FACULTY OF RESOURCE SCIENCE AND TECHNOLOGY

SOILS UNDER ENRICHMENT PLANTING: ASSESSING SOIL PROPERTIES OF REFORESTATION SITES AT GUNUNG APENG FOREST RESERVE

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Soils under Enrichment Planting: Assessing Soil Properties of Reforestation Sites at Gunung Apeng Forest Reserve

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LIST OF ABBREVIATIONS

%	Percentage
AvP	Available phosphorus
C	Carbon
EC	Electrical conductivity
FAO	Food and Agriculture Organization
N	Nitrogen
SOM	Soil Organic Matter
TN	Total nitrogen

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Soils under Enrichment Planting: Assessing Soil Properties of Reforestation Sites at Gunung Apeng Forest Reserve

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ABSTRACT

Reforestation is a reestablishment or replanting of trees and understored the plants at a site immediately after the disturbances that are cause by deforestation. The importance of reforestation is to reduce the amount of soil erosion and compaction, to minimize the exposure of the mineral soils and to help in improving the soil quality as well as to sustain soil fertility. Recently, reforestations mainly focus on mono planting species as dipterocarps species because it is the most dominant forest species. Besides, more nutrients can be found in mono planting species compared to mixed planting species. However, some study conducted had stated that the growth performance at mix planting species was better and more productive than mono planting species. Hence, questioning whether soil properties plays an important factor in determining the growth and survival rate of trees planted at different planting technique. Therefore, the main objective for this study is to identify the soil properties under reforestation sites with different planting technique (mono and mix planting). The study was conducted at Gunung Apeng Forest Reserve, Serian, Sarawak. Soil sampling was conducted at depth of 0 – 10 cm and 30 – 40 cm for both mono and mix plots respectively. The chemical and physical properties of the soil were analyzed and that include bulk density, soil texture, soil hardness, soil pH and acidity, soil organic matter (SOM), electric conductivity (EC), total nitrogen (N), and available phosphorus (AVP). The analysis was conducted via Student's t-test. The result shows that both mono and mix planting species are similar in term of soil morphology and some physicochemical properties. Hence, the information on the soil properties at both planting plots is important in order to determine the suitability of the tree species planted for reforestation purposes. However, further investigation focusing on selected soil properties is necessary in order to determine the ideal planting technique used for different type of tree species.

Keywords: Nutrients, planting technique, reforestation, soil morphology, soil properties.

Soils under Enrichment Planting: Assessing Soil Properties of Reforestation Sites at Gunung Apeng Forest Reserve

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ABSTRAK

Penanaman semula hutan adalah menubuhkan atau menanam semula pokok dan tumbuhan di tapak kawasan serta merta selepas berlakunya gangguan yang disebabkan oleh pemusnahan hutan. Kepentingan penanaman semula hutan ini adalah bertujuan untuk mengurangkan hakisan dan kepadatan tanah, untuk mengurangkan pendedahan terhadap tanah mineral dan untuk membantu dalam memperbaikai kualiti tanah dan juga untuk mengekalkan kesuburan tanah. Kini, penanaman semula hutan lebih tertumpu kepada penanaman secara mono sebagai spesis dipterocarp kerana ianya adalah spesis hutan yang paling dominan. Selain itu, nutrisi lebih banyak dijumpai pada penanaman secraa mono berbanding dengan penanaman secara campur. Akan tetapi,beberapa kajian menyatakan bahawa kadar pertumbuhan pokok pada spesis tanaman campur lebih bagus dan produktif berbanding dengan penanaman secara mono. Oleh itu, mempersoalkan bahawa aakah ciri-ciri tanah memainkan factor yang penting dalam menentukan pertumbuhan dan kadar kewujudan pokok yang ditanam pada teknik tanaman yang berbeza. Oleh itu, objecktif utama untuk kajian ini adalah untuk mengenalpasti ciri-ciri tanah di dalam kawasan penanaman semula berdasarkan teknik tanaman yang berbeza (mono dan tanaman campur). Kajian ini dijalankan di Hutan Simpan Gunung Apeng, Serian, Sarawak. Sampel tanah diambil di kedalaman 0 – 10 cm dan 30 – 40 cm untuk kedua-dua plot tersebut. Sifat kimia dan fizikal tanah dianalisa dan itu termasuklah ketumpatan tanah, tekstur tanah, kekerasan tanah, pH dan keasidan tanah, bahan organic tanah, elektrik konduktiviti, jumlah nitrogen dan kandungan fosforus yang sedia ada. Data analisis dianalisa menggunakan kaedah Student's t-test. Keputusan yang diperolehi menunjukkan bahawa kedua-dua plot tanaman mono dan tanaman campur adalah sama dari segi morfologi tanah dan sedikit berbeza untuk ciri-ciri fizikokimia. Oleh itu, maklumat mengenai ciri-ciri tanah untuk kedua-dua plot tanaman tersebut adalah penting untuk mengenalpasti kesesuaian spesis pokok yang ditanam di kawasan penanaman semula hutan simpan. Akan tetapi, penyelidikan lanjut berteraskan ciri-ciri tanah yang terpilih adalah perlu untuk mengenalpasti teknik tanaman yang lebih sesuai digunakan untuk spesis tanaman yang berbeza.

Kata kunci: Nutrisi, teknik tanaman, penanaman semula hutan, morfologi tanah, ciri-ciri tanah.

1.0 INTRODUCTION

Tropical forests are the most important natural resource on earth because of its biodiversity and environmental values. Programs that involve conservation, protection and production are very important in order to ensure the sustainability of the forest quality and productivity. In 1989, it is estimated that the total area of the natural forests in Malaysia is 19.49 million ha or approximately 56.3% (Mok, 1992). Mok (1992) also state that the major role of forest is maintaining the stability and quality of the environment by protecting soil and water resources, conserving biological diversity and preserving cultural, recreational and other intrinsic values of the forest which can enhance the quality of people's life.

In Sarawak, 70% of the total land area is still cover with natural forests (Mok, 1992). Out of the percentage, only 4.5 million ha have been constituted as the Permanent Forest Estate (PFE), 256 000 ha of Totally Protected Areas (TPA) and about 3.96 million ha State Forest. The rest of land area are mostly deconstruct for development and plantation purposes. Most of the land area has undergoes deforestation because of several reasons but mainly due to the high demand of timber thus, leading to an increase in logging activity. As stated by Jaya (2002), logging leads to reducing water quality as well as the diversity and the productivity of the biological communities. In addition, Laurance (1999) had studied that the loss of tropical forests not only will destroy the indigenous culture but also diminish the forest natural products.

In recent years, logging and agriculture development especially in oil palm plantation and timber plantations have contribute the most in deforestation of the tropical rainforests (Jong *et al*., 2001). This is because the tropical rainforests in Southeast Asia has high value of timber and rich in biodiversity (Hattori *et al*., 2013).

In addition, Ichikawa (2007) shared that the main cause of deforestation nowadays is because of the development in agriculture where people tend to destroy the natural forest for the purposes of commercial logging and swidden agriculture. According to Angelsen (1995), there is no any clear definition of deforestation. However, Ayoubi *et al*. (2011) mentioned that deforestation results in lowering the soil quality and decrease productivity thus, leading to land degradation (Karam *et al*., 2012). So, to overcome those issues several activities are being conducted including forest rehabilitation, forest plantation or reforestation and afforestation.

Karam *et al*. (2012) also suggested that forest rehabilitation is one of the best ways in order to reduce the loss of soil nutrients and poor vegetation stock (Arifin *et al*., 2010). Besides, another alternative ways suggested by Karam *et al*. (2012) is forest plantation or reforestation where the soil fertility can be maintain and degraded land can be restored to its original condition. Reforestation is defined as a "re-establishment of trees and understored plants at a site immediately after the removal of the natural forest cover" (ITTO, 2002). It is one of the methods that can help in improving the soil quality and sustain the soil fertility aside from sustaining world ecosystem. The important of reforestation is to reduce the amount of soil erosion and compaction and also minimized the exposure of the mineral soils.

Currently, the most applied method in forest rehabilitation is by enrichment planting. Enrichment planting is a method of introducing valuable species at degraded forests without eliminating the already existed species (Karam *et al*., 2012). Hattori *et al*. (2013) also state that enrichment planting is a primary method used in accelerating regeneration and rehabilitating the degraded forests. Several techniques have been introduced in replanting the forest nowadays and this includes mixed planting and mono planting species. Recently, reforestation mainly focusing on mono planting species as dipterocarp species and it is the most dominant forest species (Hattori *et al*., 2013). In addition, it is also recommended as it may provide an optimal shade conditions for the growth of dipterocarp seedlings. The environmental characteristics plays an essential roles in the tropical rainforests ecosystem and also important for the growth performance of the planted seedlings (Hattori *et al*., 2013). These characteristics include microclimate, light conditions and soil quality.

However, the soil properties in both mixed and mono planting species is varied. According to Palmiotto *et al*. (2004), it is stated that the nutrient limitation in mixed dipterocarp species can mostly be found compared to the mono planting species. This means that there is fewer nutrients found in the mix planting species compare to mono planting species. This is might be due to the high diversity on mix planting species (Velden *et al*., 2014). Based on previous study by Carnus *et al.* (2006), mixed planting species it is more productive than mono planting species if only the species planted is adapting well to the site conditions and the functional characteristics such as lights, water and soil nutrients of the planted species are sufficiently different. Norisada *et al*. (2005) also stated that the growth performance for mixed planting species is better than mono planting species.

So, the questions is that whether the soil properties plays an important role in determining the growth and survival rate of trees planted at different planting techniques. Hence, the objective of this study was to identify the soil properties under reforestation site with different planting technique (mono and mix dipterocarp species) at Gunung Apeng Forest Reserve, Serian, Sarawak. This is to determine the suitable dipterocarp species planted at different planting technique for reforestation purposes.

2.0 LITERATURE REVIEW

2.1 Deforestation and land degradation of tropical rainforest

Tropical rainforest in Malaysia according to WWF (n. d) are mostly dominated by *Dipterocarpaceae* family, hence creating the term 'dipterocarp forests' which occurs on dry land with the altitude of about 900 m above the sea level. It is classified into three types that are low dipterocarp forest (LDF) for 300 m above sea level, hill dipterocarp forest (HDF) for the elevation of 300 m to750 m above the sea level and upper dipterocarp forests for 750 m and above (WWF, n. d). However, in Sarawak, it is known as mixed-dipterocarp forest (MDF). Total land area cover in Malaysia are 330, 433 square kilometers (sq. km), of which include both Sabah and Sarawak for 73,620 sq. km and 123, 985 sq. km respectively (Jomo, Chang and Khoo, 2004).

However, the amount of the rainforest existence nowadays is decreasing as many of the forests are being developed for the sake of good life of people. WWF (n. d) stated that some state governments even have halted land clearing for agricultural purposes. Besides, a constant disturbance may affect the biodiversity, topography and climate changes. Rainforests functions as to enhance the sustainability of the environment and ecosystem. Unfortunately, more trees are being cut down and lead to land degradation.

There are several criteria that affecting the soil quality which include holding and release of water to plants, streams and subsoil, also nutrients and other chemicals, to promote sustain growth, to maintain suitable soil biotic habitats and lastly to respond to the management and able to resist degradation. However, due to the human activity and greed such as logging activity, for timber hunting purposes, many natural tropical forest has been disturbed whether for future development or for plantation purposes.

2.2 Reforestation of the degraded forest and its effort in Sarawak

The International Tropical Timber Organization or also known as ITTO (2002) stated that reforestation is a re-establishment of tree after some disturbances. In Sarawak, from year 1979 until 1995, there is an increase in the progress of reforestation. The purposes of reforestation according to FAO (2002) are to grow tropical exotic hardwood species, especially in Sarawak such as *Acacia mangium, Gmelina arborea* and *Paraserieanthes falcataria*. The listed species is somehow only begun as an experiment and as an alternative to overcome the poor performance of species planted in Sarawak from the years before. However other species is also added on the list such as *Swietenia macrophylla, Durio zibenthinus* and *Shorea macrophylla* to help in increasing the tree performance but needs a longer rotation for the shifting cultivation of the reforestation (FAO, 2002).

Reforestation product actually can be harvested for export purposes, not only for protective and protection purposes (Woon & Haron, 2002). Hence, proving that reforestation is important for current and future purposes especially its benefits toward the ecosystem and environment. According to Forest Department Sarawak (2014), timber is one of the most valuable products that highly in demand. The problem arise nowadays is that more tree are being cut down and left effect brings to the deforestation. So, to overcome those issues, Forest Department Sarawak (2014) had encountered by re-planting the tree species in that area. Eventually, the benefits gain from the replanting trees is enough to supply for the future use. Moreover, it is also because of the high demand on the forest product especially in timber, firewood and even food.

2.3 Planting Technique used in the reforestation of tropical forest

Based on Hattori *et al*. (2013) studied, it is stated that by planting an indigenous species brings out benefit in term of timber and food consumption. Indigenous species are a species that is not the main species planted in the particular area but the other species. In tropical rain forest, "environment characteristics such as microclimate, soil qualities and light conditions play essential roles in the ecosystem" (Hattori *et al*., 2013).

The most common technique used in reforestation or any forest rehabilitation is by an enrichment planting (Karam *et al*., 2012). The purpose of enrichment planting is to introduce new species in degraded forests without eliminating the existed species. Besides, in mixed dipterocarp forests under the enrichment planting, the nutrient limitations are mostly found (Palmiotto *et al*., 2004) as compared to mono planting. However, Norisada *et al*. (2005) stated that the growth performance for mixed planting species is better than mono planting.

2.4 The importance of soil properties at the mixed and mono dipterocarp forest

The soil properties plays a major role here it act as an indicator for the determination of forest productivity. In mixed and mono dipterocarp forest, the species distribution and the topography are different. Mixed dipterocarp forest is usually the lowland area whereas mono dipterocarp forest is on tropical area. Besides, Carnus *et al*. (2006) mentioned that mixed species plantations may be more productive than mono planting species with conditions if only the species planted is adapted well to the site conditions and the functional characteristics of the planted species are sufficiently different.

Palmiotto *et al*. (2004) stated that most of the lowland rain forest exists in Borneo is mixed dipterocarp forest (MDF). In MDF, the species composition and the forest structure are related with the small scale edaphic and topographic gradients. Besides, the soil nutrients availability is also directly influences with the species distribution and the community composition. Hence, indicate that the soil nutrients in the mixed forest are different compare to the mono species planting. For mono planting species, since it has high density (Velden et al., 2014) and consists of only a single type of species, hence the condition of mono planting species are classified as more to humid tropics evergreen (Hart, Hart & Murphy, 1989).

3.0 MATERIALS AND METHODS

3.1 Description of the study site

The location of the soil sampling will be conducted at Gunung Apeng Forest Reserve, Serian, Sarawak with latitude and longitude of N00°55’24.7’’, E110°38’32.2’’ (*Figure 1*). Gunung Apeng Forest Reserve is a reforestation site for the purpose of conservation. The size of the total area at Gunung Apeng Forest Reserve is 1800 ha. It is establishes in 2005 with the cooperation of Japan-Malaysia Association and Sarawak Forestry Department. According to Jaya (2002), Gunung Apeng Forest Reserve was gazette on May 8, 1958 under the Forest Ordinance 1953.

Figure 1: Location of the study site (Gunung Apeng Forest Reserve).

Based on Sarawak Soil Classification system, type of soil in the study site is Grey-White Podzolic soil. The soil derived from non-calcareous sedimentary rocks which consisting of fine and whitish sandstone. Reforestation site of Gunung Apeng Forest Reserve is classified as one of the secondary forest. Before it re-establish as reforestation site, logging activity and some paddy cultivation were being conducted.

Species found in the area include *Dryobalanops beccarii* (Kapur bukit), *Shorea macrophylla* (Engkabang jantong), *Shorea parvifolia* (Meranti sarang punai) and

Shorea falcifera (Balau Kuning) and some local fruit trees. Additional information of Gunung Apeng Forests Reserve is the climate in the area is classified as a tropical wet with a subtropical wet bio zone with the annual rainfall of 3500 mm and temperature at the range of 23°C to 33°C.

3.2 Soil sampling

Both mono and mixed dipterocarp species plot which has a size of 50 m x 50 m is divided to four subplots which comprised of 25 m x 25 m each (*Figure 2*). Hence, there will be 4 subplot created in one plot labelled with A, B, C and D. Besides, one subplot consists of 25 trees means there is 100 trees in each plot of mono and mix dipterocarp species respectively (*Figure 3*). The planting technique used is by line planting technique with the distance of 5 m x 5 m. Species planted at mono plot are *Dryobalanops beccarii* while for mixed plot, it consists of *Dryobalanops beccarii* together with other species such as *Shorea macrophylla, Shorea parvifolia*, and *Shorea falcifera*.

