Soil Suitability Assessment for Harumanis Mango Cultivation in UiTM Arau, Perlis

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Abstract. Perlis is one of the largest mango producers in Malaysia cultivating Sala, Harumanis, Thong Dam, Thong Dam Burma, and Melele. Among those types, Harumanis is the most popular and loved by many because of its aroma, texture, and sweetness. The production of quality Harumanis mango depends on the intensive care that is needed by the plant itself such as soil suitability, and climatic factors; such as weather and temperature. The soil suitability is an important role as a nutrient source by plant in maximizing plant growth. The extremely hot and prolonged weather conditions in December 2015 due to El Nino phenomenon are influencing a production of Harumanis products in Perlis on 2016. This phenomenon is effect on a soil moisture content rate for the plant growth. The aim of this study is to determine the soil suitability for the Harumanis mango cultivation in UiTM Arau, Perlis using Analytic Hierarchy Process (AHP) method. Three objectives were performed to achieve the aims which are identifying bulk density, soil pH, and organic matter content value using Inverse Distance Weight (IDW) interpolation method, determining criteria weight of parameter using AHP method, and determining soil suitability for Harumanis mango cultivation in UiTM Arau, Perlis. IDW interpolation method was done by using ArcGIS 10.5, and this method used for assuming value of the whole study area that unmeasured. AHP also applied to determine the soil suitability area for Harumanis mango cultivation. The highest weight value is representing criterion that have relative important and tendency in determining the suitability Harumanis mango cultivation. The results of this study show that 40,551 m² represent 65% of the total area of the study area is highly suitable soil for Harumanis cultivation. The percentage value is obtained based on a combination of weight criteria between bulk density, soil pH, and organic matter content, where the weight value of bulk density has the relative importance and the highest tendency to determine the soil suitability for Harumanis mango cultivation in UiTM Arau, Perlis.

1. Introduction
Mango, or its scientific name, Mangifera indica, is one of the popular choice fruits in South Asia, including Malaysia. Perlis is one of the largest mango producers in Malaysia which is cultivating various mango cultivar such as Sala, Harumanis, Thong Dam, Thong Dam Burma, and Melele [1].
Among those types, Harumanis mango becomes the top choice due to its aroma, texture and sweetness. Cultivation of Harumanis requires intensive care, especially in terms of soil fertility, water needs, and weather to produce high quality fruit crops which is free from any defects and physiological disorder. The weather condition is one of the main factors affecting yield production of Harumanis mango, where it requires a prolonged dry climate for about two months with a minimum temperature of 40°C to stimulating the flowering [2]. Besides, Harumanis trees also require dry climate at the beginning of flowering process until fruiting stage. High amount of precipitation during flowering stage might results in flower abortion thus, leads to low fruit production.

In year 2016, production of Harumanis mango in Perlis has declined from 15% to 20% due to the El Nino phenomenon that occurring in December 2015 [3]. An extremely prolonged hot weather conditions can be reducing soil moisture content, thus, affecting nutrients transport from the soil into plant cell and also biochemical processes in plant where it lowering down the yield production and reduces fruit quality especially in terms of size of fruit. Apart from climatic conditions, soil also plays an important role in the growth of Harumanis mango trees as it supply essential nutrients such as nitrogen (N), phosphorus (P) and potassium (K) which are needed by plants in maximizing the growth and ensure good quality of produce [4]. Even though all district in Perlis have the same climatic condition, however, production of Harumanis mango among different area could be variable due to the soil factor. According to [5], there are only certain areas in Perlis are classified as highly suitable for Harumanis mango cultivation. Different types of soil might have different soil properties. The suitability of an area for the cultivation of Harumanis mango depends on several factors such as variability in soil chemical and physical properties.

