasion hazard.

The marginally suitable means it needs more input to make the soils become suitable for the growth and development of sweet potato. To soil class of N (not suitable), then the constraints are permanent and very difficult to be reclaimed or require a very high cost. Based on the character of both physical and chemical properties, the research location does not have soils that belong to not suitable N (Table 2).

Almost all areas are classified as marginally suitable for sweet potato due to some biophysical and chemical soil properties and climate constraints. However, from the facts on the ground and regional development issues that sweet potato is likely to be developed. Table 4 summarized some efforts to improve the soil capability for sweet potato and also states clearly that sweet potato can be improved to suitable (S2) for the soils if organic material, lime and fertilizer P are given. Soil suitability for sweet potato is found on flat land until the slope (0-10%). For a more sloping land (> 10%) it is needed a simple conservation efforts, such as individual terrace to anticipate soil erosion.

Table 3. Agronomic requirement of sweet potato for optimal growth

Land characteristic	Field value[1]	Sweat potato[2]	
Temperature(c) Mean temperature (^{0}c)	28-42	35.5±0.95,23-30	Ogbonnaya et al, 1997,crane 1947
Water availability (wa) Rainfall (mm/year)	2500-3500	780-1200, ±300	Banuelos et al 2002, ching et al1993
Number of dry months	90 days	-	-
Oxygen availability (oa) Drainage	Somewhat ex./ excessive	Well drained	Ogbonnaya et al, 1997
Rooting condition (rc) Texture	Sandy soil 9.95%)	Sandy soil (±50%) Sandy clay loam	Cook and Smart 1995
Rough material (%) Soil depth (cm)	Minor roots >50++	- >75% (optimum)	- MARDI 2010
Nutrient retention (nr) Clay CEC (cmol/kg)	0-5(<in most area) 37-85(<40 in spodic)	Nutrient deficiency <15 (very low)	Abu Bakar 1985, Lim 1989
Base saturation (%) p H H_20	4.0-5.4 (acidic)	Not suitable under acidic condition	MARDI 2010
Organic C(%)	0.7-2	<1 and 3.8 (spodic horizon)	Abu Bakar 1985
Toxicity (Al)	Not available	Below pH5.5	DOA
Flood harzard (fh) Inundation	1	-	Armanto et al 2013

Note: The stated data represent: 1, Field value[1]: the field data from the study area: 2, sweet potato parameter[2]: the data from other studies.
Source: from field studies, Armanto et al and Usman et al

Table 4. Limitation for sweet Potato Crop Suitability

Soil Critaria	Values of Bris soil in the coastal plain		Crop Suitability
			Sweet Potato
Slope	0-3 (>6-12^0 slope) somewhat highly drained -	Baging, rudua Rhu tapai	S U
Drainage	excessively drain	Baging	
Effective soil depth	50 – 150++ cm	Jambu,rudua	S
Texture and Structure	Coarse texture and weakly (A horizon) and cemented spodic B horizon	Rhutapai,rudua bagin,jambu	
Salinity	n.d	Rudua	-
Depth of acid sulfate layer	n.d	Rhu tapai,bagi	-
Peat thickness	n.d	Baging	-
Stoniness	No stoniness	Jambu, Rudua	S
Nutrition imbalance	Moderate to serious	baging, Rhu tapai	M/n U/d

Note: S= Suitable. U= Unsuitable. M= marginally suitable (need some ameliorants) and t= texture, n-nutrient imbalance and d-drainage.

Conclusion

With regards to the results and discussion, the result of this study shows that:

1) BRIS soil series are occurring side by side which relate the coexistence of beach terraces running parallel in different elevation to the seashore lines and the main BRIS soil series are Baging, Rhu Tapai, Rudua and Jambu.