Composite soils were collected from the depth of 0 – 10 cm and 30 – 40 cm respectively at each subplot resulting in 8 composites. Since there were 4 plots, thus there are 32 of composite soils in total. The soil sample was collected on each subplot randomly on the planting lines by using soil auger. As for physical analysis sample, core ring were used to take sample at three random points on each subplot, thus results in 96 samples. After that, it is then taken to the laboratory for further analysis.

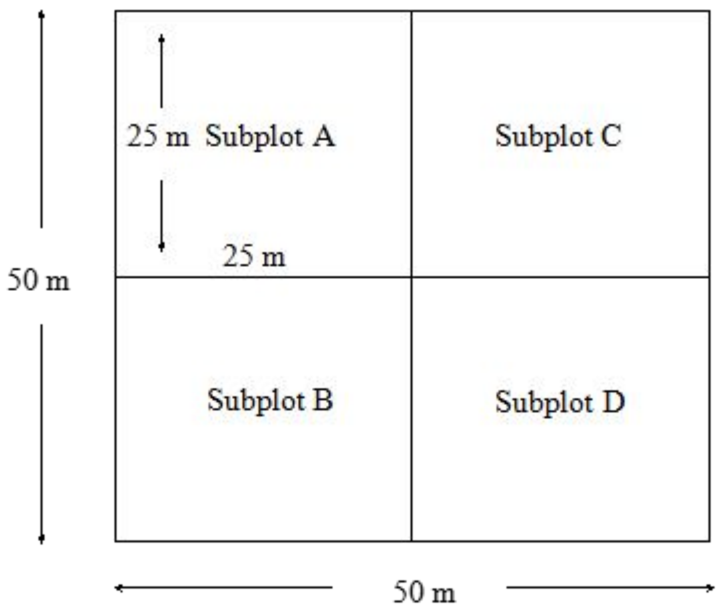

Figure 2: Study plot design

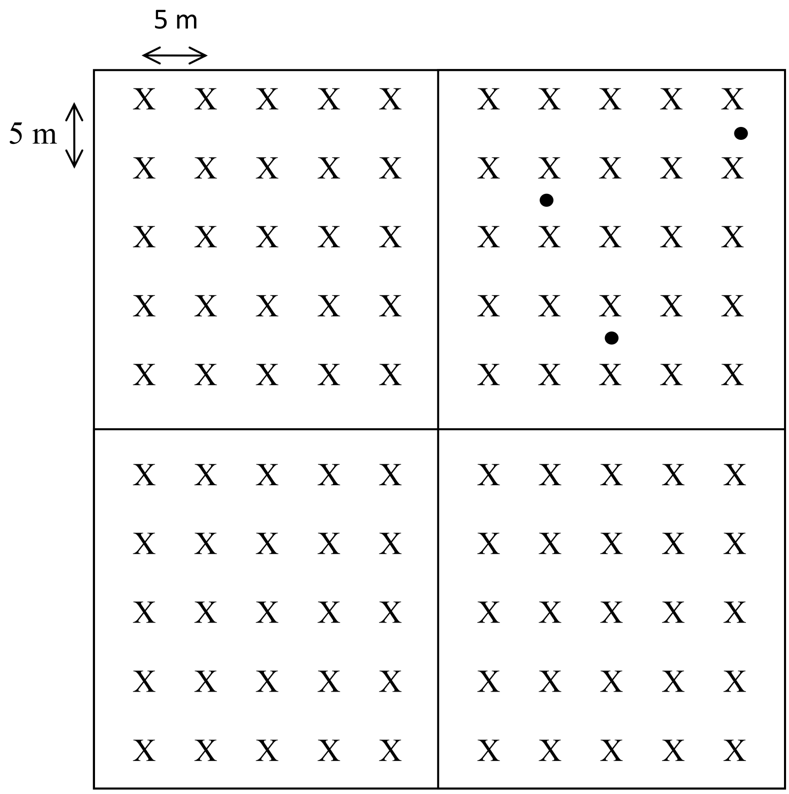

Figure 3: Trees (X) in each subplot with the distance of 5 m on the planting line.

*Black dot is where the example of sample taken randomly in each subplot.

3.3 Soil analysis

3.3.1 Soil physical analysis

The soil physical analyses conducted were bulk density, soil texture identification, soil hardness and structure. For soil texture identification, it was conducted using qualitative (“feel”) and quantitative method. As for this study, both methods were applied. Tool known as Yamanaka-type push cone penetrometer are be used to determine the soil hardness and structure on the site. Whereas for soil texture analysis, it was conducted using the pipette method (Miller & Miller, 1987).

As for bulk density, it were measured based on the weight of the oven dry solids soil per unit volume of soil. First, the fresh sample that was collected using a core ring was measured and the reading was recorded. Then, it is put inside the oven for dried overnight (24 hour) at temperature of 105ºC. After 24 hours, the readings of the oven dry sample were recorded. According to USDA (1999), bulk density of the soil was calculated based on formula as shown below:

$$\text{Bulk density (BD)} = \frac{\text{Oven dry weight of soil (g)}}{\text{Volume of the soil (cm}^3\text{)}}$$

3.3.2 Soil chemical analysis

For chemical analysis, the electrical conductivity (EC), soil pH and acidity analysis, soil organic matter (SOM), total nitrogen (TN), and available phosphorus (AvP) analysis were conducted. The first step to determine pH and acidity as well as EC analysis was by measuring 5g of soil sample then shakes with 25ml of deionized water. It was then being measured by using glass electrode of pH meter and platinum EC analysis respectively.

To measure SOM, loss in ignition method was used. 3g of soil sample that has been sieved through 0.4 mm sieve were put into the crucible and placed into the oven for 8 hour with the temperature of 550°c. Meanwhile, for available phosphorus (AvP) analysis, it were conducted by using Bray II method (Bray & Kurts, 1987), whereas Kjedahl method for total nitrogen (TN) analysis (Pereira *et al*., 2006).

For available phosphorus (AvP) analysis, it was determine by using formula as below:

$$\text{AvP} = \frac{\text{C x 14}}{\text{ODW}}$$

Where,

C	Phosphorus concentration from chart/equation (µg/ 2.5 ml)
ODW	Oven-dry sample weight (g)
14	Dilution fact

As for total nitrogen (TN), the extraction was utilized by using Kjedahl digestion technique and then the concentration was read through colorimeter. It is then calculated by using formulas as below:

$$\text{ppm TKN} = \frac{\text{75 x A}}{\text{B x C}}$$

Where,

A	mg/L displayed
B	g sample taken for digest
C	mL analysis volume of digested sample

3.4 Statistical analysis

3.4.1 Data Analysis

The statistical analysis was conducted by using Student t-test via Microsoft Excel. This is to detect any significant difference of the soil properties between mono planting and mixed planting plots.

4.0 RESULT AND DISCUSSION

4.1 Soil morphology

Table 1 below shows the summary of soil morphological properties at mono and mix planting sites in two different areas (MP 2011 – MP 2014 and MXP 2011 – MXP 2012 respectively). At MP 2011, it is located at N 01° 27. 912', E 110° 26. 863' and has an elevation of 71 m and slope 13°. The topography of the area is rolling hill and consists of *Dryobalanops beccarii* species. However, the elevation of MP2014 was 60 m and located at N 00° 55' 22.5", E 110° 38' 39.5". The slope for MP 2014 was 6° with flat topography. Based on the observation made on the field, both MP 2011 and MP2014 have four horizons that is horizon O, A, B1 and B2. For MP 2011, the horizon O with the depth of 0 – 3 cm mainly consists of litters and undecomposed *Dryobalanops beccarii* species but for MP 2014, the depth of the horizon O is 0 – 5 cm, also consists of several undecomposed *Dryobalanops beccarii* and litters.

The depth of the horizon A for both MP 2011 and MP 2014 was slightly different in depth which is 3 – 8 cm and 5 – 15 cm respectively. Based on the "feel" touch method in the field, the boundary of the surface layers were classified as gradually wavy for both sites, but the color of the soil is different. As observed, the color for A horizon at MP 2011 was reddish brown (2.5YR 4/4) while MP 2014 was brown (10YR 4/3). Besides, the soil was also classified as a silty loam soil and silty clay loam respectively. The structure of the soil at MP 2011 was weak and has granular shape meanwhile the consistency was a little bit or slightly sticky and non-plastic. However the structure for the soil at MP 2014 was weak sub-angular blocky with very fine in size and the consistency was also slightly sticky but plastic. Other than that, the roots size for both sites was also different. The size of the roots at MP 2011 was considered very fine to coarse while for MP 2014, the size was coarse.

In addition, there were also many roots found (as observed) in MP 2014 sites. But for MP 2011, the roots were only few and common. Furthermore, the organic matters exist as observed on the field for both MP 2011 and MP 2014 was low and medium respectively. There is no rock fragments found for both plots but at MP 2011, the soil was moist for A horizon. By using the penetrometer, the soil hardness for both MP 2011 and MP 2014 was increasing as it goes deep and deeper into the ground. For MP 2011, the hardness of the soil for horizon A was 12 mm whereas for MP 2014, it was 9.8 mm.

The difference in depth of the B1 horizon can clearly be seen for MP2011 and MP 2014. MP 2011 has 8 – 32 cm meanwhile MP 2014 has 15 – 40 cm. It was clearly seen that the depth of B1 horizon in MP 2011 was larger compare to B1 horizon in MP 2014. However, the soil for both sites was classified as silty clay loam. In addition, the colors of the soil for both MP 2011 and MP 2014 were classified as yellowish brown (10YR 5/8) and (10YR 5/4) respectively. The structure of the B1 horizon for both sites was sub-angular but the only differences are that at MP 2011, the structure was strong while at MP 2014, the structure was weak. This might be due to the age factor of the sites. Other than that, the size of the structure at MP 2014 was very fine. As for the soil hardness, the average value for MP 2011 was 14.4 mm meanwhile for MP 2014, it was 16.8 mm. In term of soil hardness, both horizon B1 and horizon A was similar for MP 2014. Once again, this is might due to the age factor because MP 2014 was only considering as 1 years old site. So, there was not much of changes would happen. The consistency for both mono planting sites was sticky and plastic to very plastic. There was only few roots existing in horizon B1 but the size were different for both sites. The roots size for MP 2011 was very fine to coarse while for MP 2014, the roots were medium in size. Other than that, both have low organic matter and no rock fragments as observed. However, for MP 2011, the condition of the soil was slightly moist. In addition, the boundary for both sites was diffusely wavy and smooth respectively.

Furthermore, the depth of horizon B2 for MP 2011 and MP 2014 is 32 – 65 cm and 40 – 60 cm respectively. As the result shown, there was not much difference in B2 horizon for both mono sites. Other than that, the color for MP 2011 was classified as brownish yellow (10YR 6/6), meanwhile for MP 2014, it were light yellowish brown (10YR 6/4). Type of soil in both mono planting sites was sandy loam and silty clay loam respectively. The hardness of the soil for MP 2011 and MP 2014 was 14.8 mm and 17.4 mm respectively too. Furthermore, the boundary of the B2 horizon was diffusely wavy and smooth. The structure for both mono planting sites was sub-angular and very fine in size, meanwhile the consistency was sticky. But MP 2011 was slightly plastic and MP 2014 is very plastic consistency. There were few roots exist as observed but differ in size. For MP 2011, the roots size was very fine to coarse while for MP 2014, the root size was just fine. The organic matter was very low for MP 2011 and very low for MP 2014. However, at MP 2014, there is the present of charcoal, while at MP2011, the soil condition was moist. In conclusion, there was no rock fragment found in both sites for all horizons as observed.

For mix planting sites, MXP 2011 was located at N 00° 55’ 33.3”, E 110° 38’ 09.1” with the elevation of 53 m and slope 10°. While MXP 2012 was located at N 00° 55’ 33.6”, E 110° 3’ 09.4”, has 44 m elevation and slope 11°. Both of the sites were observed as hilly topography but only MXP 2011 has slightly erosion. The soil horizon for MXP 2011 was slightly different compare to mono and MXP 2012 site because it has five horizons as observed. The horizons at MXP 2011 is O, A, B1, B2 and B3. However, for MXP 2012 sites, it has four horizon that is O, A, B1 and B2.

The depth for O horizon at both MXP 2011 and MXP 2012 was same that is 0 – 2 cm. The top of the soil is mainly compost of undecomposed leaves and litters.

For horizon A, the depth for MXP 2011 and MXP 2012 was 2 – 12 cm and 2 – 16 cm respectively. Color of the soil as observed on the field was dark grayish brown (10YR 4/2) and brown (10YR 4/3) respectively too. Type of the soil for both plots was classified as sandy clay loam with moderate sub-angular (MXP 2011) and weak angular blocky (MXP 2012) structure. The consistency of the soil in A horizon was sticky and very plastic for MXP 2011, but sticky and slightly sticky for MXP 2012. The size of the roots for MXP 2011 was medium and it were commonly found while for MXP 2012, the size of the roots was very fine and only few are found as observed. The boundary for horizon A was also different for both mixed planting sites. For MXP 2011, the boundary for A horizon was gradually wavy but for MXP 2012, it were clear and smooth. At MXP 2011, the content of organic matter waws high and the soil condition were moist. Besides, the soil hardness for MXP 2011 was 12 mm while for MXP 2012, it was 6.8 mm.

Meanwhile for B1 horizon, the depth was 12 – 28 cm and 16 – 42 cm respectively. Both were classified as sandy clay loam and brown in color (10YR 5/3). However, the structure was different as MXP 2011 has moderate but MXP 2012 has weak sub-angular blocky structure. The size of the soil structure at MXP 2011 was medium. However, the soil hardness for MXP 2011 and MXP 2012 were 14.4 mm and 16.4 mm respectively. Both of the sites have plastic consistency but MXP 2011 was slightly sticky meanwhile MXP 2012 was very sticky. Based on the observation, the roots present on B1 horizon was few to many and very few roots respectively (MXP 2011 and MXP 2012). In addition, the size of the roots for both sites was considers as fine. However, the organic matter present was medium and low respectively. Other than that, the soil boundary for horizon B1 at MXP 2011 and MXP 2012 was diffusely wavy and gradually wavy respectively.

As for horizon B2, the depth of the soil was clearly seen as MXP 2011 has 28 – 45 cm while MXP 2012 has 42 – 65 cm. The color classification was yellowish brown (10YR 5/4) and light yellowish brown in color (10YR 6/4), and also are classified as sandy clay loam for both of the sites respectively. The structure of the soil was weak and moderate sub-angular blocky with coarse and fine in size. Soil hardness for both sites was 14.8 mm and 17.4 mm respectively. Besides, the consistency for MXP 2011 was sticky and slightly plastic while at MXP 2012, it was very sticky and very plastic. Other than that, the present of the roots was fine to few for both sites but for MXP 2012, the roots size was fine to very fine. In addition, the boundary for horizon B2 is diffusely smooth and diffusely wavy for MXP 2011 and MXP 2012 respectively. Based on the observation on the field, the content of organic matter in MXP 2011 sites was medium while for MXP 2012 sites, the organic matter content was low.

Lastly, the B3 horizon at MXP 2011 plot consists of 45 – 60 cm depth, also classified as sandy clay loam and has yellowish brown in color (10YR 5/6). The soil structure was moderate sub-angular blocky with coarse in size. The soil hardness for this horizon was 15.2 mm. If using the “feel” method, B2 horizon was classified as sticky and plastic. Besides, the roots present was very fine and few, has low organic matter with moist soil condition. The boundary for B3 horizon was diffuse and smooth. As for the soil hardness, each of the horizons in mixed planting sites was increase as it goes deeper and deeper.

