RESEARCH ARTICLE

POTENTIAL AREA MAPPING FOR SEAWEED AQUACULTURE BASED ON INTERVAL TYPE-2 FUZZY SETS AND MULTI-LAYER PERCEPTRON ALGORITHM.

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Manuscript Info

Abstract

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This paper proposes a mapping model for seaweed aquaculture based on Interval Type-2 Fuzzy Sets (IT2FS) and Multi-Layer Perceptron (MLP) algorithm as a new framework to map potential area for seaweed cultivation to face uncertainty business environment. The main output of this research is a framework as a conceptual model for seaweed potential area mapping based on IT2FS and MLP; and visualization model from the proposed framework using google map API. We use MLP to learn historical data of variables that affect seaweed cultivation and predict future environment condition. The output of MLP used as input for IT2FS for inference process. The decision output from IT2FS is potential or not potential with specific prediction of production size for each region. We test our model for potential mapping in South Sulawesi's seaweed aquaculture Indonesia. The test result shows our mapping model can provide potential area with total production size each area in South Sulawesi Indonesia.

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Introduction:-

Seaweed aquaculture is one of prospective business in aquaculture industry that growth significantly in past decade. The prospective of this business is good because the growth of the seaweed aquaculture industry is good for the economy and good for the ocean and environmentally friendly. The seaweed planting growth naturally in sea and help improve sea improvement in better condition for sea creatures live. Hence it leads to promote green productivity and sustainability in aquaculture business.

According to Porse dan Rudolph (2017), the seaweed industry, comprising agar, alginate, and carrageenan extracts, continues to grow in the order of 2–3% per year with the Asia-Pacific region increasingly dominating the raw material and manufacturing aspects of the industry. The industry is increasingly being commoditized and China has become an important and, in many cases, dominant factor within all types of seaweed and some explanations to this and strategic response by the rest of the industry is also touched upon.

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The major challenges in seaweed industry is cultivated species- how are the strains to be improved and revitalized and can cultivation techniques be improved further? There is a general trend towards sustainability and, although seaweed cultivation and harvest can be sustainable, there is interest in the development of greener processes (Porse dan Rudolph 2017). Hence, mapping seaweed cultivation area is important to help decision maker determine and predict the production size and potential area according to cultivation area characteristics.

According to the reason above, mapping potential area is important to make seaweed supply chain sustain. Mapping potential area can help decision makers determine which sea location best for seaweed cultivation and predict how much production in the future. Because environmental variables are uncertain, develop mapping model and framework based on a method that can answer dynamic challenge and can adaptive to dynamic business environment is important. One scientific field that can answer this challenge is soft computing approach with IT2FS and MLP is two of many algorithms in soft computing used for learning and predicting from historical data real-time and inferencing.

Many researches about seaweed management, potential, cultivation prediction was proposed by Porse dan Rudolph (2017) about update, requirements, and outlook for seaweed industry. Liu *et al.* (2013) studied about on-land cultivation of functional seaweed products for human usage. They proposed on-line cultivation for seaweed to ensure sustainability of seaweed production for human consumption. There is no research about seaweed mapping production and answer the uncertainty aspects rom environment that affect seaweed production. Hence there is lack of research in seaweed cultivation, especially uncertainty mapping as a basis for decision making process and future direction research in seaweed management.

According to the motivation, the objective of this paper is to design seaweed potential area mapping based on uncertainty condition derived from dynamic business environment with IT2FS and MLP algorithm. The contribution of our work is we propose a model to help decision maker determines a decision and as a basic of future research development in seaweed industrial and business.

