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Multiple macro nutrients deficiency identification using fuzzy C means

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Abstract
Every plant needs nutrients for their growth. The leaf analysis in a plant can present the need of a nutrient to be determined. The macronutrients deficiency in plants can be identified by specific type of color variations using leaves image. Early identification of macronutrients can help plants in becoming suitable for the harvest and lessen the utilization of farm inputs. The proposed system implements a novel approach to identify the lack of nutrients in maize leaf images. The maize leaf images are collected from Agricultural University, Coimbatore. The input images are preprocessed where the images in RGB color space are converted to Lab model. Then C means clustering is used to segment the nutrient deficient part from leaf image. The multi-Color space based feature Extraction is used to extract the features from deficient area of maize leaf image and type of nutrients deficiency is identified using Fuzzy rule-based system that gives the percentage of nutrient deficiency affected in maize image. Then, the performance of this work is evaluated using confusion matrix.

Introduction

The real time application of image processing in the area of agriculture has extremely increased because of its growing research field. The processing includes on various agricultural objects and products like flowers, fruits, leaves and etc. The change in plant leaf color is also used as an indication to check plant health status. The lack of chlorophyll content in leaf is due to nutrient imbalances. So, the purpose of plant leaves analysis becomes very important to diagnose deficiencies of various nutritional elements and to determine them before which lead to large scale death and famine. This is necessary because there is a close relationship that exists between plants growth and nutrients efficiency. A plant's capacity to take in adequate nutrients is based on many factors such as plant age, temperature of soil, moisture content of soil nutrient availability, season and many other factors. There are about 17 essential nutrients present. Only leaf analysis can tell the deficiency of different nutrients before human eye can detect it.

A nutrient is nothing but the important components that are necessary of plant growth. All nutrients are important for a plant in different ratio in that Nitrogen, Potassium and Phosphorous are the primary nutrients needed in large quantities and the secondary nutrients include calcium, magnesium and sulphur needed in small quantities to produce optimum yields. For plants to utilize these nutrients efficiently the resources like light, heat, and water must be supplied adequately. Agricultural practices and control of diseases and insects also play important roles in crop production. Each type of plant is unique and has an optimum nutrient range as well as a minimum requirement level. Below this level, plants show nutrient deficiency symptoms. Excessive nutrient uptake can also cause poor growth because of toxicity. Therefore, the proper amount of application and the placement of nutrients are important.

Nitrogen is the one nutrient most often limiting plant growth. A comparison study between the fast-growing species and slow-growing ones with lowest N supply proves the differences in Leaf Area Ratio (LAR, leaf area: total dry mass), Specific Leaf Area (SLA, leaf area: leaf dry mass) and Leaf Mass Ratio (LMR, leaf dry mass: total dry mass) disappeared. Under optimal conditions, the fast-growing species differ from the slow-growing ones in that they had a higher N concentration. Growth analysis is often used as a tool for proper functioning of a

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plant with the Relative Growth Rate (RGR) analysis carried out using the Leaf Area Ratio (LAR) is the amount of leaf area per unit total plant weight. The Net Assimilation Rate (NAR) is defined as the rate of increase in plant weight per unit leaf area. Thus lacking in any one of these nutrients leads to less yield of the plant. Based on the deficiency obtained from soil matter the lacking nutrient is supplied through organic and inorganic fertilizer. Delay of nutrients identification makes easy the occurrence of diseases and slows down the plant development. The type of plant nutrients varies with different soil. Most of the methods for nutrients deficiency analysis from plant leaves are related with chlorophyll content measures. Previously most of the techniques are based on identification of Nitrogen nutrient deficiency in various crops.

Review of Literature
Numerous techniques and methodologies for various plants are used in this area is reviewed and briefly described here.
Mahdi M. Ali *et al.* (2012) [7] Leaf color is usually used as an indication for nutrient status and plant health. A new inexpensive, hand-held and easy-to-use technique for the detection of chlorophyll content and foliar nitrogen content in plants based on leaf colour examined, has close relationships between chlorophyll status and leaf colour were developed for particular species. Plant species identification was done on leaf images using shape matching technique with computer aids with plant leaf recognition.
Gilles Lemaire *et al.* (2008) [9] nowadays for environmental and economic reasons target yield of farmers can be lower than the potential crop yields as acceptable by soil and climatic conditions. So it is important to provide farmers crop N status diagnostic tools in order to decide the rate and the timing of N fertilizer applications. The crop yield depends on the type of soil, economic and environmental issues the management of N fertilizer adjustment to proper yield of plants requirements and determination of the N value is important for vegetative plants.
LiliMa *et al.* (2010) [10] studied the nutrient deficiency found in soya bean plant by considering six stages of growth in soya bean plant with the application of nitrogen fertilizer that