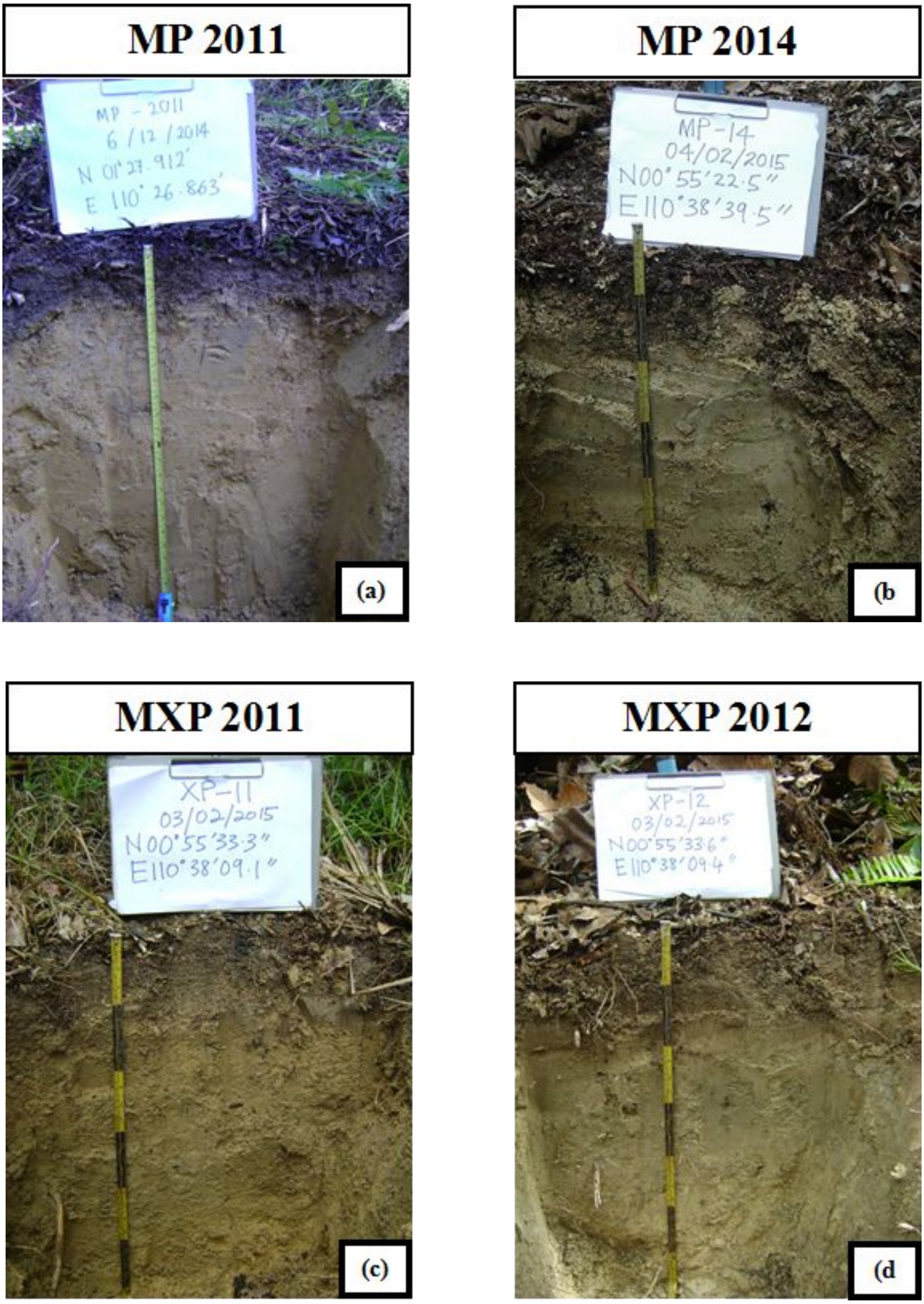

Figure 4: Soil horizon for all study sites: (a) & (b) Mono planting sites; (c) & (d) Mix planting sites

Based on the soil profile description above, both plots have similar in term of soil morphology. Generally, both mono and mix planting sites were classified as sandy soil. Even the soil color shows no differences (*Figure 4*). However, according to the summary of soil morphological properties at Table 1 below, specifically mono planting site was consider as silty clay loam meanwhile mix planting sites were sandy clay loam.

If observed properly at mono planting (*Figure 4*, (a)) for horizon A, it was a lot darker compare to the other three (*Figure 4* (b), (c), and (d)). This might be due to the high accumulation of the organic matter (FAO, 1998) on the ground surface and high activity of microorganism which cause by decomposition of the organic materials such as leaves, litters and animal manure. Besides, that might also due to the high amount of rainfall in that particular area or caused by poor drainage (FAO, 1998).

In term of soil classification, type of soil in the sampling site was classified as Red – Yellow Podzolic soil group based on the Sarawak Soil Classification System (Scott, 1963). The results also indicate that soil on both mono and mix planting was classified under the same soil group order. Table 1 below indicates the summary of soil morphological properties as observed.

Table 1: Summary of soil profile descriptions for each mono and mix planting plots

Plot	Horizon	Depth (cm)	Colour	Field texture[a)]	Consistency[b)]	Structure[c)]	Roots[d)]	Boundary[e)]	Rock fragment[f)]	Hardness (mm)[g)]
MP 2011	**(N 01° 27. 912', E 110° 26. 863')**									
	O	0 – 3	Litterfall							
	A	3 – 8	2.5YR4/4	ZL	ss/np	1/vf/gr	vf-c/fe-co	gw	n	12
	B1	8 – 32	10YR5/8	ZCL	s/p	3/m/sbk	vf-c/fe	dw	n	14.4
	B2	32 – 65	10YR6/6	SL	s/sp	2/f/sbk	vf-c/fe	dw	n	14.8
MP 2014	**(N 00° 55' 22.5", E 110° 38' 39.5")**									
	O	0 – 5	Litterfall							
	A	5 – 15	10YR4/3	ZCL	ss/p	1/vf/sbk	c/ma	gw	n	9.8
	B1	15 – 40	10YR5/4	ZCL	s/vp	1/vf/sbk	me/fe	ds	n	16.8
	B2	40 – 60	10YR6/4	ZCL	s/vp	1/vf/sbk	f/fe	ds	n	17.4
MXP 2011	**(N 00° 55' 33.3", E 110° 38' 09.1")**									
	O	0 – 3	Litterfall							
	A	2 – 12	10YR4/2	ZL	s/vp	2/f/sbk	me/co-ma	gw	n	12
	B1	12 – 28	10YR5/3	SCL	ss/p	2/m/sbk	f/fe-ma	dw	n	14.4
	B2	28 – 45	10YR5/4	SCL	s/sp	1/c/sbk	f/fe	ds	n	14.8
	B3	45 – 60	10YR5/6	SCL	s/p	2/c/sbk	vf/fe	ds	n	15.2
MXP 2012	**(N 00° 55' 33.6", E 110° 3' 09.4")**									
	O	0 – 2	Litterfall							
	A	2 – 16	10YR4/3	SCL	s/sp	1/vf/abk	vf/vfe	cs	n	6.8
	B1	16 – 42	10YR5/3	SCL	vs/p	1/vf/sbk	f/vfe-fe	gw	n	16.4
	B2	42 – 65	10YR6/4	SCL	vs/sp	2/f/sbk	vf-f/fe	dw	n	17.4

Abbreviations: [a)]Texture: SCL: Sandy Clay Loam, SL: Sandy Loam, ZCL: Silty Clay Loam, ZL: Silty Loam; [b)] Consistency: ss: slightly sticky, s: sticky, vs: very sticky, sp: slightly plastic, p: plastics, vp: very plastic; [c)] Grade: 1: weak, 2; moderate, 3: strong, Type: abk: angular blocky, sbk: subangular blocky, gr: granular, Size: vf: very fine, f: fine, m: medium, c: coarse; [d)]Root size and abundance: vf: very fine, f: fine, me: medium, c: coarse, n: none, vfe: very few, fe: few, ma: many, co: common; [e)]Boundary: abrupt, c: clear, g:gradual, d:diffuse, w:wavy, s: smooth; [f)]Rock abundant and size: fe: few, co: common, n: none, Shape: sa: subangular, fg: fine gravel; [g)]Hardness was measured using a Yamanaka-Push Cone type penetrometer. Value in parentheses refers to GPS reading and slope.

4.2 Soil Physicochemical Properties in Mono and Mix Planting Plots

4.2.1 General properties in mono and mix planting plots

Generally, both of mono and mix planting site was consider strongly acidic as the pH value was lower than 6.00 with the range of 4.46 to 5.13 respectively at both surface and subsurface layers. The range of soil organic matter was in between 4.5% to 9.1% for both planting plots thus indicate that the soil were less fertile because the soil can be consider as fertile if the organic matter was higher than 15%. According to FAO (2005), soil organic matters mainly are from any living organisms materials such as microorganism, plant and animals that undergo decomposition process. Besides, based on the soil physical characteristics, it was shown that the soil in both mono and mix planting area were classified as sandy soil. These because the amount of sandy soil was much higher compare to clay and silt with range of 56.8% to 64.8%.

The electric conductivity for mono planting sites was much higher compare to mix planting site with the value range of 18.1 µS/cm to 54.0 µS/cm and 10.6 µS/cm to 25.1 µS/cm respectively. Based on the result shown on Table 2, there was a clear significant difference between mono and mix planting sites. That might be due to the climatic change and time duration while sampling because electric conductivity is not the static parameter. It can change based on the climate and weather change. Besides, the soil salinity will increase based on the climate change (Paz *et al.*, 2012). Meanwhile, the available phosphorus content was higher in subsurface soil compare to surface soil for both mono and mix planting site respectively. Generally, surface soil contains more phosphorus compare to subsurface soil because of the humus and litters that has direct contact with the surface. However, the results shows a vice versa result which might indicate that the available phosphorus in the surface was loss due to leaching or runoff process.

In addition, moisture content of the soil for mono and mix planting sites was in between 1.4% to 2.5% respectively without taking into consideration of the surface and subsurface layers. According to FAO (2003) soil under natural vegetation generally has high porosity because of high biological activity and less interference by man. Hence, the physical quality was more superior compare to soils used for crops or grazing. In addition, soil moisture content also plays a major relationship with soil compaction. Soil compaction is determined through bulk density which acts as an indicator. Based on Table 2, range value of bulk density was in between 1.10 g cm^{-3} and 1.40 g cm^{-3} which means the soil was loss and not compact, thus means that the soil for the plot were consider as an ideal soil for the species to growth at that area. Besides, it also allowed the root growth of the planted species and accessing of the water and nutrients stored deep in the soil. Moreover, it also will results in increasing plant productivity.

However, the soil texture for both mono and mix were generally classified as sandy loam soil which means it has high porosity and low water holding capacity. Total carbon for mono planting site was in between 2.6% to 5.0% meanwhile at mix planting site, the range was in between 2.8% to 5.2%. In addition, the highest C content was observed in the surface layer (0 – 10 cm). The C/N ratio for mono and mix planting site was 21.5% to 36.9%. Besides, both mono and mix planting site has been classified as sandy soil thus means that it affected the C accumulation and stabilization. Based on the result, total C for mono planting sites was low compare to mix planting site. However, according to Balieiro et al. (2008) apart from the existing vegetation, the C contents of the mixed indigenous tree plantations should be much lower compare to mono planting species. The difference of the C stocks for both mono and mix planting sites might be due to the litter quality at the site.

Furthermore, C/N ratio also plays a major role in indicating the quality of soil organic matter. The ideal value for C/N ratio must be at least 15% or more, but excessive C/N ratio may cause organic matter in the soil decomposed incompletely. However, based on the result obtained, both mono and mix planting sites was more than 15%. Thus indicates that the C stocks are more than the N stocks in the soil. This might due to the process of N fixation that occurs naturally based on the climate and weather change.

Table 2: Soil physicochemical properties at mono and mix planting plots

Soil Physicochemical Properties		Mono Planting (n = 8)	Mix Planting (n = 8)
0 – 10 cm			
pH (H_2O)		4.46 ± 0.29	4.59 ± 0.13
Electric Conductivity	µS/cm	54.0 ± 24.4*	25.1 ± 4.9*
Soil Organic Matter	%	8.7 ± 2.3	9.1 ± 1.6
Bulk Density	g/cm^3	1.10 ± 0.17	1.15 ± 0.11
Clay	%	12.0 ± 5.3	16.8 ± 8.7
Silt	%	13.7 ± 3.0	14.9 ± 9.8
Sand	%	63.4 ± 6.7	56.8 ± 10.7
Total Carbon	%	5.0 ± 1.3	5.2 ± 0.9
Total Nitrogen	%	0.2 ± 0.1	0.2 ± 0.0
C/N Ratio		21.5 ± 1.9	23.0 ± 2.8
Available Phosphorus	mg/kg	3.9 ± 6.9	2.4 ± 1.6
30 – 40 cm			
pH (H_2O)		4.98 ± 0.29	5.13 ± 0.15
Electric Conductivity	µS/cm	18.1 ± 3.7*	10.6 ± 2.4*
Soil Organic Matter	%	4.5 ± 0.9	4.9 ± 1.1
Bulk Density	g/cm^3	1.40 ± 0.12	1.37 ± 0.07
Clay	%	15.6 ± 10.8	14.5 ± 4.2
Silt	%	13.7 ± 2.0	14.1 ± 2.1
Sand	%	64.8 ± 11.2	64.5 ± 4.3
Total Carbon	%	2.6 ± 0.5	2.8 ± 0.6
Total Nitrogen	%	0.1 ± 0.0	0.1 ± 0.0
C/N Ratio		34.2 ± 4.9	36.9 ± 5.6
Available Phosphorus	mg/kg	38.6 ± 10.5*	19.3 ± 12.4*

* indicate significant differences among sites at 5% using Student's t-test. Values after (±) symbol represent the standard deviation.

4.2.2 Acidity and nutrient retention in term of available P in mono and mix planting

Based on pH water chart below, it interpreted that mono planting was slightly acidic than mix planting. However, from the statistic aspect point of view, there were not much of differences between mono and mix planting.

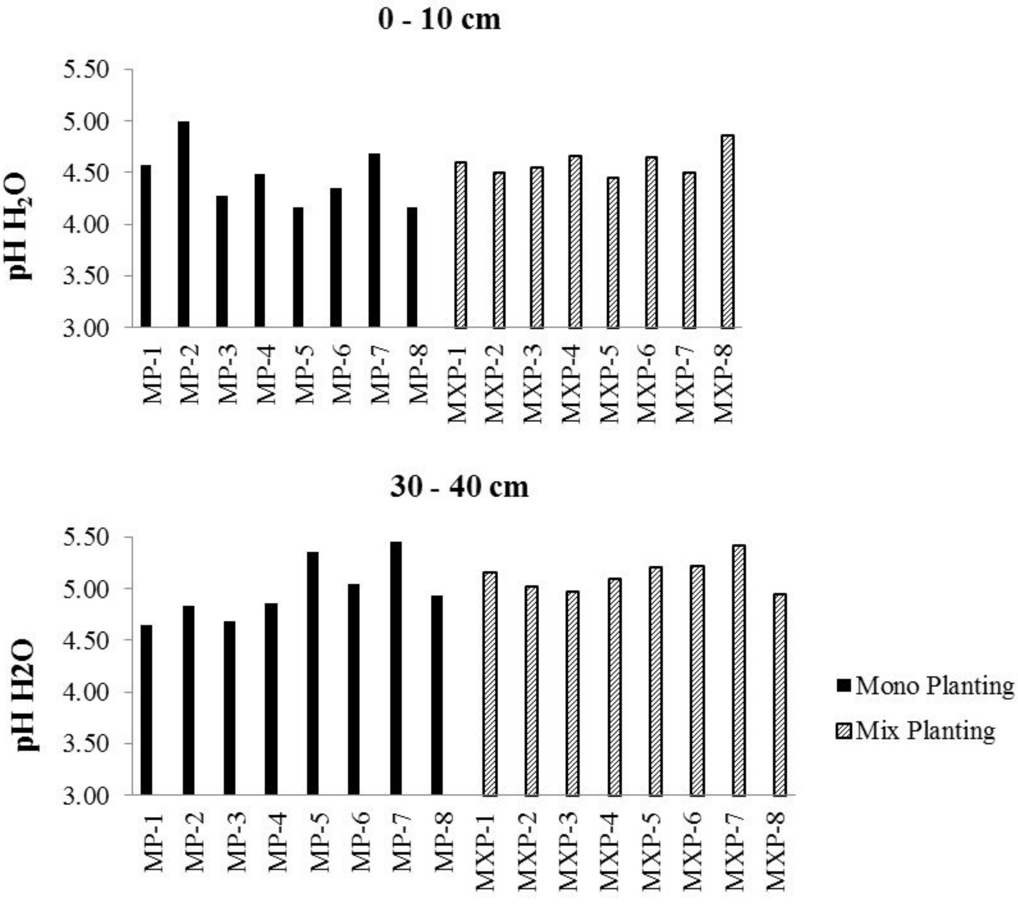

Figure 5: pH value in mono and mix planting at surface layer

Whereas, the most clear significant difference is the available phosphorus where the value (> 0.05) was 38.6 ± 10.5 and 19.3 ± 12.4 for mono and mix planting respectively. Based on general properties on Table 2 and chart on *Figure 6* below, surface layer (0 – 10 cm) has less phosphorus content compare to subsurface layer (30 – 40 cm).