The rest of this paper is constructed as follow, in this section we propose background and research motivation. The next section we proposed an IT2FS and MLP approach for seaweed potential area mapping. A study case in South Sulawesi Indonesia was used to verify our model. The next section we discuss the result of the model, and the last section we conclude this research and suggest future research recommendation.
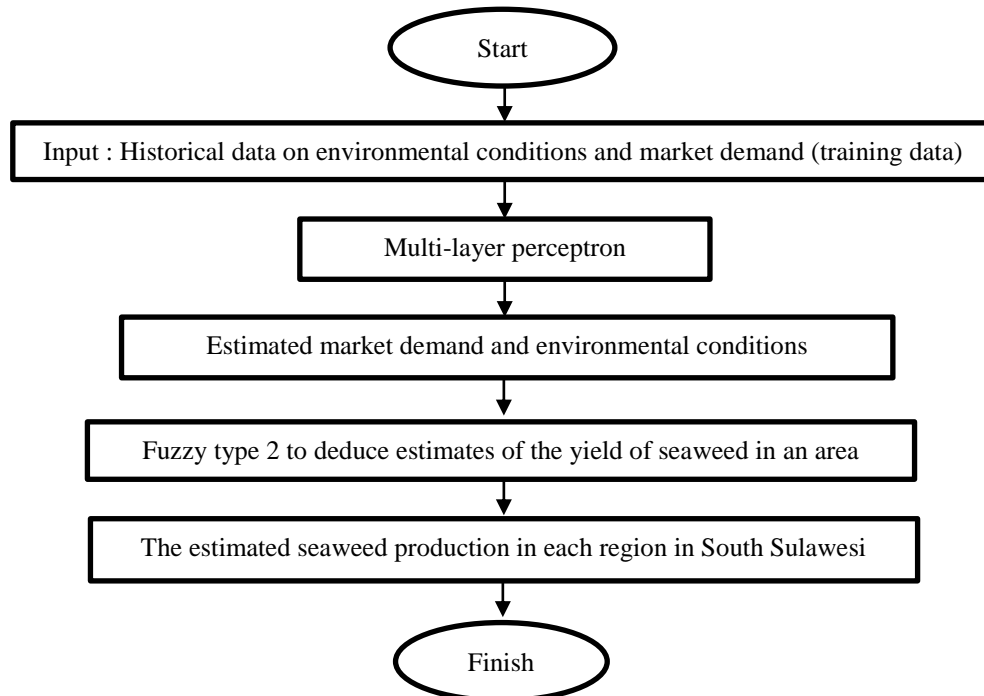
Methodology:-
To answer the uncertainty challenges in seaweed agroindustry logistics, this study uses an artificial neural network approach to study patterns and map the conditions of potential seaweed producing areas in South Sulawesi.

This artificial neural network is also used to estimate the demand for seaweed processed products both export and local consumers. The results of the pattern and mapping of the potential environmental conditions of seaweed-producing regions of artificial neural networks, are used as input to infer the estimated yield of a seaweed in an area of South Sulawesi. The type of neural network used is the Multi-layer perceptron. The approach used to deduce the amount of seaweed is the Interval Type 2 Fuzzy Logic System (IT2FLS). The stages of resolving the complexity of the uncertainty of seaweed agro-industry logistics are illustrated in Table 1

Table 1:- Stages of mapping the potential and demand for seaweed

A. Methods	*B.* Inputs	*C.* Outputs
D. Artificial Neural Network	*E.* Parameters of conditions that affect the growth of seaweed in each region. Historical data is used for training neural networks	*F.* Conditions for future estimates for each parameter that affects the growth of seaweed in each region
	G. Historical data on the demand for seaweed-based products	*H.* Estimated future demand for seaweed-based products
I. Interval Type 2 Fuzzy Logic System	*J.* Fuzzy parameters for conditions that affect the growth of seaweed	*K.* Estimated yield of seaweed in an area

If illustrated the input and output flow of each technique used, the illustration is like in Figure 1.

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                    ┌───────────┐
                    │   Start   │
                    └─────┬─────┘
                          ▼
┌─────────────────────────────────────────────────────────────────┐
│ Input : Historical data on environmental conditions and market   │
│         demand (training data)                                    │
└─────────────────────────────┬───────────────────────────────────┘
                          ▼
              ┌───────────────────────────┐
              │   Multi-layer perceptron   │
              └─────────────┬─────────────┘
                          ▼
        ┌───────────────────────────────────────────┐
        │ Estimated market demand and environmental  │
        │             conditions                      │
        └─────────────────────┬─────────────────────┘
                          ▼
    ┌───────────────────────────────────────────────────┐
    │ Fuzzy type 2 to deduce estimates of the yield of   │
    │             seaweed in an area                      │
    └─────────────────────────┬─────────────────────────┘
                          ▼
    ┌───────────────────────────────────────────────────┐
    │ The estimated seaweed production in each region    │
    │             in South Sulawesi                       │
    └─────────────────────────┬─────────────────────────┘
                          ▼
                    ┌───────────┐
                    │  Finish   │
                    └───────────┘
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Figure 1:-Stages determine the distribution map of seaweed production

Learning Pattern Data Using Artificial Neural Network :-

At this stage, the concept of artificial neural networks was implemented to study historical data for each attribute in the mapping of seaweed availability. Learning data in this method is used to predict the value of future attributes. For example, if seaweed is to be harvested in 2 months, we can predict attribute values that affect seaweed cultivation for 2 months (for example temperature). The results of this prediction are used in the next stage to predict the availability of seaweed. This stage is called the time series learning stage for attribute predictions. The neural network type used at this stage is a multi-layer perceptron (MLP).

MLP is a feedforward neural network with one or more layers between the input and output layers. Feedforward means data flows in one direction from input to output (forward). This type of neural network is trained with the backpropagation learning algorithm. MLP is widely used for classification, pattern patterning, prediction and estimation. MLP can solve problems that are not linearly separated.