In UiTM Perlis Campus, all of the Harumanis mango trees were cultivated at lateritic soil which is classified as problematic or marginal soil. This type of soil is well known due to its highly acidic properties which contribute to nutrients imbalance and require special management. The mango trees were cultivated in several plot with different soil series such as Terap series, Jitra series and Chempaka series. Due to the variability exist in soil properties of different soil series, therefore, this study was undertaken to assess the suitability of soil for Harumanis mango cultivation.

Meanwhile, there are several methods or techniques used in determining the suitability of agricultural land, such as methods of IDW and AHP. AHP or also defined as multi-criteria decision making uses a pairwise comparison matrix to calculate the individual or overall criteria weight based on individual criteria through quantitative analysis. In addition, IDW is used as a decision-making tool in the analysis of area suitability based on the value of the criteria weight [6].

2. Material and methods

2.1. Study area

This study was conducted at the Harumanis farm in UiTM Arau, Perlis with a coordinate of 6° 25' 46.9488" N and 100° 16' 11.4384" E. There are three plots in the farm area were cultivated with Harumanis mango trees with the total are of 6.269 hectares. The Harumanis cultivation is handled by Unit Ladang and Faculty of Plantation and Agrotechnology UiTM Arau, Perlis.
2.2. Soil sampling

In this study, 30 soil samples were taken from three plots (Plot A, Plot B and Plot C), whereby 10 soil samples were collected from each plot by using soil auger and core ring sampler. Soil samples were taken at a depth of 15cm from soil surface by using soil auger and air-dried at room temperature for 3 days until it completely dry. The soil samples were ground and sieved using a 2mm sieve, to separate the coarse soil and fine soil. The soil samples were stored for further analyses of soil pH and organic matter content.

2.3. Bulk density

Before the bulk density can be computed, the volume readings for the core ring were measured in order to obtain the dimensional value between the weight of the empty metal ring and the fixed weight of the soil sample. The height and diameter of core ring sampler was measured using the vernier caliper, in which is the volume was determining by using the following formula, πr²h, where r = radius of the core ring sampler, h = height of the core ring sampler. After the soil samples were collected from the field, the core ring containing moist soil samples were oven-dried at 105°C for 48 hours until all moisture were removed and soil samples achieved a constant weight. The soil bulk density and the percentage of the pore space were computed by using the following equation:

\[ \text{Bulk Density} = \frac{M_S}{V_S} \]

\[ \text{Porosity} \% = (100) - \left( \frac{P_b}{D_p} \right) \times (100) \]

Mₜ: Weight of oven-dried soil (g)
Vₜ: Volume of soil (cm³)
Pₜ: Bulk density
Dₚ: Particle density
2.4. Soil pH
Soil pH was determined by using a pH meter where it determines the level of acidity or alkalinity in soils suspended in water. The pH meter was calibrated with buffer solutions of pH prior to the analysis of samples. In this procedure, soil pH value was measured using 10 grams of air dried soil sample and 25ml of distilled water. The soil mixture was shaken by using an orbital shaker at 150 rpm for 30 minutes. This solution was left for 24 hours before soil pH reading was taken.

2.5. Soil organic matter content
Soil organic matter content was determined by using loss of weight on ignition method in which soil samples were dried in an oven at 60°C for 24 hours and followed by dry combustion in a muffle furnace at 550°C for 8 hours. By using this method, the loss of organic matter content of the material was estimated using the following equation:

Calculation for Organic Matter Content:

\[
OMC = \frac{W_1 - W_2}{S_1 \times (\frac{100}{56})}
\]

\(W_1\): Initial weight of sample (g)
\(W_2\): Final weight (g)
\(S_1\): Initial sample (g)

2.6. IDW interpolation method
IDW interpolation method was used and processed to estimate the un-sample or unknown values of soil sampling for bulk density, soil pH and organic matter content. The figures below show the information of RMSE, mean for estimation of prediction and error value for bulk density, soil pH and organic matter content by using power 2 in general properties. The weighted distance to derive the statistical surface was expressed by a diver from the measured values at a number of unknown points.
2.7. Extract by mask

The extract by mask is an extraction tool in the spatial analyst toolbox whereby its function is to extract the cells of a raster corresponding to the areas defined by a mask. Bulk Density, Soil pH, and organic matter content were used as the parameters in extract by mask, where GA layer Prediction functions as input raster, and plot area functions as an input raster or feature mask data.