ranges between 0%-150 percent in each stages. The noises were removed and the object of interest was separated between the backgrounds using minimum error threshold method. The color appearances of soya bean leaves were evaluated using RGB and HIS color space models. The extinct difference between the normal and the leaf with variation was found using image processing method.
Pugoy *et al.* (2010) [11] Rice is one of the domestic plant in worldwide and analysis in this crop is very important. The various nutrients deficiency, nutrients toxicity and the type of diseases from the leaves of rice plant using image processing technique comprising clustering and spatial analysis in order to obtain the color variations on leaf were analyzed. Sartin *et al.* (2014) [12] The use of precision agriculture to improve the agriculture production system in cotton plant to find macro nutrients deficiency especially Phosphorous deficiency using artificial neural network segmentation and Otsu method.
Wiwart *et al.* (2009) [13] using Euclidean distances between the colors of leaves at successive nodes the change of color in leaves (Faba bean, pea, and yellow pine plant) were analyzed. These color variations in leaves was due to lack of Nitrogen, Potassium, phosphorus and Inverted-V deficiency respectively.

Materials and Methods
This paper proposes a new approach to identify the deficiency of nutrients in leaves images. The proposed system follows the step shown in Figure 1. The input images are pre-processed in which images are converted from RGB to Lab color space, because Lab is one of many color spaces that separate color from intensity than RGB which is very useful in many applications. After preprocessing the nutrient deficient part is subjected to first level of segmentation. The first level of segmentation is done using C means segmentation. From that segmented images the color and texture based features are extracted they are given to second level of segmentation that classifies the nutrient deficiency in leaf. Finally fuzzy c-means algorithm is used to classify the macro nutrients especially Nitrogen, Potassium and Phosphorous deficiency present in leaves images.

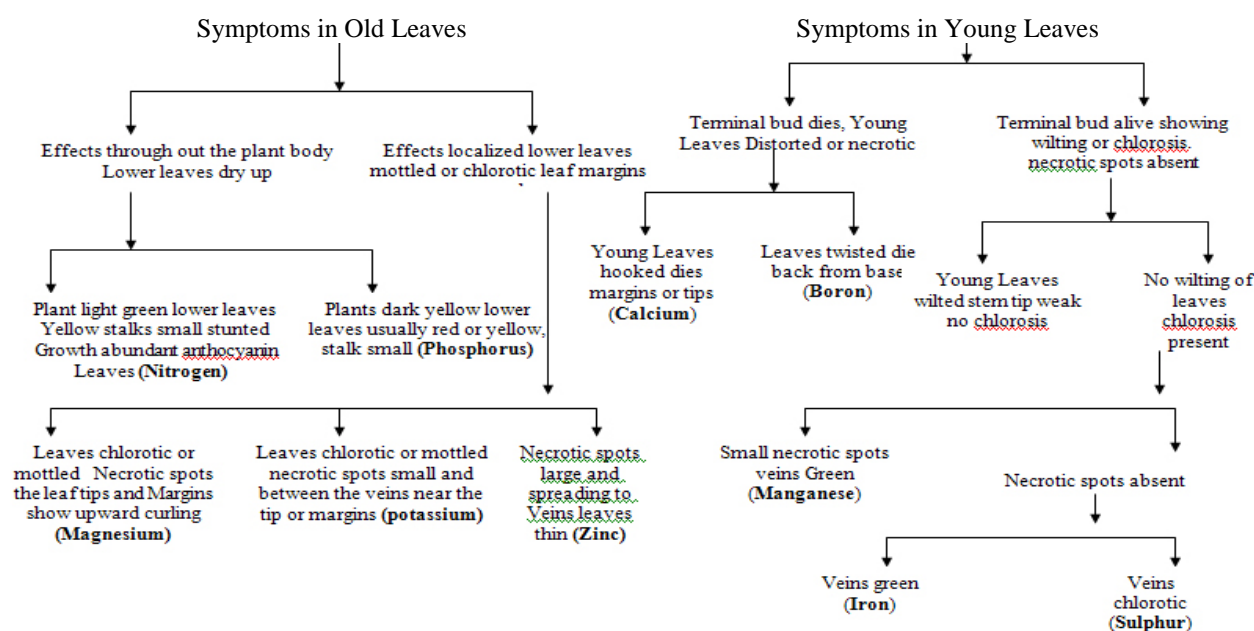**Nutrient Deficiency Symptoms Identification**

