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Coastal Sand Soils and Their Assessment for Upland Rice Cultivation in Terengganu, Malaysia

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Abstract. The research aimed to study coastal sand soils and to analyze their assessment for upland rice cultivation in Terengganu, Malaysia. Research sampling was conducted based on the soil series of the research area, i.e. Baging, Rhu Tapai, Rudua and Jambu. The works were divided into two steps, field survey activities and laboratory work. The research results showed that the 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. 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. The soil suitability was **S3-twrne** for Baging and Rhu Tapai,**S3-twrnx** for Rudua, and **S3-twrn** for Jambu with the soil productivity of around < 1, 1-2 and 2-3 tons dried paddy per ha per year respectively. The needed efforts to improve soil capability from actual to potential soil suitability for upland rice cultivation are i.e. 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 sallow spodic horizons, make terraces and mix mineral subsoils to BRIS soil to improve CEC.

Keywords: Coastal sand soils, physical assessment, upland rice, Terengganu

1. Background

Sand soils or 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. The soils are originated from sediment and located in places as diverse as along the coastal area and inland dominated by sand fraction. The coarse sand is from the sea that accumulated from the erosion of layers of steep cliffs by the sea during the monsoon seasons [1]. The soils are regarded as marginal soils. There is little progress made on the rehabilitation and revitalization of the BRIS soils without knowing their capability and suitability. MARDI has promoted to cultivate tobacco, upland rice and potatoes as well as Roselle. Allworksare successfullymanaged with very high investment and intensive capitals only for specific areas and its technology is difficult and still questionable to transfer to other BRIS soils.

2. Literature Review

Due to increase in population density and/or economic necessity, some people in Terengganucultivate upland rice on the BRIS soils, in addition to cultivating lowland rice in small valleys. Therefore, there is a necessity to determine the soil suitability based on a scientific analysis in order to ensure the long-term sustainability of the rice production on BRIS soils.

The main problems developed in the BRIS soils till today are follows, i.e. capability and suitability of the soils is not really known, changes in soil character is difficult to be estimated and managed as well as their limiting factors of soil suitabilityin detail is also unknown. Thus, we do not know which area is suitable for any particular crop until presently, these questions are still unanswerable, and thus the land remains with low production [2]. Therefore, this study aims to evaluate the soil fertility status of the dry coastal sand soils and

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to identify the main limiting factors for upland rice; increase farmer understanding of soil characteristics and fertility of their fields for better upland rice; and facilitate farmer adoption of soil amelioration practices and soil environmental protection.

Soil suitability for upland rice production prepared for the Terengganu area is basically focused on the relationship of rice yield with various parameters as follows; to find out relationship between rice yield and elevation, to investigate relationship between rice yield and soil aspect, to analyze the relationship between rice yield and slope, and to determine relationship between rice yield and use of fertilizer. The final output is a soil suitability of favorablesoils for good yield of rice in Terengganu.

3. Method

This study was conducted in Merang and its surrounding, Terengganu, Malaysia. The selected research location is based on drainage classes and spodic horizon depth, i.e. soil series of Baging, Rhu Tapai, Rudua and Jambu. The four soil series of terraces running parallel to the coastal lines were intensively observed. Pointing the sampling location was helped by the topography map of Peninsular Malaysia with map scale of 1:50,000. The soil profiles were intensively described [3] and classified according to soil taxonomy [4]. Composite soil samples were taken after completing soil profile descriptions and then analyzed in the laboratory. Soil color was determined using Munsell Soil Color Chart while bulk density was determined according to Sparks [5]. Particle-size analysis was analyzed by using hydrometer method. Weathering indices was determined according to silt/clay ratio, chemical analysis (organic carbon, soil pH, total nitrogen, CEC and exchangeable cations) were determined according to Sparks [5].

