# *Portable Soil Detection System based on Image Processing for Agriculture*


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**Abstract - Sri Lanka is a country where agriculture and cultivation are the main form of livelihood of its natives and a main form of income to the country. Therefore, selecting the best suitable crop for a specific soil type becomes the key factor at the initial stage of the process since it not only provides an anchor for the plants, but since the different properties of soil provides several other physical and chemical factors which affects the plant growth. Traditional farmers tend to cultivate crops which commonly grew in that area whereas the next generation of farmers went one step ahead to go for laboratory testing of the soil before cultivating which was highly time consuming with the distances to those labs and time taken to give the results and the results were also highly subjective due to the soil variability and the results were of low accuracy. Therefore, developing and automated soil detection and crop suggesting system is very applicable for this requirement. The developed system will predict the best suitable crop to be grown in a soil type once a photo of the soil sample is input to the system. Soil data set obtained from different parts of the country has been used to train the developed model. The dataset consisted of several categories of soil and concepts of**

**machine learning were used to analyze the dataset. Data preprocessing techniques have been used to cleanse the dataset so that the accuracy of the results will be high. After that the key attributes of a soil were recognized by the team which have been necessary for training the AI model. Then the collected data were divided considering the previously recognized soil attributes. Next, statistical analysis was conducted on attribute values of the dataset. Using that attribute values, graphs were created in order to give a better idea of the soil dataset. The system has identified the patterns of soil using analyzed data and then trained the model for prediction. The researchers have a mobile application to use these final results efficiently.**

Keywords – soil, Machine learning, crop prediction

## Introduction

Agriculture could be considered as the key livelihood of Sri Lanka. For the inhabitants in Sri Lanka especially in the dry zone their daily income depends on the harvest they obtain from their cultivations. Hence their cultivations should have a profitable harvest. One of the major reasons for the lack of yield in their plantations is the incapability of the farmers to select the best crop which suits their land. Due to this reason, there is a rapid drop in the number of people who are engaged in the agricultural sector. By the year 2020 the percentage of farmers whose main occupation is agriculture was reported as 23.73%. [1] Therefore, it is important to introduce a technique for the cultivators to select the best and the most profitable crop to be cultivated in their land.

Soil is an important influence to plants as it not only provides an anchor for the plants, but the different properties of soil which also provides several other physical and chemical factors which affects the plant growth. Among such factors are the porosity, moisture content, cation exchange rate, electrical conductivity, pH level etc. [2] These factors are manually identified using several chemical processes. If these factors could be identified precisely, easily and accurately, by combining these factors the best suitable crop/plant for a specific soil type can be determined.

Determining the properties of soil to estimate the strength of soil is one prime objective of geotechnical engineering. For this a range of traditional lab testing methods have been employed. But the data obtained from these tests are highly subjective, which even further complicates the existing variability of soil. [2]

Image processing has been incorporated with agriculture since recently and is widely expanding. Therefore, through the developed Portable soil detection system the researchers have used image processing techniques to analyze a soil sample and suggest the best suitable crop for a given soil type.

Even to date agriculture contributes to the national economy of our country at large scale. Cultivation of tea, coconut, paddy, vegetables and fruits, oilseed crops, spices etc. are among the most cultivated. When selecting a crop to be grown in a specific land most farmers tend to select a crop which commonly grows in the surrounding. This might lead to poor growth of that crop, pronging the crop to various deficiencies, reduction of harvest and they're by spending money to overcome these problems result in extra expenditure, wastage of resources and time and overall, a loss.

To minimize these problems farmers are educated to test their soil sample and determine the best suitable crop for that soil type as the variety in soil is immeasurable. The traditional testing methods used up to date in Sri Lanka are laboratory mechanical testing which occurs when the farmer takes a soil sample to the lab. For an example in order to determine the pH value of a soil sample the amount of hydrogen ions were calculated. And in order to find the electrical conductivity of the soil sample the salinity value was found by using an electrical conductivity meter. [2] But these methods are expensive, time consuming, involves much labor and also can be error prone as it's a mechanical process and is not very accurate. Hence the need of a method to make this process simple, more convenient and accurate for the farmers is seen as a gap.