Fig 1: Nutrient Deficiency Symptoms Identification

The above figure 1 shows various nutrients affected in crops and their symptoms in leaves. The nutrients deficiencies varies for old and young leaves, while the leaf is younger the deficiencies such as Calcium, boron, manganese, iron, sulphur deficiencies are affected. For Older leaves nitrogen, Magnesium, Potassium, Phosphorous and Zinc deficiencies got affected.

Here in old maize leaves, Nitrogen, Potassium, Phosphorous and Inverted-V deficiencies are detected from leaves.
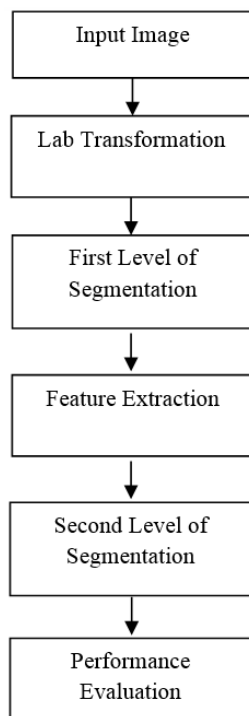

Fig 2: Overall Methodology

A. Lab *Color Transformation*

Among Color Transformation, LAB color space is a color-opponent space with dimension L for lightness and A and B for the color-opponent dimensions, based on nonlinearly compressed (e.g. CIE XYZ color space) coordinates. To describe all the colors visible to human eye, CIE L*a*b* (CIELAB) is the chosen most complete color model. The vertical L* axis represents Lightness, ranging from 0-100. The other (horizontal) axes are now represented by a* and b*. These are at right angles to each other and cross each other in the center, which is neutral (grey, black or white). They are based on the principal that a colour cannot be both red and green, or blue and yellow.

The characteristics of the Lab color space makes it suitable for extracting global color features from a digital image. Therefore we convert the analyzed RGB images into Lab format. One of the most useful characteristic of the Lab color space is that the colors are uniformly distributed in an "ab" plane, from green to red along the "a" axis and from blue to yellow along the "b" axis.

One of the most useful characteristic of the Lab color space is that the colors are uniformly distributed in an "ab" plane, from green to red along the "a" axis and from blue to yellow along the "b" axis. One color is defined by a point (a_1, b_1) in an "ab" plane of a given luminance L, and colors are changing gradually and uniformly in the plane around this point. It is important that the human eye perceives this gradual of color as a uniform one. The values of the coordinates L, a and b are real numbers when applying RGB to LAB mathematical

conversion, but for programming convenience, these values are mapped to 256 levels.
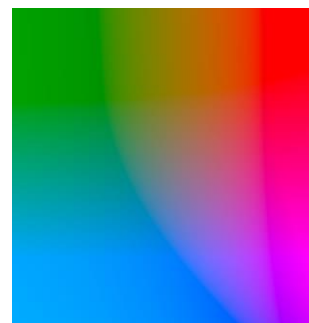

Fig 3: Color Distribution in "ab" plane for L=134

A precise color is defined in the Lab color space by a triplet (L, a, b), much like a triplet (R, G, B) defines a color in the RGB color space. However, in Lab the pair (a, b) can be viewed as a pure color, and the L coordinate gives only how darker or lighter that color is seen by the human eye.

A reduction of the number of colors is needed in order to obtain global characteristics. With the Lab color space, such a reduction can be done by considering only several "ab" planes from the total of 256. For example, if L is chosen as 134, then the color distribution for ab place looks like as shown in figure 3.

B. First Level of Segmentation

Here, first level of segmentation is done using c-means segmentation. C-means is one of the prototype-based partition technique that find user-specified K crisp clusters.