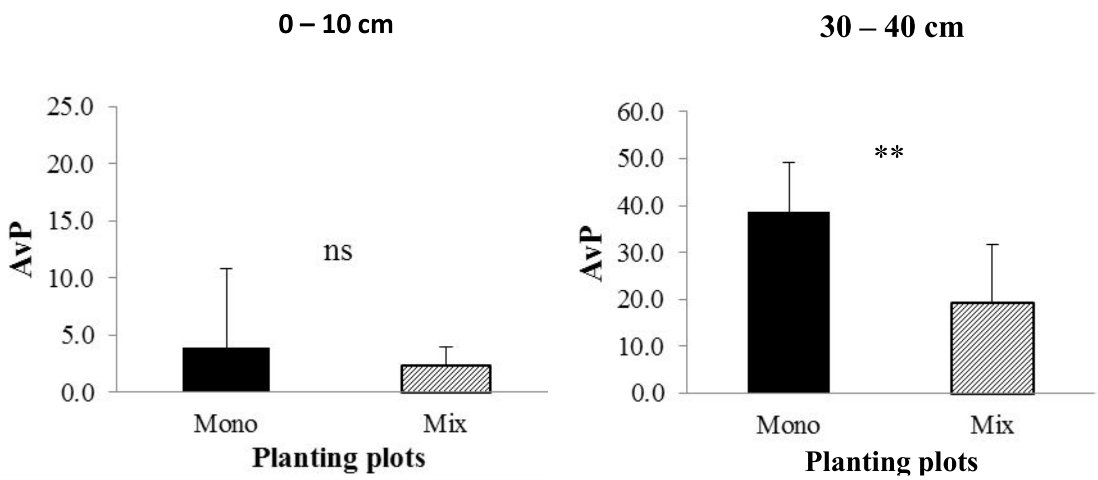

Figure 6: Available phosphorus between mono and mix planting at surface and subsurface layer.

However, based on the *Figure 7* below, the highest amount of available phosphorus was on the surface layer at mono planting sites. Surface runoff and leaching play a significant role that cause the amount of available phosphorus differ between the soil layer and horizon. A change of topography also plays a major factor on indicating the differences of the available phosphorus content for each soil layer.

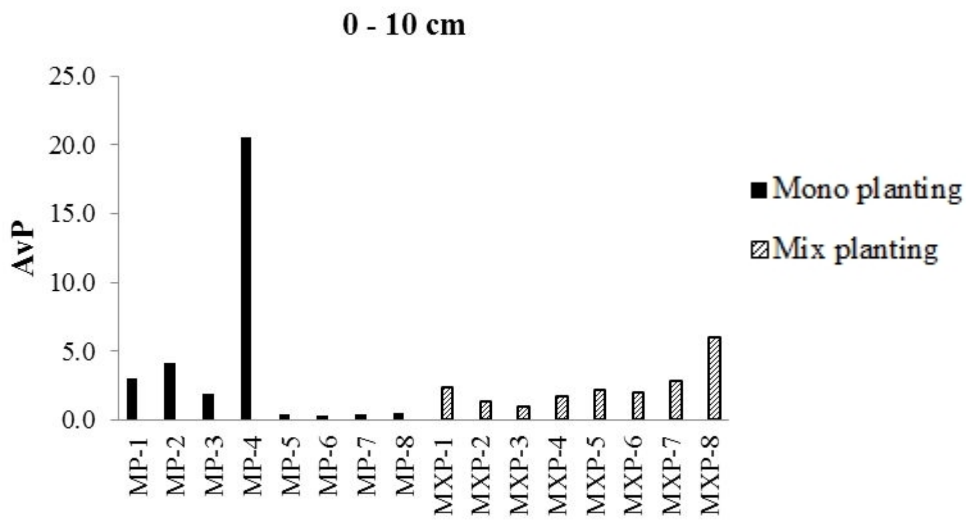

Figure 7: Available P in mono and mix planting at surface layer

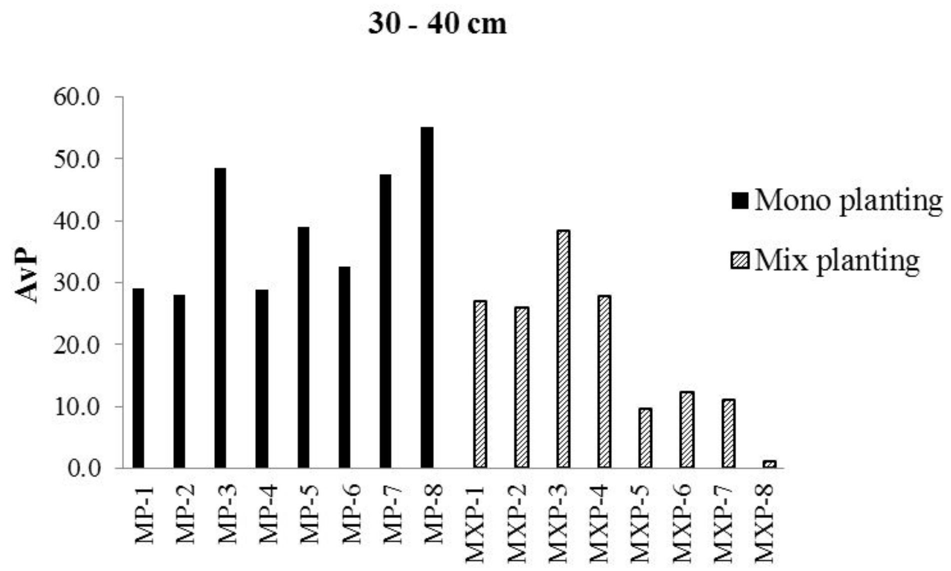

Figure 8: Available P in mono and mix planting at subsurface layer

At point MP-4 (*Figure 7*), it shows the highest amount of phosphorus content as compare to the other point at surface layer. This was due to the topography factor at the site. Based on the observation, that point located at MP 2011 where the topography of that area was slightly hilly or sloppy. Hence indicate that it might due to the surface runoff. Based on the chart shown above, the nutrient limitation was mostly found in mix planting species. It might be due to the history of that area before it establish as a secondary forest. Besides, Marin-Spiotta *et al*., (2009) stated that any disturbance that occur during reforestation can result in nutrient limitation which may affect the rates of the forest recovery and soil C accumulation.

In addition, electric conductivity also shows a significant difference between mono and mix planting. Generally, the average overall minimum value of EC in all sites was 12.0 µS/cm while the maximum value was 101.3 µS/cm without taking into consideration of mono planting and mix planting plots. Based on the data as shown by Table 2 above, the range value of EC at surface layer for mono and mix planting were

54.0 μS/cm – 25.1 μS/cm respectively. Whereas for subsurface layer, the EC value range were in between 18.1 μS/cm – 10.6 μS/cm.

Furthermore, *Figure 8* also shows the surface and subsurface soil of mono planting were much higher compare to mix planting plots. This might due to the climatic change and time duration while sampling. As proved by Paz *et al*., (2012), the soil salinity increases based on the precipitation rate in a given area. Besides, the climate condition during the sampling drastically change to rainy day, thus explain the higher value of electric conductivity at surface soil especially at mono planting sites.

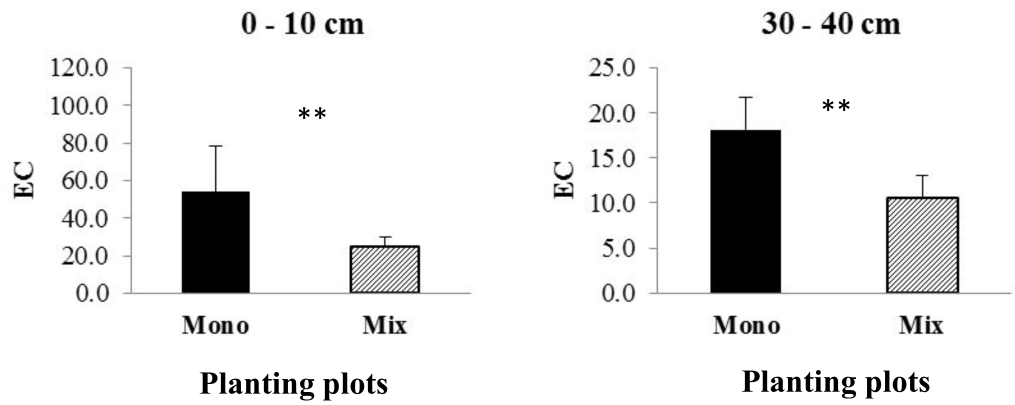

Figure 9: Significance difference between mono and mix planting at 0 – 10 cm and 30 – 40 cm soil depth.

4.2.3 Quality of soil organic matter

A great potential in improving soil quality of degraded lands was by reducing soil disturbance and providing perennial ground cover (Sauer et al., 2012). In particular, Sauer et al. (2012) also stated that soil organic matter was important featured of soil quality associated with enhanced C and nutrient cycling, optimal soil structure, improved infiltration and soil water holding capacity. In this study, soil organic matter for mono and mix planting site shows no significance difference for both surface and subsurface layer (*Figure 10*). That was because of low organic matter present in the site.

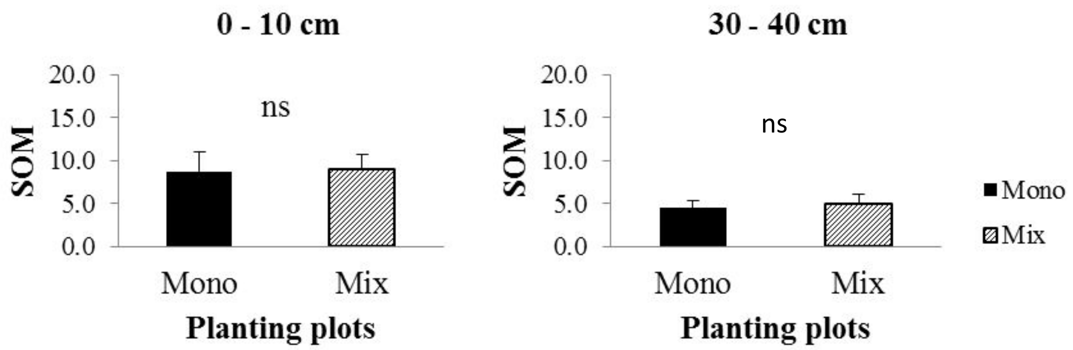

Figure 10: Soil organic matter between mono and mix planting at surface and subsurface layer.

According to USDA (1999), soils in the forest were usually have comparably low organic matter levels because of several factors such as tress produce a much smaller root mas per acre then grass and it is also do not die back annually and decompose every year. Instead, the organic matter in the forest was tied up in the wood rather than being returned to soil annually (USDA, 1999). Besides, organic matter in forest decreases rapidly with depth which means the organic matter in the subsurface layer was much lower compare to the surface layer which was cause by the fine roots of the tree species die off year by year. Moreover, *Figure 10* also shows that the amount of organic matter at the surface layer was higher compare to subsurface layer.

Referring back to the Table 2, soil texture for both mono and mix planting sites were generally classified as sandy soil because of high contain of sand (range in between 56.8% to 64.8%). Total carbon and total nitrogen does not show any significant difference either as well as C/N ratio value for mono and mix planting sites. C/N ratio plays a major role in the soil because high amount of C stocks means high sources of nitrogen supply. However, the value of C/N ratio was higher which mean the carbon content in the soil was indeed more than nitrogen. Between mono and mix planting sites, C/N ratio at mix planting site was slightly higher compare to mono planting sites for both surface and subsurface (*Figure 11*).

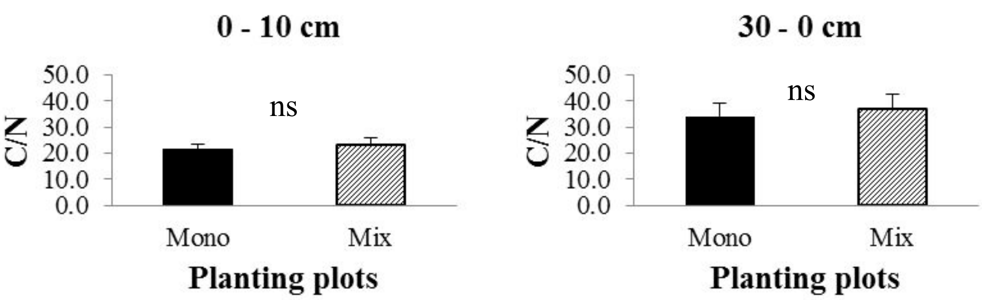

Figure 11: Carbon-Nitrogen ratio between mono and mix planting at surface and subsurface layer

4.2.4 Soil texture and compaction of soil under mono and mix planting

From the collected data which has been summarized on Table 1 above, both mono and mix planting were classified as sandy soil. Besides, from the data analysis done by laboratory method, it also shows the same results as shown on *Figure 12*. Even though the soil was categories as sandy soil, but the growth performance of the species planted has grow well. This might be due to the species planted where it adapt well to the other environment factors such as climate and water resource. Other possibility of stable growth rate was because of the organic matter in the soil. Even though the result shows that both mono and mix planting has low organic matter, it does not necessary mean that the tree cannot growth well in that condition where in fact it was only been planted for less than 5 years.

Generally, sandy soil has less ability to retain water in the soil but in term of forestation, there were other factor playing along which helps growth performance and survival rate of the species. Factors which include climate change, nutrient content in the soil and microbial activities. Besides, type of species also plays a major role in determining the growth performance of the species. Scowcroft et al. (2004) had state that a re-establishing tree especially fast growing species in deforested land can reverse changes in soil structure, their chemical properties and N transformations.

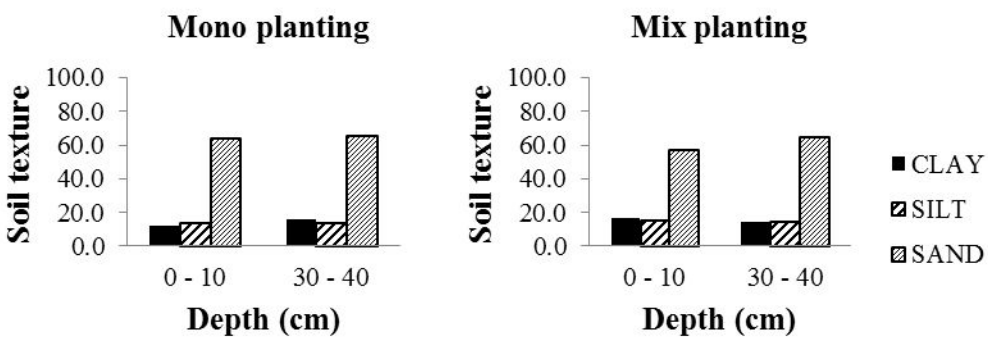

Figure 12: Soil texture for mono and mix planting plots.

5.0 CONCLUSION AND RECOMMENDATION

Generally, both mono and mix planting plots were actually similar in term of their morphological properties. However, in term of their physicochemical properties, there were slightly difference between both mono and mix planting plots. Only several properties were significantly difference and that include electric conductivity (EC), and available phosphorus (AvP). Basically, soil texture at both mono and mix planting were classified as sandy soil. From the field observation, both sites has low organic matter. Thus, indicate that mono and mix planting were classified as less fertile soil. Based on soil profile observation, both plots was more less similar. Furthermore, both planting sites was also strongly acidic as the pH value for both mono and mix planting was less than 6.00. Thus, means that it is suitable for the species to growth in term of reforestation.

In term of reforestation, the physicochemical properties of the soil was very important because nutrient cannot be applied regularly. Some nutrient such as nitrogen and phosphorus were readily available and fertilizer application in forest is also not often applied. Besides, the growth performance on mono planting sites for this research plot was much higher compare to the one in the mix planting species. Hence, conclude that soil properties were an important factor in order to determine the suitability of the species planted for reforestation purposes.

Since soil properties plays an important factor in determining the suitability of the species planted in reforestation site, it is recommended to further investigate on the nutrient pool such as N mineralization rate from organic matter under both mono and mix planting sites. This is so to determine the most ideal and suitable planting technique between mono and mix planting species.

