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The Use of Neural Network Coupled with Image Processing for Water Quality Assessment (Location: Hot Spring Mae-Khachan, Thailand)**

Wahyu Nurkholis Hadi Syahputra*, Chatchawan Chaichana+1, Wasin Wongwilai#, and Braja Manggala*

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ABSTRACT

Parameters such as pH, alkalinity, total hardness, and nitrate are important to determine the quality of agricultural purpose. Water quality testing strips are popular for testing the water. In addition to the low price, this tool is very easy to use. However, bias due to colour reading from different users exists. In this study, the evaluation of water quality with image processing coupled with the artificial neural network (ANN) model is proposed. Water quality is assessed using testing strips. Images of the strip are taken by mobile-phones and geo-tag provided by GPS. Then, colour-space transformation, image enhancement, and regions of interest (ROI) are carried out as part of the image processing stage. Finally, the ANN-multi layer perceptron (MLP) is used to obtain water quality predictions based on the results of image analysis. Based on the results of the analysis, the R2 values > 0.80 for the estimating water parameters. This research shows that the image processing coupled with ANN has the potential to get a more precise estimation value for water quality assessment. For future work, the geo-tagging application meets with the data centre system in this study offers periodic monitoring of water quality in a large area.

1. INTRODUCTION

Water is a natural resource that plays an important role and effects the life. It is used in almost every sector, for daily needs of humans and animals, in industries, and for agriculture [1]. However, agricultural sector requires more water use namely for agricultural irrigation needs. Water quality is an essential parameter for water consumption, especially in the agricultural sector [2]. Water quality affects environmental conditions around watersheds which can impact crop yields and plant growth on the agricultural land. Agricultural irrigation water sources can come from various sources such as wells, rivers, and springs [3]. Traces of toxic chemical compounds can be found in the water. Some of the chemical content of water can reduce the quality of irrigation water, resulting in decreased production and even crop failure. Some elements can benefit plants in the right concentration but can be toxic and have a negative impact on plants at high concentrations. Thus, monitoring or assessing water quality is essential, especially in irrigation areas, to ensure water quality is suitable for plants to support production, and benefit farmers [4].

Several methods for monitoring and assessing water quality have been established to ensure the water quality standards for agriculture and other usages. Conventional methods for assessing water quality includes laboratory methods which are also considered to have high accuracy, such as titrimetric methods [5], silver nanoparticles [6] to measure total hardness, and spectrophotometric methods to measure nitrate and nitrite content in water [7]. However, assessing water quality by sending water samples to the laboratory takes a long time and is expensive [8]. Also, the transportation of samples from sampling location can render false results, as the chemical composition of water can change over time. Alternatively, another measurement method developed to measure water quality is by utilizing remote sensing (RS) [9] with geographic information systems (GIS) technology [10], which offers a real-time assessment solution by utilizing satellite imagery, or images that can be taken using an uncrewed aerial vehicle (UAV) [11]. This technology offers the advantage of performing monitoring on a wide scale. However, it requires special skills to operate, and some of the tools used are expensive. The implementation of an embedded sensor system was also developed to conduct an Internet of Things (IoT) based water quality assessment. This system offers real-time monitoring via

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*Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai 50200 Thailand.

+Renewable Energy and Energy Conservation Laboratory Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai 50200 Thailand.

#Renewable Energy and Energy Efficiency Research Unit Science and Technology Research Institute, Chiang Mai University, Chiang Mai 50200 Thailand.

1Corresponding author:
Tel: +66 53 944146.
Email: c.chaichana@eng.cmu.ac.th.

smartphones that fish farming farmers can utilize.[12]. However, the cost of the system development and sensor maintenance is high and needs to be addressed.

A water test kit is one of the popular instruments used to assess water quality in real-time and on-site. In addition to its straightforward use, the price is also quite affordable for smallholders. Generally, a paper-based water test kit is used that can produce colours according to the chemical reaction between the paper and the chemical content of the water. However, the manual usage of the water kit requires the skills from the user to read the kit colours according to the available standards, in order to avoid the mis-matching of the test results. These problems can be solved by using digital image processing techniques. The computer can analyse the image with consistent results. Digital image processing has now been widely used in almost all sectors, including agriculture, to assess the level of plant health, fruit quality, and water quality [13]. It can also monitor bacterial content in wastewater. In addition to digital image processing, machine learning techniques can also be implemented for monitoring and estimating water quality [14]. Several machine learning algorithms, such as Adaptive Neural-Fuzzy Inference System (ANFIS), Radial Basis Function Neural networks (RBF-ANN), and Multi-Layer Perceptron Neural Networks (MLP-ANN), give satisfactory results for water quality estimation [15], [16].