Steps of C-Means clustering algorithm:
1. Initialization – generate the starting condition by defining the number of clusters and randomly select the initial cluster centers.
2. Generate a new partition by assigning each data point to the nearest cluster center.
3. Recalculate the centers for clusters receiving new data points and for clusters losing data points.
4. Repeat the steps 2 and 3 until a distance convergence criterion is met.

These clusters are represented by their centroids. It is viewed as a heuristic to optimize the following objective function:

$$\min \sum_{k=1}^{K} \sum_{y \, \epsilon \, C_k} f(y, d_k),$$

Where d_k is the centroid of the kth cluster C_k, and f is the distance from a data point to a centroid. The clustering process of C-means is a two-phase iterative heuristic, with data assignment and centroid update staggering successively.

In this clustering technique, the distance function is closely related to the choice of centroid types where the convergence of the two phase iteration must be guaranteed [Wu *et al.*, 2015] [4]. The arithmetic mean has higher computational efficiency and better analytical properties that limit to the classic C-means with arithmetic centroids.

It updates the space partition of the input data iteratively, where the elements of the data are exchanged between clusters based on a predefined metric (typically the Euclidian distance between the cluster centers and the vector under analysis) in order to satisfy the criteria of minimizing the

variation within each cluster and maximizing the variation between the resulting K clusters. The algorithm is iterated until no elements are exchanged between clusters.

C. Feature Extraction

Different types of features like color, texture and shape are extracted for various purposes in images. Here for classification of deficiency in leaves, color based features are essential where each color contains different pixel values.

These color features are extracted for each segment which is segmented in previous first level segmentation. Those segmented area in the leaf cannot be conformed as Nitrogen, Potassium and Phosphorous deficient. The color based features such as mean; standard deviation of the segment is taken for different color space of Lab and HSV.

The HSV color space describes colors in terms of hue, saturation, and value (brightness). This color space is chosen because Hue is a term describing a pure color that is a color not modified by tinting or shading. In additive colors, hues are formed by combining two primary colors. When two primary colors are combined in equal intensities, the result is a "secondary color". And each of its attributes corresponds directly to the basic color concepts, which makes it conceptually simple.

The segmented areas of the images are first converted into this color space and from that mean, standard deviation of that area are taken.

Mean (E) - Mean value of pixel intensities in the block is defined as arithmetic average of distribution of pixels in the block. It is computed using the function mean () in mat lab.

$$\sum_{i}^{n-1} \sum x_i / N$$

Standard Deviation (σ) - Standard deviation of pixel intensities in the block is defined as calculated using the function std () in mat lab.

$$\sigma_i^{n-1} = \sum (x - \mu)$$

Mean of the segmented area returns the mean values of the elements along different dimensions of an array. And the standard deviation of segmented area returns a row vector containing the standard deviation of the elements of each column of area.

D. Second Level of Segmentation

After extraction of features from different color space, by those features the deficiency of leaves are classified as nitrogen deficiency or Potassium and Phosphorous deficiency based on fuzzy membership rules.

Fuzzy clustering

Fuzzy clustering assigns different degrees of membership to each point where the membership of a point is shared among various clusters. Fuzzy clustering is a method where no apparent clear grouping in the data set is possible as compared with conventional hard clustering. Recently, some fuzzy interpolative reasoning methods have been presented for sparse fuzzy-rule-based systems.

The features are extracted from the feature extraction process is applied to classification process to find which nutrient is deficient in leaves images. In traditional classification methods such as minimum distance method, each pixel or each segment in the image will have an attribute equal to 1 or

0 expressing whether the pixel or segment belongs to a certain class or not, respectively. In fuzzy classification, instead of a binary decision-making, the possibility of each pixel/segment belonging to a specific class is considered, which is defined using membership functions. A membership function offers membership degree values ranging from 0 to 1, where 1 means fully belonging to the class and 0 means not belonging to the class.