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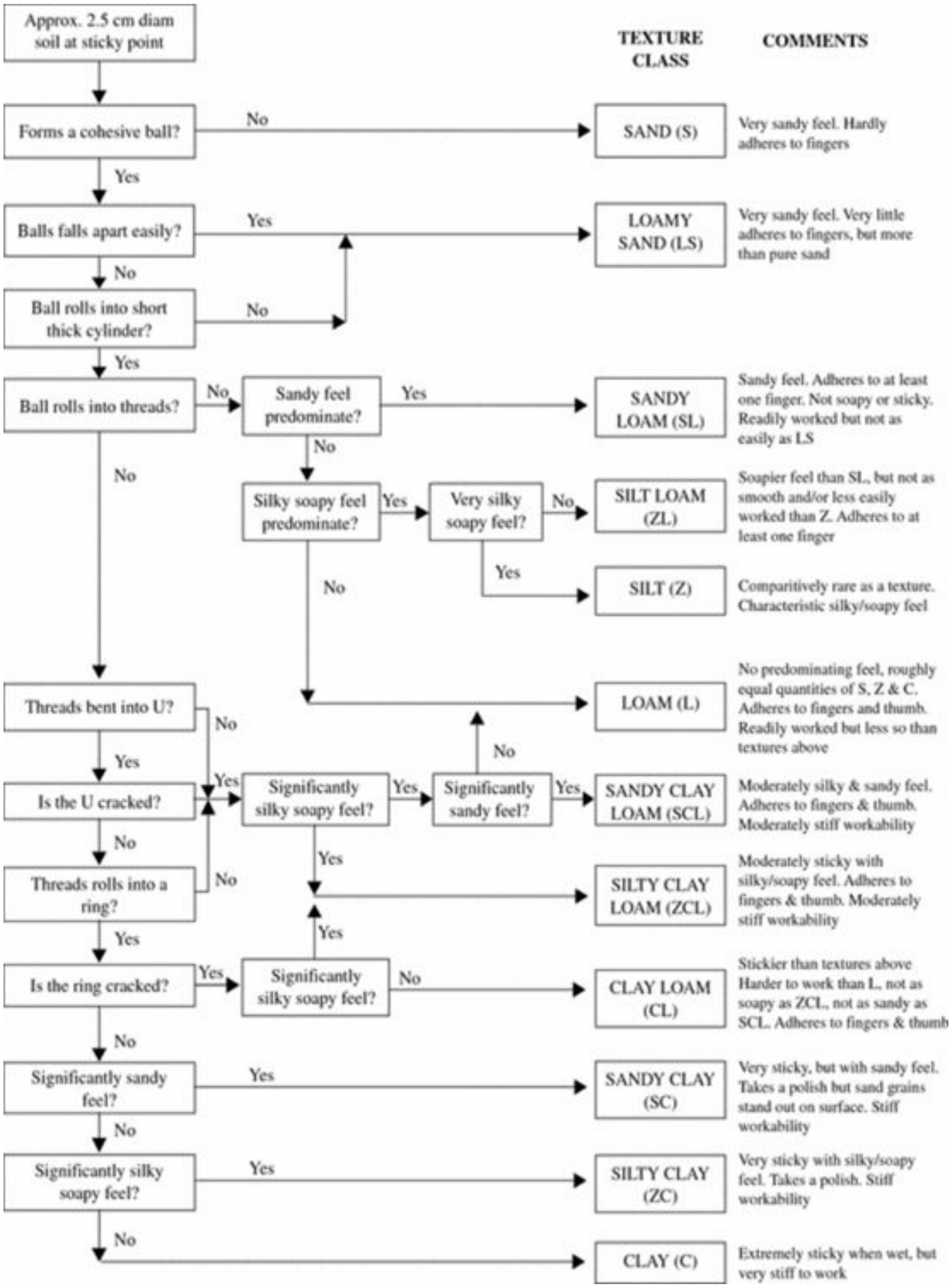
7.0 APPENDICES



Appendices 1: A guide to field assessment of feature for mineral soils in the U.K by S. Northcliff. Reading University and J. R. Landon, Booker Agricultural International.

Mottling
Abundance
Contrast

Abundance	
N : None	0%
F : Few	0-5%
C : Common	5-15%
M : Many	15-40%

Contrast		
F : Faint	harely distinguishable	(hue, value, chroma are very similar to original)
D : Distinct	distinguishable	(2 grade difference for hue, 1~2 grade difference for value, chroma)
P : Prominent	easily distinguishable	(more than 2 grade difference for hue, value, chroma)

Root
Size
Abundance

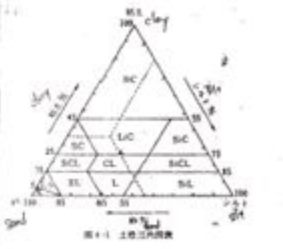
Size	
VF : Very fine	< 0.5 mm
F : Fine	0.5 ~ 2 mm
M : Medium	2 ~ 5 mm
C : Coarse	> 5 mm

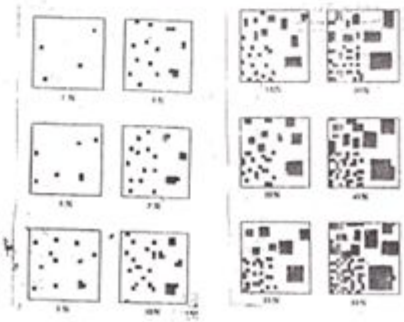
Abundance	
N : None	0%
F : Few	0~5%
C : Common	5~10%
M : Many	10~20%

Others
Organic matter
Moisture

OM Content	(value)
L : Low	5-7
M : Medium	4-5
H : High	2-3
V : Very high	1-2
O : Organic layer	<2

Moisture condition	
D : Dry	don't feel moisture
MD : Moderately dry	looks moist, but hardly feel moisture
MM : Moderately moist	feel moisture after strong grasping
M : Moist	being wet after strong grasping
W : Wet	Wet





判定法	土性
[illegible]	砂土 (S)
[illegible]	砂壌土 (SL)
[illegible]	壌土 (L)
[illegible]	シルト質壌土 (SiL)
[illegible]	埴壌土 (CL)
[illegible]	軽埴土 (LiC)
[illegible]	重埴土 (HC)

Kote's edision
2006/11/10

Horizon
Topography
Distinctness

Topography
S : Smooth
W : Wavy
I : Irregular
B : Broken

Distinctness	
A : Abrupt	< 1cm
C : Clear	1~3 cm
G : Gradual	3~5 cm
D : Diffuse	>5cm

Consistence
Stickness
Plasticness

Stickness	
NS : Non sticky	Not stick with finger
SS : Slightly sticky	Stick one finger, but not two
S : Sticky	Stick both fingers
VS : Very sticky	Strongly stick both fingers

Plasticness	
NP : Non plastic	can't make a stick
SP : Slightly plastic	can make a stick, but easy to be cut
P : Plastic	can make (2mm <) stick
VP : Very plastic	can make (1mm <) stick

Structure
Grade
Type
Size

Grade	
NS : Non structure	
W : Weak	barely distinguishable
M : Moderate	distinguishable
S : Strong	clearly distinguishable

Size (mm)	G	B	Pr	Pl
VF : Very fine	<1	<5	<10	<1
F : Fine	1~2	5~10	10~20	1~2
M : Medium	2~5	10~20	20~50	2~5
C : Coarse	5~10	20~50	50~100	5~10
VC : Very coarse	>10	>50	>100	>10

Type
CR : Crumb
GR : Granular
AB : Angular blocky
SB : Subangular blocky
CO : Columnar
PR : Prismatic
PL : platy
(non-structure)
SG : Single grain
MA : Massive

Rock fragument
Abundance
Shape
Size
Weathering

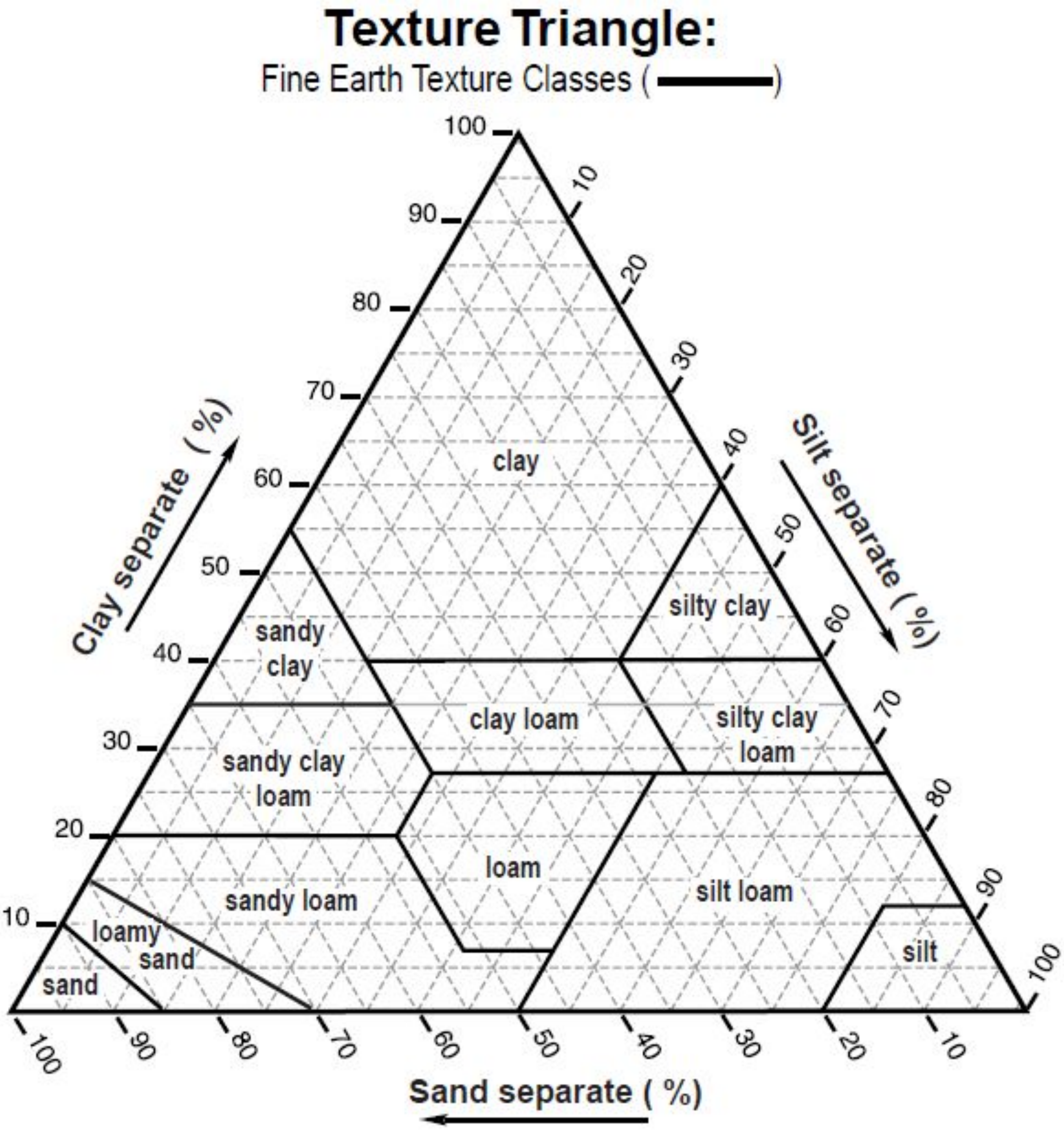
Abundance	
N : None	0%
F : Few	0~5%
C : Common	5~10%
M : Many	10~20%
A : Abundant	20~50%
D : Dominant	>50%

Shape
A : Angular
SA : Subangular
SR : Subrounded
R : rounded

Size (cm)	
FG : Fine gravel	0.2~1
G : Gravel	1~5
S : Stone	5~10
LS : Large stone	10~20
B : Boulder	20~30
LB : Large boulder	>30

Weathering	
F : Fresh	fresh
SL : Slightly weathered	still hard
W : Weathered	breakable with hand
ST : Strongly weathered	easily breakable

Appendices 2: Guidelines to determine soil morphological characteristics



Appendices 3: Guideline to determine soil texture

Data sheet for Soil Profile Description

Profile No.		Location		Land use or vegetation		Elevation	Weather	Date	Surveyor
Physiography				Topography		Erosion		Soil name	
Parent material				Ground water (m)		Drainage		Slope	
Horizon symbol									
Depth of top and bottom of horizon									
Boundary horizon		A C G D	A C G D	A C G D	A C G D	A C G D	A C G D	A C G D	A C G D
Form of boundary		S W I B	S W I B	S W I B	S W I B	S W I B	S W I B	S W I B	S W I B
Color	Wet								
Texture									
Consistence	Stickiness	NS SS S VS	NS SS S VS	NS SS S VS	NS SS S VS	NS SS S VS	NS SS S VS	NS SS S VS	NS SS S VS
	Plasticity	NP SP P VP	NP SP P VP	NP SP P VP	NP SP P VP	NP SP P VP	NP SP P VP	NP SP P VP	NP SP P VP
	Consistence (moist)	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI
Structure	Grade	W M S	W M S	W M S	W M S	W M S	W M S	W M S	W M S
	Type	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA
	Size	VF F M C VC	VF F M C VC	VF F M C VC	VF F M C VC	VF F M C VC	VF F M C VC	VF F M C VC	VF F M C VC
Hardness	(mm)								
Rock fragment	Abundance	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D
	Shape	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R
	Size	-	-	-	-	-	-	-	-
	Weathering	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW
Mottling	Abundance	F C M	F C M	F C M	F C M	F C M	F C M	F C M	F C M
	Size	F M C	F M C	F M C	F M C	F M C	F M C	F M C	F M C
	Contrast	F D P	F D P	F D P	F D P	F D P	F D P	F D P	F D P
	Color	/	/	/	/	/	/	/	/
Organic matter		L M H V O	L M H V O	L M H V O	L M H V O	L M H V O	L M H V O	L M H V O	L M H V O
Root	Size & abundance								
Others. i.e. Moisture									

Prepared by M.Effendi. W, UNIMAS

Appendices 4: Example of data sheet for soil profile description

Profile No. **MP 2011**		Location **(N 01° 27. 912', E 110° 26. 863')**		Land use or vegetation **Secondary forest**		Elevation **71 m**	Weather **Sunny**	Date **06/12/2014**	Surveyor **Sonia**
Physiography				Topography **Rolling hills**		Erosion		Soil name	
Parent material **Shales mixed sandstone**				Ground water (m)		Drainage		Slope **13°**	
Horizon symbol		**O**	**A**	**B1**	**B2**				
Depth of top and bottom of horizon		**0 - 3 cm**	**3 - 8 cm**	**8 - 32 cm**	**32 - 65 cm**				
Boundary horizon		A C G D	A C **(G)** D	A C G **(D)**	A C G **(D)**	A C G D	A C G D	A C G D	A C G D
Form of boundary		S W I B	S **(W)** I B	S **(W)** I B	S **(W)** I B	S W I B	S W I B	S W I B	S W I B
Color	Wet		**2.5YR 4/4**	**10YR 5/8**	**10YR 6/6**				
Texture			**ZL**	**ZCL**	**SL**				
Consistence	Stickiness	NS SS S VS	NS **(SS)** S VS	NS SS **(S)** VS	NS SS **(S)** VS	NS SS S VS	NS SS S VS	NS SS S VS	NS SS S VS
	Plasticity	NP SP P VP	**(NP)** SP P VP	NP SP **(P)** VP	NP **(SP)** P VP	NP SP P VP	NP SP P VP	NP SP P VP	NP SP P VP
	Consistence (moist)	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI
Structure	Grade	W M S	**(W)** M S	W M **(S)**	W **(M)** S	W M S	W M S	W M S	W M S
	Type	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL **(GR)** CR SG MA	PR CO AB **(SB)** PL GR CR SG MA	PR CO AB **(SB)** PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA
	Size	VF F M C VC	**(VF)** F M C VC	VF F **(M)** C VC	VF **(F)** M C VC	VF F M C VC	VF F M C VC	VF F M C VC	VF F M C VC
Hardness	(mm)		**12.0**	**14.4**	**14.8**				
Rack fragment	Abundance	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D
	Shape	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R
	Size	-	-	-	-	-	-	-	-
	Weathering	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW
Mottling	Abundance	F M C	F M C	F M C	F M C	F M C	F M C	F M C	F M C
	Size	F M C	F M C	F M C	F M C	F M C	F M C	F M C	F M C
	Contrast	F D P	F D P	F D P	F D P	F D P	F D P	F D P	F D P
	Color	/	/	/	/	/	/	/	/
Organic matter		L M H V O	**(L)** M H V O	**(VL)** M H V O	**(VL)** M H V O	L M H V O	L M H V O	L M H V O	L M H V O
Root	Size & abundance		**VF-C/FE-CO**	**VF-C/FE**	**VF-C/FE**				
Others. i.e Moisture			**Moist**	**Slightly moist**	**Slightly moist**				

Appendices 5: Soil profile for mono planting plot MP 2011.