2) Soil fertility status of soil series are classified as very low to low, except Base Saturation because the soils are strongly influenced by sea movement.
3) The nutritional soil suitability for Baging and Rhu Tapai where mostly M/nU/d, with SU at the slope for Rudua, and Jambu are mostly S with no trace of some soil criteria.
4) However the needed efforts required improving soil capability from actual to potential soil suitability for sweet potato cultivation can be seen in the agronomic requirement table above. Hence, cover the soils with mulch, make sprinkle irrigation, make dam for water holding and retention, give and maintain organic matters in the soils and do not burn biomass, fertilize soils with NPK and organic fertilizers, do wash elements of Na and H and break down shallow spodic horizons, make terraces and mix mineral subsoils to BRIS soil to improve CEC.

ACKNOWLEDGMENTS
The authors wished to acknowledge the supports provided by Universiti Malaysia Terengganu, Malaysia, Ramat Polytechnic Maiduguri, Nigeria and Sriwijaya University, Indonesia for giving permission to publish this paper.

REFERENCE

Abu Bakar, O. 1985. A comparison of selected Entisols and Spodosols occurring in peninsular Malaysia and peninsular florida (PhD thesis). University of florida, USA.204 pp.
Armanto, M.E., M.A. Adzemi, E. Wildayana and Usman M. Ishaq. Coastal Sand Soils and their Assessment for Upland Rice Cultivation in Terengganu, Malaysia. Proceedings of 2013 International Seminar on Climate Change and Food Security 2013. 24-25October 2013. ISBN 978-1-84626-xxx-x
Armanto, M.E., M.A. Adzemi, E. Wildayana and M.S. Imanudin. Land Evaluation for Paddy Cultivation in the Reclaimed Tidal Lowland in Delta Saleh, South Sumatra, Indonesia. Journal of Sustainability Science and Management. 2013. Vol 8(1): 32-42. June 2013. ISSN 1823-8556.
Banuelos, G.S., D.R. Bryla and C.G. Cook. 2002. Vegetative production of kenaf and canola under irrigation in central California. Industrial Crops and Products.15: 237-245.
Blume, H.P., K. Stahr and P. Leinweber. 2011. Bodenkundliches Praktikum: Eine Einführung in pedologisches Arbeiten für Ökologen, insbesondere Soil- und Forstwirte, und für Geowissenschaftler. 3. neubearbeitete Auflage. Springer Verlag, Germany.
Cook, C.G., J.L. Riggs, J.R. Smart and B.A. Mullin-Schading. 1995. Evaluation of six kenaf cultivars for resistance to Phymatotrichum omnivorum. Industrial Crops and Products. 4: 229-232
Department of Agriculture (DOA). 2010. MINISTRY OF Agriculture and Agro-Based Industry, Putrajaya, Malaysia.
Djaenudin, D., H. Marwan, H. Subagyo dan A. Hidayat. Petunjuk Teknis Evaluasi Lahan untuk Komoditas Pertanian. Balai Besar Litbang Sumberdaya Lahan Pertanian, 2011. Badan Litbang Pertanian, Bogor. 36
Malaysia Agriculture Research Development Instite (MARDI).Cara-Cara Menanam Kenaf Untuk Pengeluaran Serat dan Biomassa. Selangor, Malaysia (Malay Language) http://www.mardi.gov.my
Ogbonnaya, C.I., H. Roy-Macauley, M.C. Nwalozie and D.J.M. Annerose. 1997.Physical and histochemical properties of kenaf (Hibiscus cannabinus L.) grown under water deficit on a soil. Industrial Crops and Products. 7:9-18.
National Tobacco Board (NTB), 2009. In: Bengkel JTC (UPM-LTN) Penyelidikan Kenaf- tembakau UPMKe-2. 15 April 2009. Universiti Putra Malaysia, Serdang, Malaysia.
Ritung, S., Wahyunto, F. Agus, and H. Hidayat. 2007. Guidelines of Land Suitability Evaluation. With a Case Map of Aceh Barat District. Indonesian Soil Research Institute and World Agroforestry Centre, Bogor.
Usman M. Ishaq, H.M. Edi Armanto and Adzemi bin Mat Arshad. Performances of BRIS Soils Genesis and Classification in Terengganu, Malaysia. Journal of biology, agriculture and healthcare.ISSN2224-2308 (paper)ISSN 2225-093X (online) Vol.3, No.20, 2013.