μ_f is the fuzzy membership function over the image segmented area. μ_f is called membership degree, which ranges from 0 to 1 over that domain. μ_f can be a Trapezoidal, Gaussian, Triangular, or other standard functions depending on the application
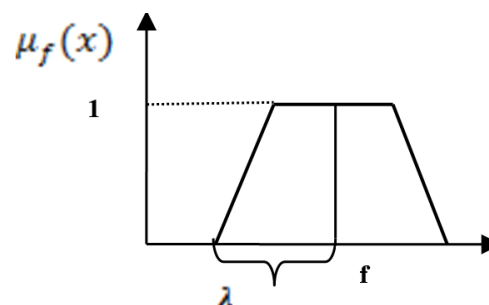

Fig 2: Trapezoidal Function

$$\mu_f(x) = \min\left\{ 2 - 2\left(\frac{|f-x|}{\lambda}\right), 1 \right\}, \quad \text{for} \quad f - \lambda \leq |f - x| \leq f + \lambda; \ \mu(x) = 0$$

Where, f is the x coordinate of the middle point of the trapezoidal function or the x coordinate of the peak of the triangular function and λ equals half of base of triangle or half of the long base of the trapezoidal.

Here, the extracted features are different color space for each segmented area in the image is used by which fuzzy rules are created. The feature of segmented area that matches with the fuzzy rules defined for each class gives the leaves deficiency. Each segment receives a degree specifying the similarity of the segment to each class. The segments which have high similarity degrees will be assigned to the associated class after defuzification of the results.

A Fuzzy Inference System (FIS) is a way of mapping an input space to an output space using fuzzy logic.

In general, a fuzzy inference system consists of four modules:

- Fuzzification module: transforms the system inputs, which are crisp numbers, into fuzzy sets. This is done by applying a fuzzification function.
- Knowledge base: stores IF-THEN rules provided by experts.
- Inference engine: simulates the human reasoning process by making fuzzy inference on the inputs and IF-THEN rules.
- Defuzzification module: transforms the fuzzy set obtained by the inference engine into a crisp value.

Fuzzy inference methods are classified in direct methods and indirect methods. Direct methods, such as Mamdani's and Sugeno's, are the most commonly used (these two methods only differ in how they obtain the outputs). Indirect methods are more complex.

Mamdani's method is the most commonly used in applications, due to its simple structure of 'min-max' operations.

The deficiency of nitrogen, potassium and Phosphorous in maize leaves contains specific color features are each

deficiency. These color features are values are taken for fuzzy membership rules where each segmented area matches with any of deficiencies of nitrogen, potassium and phosphorous. This function is used to identify the deficiency area in the maize leaf image.

- If (diffg is green) and (A mean is A mean) and (L mean is L mean) then (output1 is green seg.)
- If (orange is or) then (output1 is Nitrogen)
- If (diffb is blue) and (diffg is red) then (output1 is Potassium)
- If (diffg is green) and (A mean is A mean) and (L mean is l mean) then (output1 is In V)

- Where, diffg is the difference obtained from the mean of 'R' space and mean of 'G' from the obtained segment, diffb is the difference obtained from the mean of 'G' space and mean of 'B' from the obtained segment. A mean is the mean obtained from 'a' space from Lab color space. L mean is the mean of the 'L' space from Lab color space. Then the resulted output is taken as green seg, Nitrogen, Potassium and In V for the deficiencies.

Experimental Results
In this paper, deficiency of nitrogen, phosphorous, potassium and In V are detected. Find out these types lack of nutrients in maize crop image. The Maize crop is collected from Tamil Nadu Agricultural University, Coimbatore.
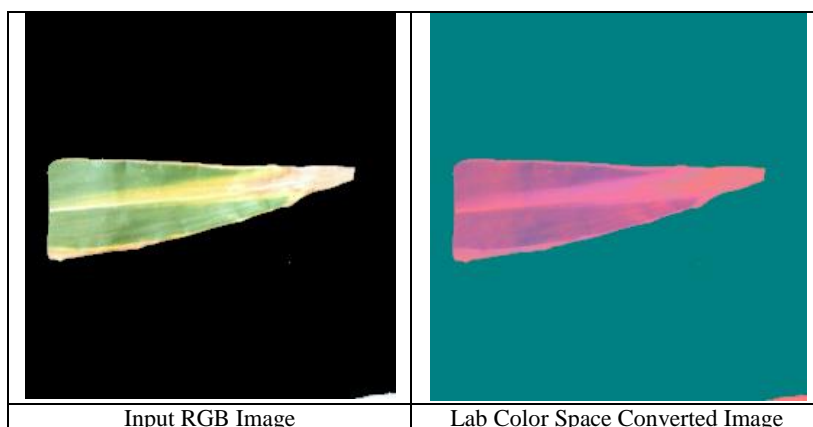

