Analysis of the relationship between leaf color spectrum and soil plant analysis development

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Abstract. Assessment nutrient content of maize leaf is particularly important in achieving higher grain yield. Characterization of leaf chlorophyll involves routine Soil Plant Analyzer Development (SPAD) reading particularly at critical stage of growth development. The objective of the study was to assess the color spectrum of maize leaf in relation to the chlorophyll content by using Random-forest modeling. genotypes of corn plants based on the characters of the ear and kernel using a logistic regression model. The research was conducted at IP2TP Bajeng in 2021 by planting maize varieties at various fertilizer level. RGB data of maize leaf was recorded by using Hamamatsu sensor (Hamamatsu, Japan), and converted to HIS, HSV and LAB color spectrum. The results indicated that Random-forest model with 20-fold validation indicated the highest accuracy as compared to the other fold-range. Among the tested model, integration of Random-forest model to LAB (Light, red/green coordinate, and the yellow/blue coordinate) color spectrum provided the best model performances with RMSE (4.77), MSE (22.76), MAE (3.80) and R² (0.853). This value indicates that the use of Hamamatsu color sensor and converted into LAB color spectrum provided the best SPAD (Soil Plant Analyzer Development) reading with high accuracy and consistency of results. Thus, digital based model can be integrated with manual selection for fast and precise nutrient monitoring.

1. Introduction

Chlorophyll is a photosynthetic pigment found in the leaves of plants, absorbs red, blue and purple light, and reflects green light which causes plants to acquire their characteristic color. Chlorophyll is found in chloroplasts and utilizes absorbed light as energy for light reactions in the process of photosynthesis. Healthy plants that are capable of maximum growth generally have a greater amount of chlorophyll than unhealthy plants. This amount of chlorophyll can be used to identify the growth rate and fertility of plants which can later be linked to predict the production of these plants.

Nitrogen is part of the leaf chlorophyll-forming material so that it can be used as an alternative guide in determining the N status of leaves [1] or the adequacy of N nutrients in maize plants [2]. Chlorophyll concentration is positively correlated with the amount of trapped light energy and utilize the excitation energy to fix atmospheric carbon dioxide [1] into 3-phosphoglycerate, glucose and its derivatives. Leaf chlorophyll is the principal photosynthetic biochemical which contain majority of leaf nitrogen damages the leaf chlorophyll and then subsequently lowers photosynthetic efficiency of maize [4]. Along the leaf area, the central leaves usually contain a relatively higher Nitrogen content prior to anthesis and then starts
declining up to 2-week after the anthesis [5]. The N concentration is highest in the central leaves when the plants cross the age of five weeks after anthesis in comparison to pre anthesis to fourth week of anthesis.

Rapid determination of N status can be assessed through a modern digital Soil Plant Analyzer Development (SPAD)-502 (SPAD-502 Konica Minolta Sensing Inc., Japan). During the SPAD measurement, the equipment will produce a digital number that highly correlated to the total amount of chlorophyll a and chlorophyll b in thylakoid membrane in the leaf mesophyll chloroplasts. The SPAD observation obtained from it is highly and positively correlated with leaf Chlorophyll and N contents [6]. Simultaneously, the device has been used to estimate leaf N concentration from the SPAD measure. Dwyer et al. [5] reported that the SPAD measure at central leaves is correlated to the leaf N content in slightly quadratic pattern in maize.

Various studies indicated that leaf chlorophyll as measured by SPAD (Soil Plant Analysis Development) was significantly positively correlated with the NO3-N content of soil at a depth of 0-30 cm [7] and positively correlated with leaf N levels which were destructively analyzed [2]. SPAD is a digital tool to measure the relative amount of leaf chlorophyll without harming plant leaf. In addition to the chlorophyll meter, the nutrient adequacy of N in maize can also be measured by leaf color chart [8]. LCC has been used for the management of N fertilization in rice [9,10] and wheat [11]. This study aims to assess the color spectrum of maize leaf in relation to the chlorophyll content by using Random forest modeling approach.

