Soil color as indicator for fruit garden soil assessment and recommendation

Vo Quang Minh[1*], Pham Thanh Vu[1], Thai Thanh Du[1], Le Van Khoa[2], Tran Kim Tinh[2]

(1. Cantho University, College of Environment and Natural Resources, Department of Land Resources, 3/2 Street, Ninh Kieu District, Cantho City, 900000, Vietnam

2. Cantho University, College of Agricultural, Department of Soil Science, 3/2 Street, Ninh Kieu District, Cantho City, 900000, Vietnam)

Abstract: The soil organic carbon (C) content played an important factor in soil fertility for crop yield, but in wider regions, the estimation in the fields require costly to analyze. The study objectives were to use soil color as an indicator for assessment and correlation with the soil organic C content as the soil degradation indicator from 82 soil samples of the study area in Hau Giang province, Vietnam. The results showed that when the soil has the same humidity, the soil has a different Value and Chroma but the same Munsell Hue color. The organic C content is ranging from 1.32% to 5.6%. There was the negative significant correlation between Munsell soil color properties and organic C content, as Value ($r = -0.75^{**}$ air-dry, $r = -0.74^{**}$ moist); Chroma ($r= -0.55^{**}$ air-dry, $r = -0.66^{**}$ moist). Especially for topsoil layers, soil color is a useful predictor of organic C content. This study indicates that the Munsell soil colors can predict the fruit garden soil organic C in moist conditions. However, more analysis on the other soils with different soil properties for a further recommendation.

Keywords: soil organic C, munsell, soil color, indicator

Citation: Minh, V. Q., P. T. Vu, T. T. Du, L. V. Khoa, and T. K. Tinh. 2023. Soil color as indicator for fruit garden soil assessment and recommendation. Agricultural Engineering International: CIGR Journal, 25 (2):34-44.

1 Introduction

Typical agricultural practices such as excessive agrochemicals, tillage in moist soil conditions, and luxury irrigation have degraded soils. The organic matter content decline is becoming a significant soil degradation process (Diacono and Montemurro, 2010). The degraded soil fertility evaluation requires complicated methods and consuming time. The agricultural extension workers and farmers are hard to implement. However, some soil properties, such as soil color, are closely related to each other. According to Henry (1990), soil colors are related to other soil properties and are easily identifiable. The soil colors use to identify the soil use information in conjunction with different properties.

In contrast, the organic matter content plays an essential role in soil fertility evaluation. According to Gobin et al. (1998), the organic matter content affects soil color depending on the soil data. The darker Color often indicates the high rate of organic matter decomposition. Thus, the living organisms and dead organic matter decomposing into black humus (NRCS., 2021). The soil color reflects the difference between minerals, organic matter content, soil texture and is quickly determined. Therefore, colors are essential to distinguish soil types, especially for soils with high mineralization (Stoner et al., 1980).

Received date: 2021-08-22 **Accepted date:** 2022-12-29

* **Corresponding author: Vo Quang Minh,** Ph.D., Cantho University, College of Environment and Natural Resources, Department of Land Resources, 3/2 Street, Ninh Kieu District, Cantho City, 900000, Vietnam . Email: vqminh@ctu.edu.vn. Tel: (84)0913604101 .

The study's objective is to determine the correlation between Munsell soil color values with the fruit garden soil organic C content. The resulting base on soil color evaluation and correlation to rapidly diagnose soil organic C content can recommend evaluating the level of fruit garden soil degradation.

The territory of the study area in the Mekong delta lies between 9 ° 30'35 and 10 ° 19'17 North and from 105 ° 14'03 to 106 ° 17'57 East (Figure 1). The terrain height is less than 2 meters above sea level. The total land area is 162,171 ha, agricultural land is 141,217 ha occupied 87.08% of the natural region (statistical data 2014).

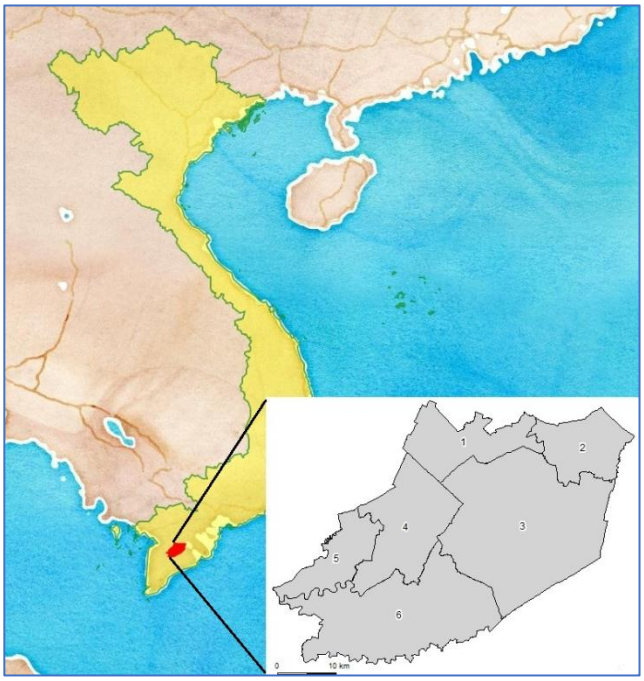

Figure 1 The study area in VietNam

2 Materials and methods

2.1 Soil sample collection

Topsoils of 82 fruit garden soil samples at different ages were collected (< 10; 12-18; 22-28; and >30 years old) for analyzing soil organic C and soil color (Figure 2).

