DOI: http://dx.doi.org/10.32571/ijct.1107128 **E-ISSN: 2602-277X**

International Journal of Chemistry and Technology

http://dergipark.org.tr/ijct

Research Article

Automatic soil ph level detection using extreme learning machine via image processing

Kutalmis TURHAL[1], Umit Cigdem TURHAL[2,*]

[1]*Biosystems Engineering Department, Agriculture and Natural Sciences Faculty, Bilecik Seyh Edebali University, Bilecik, Türkiye*

[2]*Electric and Electronics Engineering Department, Engineering Faculty, Bilecik Seyh Edebali University, Bilecik, Türkiye*

Received: 21 April 2022; Revised: 4 June 2022; Accepted: 5June 2022

*Corresponding author e-mail: ucigdem.turhal@bilecik.edu.tr

Citation: Turhal, C. U.; Turhal, K. *Int. J. Chem. Technol.* **2022**, 6 (1), 56-60.

ABSTRACT

The pH values in the soil, that is, the acid or basic structure of the soil, affects the amounts of nutrients that the plant receives from the soil. For the plant to take the main nutrients in the soil and grow is only possible at suitable pH values. In this paper a novel soil pH level detection method based on optical imaging is proposed. As the level detection algorithm an Extreme Learning Machine (ELM) is used. In the constructed model while the RGB values of the true color soil images and pH index are used as the inputs of ELM the pH level of soil images are used as the output of ELM. In the experimental studies fifty soil sample images obtained from the literature are used. And a significantly high pH level detection performance of 97.5 % is obtained. This result reveals that the proposed method is a significantly important method to determine the pH levels of soil samples and could be a strong alternative to the traditional methods.

Keywords: Soil pH, optical imaging, extreme learning machine, data classification.

Görüntü işleme yoluyla aşiri öğrenme makinesi kullanilarak otomatik toprak ph seviye tespiti

ÖZ

Topraktaki pH değerleri yani toprağın asit veya bazik yapısı bitkinin topraktan aldığı besin maddelerinin miktarlarını etkiler. Bitkinin topraktaki temel besin maddelerini alması ve büyümesi ancak uygun pH değerlerinde mümkündür. Bu makalede optik görüntülemeye dayalı yeni bir toprak pH seviyesi tespit yöntemi önerilmiştir. Seviye tespit algoritması olarak bir Aşırı Öğrenme Makinesi (AÖM) kullanılmıştır. Oluşturulan modelde AÖM girdisi olarak gerçek renkli toprak görüntülerinin RGB değerleri ve pH indeksi kullanılırken, AÖM çıktısı olarak toprak görüntülerinin pH seviyesi kullanılmıştır. Deneysel çalışmalarda literatürden elde edilen 50 adet toprak örneği görüntüsü kullanılmıştır. Ve % 97.5 değerinde önemli ölçüde yüksek bir pH seviyesi algılama performansı elde edilmiştir. Bu sonuç, önerilen yöntemin toprak örneklerinin pH seviyelerini belirlemede oldukça önemli bir yöntem olduğunu ve geleneksel yöntemlere güçlü bir alternatif olabileceğini ortaya koymaktadır.

Anahtar Kelimeler: Toprak pH'ı, optik görüntüleme, aşırı öğrenme makinesi, veri sınıflandırma.

1. INTRODUCTION

Soil is a substance that consists of the decomposition products of rocks and organic materials in various scales that contains a wide world of living things and valuable life source for plants.[1,2] In agricultural applications the chemical contents of the soil have to be known before the cultivation in order to increase the product yield. By systematic analysis of soil its type and general structure could be determined.[3] Among the contents, the pH value, which is used to define the acidity or basicity degree of the soil, is an important factor indicating soil health. If the pH value in the soil is less than 4.5, it is defined as strong acid, between 4.6-5.5, medium acid, between 5.6-6.5, neutral, between 6.6-7.5, slightly alkaline, and above 8.5 as strongly alkaline.[4] Plants could grow in the soil that has appropriate pH values by means of taking the main nutrients. The fact that the pH value in the soil is at its limit values may cause the plant not to receive the nutritions in the soil or it may become toxic for the plant due to excessive dissolution of the nutritionas.[5] Even if there are enough main nutrients (nitrogen (N),

