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Analysis of Spatial Distribution of Soil Moisture Content for Different Soil Layers in Mango Greenhouse

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Abstract. Water content in soil or generally known as soil moisture plays an important role in plant growth. In moving towards a better farm management in precision agriculture concept, it is vital to maintain the uniform growth of plants by preserving the same amount of moisture in the soil. In this study, spatial distribution analysis of soil moisture content was conducted to observe the variability of topsoil and subsoil. A total of 80 soil samples were collected randomly and analysed using the gravimetric method. The data were used to produce soil moisture distribution maps using ArcGIS software. The results show subsoil layer has higher moisture content compared to the topsoil layer with a mean value of 26.17% and 22.84%, respectively. Even though the maps revealed two different patterns of moisture content, both layers fall in high moisture class (21.01% – 28%) with less variation. Thus, this indicates both layers have sufficient amount of moisture content for mango growth and irrigation water supply was adequate.

1. Introduction

Soil is one of natural resources that can be found on earth's surface. The soil generally contain mineral components, air, water, and organic matter. Soil plays an important role in supporting growth of plants by holding roots firmly and supplying mineral and water. Therefore, soil should be able to hold right amount of water as per plant water requirement. Water content or moisture content in soil normally differ according to soil type, weather condition and water supply.

In a greenhouse, irrigation system installed is a sole water supply. The irrigation systems can be in a type of sprinkler, micro, drip and others. Among these types, drip irrigation is the most suitable and best irrigation system for mango plant grown in greenhouse because the systems greatly reduces water used. The water supply through this system has a direct relationship to soil moisture content. As water supply is important for plant growth, it is necessary to ensure the soil moisture is at sufficient amount needed by plant.

In precision farming concept, it is important to maintain the uniformity of plant growth for better management practice. Therefore, it is an urge in reducing any variability that might occur. One of the most important input parameter is soil. Several researchers have agreed that the best way to access soil variation is through soil mapping. Brevik et al. [1] stated that, soil mapping is the key in advancement of knowledge of soil.

Even though, many soil mapping method was produced and used since 19th century, nonetheless it still could not meet additional requirement needed in soil mapping. Starting 21st century, many researcher has started to added other elements in soil mapping in parallel with geospatial revolution to improve the accuracies in presenting the data. This includes geographic positioning systems, geographic information systems and recently remote sensing ([2]-[4]). All techniques have its function to collect related data, analysis the data and predict information related to soils to create the soil mapping.

Among all types of soil mapping, soil moisture and soil nutrient mapping are very decisive. Lei Yang et al., [5] in their study stated that, soil moisture and its spatial variation are closely related with plant growth. According to Zhang C. et al. [6] stated that the based on spatial distribution map of soil moisture is useful for managing the precision irrigation in time, analyse the water requirement of plant and predict the variation of soil.

As water supply is important for plant growth, this study aim to map the soil moisture variation at two soil layers; topsoil and subsoil. Mapping these two layers may indicate the adequateness of water supply as subsoil layer is where the active root zone is located. In previous research [7], it is said that soil moisture present in topsoil horizon layer has shown maximum variation compared to subsoil horizon layer in open space area. Despite the fact that there is quite similar research that has been done in this area, however, none has been investigated on the variation of this parameter in high density planting system greenhouse with less environmentally depended.

2. Materials and methods

The study was carried out in one of 50 greenhouses at Sustainable Agrotechnology Institute (InSAT), Universiti Malaysia Perlis (UniMAP), Sg. Chuchuh, Padang Besar, Perlis. The mean temperature of the area is about 32°C at daytime and the relative humidity is about 80.7%. The average elevation of the area is about 53m above the level sea level. The selected greenhouse (GH19) was planted with a total of 212 Harumanis mango. The greenhouse has a dimension 24.2 m wide and 84 m length.

