❒ 989

Soil Characterization and Classification: A Hybrid Approach of Computer Vision and Sensor Network

Abrham Debasu Mengistu, Dagnachew Melesew Alemayehu
Departement of Computing, Bahir Dar University, Ethiopia

Article Info	ABSTRACT
	This paper presents soil characterization and classification using computer vision & sensor network approach. Gravity Analog Soil Moisture Sensor with arduino-uno and image processing is considered for classification and characterization of soils. For the data sets, Amhara regions and Addis Ababa city of Ethiopia are considered for this study. In this research paper the total of 6 group of soil and each having 90 images are used. That is, form these 540 images were captured. Once the dataset is collected, pre-processing and noise filtering steps are performed to achieve the goal of the study through MATLAB, 2013. Classification and characterization is performed through BPNN (Back-propagation neural network), the neural network consists of 7 inputs feature vectors and 6 neurons in its output layer to classify soils. 89.7% accuracy is achieved when back-propagation neural network (BPNN) is used.

Corresponding Author:

Abrham Debasu Mengistu,
Departement of Computing,
Bahir Dar University,
Ethiopia.
Email: abrhamd@bdu.edu.et

1. INTRODUCTION

Agricultural production has been highly dependent on natural resources for centuries. The maintenance of good soil quality is vital for the environmental and economic sustainability of annual cropping. A decline in soil quality has a marked impact on plant growth and yield, grain quality, production costs and the increased risk of soil erosion [1]. The field of Computer vision and digital image processing (DIP) is continuously evolving and is finding many applications in several fields. Soil classification and characterization is an important aspect of geotechnical engineering which has been given a great amount of attention since the past few years. Image data in geosciences are common and require processing and measurement schemes that range from small microscopic scales to large remote sensing scales. They focused mainly to the first category and specifically in images of thin soil sections. The goal of soil micro morphology, as a branch of soil science, is the description, interpretation, and measurement of components, features, and fabrics in soils at a microscopic level. In this paper the author focused on texture analysis and segmentation techniques of the given soil type [2].

The technology of computer vision and sensor network advancement is gradually finding applications in different problem domains like in the areas of health and GIS industries. Efforts are being geared towards the replacement of human operator with automated systems, as human operations are usually inconsistent and non efficient. Automated systems in most cases are faster and more precise. However, there are some basic infrastructures that must necessarily be in place in automation. In this research we will apply both computer vision and sensor network to characterize soils and classifies soil type so as proper measurement has to be taken to maximize the agricultural production [3].

David C. Marvin, et al., in their work stated that recent research on sensor networks has focused on networking techniques and networked information processing suitable for highly dynamic environments and resource-constrained sensor nodes. Sensor nodes have decreased in size and are much cheaper, resulting in the emergence of many new civilian applications from environment monitoring to vehicular and body sensor networks [4]

Mingyuan Zhang, et al., in their work entitled as "Applying Sensor-Based Technology to Improve Construction Safety Management" stated that the development of sensor-based technologies has greatly improved information collection, data transmission and processing, which can serve as the foundation of the modernization of construction safety management. After nearly two decades of development, sensor-based technologies have facilitated the transformation from experimental exploration to practical applications. The applications of sensor-based technology in construction safety management have become the focus of current research [5]. In this research work, computer vision and sensor network are considered to characterize soils and classifies soil type so as proper measurement has to be taken to maximize the agricultural production.

Depending on the knowledge and experience of the expert it is difficult to characterize and classify soil. So Different methods have been used to classify soil to their corresponding class and characterize the moisture level. Pravat Kumar Shit, et al., conducted a study to estimate soil crack for moisture analysis, from the experiment 72.7% is archived [6]. K. Srunitha, et al., conducted a study to classify soil. The authors have used texture and color as a feature vector and support vector machine to classify soil types. Besides, they stated that, Soil characteristics identification and classification is very important in agriculture to avoid agricultural product quantity loss [7]. Therefore this paper focused on classification and characterization of soil using a hybrid approaches of computer vision and sensor network approaches.

2.   LITERATURE REVIEW

Different researchers have been conducted their researches in application of computer vision techniques related to agriculture. These are discussed as follow.

