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On the Classification Characteristics of Soils in Myanmar

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ABSTRACT: Myanmar's soil is diverse in terms of climate and topography, including the central dry zone, hilly and upland areas, deltas, and coastal zones. As a result, crops such as rice, sesame, groundnuts, green gram, and maize are grown as major crops. Some soils are difficult to cultivate due to topographic constraints and permanent forests. Soil fertility was classified according to the physical and chemical characteristics. Based on these data, classification, and a soil survey, a soil map was made by the Land Use Division of Myanmar Agriculture Service. Myanmar's soil was classified into 24 soils according to the WRB classification by FAO/UNESCO, and soil maps were produced at the national level and for each of the 14 states and divisions. This study sought to contribute to efficient land use and sustainable agricultural development in Myanmar by understanding Myanmar's agricultural conditions and soil types.

Key words: Soil type, Soil Characteristic, Soil Map, Myanmar

INTRODUCTION

Union of Myanmar is a tropical and one of the developing countries in Asia and situated in the western end of Southeast Asia, within 9°58' to 28°31' N latitude and 92°09' to 101°10' E longitude ranges. The total land area of Myanmar is around 680 thousands km^2. The central and lower parts of the country are plains surrounded by hilly regions with altitudes varying from 915 to 2,134 m in the western, northern and eastern parts (Ministry of Agriculture and Irrigation, 2000). Myanmar is divided into seven states (Mon, Rakhine, Kachin, Kayin, Kayah, Chin, and Shan) and eight divisions (Yangon, Ayeyarwaddy, Bago, Magway, Mandalay, Naypyitaw, Sagaing, and Tanintharyi). The whole country of Myanmar belongs to the tropical to subtropical monsoon climate with three seasons: Summer Season (from February to May), Raining Season (from June to September) and Winter Season (from October to January). The cultivated land area in Myanmar is around 11 million ha, occupying 16% of the total land area, and is still producing in an improving crop yield level (Egashira and Than, 2006). Myanmar is an agricultural country, and the agricultural sector is the main pillar of the country's economy. The current population of Myanmar is 55,441,349 as of Thursday, May 4, 2023, based on Worldometer elaboration of the latest United Nations data. More than 70% of population is living in rural areas, and 65% of the total labor force is engaged in the agricultural sector, about 52% of the country's total area is still covered with forests. The land use pattern has distinctly changed between 1996 and 2002 because the agriculture and forestry sectors have been rapidly developed during the last decade (Guppy et al., 2017). Soil classification especially based on soil survey in 1955-1957 was performed under the Agricultural Planning Commission. after that, The Land Use Division of Myanmar Agriculture Service (LUD) modified old classification system in 1970 based on the FAO/UNESCO Classification and made a new soil Map of Myanmar. This paper was conducted to review understanding the diverse soil types and agricultural conditions of Myanmar from various literatures (LUD; Taft, 2016; Wikimedia) and contribute to sustainable agricultural development.

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MATERIALS AND METHODS

State and Division

Myanmar is located on the Indochina Peninsula and is divided into 14 states and divisions. The capital is Naypyidaw in Mandalay Division, and the biggest city is Yangon in Yangon Division. The total area of Myanmar is 676,590 km^2 and the largest country among the countries of the Indochina Peninsula(Fig. 1). Fig. 1 is shown to the explanation on Myanmar of Wikipedia

Crops

The agriculture sector is one of the most important sectors of the country's economy. In Myanmar, 70 percent of the country's population live in rural areas, and their livelihood drives the agriculture sector as an important growth engine of rural development. There are many different kind of crops cultivated in each State and Region. The main cultivated crops by DOA(2022) are as following;

1) Paddy, 2) Maize, 3) Groundnut, 4) Sesame, 5) Sunflower, 6) Black gram, 7) Green gram,

8) Pigeon pea, 9) Cotton and 10) Sugarcane

Table 1. Total cultivated area and yield of main crops, 2021-2022. (DOA).

No.	Main Crips	Cultivated Area (ha)	Harvested Area (ha)	Yield (kg/ha)
1	Paddy	701,034	671,386	3,892
2	Maize	601,506	600,667	3,897
3	Groundnut	1,216,474	1,216,466	1,466
4	Sesame	1,535,093	1,434,859	465
5	Sunflower	441,268	441,007	750
6	Green gram	1,200,382	1,199,751	1,292
7	Black gram	946,455	946,450	1,442
8	Pigeon pea	424,133	424,133	1,071
9	Cotton	159,426	159,426	1,756
10	Sugarcane	165,345	165,345	58,731

Fig. 1. State and Division of Myanmar (http://en.wikipedia.org/wiki/Myanmar).

Topography

Topographically, the country can be roughly divided into three main parts, namely the western hills region, the central valley region, and the eastern hills region. In the western portion, the Rakhine mountain ranges and Chin hills have undulating hills with altitudes over 914 m above mean sea level. The central valley region is about 300 m of elevation. The eastern hills' region is about 914 m to 1,219 m above sea-level. As mountain ranges in Myanmar generally run in the north to south direction, the river systems also flow from north to south. The Ayeyawady (Fig. 2) is the main river in the country and navigable for about 1,450 km from Yangon. The Ayeyawady River was started flowed by the combination of Mali Hka and Mai Hka Rivers (Fig. 2) in the northern mountain in Kachin State. The Chindwin River (Fig. 2) is navigable for some 563 km from its confluence with the Ayeyawady River. These two rivers constitute the most important inland water transport network for locally produced agricultural products and forest products. The upper reached of the Salween River (Fig. 2) flowed from the southern part of the China and then though the Shan State in Myanmar. The Sittaung River (Fig. 2) is the shortest one among the principal rivers in Myanmar (Guppy et al., 2017). The topography is generally low in the coastal and deltaic regions (Taft, 2016). Annual rainfall in the coastal and deltaic region is 5,000 mm whereas it is only

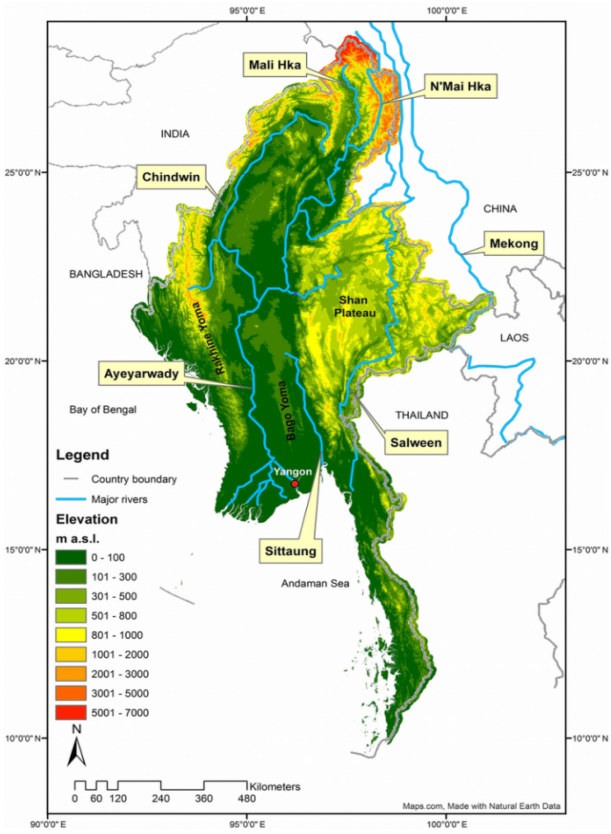

Fig. 2. Map of Myanmar, including the state border, major rivers, and mountain ranges (Taft, 2016).

about 600 mm in the Central Dry Zone (CDZ) of Myanmar. During the summer seasons, especially March and April, the highest temperature in the Central Myanmar is above 43°C while it is about 36°C in Northern Myanmar and 29°C in Shan State. In Central Dry Zone, crop farming is not sustainable for living because of the constraints of agro-climatic conditions with erratic rainfall, high temperature and frequent drought.