DOI: http://dx.doi.org/10.32571/ijct.1107128 E-ISSN: 2602-277X

phosphorus (P), potassium (P)) in a soil that is too acidic or too basic, the plant cannot absorb these elements or has difficulty taking them.[6] The pH value of soil directly affects the growth of the plant. When it is between 6.0 and 7.5, the plant can easily take up the nutrients in the soil. If the pH value in the soil is too acidic, some nutrients such as nitrogen, phosphorus, and potassium in the soil are less. On the contrary, although it is strongly alkaline, nutrients such as iron, manganese, and phosphorus are scarce in the soil.[6] When the soil pH value is 8 and above, plants cannot be grown in that soil.[7] The color of the soil also gives us information about the structure of the soil. Organic matter, presence of water, oxidation and pH are the factors that determine the color association in soil.[8]

Traditionally colorimetric and electrometric methods are used to determine soil pH. Although the colorimetric method using dyes or indicators whose colors can change according to the H ion activity in the environment is practical, it is not sensitive. Except for the test kits used to approximate soil pH in the field, indicators are not preferred for pH determination in soil. Today, pH determinations in soil are generally made using electrometric methods using a pH meter. The principle of the method is to measure the hydrogen ion activity of the soil, which is mixed with water or saturated with water in certain proportions, with a pH meter.[9] However these methods have some disadvantages such that they require expertise and long time requirements. They also are not automatic and some results are not purely objective, they are expert dependent. In the study given in the authors presented a literature survey related to automatic soil nutrients detection methods applied to eliminate the disadvantages of the traditional methods.[10] Accordingly, Chen and co-workers,[11] presented a study that determined the soil potassium level by using a machine learning algorithm that is Support Vector Machines (SVM) algorithm on plant leaf images. The starting point of this study was the visual changes in the plant leaf caused by the potassium level in the soil. Li and co-workers,[12] on the other hand, carried out the determination of soil nitrogen content using the Uniform variable elimination – extreme learning machine (UVE-ELM) method on a hyperspectral image. Similarly, Aitkenhead and co-workers,[13] carried out a study on hyperspectral images to detect NPK values of soil. However hyperspectral imaging is unpractiable in terms of obtaining images. In this study we proposed a novel optical imaging based soil pH level detection method using ELM. This method only performs soil pH level detection using the RGB images of soil samples acquired with a camera or with a smartphone on the working area. In the constructed ELM, inputs are the RGB values and the pH indices of soil images and the output is the measured pH values of soil samples. It automatically determines the pH level of the soil sample only using the soil image and doesn't require any measurements or any expertise as in the traditional methods. The contributions of the proposed method can be summarized as follows: As far as we know from the literature:

- It is the first time in the literature an automatic soil pH level detection algorithm is proposed.
- Detection of soil pH level has been performed without using any measurements in contrast to the traditional methods.
- Extreme Learning Machine is used for the first time in the literature to detect the pH level for soil samples.
- It does not require additional equipment as it uses the image data captured in the farming area, so it is cost-effective, time-effective and also user friendly which allows farmers usage ease.
- Traditional methods are based on some kind of measurement. However, since the proposed method is based on only a computer aided system, it is a precious alternative method for determining the pH level of the soil samples.
- It can also be extended to the other soil properties detection.

The rest of the paper is organized as follows: Materials and methods are given in the second section, then results and discussion and conclusion are given.

2. MATERIALS AND METHODS

2.1. Materials

Fifty soil sample images as given in Figure 1 collected from the Nathnagar block of Bhagalpur district are used as the soil dataset.[14] The images in JPEG format were captured using a digital camera. A true color digital image with the size of mxn has three color components as Red (R), Green (G) and Blue (B). The true colors are the composition of these three components in various values. In Figure 2, RGB color components of the soil sample images given in Figure 1 and their pH values measured by traditional methods are given.

