SMART PLANT DISORDER IDENTIFICATION

Group ID: 2020-025

Individual Project Proposal Report

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The supervisor/s should certify the proposal report with the following declaration. The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

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Signature of the Supervisor   Date

(Dr. Janaka Wijekoon)

Abstract

Plant require nutrients for the survival and growth. Inadequate supply of nutrients causes nutrient deficiencies in plants that result in poor yield and the use of bad agricultural practices for its rectification. Currently there prevails a crisis of a lack of nutritive soil due to over exploitation of the topsoil available for agriculture. In stark contrast is the increasing requirement in food in the current society. In order to meet this requirement without degrading the soil further with the addition of unnecessary amounts of chemical fertilizers it is necessary to identify a plant undergoing stress due to nutritive deficiencies and treating it with only the appropriate amounts of fertilizer. This will ensure proper yield is produced while the soil isn’t harmed. This research aims in identifying the stage of the nutrition disorder to recommend the necessary amount of fertilizer required. This is done with the aid of cutting-edge image processing and machine learning techniques. Early detection of nutritive disorders with the help of these techniques can provide accurate results. Investigating it’s possibility is the main purpose of this research.

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RGB – Red, Green, Blue

1. INTRODUCTION

1.1 Background

Nutrients are absorbed by plants through the soil to meet the various nutrient requirements [1]. A lack of the required concentrations of nutrients in a plant will result in plant deficiency disorders. However, the prolonged use of bad conventional agricultural practices has already degraded soil nutrients significantly [2]. Owing to this, currently, close to 70% of the topsoil used for plant growth has been degraded [4]. Thus, the soil available for plant growth shows severe deficiency in nutrition which will hamper the growth of the plant.

Meanwhile, the demand for food production is on a rise, requiring 50% more within the next 50 years [4]. It is abundantly clear of the difficulty in meeting this requirement if necessary actions aren't taken to rectify this situation.

Soil degradation has occurred prior to the green revolution [1]. However, a rapid increase was seen with its beginning [3]. The reason for this is the introduction of fertilizers, pesticides and high yield producing varieties of seeds [5] which contributed to the over-use of soil at a faster pace [3]. In order to solve the current crisis sustainable agricultural practices are required. Sustainable agricultural practices are mostly a combination of using natural and artificial means of maintaining the soil nutrition [2].

Globally the importance of soil nutrient management has become evident. Owing to the unique interlinking nature of agriculture with other industries and domains, solving this problem will directly contribute to achieving several other sustainable development goals set out by the United Nations (UN). The eradication of poverty, hunger, acting on behalf of climate change and reducing the wastage of water are all impacted by the degradation of soil.

The world development report of 2008, 'Agriculture for Development' shows, 10 years ago, in Sub-Saharan Africa, 49% of the population lived on less than 1$ a day. Meanwhile, the report also states they accounted for roughly a third of the overall growth in agriculture, within the period of 1993 – 2005 [6]. These facts show the interlinkage between poverty and agriculture. In the same manner, the region also has the highest prevalence in hunger at 23.2 percent in 2017, according to the data provided by the UN. Showing the impact of the soil degradation problem to be global.

One of the major reasons contributing to soil degradation is the addition of chemical fertilizers surpassing the required amounts [4]. The overall solution proposed by the research group is a smart nutrition disorder identification system able to identify a nutrition disorder accurately, and, recommend the necessary remedy. Since the most commonly added nutrients are Nitrogen (N), Phosphorus (P) and Potassium (K)the scope of the research has been confined to those three chemicals [7]. The contribution from the component in this document is to identify the degree of the disorder in a plant already classified as deficient in a nutrient, and subsequently predict the appropriate remedy, ensuring the addition of fertilizers only in necessary proportions. However, this requires better understanding of soil, it's nutrient management methods and requirements by plants.