2.8. Reclassify

The value of bulk density, soil pH, and organic matter content will be reclassified based on the range of value. The reclassify layer for Bulk Density, Soil pH, and Organic Matter Content were classified into low to high range based on color values. Next, the Reclass_bd3, Reclass_pH, and Reclass_omc were estimated using the natural break of reclassify method. The range value was classified based on 1 (high), 2 (medium), and 3 (low).
2.9. Analytical Hierarchy Process (AHP)

There were three steps performed through AHP to determine the relative importance and value of the suitability variables, which are pairwise comparison matrix of the selected criteria’s, normalized pairwise comparison matrix and computation of criterion weights, and criteria weight by compute consistency matrix’s. The calculation of pairwise comparison matrix included three variables namely parameter of Bulk Density (A), Soil pH (B), and Organic Matter Content (C) in soil suitability to be compared between each other in obtaining the value of relative importance between the variables. Thus, in a normalized pairwise comparison matrix, the criteria weight and ratio for each variable were obtained by using the following equation:

\[
\text{Criteria weight (W)} = \frac{\text{WS}}{N}
\]

Where WS: Weight Sum Value

N: Total of parameter

Next, in order to obtain the ratio value, the scale of the significance of the variable was divided by the overall scale of the variable for each column with the following equation;

\[
\text{Ratio (R)} = \frac{\text{WS}}{\text{W}}
\]

Where WS : Weight Sum Value

W : Criteria Weight

Other than that, consistency index (CI) value showed the consistency of weights derived from a pairwise comparison matrix, and consistency ratio (CR) was used to indicate the likelihood that the matrix judgments were generated randomly. The calculation of CI and CR are shown in the following equation;

\[
\text{CI} = \frac{\lambda - N}{N - 1}
\]

Where \( \lambda \): Lambda Max

N: Total of parameter

\[
\text{CR} = \frac{\text{CI}}{R}
\]

Where CI: Consistency Index

R: Ratio

Table 1. Pairwise Comparison Matrix for The Criteria and Consistency Metrics

| Criterion            | Bulk Density (A) | pH (B) | Organic Matter (C) | weighted sum value | Criteria Weight | Ratio |
|----------------------|------------------|--------|--------------------|--------------------|-----------------|-------|
| Bulk Density (A)     | 0.59             | 1.03   | 0.40               | 2.02               | 0.59            | 3.42  |
| pH (B)               | 0.20             | 0.34   | 0.60               | 1.14               | 0.34            | 3.33  |
| Organic Matter (C)   | 0.10             | 0.04   | 0.07               | 0.20               | 0.07            | 3.04  |

Lambda Max (\( \lambda \)) 3.26
Consistency Index (CI) 0.13
Consistency Ratio (CR) 0.10
3. Results and Discussion
The result of this study will show a map of Soil Suitability for Harumanis cultivation in UiTM Arau, Perlis. Other than that, the result of the interpolation value on Bulk Density, Soil pH and Organic Matter, and criteria weight of parameter using AHP method in the study area will also be shown.

3.1. Interpolation value on bulk density

![Interpolation Value On Bulk Density](image)

Figure 5. Interpolation Value on Bulk Density Using IDW Method

![Reclassify Bulk Density value by Natural Break](image)

Figure 6. Reclassify Bulk Density value by Natural Break
Figure 5 shows the interpolation value on bulk density using IDW method. The value of bulk density is represented by the stretched color of rendering raster data for each soil sample. The range value was re-classified into three classes by using natural break namely low, medium, and high value. Based on the category range shown, the low values was 1.105 to 1.265, the median value was 1.265 to 1.327, and the high values was 1.327 to 1.484 (Figure 6). High bulk density indicates low porosity and compaction of the soil, which can lead to limited root growth and poor air and water flow in the soil [7]. Based on the bulk density value, three soil samples showed the high range value namely sample A2, A4, and B9, while A5, A7, A8, A10, B5, B7, C1, C5, C6, and C7 showed the low range in the bulk density value.