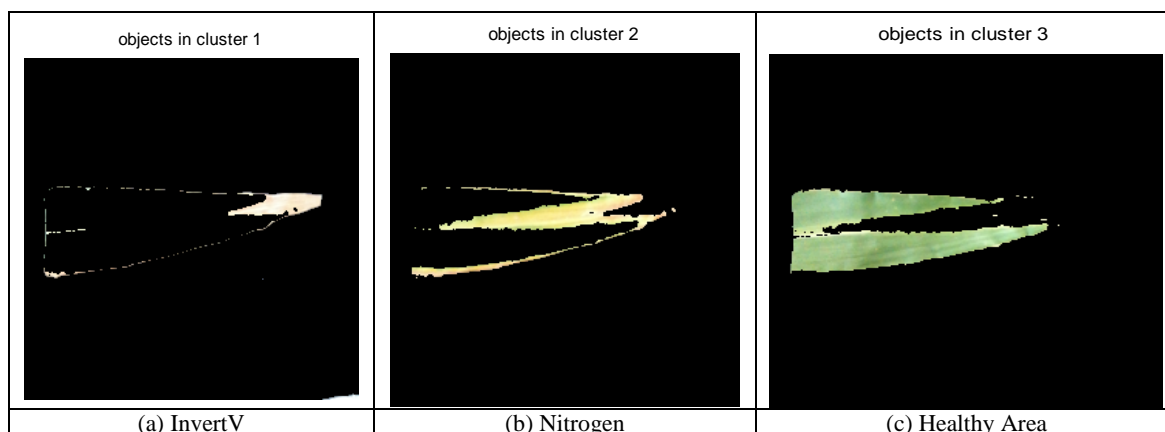| Input RGB Image | Lab Color Space Converted Image |

Fig 3: Input Maize crop

| (a) InvertV | (b) Nitrogen | (c) Healthy Area |

Fig 4: C-Means cluster segmentation

Table 1: Percentage of Nutrient Deficiencies

Image	Healthy Area	Nitrogen	Inverted V
Input Image	58.8638%	29.1323%	12.5709%

The above table 1, shows the percentage of nutrient deficiencies detected in the image. Here for the figure 3(a), the nutrient area of Healthy area, Nitrogen and Invert V percentage aregiven in table 1.Where nearly 40% of leaf area is affected by Nitrogen and Inverted V deficiency.

Table 2: Confusion Matrix

		Predicted Class				
		Healthy Green	Inverted V	Nitrogen	Phosphorous	potassium
Actual Class	Healthy Green	1	0	0	0	0
	Inverted V	0	1	0	0	0
	Nitrogen	0	0	1	0	0
	Phosphorous	0	0	0	0	0
	potassium	0	0	0	0	0

Table 2 gives confusion matrix for the actual and predicted class. Here Healthy Green, Inverted V Nitrogen, Phosphorous, potassium is taken as actual and predicted class.

From the result, the predicted class of Healthy Green, Inverted V and Nitrogen is obtained accurately for the actual class.
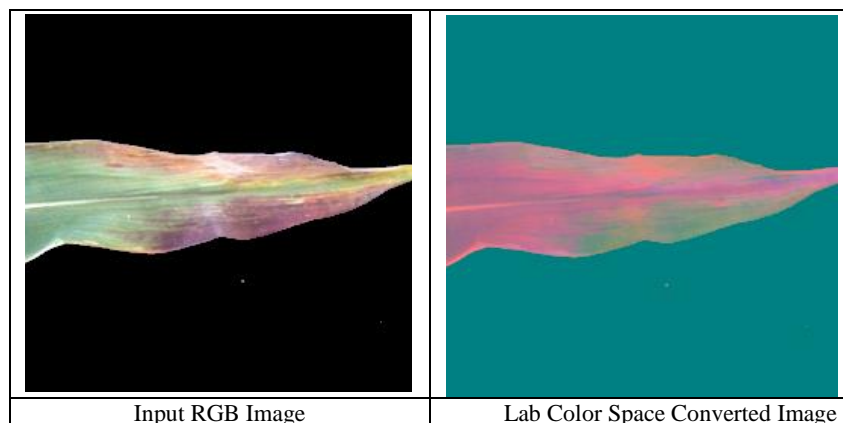