Most farmers now have access to a mobile phone with a camera. If they can take a photograph of the soil sample and if the crop is suggested by the app at that instance itself, much time and effort in taking them to a lab will be saved, accuracy of the result will be higher, the extra expenses which have to be borne in selecting an unsuitable crop will not have to be spent and overall increase the harvest and profit for the farmer.

This paper is organized as follows: Section two discuss the work related to the domain and the section three discuss about the methodology in detail. Furthermore, it examines about the model and mobile application. The final sections of the paper discuss about the conclusions and the future work.

## Related works

This section describes about some of the work related to the domain of the study.

In a research study which was conducted by Gheorghe C., Dean T.A. and Filip N. under the title of Image processing techniques used in soil moisture analysis the researchers have adopted a methodology by which they have obtained several pictures of a large field located nearby Cluj - Napoca city through a quadcopter and processed them in MATLAB software. The intensity of the original RGB image was determined by using MATLAB codes and that was compared with the black and white image pixel's intensities. In this methodology the researchers have converted the original RGB image to a gray scale image and that image was converted to a high contrast gray scale image. Then the coordinate matrices were obtained from the above images and the intensity level was set on the z axis using image processing algorithms. It was found out that the contrast enhanced black and white images can produce easier to see results at first glance and also the contours of the grass parcels are better defined in this image than in the other two images. [3]

Yuanjun Zhu, Yungiang Wang, Mingan Shao and Robert Hortan has published a research article under the title of Estimating soil water content from surface digital gray level measurements under visible spectrum. The researchers have adopted a methodology where the soil samples were initially passed through a 2 mm sieve and dried at 108 $^{0}$C. The soils were then packed into small cylinders and water saturated. The images were taken using a digital camera. The packed soil samples were allowed to dry. At selected times during drying, the samples were weighed to determine the soil water content and surface images were obtained. All the images taken were converted to gray scale images and the gray level was determined. It was observed by the researchers that in dry soil the surface gray level is increased and in the wet soil the gray level is very less. For saturated soil the gray level is at its minimum. In this research statistical characteristics of the surface gray levels were described by using different mathematical models and formulas. [4]

The scientists G.H.A. Janaka J. Kumara, Kimitoshi Hayano and Keita Ogiwara has conducted a research study under the title of Image Analysis Techniques on Evaluation of

Particle Size Distribution of Gravel. The researchers have adopted a methodology where the particles were arranged on a transparent sheet without touching or overlapping each other. Then the images were captured using a Nikon D7000 camera. Then the images were analyzed by using the ImageJ software. Then the images were converted into binary images and image processing techniques such as erode, dilate and fill holes were applied on the images respectively. Area, minor and major axes and shape characteristics such as roundness, perimeter and circularity were measured in the image analysis. The volume of the particles was determined by the results of the image analysis. [5]

Research done by scientists Pengcheng Han, Daming Dong, Xiande Zhao, Leizi Jiao, Yun Lang had developed a Smartphone-based soil color sensor for soil type classification. In this research they mainly compared and analyzed the roles of the visible spectrum and machine vision adopted in soil classification. They directly used the CMOS device of the mobile phone as the sensor and the flashgun of the phone as the light source. After they captured pictures, the pictures of each soil type were treated with the Matlab7.0 as their data set. By doing more spectral curves they obtained the visible reflectance spectral curve of each soil type. Different types of soils were different in the visible spectrum characteristics. Using these visible spectrum reflection characteristics, they managed to detect the soil colors of each soil type. [6]