Figure 2 Fruit garden of the study area.

2.2 Methods of implementation

2.2.1 The estimation of soil color

The soil color (Hue, Value, Chroma) is estimated using the Munsell soil color chart for soil samples at the dry and moist conditions (Figure 3):

Dry soil sample: Weigh 50 g dry soil at 100°C for 8 hours. After drying, the samples' soil color is determined, with the Munsell hue (a specific color), value (brightness), and chroma (color intensity)

Moist soil sample: Weigh 50 g of soil in a sample container and covered it with a cloth to allow water to penetrate, and most of the soil pores are filled with water (about 2 hours) to increase the soil moisture content up to the field conditions. The soil samples treat to stand until there is no water left in the tube. Soil color determines the moist or dry soil conditions.

Soil samples compare at the same conditions of light and time.

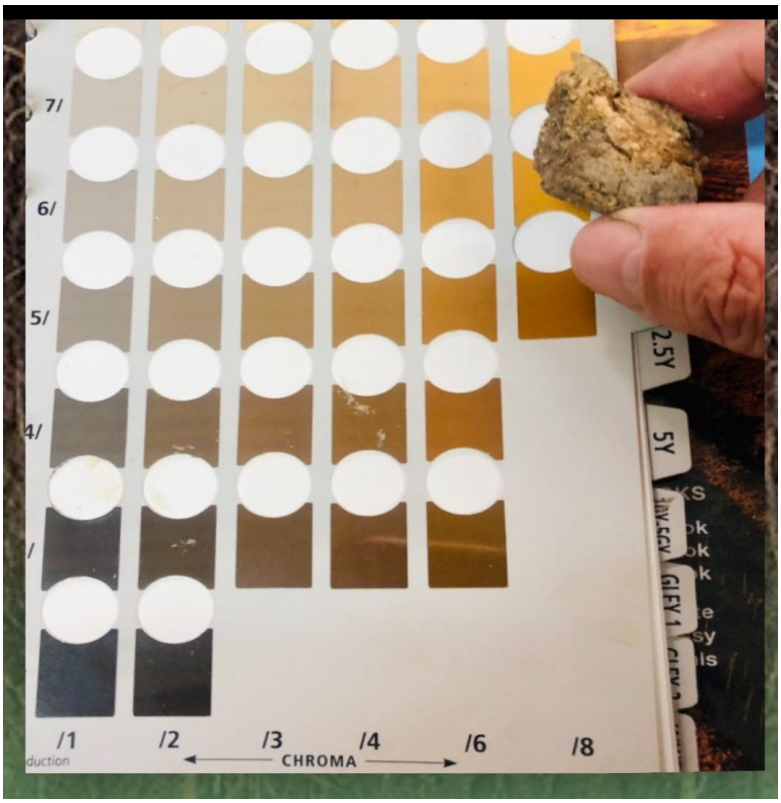

Figure 3 Munsell Soil color estimation.

2.2.2 The analysis of the Soil Organic Carbon

The determination of soil organic C base on the Walkley-Black chromic acid wet oxidation method. Oxidizable organic carbon in the soil oxidizes by 0.167M $K_2Cr_2O_7$ solution in concentrated H_2SO_4. (Department of Soil Science Lab, Cantho University)

2.2.3 The Red Index (RF) determination

The RF index calculates to estimate the effect of the soil background color and organic carbon content. Red Index (RF) calculated according to Satana (1984). The correlation between the soil RF index at moist and dry conditions with Organic C content calculated as in equation (1):

$$RF = (10 - H) + C/V \quad (1)$$

In which:

RF: Red Index of soil.

H: Value of Munsell Hue

C: Value of Munsell Chroma

V: Value of Munsell Value

2.2.4 Analyzing the correlation between Munsell soil color and soil organic C content.

The Munsell soil color measures separately according to Value, Chroma, and Hue. The linear correlation analysis of each pair of C content with Munsell Hue, Value, Chroma, and between Munsell soil color and organic matter content, and between Munsell soil color and organic matter at the different fruit garden ages (< 10; 12-18; 22-28; and >30 years old).