Profile No.	Location	Land use or vegetation	Elevation	Weather	Date	Surveyor
MP 2014	**N 00° 55' 22.5", E 110° 38' 39.5"**	**Secondary forest**	**60 m**	**Cloudy/Sunny**	**04/02/2015**	**Sonia**
Physiography		Topography **Flat**	Erosion		Soil name **Grey-White Podzolic**	
Parent material		Ground water (m)	Drainage		Slope **6°**	

Horizon symbol		**O**	**A**	**B1**	**B2**				
Depth of top and bottom of horizon		**0 - 5 cm**	**5 - 15 cm**	**15 - 40 cm**	**40 - 60 cm**				
Boundary horizon		A C G D	A C (G) D	A C G (D)	A C G (D)	A C G D	A C G D	A C G D	A C G D
Form of boundary		S W I B	S (W) I B	(S) W I B	(S) W I B	S W I B	S W I B	S W I B	S W I B
Color	Wet		**10YR 4/3**	**10YR 5/4**	**10YR 6/4**				
Texture			**ZCL**	**ZCL**	**ZCL**				
Consistence	Stickiness	NS SS S VS	NS (SS) S VS	NS SS (S) VS	NS (SS) S VS	NS SS S VS	NS SS S VS	NS SS S VS	NS SS S VS
	Plasticity	NP SP P VP	NP SP (P) VP	NP SP P (VP)	NP SP P (VP)	NP SP P VP	NP SP P VP	NP SP P VP	NP SP P VP
	Consistence (moist)	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI
Structure	Grade	W M S	(W) M S	(W) M S	(W) M S	W M S	W M S	W M S	W M S
	Type	PR CO AB SB PL GR CR SG MA	PR CO AB (SB) PL GR CR SG MA	PR CO AB (SB) PL GR CR SG MA	PR CO AB (SB) PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA
	Size	VF F M C VC	(VF) F M C VC	(VF) F M C VC	(VF) F M C VC	VF F M C VC	VF F M C VC	VF F M C VC	VF F M C VC
Hardness	(mm)		**9.8**	**16.8**	**17.4**				
Rack fragment	Abundance	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D
	Shape	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R
	Size	-	-	-	-	-	-	-	-
	Weathering	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW
Mottling	Abundance	F M C	F M C	F M C	F M C	F M C	F M C	F M C	F M C
	Size	F M C	F M C	F M C	F M C	F M C	F M C	F M C	F M C
	Contrast	F D P	F D P	F D P	F D P	F D P	F D P	F D P	F D P
	Color	/	/	/	/	/	/	/	/
Organic matter		L M H V O	L (M) H V O	(L) M H V O	(L) M H V O	L M H V O	L M H V O	L M H V O	L M H V O
Root	Size & abundance		**C/MA**	**ME/FE**	**F/FE**				
Others. i.e Moisture			**-**	**-**	**Charcoal**				

Appendices 6: Soil profile for mono planting plot MP 2014.

Profile No. **MXP 2011**	Location **N 00° 55' 33.3", E 110° 38' 09.1"**	Land use or vegetation **Secondary forest**	Elevation **53 m**	Weather **Sunny/Cloudy**	Date **03/02/2015**	Surveyor **Sonia**
Physiography		Topography **Hilly**	Erosion **Slightly erosion**		Soil name **Grey-White Podzolic**	
Parent material		Ground water (m)	Drainage		Slope **10°**	

Horizon symbol		**O**	**A**	**B1**	**B2**	**B3**			
Depth of top and bottom of horizon		**0 - 2 cm**	**2 - 12 cm**	**12 - 28 cm**	**28 - 45 cm**	**45 - 60 cm**			
Boundary horizon		A C G D	A C **(G)** D	A C G **(D)**	A C G **(D)**	A C G **(D)**	A C G D	A C G D	A C G D
Form of boundary		S W I B	S **(W)** I B	S **(W)** I B	**(S)** W I B	**(S)** W I B	S W I B	S W I B	S W I B
Color	Wet		**10YR 4/2**	**10YR 5/3**	**10YR 5/4**	**10YR 5/6**			
Texture			**ZCL**	**SCL**	**SCL**	**SCL**			
Consistence	Stickiness	NS SS S VS	NS SS **(S)** VS	NS **(SS)** S VS	NS SS **(S)** VS	NS SS **(S)** VS	NS SS S VS	NS SS S VS	NS SS S VS
	Plasticity	NP SP P VP	NP SP P **(VP)**	NP SP **(P)** VP	NP **(SP)** P VP	NP SP **(P)** VP	NP SP P VP	NP SP P VP	NP SP P VP
	Consistence (moist)	LO VFR FR FI VFI EFI	LO VFR **(FR)** FI VFI EFI	LO VFR **(FR)** FI VFI EFI	LO VFR **(FR)** FI VFI EFI	LO VFR **(FR)** FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI
Structure	Grade	W M S	W **(M)** S	W **(M)** S	**(W)** M S	W **(M)** S	W M S	W M S	W M S
	Type	PR CO AB SB PL GR CR SG MA	PR CO AB **(SB)** PL GR CR SG MA	PR CO AB **(SB)** PL GR CR SG MA	PR CO AB **(SB)** PL GR CR SG MA	PR CO AB **(SB)** PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA
	Size	VF F M C VC	VF **(F)** M C VC	VF F **(M)** C VC	VF F M **(C)** VC	VF F M **(C)** VC	VF F M C VC	VF F M C VC	VF F M C VC
Hardness	(mm)		**12.0**	**14.4**	**14.8**	**15.2**			
Rack fragment	Abundance	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D
	Shape	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R
	Size	-	-	-	-	-	-	-	-
	Weathering	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW
Mottling	Abundance	F M C	F M C	F M C	F M C	F M C	F M C	F M C	F M C
	Size	F M C	F M C	F M C	F M C	F M C	F M C	F M C	F M C
	Contrast	F D P	F D P	F D P	F D P	F D P	F D P	F D P	F D P
	Color	/	/	/	/	/	/	/	/
Organic matter		L M H V O	L M **(H)** V O	L **(M)** H V O	L **(M)** H V O	**(L)** M H V O	L M H V O	L M H V O	L M H V O
Root	Size & abundance		**ME/CO-MA**	**F/FE-MA**	**F/FE**	**VF/FE**			
Others. i.e Moisture			**Moist**	**Moist**	**Moist**	**Moist**			

Appendices 7: Soil profile for mix planting plot MXP 2011.

Profile No.	Location	Land use or vegetation	Elevation	Weather	Date	Surveyor
MXP 2012	**N 00° 55' 33.6", E 110° 3' 09.4"**	**Secondary forest**	**44 m**	**Sunny**	**03/02/2015**	**Sonia**
Physiography		Topography **Hilly**	Erosion		Soil name **Grey-White Podzolic**	
Parent material		Ground water (m)	Drainage		Slope **11°**	

Horizon symbol		**O**	**A**	**B1**	**B2**				
Depth of top and bottom of horizon		**0 - 2 cm**	**2 - 16 cm**	**16 - 42 cm**	**42 - 65 cm**				
Boundary horizon		A C G D	A **C** G D	A C **G** D	A C G **D**	A C G D	A C G D	A C G D	A C G D
Form of boundary		S W I B	**S** W I B	S **W** I B	S **W** I B	S W I B	S W I B	S W I B	S W I B
Color	Wet		**10YR 4/3**	**10YR 5/3**	**10YR 6/4**				
Texture			**SCL**	**SCL**	**SCL**				
Consistence	Stickiness	NS SS S VS	NS SS **S** VS	NS SS S **VS**	NS SS S **VS**	NS SS S VS	NS SS S VS	NS SS S VS	NS SS S VS
	Plasticity	NP SP P VP	NP **SP** P VP	NP SP **P** VP	NP SP P **VP**	NP SP P VP	NP SP P VP	NP SP P VP	NP SP P VP
	Consistence (moist)	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI	LO VFR FR FI VFI EFI
Structure	Grade	W M S	**W** M S	**W** M S	W **M** S	W M S	W M S	W M S	W M S
	Type	PR CO AB SB PL GR CR SG MA	PR CO **AB** SB PL GR CR SG MA	PR CO AB **SB** PL GR CR SG MA	PR CO AB **SB** PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA	PR CO AB SB PL GR CR SG MA
	Size	VF F M C VC	**VF** F M C VC	**VF** F M C VC	VF **F** M C VC	VF F M C VC	VF F M C VC	VF F M C VC	VF F M C VC
Hardness	(mm)		**6.8**	**16.4**	**17.4**				
Rack fragment	Abundance	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D	N F C M A D
	Shape	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R	A SA SR R
	Size	-	-	-	-	-	-	-	-
	Weathering	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW	F SLW MW STW
Mottling	Abundance	F M C	F M C	F M C	F M C	F M C	F M C	F M C	F M C
	Size	F M C	F M C	F M C	F M C	F M C	F M C	F M C	F M C
	Contrast	F D P	F D P	F D P	F D P	F D P	F D P	F D P	F D P
	Color	/	/	/	/	/	/	/	/
Organic matter		L M H V O	**L** M H V O	**L** M H V O	**L** M H V O	L M H V O	L M H V O	L M H V O	L M H V O
Root	Size & abundance		**VF/VFE**	**F/VFE-FE**	**VF-F/FE**				
Others. i.e Moisture									

Appendices 8: Soil profile for mix planting plot MXP 2012.

BULK DENSITY

Plot: MP 2011 **Depth: 0 – 10 cm** **Date: 09/12/2014**

Samples	Empty box (cm³)	Empty box + wet sample (cm³)	Wet sample (g)	Dried sample + box (g)	Dried sample (g)	Volume of the soil (cm³)	Bulk Density (g/cm³)
A1	2.764	170.793	168.029	106.304	103.540	100	1.035
A2	3.020	189.015	185.995	150.635	147.615	100	1.476
A3	3.216	144.440	141.224	132.320	129.104	100	1.291
B1	5.124	164.970	159.846	125.262	120.138	100	1.201
B2	5.162	160.969	155.807	115.585	110.423	100	1.104
B3	5.084	159.840	154.756	116.877	111.793	100	1.118
C1	5.102	174.172	169.070	114.966	109.864	100	1.099
C2	5.073	143.589	138.516	94.0320	88.9590	100	0.890
C3	4.977	132.520	127.543	94.6520	89.6750	100	0.897
D1	4.999	138.402	133.403	83.6300	78.6310	100	0.786
D2	4.984	155.513	150.529	116.702	111.718	100	1.117
D3	5.123	136.245	131.122	98.6880	93.5650	100	0.936

Appendices 9: Raw data for bulk density at surface layer for mono planting plot MP 2011.

BULK DENSITY

Plot: MP 2011 **Depth: 30 – 40 cm** **Date: 09/12/2014**

Samples	Empty box (cm^3)	Empty box + wet sample (cm^3)	Wet sample (g)	Dried sample + box (g)	Dried sample (g)	Volume of the soil (cm^3)	Bulk Density (g/cm^3)
A1	4.939	174.181	169.242	137.220	132.281	100	1.323
A2	4.948	154.663	154.663	149.715	115.299	100	1.153
A3	5.044	173.591	168.547	136.494	131.450	100	1.315
B1	5.083	189.143	184.060	154.820	149.737	100	1.497
B2	4.947	188.920	183.973	153.580	148.633	100	1.486
B3	4.984	183.641	178.657	154.165	149.181	100	1.492
C1	5.083	176.243	171.160	137.021	131.938	100	1.319
C2	5.011	182.532	177.521	136.752	131.741	100	1.317
C3	5.006	179.655	174.649	137.265	132.259	100	1.323
D1	4.912	181.520	176.608	141.950	137.038	100	1.370
D2	4.892	174.419	169.527	136.224	131.332	100	1.313
D3	4.992	173.628	168.636	135.333	130.341	100	1.303

Appendices 10: Raw data for bulk density at subsurface layer for mono planting plot MP 2011.

BULK DENSITY

Plot: MP 2014 **Depth: 0 – 10 cm** **Date: 07/02/2015**

Samples	Empty box (cm³)	Empty box + wet sample (cm³)	Wet sample (g)	Dried sample + box (g)	Dried sample (g)	Volume of the soil (cm³)	Bulk Density (g/cm³)
A1	5.058	173.618	168.560	135.375	130.317	100	1.303
A2	5.030	176.436	171.406	130.17	125.140	100	1.251
A3	5.041	180.883	175.842	135.384	130.343	100	1.303
B1	5.127	168.147	163.02	127.718	122.591	100	1.226
B2	5.041	164.333	159.292	120.793	115.752	100	1.158
B3	5.063	166.620	161.557	124.638	119.575	100	1.196
C1	5.111	103.531	98.000	69.601	64.490	100	0.645
C2	5.117	152.444	147.327	106.714	101.597	100	1.016
C3	5.052	118.405	113.353	86.494	81.442	100	0.814
D1	5.232	170.497	165.265	126.912	121.680	100	1.217
D2	5.063	161.647	156.584	118.766	113.703	100	1.137
D3	5.096	163.259	158.163	118.151	113.055	100	1.131

Appendices 11: Raw data for bulk density at surface layer for mono planting plot MP 2014.

<u>**BULK DENSITY**</u>

Plot: MP 2014 **Depth: 30 – 40 cm** **Date: 07/02/2015**

Samples	Empty box (cm³)	Empty box + wet sample (cm³)	Wet sample (g)	Dried sample + box (g)	Dried sample (g)	Volume of the soil (cm³)	Bulk Density (g/cm³)
A1	5.039	195.260	190.221	159.539	154.500	100	1.545
A2	4.958	199.293	194.335	162.383	157.425	100	1.574
A3	5.129	199.606	194.477	163.160	158.031	100	1.580
B1	5.154	186.706	182.000	148.900	143.746	100	1.437
B2	5.102	184.480	179.378	146.783	141.681	100	1.417
B3	5.026	189.880	184.854	152.047	147.021	100	1.470
C1	5.124	175.457	170.000	141.247	136.123	100	1.361
C2	5.015	136.706	131.691	108.025	103.010	100	1.030
C3	6.159	177.219	171.060	139.480	133.321	100	1.333
D1	4.885	190.095	185.210	154.097	149.212	100	1.492
D2	4.973	195.039	190.066	159.255	154.282	100	1.543
D3	4.877	190.875	185.998	156.713	151.836	100	1.518

Appendices 12: Raw data for bulk density at subsurface layer for mono planting plot MP 2014.

BULK DENSITY

Plot: MXP 2011 **Depth: 0 – 10 cm** **Date: 05/02/2015**

Samples	Empty box (cm^3)	Empty box + wet sample (cm^3)	Wet sample (g)	Dried sample + box (g)	Dried sample (g)	Volume of the soil (cm^3)	Bulk Density (g/cm^3)
A1	3.401	179.402	176.001	139.460	136.059	100	1.361
A2	3.287	182.655	179.368	140.338	137.051	100	1.371
A3	3.200	176.667	173.467	136.688	133.488	100	1.335
B1	3.081	158.834	155.753	114.159	111.078	100	1.111
B2	3.517	136.176	132.659	98.362	94.845	100	0.948
B3	3.354	147.903	144.549	107.458	104.104	100	1.041
C1	3.717	160.531	156.814	115.175	111.458	100	1.115
C2	3.555	159.681	156.126	114.125	110.5700	100	1.106
C3	3.017	166.760	163.743	122.364	119.3470	100	1.193
D1	2.763	144.434	141.671	108.582	105.8190	100	1.058
D2	3.263	129.572	126.309	96.690	93.427	100	0.934
D3	3.705	148.92	145.215	110.211	106.5060	100	1.065

Appendices 13: Raw data for bulk density at surface layer for mix planting plot MXP 2011.

BULK DENSITY

Plot: MXP 2011 **Depth: 30 – 40 cm** **Date: 05/02/2015**

Samples	Empty box (cm^3)	Empty box + wet sample (cm^3)	Wet sample (g)	Dried sample + box (g)	Dried sample (g)	Volume of the soil (cm^3)	Bulk Density (g/cm^3)
A1	2.603	186.644	184.041	148.625	146.022	100	1.460
A2	3.221	174.767	171.546	139.447	136.226	100	1.362
A3	3.169	181.275	178.106	143.881	140.712	100	1.407
B1	5.028	188.766	183.738	150.197	145.169	100	1.452
B2	4.947	188.723	183.776	150.269	145.322	100	1.453
B3	4.952	179.107	174.155	140.400	135.448	100	1.354
C1	5.060	185.627	180.567	147.633	142.573	100	1.426
C2	4.974	186.093	181.119	147.682	142.708	100	1.427
C3	5.000	187.203	182.203	149.966	144.966	100	1.450
D1	5.003	163.676	158.673	128.960	123.957	100	1.240
D2	5.045	186.503	181.458	147.778	142.733	100	1.427
D3	4.868	178.06	173.192	136.219	131.351	100	1.314

Appendices 14: Raw data for bulk density at subsurface layer for mix planting plot MXP 2011.