Soil physical and chemical properties of Myanmar

Soil physical and chemical properties greatly influence on crop production (Arévalo et al., 2015)), and different soil management (Lynn, 2022). Among soil physicochemical properties, soil depth and nutrient contents follow the classification criteria below. Additionally, the description for Myanmar soil includes soil texture and pH. For the methods of soil analysis in Myanmar, the sedimentation analysis was used for soil texture, and 1:5 (Soil : Water Suspension) method was used for pH, and Kjedahl's method was used for total nitrogen, and Olsen method for alkaline and natural soil and Bray method for acid soil were used for available phosphorus, and Flame Photometric method (1M ammonium acetate) was used for exchangeable potassium.

Table 2. The level of plant nutrients contained at a 15 cm soil depth.

No.	Nutrients	Low (mg·100g^{-1} soil)	Medium (mg·100g^{-1} soil)	High (mg·100g^{-1} soil)
1	Nitrogen(N)	< 4	4-6	≥ 6
2	Phosphorus(P)	< 5	5-10	≥ 10
3	Potassium(K)	< 10	10-20	≥ 20

Soil depth is divided into three kinds as following:

a. Thick: >36 inches, b. Medium: 20-36 inches, c. Thin : <20 inches

The levels of plant nutrient constituents in soil are consider as show in following Table 2.

The physical and chemical properties of Myanmar's soils are shown in Table 3. Soil depth in most regions except for Rakhine is medium or deeper. Soil pH is mostly acidic, phosphorus content is generally low.

Soil Classification

Myanmar's soil classification system followed the zonal soil classification derived from soil survey based on data of aerial photo interpretations in the 1950s when soil classification was first introduced, but since the 1970s, soil classification has been followed by applying WRB (World Reference Base) by the International Union of Soil Sciences(IUSS) and FAO/UNESCO Classification. In this paper, all of these soil classification is described, but the soil map is explained according to WRB classification

RESULTS AND DISCUSSION

A. Soil Classification

(1) Zonal Soil Classification

Soils can be classified into zonal soils, intrazonal and azonal soils. Zonal soils are classified generally based on climate and grouped into four zones, namely Tropical Wet Zone, Tropical Dry Zone, Subtropical Zone and Temperate High Mountain Zone. Soils of Tropical Wet Zone include red-brown forest soils, yellow-brown forest soils and lateritic soils and laterites. Soils in the Tropical Dry Zone include cinnamon soils, red-brown savanna soils, dark compact savanna soils, Solonetz (alkaline) soils, Solonchak (Saline) soils and primitive gravelly soils of savanna. Soils in the subtropical zone include red earths and yellow earths. Soils in the Temperate High Mountain Zone include brown mountain-forest soils,

Table 3. Soil physical and chemical properties of Myanmar (LUD, Land Use Division).

Sr. No.	States / Region	Area(ha) Approxi-mately	Soil Depth	Soil Texture	pH (1:5)	Soil Nutrients (Average)		
						N	P	K
1	Kachin	8,907,977	Thick	Loamy sand, Sandy loam, Clay, Loam, Clay loam, Silty clay, Sandy clay	4.5-8	Medium	Low	High
2	Kayah	1,173,652	Medium	Clay loam, Sandy loam	5-6.8	Medium	Medium	Medium
3	Kayin	3,039,572	Medium	Clay, Clay loam, Sandy loam, Clay loam, Silty loam, Sandy clay	4.0-6.7	Medium	Low	Medium
4	Chin	3,603,425	Medium	Silty loam, Clay loam, Sandy loam	5-7.5	-	-	-
5	Sagaing	9,374,244	Medium	Loamy sand, Sandy loam, Clay, Clay loam, Silty clay, Sandy clay	4.5-8.5	Low	Low	Medium
6	Taninthar-yi	4,336,265	Medium	Clay loam, Sandy Loam, Silty Clay, Clay, Silty loam, Sandy clay	4-6	Low	Low	Medium
7	Bago	3,942,123	Thick/Medium	Clay loam, Silty loam, Loamy sand, Sandy loam, Sandy clay, Clay	4-6.7	Low	Low	High
8	Magway	4,483,970	Thick/Medium	Sandy loam, Clay, Clay loam, Silty loam, Sandy clay	5-8.5	Low	Low	Medium
9	Mandalay	3,796,136	Thick/Medium	Silty clay, Clay, Clay loam, Sandy loam	5-8.5	Medium	Low	Medium
10	Mon	1,230,188	Thick/Medium	Clay loam, Loamy sand, Clay, Sandy loam, Loam, Silty clay, Sandy clay	4.5-6.7	Medium	Low	Medium
11	Rakhine	3,679,374	Thick/ Medium /Thin	Loamy sand, Clay, Clay loam, Silty clay, Sandy clay, Sandy loam	4-6.7	Medium	Low	Medium
12	Yangon	1,028,109	Thick/ Medium	Loamy sand, Clay, Sandy loam, Clay loam, Clay, Silty loam, Fine sand, Coarse sand	4.5-6.8	Medium	Low	Medium
13	Shan	15,506,195	Thick/ Medium	Clay loam, Silty loam, Clay, Sandy loam	5-6.5	Medium	Low	Medium
14	Ayeyar-wady	3,504,682	Thick/ Medium	Loamy Sand, Clay, Sandy loam, Clay loam, Silty loam, Sandy clay, Fine sand, Coarse sand	4.5-8	Medium	Low	Medium

mountain-meadow alpine soils and mountain sod soils. Intrazonal soils are grouped by the complex of the meadow, swampy and alluvial soils of river valleys and lowlands. This group includes alluvial soils, swampy soils and various meadow soils (alluvial, gley, alkaline, saline, swampy and swampy carbonate soils). Azonal soils are youthful due to hardness of parent material, rapid rate of erosion or deposition and insufficient length of time. Such soils are saline mud, silt, alluvium, gravelly soils, turfy primitive soils and turfy carbonate soils (Ministry of Forest 2005).

a. **Red-brown forest soils** developed under tropical evergreen forests and wet tropical monsoon forests mostly at altitudes between 300 m and 1,300 m above sea level. These soils have the average humus content of 2% and the pH value is between 5.5 and 6.5. Such soils are generally found in the area between East-West trending the Ayeyawady River and northeast-southwest trending the Shweli River. Red-brown forest soils, together with mountain red brown forest soils, primitive crushed stone soils are found in Taninthayi, Southern Mon-Kayin, Rakhine Yoma and south-western Chin areas.

b. **Yellow-brown forest soils** are widespread under wet tropical monsoon forests at altitudes between 100 and 450 m above sea-level. The humus content is on average between 2 and 4%. The pH value is between 4.5 and 6.5 and the water holding capacity is 30-35%. Such soils occur in hilly areas between the Chindwin and Ayeyawady Rivers, in lower hills of the Bago Yomas, Rakhine Yomas and Taninthayi Yomas. At higher altitudes, these soils are replaced by Yellow-brown mountain forest soils. They are suitable for forest plantation.

c. **Lateritic soils and laterites** are found at altitude below 100 m above sea-level. The humus content is 1.5 to 3% and pH value is between 4 and 5. These soils occur in Taninthayi, Mon, Kayin, Southern Bago mountain ranges and southern Rakhine mountain ranges areas. Such soils are suitable for rubber plantation, fruit trees

and horticulture (Ministry of Forest 2005).

d. Light Cinnamon soils occur along the belt surrounding the Dry Zone and dark Cinnamon soils develop at relatively wet sites. Humus content varies between 1% in light cinnamon to 3-5% in dark cinnamon. The pH value is between 5.5 and 6.5. These soils are suitable for agriculture when properly irrigated. Soils have been cultivated for centuries and are predominantly coarse-textured in the southern CDZ, with increasing surface clay contents in the northern CDZ (Guppy et al., 2017).