3 Results and discussion

3.1 The correlation between soil color and organic C content

The results show that each Munsell color data includes three parameters: color spectrum (Hue), color brightness (Value), color purity (Chroma). Since the study area has the lowest C content of 1.32%, corresponding to Munsell color of 7.5YR7.5/2 for dry soil samples and moist soil samples 10YR 5/3, the highest organic C content is 5.60% compares to Munsell color of 7.5YR 5.5/1 for dry soil and moist soil samples, 10YR 2.5/1.5.

3.2 The correlation between organic C content and Color brightness

Munsell Value or Colour brightness indicates how much light is reflected or emitted by the object. Munsell Chroma refers to the purity degree or Chroma color strength (C), denoting the light source's monochromatic color intensity.

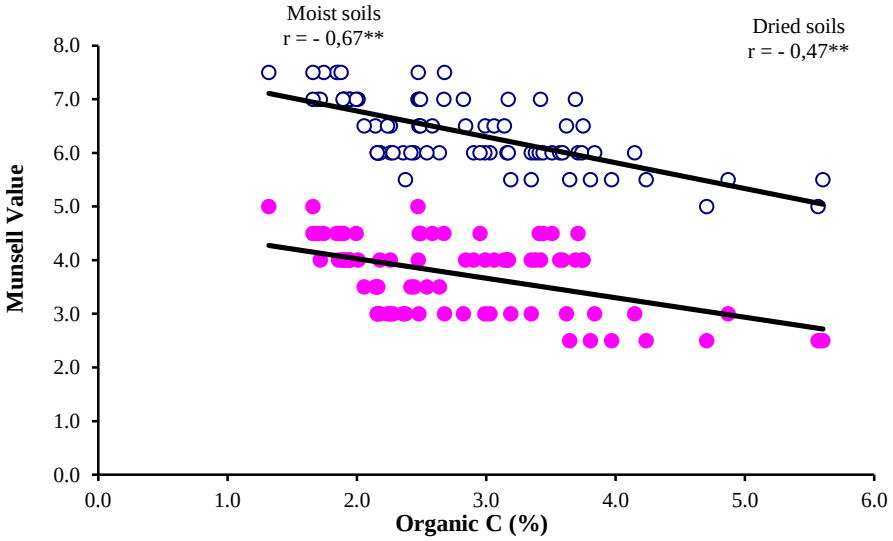

Figure 4 Correlation between Organic C and the Value of Munsell soil color

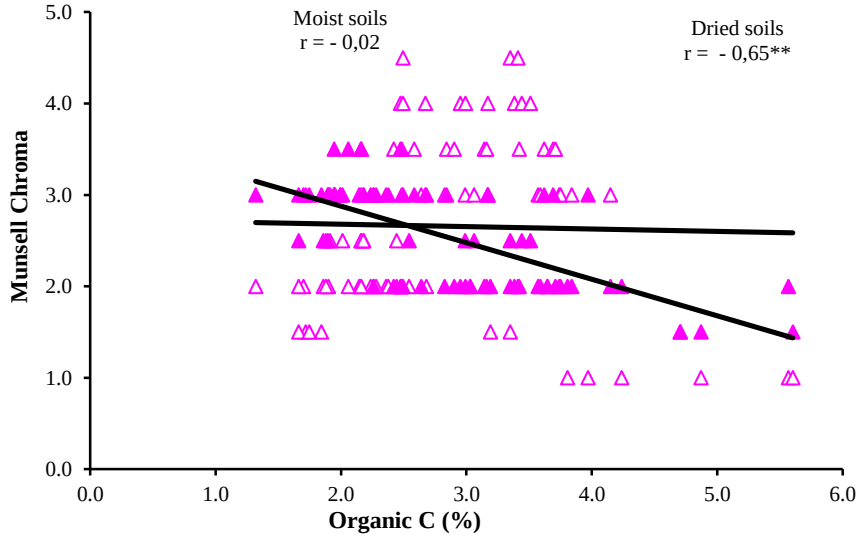

Figure 5 Correlation between Organic C and the Chroma of Munsell soil color

In the Figure 4 and 5, there was a negative correlation between the organic C content and the color brightness (Value), and purity (Chroma) of fruit garden soil, (Value: r = -0.75** and r = -0.74**; r = -0.5 ** Chroma and r = -0.66**, respectively). The results show that organic C content decreases, the soil's Color is fading (the greater the color value), and vice versa; when the surface layer soil color becomes darker, the soil has organic C content higher in the same humidity. This correlation result is also consistent with the

previously studied results between soil color and organic C content. In a large area, the correlation coefficient r = -0.77 to r = -0.84, as of Steinhardt and Franzmeier (1979), Pitts et al. (1983), Griffis (1985), and lower than the results of Fernandez et al. (1988) on two soils in India. Which has a very high correlation coefficient between the content of organic C and the Munsell color value in moist soil correlation coefficient is (r = -0.97), and dry soil correlation coefficient (r = -0.96). It means, when the C content increases, the color Munsell value, chroma of the Color all tend to decrease in both dry soil and moist soil conditions. The Munsell color Hue does not change in the same light and humidity condition, but its Munsell color Chroma and Value change. The Munsell color Value and Chroma correlate with the organic C content in the same soil with the same texture. The correlation coefficiency of Munsell color Value and Chroma in moist soil samples is higher than in dry soil, and color Value is higher than Color Chroma.