Shima Ramesh Maniyath, Mr. Ramachandra Hebbar, Dr. S Rama Subramoniam, Akshatha K N, Architha L S had developed a method to detect the soil color using digital image processing. The authors bring some information about the background of the problem and they use the Munsell chart to compare the soil colors using image processing. According to this research they had generated a database about the soil colors using soil Munsell chart. And this literature shows that even the comparing soil sample image was not clear which means that it contains noises, that they had used median filter as their noise removing filter and used thresholding segmentation to do the segmentation. And they used K-Nearest Neighbor (KNN) as their soil color classification algorithm. It is a supervised machine learning technique. KNN classifier could be taken as a successful technique to detect the soil color because of its simplicity and it is relatively speed. [7]

Fitri Utaminingrum and Ihwanudien Hasan Robbani had proposed an algorithm to detect the soil color using image processing. This research paper shows that the Soctect algorithm is consisting of five main steps, namely, creating database, first filtering process, segmentation, and second filtering process and color matching process. A median filter method is used to get the clear image. And they segmented the image by using K-means segmentation method. Furthermore, the segmented image will be filtered again by using median filter method. In this method they have used Euclidean distance to match the layers of image soil with the color in the database. They use this algorithm to detect the soil colors of different layers in soil sample. [8]

## Methodology

This section explains the methodology for implementing the proposed portable soil detection system.

### A. System Architecture

The system design of the soil type detection system shows objects and communication, preprocesses and special algorithms, state machines and tools, techniques, libraries, third party tools and implementation environments which are used in the implemented project in detail.

Figure 1 shows the component diagram of the developed system.

**Component diagram**

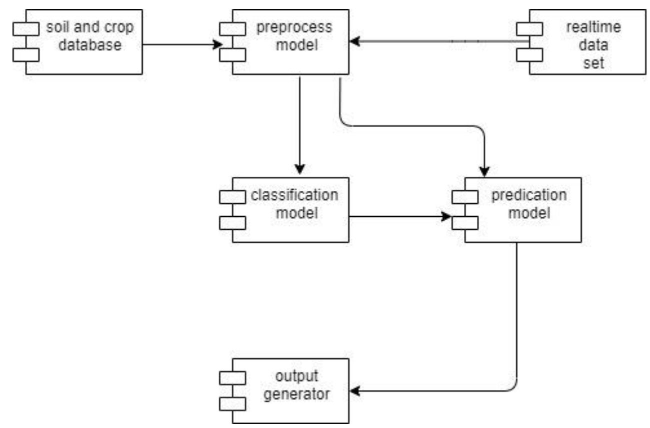



*Figure 1 Component Diagram*

**Components**

**Preprocess model**

The format of the data has to be changed in to a proper format in order to achieve best result from the AI model. Therefore, prior inserting the data in to the model the data has to be preprocessed. The soil types and their properties in the soil database and the real time data are preprocessed in this module. Preprocessing plays a vital role in AI as the data may contain missing values, null values and some incomplete data. By preprocessing the data will be cleaned and the missing values will be filled. Through preprocessing the key soil attributes could be identified which is useful for model training.

**Classification model**

The classification model will conduct statistical analysis on the dataset and create graphs on the dataset to give a clearer idea. After analyzing the dataset, the patterns and trends of the soil attributes can be identified.

**Predication model**

In this component the prediction model will predict the soil type using the preprocessed and the classification dataset. For this purpose, the AI model will be trained using the preprocessed and the classification data.

**Output Generator**

With the use of the predicted data of from the predication model, the output generator will generate its output. This output will either be the soil type or suggested crop depending on the result requested by the user and it will be displayed on the screen.

**Realtime Dataset**

The real-time dataset of this application involves with the different soil types and crop types updated to the database by the admin. This will be done occasionally by the admin with the advent of an unexisting soil type or crop type in the database.