Based on Pham *et al.* (2017), MLP is a type of neural network approach that is quite well known for being used in predictions on mapping problems. The MLPNN structure includes three layers, namely input, hidden and output layers. The number of neurons is equivalent to the input layer, in this case neurons in the input layer are one with the output of the neural network as well 1. The performance of MLP is influenced by the connection of weights between the input and hidden layers and between the hidden layer and output. These weights are determined and updated based on the training stages based on the backpropagation algorithm (Haykin 2009). The hidden layer design in this research is $2n + 1$ where n is the number of inputs on each node as illustrated in Figure 2.
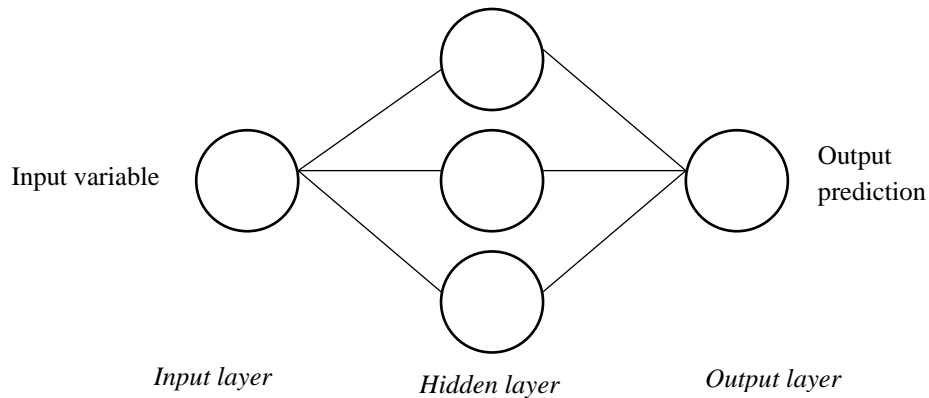
Figure 2:- Artificial neural network structure

The components for building an artificial neural network are as follows:

Activation function
If the multilayer perceptron has a linear activation function in all neurons, it means that there is a linear function that maps the weights of input to output on each neuron, then using linear algebra easily proves that each layer will be reduced to standard 2 input-output layers model. What makes MLP different is that some neurons use a non-linear activation function that is developed to model the frequency of potential actions, or the dismissal of biologically neurons in the brain. This function is modeled in several ways. The two main functions of the activation function used in the current application are multiple sigmoids which are formulated as follows:

$$y(v_i) = tanh(v_i) \text{ dan } y(v_i) = (1 + e^{-v_i})^{-1}$$

where the forming of the function is a hyperbolic tangent with a range between -1 to 1. The next function is a logistic function with a form that is almost the same as the tangent function but ranges from 0 to 1. The function has y_i notation as the output of the i-node (neuron) and v_i are the number of weights from the synaptic input.

Layer
A multi-layer perceptron consists of three or more layers (input and output layers with one or more hidden layers) from non-linear activation nodes and this type of neural network is classified as a deep neural network. MLP is a type of fully connected neural network, each node in one layer relates to a specific weight on each node in the next layer.

The learning process uses the backpropagation algorithm
The learning process occurs in the perceptron by changing the weight connections of each part of the data that is processed, based on the number of errors at the output compared to the desired results. This process is one example of supervised learning and is carried out using the backpropagation algorithm approach, which is a generalization of the least squares algorithm in a linear perceptron. An error in the output node j in the data to n is defined as:

$$e_j(n) = d_j(n) - y_j(n)$$

Where d is the target value and y is the value generated from the perceptron. Furthermore, weight correction is made on each node based on the correction which has the minimum output error value, which is expressed as

$$\mathcal{E}(n) = \frac{1}{2} \sum_j e_j^2(n)$$

using gradient descent, changes to each weight are formulated as

$$\Delta w_{ji}(n) = -\eta \frac{\partial \mathcal{E}(n)}{\partial v_j(n)} y_i(n)$$

where y_i is the output of the previous neuron and η is the rate of learning the neural network, which is chosen to ensure that the weight can produce convergence quickly without producing high output variations. This is based on changes in weight from the *k*-node that represents the output layer. To change the weight in the hidden layer, it is necessary to change the weight on the output layer based on the derivation of the activation function described earlier. This approach represents backpropagation from the activation function.

Implementation of Artificial Neural Networks:-
Implementation of artificial neural networks in research is carried out by supporting the Neuroph framework. The y_i output value generated in the artificial neural network process is used as input of the fuzzy process at the next stage. The input used in the implementation of the neural network uses the neuroph framework. Inputs used in the research for learning patterns of data on artificial neural networks are salinity, wave height, phosphate level, dissolved oxygen, wave velocity, nitrate concentration, depth, protection and pH which are important attributes in determining the amount of seaweed produced at certain period.

Salinity is the level of salt content in water. Usually expressed in units of permits. This amount is expressed in units of weight (grams) of solid material (for example NaCl) contained in 1000 grams of sea water. Salinity is an important environmental factor that influences the ability to survive, growth and distribution in many aquatic organisms, one of which is seaweed (Kumlu and Jones, 1995; Kumlu *et al.*, 1999, 2000). The choice of location and control of salinity in the area of seaweed cultivation can increase growth and development of seaweed commodity production (Chand *et al.* 2015).