3.3 The correlation between RF index and soil color

RF index is a red quantitative index on the soil layer (Santana, 1984). According to Max et al. (1943), physical forms also affect the soil color factor in all soil types, including the parent rock materials. Therefore, the RF index calculates whether the red index affects the soil color adds the correlation factors.

Determination of RF index on the soil surface is based on the basic rules of Munsell color and calculated by the formula (Santana, 1984):

RF = (10 - H) + C / V

This formula calculates the RF value in dry (RF-d) and moist soil (RF-w).

The results show no correlation between the RF index and organic C content for both moisture conditions. The range of organic C influences the topsoil color of fruit garden soil. The RF red index is often related to Fe mottles density. This result is suitable with the research results of Breemen (1976). When observed under the microscope, the yellow soil mottles are mostly jarosite minerals. According to Annabelle et al. (2010), Jarosite presence as pale yellow mottles (Munsell soil color 2.5Y 8/6) in the sulfuric horizon of acid sulfate soils. Only a few mottles are goethite, and brown and red mottles in the soils are mainly goethite, sometimes goethite combined with jarosite and hematite minerals.

3.4 The correlation between soil organic C and soil color

The results show that the surface Munsell soil's Color correlates with organic C content. Therefore, it is possible to rely on the regression equation to estimate the C content by determining the soil color. A multivariate regression equation based on Munsell Hue Values and Chroma color can calculate organic C content. However, because the Munsell Hue color does not change in the same condition, the regression equation has only two values of color Value and Chroma. Therefore, the regression equation between organic C content and the color values can be used to estimate organic C content.

Dry soil: C (%) = 9.02 - 0.83 x (Munsell Value) - 0.53 x (Munsell Chroma) (2)

Moist soil: C (%) = 7.32 - 0.78 x (Munsell Value) - 0.77 x (Munsell Chroma) (3)

3.5 The prediction of C content on fruit garden soils

The predicted organic C, estimated from Equations 2 and 3, of fruit garden soils under moist and dry soil conditions are showing that :

For dry soil samples: the C content estimate as compared to the C results, the error is small, more significant than 0.25 accounted for 36.54%, errors greater than 0.25 but smaller than 0.5 accounted for 13.46%, errors greater than 0.5 but smaller than one accounted for 44.23%, and errors more significant than one accounting for 5.77%.

For moist soil samples: the error compared to C analyzed are less than 0.25, accounting for 51.92%, errors greater than 0.25 are smaller than 0.5, accounting for 23.08%, errors greater than 0.5 are smaller than 1 accounted for 17.31%, errors more significant than one account for 7.69%.

Then the moist soil samples have a minor error when compared to dry soil samples.

3.6 The comparison between the analyzed and estimated organic carbon content

Under dry soil conditions, there is a positive correlation coefficient (r=0.81**) between C analysis and C calculated. The error difference is less than 0.5 (about 50% of the total soil samples) (Figure 7). The estimation of organic C based on Munsell color has relatively high reliability compared to the results of the analyzed C content.

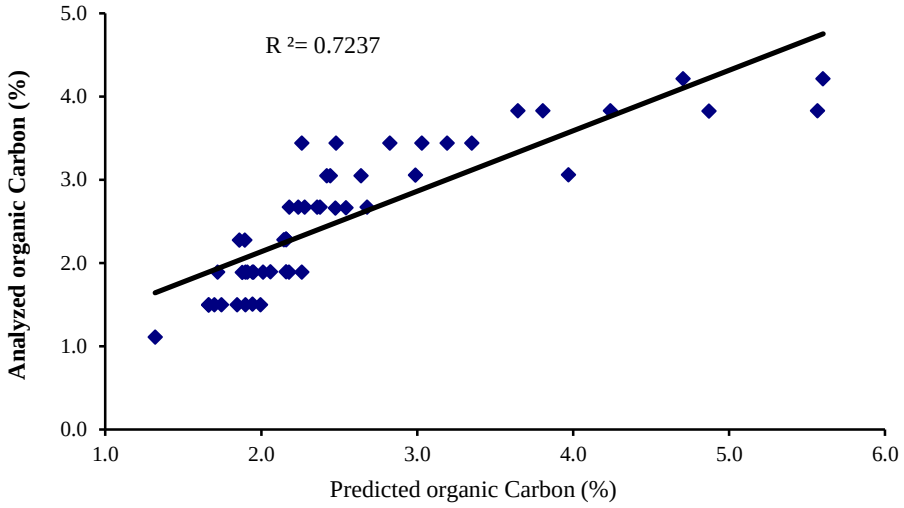

Figure 6 Correlation between the analyzed and estimated C in dry soil conditions.