BULK DENSITY

Plot: MXP 2012 **Depth: 0 – 10 cm** **Date: 06/02/2015**

Samples	Empty box (cm³)	Empty box + wet sample (cm³)	Wet sample (g)	Dried sample + box (g)	Dried sample (g)	Volume of the soil (cm³)	Bulk Density (g/cm³)
A1	5.022	156.055	151.033	116.804	111.782	100	1.118
A2	4.937	160.359	155.422	118.343	113.406	100	1.134
A3	5.143	157.473	152.330	114.351	109.208	100	1.092
B1	5.203	162.356	157.153	122.668	117.465	100	1.175
B2	5.006	153.878	148.872	119.068	114.062	100	1.141
B3	5.006	162.881	157.875	121.955	116.949	100	1.169
C1	4.929	158.114	153.000	121.801	116.872	100	1.169
C2	5.163	159.949	154.786	119.238	114.075	100	1.141
C3	5.109	154.619	149.510	117.971	112.862	100	1.129
D1	5.030	162.124	157.094	127.603	122.573	100	1.226
D2	5.041	172.632	167.591	134.519	129.478	100	1.295
D3	5.073	153.785	148.712	113.033	107.960	100	1.080

Appendices 15: Raw data for bulk density at surface layer for mix planting plot MXP 2012.

BULK DENSITY

Plot: MXP 2012 **Depth: 30 – 40 cm** **Date: 06/02/2015**

Samples	Empty box (cm^3)	Empty box + wet sample (cm^3)	Wet sample (g)	Dried sample + box (g)	Dried sample (g)	Volume of the soil (cm^3)	Bulk Density (g/cm^3)
A1	5.016	172.889	167.873	136.432	131.416	100	1.314
A2	4.992	175.234	170.242	137.789	132.797	100	1.328
A3	5.074	175.222	170.148	137.962	132.888	100	1.329
B1	5.032	179.780	175.000	143.598	138.566	100	1.386
B2	5.196	185.853	180.657	149.155	143.959	100	1.440
B3	5.076	189.219	184.143	155.397	150.321	100	1.503
C1	5.082	161.567	156.000	128.747	123.665	100	1.237
C2	4.940	167.584	162.644	133.385	128.445	100	1.284
C3	5.128	170.831	165.703	124.496	119.368	100	1.194
D1	5.153	178.574	173.421	141.081	135.928	100	1.359
D2	5.137	176.831	171.694	140.646	135.509	100	1.355
D3	5.216	180.905	175.689	143.790	138.574	100	1.386

Appendices 16: Raw data for bulk density at subsurface layer for mix planting plot MXP 2012.

SOIL ORGANIC MATTER

Plot: MP 2011 **Date: 15/02/2015**

		105°C						550°C					
Samples	**Mass of crucible after 1 day (g)**	**Mass of crucible after 2 days (g)**	**Mass of crucible + 3 g of soil before furnance (g)**	**Initial weight of soil before oven (g)**	**Mass of crucible + soil after oven-dry 1 day (g)**	**Soil weight after oven (MC)**	**Loss of MC after oven (g)**	**Mass of crucible + soil after furnance (g)**	**Soil weight after furnance (g)**	**Moisture content (%)**	**Mineral contents**	**SOM (%)**	**TC (%)**
Depth: 0 – 10 cm													
A	17.716	17.718	20.719	3.001	20.666	2.948	0.053	20.484	2.766	1.766	92.169	7.831	4.542
B	16.391	16.393	19.393	3.000	19.334	2.941	0.059	19.148	2.755	1.967	91.833	8.167	4.737
C	14.796	14.796	17.796	3.000	17.701	2.905	0.095	17.414	2.618	3.167	87.267	12.733	7.386
D	17.537	17.536	20.537	3.001	20.452	2.916	0.085	20.203	2.667	2.832	88.870	11.130	6.456
Depth: 30 – 40 cm													
A	16.082	16.080	19.081	3.001	19.032	2.952	0.049	18.911	2.831	1.633	94.335	5.665	3.286
B	15.178	15.178	18.178	3.000	18.148	2.970	0.030	18.097	2.919	1.000	97.300	2.700	1.566
C	16.805	16.804	19.804	3.000	19.759	2.955	0.045	19.649	2.845	1.500	94.833	5.167	2.997
D	18.296	18.295	21.296	3.001	21.251	2.956	0.045	21.161	2.866	1.500	95.501	4.499	2.609

Appendices 17: Raw data for soil organic matter at mono planting plot MP 2011.

SOIL ORGANIC MATTER

Plot: MP 2014 **Date: 15/02/2015**

		105°C						550°C					
Samples	**Mass of crucible after 1 day (g)**	**Mass of crucible after 2 days (g)**	**Mass of crucible + 3 g of soil before furnance (g)**	**Initial weight of soil before oven (g)**	**Mass of crucible + soil after oven-dry 1 day (g)**	**Soil weight after oven (MC)**	**Loss of MC after oven (g)**	**Mass of crucible + soil after furnance (g)**	**Soil weight after furnance (g)**	**Moisture content (%)**	**Mineral contents**	**SOM (%)**	**TC (%)**
Depth: 0 – 10 cm													
A	16.114	16.114	19.114	3.000	19.053	2.939	0.061	18.861	2.747	2.033	91.567	8.433	4.892
B	16.808	16.810	19.811	3.001	19.758	2.948	0.053	19.607	2.797	1.766	93.202	6.798	3.943
C	15.300	15.301	18.301	3.000	18.255	2.954	0.046	18.129	2.828	1.533	94.267	5.733	3.326
D	15.571	15.571	18.571	3.000	18.505	2.934	0.066	18.300	2.729	2.200	90.967	9.033	5.240
Depth: 30 – 40 cm													
A	17.279	17.278	20.278	3.000	20.24	2.962	0.038	20.151	2.873	1.267	95.767	4.233	2.456
B	15.640	15.640	18.641	3.001	18.592	2.952	0.049	18.490	2.850	1.633	94.968	5.032	2.919
C	16.097	16.095	19.096	3.001	19.057	2.962	0.039	18.975	2.880	1.300	95.968	4.032	2.339
D	14.291	14.292	17.293	3.001	17.248	2.956	0.045	17.155	2.863	1.500	95.402	4.598	2.667

Appendices 18: Raw data for soil organic matter at mono planting plot MP 2014.

SOIL ORGANIC MATTER

Plot: MXP 2011 **Date: 15/02/2015**

	105°C							550°C					
Samples	**Mass of crucible after 1 day (g)**	**Mass of crucible after 2 days (g)**	**Mass of crucible + 3 g of soil before furnance (g)**	**Initial weight of soil before oven (g)**	**Mass of crucible + soil after oven-dry 1 day (g)**	**Soil weight after oven (MC)**	**Loss of MC after oven (g)**	**Mass of crucible + soil after furnance (g)**	**Soil weight after furnance (g)**	**Moisture content (%)**	**Mineral contents**	**SOM (%)**	**TC (%)**
Depth: 0 – 10 cm													
A	16.017	16.018	19.018	3.000	18.935	2.917	0.083	18.690	2.672	2.767	89.067	10.933	6.342
B	16.085	16.085	19.087	3.002	18.990	2.905	0.097	18.753	2.668	3.231	88.874	11.126	6.454
C	16.650	16.650	19.650	3.000	19.586	2.936	0.064	19.431	2.781	2.133	92.700	7.300	4.234
D	15.770	15.769	18.770	3.001	18.686	2.917	0.084	18.464	2.695	2.799	89.803	10.197	5.915
Depth: 30 – 40 cm													
A	18.350	18.348	21.348	3.000	21.276	2.928	0.072	21.184	2.836	2.400	94.533	5.467	3.171
B	16.630	16.628	19.628	3.000	19.565	2.937	0.063	19.463	2.835	2.100	94.500	5.500	3.190
C	16.397	16.396	19.397	3.001	19.343	2.947	0.054	19.271	2.875	1.799	95.801	4.199	2.435
D	18.251	18.251	21.252	3.001	21.179	2.928	0.073	21.082	2.831	2.433	94.335	5.665	3.286

Appendices 19: Raw data for soil organic matter at mix planting plot MXP 2011.

SOIL ORGANIC MATTER

Plot: MXP 2012 **Date: 15/02/2015**

	105°C							550°C					
Samples	**Mass of crucible after 1 day (g)**	**Mass of crucible after 2 days (g)**	**Mass of crucible + 3 g of soil before furnance (g)**	**Initial weight of soil before oven (g)**	**Mass of crucible + soil after oven-dry 1 day (g)**	**Soil weight after oven (MC)**	**Loss of MC after oven (g)**	**Mass of crucible + soil after furnance (g)**	**Soil weight after furnance (g)**	**Moisture content (%)**	**Mineral contents**	**SOM (%)**	**TC (%)**
Depth: 0 – 10 cm													
A	17.730	17.731	20.731	3.000	20.654	2.923	0.077	20.442	2.711	2.567	90.367	9.633	5.588
B	16.282	16.280	19.281	3.001	19.228	2.948	0.053	19.057	2.777	1.766	92.536	7.464	4.330
C	17.039	17.037	20.037	3.000	19.965	2.928	0.072	19.796	2.759	2.400	91.967	8.033	4.660
D	18.291	18.291	21.291	3.000	21.228	2.937	0.063	21.059	2.768	2.100	92.267	7.733	4.486
Depth: 30 – 40 cm													
A	16.349	16.348	19.348	3.000	19.28	2.932	0.068	19.173	2.825	2.267	94.167	5.833	3.384
B	16.380	16.380	19.380	3.000	19.345	2.965	0.035	19.280	2.900	1.167	96.667	3.333	1.933
C	17.773	17.773	20.775	3.002	20.707	2.934	0.068	20.595	2.822	2.265	94.004	5.996	3.478
D	16.963	16.961	19.962	3.001	19.924	2.963	0.038	19.854	2.893	1.266	96.401	3.599	2.087

Appendices 20: Raw data for soil organic matter at mix planting plot MXP 2012.

SOIL TEXTURE

Plot: MP 2011 **Depth: 0 – 10 cm** **Date: 16/01/2015**

Samples	Initial weight of the sample (g)	Weight of the beaker-1 (g)	Weight of the beaker-2 (g)	Average weight of the beaker (g)	Weight of sample + beaker (After oven)	(g)	(%)
CLAY							
A	10.00	10.026	10.028	10.027	10.046	0.019	19.000
B	10.00	9.744	9.746	9.745	9.758	0.013	13.000
C	10.01	9.674	9.674	9.674	9.690	0.016	16.000
D	10.00	10.133	10.134	10.1335	10.152	0.018	18.500
SILT							
A	10.00	9.975	9.975	9.975	10.004	0.029	10.000
B	10.00	9.663	9.664	9.664	9.688	0.025	11.500
C	10.01	9.470	9.472	9.471	9.501	0.030	14.000
D	10.00	10.018	10.018	10.018	10.051	0.033	14.500

Samples	SOM (%)	MC (%)	SAND (%)	Total (%) of clay+silt+sand
A	7.831	1.766	61.403	90.403
B	8.167	1.967	65.366	89.866
C	12.733	3.167	54.100	84.100
D	11.130	2.832	53.038	86.038

Samples	Clay	Silt	Sand	Textural class
A	21.017	11.062	67.921	Sandy Clay Loam
B	14.466	12.797	72.737	Sandy Loam
C	19.025	16.647	64.328	Sandy Loam
D	21.502	16.853	61.645	Sandy Clay Loam

Appendices 21: Raw data for soil texture at surface layer on mono planting plot MP 2011.

SOIL TEXTURE

Plot: MP 2011 **Depth: 30 – 40 cm** **Date: 16/01/2015**

Samples	Initial weight of the sample (g)	Weight of the beaker-1 (g)	Weight of the beaker-2 (g)	Average weight of the beaker (g)	Weight of sample + beaker (After oven)	(g)	(%)
CLAY							
A	10.00	9.450	9.450	9.450	9.490	0.040	40.000
B	10.00	9.928	9.926	9.927	9.937	0.010	10.000
C	10.00	9.634	9.636	9.635	9.655	0.020	20.000
D	10.00	9.743	9.742	9.743	9.759	0.017	16.500
SILT							
A	10.00	10.206	10.206	10.206	10.260	0.054	14.000
B	10.00	9.654	9.652	9.653	9.678	0.025	15.000
C	10.00	9.665	9.663	9.664	9.695	0.031	11.000
D	10.00	9.888	9.887	9.888	9.918	0.031	14.000

Samples	SOM (%)	MC (%)	SAND (%)	Total (%) of clay+silt+sand
A	5.665	1.633	38.702	92.702
B	2.700	1.000	71.300	96.300
C	5.167	1.500	62.333	93.333
D	4.499	1.500	63.501	94.001

Samples	Clay	Silt	Sand	Textural class
A	43.149	15.102	41.749	Clay
B	10.384	15.576	74.039	Sandy Loam
C	21.429	11.786	66.786	Sandy Clay Loam
D	17.553	14.893	67.554	Sandy Loam

Appendices 22: Raw data for soil texture at subsurface layer on mono planting plot MP 2011.

SOIL TEXTURE

Plot: MP 2014 **Depth: 0 – 10 cm** **Date: 13/03/2015**

Samples	Initial weight of the sample (g)	Weight of the beaker-1 (g)	Weight of the beaker-2 (g)	Average weight of the beaker (g)	Weight of sample + beaker (After oven)	(g)	(%)
CLAY							
A	10.00	9.633	9.637	9.635	9.643	0.008	8.000
B	10.02	9.603	9.605	9.604	9.611	0.007	7.000
C	10.00	9.610	9.610	9.610	9.616	0.006	6.000
D	10.00	9.644	9.645	9.645	9.653	0.008	8.500
SILT							
A	10.00	9.724	9.723	9.7235	9.743	0.019	11.500
B	10.02	9.87	9.872	9.871	9.892	0.021	14.000
C	10.00	9.546	9.544	9.545	9.571	0.026	20.000
D	10.00	10.029	10.028	10.029	10.051	0.022	14.000

Samples	SOM (%)	MC (%)	SAND (%)	Total (%) of clay+silt+sand
A	8.433	2.033	70.034	89.534
B	6.798	1.766	70.436	91.436
C	5.733	1.533	66.734	92.734
D	9.033	2.200	66.267	88.767

Samples	Clay	Silt	Sand	Textural class
A	8.935	12.844	78.221	Loamy Sand
B	7.656	15.311	77.033	Sandy Loam
C	6.470	21.567	71.963	Sandy Loam
D	9.576	15.772	74.653	Sandy Loam

Appendices 23: Raw data for soil texture at surface layer on mono planting plot MP 2014.

SOIL TEXTURE

Plot: MP 2014 **Depth: 30 – 40 cm** **Date: 13/03/2015**

Samples	Initial weight of the sample (g)	Weight of the beaker-1 (g)	Weight of the beaker-2 (g)	Average weight of the beaker (g)	Weight of sample + beaker (After oven)	(g)	(%)
CLAY							
A	10.00	9.883	9.882	9.883	9.894	0.011	11.500
B	10.00	9.773	9.773	9.773	9.783	0.010	10.000
C	10.00	9.575	9.575	9.575	9.581	0.006	6.000
D	10.01	9.474	9.473	9.474	9.484	0.010	10.500
SILT							
A	10.00	9.676	9.676	9.676	9.702	0.026	14.500
B	10.00	9.924	9.923	9.924	9.945	0.021	11.500
C	10.00	9.452	9.45	9.451	9.474	0.023	17.000
D	10.01	9.811	9.811	9.811	9.834	0.023	12.500

Samples	SOM (%)	MC (%)	SAND (%)	Total (%) of clay+silt+sand
A	4.233	1.267	68.500	94.500
B	5.032	1.633	71.835	93.335
C	4.032	1.300	71.668	94.668
D	4.598	1.500	70.902	93.902

Samples	Clay	Silt	Sand	Textural class
A	12.169	15.344	72.487	Sandy Loam
B	10.714	12.321	76.965	Sandy Loam
C	6.338	17.957	75.705	Sandy Loam
D	11.182	13.312	75.506	Sandy Loam

Appendices 24: Raw data for soil texture at subsurface layer on mono planting plot MP 2014.