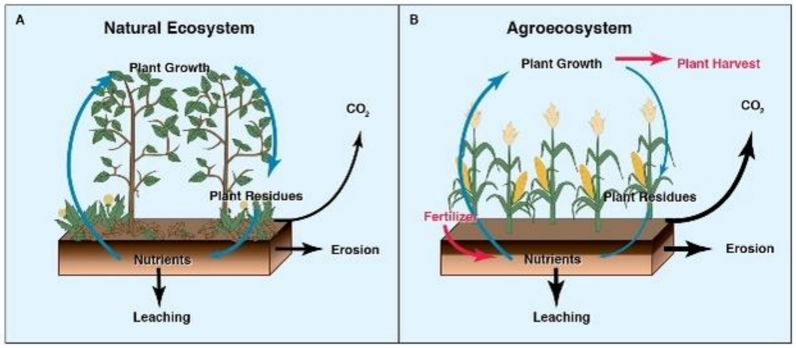

Figure 1.1 Nutrient Cycle in natural eco-systems and agro-ecosystems

Source: Adapted from [2]

Soil is similar in nature to a living organism and a has a very dynamic nature to it [4]. Naturally it cycles the many nutrients present within through many interactions by the multitude of microbes present in it [2]. Figure 1.0 shows the natural cyclical nature of nutrients. It also shows the constant removal of nutrients from the soil in agriculture through harvesting, which, results in breaking the cycle of nutrients returning to the soil [2]. Furthermore, it shows more likelihood in nitrate leaching, soil degradation and soil erosion in agricultural practices. Thus, maintaining necessary quantities of soil nutrients required for plants is a constant requirement to obtain the good yields in an environmentally friendly manner.

Meanwhile, plant nutrition requirement varies amongst species and based on the growth stage it undergoes [8]. Furthermore, the presence of a nutrition deficiency in a plant doesn't necessarily mean the soil also lacks the same nutrient. Rather, due to a variety of other reasons the absorption of nutrients from the soil may be hindered [8]. The lack of optimum temperature, water, Ph or even the sedimentation of deposits could prevent the uptake of necessary nutrients. Thus, maintaining the soil nutrients needs to be done carefully, taking all such factors into consideration.

Maintaining the soil nutrition requires the identification of its varying nature. Identifying the nutrient deficiencies in plants could be a first indication of soil nutrient deficiencies. Plant diseases and nutrition deficiencies are of similar nature and can be identified mainly through the symptoms appearing on the plant leaf [8]. As in the case of identifying plant disease severity by means of visual estimation carried out by experts is error prone and inaccurate [9]. Recently a growing number of studies have shown to identify plant diseases and disorders through image processing and machine learning techniques [8, 10, 11]. Some studies [9] show the accuracy of image analysis being higher than that of the visual rater. This research aims in identifying the degree of the nutrition deficiency based on the severity of the symptoms observed for a selected type of crop through such techniques. However, due to the nature of the soil nutrition disorders as outlined in the previous paragraph, this component will take into consideration the output of soil composition measured by another component in the same project to identify the remedy correctly.

The subsequent sections show the literature survey carried out, identified research gaps, proposed methodology and the requirements needed for the completion of this research component.

1.2 Literature Survey

The degree of a nutrition disorder requires in identifying the severity of the disorder at a certain stage. In plants the amount of nutrition required varies amongst different growth stages [8]. In order to identify the degree of a nutrition deficiency, currently soil analysis or leaf analysis is carried out [8] in the field. Both soil analysis and leaf analysis require expert training to conduct and laboratory facilities [8]. Furthermore, they are both time consuming and cannot be practically applied in the field by most independent farmers. In this case, farmers usually add fertilizers based on the instructions provided during field trials etc [12]. According to the soil researchers at the Kahagolla Agri Institute of Bandarawela, Sri Lanka this process is usually continued without assessing the nutrient content in the plants or the soil unless a special requirement arises. The general practice of applying fertilizer is done in this manner.

Apart from this the nutrient deficiency degree has been identified in several works of research carried out with the use of image processing and machine learning. However, it must be noted the amount of research carried out on plant nutrition disorder identification using image processing and machine learning is relatively low. The research works identified have usually been done to identify a nutrition deficiency from a set of deficiencies within one plant. Thus, the overall research work done to analyse the severity of a nutrition deficiency is substantially lower. However, from the literature reviewed thus far, the identification of nutrition deficiency at different growth stages for maize, rice and tomato plants will be discussed in this section.

The research paper on 'Identifying the nutrient disorder based on the temporal dynamics of the leaf morphology and colour' [14] discusses the usage of morphological and colour features to distinguish the leaf growth status. The Relative Growth Rate (RGR) has been used to assess the dynamic morphological or colour changes in the plants with respect to the deficiencies. The data sets were then collected during an interval of every 3 days each and 6 days each. Meanwhile, the images were collected in a closed setting to reduce the external effects and a desk scanner was used for this purpose. Finally, the collected data samples were then processed with the use of MATLAB 2013b.