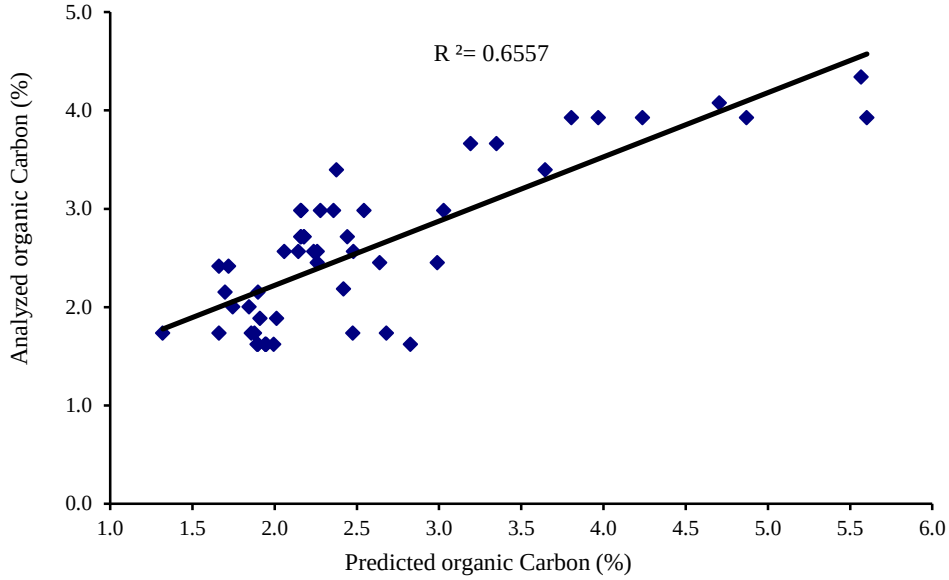

Figure 7 Correlation between the analyzed and estimated C in moist soil conditions.

According to Figure 6, there is a high positive correlation (r=0.85**) between the estimated and analyzed organic C content. The estimated and distributed organic C content error is <0.5 (about 50% of the total soil samples). It showed a correlation when using soil surface color for C calculation.

Thus, when estimating C content on the moist soil samples, it is more reliable when evaluating the dry soil samples for fruit gardens.

3.6 The correlation between the fruit garden ages and soil color

The soil color and organic C content correlated with the previous section. In comparison, organic C correlates with fruit garden soil degradation. The identification of the fruit garden's soil degradation levels can base on the Color of the topsoil.

The results of correlation from soil samples of 4 different age fruit gardens, under ten years cultivation, 12 to 18 years, 22 to 28 years, and over 30 years of age are shown as follows:

3.6.1 Fruit garden age less than ten years old

Figures 8 and 9 show that in the Fruit gardens soils less than ten years old, Munsell color Value, Chroma in dry soil samples, and moist soil samples all negatively

correlate with organic C contents. It means the higher range of organic C, the lower Value, and Chroma of Munsell soil colors.

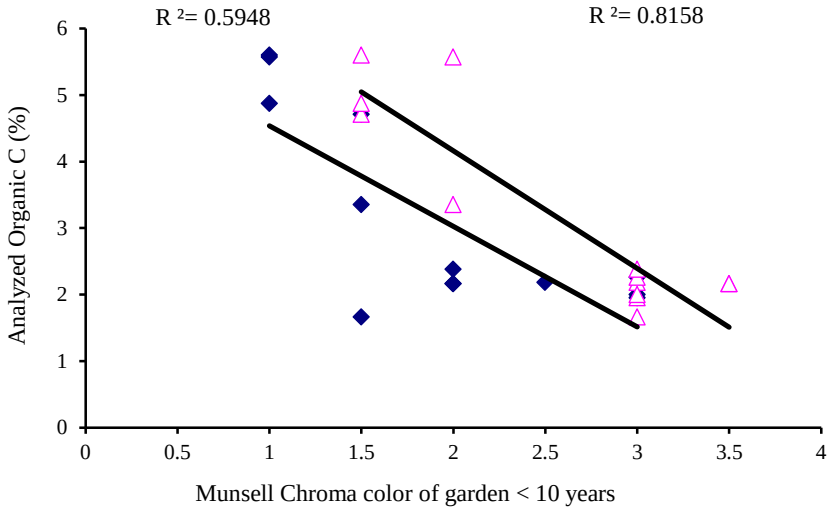

Figure 8 Relationship between Munsell Chroma color and analyzed organic C in garden <10 years old.