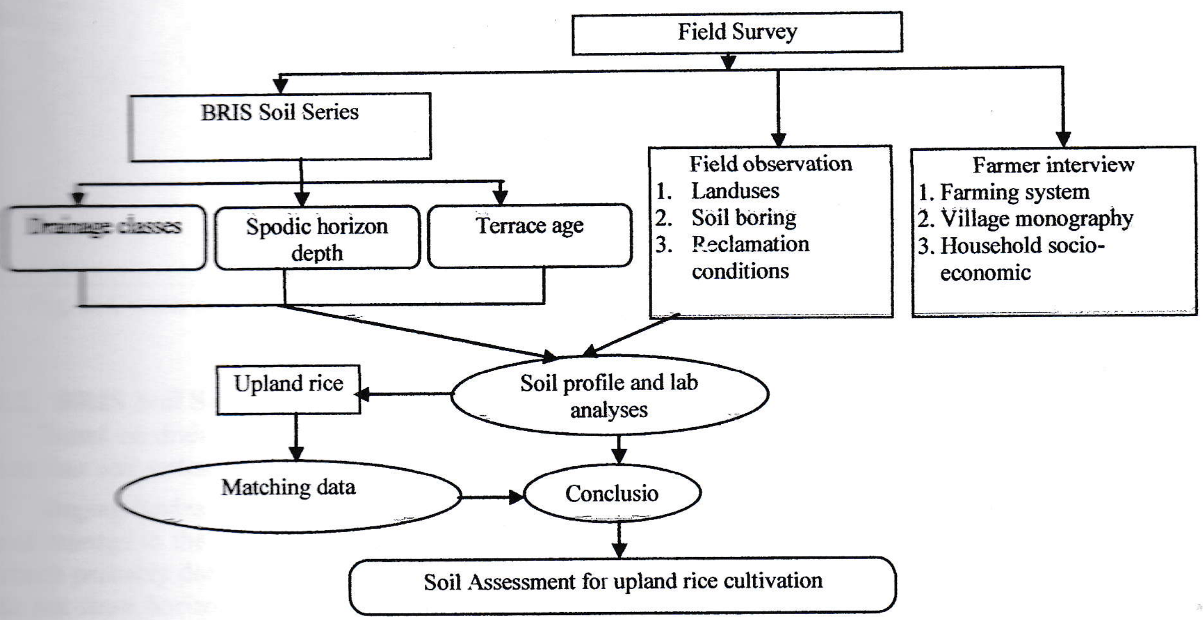

Fig. 1: Flowchart of field activities and data analysis

4. Result and Discussion

4.1. Climate, Geomorphology and Geology of Merang

The Merang is located about 30 km to the north of Kuala Terengganu and in the District of Setiu in the central section of Terengganu state and mostly dominated by the long coastline. Research location (Kampung Merang) is sited geographically at **Longitude:** 102° 53' 06" E and **Latitude:**5° 31' 44" N. Merang in the northern part is bordered with South China Sea, in the southern with the Batu Rakit, in the eastern with the South China Sea, while in the western part with the Permaisuri city and Ulu Chalok.

Merang is characterized by uniformly high temperature and the annual rainfall is above 2,500 mm. The moisture regime of the well drained areas is either udic or perudic. The slight variation in climate may have

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some influence on the genesis of the soils. The temperature in the soil can be as high as 45 °C during the afternoon of a hot day. The research area is continually affected by the forces of the monsoon. Due to the high rainfall and temperature coupled with the sandy nature of the parent materials, the process of leaching and eluviations in the soils are assumed to be very active.

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 [1]. 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.