e. Red-brown savanna soils are typical soils of the Dry Zone and cover the central part of Myanmar. The humus contents are below 2% and nitrogen and available phosphorus contents are also low. The pH varies from 6.5 to 8 and it may reach 9 in extreme cases. These soils are suitable for dry farming but soil erosion is the main problem.

f. Dark compact savanna soils are mostly found in flat, even terrain and alluvial in the dry zone of central Myanmar. The pH value is ranging from 6 to 8.5 and humus content is only about 1%. Saline and alkaline should be checked and remedied. Suitable irrigation system is essential for successful utilization of the land.

g. Gravelly soils of savanna are also found in the Dry Zone of central Myanmar. These soils consist of stone fragments with small residues of humus and such soils are not suited for agriculture. Only indigenous species such as (Than, Dahat, Thanakha, etc…) should be planted.

h. Red earths occur at altitudes around 1,000 m above sea-level and mountain red earths are found at relatively higher altitudes. These soils cover the area from eastern Mandalay division, eastern Kayin, Kayah to large parts of Shan Plateau. The humus content is between 2 and 4% in the light red earths and may be up to 8% in dark red earths. The pH value is between 6 and 7. Such soils are suitable for diversified agriculture.

i. Yellow earths soils occur on level surfaces or slopes at lower altitudes on the Shan limestone plateau. They are less suited for agriculture when compared to red earths. Mountain Sod soils are found in Mountain Popa area and best suited for forestry purposes. Meadow soils are the best soils for paddy cultivation in Myanmar (Ministry of Forest 2005).

(2) WRB Soil Classification by IUSS & FAO/UNESCO

Soils on the hilly region were characterized by domination of kaolinite over other minerals in the clay fraction, whereas soils from the inland valley, meander floodplain and deltaic plain were dominated by mica, its transformation products such as vermiculite, smectite and mixed-layer mineral, or chlorite-vermiculite intergrade as a chloritization product, depending on the physiography of them. The parent materials in some hilly regions of southern Shan State are mostly limestone. Although in inland valleys of Mandalay Division are limestone sediment, the parent materials in meander floodplain areas are alluvium and in some Deltaic plain of Yangon Division are alluvium, old alluvium and limestone sediment. Meander floodplain of Bago Division is alluvium and limestone sediment (Egashira & Than, 2006). Parent material/mineralogy is widely recognized as an important soil-forming factor along with climate, biota (vegetation), relief (drainage) and time (Wilson 2019). The characteristics and soil types are difference depend on the parent materials. In Myanmar, there are five soil groups like as ① Fluvisols & Gleysols, ② Leptosols, Cambisols & Andosols, ③ Vertisols, ④ Luvisols & Nitisol, ⑤ Acrisols and Ferralsols based on WRB (World Reference Base for Soil Resources) by IUSS and FAO/UNESCO soil classification. Please refer to the WRB for definitions of the soil names in each group. There are 24 main soil types based on WRB (1974) in Myanmar. The different types of soil characteristics are described as following:

a. Alluvial Soils (Fluvisol)

Depending on the soil texture classification such as sand, slit and clay, the soils which contain large amount of silt are classified as alluvial soils. These soils can be found in any region of the country especially in the river basin plains, deltas, former lakes and coastal areas. The soil reaction is usually neutral and being young soils because of the development from recent alluvial deposits of the river plains, therefore rich in plant nutrients. These soils are pervious, easily tilled and very important soils for agriculture and suitable for rice, plantation crops, vegetables, pulses and beans, chili, sugarcane and maize (Land Use Division).

b. Meadow Soils (Gleysol)

There are different subtypes of Meadow soils. The meadow soils or paddy soils are widely occurring in the different parts of Myanmar in river plains, delta and low coastal plains and valleys. All types of Meadow soils have thick solum and mostly clayey texture and most suitable for paddy cultivation (Land Use Division).

c. Meadow Swampy Soils (Humic Gleysol)

These soils occur in the regions of lower depressions where the lands are flooded for more than 6 months in a year. The texture of these soils is clayey to clay and

usually having very strong acid reaction, and contain large amount of iron. Moreover the soils with long periods of moisture content may contain large amount of aluminium and soluble iron, sulphur and manganese by chemical process and can be toxic to plants. The humus content is high and usually deficient in phosphorus and potassium. Rice and Jute can be grown on these soils after the floods recede (Land Use Division).

d. Meadow Carbonate Soils (Calcaric Gleysol)

These soils can be occurred in the upper part of the Dry Zone with light colour classified depend on characteristics. Mostly have neutral reaction, whereas, some have the alkaline reaction. The Meadow Carbonate soils can also be found in that region. In spite of these soils are deficient in plant nutrients, this can be used for the cultivation of pulses and vegetables (Land Use Division).

e. Lateritic Soils (Plinthic Ferralsol)

These soils mostly occurred in the lower slope areas of the hills of Bago Yoma, Rakhine Yoma and Dawna hill range in lower Myanmar and in the areas of well drained low uplands and the foot of low hills with the elevation is not higher than 91 m above sea level. These soils are formed under the influence of the tropical forests with wet tropical monsoon climate of rainfall in 2,032-50,800 mm. Morphologically, these soils found the yellow or yellow brown and reddish brown colour due to the presence of iron with oxidation and reduction processes. In some places the horizons of pisolithic laterite are found at the depth of 45.72 to 50.80 cm, whereas, in other places they are not found at the depth below 121.92 and 152.4 cm. The humus content of these soils in forest area is high, but can be less in the deforested areas. The soil reaction is acidic in the upper horizon and can be more acidic at the lower horizons. The available plant nutrients are very low in these soils and suitable for cash crops and garden such as durian and mango (Swe et al., 2015).

f. Red Brown Forest Soils (Rhodic Ferralsol)

These soils are the typical soils of tropical ever green forest of Myanmar and also formed under the influence of tropical evergreen forests with the annual rainfall about 2,032 to 5080 mm. These soils occur on the well-drained hill slopes at the elevation from 304 to 1,219 m above sea level and also occur on the hill slopes of Rakhine mountain range, Taninthayi and Dawna range. Some are also found at the low uplands. The soils are well structured with good drainage, medium to heavy loamy texture and slightly acid with the pH value ranging from 5.5 to 6.5. The soils contain moderate amount of plant available nutrients. These soils can be regarded as forest land of good productivity however the soils on the lower elevation are suitable for gardens and plantation (Swe et al., 2015).

g. Yellow Brown Forest Soils (Xanthic Ferralsol)

The Yellow Brown Forest soils widely occur in covering the low hills of Bago Yoma, foot hills of Taninthayi Yoma, Rakhine Yoma and sloping areas at the bottom of northern hilly region up to the approximate north latitude of 25 degrees. These soils are closely connected with the Red Brown Forest soils in their distribution and usually replacing them down the slope. They mainly occur in the region of gentle slopes of low hills and foot hills at the elevation of 91 to 457 m above sea level. These soils are typical for the monsoon or tropical mixed deciduous forests and contain the clay and humus percentage more than the Red Brown Forest soils and the great majority for good garden lands (Swe et al., 2015).

h. Dune Forest and Beach Sand (Arenosol)

These soils can be found only along the coastal line of Myanmar. These areas are not very important soils for agriculture. The coastal line should be under wind and water erosion control and utilized for holiday resorts (Land Use Division).

i. Kanasotal soils (Solonchaks)

It is a pale or grey soil type found in arid to subhumid, poorly drained conditions. Solonchaks are largely confined to the arid and semi-arid climatic zones and to coastal regions in all climates. Common international names are ‘saline’ and ‘salt-affected soils. These soils can be found only at the coastal line of Tanitharyi and some areas of the Ayeyarwady Delta region.

j. Gleyic soils (Solonchaks)

Mostly AC- or ABC- profiles are often with gleyic properties at some depth. In low-lying areas with a shallow water table, salt accumulation is strongest at the surface of the soil. The horizon differentiation of Solonchaks is normally determined by other factors than their high salt content. Many saline soils in waterlogged backswamps are Gleyic Solonchaks. These soils mostly occur in the coastal areas of Ayeyarwady Delta.