2. Methods
The research was conducted in May-August 2021 at IP2TP Bajeng, South Sulawesi. Hybrid maize variety was planted at coverage area of 0.1 ha. The first fertilization was done at 14 days after planting with Urea 150 kg/ha and Ponska 100 kg/ha respectively. The second fertilizer was at 30 days after planting with Urea fertilizer as much as 200 kg/ha. Fertilizer was done manually about 7 cm beside the plant and covered again with soil. Nutrient deficiency was assessed at 45-50 day after planting by measuring color leaf. The red, green, blue (RGB) information of the maize leaf was taken using a Hamamatsu visible color sensor S-13683-02WT (Hamamatsu, Japan). The S-13683-02WT RGB color sensor was integrated in Arduino Mega and the sketch was written in Arduino 1-8-15 for Windows. The RGB color spectrum was then pre-processed into various color spectrum such as HIS, HSV and Cie-LAB.

RGB Color Space (Red, Green, Blue) color space is a combination of primary colors, namely red, green, and blue, which are commonly used by computer monitors or televisions. The resulting color comes from a combination of three colors and each has a value of 8 bits red, 8 bits green, and 8 bits blue. The mixture of the three primary colors in a balanced proportion will produce shades of gray. If these three colors are fully saturated, it will produce white (Pratt, 2007).

HSV Color Space (Hue, Saturation, Value) model shows the color space in the form of three main components, namely hue, saturation, and value (also called brightness). Hue is an angle from 0 to 360 degrees. Usually 0 is red, 60 degrees is yellow, 120 degrees is green, 180 degrees is cyan, 240 degrees is blue and 300 degrees is magenta. Hue indicates the type of color (such as red, blue, yellow), i.e. the place of color are found in the color spectrum. The saturation of a color is a measure of how pure the color is due to the influence of white. Like red, with the influence of white, the red color varies from red to pink, which means the hue is still red but the saturation value is reduced.

The HSI model is a color system that is closest to the way the human eye works. HSI combines information, both color and grayscale from an image. Hue and saturation in this case
is the same as Intensity is a suitable term used to describe a color other than Hue and Saturation. The value I=0 (an extreme situation that may occur) represents the color black. As known to HSV, the difference is only in intensity (I) which is a gray scale (grayscale) which is very suitable in interpreting monochromatic color levels. So that with the gray level, it can be measured and interpreted easily.

Defined by the Commission Internationale de l’Eclairage (CIE), the L\text{*}a\text{*}b\text{*} color space is modeled after another color theory which states that two colors cannot be red and green at the same time or yellow and blue at the same time. As shown below, L* represents Light, a* is the red / green coordinate, and b* is the yellow / blue coordinate. The delta/ difference for L* (ΔL*), a* (Δa*) and b* (Δb*) can be positive (+) or negative (−). The total difference, Delta E (ΔE*), is always positive.

After converting RGB color spectrum into HSV, HIS, and Lab, all data were processed in Orange open source software for modeling the relationship between each color spectrum with leaf chlorophyll (SPAD reading). Four indices were used to assess the Random forest performance i.e. MAE, RMSE, MSE and R^2.

3. Result And Discussion

The research empowering open-source “Orange” tools for processing and data generation by using Random-forest data mining. Random Forest is one of the from the development of the Classification method and Regression Tree (CART) with apply bootstrap aggregating method (bagging) and random feature selection [12]. Workflow Random-forest model generation and prediction is shown in Figure. 1. We employed a cross-validation method for evaluating and validating the accuracy of the model built on the maize leaf SPAD reading datasets.

![Figure 1. Interrelation diagram of Random forest prediction](image)

Cross-Validation is among the popular method for evaluating/validating the precision of a model built on a given dataset. K-fold is one of the popular Cross-Validation methods by folding the data as much as K and repeating the experiment as much as K as well. Then, experimenting with using data already on the partitions will be repeated 5-times (K = 20), 10-times (K = 20) and 20-times (K = 20). However, the Test partition's data position is different in
each iteration. Four indices were used to assess the Random forest performance i.e. MAE, RMSE, MSE and \( R^2 \).

Results of three types of cross validation of color spectrum are shown in Table 1 to Table 3. RGB, HIS and LAB color spectra show an increase in accuracy along with an increase in the value of fold cross validation. However, the HSV color spectrum did not show an increase in accuracy as the cross-validation value increased. The accuracy (\( R^2 \)) of the HSV model decreased at 10-fold cross validation, namely 0.830. However, the value of the performance model again increased at 20-fold cross validation.