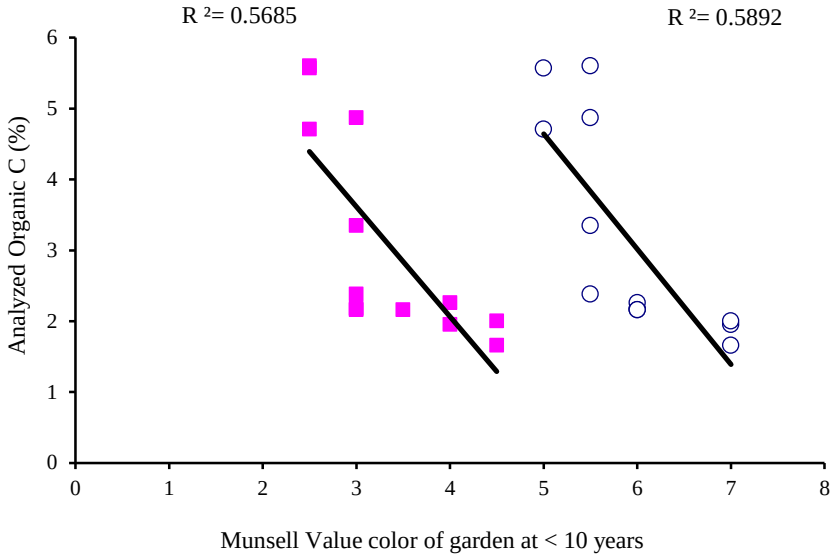

Figure 9 Correlation between Munsell value color with analyzed organic C in the garden <10 years old

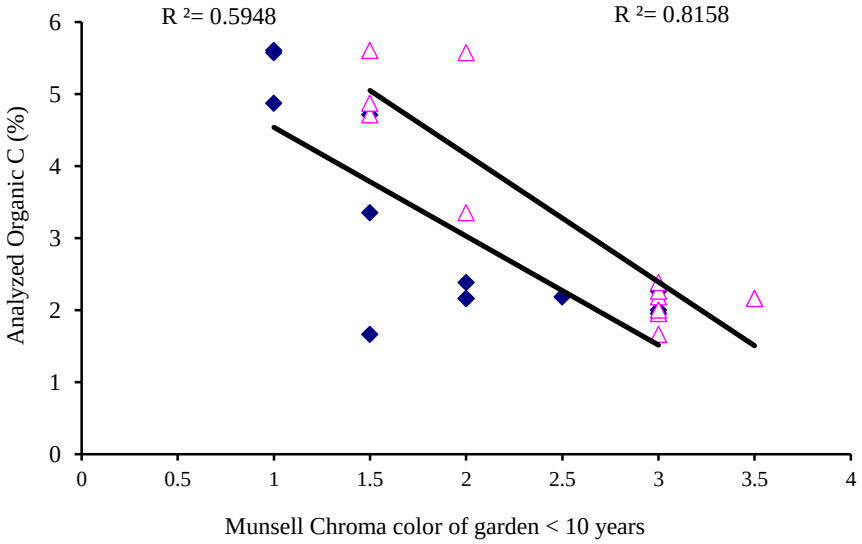

Figure 10 Correlation between analyzed organic C with Munsell Chroma color of the garden at 12 to 18 years old

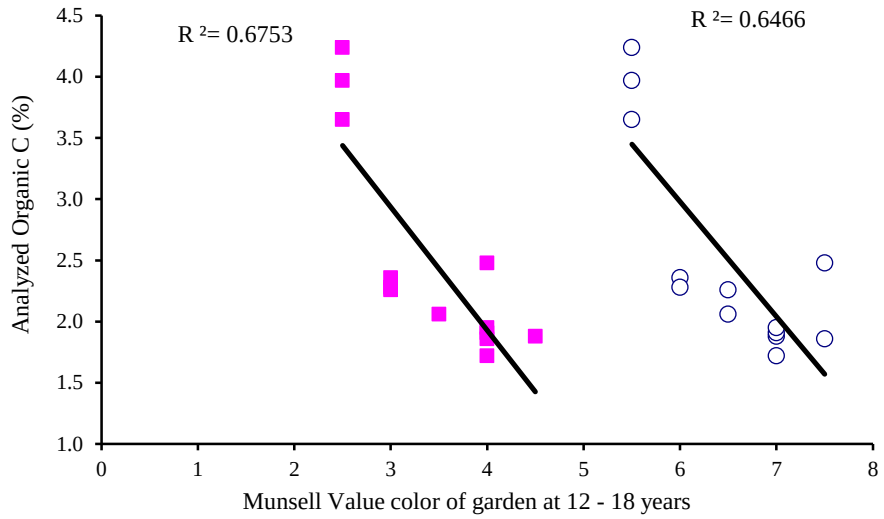

Figure 11 Correlation between analyzed organic C with Munsell Value Color of the garden at 12 to 18 years old