k. Mangrove Forest Soils (Fluvisols)

These soils occur in very small area along the coastal line of Myanmar, especially in the region of Ayeyarwady Delta, Myeik archipelago and islands of Rakhine coast line. These are marine flat lowlands which

are affected by daily tides. The lands are only suitable for prawn breeding, beach resorts and establishing mangrove firewood forests (Swe et al., 2015).

l. Catena of Luvisol on slopes, Vertisol in flat land

Upland, well-drained soils are usually reddish-brown (Pitio Ndyeshumba, 1995). On the middle and lower parts of the slope, drainage is slower partly because of the moisture seeping downslope from the upper soils. These soils remain moist longer and dry out less frequently and less completely; this leads to an increasing degree of hydration of the iron. The red color changes to a brown or yellow one; the hydrated iron are mainly limonite and goethite. The color changes are not sudden; there is a gradual change from the original reddish-brown of the upper soils to orange-brown and then to yellow-brown and sometimes brownish yellow on the lower slopes (Gerrard,1981). Vertisols are clayey soils, which have deep, wide cracks on some occasions during the year and slickensides within 100 cm of the soil surface. They shrink when dry and swell when moistened (Eswaran and Reich, 2005). Vertisols commonly occur in low and flat relief forms, like lowlands, valleys, forefront of mountain ranges, former lake bottoms, the lower terraces and have the high content of expending clay and form deep wide cracks from the surface downward when they dry condition, mainly in tropical, semi-arid to (sub) humid climates.

m.Saline Swampy Meadow Gley (Gley-Gleysol)

Saline Swampy Meadow Gley soils occur in Ayeyarwady Delta and along the river bands of the Gulf of Motama and the marine flat lowlands which were influenced by the tidal sea water. These soil are always s salty. The land can only be utilized for prawn breeding and mangrove firewood forests because these soils are high salinity and whole year tidal sea water (Swe et al., 2015).

n. Yellow Brown Dry Forest and Indaing Soils (Ornithic Cambisol)

These soils occur on low upland plains in the Dry zone area. The lands are dry and sandy, so can be utilized for forests and dry cropping on uplands (Swe et al., 2015).

o. Light Forest Soils (Nitisol)

These soils mostly occur on the very gently sloping alluvial-diluvial under mountainous plains in the Dry zone area and also found on the lowest parts of the slopes in the Shan Plateau. The physical properties of these soils are very favorable and in spite of being sandy they are pervious and not heavy to work. They generally have good fertility which is connected with their position in the under mountainous plains, and there is a permanent supply of nutrients from the surrounding mountains by the surface run-off. These soils are suitable for the cultivation of "Ya" crops (dry cropping on uplands) (Swe et al., 2015).

p. Red Brown Savanna Soils (Luvisol)

These soils are mostly found in the undulating relief of the hill slopes and low uplands which are sandy and usually well drained. The soil reaction is about neutral in the top soil and neutral or slightly alkaline in the subsoil (pH ranges from 7.0 to 8.0). The soil contains a certain amount of lime and is rich in calcium and magnesium, however low in other nutrients except potassium. These soils are the most important land resources of the Dry zone area. Most of the areas are ploughed and cultivated (Swe et al., 2015).

q. Dark Compact Soils (Vertisol)

The dark compact soils occur in the Dry Zone mostly in the level plains of Sagaing, Mandalay and Magway divisions and on the lowlands near the rivers and broad depression in the areas of Red Brown Savanna Soils. These soils are very important for agriculture in the Dry Zone and deep, mostly composed of clayey materials and located on the level plains and the best soils for irrigated farming. These soils contain the highest amount of clay and also are very difficult to work when it is too dry or having excessive moisture. The humus content of these soils are very low, therefore in the dry state, they are deeply cracked, but after rains they turn into mud and very sticky. The infiltration of these soils is very poor and should be carefully taken for saline and alkali problems. The soil is alkaline and having pH ranging from 7 to 9, and strongly calcareous. These soils are deficient in nitrogen and phosphorus exception of potassium. The soils contain a considerable amount of calcium and magnesium and can be used for "Ya" crops in addition to rice under irrigation (Swe et al., 2015).

r. Red Earth and Yellow Earth (Acrisol)

The Red Earths soils are the most dominating soils in Shan Plateau and northern mountainous region at the elevation of more than 914 m. The Shan Plateau is completely covered with these soils. They are well drained and easy to plough. The soil reaction is slightly acid to neutral with pH ranging from 6 to 7. However, the Yellow Earths soils are more acidic, clay percentage and humus content than the Red Earth. Iron and alluminium contents are also very high. Nitrogen and phosphorus are very deficient. The Red Earths is the typical soils for agriculture in Shan state and potassium content is high. These soils have

good structure, well drained, and easy to plough, therefore very suitable for cultivation of seasonal and perennial crops. However, due to relief and slopes, erosion control measures are required. The Yellow Earths soils can only be utilized for gardens, flowers and forests (Swe et al., 2015).

s. Mountainous Yellow and Red Brown Soils (Histic Cambisol and Chromic Cambisol)

These soils occur on the mountainous terrain in the Shan Plateau with the elevation from 1,219 to 1,828 m. The soils should be under forest. Forest conservation and soil erosion control measures are very important for these soils (Swe et al., 2015).

t. Chin Hills Complex Soils (Ferralic Cambisol)

These soils are found on the high mountainous belt of the Chin Hills with the elevation of 1,219 to 1,828 m and less structured having bedrock in the lower horizons therefore the dangerous of landslide happens during the rainy season. These soils are only suitable for forest conservation and plantation crops (Swe et al., 2015).

u. Northern Hills Complex Soils (Ornithic Cambisol)

These soils occur on the very high northern mountainous region of Myitkyina areas and can only be utilized for forest conservation and also necessary to be undertaken for soil conservation (Swe et al., 2015).

v. Alpic Complex Soils (Gelic Cambisol)

These soils occur most of the northern area of Myanmar especially in Putao District with the elevation of 1,828 to 3,048 m above sea level where the tops of the mountains are covering with snow for the whole year, therefore these areas should be preserved for the picturesque resources of the country (Swe et al., 2015).

w. Popa Complex Soils (Andosol)

These soils are formed at the volcanic region of Popa in Myingyan District of Central Myanmar and cannot be found elsewhere in the country. These soils areas can be utilized for forest conservation and preservation natural picturesque landscape (Land Use Division).

x. Crushed Stone (Leptosol)

These soils widely occur in the area of low hills, sharpest and eroded slopes of the eastern side Rakhine Yoma in Magway Region. These territories are covered with the open cover of low shrubs with spines and sparse dry grasses. The surface layer of the soils is just a mixture of crushed stones with some quantity of slightly humified fine earth and often covered with crushed sand stone and lime concretions. These soils are totally unsuitable for cultivation and should only be used for forests (Swe et al., 2015).

B. Soil Map of Myanmar

The number of academicians from agriculture, forestry, geology and geography have reported the soils observed in various parts of the country in their own ways. In 1957, Myanmar soil scientists from Land Use Bureau conducted soil surveys in cooperation with Russian soil scientists and conducted zonal soil classification reflecting climate and vegetation. After that, Land Use Division of Myanmar Agriculture Service in 1970 modified the old classification system to WRB soil classification. The division made the first Schematic Soil Map of Myanmar (Fig. 3) showing 24 major soil types, based on the WRB soil classification.