The method of monitoring and estimating water quality by utilizing a water test kit to produce a more accurate quantitative water quality estimate was developed in this study. The implementation of image processing and machine learning techniques is evaluated to quantitatively determine water quality based on data from the water test kit. In addition to water quality estimation, this study also provides detailed location information in GPS coordinates as geo-tagging for periodic water quality analysis or monitoring [17].

2. MATERIALS AND METHODS

In this study, three primary stages are carried out, namely the stage of data retrieval, digital image processing, and data analysis using machine learning algorithm, artificial neural network (ANN). Figure 1 shows an illustration of the implementation of the research. This study utilizes the GPS feature on the mobile phone to generate coordinates. The water-test kit was dipped into the measured water sample and waited for the probe to change colour, then take the image of the water test kit using the camera. The images stored in the mobile-phone memory were then transferred to the cloud storage data center.

A water test kit (ECO-CHECK, USA) and an 8 MP Smartphone camera (Samsung GT-19300, KOREA) were used in this study. Sampling was conducted at Mae Khachan hot springs (19.11472, 99.46222), Chiang Rai Province, Thailand as shown in Figure 2.

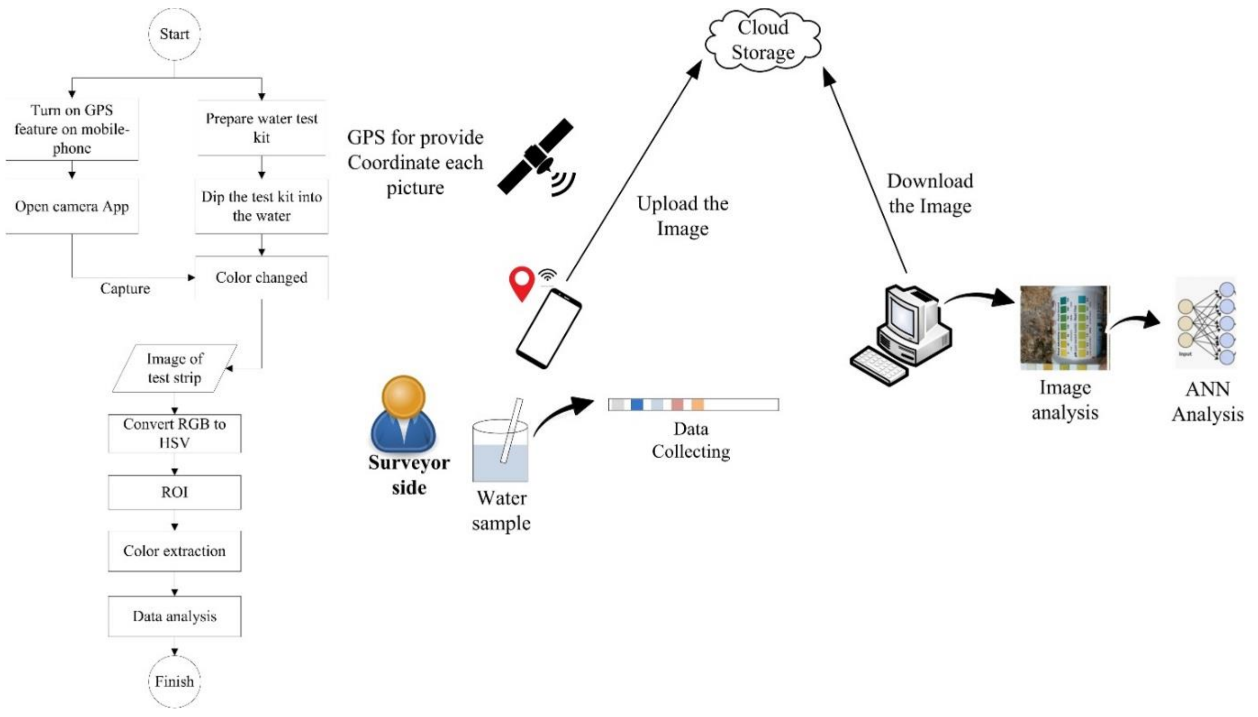

Fig. 1. (a) Flowchart of research; (b) Workflow.