Ashok and Snehamoy, in their work entitled as "Computer vision-based limestone rock-type classification using probabilistic neural network" presented Rock-type identification for lime stone mine. In this paper, a computer vision based rock type classification system is proposed without human intervention using probabilistic neural network (PNN). In this research paper the authors are used the color histogram features as an input. In the paper the color image histogram based features includes weighted mean, skewness and kurtosis features are extracted for all three color space red, green, and blue. In this paper, a total nine features are used as input for the PNN classification model. Then they found out the error rate for identification is below 6% [8]. Anastasia & Petros, presented soil image segmentation and texture analysis using computer vision approach. The author proposed joint image segmentation methods for soil images and feature measurements [9].

Sun–ok chung, et al., studied Soil Texture Classification Algorithm Using RGB Characteristics of Soil Images. The authors found that soil texture has traditionally been determined in the laboratory using pipette and hydrometer methods that require a considerable amount of time, labor, and expense. In this paper, soil texture classification using RGB histograms was investigated to solve the above mentioned problem. In this paper, when soils were classified using USDA soil texture classification, the laboratory method and image processing method produced the same results for 48% of the samples [10]

Małgorzata and Piotr, in this research paper the authors have shown that detection of soil pore structure using an image segmentation approach. In this study, a density based clustering method on tomography sections of soil is considered [11].

Bhawna, et al., studied determination of Soil pH by using Digital Image Processing Technique. In Agriculture sector the parameters like quantity and quality of product are the important measures from the farmers' point of view. Soil is recognized as one of the most valuable natural resource whose soil pH property used to describe the degree of acidity or basicity which affects nutrient availability and ultimately plant growth [12].

Ali M, et al., in this research paper, Image texture analysis and neural networks for characterization of uniform soils are studied. Supervised back-propagation neural network is used for this study. The authors have tested neural network with considerable accuracy [13].

Umesh K, et al., in this paper the authors presented "Testing of Agriculture Soil by Digital Image Processing". This paper helps to determine the amount of fertilizer and pH of soil that must be applied. 80 soil samples their pH value tested in government soil testing Lab are considered in this study. In their work, when the software is tested the software gives 60-70% accuracy [14].

A. V. Bilgili, et al., studied on wavelet Analysis of soil reflectance for the characterization of soil properties. The authors have used Wavelet analysis, hyperspectral near-infrared (NIR) and mid-infrared (MIR) reflectance spectra of soil material to characterize the given soil [15].

M. Barber, et al., in their work entitled as "A Novel method for 2-D Agricultural soil roughness characterization based on a laser scanning technique" presented laser profiler the determination of agricultural soil roughness. When tested with the RMS height S and correlation length L in 1 m x 0,3 m parcels with a 20-30% error in heights and 1- 10% error in horizontal lengths [16].

Richard J. Flavel, et al., studied about the applications of image processing and analysis in plant root systems in soil using imageJ plat form. The authors have used x-ray tomography 3D images[17].

Małgorzata Charytanowicz and Piotr Kulczycki, in their work entitled as, "An Image Analysis Algorithm for Soil Structure Identification" the authors presented an image segmentation approach for detecting the soil pore structures that have been studied by way of soil tomography sections. In this paper, density-based clustering and nonparametric kernel estimation methods had been considered for this study [18].

Masayuki Tamura and Weiping Li, studied detection of soil liquefaction areas in case of Kantou region of Japan. In this paper, multi-temporal PALSAR coherence data is considered[19].

K. Srunitha and S. Padmavathi, studied the performance of SVM for soil classification using image processing techniques. In this research paper, the authors stated that soil characteristics identification and classification is very much important and helps to avoid agricultural product quantity loss. The authors have used image acquisition, image preprocessing, feature extraction and classification. Texture and color feature are considered for feature vector; texture feature are extracted using low pass filter and Gabor filter. Besides, color features are extracted using HSV[20].

According to Mrutyunjaya R. Dharwad, et al., Moisture content in soil is one of the main component which plays important role in yield of crops. In this paper the authors focused on software development for soil moisture assessment. The main objective of the authors was to turn the manual process to a software application using image processing technique. Image of the soil with different moisture content are collected and preprocessed to remove the noise of source image. The authors have used color and texture feature vector as an input in soil moisture assessment software [21].

Sanjay Kumawat, et al., in their work stated that the farmers are suffering from the lack of rains and scarcity of wate. In this paper, the main objective was to provide an automatic irrigation system thereby saving time, money & power of the farmer. In this work moisture sensors are considered anad installed on the field. Whenever there is a change in water content of soil these sensors sense the change gives an interrupt signal to the micro-controller For capturing the images, the phone camera is used and after processing the captured image the PH value of the soil is determined and accordingly crops or plants are suggested that can be grown in that field [22].