C. Soil Map on State and Division of Myanmar

Soil type is initially importance to know the basic factor in agriculture and foundation of construction**.** Land Use Division (LUD) under the Department of Agriculture has been developed soil type mapping of Myanmar (Fig. 4 –

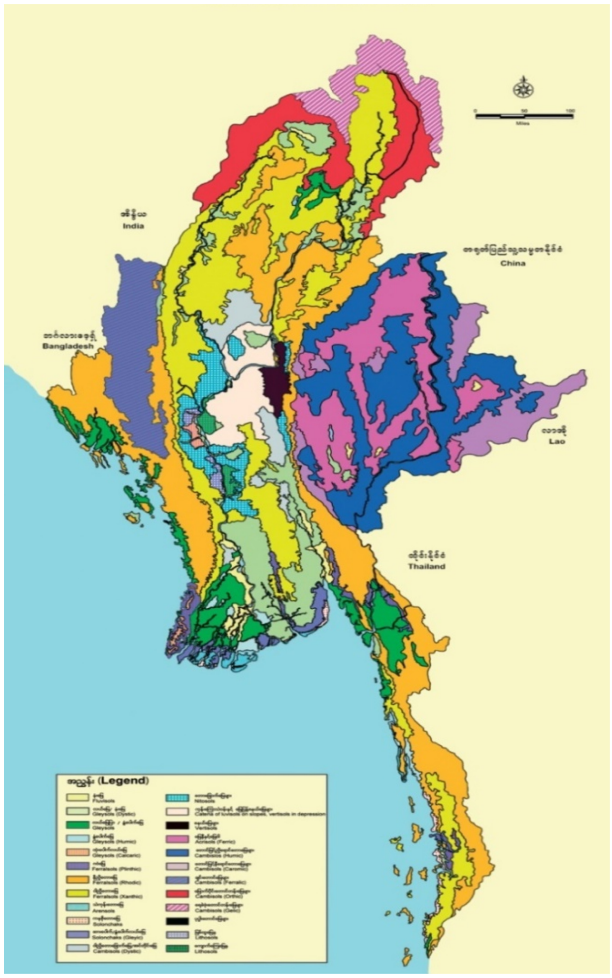

Fig. 3. Soil Map of Myanmar.

Fig. 17). Nutrient content and crop suitability maps are also developing for a certain area.

The soils of Kachin state were categorized into 7 types including alluvial soil (Fig. 4), and Yellow brown forest soil occupies the largest area. The soils of Kayah state were categorized into 3 types soil like as Medow & Medow alluvial soil, Red earth & yellow earth soil, Mountainous brown forest soil (Fig. 5). Kayin state showed 5 types soil including Red brown forest soil (Fig. 6). Mon state showed 8 types soil (Fig. 7), and Rakhine state showed 5 types soil (Fig. 8). The soils of Shan state were categorized into 7 types soil with Mountainous brown forest soil, and Red earth & Yellow earth soil predominating (Fig. 9). Mandalay division showed 11 types soil (Fig. 10), and Yangon division showed 8 types soil, mainly Medow & Medow alluvial soil (Fig. 11). Ayeyarwardy division showed 11 types soil (Fig. 12), and Bago division showed 9 types soil, mainly Medow & Medow alluvial soil (Fig. 13). Nay Pyi Taw division showed 11 types soil (Fig. 14), and Magway division showed 10 types soil (Fig. 15). The soil of Sasgaing division were categorized into 11 types soil, mainly Yellow brown forest soil (Fig. 16), and Tanintharyi division showed 8 types soil with Red brown forest soil predominating (Fig. 17). Chin state showed 3 types soil (Fig. 18).

DISCUSSION

The soils, in the Central Dry Zone and Ayayarwady delta region areas are the most intensely used by agriculture in country and the soil factors are slightly different each other. In Central Dry Zone area soils are mostly cultivated by the upland crops and some areas are mainly cultivated by the paddy depend on soil type. On the other hand, in Ayayarwady delta region soils are mostly suitable for the cultivation of lowland crop, so nearly all of the areas are cultivated by paddy and mainly produced for rice. Another all river side basin plain areas are mainly the alluvial soils by the transportation of sediment along the river basin and commonly used for agriculture because the soil fertility is very good and suitable for corps cultivation. The soils, along the coastal region and lower part of the Myanmar are mainly cultivated by perennial crops like that rubber and palm oil crops because these area soil types and climatic condition are mostly suitable for perennial crops. Most of the hilly region areas are usually covered by forests and some areas are used by agriculture as shifting cultivation and some areas are cultivated by orchard crops like that orange, apple, pine apple, sunkit fruit, tea, coffee, likchee, and many other traditional food crops because of the suitability of soil types and climatic condition.

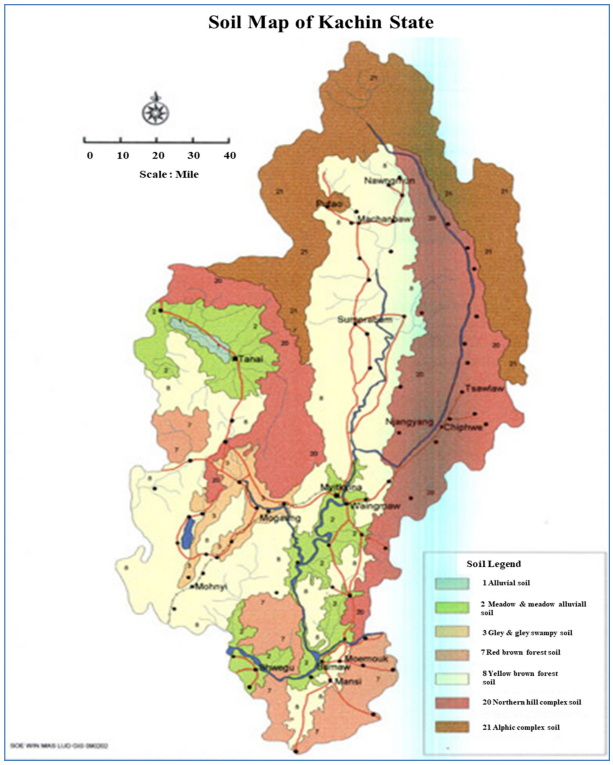

Fig. 4. Soil Map of the Kachin State.

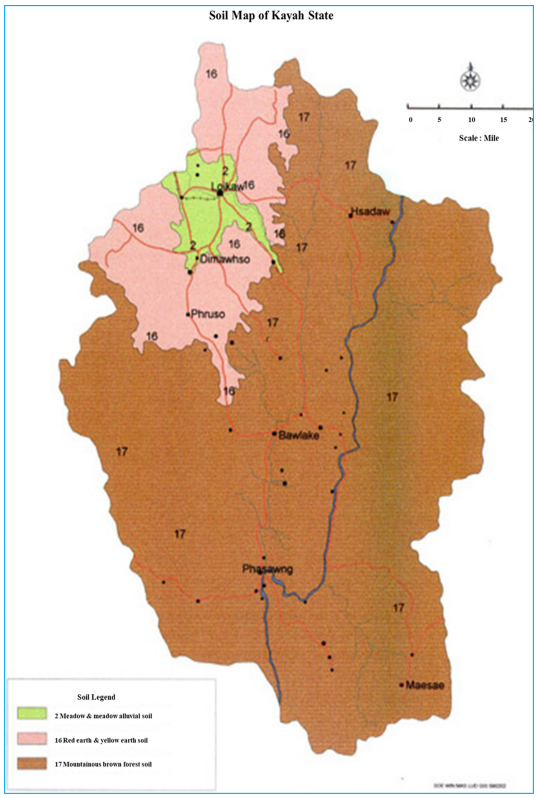

Fig. 5. Soil Map of the Kayah State.