For identification of the nutrition disorders in the same research paper discriminant analysis has been used for machine learning. Thus, this paper has used an unsupervised model in identifying the degree of the nutrition disorders for N, P and K. The experiment carried out was done by collecting specific data sets for two phases of growth in area, length and colour observed in rice leaves. The accuracy levels observed for identification of the deficiency symptoms for each phase was 73.7% and 71.4%.

While the previous paper studied the two specific growth phases 'Use of artificial vision techniques for diagnostic of Nitrogen nutritional status in Maize plants' [11] studied the accuracy in obtaining results for identification of Nitrogen deficiency stage based on the location of the plant leaf. The results showed marked differences based on location with an accuracy of 98% in the mid area of the leaf showing the highest in being identified. Meanwhile, the method used was a combination of techniques referred to as artificial vision system using Gabor wavelets techniques in feature extraction, fractal dimension used with machine learning. Even-though the research didn't provide enough insight into the processes of machine learning a wide variety of feature extraction methods were employed in the system. However, the important factor to note between the two works above are the different parameters in leaves that could be used in investigating nutrient deficiencies. A data set that could be used to train the model to identify the relevant disorders accurately in other plants, subsequent to training would be helpful. While the former used area of the leaf to measure the deficiency symptoms the latter used the changes in features in different parts of the leaf.

The research on identifying macronutrient deficiencies on the development of tomato plant using Convoluted Neural Network (CNN) in forecasting and classifying [15] has used Inception-ResNet v2 architecture with autoencoder and ensemble averaging as a means of validation. While ensemble averaging is a technique used to improve the performance of machine learning [14], the autoencoder is used to train the neural network [15]. All plants were grown in a green house environment and the accuracy of rates were 87.273%, 79.091% and 91% for the Inception-ResNet v2 model, the autoencoder and ensemble averaging respectively.

The Inception-ResNet v2 model proposed is of supervised nature while the autoencoder uses unsupervised machine learning in the classification of the disorders. While both models were based on CNN using several feature maps, the ensemble averaging technique has been used to combine the two models and bring about an increase in predictive accuracy. The images collected for the dataset was through a mobile phone and a digital camera [15]. Even though the research was carried out to show the nutrition disorders at the various stages in the tomato plant, the paper didn't elaborate as mentioned in the first two about the stages. However, these three papers allow a comparison in the models used, the accuracy achieved in identifying disorder degrees for the relevant models and the methods used in obtaining a data set. This comparison helps to identify the research gaps that can be covered in this research component as opposed to what has already been covered.

1.3 Research Gap

It is clearly indicated in the introduction that there exists a problem where soil nutrition levels are receding rapidly and the need for more sustainable practices in agriculture which don't exploit the soils. Through the literature survey however, it can be easily seen the solution to this problem is impractical and infeasible. Moreover, the current research work done is to predominantly study the techniques of image processing and machine learning in identifying the disorders rather than provide a practical solution.

Adding only the necessary amounts of nutrients into the soil to sustain the plant nutrient requirement is the solution to the overall problem at hand. This can be possible only if the nutrient disorders with the relevant stage is identified to recommend the most appropriate remedy. While the literature survey above shows none of the academic research recommending a suitable remedy, this research project aims in doing so by identifying the relevant stage of the disorder by taking the plant growth stage and the soil composition into consideration. The soil composition will be analysed and the outputs will be provided for this component by another researcher handling it separately.

1.4 Research Problem

The main research problem is in finding the most suitable method for the identification of nutritional disorders accurately whilst recommending the suitable remedy by using image processing and machine learning technologies. The research problem further extends in devising the solution to be practically usable in the field and as cost effective as possible to ensure the beneficiaries of a fully working solution.

1.4.1 Research Questions

Several research questions stem down from the afore-mentioned research problem. The research questions can be categorized as stemming from

- Setting up the control experiment and factors associated with it
- Technological means used to devise the solution

While setting up the control experiment research questions pertaining to the growth stages and the relevant nutrition requirements will be answered. Furthermore, the procedure to be followed in obtaining the data sets of the growth stages at predetermined time intervals or varied soil nutrients will also need to be decided. This is also a research question that needs to be answered based on the type of crop grown and its nutrient requirements at various stages.