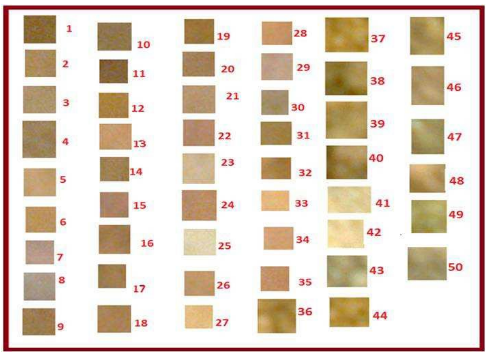


Figure 1. The soil samples data set.[14]

DOI: http://dx.doi.org/10.32571/ijct.1107128 E-ISSN: 2602-277X

2.2. Methods

Extreme Learning Machine (ELM) is a kind of neural network and is proposed for single hidden layer feedforward Neural Networks originally.[15] In contrast to traditional neural networks, hidden nodes parameters, input biases and weights are randomly selected while the output weights are analytically determined in ELM. A number of hidden nodes is the only parameter needed to be defined. So the learning process of the network is performed fastly. It has three layers: the input layer, the hidden layer and the output layer as can be seen in Figure 3. It has a good generalization performance and a fast learning speed, due to direct learning.

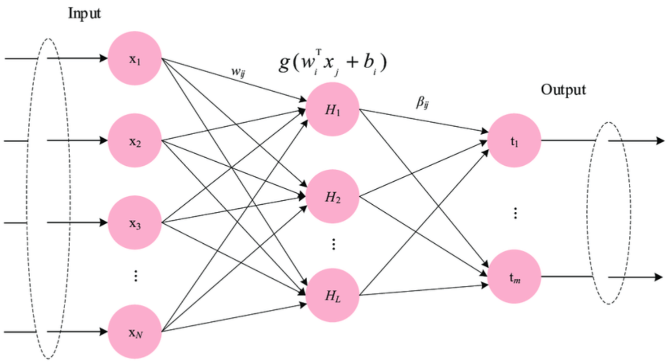
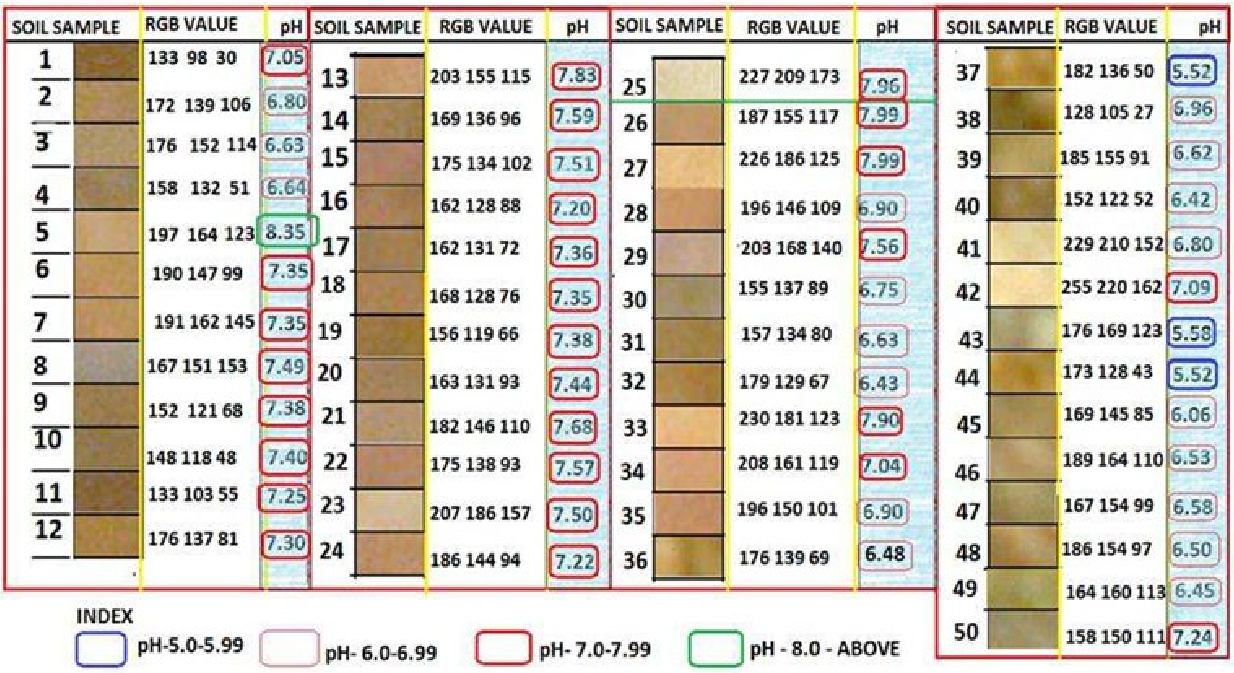