2.1. Soil Sampling

40 plant locations were selected using random grid sampling technique for soil sample collection. The samples were taken after an hour of irrigation. The greenhouse was irrigated on once-daily basis as the plants are at flowering stage. Overall, there are 80 samples, with 40 samples collected for topsoil (at depth 0-15cm) and another 40 samples for subsoil (at depth 15-30cm). Each soil sample weight around 50g.

Soil moisture content of each sample was measured using gravimetric method. This method uses hot oven to dry the sample. This standard method is commonly and widely used because it gives high accuracy, more simple procedure, reliability results. The moisture content was calculated by the following equation:

$$\text{Moisture content (\%)} = \frac{W2-W3}{W3-W1}\ X\ 100 \qquad (1)$$

Where W1 is weight of empty can (g), W2 is weight of moist soil + can (g) and W3 is weight of dried soil + can (g).

2.2. Interpolation and Mapping Method

To create a mapping in any of geographic information system (GIS) tool, Global Positioning System (GPS) data were collected at plant sample locations. A data of latitude, longitude and elevation were gathered and received using Topcon GR-5 instrument. The GPS and soil information data were imported in ArcGIS software to map the soil moisture. An interpolation method Inverse Distance Weighted (IDW) was adapted as it is simple and accurate method since known data were quite close to one another. This method calculates the unknown values based on a power of the Euclidean distance between the measured location and unknown location [8].

3. Results and discussion

3.1 Soil Moisture Data

Table 1 shows basic statistical value of soil moisture data for topsoil and subsoil layers. The soil moisture varies from 23.80 to 28.00% and from 21.06 to 24.50% for topsoil and subsoil layer, respectively. It can be seen that; topsoil layer has higher mean value compared to subsoil. However, the difference in mean value of both layers is very small (3.33%).

Table 1. Basic Statistical Values of the Soil Moisture Data

Parameter	Topsoil	Subsoil
Count (n)	40	40
Minimum (%)	23.80	21.06
Maximum (%)	28.00	24.50
Mean (%)	26.17	22.84
Standard Deviation	0.980	1.060
Skewness	0.170	0.020
1st Quartile (%)	25.34	22.19
Median (%)	25.91	22.63
3rd Quartile (%)	26.88	23.73

In view of results obtained, the standard deviations were low for both layers. This shown that, there are less variations in soil moisture data. In addition, the skewness values for topsoil and subsoil layers were near to 0. Hence, it can be interpreted that the data were normal distributed and approximately symmetrical.

3.2 Spatial Distribution of Soil Moisture

Soil moisture variation or distribution maps were created using ArcGIS and classified into several classes based on the percentage of soil moisture. By refereeing to several literatures, the highest moisture percentage that the soil of a type clay can hold is around 35 to 39%. For that reason, five classes of range have been setup covering from 0 to 35% moisture. The classes are; very low, low, moderate, high and very high (see Table 2).

Nevertheless, this range cannot clearly present the variation of soil moisture as all 80 soil moisture data fit in only one class, which is high (21.01% to 28.00%). Consequently, the subclasses were created by diving the high class (21.01% to 28.00%) to five subclasses of High I, High II, High III, High IV and High V as in Table 3.

Table 2. Classification of soil moisture

Classes	Soil Moisture Content (%)
Very Low	0 - 7
Low	7.01 - 14
Moderate	14.01 - 21
High	21.01 - 28
Very High	28.01 - 35

Table 3. Subclasses range for ‘High’ class

Classes	Soil Moisture Content (%)
High I	21.01 – 22.40
High II	22.41 – 23.80
High III	23.81 – 25.20
High IV	25.21 – 26.60
High V	26.61 – 28.00

Figure 1 shows two soil moisture maps for topsoil and subsoil. The variations or distributions of soil moisture content in greenhouse were discussed based on this figure. Selected color fills were chosen to indicate the subclasses; grey (High I), green (High II), yellow (High III), blue (High IV) and red (High V).