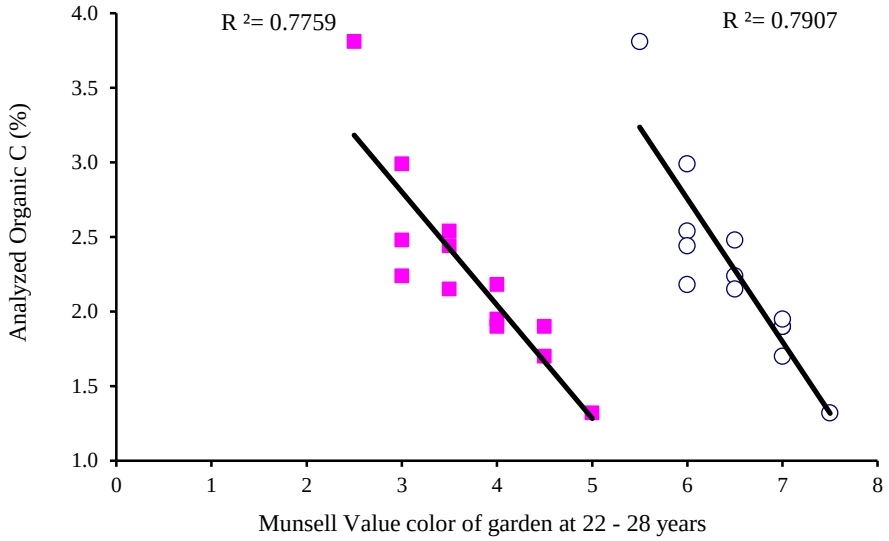

Figure 12 Correlation between analyzed organic C with Munsell value color of garden 22-28-year-old

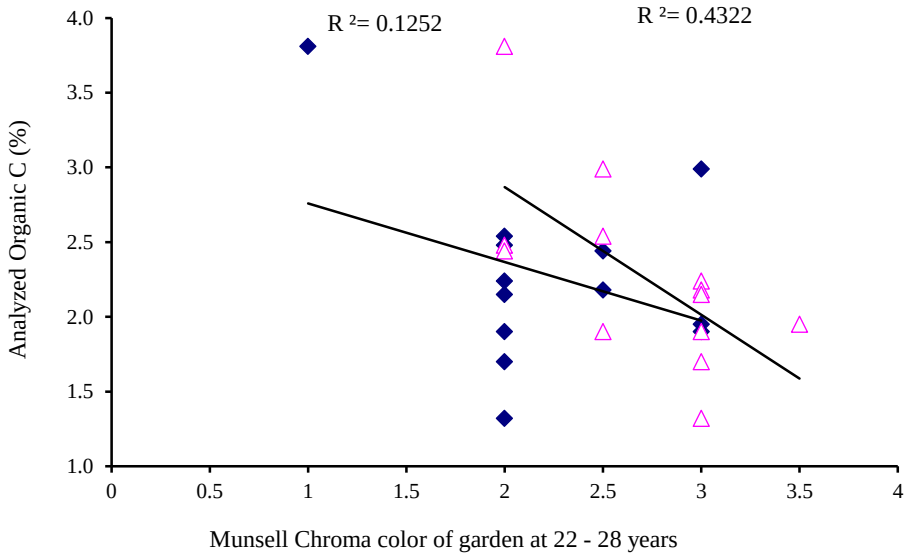

Figure 13 Correlation between analyzed organic C with Munsell Chroma color of garden 22-28-year-old

3.6.2 Fruit garden age from 12 to 18 years old

Figures 10 and 11 show a correlation between Munsell color properties and organic C content on fruit garden soil 12 -18 years old. Again, the correlation dry moist soil samples value is lower than moist soil samples.

3.6.3 Fruit garden age from 22 to 28 years old

Figures 12 and 13 show that the Munsell Value color ranging from 2 to 3 for moist soil samples and 6 to 7.5 for dry soil samples; the Munsell Chroma color ranges from 2 -2.5 for moist soil samples, varying from 2.5 to 3 for dry soil samples. Thus, the significant level of Munsell value color in moist soils is higher than in dry soil. Still, the Munsell Chroma of dry soil samples has a higher correlation coefficient than moist soil samples.

3.6.4 Fruit garden age greater than 30 years old.

According to the age of the fruit garden soil samples, at dried and moist, Figures 14 and 15show the correlations between the content of organic matter and Munsell soil colors. Based on the Munsell Value color, the correlation coefficient is higher than the Munsell chroma color.