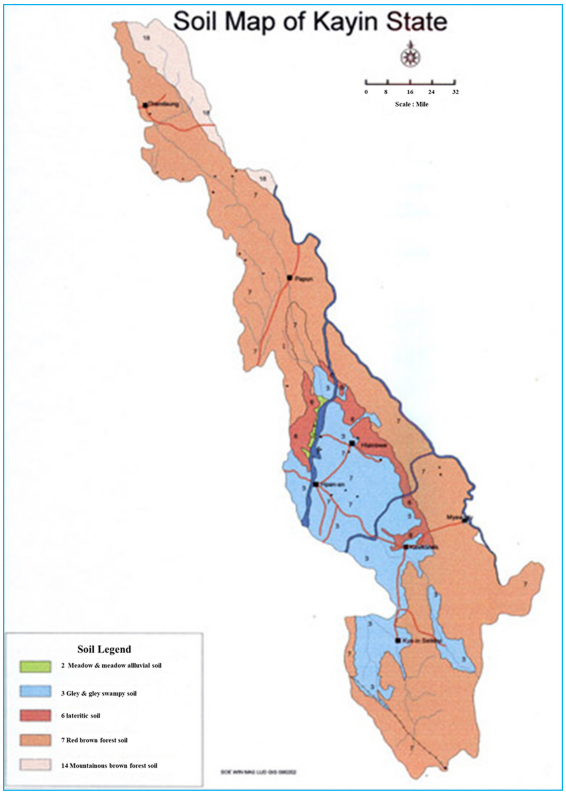

Fig. 6. Soil Map of the Kayin State.

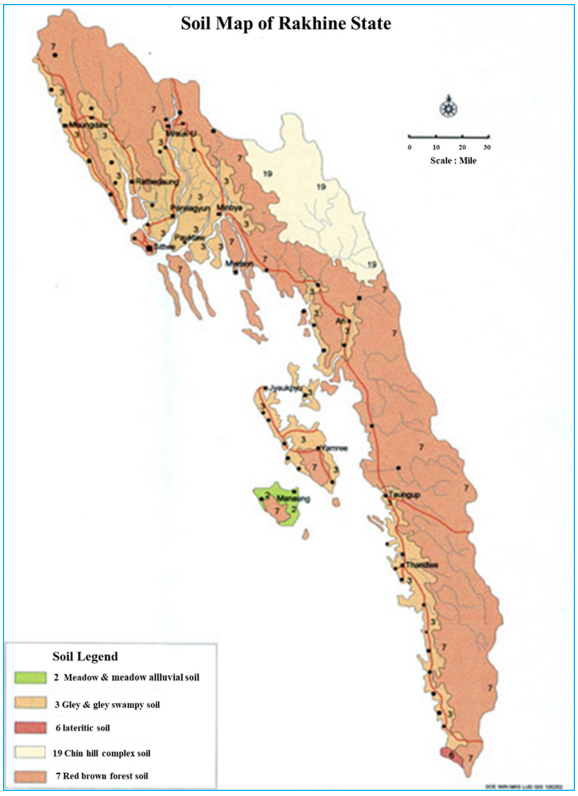

Fig. 8. Soil Map of the Rakhine State.

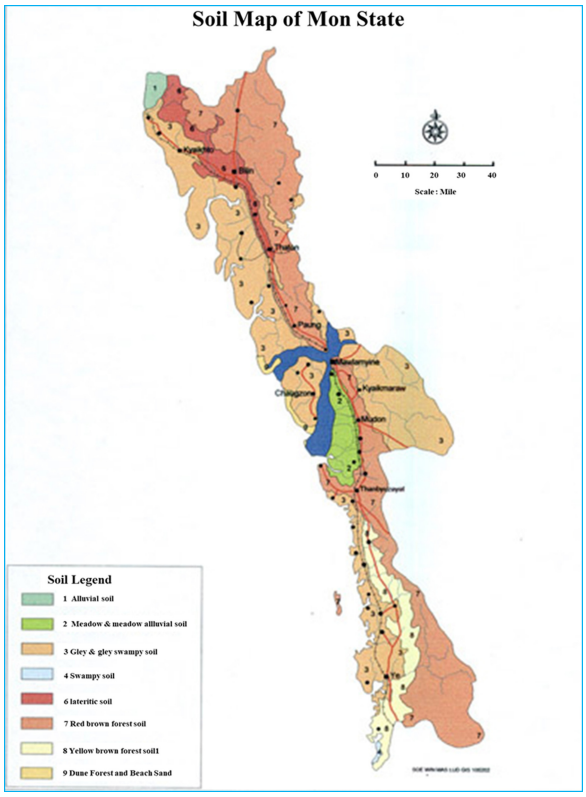

Fig. 7. Soil Map of the Mon State.

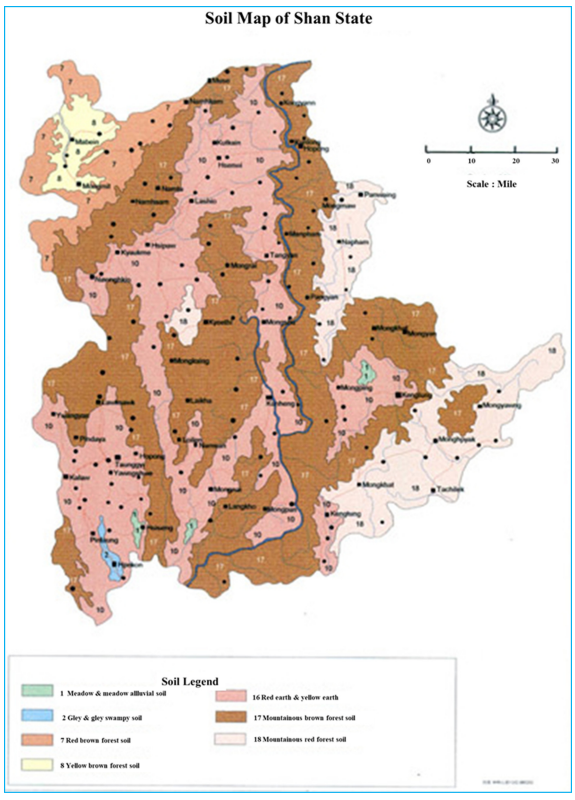

Fig. 9. Soil Map of the Shan State.

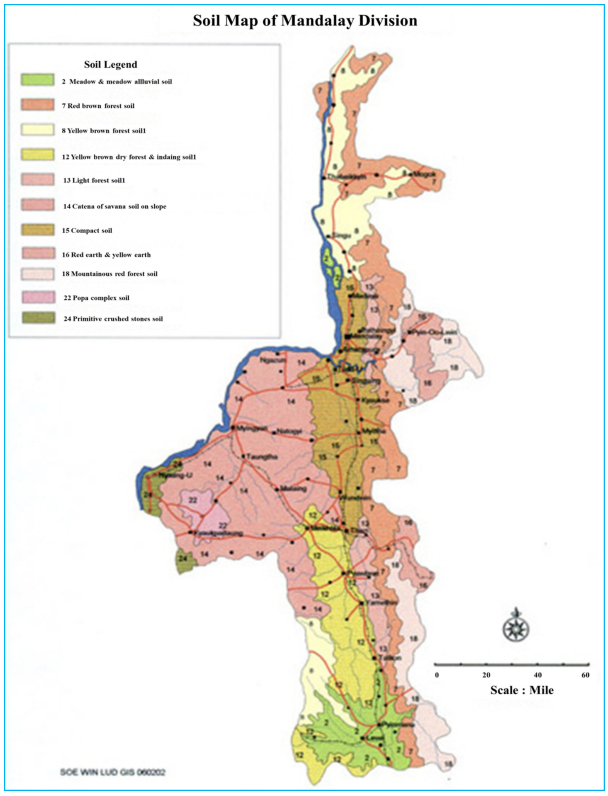

Fig. 10. Soil Map of the Mandalay Division.