Nimisha Singh and Rana GillRetinal, studied on identification of Retinal disease In this paper, the authors have proposed the segmentation and use machine learning approaches to detect the true retinal part in addition they stated that preprocessing is done on the original image using Gamma Normalization which helps to enhance the image that can gives detail information about the image then the segmentation is performed on the Gamma Normalized image by Superpixel method. Finally feature generation must be done and machine learning approach helps to extract true retinal area and 96% accuracy is achieved [23].

Heru Purnomo Ipung, Handayani Tjandrasa, in this paper the authors focused on an urban road materials vision system using narrow band near infrared imaging. This paper proposed imaging indexes evaluation from experiment results to identify those urban road materials. The proposed multi-spectral imaging indexes were able to show the potential to classify the selected urban road materials, another approach may need to clearly distinguish between concrete and aggregates [24].

3.   RESEARCH METHODS

To collect the data set Canon EOS Digital and IP camera is used to capture the image directly, and both video and offline images are included in order to have a good data set form all perspective. The data contains noises because they were captured in uncontrolled environments. Having such types of data set, it was very helpful to classify and characterize the given soil. This study carried out on Amhara and Oromia regions of Ethiopia, located at northern and southern part of Ethiopia.

The total of 6 group of soil and each having 90 images are considered for this study. That is, form these 540 images were record. In addition, each images size is 256 by 256 is taken. Once the data set collected, pre-processing and noise filtering steps are performed to achieve the goal of the study through MATLAB, 2014. The other part is measuring the moisture level of soil using sensor. In this study, Gravity

Analog Soil Moisture Sensor is considered because this sensor is easy to interface. Besides, ARDUINO UNO is used to interface moisture sensor and sketch nov ARDUINO IDE is used to program moisture sensor.

4. SOIL CHARACTERIZATION AND CLASSIFICATION

Soil characterization and classification system consists of three basic parts: computer vision, sensor and classification. The images of soil samples were captured in different areas of Ethiopia. Back-Propagation Artificial nueral network was used for classification and characterization of images in to different classes as shown in Figure 1.
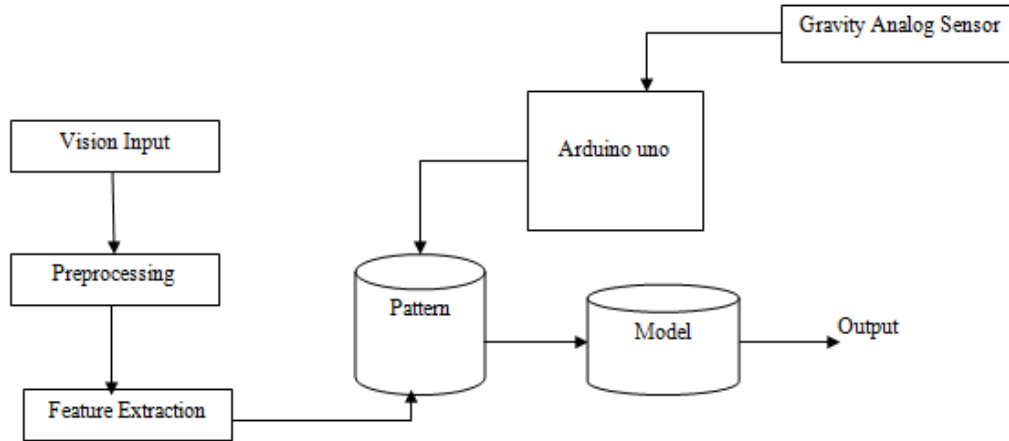