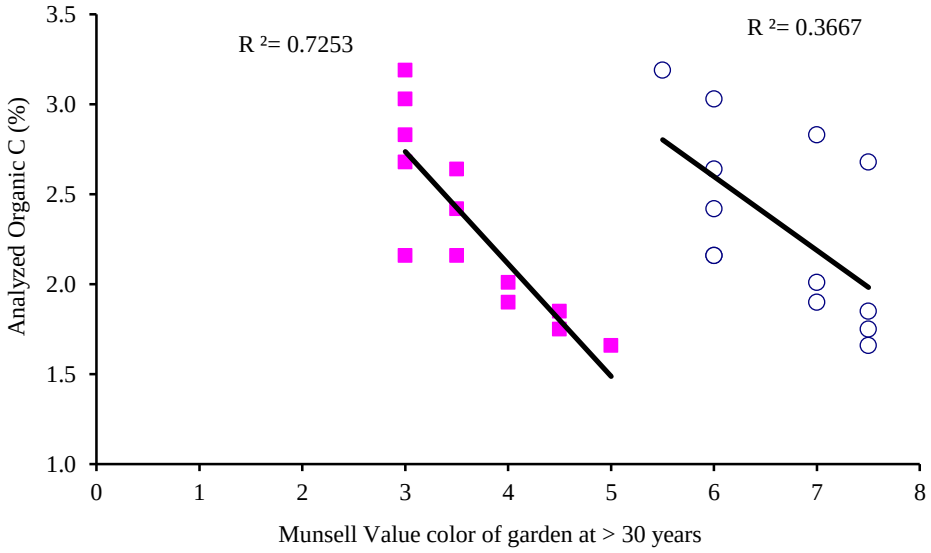

Figure 14 Correlation between analyzed organic C with Munsell value color of the garden at >30 years old

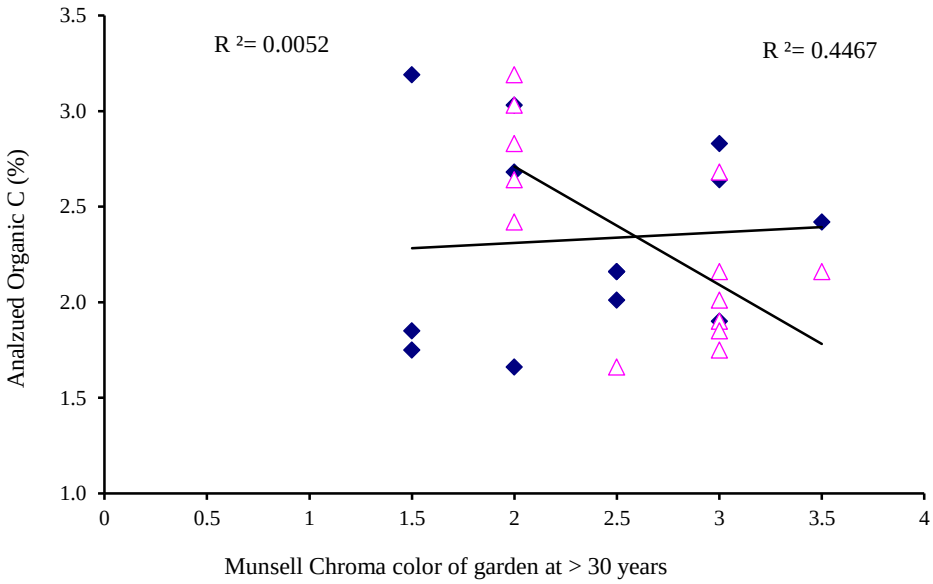

Figure 15 Correlation between analyzed organic C with Munsell chroma color of the garden at >30 years old

The correlation coefficient of Munsell Value color in moist soil samples is higher than in dried soil samples. According to Vo et al. (2004), organic C on the surface of citrus fruit gardens in Can Tho, a 33-year-old garden, have lower organic C than younger garden age. According to Ngo (2008), soils with a

garden age of fewer than ten years assess to have a high level of organic C, the age of gardens greater than ten years old has an average organic C content. It suggests that to identify the degradation levels of fruit garden soils, we can rely on topsoil color brightness (Munsell Value color) in moist soil conditions. The higher the garden age, the lower the organic C content, then the lighter, the younger garden age in the same humidity condition.

We can use soil color brightness (Munsell Value color) and purity (Chroma) at moist soil conditions to assess the soil organic C levels is low, medium, or high. Otherwise, the soil colors can use to estimate the levels of garden soil degradation. It is possible to assist the farmers or extension workers in quickly identify the levels of organic C content and then the degradation of garden soil. They can imagine when the soil needs to supplement nutrients. When necessary to apply fertilizer to avoid fertilizer waste to help farmers reduce costs, protect the environment, and reduce soil degradation.

4 Conclusions

The organic C content inversely correlates with Munsell Value and Chroma's parameters in dried and moist samples of fruit garden soils. Based on Munsell soil color parameters, in the same soil sample, the soil moisture content affects the prediction of organic C content. The Munsell soil color has the same Hue at the same humidity condition, but the Value and Chroma are different.

The correlation between soil color and organic C content does not affect by the RF index.

Based on soil color regression, the predicted organic C content has a high correlation coefficient at dry and moist soil moisture conditions.

The soil color can predict the soil organic C as the levels of fruit garden soils degradation. The darker the soil color, the higher soil organic C levels. Then the lower level of fruit garden soil degradation. According to the Munsell color parameters in moist soil conditions, the degree of degradation of fruit garden soil can predict based on the surface soil color.

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