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Assessment and Evaluation of Bris Soil and its Implication on Maize Crop in Merang- Terengganu Region of Malaysia

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Abstract

The research objectives focus on the evaluation of the physical properties of BRIS soil; to investigate the limiting factors for maize crop; also to create the awareness of the farmers as to the fertility and soil characteristics for better maize production and the effort to increase maize 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. 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 maize per ha per year respectively. The needed efforts to improve soil capability from actual to potential soil suitability for maize 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 shallow spodic horizons, make terraces and mix mineral subsoils to BRIS soil to improve CEC.
Keywords: Assessment, Evaluation, Bris Soil Series, Physiography, Maize, Terengganu,

1. Introduction

Sandy 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 (Armanto et al 2013). 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, the main objective of this article is to evaluate the physical properties of BRIS soil; to investigate the limiting factors for maize crop; also to create the awareness of the farmers as to the fertility and soil characteristics for better maize production and the effort to increase maize crop production.

2. Methodology

2.1Description 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). Evaluation of soil fertility status

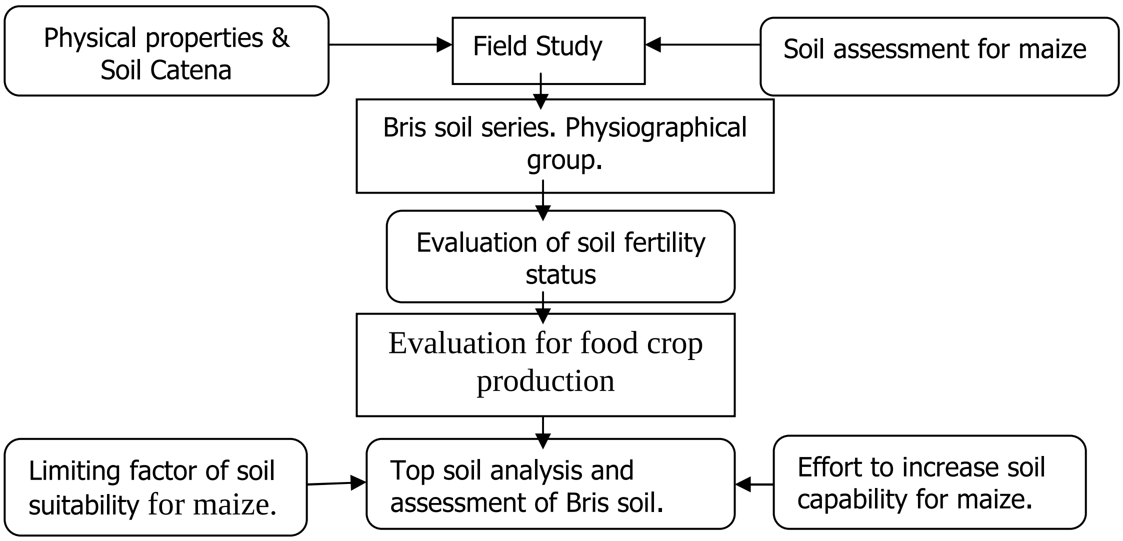

Figure 1. Map of thought for land Assessment.

3.Results and discussions

3.1 Field Surveying

In order to achieve the main objective of this study the ground truth observations and to collect the geo-information on the physical, chemical and environmental soil characteristics with a well defined satellite images that will point at the geo-references of the study area. Soil sampling was performed by soil pits and borings. Prior to the study area surveyed, the sampling location and transect lines were determine with the use of SPOT satellite images or any imageries available. Each and single soil was represented by not less than one or two sampling point. As the field observation continues to make transect in study area, all the main landscape were specifically studied from the cross sectional transect linking one shore point and the onshore in relation to the physiographical variation on the soil mapping unit.

The most dominated soil which represents the SMU were carefully observed during the excavation of the pit and at times with the soil auger, in order to classified and describe the soil profile. In the area where there is difficulty or rugged terrain a 50cm by 50cm mini pit is dogged so as to investigate whether the soil profile is significant among the others. However, in checking the consistency of the sample soil properties and the rate of similarity of the soil dominant group, soil auger where use in every SMU to authenticate the limitation of poor drainage in the ridges and swales soils. Therefore, each soil group was taken and represented by the soil profile horizon for the purpose of soil analyses in the laboratory. Every soil taken from the pit or auguring was coded for advance use.

The field observations were base on FAO (1978; 2005). Soil classification at group and subgroup level was base on Keys to Soil Taxonomy (Soil Survey Staff 2003). The important of field observation is aim at collecting the soil profile characteristic, as well the soil horizon base on the soil profile evaluation, which includes sulfidic material (if any, and evaluated by the use of H_20_2), soil texture (with the help of finger technique), soil pH (measured in distilled water and an electrolyte solution of 0.01 N KCL). The use of field survey was also apply in order to check the slop data and as well the surface and subsurface drainage (with abney level) which can be express by grey and mottle soil colors using the Munsell soil color chart. Data of monthly rain fall were collected from Malaysia meteorological station. A number of soil samples were collected and observed in the field with the use of auger base on the variation of the SMU. Soil sample from each profile were collected, tagged with label and represent the profile location.