Wave height is due to the wind above the sea and because of the tangential pressure of water particles. Wave height affects sea wave height conditions suitable for seaweed growth ranging from 10-30 cm (Agricultural research and development agency 1990). High and large ocean seaweed cultivation area so that seaweed becomes damaged and is uprooted and carried by the waves.

Phosphate content is an important composition in the cultivation area to increase the growth of seaweed, so that phosphate concentration can affect the fertility and productivity of water lands (Bahri *et al.* 2016). Phosphate deficiency will reduce the productivity of seaweed commodities in the cultivation area. Minimum phosphate requirements for seaweed growth are influenced by nitrogen levels. According to Fritz (1989), the smallest limit of phosphate concentration to produce optimum seaweed growth ranges from 1,018-0,090 mg / PO4-P if nitrogen is in the form of nitrate, and if nitrogen is in the form of ammonium, the highest limit ranges from 1.78 mg / 1 PO4- P.

Dissolved oxygen is an important element in the respiration process and decomposition of organic material by microorganisms. Dissolved oxygen in water is the biggest substance in the marine habitat environment. This component is needed by marine animals, microorganisms and aquatic plants including seaweed. The amount of dissolved oxygen changes in marine habitat is significantly affected by temperature, where the higher the temperature the higher the dissolved oxygen concentration. The life of seaweed depends on the ability of seawater to maintain the minimum concentration of oxygen needed for the growth process.

The speed of seawater influences the growth of seaweed because it helps growth to be better due to seaweed getting food sources carried by the flow of sea water. The movement of sea water also avoids fluctuations in salinity and water temperature. The speed of seawater that is good for the growth of seaweed is in the range of 20-40 cm / s (Sediadi dan Budihardjo 2000).

According to Passerini *et al.* (2016), temperature is one of the factors that influence metabolism and survival ability of seaweed. Seawater temperature significantly affects photosynthesis rates and growth rates, where the maximum photosynthetic rate is in temperatures ranging from 20-30 oC (Glenn and Doty 1981, Mairth et al 1995, Ding et al 2013 and Redmond 2014).

Nursidi *et al.* (2017) stated that, an increase in nitrate would increase the growth of seaweed. An increase in the availability of nitrate sources is a sign that there is an increase in the amount of protein contained (Martins *et al.* 2011). Nitrogen is considered as the main nutrient for the growth of seaweed in the ecosystem maritime (Hanisak 1990).

Adipu *et al.* (2013) if the water depth is more than 10 meters, it will cause the cost of installing cultivation facilities and containers to be more expensive and more complex. Good water depth for Eucheuma cottonii seaweed cultivation is 30-60 cm at low tide for fast-moving, off-shore and 2-15 m methods for floating raft method, long line method and Path system. This condition is to avoid the drought of seaweed and optimize sunlight.

The protection of the cultivation area is one of the important factors in the growth and development of seaweed. The selection of cultivation locations in protected areas will reduce the impact of damage on marine organisms (Putra

2011). Based on Samad (2011), the open sea area will produce large sea waves and strong blowing angina, so it is not recommended as an area for seaweed cultivation. Sediadi dan Budihardjo (2000) stated that seaweed cultivation locations must be protected to avoid physical damage due to exposure to wind and large waves.

The degree of acidity (pH) in seaweed cultivation also affects seaweed cultivation. Effendi (2003), states that water with a pH level less than 4 and more than 9.5 can cause death in seaweed cultivation.

All factors that influence the cultivation of seaweed above are identified and used as input on the multi-layer perceptron neural network to produce the same variable for the following years. The design of this artificial neural network is called multi-input, multi output (MIMO). The design form is illustrated in Figure 3.

Hidden layer
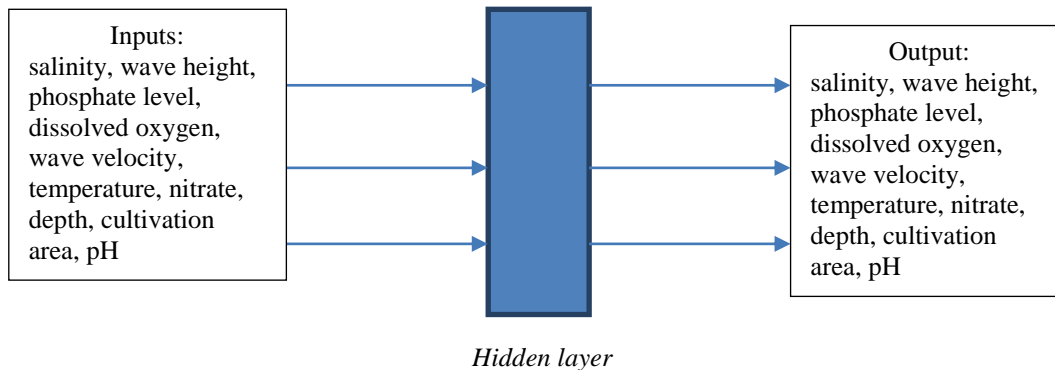
Figure 3:-MIMO illustration on multi-layer perceptron