3.2. Interpolation value on soil pH

![Interpolation Value on Soil pH using IDW Method](image)

**Figure 7.** Interpolation Value on Soil pH using IDW Method
Figure 7 shows the interpolation value on soil pH using IDW method. The value of soil pH is represented by the stretched color of rendering raster data for each soil sample. The range value was re-classified into three classes by using natural break namely low, medium, and high value. Based on the range of classes represented, the low value was 4.64009 to 5.22002, medium value was 5.22002 to 5.548061, and high value was 5.548061 to 6.13971 (Figure 8). Based on the values, it is found that plots B and plots C namely B1, B5, C2, C3, C4, and C10 were more tends to the ideal soil pH for mango cultivation, which is in the range of 5.5 to 7.5 (weakly acid to weakly alkaline). This indicates that, the acidity of the soil is too high or too low will affect the growth rate of the plant to absorb nutrients from the soil. Where, acidic soils have low pH and high hydrogen ion concentration, and alkaline soils have very high pH values and very low hydrogen ion concentrations [8].

3.3. Interpolation value on organic matter content

Figure 9. Interpolation Value on Organic Matter Content Using IDW Method
Figure 9 shows the interpolation value on organic matter content using IDW method. The value of organic matter content is represented by the stretched color of rendering raster data for each soil sample. The range value was re-classified into three classes by using natural break namely low, medium, and high value. Where, high value of soil organic content can affect fertility and the formation of soil structure for cultivation. Based on the range of classes represented, the low value was 0.127201 to 0.129907, medium value was 1.264902 to 1.331441, and high value was 1.327066 to 0.134899 (Figure 10). Based on the bulk density value, two soil samples namely c5 and A5, showed a high value of organic content compared to others in the study area.

3.4. Criteria weight of parameter using AHP method

**Table 2. Pairwise comparison matrix of the selected criteria’s**

| Criterion (parameter) | Bulk Density (A) | pH (B) | Organic Matter (C) |
|-----------------------|------------------|--------|--------------------|
| Bulk Density (A)      | 1.00             | 3.00   | 6.00               |
| pH (B)                | 0.33             | 1.00   | 9.00               |
| Organic Matter (C)    | 0.17             | 0.11   | 1.00               |
| SUM                   | 1.50             | 4.11   | 16.00              |

**Table 3. Normalized pairwise comparison matrix and computation of criterion weights**

| Criterion (parameter) | Bulk Density (A) | pH (B) | Organic Matter (C) | SUM | Criteria Weight |
|-----------------------|------------------|--------|--------------------|-----|-----------------|
| Bulk Density (A)      | 0.67             | 0.73   | 0.38               | 1.77| 0.59            |
| pH (B)                | 0.22             | 0.24   | 0.56               | 1.03| 0.34            |
| Organic Matter (C)    | 0.11             | 0.03   | 0.06               | 0.20| 0.07            |
| SUM                   | 1.00             | 1.00   | 1.00               | 3.00| 1.00            |
Table 4. Result of Criteria Weight by Compute Consistency Matrix’s

| Criterion          | Bulk Density (A) | pH (B) | Organic Matter (C) | weighted sum value | Criteria Weight | Ratio |
|--------------------|------------------|--------|--------------------|--------------------|-----------------|-------|
| Bulk Density (A)   | 0.59             | 1.03   | 0.40               | 2.02               | 0.59            | 3.42  |
| pH (B)             | 0.20             | 0.34   | 0.60               | 1.14               | 0.34            | 3.33  |
| Organic Matter (C) | 0.10             | 0.04   | 0.07               | 0.20               | 0.07            | 3.04  |