Meanwhile, the technological means used to devise the solution will require investigating the best possible methods of image processing to be used, machine learning models to be used and the means of ensuring the solution’s portability and practicality in field use.

2. OBJECTIVES

2.1 Main Objectives

The main objective of this component is identifying the degree of nutrition deficiency accurately by using image processing and machine learning techniques. Next it is also equally important to use the data supplied through soil analysis to devise the most suitable remedy based on the nutrition deficiency stage identified. These are the two objectives in this research component.

2.2 Specific Objectives

The specific objectives in this component is firstly to study the growth stages and the nutritive requirements of the selected plant. Next, the selection of the most suitable image processing techniques and machine learning models for the identification of the deficiency stage of the plant concerned. Finally, devising a method to correlate the deficiency stage with the soil analysis inputs to provide the most appropriate remedy.

3. METHODOLOGY

3.1 Approach

The proposed methodology firstly requires the controlled experiment to be set up at the Kahagolla research institute in Bandarawela, Sri Lanka (discussions are currently underway to formally facilitate such experiments) to study the growth stages and the relevant nutrient requirements. This is currently been discussed to be done in a controlled manner by varying the fertilizer content in the soil for the research purpose. While the crop has not been selected yet, it will most likely be based on the availability of the research center.

Secondly, a thorough study on image processing and machine learning techniques is required to identify the best techniques to be used in identifying the deficiency symptoms. While the 'N', 'P' and 'K' varieties of the nutrition disorders to be analysed show distinct symptoms in corn as in the figures below, the degree of 'N' in corn also shows a significant difference. This indicates in the possibility of identifying the stages of nutrient deficiency. The spread of a colour, the intensity of the colour are parameters that are to be used in this regard.

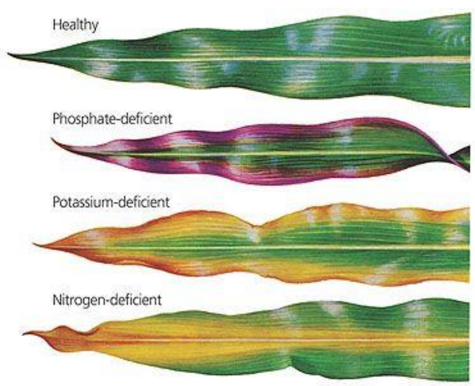

Figure 3.1 (a) Nutrient deficiencies in Corn

Source: Adapted from [16]

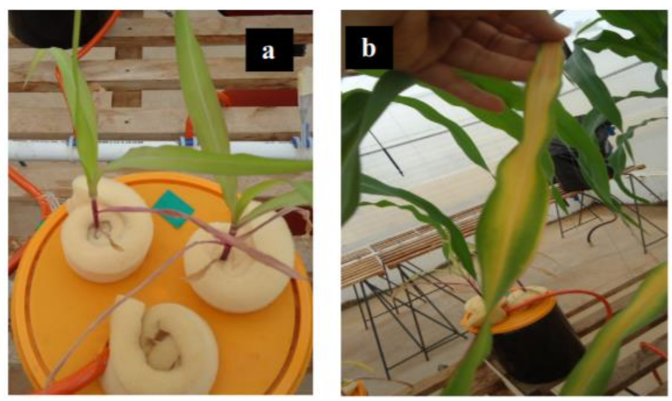

Figure 3.1 (b) complete N deficiency at 24 days Figure 3.2(b) 20% N deficiency at 35 days

Source: Adapted from [11]

Next data set collections will be carried out and finally, testing of the trained data set will ensue.

For image processing, RGB images will be required in large quantities including the various factors that affect image quality considering sunlight, time of day etc. A certain amount of image processing is carried out on the classified leaf indicating the nutrition disorder. This is done to identify the severity of the disorder. Here, object detection and image segmentation of image processing will be carried out with the use of the RCNN model where through image segmentation the symptoms will be observed on a pixel level classifying the severity of the disorders.

Next, these images will need to be trained using multiple models to identify the various degrees of nutritional disorders. A model each will be required to identify each stage for a given plant. Then these multiple models will need to be integrated or layered in the proposed CNN. Initial training of the neural network will use several test images like balloons or flowers. By including transfer learning feature extraction is to be automated. Next with the use of data sets that are obtained by public depositories like Kaggle etc the model is further trained. Finally, the data set collected will be used to observe the conclusion of the neural model. Some technological requirements would be to use machine learning (ML) frameworks such as Tensorflow python, keras libraries and google co labs.