Inferential Process (Inference) Using the Interval Approach Type 2 Fuzzy Logic System (IT2FLS) :-
IT2FLS is used to estimate the total availability of seaweed based on historical data through the inferencing approach. The selection of the inferential approach uses IT2FLS because of the concept of uncertainty in defining fuzzy membership that cannot be modelled using the fuzzy type 1 approach. Uncertainty is very suitable to use in the case of industrial raw material availability that requires special specifications and consumer demand patterns that tend to fluctuate. The stages of the inferencing approach using IT2FLS are shown in Figure 4. This approach is very much used for controls, rule-based classification cases, and cases with approximate values because IT2FLS is designed to minimize errors generated.
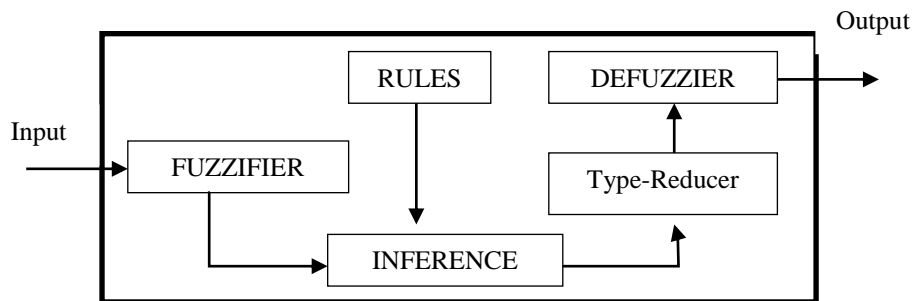
Figure 4:-Type 2 fuzzy logic system framework (Mendel *et al.* 2006).

The IT2FLS philosophy in answering uncertainty has several calculation structures that tolerate the following uncertainties:
1. The use of words that are used on antecedents and consequents of fuzzy rules, because the use of words can have different meanings for each person.
2. Uncertainty in consequents, because when rules are defined on fuzzy logic, they usually produce different consequences for each of the same rules.
3. Fuzzy membership function parameters. Because when the parameters are optimized using noisy training data, the parameters will have uncertainty.

In Figure 4 the measured input (crisp) is first transformed into a fuzzy set in fuzzifier blocks because the input is a fuzzy set that can activate fuzzy rules (not numbers). After input is fuzzy, the results of fuzzy functions are mapped into the output of fuzzy sets through the process of inferencing. The process is solved by calculating each rule using fuzzy set theory, using a fuzzy set mathematical approach, to produce output from each rule with the help of an inferencing mechanism. If there are as many as M rules, the set of fuzzy inputs is processed through the process of inferencing by activating only the related rules (subset) that correspond to the input into the inferencing process which has at least 1 rule and is usually smaller than M. The inferencing process is solved by one rule at the same time so that the output produced is infernal output from one or more specific rules used for each input and produces a set of fuzzy outputs.

The study used the association rule approach of Zaki *et al.* (2014) to determine rules by considering the support and confidence of each rule. Rules are generated based on data, not based on experts, which are generally used to generate fuzzy rules. This is based on the availability of seaweed data and can produce the design of seaweed agroindustry logistics systems that are more robust to the conditions of the business environment that are vulnerable to uncertainty. This concept is carried out by generating rules from previous historical data, so that the fuzzy rules used for the inferencing process are rules derived from the concept of association rules.

Type 1 fuzzy logic system, the process of producing output is called the defuzzification process, which is done by mapping fuzzy sets into numbers. There are several ways to do this process, first is to calculate the combination of outputs generated in the inferencing process of fuzzy rules and calculate the center of gravity of the fuzzy membership function, calculate the weighted average of the center of gravity technique of each rule outcome and so on.

In type 2 fuzzy logic systems, the defuzzification process becomes a little more complex, because to change the output in the form of numbers generated from the process of inferencing the fuzzy rules generally requires two stages. The first stage is called type-reduction, which is the reduction of IT2FLS into a fuzzy type 1 set. The second stage is processing output which is also called defuzzification. Because the set resulting from type-reduction in the fuzzy type-2 set is always in the form of interval numbers. The defuzzification process produces a value in the form of an interval.

Based on Figure 8, there are 2 kinds of output from IT2FLS, namely crisp numerical values and type-reduction result set. Output produces uncertainty measurement results that flow through the stages of IT2FLS. As a result of the uncertainty of input that activates the rules of inferencing both rules that have aspects of uncertainty in antecedents, consequents, or both. Type-reduction can provide a measure of the uncertainty in the crisp output value of IT2FLS.