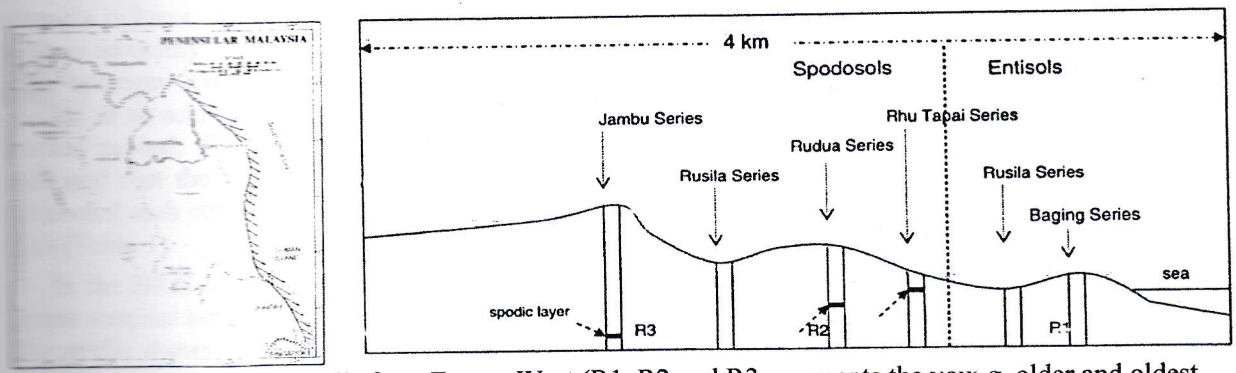

Fig. 2: Catena of BRIS soils from East to West (R1, R2 and R3 represents the young, older and oldest terraces respectively, modified from Roslan*et al*[6]

4.2 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.

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**water 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.

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Rudua Series. Rudua series are somewhat **excessively 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 eluvial 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.

4.3. Evaluation of 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 1).

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.

4.4. Soil Assessment for Upland Rice Cultivation

The most important upland rice growing environment is climate, physical conditions and soil fertility. According to Djaenudin *et al* [7], soil suitability for upland rice is classified into S1 class (highly suitable), S2 (suitable), S3 (marginally suitable), and N (not suitable). The limiting factors for the development of upland rice 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, coarsematerials 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 sulfidicmaterials (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 upland rice. 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 upland rice due to some biophysical and chemical soil properties and climate constraints. However, from the facts on the ground and regional development issues that upland rice is likely to be developed. Table 3 summarized some efforts to improve the soil capability for upland rice. Table 3 states clearly that upland rice can be improved to suitable (S2) for the soils if organic material, lime and fertilizer P are given. Soil suitabilityfor upland rice 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 1. 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	3.83	3.92	4.10	3.13
15	bar	2.67	2.74	3.03	2.03

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), Roslan *et al*[6] (2010) and Nafis [8]

Table 2. Limiting factors of soil suitability classes for upland rice in the research site

Soil Series	Sub class*/	Limiting Factors	Yields (ton paddy/ha/year)
Baging & Rhu Tapai	S3-twrne	Soil temperature, water availability (humidity), rooting medium (soil drainage, soil texture), holding capacity of soil nutrients (CEC, pH, and organic C), erosion and abrasion hazard	< 1
Rudua	S3-twrnx	Soil temperature, water availability (humidity), rooting medium (soil drainage, soil texture), holding capacity of soil nutrients (CEC, pH, and organic C) and poisoning (salinity and spodic horizons)	1-2
Jambu	S3-twrn	Soil temperature, water availability (humidity), rooting medium (soil drainage, soil texture), holding capacity of soil nutrients (CEC, pH, and organic C)	2-3

Explanation: */ t: Soil temperature (It is difficult to be managed), w: Water availability (It needs drainage system and ameliorant), r: Rooting medium, n: Holding capacity of soil nutrients (very low soil fertility), x: Poisoning (high salt content and spodic horizon which limits upland rice growth), e: Erosion and abrasion hazard

Source: Results of field observation and laboratory analyses (2013)

Table 3. Efforts to increase soil capability for upland rice

Soil suitability		Efforts to increase soil capability for upland rice from actual to potential soil suitability
Potential	Actual	
S2	S3-twrne	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, mix mineral subsoils to BRIS soil to improve CEC and Make terraces
S2	S3-twrnx	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, mix mineral subsoils to BRIS soil to improve CEC, do wash elements of Na and H and break down sallow spodic horizons (spodic depth of less 30 cm)
S2	S3-twrn	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 and mix mineral subsoils to BRIS soil to improve CEC

5. Conclusion

Based on the results and discussion, the result of this study revealed as following that:

1. The 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 soil suitability was **S3-twrne** for Baging and Rhu Tapai,**S3-twrnx** for Rudua, and **S3-twrn** for Jambu with the soil productivity of around **< 1, 1-2** and **2-3** tons dried paddy per ha per year respectively
4. The needed efforts to improve soil capability from actual to potential soil suitability for upland rice cultivation are i.e. 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 sallow spodic horizons, make terraces and mix mineral subsoils to BRIS soil to improve CEC.

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