Hence each soil sample collected was analyzed for different purpose such as soil texture (hydrometer technique), ph (glass, with electrolyte solution), organic content (Walkley and Black), total N (kjeldahl digestion), Particle size distribution will be performed using the Bouyoucos-method (hydrometer method). CEC will be determined after leaching with 1.0 M ammonium acetate pH 7.0 Exchangeable K, Ca and Mg were determine by ammonium acetate solution and measured by flame photometer for K and by AAS (Atomic Absorption Spectrometer) for Ca and Mg. Na is not reported because of its very low contend in the soils. Total P will be determined by perchloricsulphuric acid method and measured by a spectrometer. Available P will be extracted by the Bray 2 (acid fluoride) solution and measured by a spectrometer. Exchangeable Al will be determined by the aluminum method and measured by a spectrometer. Base saturation will be calculated as the sum of exchangeable cations (Sparks et al., 1996): Al-saturation will be calculated using the following form:

Al-saturation: Exchangeable Al/ (Ca +Mg + K + Al exchangeable) x 100%

Base saturation: (K + Mg + Ca) / CEC x100 %.

3.2 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/presence 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.

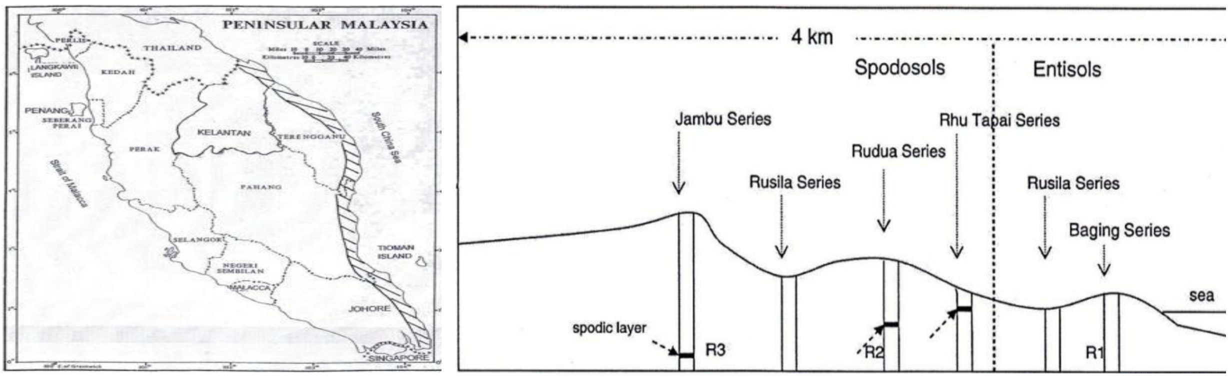

Figure 2. Catena of BRIS soils from East to West (R1, R2 and R3 represents the young, older and oldest terraces respectively, modified from Armanto et al 2013 and Usman et al 2013.

3.3 Soil Assessment for Maize Cultivation

The most important Maize growing environment is climate, physical conditions and soil fertility. According to Djaenudin et al, soil suitability for Maize is classified into S1 class (highly suitable), S2 (suitable), S3 (marginally suitable), and N (not suitable). The limiting factors for the development of Maize 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 Maize. 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.

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

3.4 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 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.

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 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.

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 Usman et al 2013.

3.5 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.

3.6 Evaluation of the field characteristic for food crops Production

During the field works, the soil evaluation was carried out for 4 soil profiles in the selected locations. The field descriptions of pits' borings and landscapes are generally, some guidelines for evaluating Bris soil in Merang – Terengganu plains. The utilization of sandy beach soil is necessary as only 5 – 10 % of 154,000 ha in Malaysia are being used for crop production, such as tobacco cultivation (NTB 2009; DOA 2010). Therefore, replacing tobacco with crops such as maize, kenaf and veggies which are environmental friendly will in turn enhance the suitability assess in the study area for a better crop production.

With the utilization of land evaluation in beach ridge soil classification system i.e., Soil Crop Suitability Classification which is the ability to use the available data collected during the field study and the prospect to use it in the production of maize crop is a way out and has frequently been used to evaluate the fertility status of soil in Peninsular Malaysia. However, the classification system is used mainly for the purposes of crop yield and growth which is basically on physical limitations and in some cases chemical limitation properties as well.

From the data in table 2, the most limiting factor is soil texture follow by nutrient retention; it is likely that some available management can upgrade the suitability class from actual to the potential suitability class, thus the texture is weakly structure, in such a way that the water impedes nutrients through the soil horizon. From the top soil to lower or adjacent ground level as quickly as the root can take up water and also the adverse effects of evapotranspiration. Furthermore, this reduces the nutrients state as most of it are quickly or excessively moved laterally during the flow of water through the soil horizon as a result of the large pore spaces which shift and disperse the nutrients to the lower elevation in the substrate, through water movement.

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

Table 3. Limiting factors of soil suitability classes for maize in the research site

Soil Series	Sub class*/	Limiting Factors	Yields (ton maize/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 maize growth), e: Erosion and abrasion hazard.

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

Table 4. Efforts to increase soil capability for maize

Soil suitability		Efforts to increase soil capability for maize 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 shallow 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

4. 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 maize per ha per year respectively.
4) The needed efforts to improve soil capability from actual to potential soil suitability for maize 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 shallow spodic horizons, make terraces and mix mineral subsoils to BRIS soil to improve CEC.

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