**B. Model**

Convolutional Neural Network model has been used for soil color classification since it is one of best applied algorithm for image and video classification. The model consists with 3 convolutional layers, 2 max pooling layers, 2 dropout layers and 2 dense layers. Created a dataset of different types of soil sample images for the training purpose and split that data into train data and testing data. For that 80% of data were used as train data and other 20% used as test data. A similar model was used to determine the moisture level of soil.

```python
#### CREATING THE MODEL FOR COLOR CLASSIFICATION
def myModel():
    noOfFilters = 60
    sizeOfFilter1 = (5, 5)
    sizeOfFilter2 = (3, 3)
    sizeOfPool = (2, 2)
    noOfNodes = 500

    model = Sequential()
    model.add((Conv2D(noOfFilters, sizeOfFilter1, input_shape=(imageDimensions[0],
                                                          imageDimensions[1], 1), activation='relu')))
    model.add((Conv2D(noOfFilters, sizeOfFilter1, activation='relu')))
    model.add(MaxPooling2D(pool_size=sizeOfPool))
    model.add((Conv2D(noOfFilters // 2, sizeOfFilter2, activation='relu')))
    model.add((Conv2D(noOfFilters // 2, sizeOfFilter2, activation='relu')))
    model.add(MaxPooling2D(pool_size=sizeOfPool))
    model.add(Dropout(0.5))
    model.add(Flatten())
    model.add(Dense(noOfNodes, activation='relu'))
    model.add(Dropout(0.5))
    model.add(Dense(noOfClasses, activation='softmax'))

    model.compile(Adam(lr=0.001), loss='categorical_crossentropy', metrics=['accuracy'])
    return model
```

```python
#### EVALUATE USING TEST IMAGES
score = model.evaluate(X_test, y_test, verbose=0)
print('Test Score = ', score[0])
print('Test Accuracy =', score[1])
```

```
Test Score =  0.3170274496078491
Test Accuracy = 0.8945147395133972
```

*Figure 2 - color classification model test accuracy-*

```
#### EVALUATE USING TEST IMAGES
score = model.evaluate(X_test, y_test, verbose=0
print('Test Score = ', score[0])
print('Test Accuracy =', score[1])

Test Score =  0.9171807765960693
Test Accuracy = 0.715976357460022
```

*Figure 3 - moisture classification model test accuracy-*

### C. Image processing techniques

Image processing techniques were used to determine the grain size of the soil sample. The selected soil sample image has been converted to a black and white image. And the image was thresholded using scikit-image threshold otsu function. The areas of thresholded image which were highlighted were labeled. The equivalent diameter of the labeled areas was calculated using measure library from scikit-image. The values obtained for the equivalent diameter of the labeled areas were categorized in to two categories. From the number of areas falling into each of these categories the category into which the majority of the areas are falling is considered as the grain size of the soil.