Figure 1. Soil characterization & classification model

4.1. Computer Vision

The images of soil sample were collected in Gonder, Metema, Dejen and Addis Ababa areas of Ethiopia. To have the same illumination and temperature images are recorded in both in the morning and afternoon time. In this study, both offline captured and online captured images are considered this helps us to enhance the computer vision system. After capturing the image the next step is enhancing the contrast of the image and resizing the image to 256 by 256. The other step in this part is extracting representing features. In this paper, hsvHist, autoCorrelogram color_moments, meanAmplitude, msEnergy, wavelet_moments are extracted from the image and moistures are extracted from the sensors. Figure 2 shows the computer vision prototype.
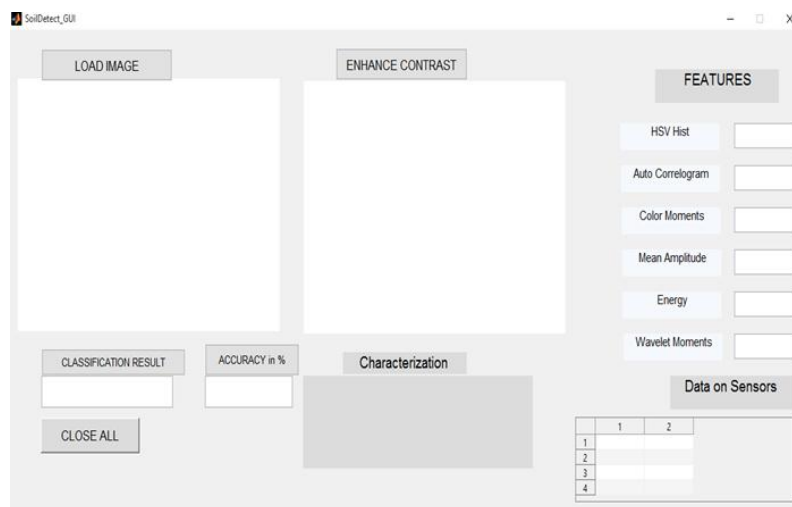

Figure 2. Computer vision prototype

4.2. Sensor

Brett Robinson [25], pointed out that devices for measuring soil moisture. Besides, the difficulty of interpreting soil moisture data, the main limitations to deploying soil moisture sensors in dryland grain production are likely to be: (a) complexity, (b) cost, (c) uncertainty, (d) safety regulations, (e) installation problems and (f) operating problems. The authors also pointed that Watermark sensors and tensiometers do not work in dry soils, and can be excluded from High frequency, buried capacitance sensors (Sentek, Decagon and Vegetronix) are the best but in this study Gravity Analog Soil Moisture Sensor For Arduino is considered. Figure 3 shows the moisture sensor.
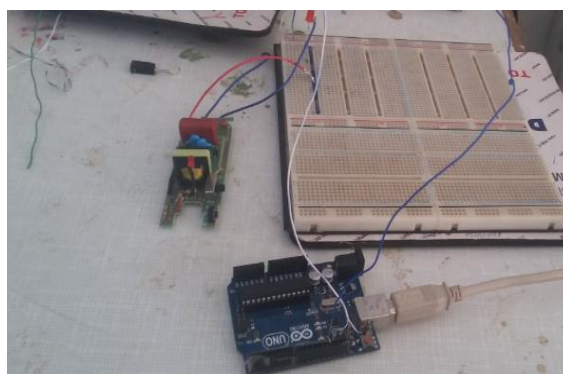
Figure 3. Moisture Sensor

4.3. Back-Propagation Artificial Neural Network

As shown in Figure 3 the network needs 7 inputs of the combined feature vectors of physical and moisture of a given soil and 6 neurons in its output layer to classify soils. The hidden layer has 26 neurons. This number was picked by trial and error methods, if the network has trouble of learning capabilities, and then neurons can be added to this layer. There is a significant change when we increase the number of hidden layers neurons until 21, 24 and 26 but there is no change when the number of hidden layer neurons increases above 26. Each value from the input layer is duplicated and sent to all of the hidden nodes.