Figure 3. Extreme Learning Machine.[16]



SOIL SAMPLE	RGB VALUE	pH	SOIL SAMPLE	RGB VALUE	pH	SOIL SAMPLE	RGB VALUE	pH	SOIL SAMPLE	RGB VALUE	pH
1	133 98 30	7.05	13	203 155 115	7.83	25	227 209 173	7.96	37	182 136 50	5.52
2	172 139 106	6.80	14	169 136 96	7.59	26	187 155 117	7.99	38	128 105 27	6.96
3	176 152 114	6.63	15	175 134 102	7.51	27	226 186 125	7.99	39	185 155 91	6.62
4	158 132 51	6.64	16	162 128 88	7.20	28	196 146 109	6.90	40	152 122 52	6.42
5	197 164 123	8.35	17	162 131 72	7.36	29	203 168 140	7.56	41	229 210 152	6.80
6	190 147 99	7.35	18	168 128 76	7.35	30	155 137 89	6.75	42	255 220 162	7.09
7	191 162 145	7.35	19	156 119 66	7.38	31	157 134 80	6.63	43	176 169 123	5.58
8	167 151 153	7.49	20	163 131 93	7.44	32	179 129 67	6.43	44	173 128 43	5.52
9	152 121 68	7.38	21	182 146 110	7.68	33	230 181 123	7.90	45	169 145 85	6.06
10	148 118 48	7.40	22	175 138 93	7.57	34	208 161 119	7.04	46	189 164 110	6.53
11	133 103 55	7.25	23	207 186 157	7.50	35	196 150 101	6.90	47	167 154 99	6.58
12	176 137 81	7.30	24	186 144 94	7.22	36	176 139 69	6.48	48	186 154 97	6.50
									49	164 160 113	6.45
									50	158 150 111	7.24

INDEX: pH-5.0-5.99; pH- 6.0-6.99; pH- 7.0-7.99; pH - 8.0 - ABOVE

Figure 2. The soil samples data set with RGB values and corresponding measured pH values. [14]

In the proposed study the pH level detection is performed according to the RGB values of soil image pixels. In [10] authors reveal the relationship between the RGB values of different soil samples images and their measured pH values using traditional methods. They also defined a pH index via the RGB values as it is given in Equation 1.

$$pH\ index = \left(\frac{R}{G}\right)/B \quad (1)$$

In our study based on this idea we created an ELM network whose inputs are the RGB values of image pixels and the pH indices and the output is the pH level of that soil sample which is determined by the measured pH value using the traditional methods. This method is basically a classification namely a supervised learning algorithm so it includes a training step and a testing step. At first the dataset given in Table 1 is splitted into two as the training set and the test set. While in the training step using the training data set a classification model is constructed, in the testing step using the test data set classification performance of the model is evaluated. The created model detects the pH level of soil samples without any physical measurements but only using the soil image R, G, B values and the corresponding pH indices. Once the model is constructed and the accuracy performance is revealed then by applying it for a new soil sample the pH level of that sample can be determined. In the testing step the test data attributes (R, G, B values and pH indices) are given to the constructed classification model as the inputs. Then the class labels (pH levels) are predicted using the model. The performance of the proposed model is performed by the comparison of each testing object's predicted class label with the actual class labels in the data set. Thus using this classification algorithm, the unknown sample class label (the pH level) is detected using the known attribute values (the R, G, B and the pH index).