2.1 Data Collection

At the data collection stage, the GPS feature on the smartphone is activated to get the coordinates of each sample location. Samples were collected from the Mae Khachan hot spring and the watershed around the hot spring, which is used to irrigate agricultural land. Figure 2 shows a map of the location of data collection. There are several procedures for using the water test kit, namely, first, dip the water test kit into the water sample for 2 seconds, then wait for 25 seconds to see the color change on the water test kit. The water quality parameters that can be measured by the water test kit used in this study are nitrate (NO3-), total hardness, total alkalinity, and pH. After the water test kit changes color, picture of the water test kit was taken using the smartphone camera. Each captured image contains coordinate location information. At each sampling location, four images were taken, namely images of color changes in the nitrate (NO3-), total hardness, total alkalinity, and pH.

2.2 Image Processing

For the digital image processing several software packages, namely ImageJ and Jupyter Notebook were used. There are two stages in digital image processing, namely, image conversion from RGB mode generated by the camera into hue, saturation, value (HSV) mode (Figure 3a) and the round of interest (ROI) determination (Figure 3b). The stages of image conversion are carried out using the OpenCV algorithm. The purpose of converting the image into HSV mode is to see the characteristics of the water test kit image in more detail [18]. After the RGB to HSV image conversion stage, ROI determination stage is carried out to analyze the water test kit image in more detail [19]. Image with HSV method can detect light reflectance due to residual water more clearly.

The remaining water in the water test kit causes light reflection in the resulting image so that ROI is carried out in areas where there is no light reflection by the remaining water in the water test kit (Figure 3b). The area where the light is reflected with the HSV model can be easily identified (Figure 3c).

Fig. 2. Coordinates of each location generated by GPS.

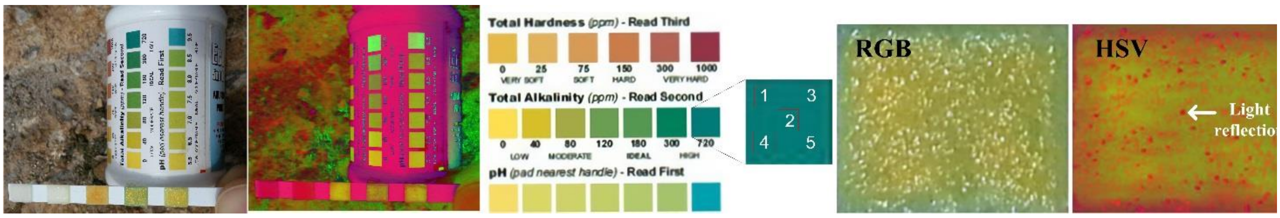

Fig. 3. Image processing step. (a) Image conversion from RGB to HSV mode; (b) ROI; (c) Comparison of RGB and HSV to recognize the light reflection due to water.

2.3 ANN Analysis

The machine learning algorithm used in this study is ANN with multilayer perceptron (MLP). ANN consists of 3 parts, namely the input layer (I), the hidden layer (H), and the output layer (O) [17]. This study extracted the color/RGB data and HSV from the images and input them into the neural networks for training and testing. The parameters used as input layers are the values of R, G, B, H, S, V, brightness, and standard values contained in the water test kit. The number of hidden layers used in this study are three. Figure 4, presents the ANN architecture. The jupyter notebook software was used in this study for machine learning analysis.

Furthermore, to test the performance of the ANN to estimate water quality based on image information, the calculation of the coefficient of determination and RMSE is carried out using Equation (1).

$$RMSE = \sqrt{\sum_{x=1}^{n} \frac{(O_x - A_x)^2}{n}} \tag{1}$$

Where, Ox is the actual value, Ax is the predicted value and n is number of samples [17].

3. RESULTS AND DISCUSSION

3.1 Water Quality Estimation

The use of water test kits to assess water quality, quickly and in real-time needs to be evaluated because the range of values are quite extensive between each concentration levels. This can cause bias in quantitative water quality readings. The implementation of digital image processing for quantitative water quality estimation based on the measurement results by the water test kit can present quantity data from more specific water quality parameters. A comparison between manually reading results and with image processing is presented in Table 1. Prediction using the ANN technique produces a more specific value than the measurements using visual observation.

3.2 Data Analysis

The image data contains information on R, G, B, H, S, V, and brightness values. The data illustrates the quantitative estimation of water quality which varies at the data collection location. After obtaining the water quality estimation value quantitatively based on the image from the water test kit, ANN presents the determination coefficient value (R^2) of each parameter. Based on the analysis results, the resulting R^2 values are 0.80, 0.85, 0.86, and 0.80 for the estimated pH, alkalinity, total hardness, and nitrate parameters respectively. To find out how far the estimated values deviations, the RMSE test is carried out, which produces values of 0.26, 8.02, 10.01, and 5.25 for pH, alkalinity, total hardness, and nitrate respectively. Table 2 presents the data of the coefficient of determination (R^2) and RMSE of the analysis results.