5.   EXPERIMENT AND RESULTS

In this research, two different methods are used. Namely Computer vision and Sensor are used to classify and characterize the given soil. To begin with, the physical and moisture level features are used for both training and testing for BPNN (Back-Propagation Artificial Neural Network) as shown in Figure 4. There are two basic phases of pattern classification. They are training and testing phases. In the training phase, data is repeatedly presented to the classifier, in order to obtain a desired response. In testing phase, the trained system is applied to data that it has never seen to check the performance of the classification. Hence, we need to design the classifier by partitioning the total data set into training and testing data set. From the total dataset of 540 images 70% was used to build training and the remaining 30% of the total was used for testing data. The experiment was conducted for 10, 15, 20, 25 and 30 hidden neurons this help us to examine the performance of the network. In BPNN, needs 7 inputs neurons of the combined feature vectors of physical and moisture level features and 6 neurons in its output layer to classify soils to their corresponding class. The hidden layer has 26 neurons. There is a significant change when we increase the number of hidden layers neurons until 10, 15, 20, 25, and 30 but there is no change when the number of hidden layer neurons increases above 26. As indicated in Figure 5, the result showed that there was 89.7% success for 26 hidden neurons using the combined feature vector of physical and moisture level features. The aim of the research paper is to classify and characterize soils using the hybrid approaches of computer vision and sensor network. In this paper, computer vision and sensor network together with BPNN are used and the accuracy of the system are presented, and the results of BPNN were discussed and promising results were obtained. The computer vision and sensor network for the characterization and classification of soil can be further investigated. The work can also be seen in depth and researched by the different machine learning techniques, characteristics of its physical and chemical in connection to image techogy.
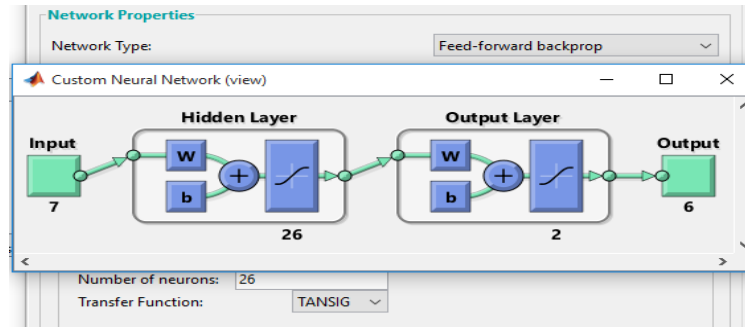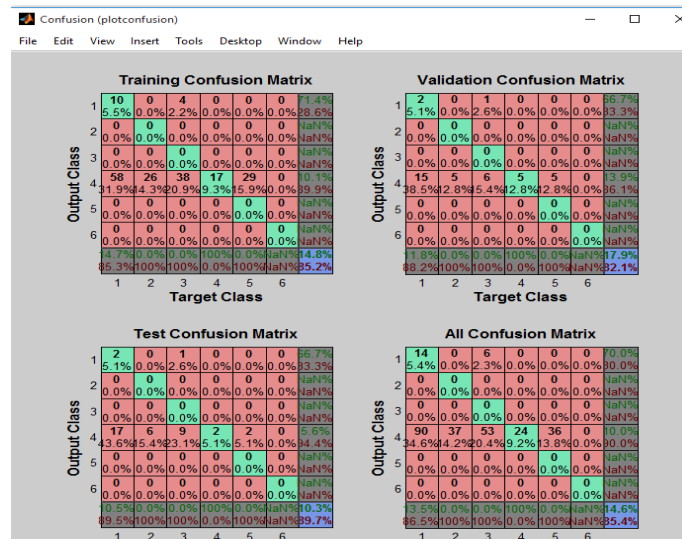
Figure 4. BPNN

Figure 5. Result of classifiers

Table 1 shows the comparison of work.

Table 1. Comparison of work

Author Name	Methodology	Findings
Pravat Kumar Shit, et al.	ERDAS Imagine v8.5 and image processing techniques	The paper focused on crack perdition and the authors haven't used any classification techniques.
Małgorzata Charytanowicz and Piotr Kulczycki	Complete Gradient Clustering Algorithm for Soil Structure Identification.	This paper presents an image segmentation approach for detecting the soil pore structures
K. Srunitha and S. Padmavathi	Image processing and SVM classifier for classification of soils	The paper focused on the performance of SVM in classification of soils as clay, loam, sandy, peat. From the experiment 74.4 % accuracy is achieved.
Ashok Kumar Patel, Snehamoy Chatterjee	Image processing and Probabilistic neural network (PNN)	The author focused on rock type identification using PNN and form the experiment The result shows that for the GGL rock type, there are misclassification error of 16%.
Mrutyunjaya R. Dharwad, et al.,	Digital images to estimate soil moisture of six soils	The author consider HSV color space to identify the moisture
Abrham Debasu and Dagnachew Melesew	Soil classification and characterization using computer vision and sensor network approaches. In our research paper six types of soil is considered and BPNN is used to classify and characterize the soil	The main finding on this research is physical feature vector like texture and color is not adequate to classify and characterize the moisture levels. So as to increase the performance sensor is used. From the experiment 89.7 % accuracy is achieved