The integration of the input obtained from component 3 will be done next. A rule based system will be used where when certain criteria are met through results from the neural networks and the component three it should be able to identify the reason which would have a specific recommendation.

Next a testing phase will be carried out to check the effectiveness of the model.

3.2 System Overview diagram

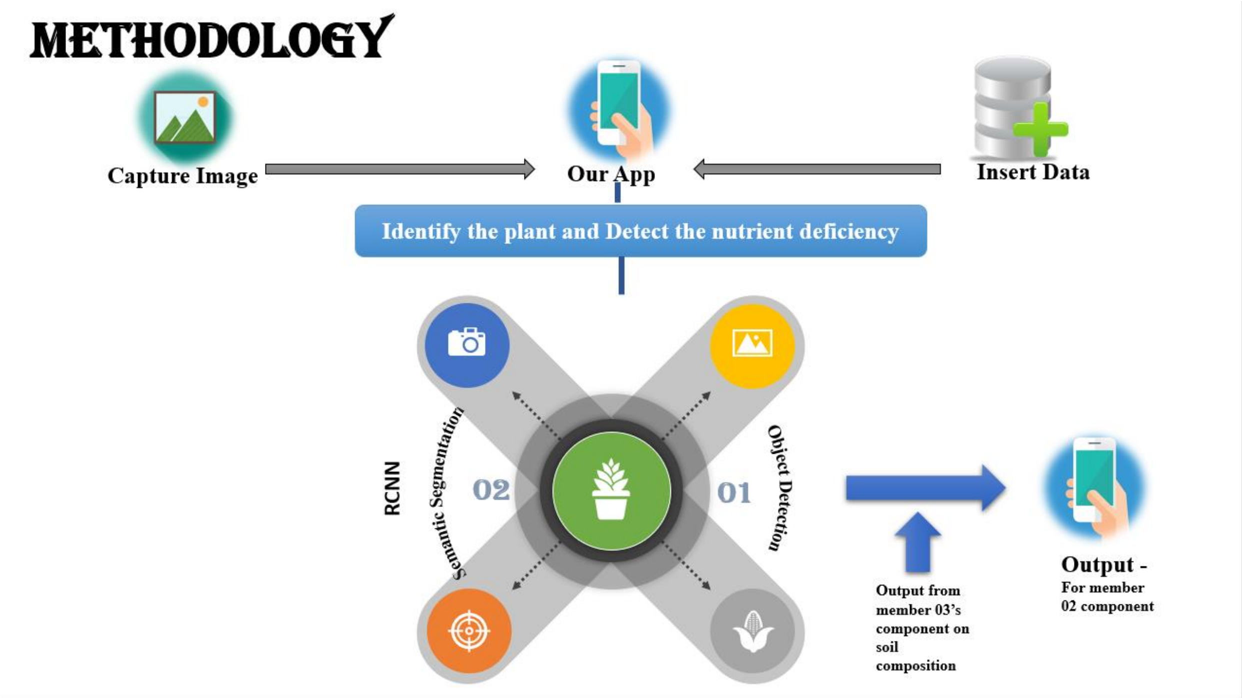

Figure3.2 System Overview diagram

The proposed system overview diagram can be seen in the above figure 3.2 which shows the classification of the image according to it's severity using the semantic segmentation and object detection techniques aided by the RCNN model, which with the input from soil composition is able to predict the recommended remedy.

4. PROJECT REQUIREMENTS

4.1 User Requirements

- The user must have the ability to capture an image of crop leaves from within the app.
- The user should be able to input the number of weeks of the image of the plant uploaded
- User should be able to identify the degree of nutrient disorder and analyse reason based on IoT input
- The user should be able to retake the test

4.2 System Requirements

- Use a mobile platform
- Use RCNN techniques
- Be user friendly for farmers; simple Graphical User Interface

5. CONCLUSION AND RECOMMENDATIONS

The research proposal suggested could contain changes in the future owing to the varying nature of the experiment conducted to identify the growth stages of the plant. This will be done with enough justification with the objective of accurately meeting the research objectives and gaps identified. Identification of the plant nutrient disorders is incomplete without investigating the degree of nutrition deficiency. While it has certain novel elements in its' investigation, the component in the proposal aims in managing the different challenges while achieving objectives to the best possible extent.

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