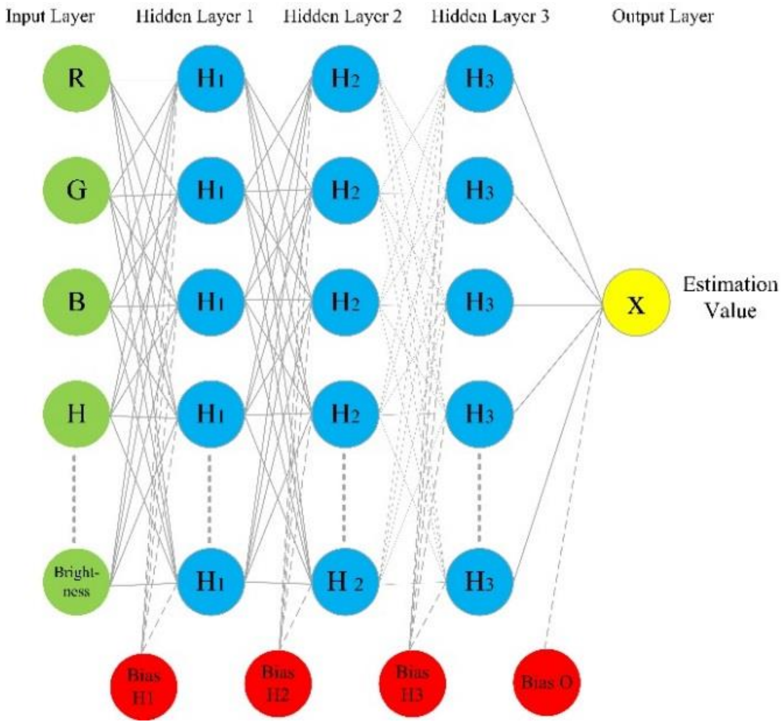

Fig. 4. Artificial neural network architecture

Table 1. Comparison between conventional estimation and ANN method.

Visual observation		ANN Estimation	
pH	Total Alkalinity (ppm)	pH	Total Alkalinity (ppm)
8	300	8.21	184.33
9.5	720	8.98	592.67
9.5	720	8.92	577.33
6.5	40	6.31	77.67
8.5	720	8.65	458.33
7	80	6.69	75.33

Table 2. Accuracy and RMSE generated using ANN.

Parameter	R^2	RMSE
pH	0.80	0.26
Alkalinity	0.85	8.02
Hardness	0.86	10.01
Nitrate	0.80	5.25

Table 2 shows that the R2 values are close to 1. ANN technique predicts that it can produce estimates of several water quality parameters quite well between the estimation results with visual observations and the estimation results with the ANN technique.

3.3 Water Quality Assessment for Irrigation

The water resource for agricultural irrigation come from different sources. In determining water quality quantitatively, it can be done by calculating the concentration of the chemical content of the water. Some of the chemical elements in water will be beneficial if they follow water quality standards for each need. For irrigation purposes, the chemical elements in the water should not be toxic to plants. Excessive chemical content in irrigation water can cause a decrease in productivity, decrease soil fertility, and decrease the efficiency of nutrient uptake by plants. This will cause losses for farmers.

The graph in Figure 5 compares water quality parameters pH, alkalinity, total hardness, and nitrate at the center of hot water and the river area that will enter agricultural land. The graph shows that the pH tends to be high in the hot springs, up to 9 and the pH decrease in the irrigation watershed [20]. In the alkalinity parameter, hot springs have high alkalinity, and watersheds entering agricultural land have low alkalinity. High alkalinity exerts the most significant effects on growing medium fertility and plant nutrition. In the total hardness parameter, the hot spring has a higher value than the watershed that will enter agricultural land. Although the hardness of water does not directly affect plants. The hardness can affect soils by bicarbonates, thus having an indirect impact on plant growth. As for the nitrate parameter is relatively the same between hot springs and watersheds for agricultural land.

In water, the pH indicates the degree of acidity. A good pH value for irrigation ranges from 6 to 9 [21]. At several points, the water quality measurements showed that the pH ranged from 6 to 8, so based on the pH value, the water from the Mae-Khachan spring was still feasible to be used as irrigation water. The alkalinity of water describes the capacity of water to neutralize acids or the number of anions in water that can neutralize hydrogen cations. Total hardness describes the content of certain minerals in the water, such as calcium (Ca) and magnesium (Mg). Meanwhile, high nitrate concentrations in waters can stimulate the growth and development of aquatic organisms if supported by the availability of nutrients.