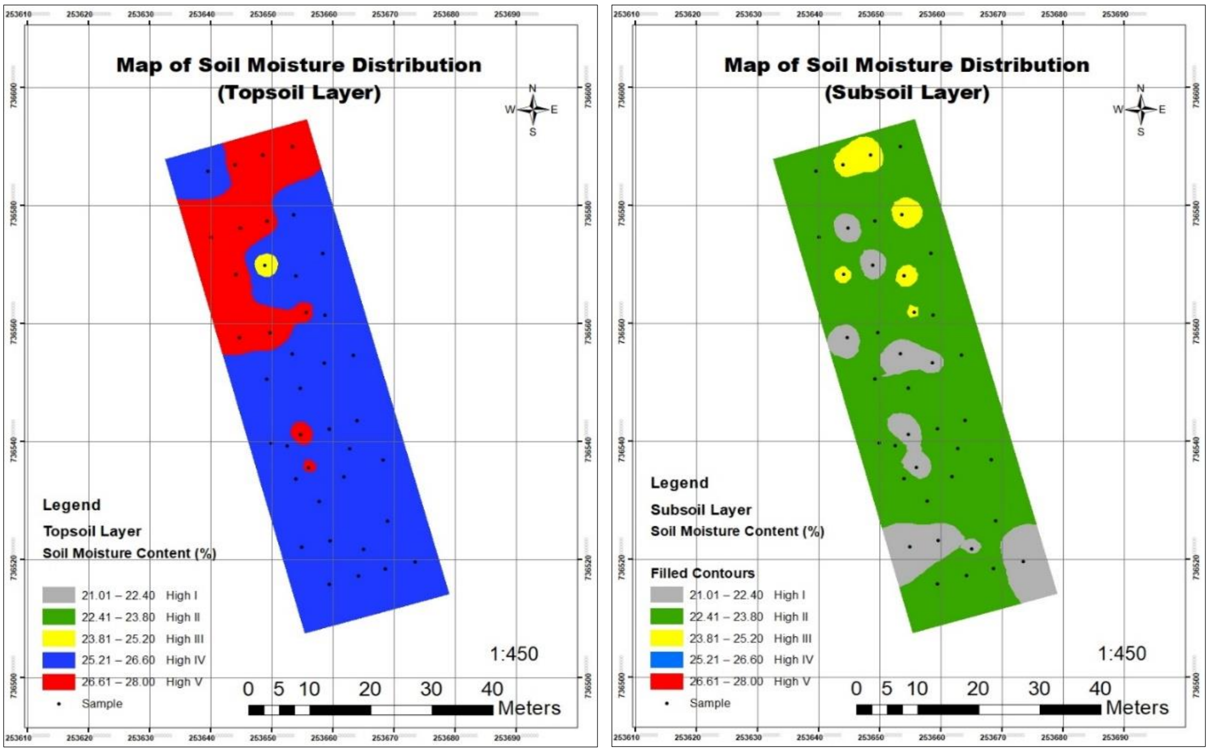

Figure 1. Soil Moisture Distribution Map of Topsoil (a) and Subsoil Layers (b).

The soil moisture distribution map shows difference color fill and pattern for both layers. For topsoil layer, it was filled with colors of yellow, blue and red which ranging from High III to High IV. This layer was dominated by blue color, however the red color did exist and has concentrated at northwest of the greenhouse. It is predicted that, high moisture for red region was because the area was slightly lower in elevation although the soil was leveled before greenhouse was built. This has been crossed validate with elevation data collected during GPS data captured. Indirectly, it can be said that certain fraction of irrigation water might seep and run-off towards lower elevation area before it infiltrate into soil. This was in agreement with research study [9]. Soil moisture and elevation also understood to have an inverse relationship to one another [10].

On the other hand, the subsoil layer was filled with grey, green and yellow colors from High 1 to High III class. The green color vastly occupied the layer with seven gray and five yellow spots. The spots were scattered in that layer. Again, they yellow spots with a higher moisture value was seen on northwest and this may be related to above reason in topsoil layer. As the topsoil layer possess more water, more water will be assumed to infiltrate.