SOIL TEXTURE

Plot: MXP 2011 **Depth: 0 – 10 cm** **Date: 13/03/2015**

Samples	Initial weight of the sample (g)	Weight of the beaker-1 (g)	Weight of the beaker-2 (g)	Average weight of the beaker (g)	Weight of sample + beaker (After oven)	(g)	(%)
CLAY							
A	10.00	9.913	9.911	9.912	9.928	0.016	16.000
B	10.01	9.725	9.725	9.725	9.745	0.020	20.000
C	10.00	9.722	9.721	9.722	9.733	0.012	11.500
D	10.01	9.88	9.879	9.880	9.898	0.018	18.500
SILT							
A	10.00	9.785	9.786	9.786	9.810	0.025	8.500
B	10.01	9.841	9.841	9.841	9.867	0.026	6.000
C	10.00	9.711	9.771	9.741	9.790	0.049	37.500
D	10.01	9.915	9.916	9.916	9.943	0.027	9.000

Samples	SOM (%)	MC (%)	SAND (%)	Total (%) of clay+silt+sand
A	10.933	2.767	61.800	86.300
B	11.126	3.231	59.643	85.643
C	7.300	2.133	41.567	90.567
D	10.197	2.799	59.504	87.004

Samples	Clay	Silt	Sand	Textural class
A	18.540	9.849	71.611	Sandy loam
B	23.353	7.006	69.641	Sandy Clay Loam
C	12.698	41.406	45.896	Loam
D	21.263	10.344	68.392	Sandy Clay Loam

Appendices 25: Raw data for soil texture at surface layer on mix planting plot MP 2011.

SOIL TEXTURE

Plot: MXP 2011 **Depth: 30 – 40 cm** **Date: 13/03/2015**

Samples	Initial weight of the sample (g)	Weight of the beaker-1 (g)	Weight of the beaker-2 (g)	Average weight of the beaker (g)	Weight of sample + beaker (After oven)	(g)	(%)
CLAY							
A	10.00	9.859	9.858	9.859	9.874	0.016	15.500
B	10.00	9.568	9.568	9.568	9.587	0.019	19.000
C	10.00	9.816	9.816	9.816	9.83	0.014	14.000
D	10.00	9.788	9.788	9.788	9.809	0.021	21.000
SILT							
A	10.00	9.793	9.793	9.793	9.820	0.027	11.500
B	10.00	9.861	9.86	9.861	9.891	0.031	11.500
C	10.00	9.935	9.934	9.935	9.963	0.028	14.500
D	10.00	9.776	9.776	9.776	9.809	0.033	12.000

Samples	SOM (%)	MC (%)	SAND (%)	Total (%) of clay+silt+sand
A	5.467	2.400	65.133	92.133
B	5.500	2.100	61.900	92.400
C	4.199	1.799	65.502	94.002
D	5.665	2.433	58.903	91.903

Samples	Clay	Silt	Sand	Textural class
A	16.823	12.482	70.695	Sandy Loam
B	20.563	12.446	66.991	Sandy Clay Loam
C	14.893	15.425	69.681	Sandy Loam
D	22.850	13.057	64.092	Sandy Clay Loam

Appendices 26: Raw data for soil texture at subsurface layer on mix planting plot MXP 2011.

SOIL TEXTURE

Plot: MXP 2012 **Depth: 0 – 10 cm** **Date: 13/03/2015**

Samples	Initial weight of the sample (g)	Weight of the beaker-1 (g)	Weight of the beaker-2 (g)	Average weight of the beaker (g)	Weight of sample + beaker (After oven)	(g)	(%)
CLAY							
A	10.01	9.649	9.650	9.650	9.685	0.036	35.500
B	10.00	9.762	9.763	9.763	9.775	0.013	12.500
C	10.00	9.841	9.841	9.841	9.855	0.014	14.000
D	10.00	9.902	9.901	9.902	9.908	0.007	6.500
SILT							
A	10.01	9.738	9.737	9.738	9.787	0.050	14.000
B	10.00	9.571	9.571	9.571	9.598	0.027	14.500
C	10.00	10.301	10.299	10.300	10.327	0.027	13.000
D	10.00	9.567	9.567	9.567	9.590	0.023	16.500

Samples	SOM (%)	MC (%)	SAND (%)	Total (%) of clay+silt+sand
A	9.633	2.567	38.300	87.800
B	7.464	1.766	63.770	90.770
C	8.033	2.400	62.567	89.567
D	7.733	2.100	67.167	90.167

Samples	Clay	Silt	Sand	Textural class
A	40.433	15.945	43.622	Clay
B	13.771	15.974	70.254	Sandy Loam
C	15.631	14.514	69.855	Sandy Loam
D	7.209	18.299	74.492	Sandy Loam

Appendices 27: Raw data for soil texture at surface layer on mix planting plot MXP 2012.

SOIL TEXTURE

Plot: MXP 2012 **Depth: 30 – 40 cm** **Date: 16/01/2015**

Samples	Initial weight of the sample (g)	Weight of the beaker-1 (g)	Weight of the beaker-2 (g)	Average weight of the beaker (g)	Weight of sample + beaker (After oven)	(g)	(%)
CLAY							
A	10.00	9.728	9.728	9.728	9.742	0.014	14.000
B	10.00	9.856	9.857	9.857	9.866	0.009	9.500
C	10.01	10.114	10.115	10.115	10.129	0.015	14.500
D	10.01	9.915	9.914	9.915	9.923	0.008	8.500
SILT							
A	10.00	9.814	9.815	9.815	9.844	0.030	15.500
B	10.00	9.868	9.868	9.868	9.892	0.024	14.500
C	10.01	9.776	9.777	9.777	9.807	0.031	16.000
D	10.01	9.706	9.707	9.707	9.732	0.025	17.000

Samples	SOM (%)	MC (%)	SAND (%)	Total (%) of clay+silt+sand
A	5.833	2.267	62.400	91.900
B	3.333	1.167	71.500	95.500
C	5.996	2.265	61.239	91.739
D	3.599	1.266	69.635	95.135

Samples	Clay	Silt	Sand	Textural class
A	15.234	16.866	67.900	Sandy Loam
B	9.948	15.183	74.869	Sandy Loam
C	15.806	17.441	66.753	Sandy Loam
D	8.935	17.869	73.196	Sandy Loam

Appendices 28: Raw data for soil texture at subsurface layer on mix planting plot MXP 2012.

pH AND ELECTRIC CONDUCTIVITY (EC)

Plot: MP 2011 **Date: 18/12/2014**

Samples	Depth (cm)	Initial weight (g)	EC	pH
A1	0 – 10	5.00	53.7	4.63
A2	0 – 10	5.00	52.6	4.58
A3	0 – 10	5.00	54.9	4.54
B1	0 – 10	5.01	65.9	5.05
B2	0 – 10	5.01	70.9	4.98
B3	0 – 10	5.00	54.4	4.97
C1	0 – 10	5.00	98.7	4.29
C2	0 – 10	5.00	104.0	4.28
C3	0 – 10	5.00	101.3	4.27
D1	0 – 10	5.00	65.1	4.48
D2	0 – 10	5.01	73.6	4.52
D3	0 – 10	5.01	72.3	4.48
A1	30 – 40	5.01	18.4	4.68
A2	30 – 40	5.00	20.0	4.62
A3	30 – 40	5.00	16.8	4.66
B1	30 – 40	5.00	14.3	4.84
B2	30 – 40	5.00	16.9	4.81
B3	30 – 40	5.00	20.9	4.84
C1	30 – 40	5.00	16.6	4.65
C2	30 – 40	5.01	27.7	4.76
C3	30 – 40	5.01	29.5	4.68
D1	30 – 40	5.00	19.3	4.82
D2	30 – 40	5.00	24.2	4.85
D3	30 – 40	5.00	19.9	4.91

Appendices 29: Raw data for soil pH and EC for mono planting plot MP 2011.

pH AND ELECTRIC CONDUCTIVITY (EC)

Plot: MP 2014 **Date: 10/02/2015**

Samples	Depth (cm)	Initial weight (g)	EC	pH
A1	0 – 10	5.01	39.3	4.24
A2	0 – 10	5.01	43.3	4.07
B1	0 – 10	5.00	33.0	4.36
B2	0 – 10	5.00	33.6	4.33
C1	0 – 10	5.01	23.9	4.68
C2	0 – 10	5.00	25.0	4.69
D1	0 – 10	5.00	45.7	4.13
D2	0 - 10	5.00	41.3	4.20
A1	30 – 40	5.01	25.0	5.73
A2	30 – 40	5.00	10.4	4.97
B1	30 – 40	5.00	15.52	4.87
B2	30 – 40	5.00	20.6	5.22
C1	30 – 40	5.00	22.0	5.66
C2	30 – 40	5.00	10.19	5.26
D1	30 – 40	5.01	11.77	4.90
D2	30 – 40	5.01	12.29	4.97

Appendices 30: Raw data for soil pH and EC for mono planting plot MP 2014.

pH AND ELECTRIC CONDUCTIVITY (EC)

Plot: MXP 2011 **Date: 10/02/2015**

Samples	Depth (cm)	Initial weight (g)	EC	pH
A1	0 – 10	5.00	17.40	4.60
A2	0 – 10	5.02	16.96	4.57
B1	0 – 10	5.00	33.40	4.52
B2	0 – 10	5.01	32.60	4.48
C1	0 – 10	5.01	26.10	4.58
C2	0 – 10	5.00	25.50	4.50
D1	0 – 10	5.00	26.80	4.63
D2	0 - 10	5.01	13.98	4.68
A1	30 – 40	5.00	8.37	5.21
A2	30 – 40	5.00	7.93	5.09
B1	30 – 40	5.01	7.23	4.97
B2	30 – 40	5.00	13.17	5.07
C1	30 – 40	5.00	9.96	4.75
C2	30 – 40	5.00	13.36	5.18
D1	30 – 40	5.00	6.32	5.07
D2	30 – 40	5.01	6.64	5.10

Appendices 31: Raw data for soil pH and EC for mix planting plot MXP 2011.

pH AND ELECTRIC CONDUCTIVITY (EC)

Plot: MXP 2012 **Date: 10/02/2015**

Samples	Depth (cm)	Initial weight (g)	EC	pH
A1	0 – 10	5.01	30.7	4.42
A2	0 – 10	5.00	28.4	4.45
B1	0 – 10	5.00	25.4	4.71
B2	0 – 10	5.01	21.6	4.56
C1	0 – 10	5.00	26.1	4.50
C2	0 – 10	5.00	25.7	4.49
D1	0 – 10	5.00	25.3	4.83
D2	0 - 10	5.00	24.9	4.87
A1	30 – 40	5.00	13.7	5.18
A2	30 – 40	5.00	14.6	5.21
B1	30 – 40	5.01	9.03	4.91
B2	30 – 40	5.01	13.7	5.53
C1	30 – 40	5.00	9.70	5.41
C2	30 – 40	5.00	15.29	5.41
D1	30 – 40	5.01	8.79	5.00
D2	30 – 40	5.00	10.9	4.87

Appendices 32: Raw data for soil pH and EC for mix planting plot MXP 2012.

TOTAL NITROGEN (TN)

Plot: MP 2011 **Date: 19/03/2015**

Samples	Depth (cm)	mg/L	TN (%)	TN (g/kg)
A	0 – 10	16.9	0.2535	2.5350
B	0 – 10	14.6	0.2190	2.1900
C	0 – 10	21.1	0.3165	3.1650
D	0 – 10	19.8	0.2970	2.9700
A	30 – 40	5.5	0.0825	0.8250
B	30 – 40	3.2	0.0480	0.4800
C	30 – 40	6.6	0.0990	0.9900
D	30 – 40	4.9	0.0735	0.7350

Appendices 33: Raw data for total nitrogen on mono planting plot MP 2011.

Plot: MP 2014 **Date: 19/03/2015**

Samples	Depth (cm)	mg/L	TN (%)	TN (g/kg)
A	0 – 10	15.5	0.2325	2.3250
B	0 – 10	11.1	0.1665	1.6650
C	0 – 10	10.4	0.1560	1.5600
D	0 – 10	14.9	0.2235	2.2350
A	30 – 40	3.8	0.0570	0.5700
B	30 – 40	6.1	0.0915	0.9150
C	30 – 40	5.6	0.0840	0.8400
D	30 – 40	4.7	0.0705	0.7050

Appendices 34: Raw data for total nitrogen on mono planting plot MP 2014.

TOTAL NITROGEN (TN)

Plot: MXP 2011 **Date: 19/03/2015**

Samples	Depth (cm)	mg/L	TN (%)	TN (g/kg)
A	0 – 10	16.4	0.2460	2.4600
B	0 – 10	18.0	0.2700	2.7000
C	0 – 10	13.1	0.1965	1.9650
D	0 – 10	14.0	0.2100	2.1000
A	30 – 40	5.4	0.0810	0.8100
B	30 – 40	6.6	0.0990	0.9900
C	30 – 40	4.1	0.0615	0.6150
D	30 – 40	5.2	0.0780	0.7800

Appendices 35: Raw data for total nitrogen on mix planting plot MXP 2011.

Plot: MXP 2012 **Date: 19/03/2015**

Samples	Depth (cm)	mg/L	TN (%)	TN (g/kg)
A	0 – 10	19.5	0.2925	2.9250
B	0 – 10	12.5	0.1875	1.8750
C	0 – 10	14.0	0.2100	2.1000
D	0 – 10	13.6	0.2040	2.0400
A	30 – 40	4.8	0.0720	0.7200
B	30 – 40	4.0	0.0600	0.6000
C	30 – 40	5.9	0.0885	0.8850
D	30 – 40	4.5	0.0675	0.6750

Appendices 36: Raw data for total nitrogen on mix planting plot MXP 2012.

AVAILABLE PHOSPHORUS (AvP)

Plot: MP 2011 **Date: 13/02/2015**

Samples	Depth (cm)	Absorbance (nm)	Standard (ppm)	Amount (sample)	P (mg/kg)
Blank		-0.0596	0.0000	10	0
A	0 – 10	0.0151	0.0695	10	3.0360
B	0 – 10	0.0207	0.0939	10	4.1000
C	0 – 10	0.0092	0.0436	10	1.9025
D	0 – 10	0.0100	0.4708	10	20.5540
A	30 – 40	0.0267	0.6660	10	29.0777
B	30 – 40	0.0258	0.6442	10	28.1291
C	30 – 40	0.0451	1.1096	10	48.4460
D	30 – 40	0.0265	0.6617	10	28.8923

Appendices 37: Raw data for available phosphorus on mono planting plot MP 2011.

Plot: MP 2014 **Date: 16/02/2015**

Samples	Depth (cm)	Absorbance (nm)	Standard (ppm)	Amount (sample)	P (mg/kg)
Blank		-0.0661	0.0000	10	0
A	0 – 10	0.0243	0.0085	10	0.3691
B	0 – 10	0.0240	0.0070	10	0.3050
C	0 – 10	0.0244	0.0089	10	0.3890
D	0 – 10	-0.0009	0.0119	10	0.5216
A	30 – 40	0.0362	0.8943	10	39.0490
B	30 – 40	0.0145	0.3741	5	32.6706
C	30 – 40	0.0873	1.0862	10	47.4252
D	30 – 40	0.0441	1.2618	10	55.0922

Appendices 38: Raw data for available phosphorus on mono planting plot MP 2014.

AVAILABLE PHOSPHORUS (AvP)

Plot: MXP 2011 **Date: 13/02/2015**

Samples	Depth (cm)	Absorbance (nm)	Standard (ppm)	Amount (sample)	P (mg/kg)
Blank		-0.0596	0.0000	10	0
A	0 – 10	0.0111	0.0519	10	2.2651
B	0 – 10	0.0062	0.0304	10	1.3259
C	0 – 10	0.0272	0.0211	10	0.9196
D	0 – 10	0.0049	0.0373	10	1.6265
A	30 – 40	0.0248	0.6210	10	27.1153
B	30 – 40	0.0238	0.5981	10	26.1121
C	30 – 40	0.0356	0.8799	10	38.4171
D	30 – 40	0.0256	0.6395	10	27.9212

Appendices 39: Raw data for available phosphorus on mix planting plot MXP 2011.

Plot: MXP 2012 **Date: 16/02/2015**

Samples	Depth (cm)	Absorbance (nm)	Standard (ppm)	Amount (sample)	P (mg/kg)
Blank		-0.4444	0.0000	10	0
A	0 – 10	0.0076	0.0488	10	2.1327
B	0 – 10	0.0068	0.0452	10	1.9715
C	0 – 10	0.0110	0.0634	10	2.7701
D	0 – 10	0.0277	0.1365	10	5.9593
A	30 – 40	0.0476	0.2230	10	9.7364
B	30 – 40	0.0613	0.2828	10	12.3475
C	30 – 40	0.0551	0.2556	10	11.1597
D	30 – 40	0.0029	0.0284	10	1.2404

Appendices 40: Raw data for available phosphorus on mix planting plot MXP 2012.