Lambda Max \( (\lambda) \) 3.26  
Consistency Index (CI) 0.13  
Consistency Ratio (CR) 0.10

The criteria weight for each parameter was determined through the use of pairwise comparison matrix in AHP method. Table 2 shows the computation of Pairwise comparison matrix of the selected criteria’s, and (Table 3) show normalized pairwise comparison matrix and computation of criterion weights, where total sum of criteria weight must be 1. The computation result of the weighted sum value for bulk density was 2.02, soil pH was 1.14, and organic matter was 0.20 after each variable computed in the row line (Table 4). Then, the criteria weight was determined by dividing the weighted sum value by total parameters, where the value of bulk density was 0.59 representing 59 %, soil pH was 0.34 representing 34 %, and organic matter content was 0.07 representing 7 %. Through the calculation results made in this AHP method, the CR value is used to indicate whether the randomly generated matrix evaluation is acceptable or not. A consistency ratio (CR) of 0.10 or less indicates a reasonable level of consistency [9]. In a particular soil suitability, the CR is 0.10 indicating that the soil characteristics comparison is consistent and the relative weight is accurately selected. The range of criteria weight value, the bulk density showed the high value of relative importance and dominant compared to other variables in the suitability of the soil for Harumanis mango cultivation in UiTM Arau Perlis.

3.5. Map of soil suitability for harumanis mango cultivation in UiTM Arau, Perlis

![Figure 11. Soil suitability area in plot A, B, and C separate in higher suitability, high suitability, and medium suitability](image-url)
Table 5. Resulting overall areas for different suitability classes

| Criterion | Weightage Value | Area (m²) | Percentage (%) |
|-----------|-----------------|-----------|----------------|
| Bulk Density, pH, and Organic Matter | Higher Suitability | 17,323 | 27 |
| | High Suitability | 40,551 | 65 |
| | Medium Suitability | 4,819 | 8 |
| SUM | | 62,693 | 100 |

Figure 11 shows the soil suitability area in plot A, B, and C separated in higher suitability, high suitability, and medium suitability for Harumanis mango Cultivation in UiTM Arau, Perlis. The combination of the weightage values of the three variables for Bulk Density, Soil pH, and Organic Matter Content were made using a weight overlay tool. Through the evaluation of the pairwise comparison matrix method in this AHP, it was found that the area of highest suitability was 17323 m², equivalent to 27%, area for high suitability was 40551 m², equivalent to 65%, and area for medium suitability was 4819 m², equivalent to 8%. This percentage of suitability was estimated by criteria weight value, where bulk density was higher at 59%, soil pH was 34%, and the organic matter content was 7%. This means that the bulk density variable has the relative importance and the highest tendency to determine the soil suitability for Harumanis mango cultivation in UiTM Arau, Perlis.

4. Conclusion

As a conclusion, assessment of soil properties is important in order to determine suitability of soil for cultivation of crop as this could affect plant growth, nutrients supply, and production of yield. The suitability of soil for the Harumanis mango cultivation in UiTM Arau, Perlis was determined based on three variables, namely, soil bulk density, soil pH and soil organic matter content by using AHP method. The IDW interpolation method was used for the purpose of obtaining a calculated un-sample value based on the measured sample value covered in the study area where IDW interpolation is an effective approach that enforces the criterion that the estimated value of a point is determined by nearby sampling points rather than by those further apart. An interpolation value on soil bulk density, soil pH, and soil organic matter content is represented in stretched color of rendering raster data for each soil sample based on reclassification of range in categories of low, medium, and high value. Besides, this study used a pairwise comparison matrix in the AHP method for obtaining value criteria weight based on a scale pairwise comparison matrix to classify each criteria. The interpolated data would be useful for the UiTM’s farm management unit as it provides a relative important fundamental data for implementation of precision farming and soil crop suitability was determined.

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