REFERENCES
[1] Mengistu Alemayehu, "Country Pasture/Forage Resource Profiles", Unpublished FAO,2010.
[2] Kshitija S. Naphade, "Soil characterization using digital image processing", Lehigh University, Unpublished Theses and Dissertations, 2000.
[3] Tinku Acharya & Ajoy K. Ray, "Image Processing Principles and Applications", A John Wiley & SONS, MC., Publication, 2005.
[4] David C.Marvin & etal, "Integrating technologies for scalable ecology and conservation", ScienceDirect, 2016.
[5] Mingyuan Zhang & etal, "Applying Sensor-Based Technology to Improve Construction Safety Management", MDPI Sensors, 2017.
[6] Pravat Kumar Shit, Gouri Sankar Bhunia, Ramkrishna Maiti, "Soil crack morphology analysis using image processing techniques", *Springer*, 2015.
[7] K. Srunitha , S. Padmavathi, "Performance of SVM classifier for image based soil classification", IEEE, 2016.
[8] Ashok Kumar Patel and Snehamoy Chatterjee, "Computer vision-based limestone rock-type classification using probabilistic neural network", *Science Direct*, 2016.
[9] Anastasia Sofou and Georgios Evangelopoulos, "Soil Image Segmentation and Texture Analysis: A Computer Vision Approach", *IEEE Geoscience and Remote Sensing Letters*, 2005.
[10] Sun–Ok Chung, Ki–Hyun Cho, Jin–Woong Cho, Ki–Youl Jung and Takeo Yamakawa, "Soil Texture Classification Algorithm Using RGB Characteristics of Soil Images", Fukuoka 812–8581, Japan, 2012.
[11] Małgorzata Charytanowicz and Piotr Kulczycki, "An Image Analysis Algorithm for Soil Structure Identification", *Springer International Publishing Switzerland*, 2015.
[12] Bhawna J. Chilke, Neha B. Koawale and Divya M. Chandran, "Determination of Soil pH by using Digital Image Processing Technique-A Review", *IJRITCC*, 2017.
[13] Ali M. Ghalib, Roman D. Hryciw, Seung Cheol Shin, *"Image texture analysis and neural networks for characterization of uniform soils"*, Proceedings of the 2000 International Computing Congress on Computing in Civil Engineering - Boston, MA, USA, 671-682.
[14] Umesh Kamble, Pravin Shingne, Roshan Kankrayane, Shreyas Somkuwar, Prof.Sandip Kamble, "Testing of Agriculture Soil by Digital Image Processing", *IJSRD*, 2017.
[15] A.V. Bilgili, W.D. Hively, H. van Es, L.Gaston, "Wavelet Analysis of Soil Reflectance for the Characterization of Soil Properties", conference.ifas.ufl.edu/SSC/pdf/BilgiliA.pdf.
[16] M. Barber, C. Pepe, P. Perna, F. Grings, J. Jacobo Berlles, M. Thibeault, H. Karszenbaum, "A novel method for 2-d agricultural soil roughness characterization based on a laser scanning technique", *IEEE*, 731-733, 2008.
[17] Richard J. Flavel, et al., "An image processing and analysis tool for identifying and analysing complex plant root systems in 3D soil using non-destructive analysis: Root1", PLoS One, 2017.
[18] Małgorzata Charytanowicz,Piotr Kulczycki, "An Image Analysis Algorithm for Soil Structure Identification", *Springer, Intelligent Systems* 2014.
[19] Masayuki Tamura & Weiping Li, "Detection of soil liquefaction areas in the Kantou region using multi-temporal InSAR coherence", *IEEE*, 2013.
[20] K. Srunitha and S. Padmavathi, *"Performance of SVM classifier for image based soil classification"*, Signal Processing, Communication, Power and Embedded System (SCOPES), 2016 International Conference.
[21] Mrutyunjaya R. Dharwad, et al.," Estimation of Moisture Content in Soil Using Image Processing", *International Journal of Innovative Research & Development*, 2014.
[22] Sanjay Kumawat, et al., "Sensor Based Automatic Irrigation System and Soil pH Detection using Image Processing", *IRJET*, 2017.
[23] Nimisha Singh and Rana GillRetinal, "Retinal Area Segmentation using Adaptive Superpixalation and its Classification using RBFN", *IJECE*, 2016.
[24] Heru Purnomo Ipung, Handayani Tjandrasa "Urban Road Materials Identification using Narrow Near Infrared Vision System", *IJECE*, 2017
[25] Brett Robinson, "Devices for measuring soil moisture: Selecting sensors for use with the Soil Water App", Grains research and Development Corporation", 2010.