As whole, it can be said that, topsoil and subsoil layer can be represented by blue (High IV) and green (High II) class, respectively as the color spread widely in that particular layer. Clearly, as expected, topsoil layer has higher soil moisture content compared to subsoil layer. This may be correlated to the infiltration process. The movement of water downwards or called infiltration process from topsoil to subsoil is happened respectively to time and textural of a soil. There are few more factors that may influence infiltration time or rate such as soil porosity, soil texture, and vegetation ([11] – [12]). On the other hand, some water or moisture in topsoil may be lost before it may infiltrate. This may be due to runoff and evaporation process. According to Li Rong et al., [10] it is said that higher soil water evaporation and vegetation cover transpiration in the topsoil and subsoil layers plays a responsible role in soil moisture content.

4. Conclusion

In this study, the soil moisture mapping of both layers have represented a better visual picture of moisture variation. Both maps have shown different spatial variation and distribution of moisture content even though all data fall in high moisture content class. There is less variation of moisture content throughout each soil layers can be seen. Therefore, it can conclude that; spatial distribution of the soil moisture content may be affected by several factors and soil depth has an inverse relationship with soil moisture content. The maps may help the farmers to reduce the variability (i.e supplying more water to lower soil moisture spots) and uncertainties that might occur in future.

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References

[1] Brevik, E. C., Calzolari, C., Miller, B. A., Pereira, P., Kabala, C., Baumgarten, A., & Jordán, A., 2016. Soil mapping, classification, and pedologic modeling: History and future directions. Geoderma, 264, 256-274.
[2] Lagacherie, P., 2008. Digital soil mapping: a state of the art. In: Hartemink, A.E., McBratney, A., Mendonça-Santos, M.L. (Eds.), Digital Soil Mapping with Limited Data. Springer, Dordrecht, The Netherlands, pp. 3–14. http://dx.doi.org/10.1007/ 978-1-4020-8592-5_1.
[3] McBratney, A.B., Mendonça Santos, M.L. & Minasny, B., 2003. On digital soil mapping. Geoderma 117, 3–52.
[4] Scull, P., Franklin, J., Chadwick, O.A. & McArthur, D., 2003. Predictive soil mapping: a review. Prog. Phys. Geogr. 27, 171–197.
[5] Lei Yang, L. C., 2015. Effects of vegetation restoration on the spatial distribution of soil moisture at the hillslope scale in semi-arid regions. In CATENA, 138-146.
[6] Zhang C., Liu S., Fang J., &Tan K., 2008. Research on the Spatial Variability of Soil Moisture Based on GIS. The International Federation for Information Processing, 719-727
[7] Liding Chen, Z. H., 2007. The effect of land cover/vegetation on soil water dynamic in the hilly area of the loess plateau, China. In CATENA, 200-208
[8] Chen, H., Fan, L., Wu, W. et al. Environ Monit Assess, 2017. 189: 525.
[9] Grayson, R.B., Western, A.W. & Chiew, F.H.S. 1997. Preferred states in spatial soil moisture patterns, local and nonlocal controls. Water Resour. Res. 33, 2897–2908
[10] Li Rong, X. D. (2017). Soil Moisture Variation in a Farmed Dry-Hot Valley Catchment Evaluated by a Redundancy. WATER, 92.
[11] Lipiec, J., Kuś, J., Słowińska-Jurkiewicz A., & Nosalewicz, A. 2006. Soil porosity and water infiltration as influenced by tillage methods. Soil and Tillage Research, 89(2), 210-220
[12] N.B. English, J.F. Weltzin, A. Fravolini, L. Thomas, D.G. Williams, 2005. The influence of soil texture and vegetation on soil moisture under rainout shelters in a semi-desert grassland. Journal of Arid Environments, 63 (1), 324-343