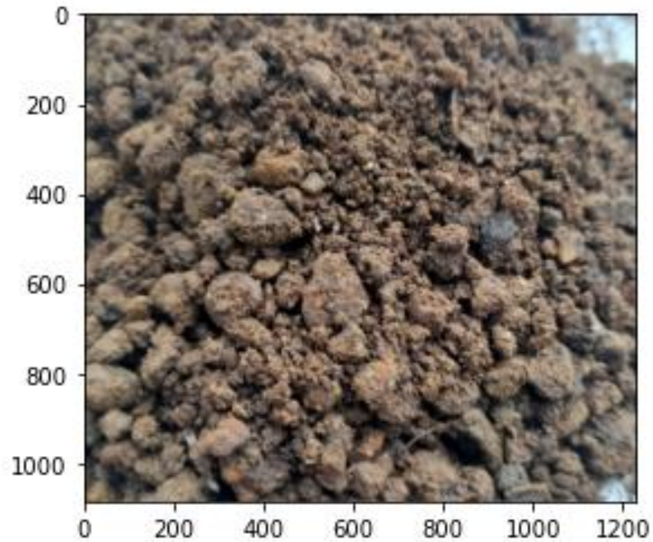



*Figure 4 – original*

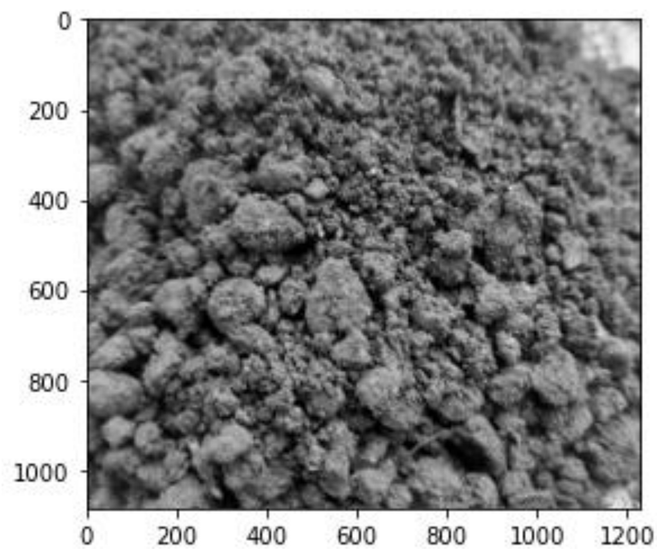



*Figure 5- black & white*

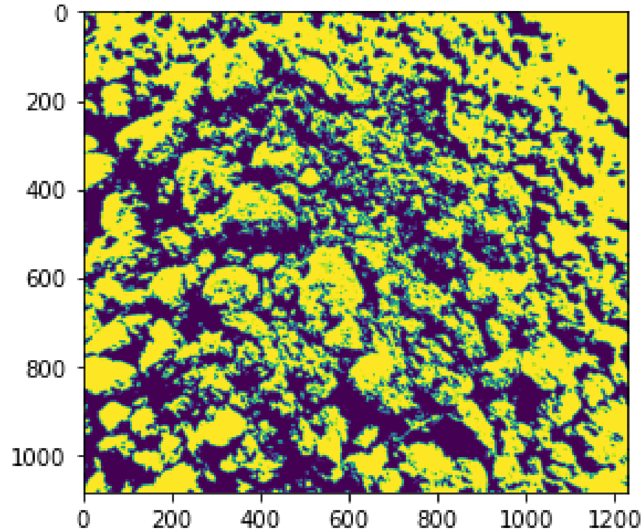



*Figure 6- Thresholded*

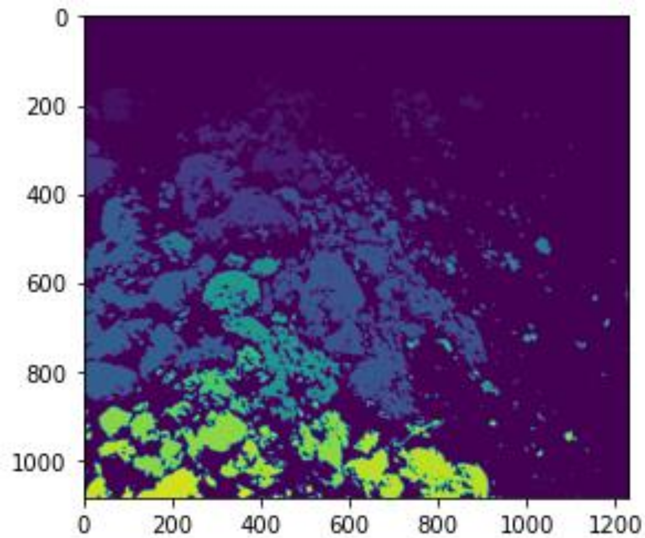



*Figure 7- labeled*

**D. Mobile Application**

The mobile application was developed using android JDK. The application gets the location of the end user through GPS technology or by manually entering the location. The user can upload the image of the soil sample using the camera of the mobile phone or by uploading a photo from the gallery. The predicted results could be viewed by the user by selecting either the predict soil type option or the predict crop type option. When displaying the soil type moisture level and the grain size of soil is also displayed. When displaying the suggested crop types the amount of water to be added is also displayed according to the grain size. Through the developed mobile application, the administrator can login to the system and update and add new soil types or crop types.