Result and Discussion :-
Data Pattern Learning Results to Predict Environmental Conditions in Seaweed Producing Areas:-
Learning pattern data to predict the environmental conditions of potential areas to produce seaweed using the Multi-Layer Perceptron type neural network technique. This technique is implemented with the help of the Neuroph framework in the Java programming language. The first stage is carried out data learning process so that artificial neural network models are designed to be able to recognize data patterns so that they can be used to predict conditions in subsequent years in the seaweed growth environment of each district in South Sulawesi. The sample data for input is the sample data for the nth year and the sample data for output is the sample data to n + 1. The design of the neural network implementation uses the MLP approach with the sigmoid transfer function and the learning rules using backpropagation based on the Neuroph framework described in Figure 5.
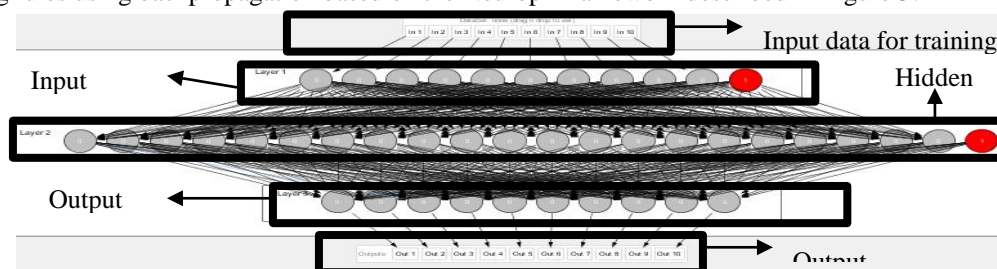

Figure 5:- Artificial neural network design for multi-layer perceptron in the study

The ten variables that are input and output in MLP have been explained in the discussion of the methodology of this study include salinity, wave height, phosphate level, dissolved oxygen, wave speed, nitrate concentration temperature, depth, protection and pH which are important attributes in determining the amount of seaweed produced at certain periods. After training, the weights at each node will adjust based on the pattern of data used as training. The data is first normalized so that artificial neural networks are able to produce errors close to 0 at the time of Epoch. The results of the weight in training data with a learning rate of 0.2 and momentum 0.7 are represented in Figure 6.
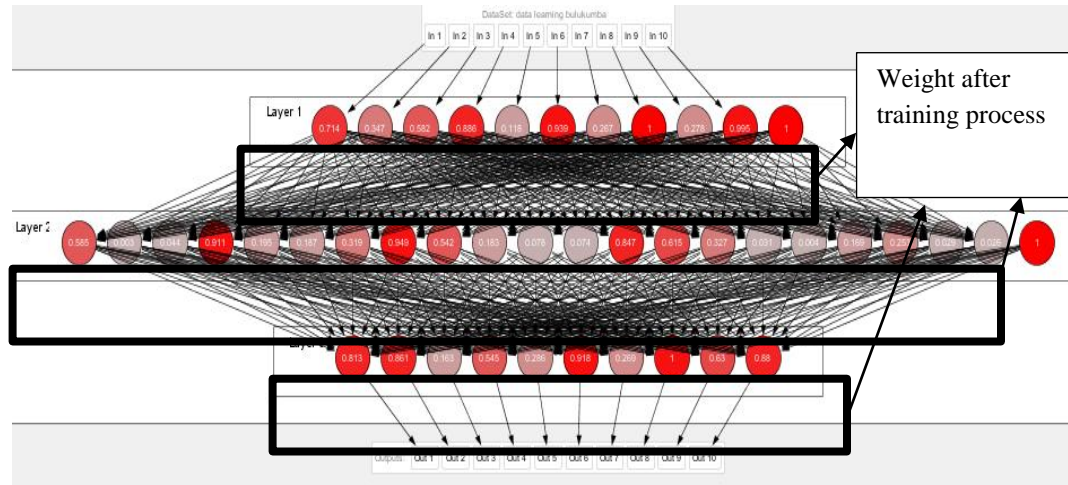
Figure 6:- Results of weight per neuron after the training process

While the errors generated in the training process are represented in Figure 7 The y axis is the total error and the x axis is iteration (Epoch) whose value of error is almost close to 0 so that it can be said that the generated neural network model is quite good.

If it is observed, the weight size is in accordance with the range of data that is input to the training data. After the Iteration (epoch) to 7700 there is a constant error which indicates that the artificial neural network model is able to recognize data patterns and discard some inputs that are not needed in the learning process. This model of artificial neural network will be used to estimate the data of the following years as an estimate of environmental conditions that affect the yield of seaweed in an area. The current year data will be added as training data on artificial neural networks so that the process of introducing and learning data in the MLP model is getting better.