| Input RGB Image | Lab Color Space Converted Image |

Fig 5: Input Maize crop

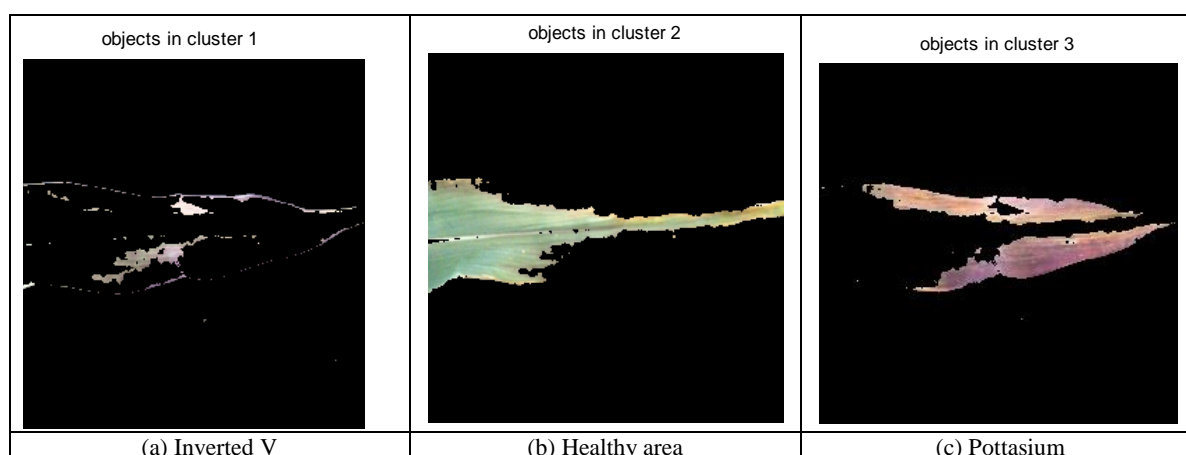| (a) Inverted V | (b) Healthy area | (c) Pottasium |

Fig 6: C-Means cluster segmentation

Figure 3&5 illustrates the input maize crop where a) shows the input RGB image b) RGB to Lab color space converted image, and then Lab color space image is segmented using c-means cluster. In this c-means, three type of cluster is obtained. After segmentation, feature extraction is applied through different color space for these three clusters. The output of the respective three cluster features are given to the input for fuzzy membership function. Through fuzzy membership function, find out the deficiency of Invert V is illustrate in figure 4(a), deficiency of nitrogen is shown in figure 4(b) & 6(a) and healthy area is segmented and classified by fuzzy membership function is given in figure 4(c) & 6(b) and deficiency of potassium is shown in figure 6(c).

Table 3: Percentage of Nutrient Deficiencies

Image	Healthy Area	Potassium	Inverted V
Input Image	53.0105%	37.2692%	10.3877%

The above table 3, shows the percentage of nutrient deficiencies detected in the image. Here for the figure 3(a), the nutrient area of Healthy area, Potassium and Invert V percentage are given in table 1. Where nearly 50% of leaf area is affected by potassium and Inverted V deficiency.

Table 4: Confusion Matrix

		Predicted Class				
		Healthy Green	Inverted V	Nitrogen	Phosphorous	potassium
Actual Class	Healthy Green	1	0	0	0	0
	Inverted V	0	1	0	0	0
	Nitrogen	0	0	0	0	0
	Phosphorous	0	0	0	0	0
	potassium	0	0	0	0	1

Table 4 gives confusion matrix for the actual and predicted class. Here Healthy Green, Inverted V, Nitrogen, Phosphorous, Potassium is taken as actual and predicted class.

From the result, the predicted class of Healthy Green, Inverted V and Potassium is obtained accurately for the actual class.

Conclusion

This paper uses a novel approach to detect and classify the nutrient deficiency in leaf images. From the experimental result it is clearly observed that the proposed method provides better result than existing method The multi-Color space based Feature Extraction Algorithm is used to extract the features from deficient area of leaf image and type of nutrients deficiency is identified using Fuzzy rule-based system and c-means classification technique. This fuzzy classification shows the percentage of nutrient deficiencies of nitrogen, potassium, invert V and healthy area in maize crop image. Then, the performance of this work is evaluated using Confusion matrix.

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