DOI: http://dx.doi.org/10.32571/ijct.1107128 E-ISSN: 2602-277X

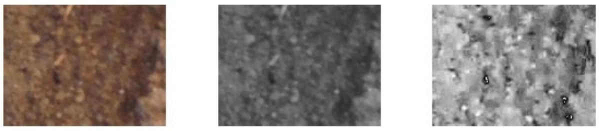
Table 1. A sample of soil data set used in this study.

ELM Inputs					**ELM Output**	**ELM Output**
No	R	G	B	pH index	**Measured pH**	**Discrete pH**
1	133	98	30	0,0452	**7,05**	**Positive**
2	172	139	106	0,0116	**6,8**	**Positive**
3	176	152	114	0,0101	**6,63**	**Positive**
4	158	132	51	0,0234	**6,64**	**Positive**
5	197	164	123	0,0097	**8,35**	**Negative**
6	190	147	99	0,013	**7,35**	**Positive**
7	43	176	169	123	**5,58**	**Negative**
8	44	173	128	43	**5,52**	**Negative**
9	152	121	68	0,0184	**7,38**	**Positive**
10	148	118	48	0,0261	**7,4**	**Positive**

In this study besides the RGB images different color spaces such as gray scale image and HSV color space are also evaluated. In order to obtain a gray scale image from a RGB image the formula given in Equation 2 is used. The intensity value of pixels of grayscale image varies between 0-255. While 0 is corresponding to black color 255 corresponds to white color. And the values between 0 and 255 correspond to the gray colors between the black and white. The HSV color space has three components that are Hue (H), Saturation (S) and Value (V) respectively. In this color space, Hue represents the color component while Saturation controls the amount of color used and Value controls the brightness of the color. Thus for the studies related to the color information only the Hue component of HSV color space is used. In Figure 4 a soil sample image and its corresponding gray scale image and Hue component image are given.

$$Gray\ Scale\ İntensity = 0.2989.R + 0.5870.G + 0.1140.B \quad (2)$$

$$Hue = \left(60.\frac{G-B}{R-B}\right) + 360 \quad (3)$$



a b c

Figure 4. Different color space representations of a soil sample image. a) Original image, b) Gray scale image of the original sample, c) Hue component of the HSV color space image of the original sample.

3. RESULTS AND DISCUSSION

The confusion matrix belonging to the experimental studies performed on the testing data set is as given in Figure 5. A preprocessing step is performed before the experimental studies in the data set. In the preprocessing step the measured continuous pH values in Table 1 are converted to discrete pH values to be the Positive and the Negative two class. In this conversion while the Positive class indicates the pH values between 6.00 and 7.50 which is appropriate for plant growing the Negative class indicates the other pH values which does not allow the plant to grow. In the experimental studies 10 fold cross validation is used and 97.5 % pH level detection accuracy is obtained in the test data set which is a significantly high performance. Same experimental study is performed using both the gray scale images and HSV color space of images. In both it is obtained 97.5 % accuracy as it is the case using the RGB values. Same experimental study is also performed using another machine learning algorithm named decision trees (J48) and using the J48 algorithm 72% accuracy is obtained in the experimental studies.

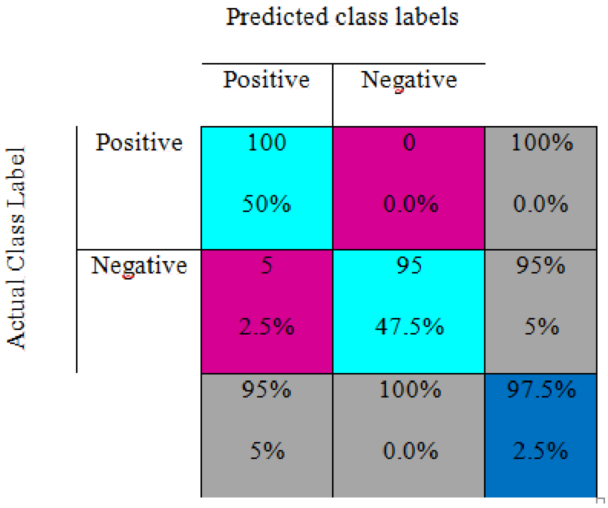


Figure 5. Confusion matrix of the test data set.