These results are integrated with the help of Google Map on Android programming which is also Java based as a map of environmental conditions for the next year (2018). Examples of the results of estimates of environmental conditions in May 2018 in East Luwu District are shown in Figure 7.
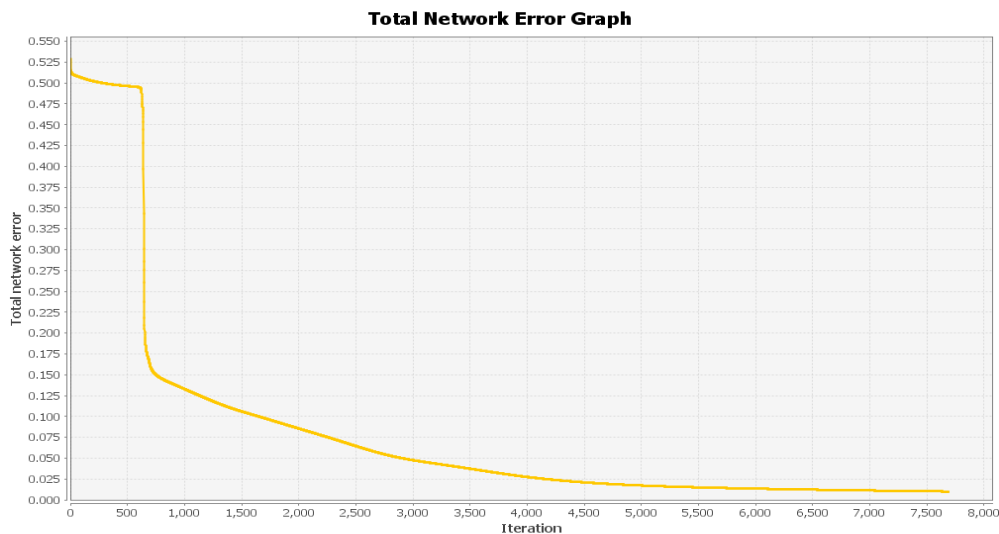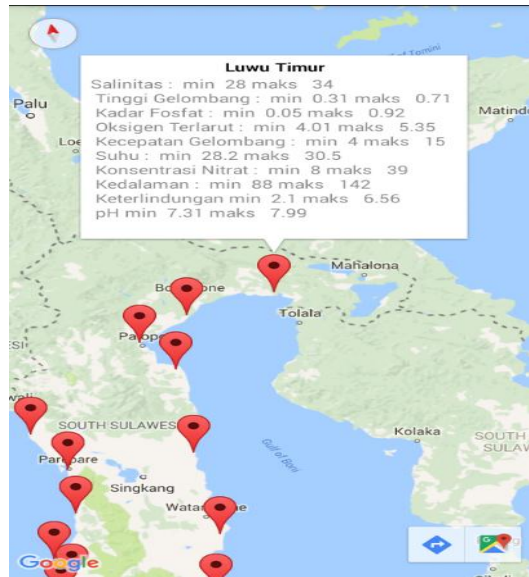
Figure 8:- Example of conditions for East Luwu for May 2018

Interval Based Inference Model Type 2 Fuzzy Logic System (IT2FLS) for Inferential Process Areas with Potential Seaweed Producers:-