## Results and discussion

This section discusses the results of the developed system. The main two objectives of this developed system are how to predict the soil type according to the soil color, grain size and moisture level and to display the suitable crop types according to the predicted soil type. The accuracy of the predicted results was successfully verified during the user acceptance testing done with the involvement of an external user. A higher accuracy was established for the samples falling under the categories of the samples in the data set.

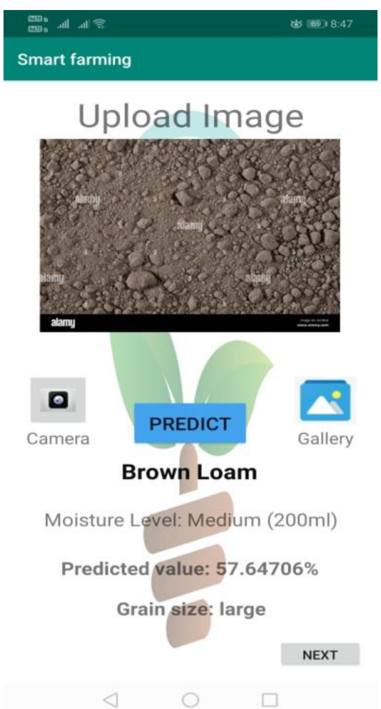
```
To enable them in other operations, rebuild TensorFlow with the
appropriate compiler flags.
class: Red Laterite  ,  Prediction : 90.19243717193604
[Finished in 22.1s]
```

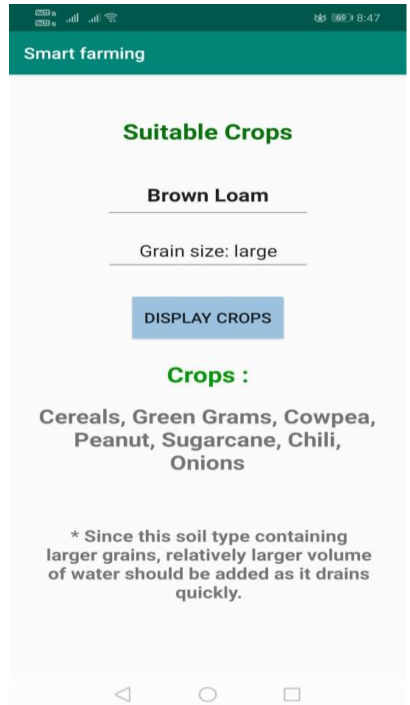
*Figure 8– color classification prediction results*

```
To enable them in other operations, rebuild TensorFlow with the
appropriate compiler flags.
Moisture Level: Medium (200)  ,  Prediction : 91.42985939979553
[Finished in 10.6s]
```

*Figure 9– moisture classification prediction results*

The results obtained through the above objectives are displayed in the developed mobile application.




## Conclusion

In order to determining the properties of a range of traditional lab testing methods have been employed which is highly time consuming and costly.

Image processing has been incorporated with agriculture since recently and is widely expanding. Therefore, through the developed Portable soil detection system the researchers have used image processing techniques to analyze a soil sample and suggest the best suitable crop for a given soil type in less than 5 seconds.

By analyzing the results obtained it could be concluded that the color of the soil, grain size and the moisture level heavily affect the type of the soil sample and the type in turn will have a stronger impact on the crops to be grown in the respective land. By recognizing the above-mentioned factors, the farmers whose livelihood depending on agriculture can increase their harvest and improve their profits.

## Future developments

As future developments for this system the researchers are expecting to increase the parameters from which the soil type is detected which will result in increasing the accuracy of the output. Furthermore, they hope to consider the weather details as well when suggesting the suitable crop types. Another development that the researchers are expecting to do is to enhance this system to be compatible with other operating systems such as iOS. Also, they expect to increase the size of the data set by collecting more sample images from different parts of the country to enhance the scope of the application.

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Other than them, the researchers need to thank all our batch-mates who helped us to research about image processing techniques and soil sample collection process, other technologies and methodologies that the researchers have to use when implementing the system.

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