4. CONCLUSIONS

In precision agricultural cultivation applications the use of machine learning algorithms are important alternatives to the traditional methods. Because while they are providing an automatic, time effective and cost effective they also don't require any expertise. Besides, in the proposed method it does not need to transport soil samples to a laboratory or another place, and it does not require any technical sensing equipment. The only need is a camera or simply a smartphone. According to the experimental studies performed in this study it is shown that the proposed pH level detection method only using the soil images provides significantly high pH level detection performance for soil samples. The accuracy results obtained in this study reveals that the proposed method is a significantly important method to determine the pH levels of soil samples and could be a strong alternative to the traditional methods. It is thought that the proposed study will be an important guide for researchers studying in this field. We are planning to transform this study, which is presented in our future studies, into a larger-scale research in this field on a larger data set that we will construct ourselves in terms of the

DOI: http://dx.doi.org/10.32571/ijct.1107128 E-ISSN: 2602-277X

machine learning algorithms that are used and the soil properties.

Conflict of interests

The authors declare that they have no known competing financial interests or conflicts that could have appeared to influence the work reported in this paper.

REFERENCES

1. Kabała, C.; Charzyński, P.; Chodorowski, J.; Drewnik, M.; Glina, B.; Greinert, A.; ... & Waroszewski, J. **2019**. *Soil Science Annual*, 70 (2).

2. Kalev, S. D. & Toor, G. S. *In Green Chemistry* **2018** 339-357.

3. Eyre, S. R. *Routledge* **2017**.

4. Ateş K., ve Turan K. *Türkiye Tarımsal Araştırmalar Dergisi Turk J agric Res.* **2015**, 2,108-113.

5. Maltaş A. Ş. Antalya Merkez-ilçe Örtüalti Güzlük Domates (solanum lycopersicum l.) Yetiştiriciliğinde Farkli Asit Uygulamalarinin Toprak Ph'si Üzerine Etkileri ile Bitki Beslenme Durumlarinin Araştirilmasi. Yüksek Lisans Tezi, Akdeniz Üniversitesi Fen Bilimleri Ens. Toprak Bilimi ve Bitki Besleme Anabilim Dalı,2013

6. Buckman, H.O. and Brady, N.C. Weil, R.R. *The nature and properties of soils*, 13thEdition. Prentice Hall, 2002.

7. Güneri M.; Mısırlı A.; Yokaş İ. *Ege Üniv. Ziraat Fak. Derg.,* **2009**, 46 (3), 181-189.

8. Hyun, B. K.; Lee, Y.; Ryu, C. H., & Cho, Y. *Korean Journal of Soil Science and Fertilizer*, **2022**, 55 (1), 48-57.

9. Kacar Burhan, Toprak Analizleri, Ankara, 2009.

10. Potdar, R. P., Shirolkar, M. M., Verma, A. J., More, P. S., & Kulkarni, A. *Journal of Plant Nutrition*, **2021**, 44(12), 1826-1839.

11. Chen, L., S. Huang, Y. Sun, E. Zhu, and K. Wang. *Journal of Spectroscopy*, **2019**, 1–8.

12. Li, H., S. Jia, and Z. Le. *Sensors*, **2019**, 19 (20), 4355.

13. Aitkenhead, M. J., G. J. Gaskin, N. Lafouge, and C. Hawes. *Sensors*, **2017**, 17 (1), 99.

14. Kumar, V., Vimal, B. K., Kumar, R., & Kumar, M. *Journal of Applied and Natural Science* **2014**, 6(1), 14-18.

15. Huang, G. B., Zhu, Q. Y., & Siew, C. K. *Neurocomputing*, **2006**, 70(1-3), 489-501.

16. Deng, W., Ye, B., Bao, J., Huang, G., & Wu, J. *Metals*, **2019**, 9(2), 155.