Table 3 presents the correlation between each water quality parameter. Parameters pH and alkalinity have a strong positive correlation where the increase in pH will be accompanied by an increase in the alkalinity of the water [22].

Table 3. Correlation each parameter.

Parameter	pH	Alkalinity	Hardness	Nitrate
pH	1	0.83	0.02	0.45
Alkalinity		1	0.04	0.23
Hardness			1	0.06
Nitrate				1

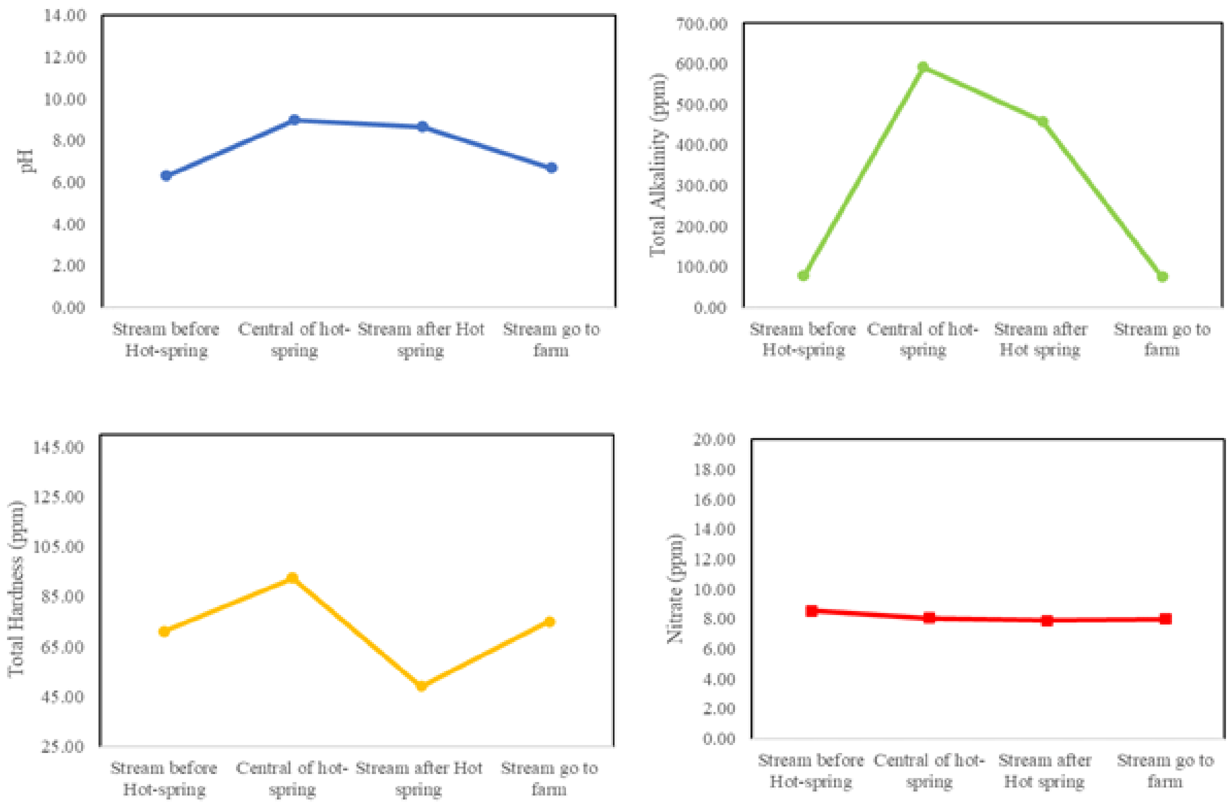

Fig. 5. Comparison of parameter between hot spring and river.

4. CONCLUSION

Water is essential to support agricultural production. This study develops a digital image processing method combined with machine learning analysis with the ANN- MLP algorithm to estimate water quality based on the concentration levels of several elements based on data taken with a water test kit. Digital image processing with ANN showed promising results with 0.80, 0.85, 0.86, and 0.80 for the estimated pH, alkalinity, total hardness, and nitrate, respectively. In this study, the images taken are equipped with GPS information which is geo-tagging. The use of this GPS will assist in monitoring water quality regularly.

The model developed in this research can be integrated with the data center to make it easier to analyze water quality in an area regularly. The system developed is on a low-cost basis which provides benefit for small stakeholders.

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