### Table 1. Results of 5-fold cross validation of color spectrum

| Color Spectrum | RMSE | MSE  | MAE  | \( R^2 \) |
|----------------|------|------|------|-----------|
| RGB            | 5.08 | 25.82| 4.29 | 0.830     |
| HSV            | 4.89 | 23.98| 3.99 | 0.846     |
| HSI            | 4.23 | 28.24| 4.24 | 0.824     |
| LAB            | 4.96 | 24.07| 3.79 | 0.846     |

### Table 2. Results of 10-fold cross validation of color spectrum

| Color Spectrum | RMSE | MSE  | MAE  | \( R^2 \) |
|----------------|------|------|------|-----------|
| RGB            | 5.06 | 25.62| 4.10 | 0.840     |
| HSV            | 5.37 | 28.64| 4.18 | 0.810     |
| HSI            | 4.91 | 25.93| 4.21 | 0.830     |
| LAB            | 4.81 | 23.17| 3.89 | 0.850     |

### Table 3. Results of 20-fold cross validation of color spectrum

| Color Spectrum | RMSE | MSE  | MAE  | \( R^2 \) |
|----------------|------|------|------|-----------|
| RGB            | 4.80 | 23.95| 3.81 | 0.851     |
| HSV            | 4.88 | 23.85| 3.92 | 0.852     |
| HSI            | 4.91 | 24.16| 3.98 | 0.844     |
| LAB            | 4.77 | 22.76| 3.80 | 0.853     |

A total of four color spectrums were also evaluated for their respective performances of RGB, HSV, HSI and LAB. Based on the results of the analysis using four indices models, it was found that the LAB color spectrum at 20-fold cross validation gave the highest accuracy values, namely RMSE (4.77), MSE (22.76), MAE (3.80) and \( R^2 \) (0.853).

Figure 1-4 showed scatter diagram of measured SPAD Vs Random forest prediction by using RGB RGB, HSV, HSI and LAB color spectrums. Coefficient of determination was used to assess the relationship between SPAD reading and Random-Forest prediction. SPAD readings, regardless the maize leaf indicated a similar trend as the leaf Nitrogen has a strong correlations between them. The correlations between SPAD reading and Random Forest prediction were strong and significant. Nevertheless, the SPAD measurements derived from the LAB color spectrum were slightly better correlated than the other color spectrums. The HSI color spectrum showed the lowest correlation with SPAD reading.
Figure 2. Scatter diagram of measured SPAD Vs Random forest prediction by using RGB

Figure 3. Scatter diagram of measured SPAD Vs Random forest prediction by using HSI
As the leaf color is commonly determined by their content in chlorophylls, visible color spectrum might have a great advantage to be used as a cheap and affordable tool for leaf nutrition evaluation. The leaf scans showed how the more N fertilizer was added, the greener the leaves were and the correlations of visible color (LAB) against N and chlorophyll were strong. However, considering that RGB canopy derived indices are known as effective measurements of green biomass, the strong correlations reported with the leaf N content might be more related to the N fertilization effects on growth rather than the leaf N content itself. Gracia-Romero et al.[13] came to the same conclusion while studying the performance of RGB and multispectral indices assessing leaf phosphorous content in a maize trial. Nevertheless, one of the main benefits of the canopy images is to enable assessing the heterogeneity of the plot as a whole.

Thus, canopy measurements have the potential to minimize the influences of the sampling location of the leaf better than the leaf-clip sensors, where the averaged values of 5–10 leaves...
and a sampling area of solely 6 mm² (for both Dualex and SPAD) is assumed to be a representative measure of the plot. Attempts to improve the representativity of the single-leaf measurements, imply measuring always the same kind of leaves (flag leaves, top leaf), while paying attention that leaves are fully intact, clean and free of signs of disease or damage [14]. However, the variability within the canopy is assumed to be captured with few measurements of individual leaves.

4. Conclusions

Our study indicated that maize leaf visible color spectrum proved to be good indicators of nitrogen content inside the leaf. An affordable visible color sensor integrated in Arduino was also proved to rapid assessment of leaf chlorophylls in maize hybrid. Nevertheless, the SPAD measurements derived from the LAB color spectrum were slightly better correlated than the other color spectrums. The HSI color spectrum showed the lowest correlation with SPAD reading. The LAB color spectrum at 20-fold cross validation gave the highest accuracy values, namely RMSE (4.77), MSE (22.76), MAE (3.80) and R² (0.853). As a low-cost tool in comparison to the more specialized leaf measurement tools, the toolkit is a promising approach for precision agriculture and crop management.

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