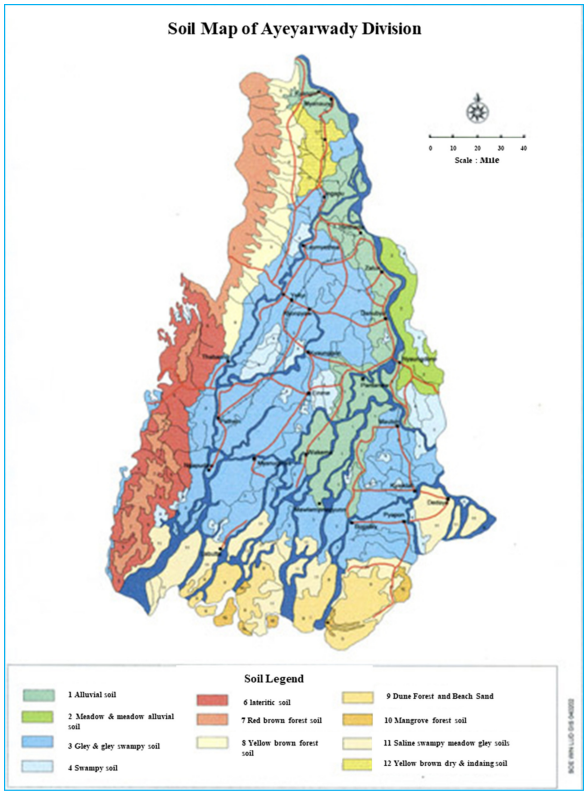

Fig. 12. Soil Map of the Ayeyarwady Division.

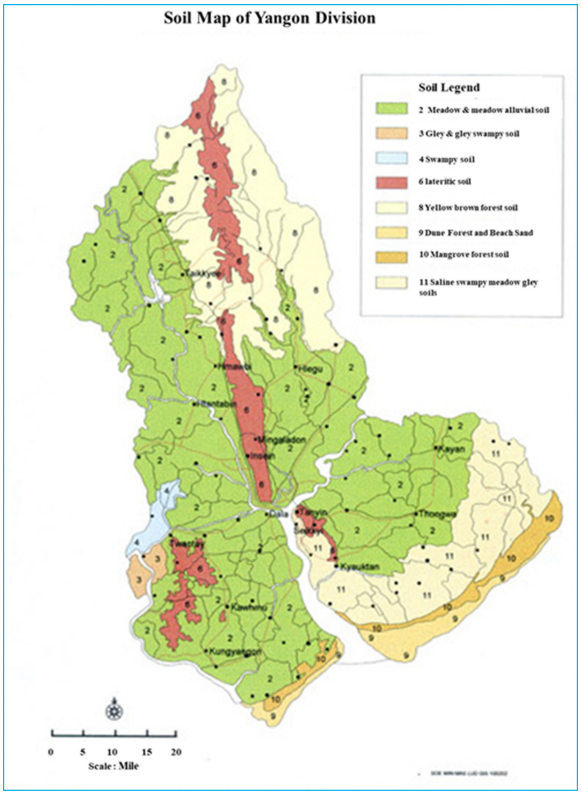

Fig. 11. Soil Map of the Yangon Division.

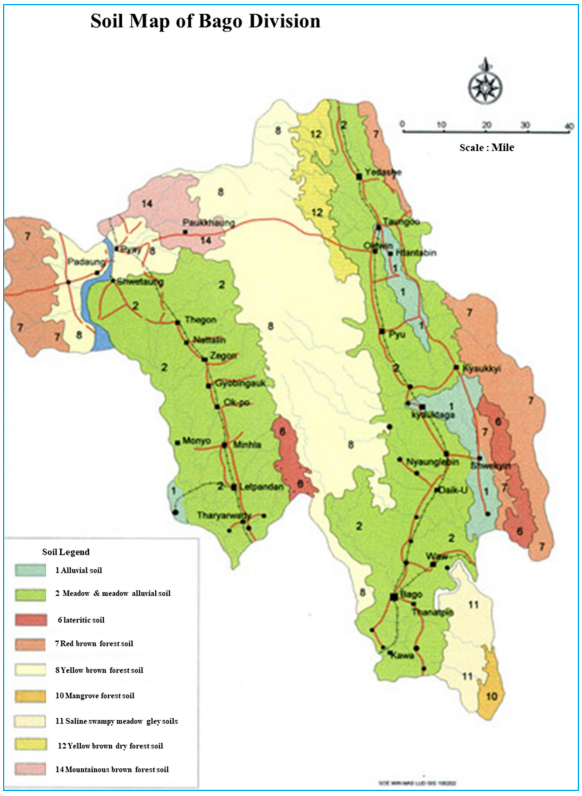

Fig. 13. Soil Map of the Bago Division.

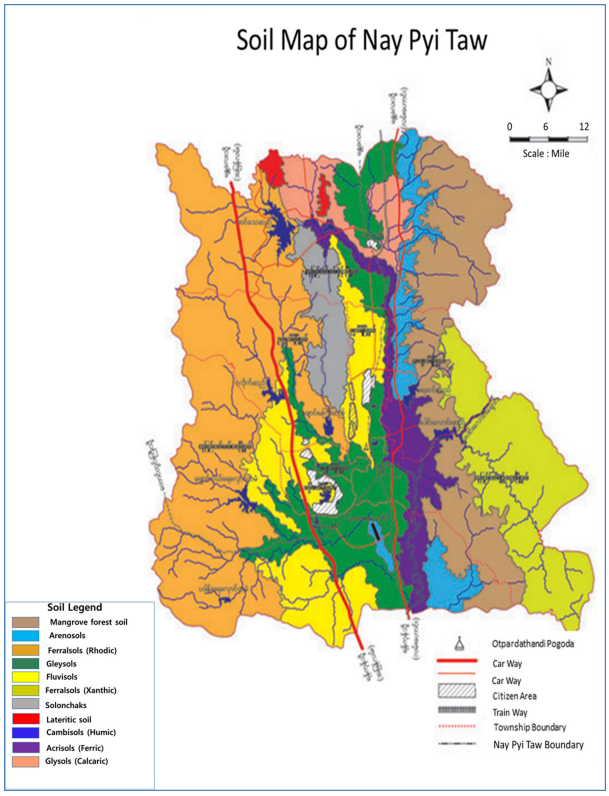

Fig. 14. Soil Map of the Nay Pyi Taw Division.

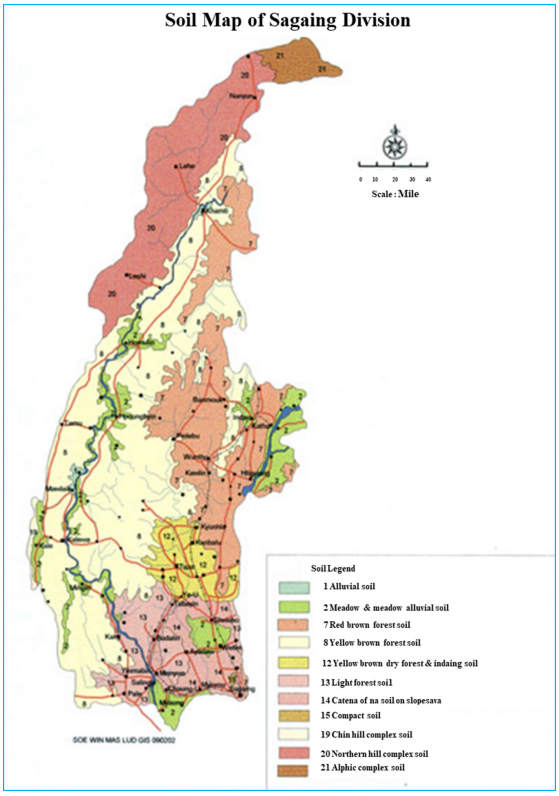

Fig. 16. Soil Map of the Sasgaing Division.

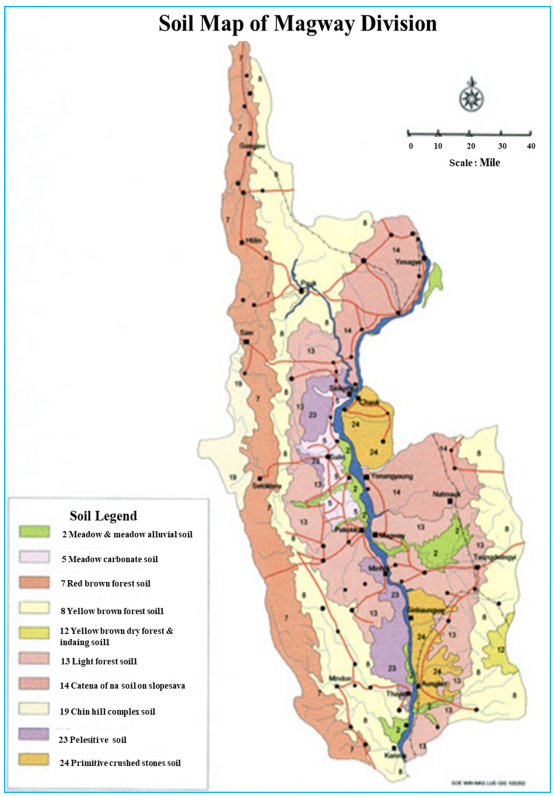

Fig. 15. Soil Map of the Magway Division.

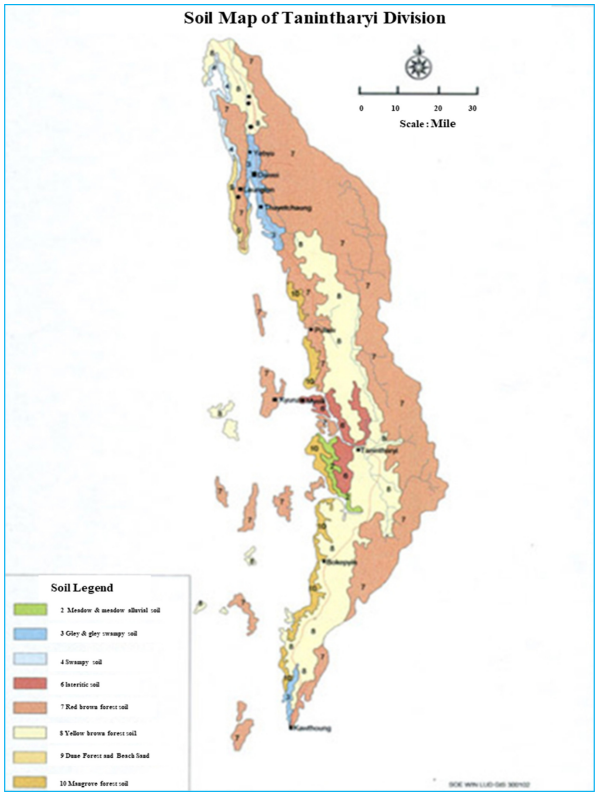

Fig. 17. Soil Map of the Tanintharyi Division.

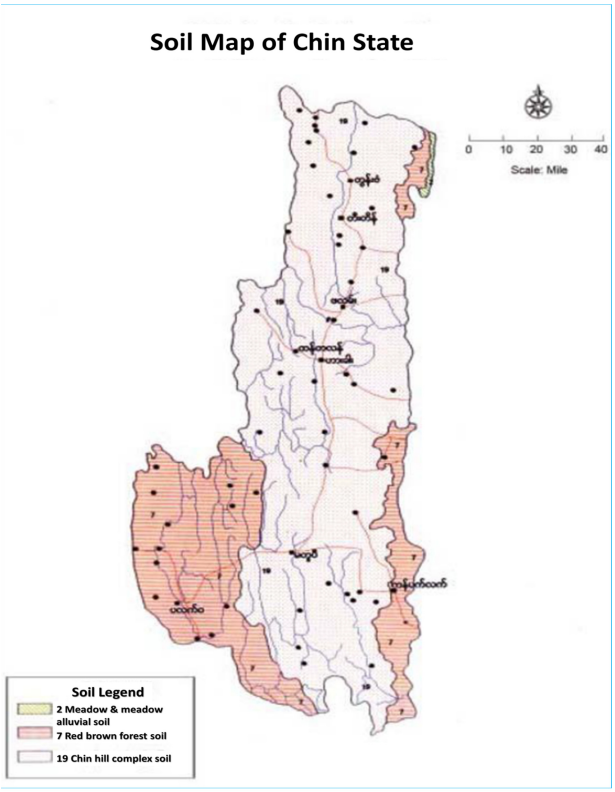

Fig. 18. Soil Map of Chin State

적 요

미얀마의 토양은 기후와 지형적으로 중앙 건조 지대, 구릉지 및 고지대, 삼각주, 해안 지대를 포함하고 있어 토양생성적으로 다양하며, 그로 인해 벼, 들깨, 땅콩, 녹두, 옥수수 등 다양한 작물이 주요한 작물로 재배되고 있다.

토양 중 일부는 지형적 제약과 영구 산림으로 인해 작물 재배는 어려우며, 토양의 물리적, 화학적 특성에 따라 비옥도를 구분하였다. 이러한 자료와 토양 조사를 바탕으로 토양을 분류하고 지도를 작성하였다.

미얀마의 토양은 국제토양분류체계(WRB)에 따라 24개의 토양으로 분류되며, 토양도는 전국단위 및 14개의 주와 구별로 제작되었다. 본 논문은 이러한 특성을 가진 미얀마의 농업 여건과 다양한 토양 유형을 이해함으로서 미얀마에 대한 효율적인 토지 이용과 지속 가능한 농업 발전에 기여하고자 하였다.

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REFERENCES

Arévalo-Gardini, E., Canto, M., Alegre, J., Loli, O., Julca, A., Baligar, V. 2015. Changes in Soil Physical and Chemical Properties in Long Term Improved Natural and Traditional Agroforestry Management Systems of Cacao Genotypes in Peruvian Amazon. *PLOS ONE*. 10:e0132147.

DOA (Department Of Agriculture). 2022. Project Planning. Management and Evaluation Division. DOA. Ministry of Agriculture, Livestock and Irrigation, Myanmar.

Egashira, K., Than, A.A. 2006. Cropping characteristics in Myanmar with some case studies in Shan State and Mandalay Division. *J. Fac. Agr. Kyushu Univ.* 51:373-382.

Eswaran, H., Reich, P.F. 2005. World Soil Map. Elsevier. Encyclopedia of Soils in the Environment.

Gerrald, A.J. 1981. Soils and Landforms: An Intergration of Geomorphology and Pedology. Allen and Unwin. London.

Guppy, C., Win, S.S., Win, T., Thant, K.M., Phyo, K.N. 2017. Soil Nutrient Limitations Define Farming Systems in Central Dry Zone of Myanmar. Myanmar Soil Fertility and Fertilizer Management Conference Proceedings. Department of Agricultural Research-2017.

IUSS Working Group WRB. 2022. World Reference Base for Soil Resources. International soil classification system for naming soils and creating legends for soil maps. 4th edition. International Union of Soil Sciences (IUSS), Vienna, Austria.

LUD (Land Use Division). Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation, the Republic of Union of Myanmar.

Lynn, T.M., Kyaw, E.P., Yu, S.S., Lin, K.Z., Mon, H., Zhran, M., Aung, N.N., Thant, S., Oo, N.N. 2022. Investigation on the Variations of Soil Properties of different Agricultural Soils in Central Myanmar. *Journal of Scientific and Innovative Research.* 11:1-7.

Ministry of Agriculture and Irrigation. 2000. Myanma Agriculture Service and Current Situation of Some Major Crops. Yangon, Myanmar. p. 32.

Ministry of Forest. 2005. National Action Programme of Myanmar to Combat Desertification in the Context of United Nations Convention to Combat Desertification (UNCCD).

Pitio Ndyeshumba. 1995. Soil and Land Use Catenas. A Case Study of Amani Sub-Catchment, East Usambara Mountains. Tanzania.

Swe, P.P., Htun, S.S., Win, B.N. 2015. A Comparative Study of the Physio-chemical Properties in Soil Profile Under Different Forest Types. Leaflet No.23/2015.

Taft, L., Evers, M. 2016. A review of current and possible future human–water dynamics in Myanmar's river basins. *Hydrol. Earth Syst. Sci.* 20:4913-4928.

Wikimedia. Myanmar. https://en.wikipedia.org/*wiki/Myan*mar

Wilson, M.J. 2019. The Important of Parent Materials in Soil Classification: A Review in a Historical Context. Catena. p. 128.