The process of inferencing the IT2FLS was done by first designing the Fuzzy membership function for input variables, namely 10 Variables resulting from the output of artificial neural networks for environmental conditions in areas that are thought to have the potential to produce seaweed. One example of the membership function for salinity in Figure 9.
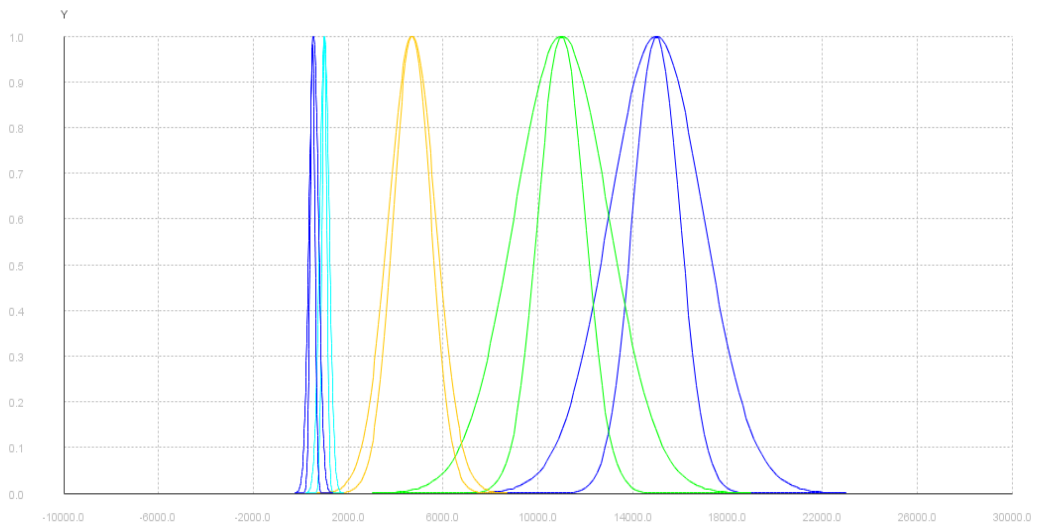
which is not potential, medium, and high potential. The function is presented in Figure 10.
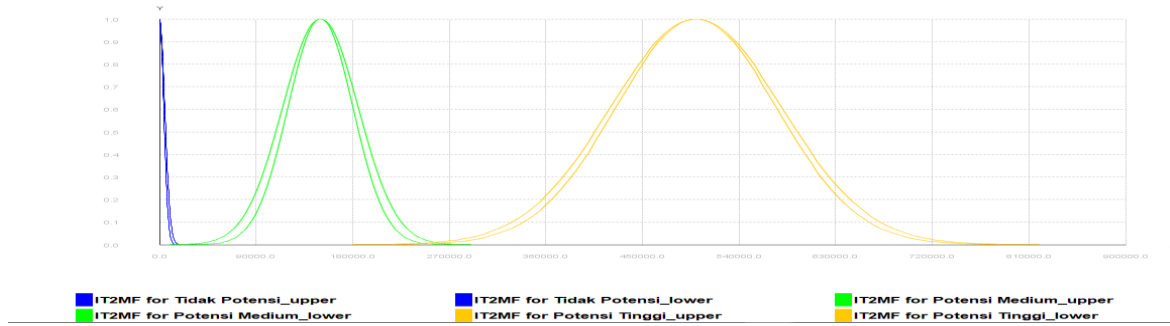
**Figure 10**:- Output membership function (regional potential)

Fuzzy membership function in the form of a normal curve because it is designed based on training data used in artificial neural networks and membership is determined based on some previous research in the specific field of environmental variables that affect the growth of seaweed (references are presented in the explanations of variables in the research methodology section)

While the rules designed for the inference process use association rules which are calculated with the help of WEKA software with the top 5 examples as follows (Table 2).

Table 2:- The top 5 rules for inference processes use association rules

Antecedent	Consequent	Confidence
If medium wave height, salinity, portable ground water, phosphate is suitable, oxygen is lively	Potential	0.80
If medium wave height, current velocity is appropriate, temperature is appropriate	Potential	0.80
If the temperature is suitable, the Nitrate is appropriate, the depth is appropriate, the protection is appropriate, the pH is appropriate	Potential	0.80
If the phosphate is suitable, the temperature is suitable, nitrate is appropriate	Potential	0.80
If velocity is appropriate, phosphate is appropriate, depth is appropriate, temperature is appropriate	Potential	0.80

The results of this inferencing process are estimates of the potential number of productions in an area in South Sulawesi. IT2FLS is integrated with Googlemap using the Java-based Android programming language so as to produce a potential map with an example of East Luwu district in Figure 11. Estimated land area is done by dividing the total estimated production per estimated yield per ha.
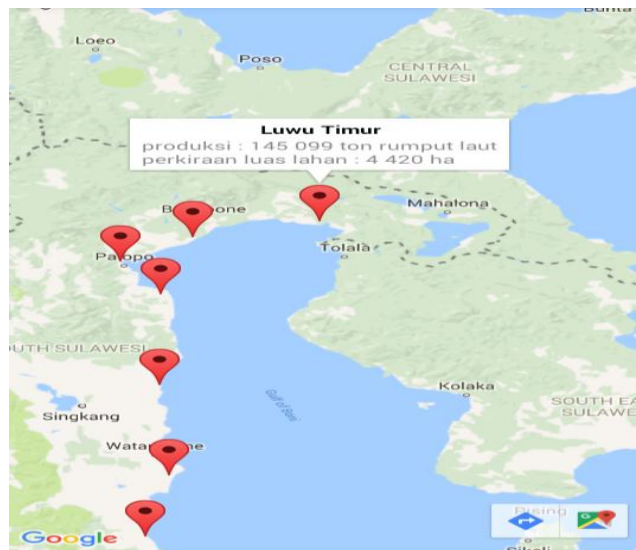
Conclusion :-

The results of the artificial neural network design to estimate the amount of seaweed demand and potential areas for leut grass development show that the resulting training process error is close to 0 so that the design of the artificial neural network can be said to be good. Regional potential using artificial neural networks is integrated with IT2FLS to produce a mapping of regional potential and an estimate of the amount of seaweed produced by a region in a given year. The mapping framework in this research can be used to help decision maker in planting and planning seaweed aquaculture and also can be integrated with other system to help decision making process such as optimization and other computational research in seaweed business. We suggest future research in development optimization model as successor of this research in strategic level for seaweed business development. The optimization model such as planning seaweed industrial development, downstream process, logistic, trading and other research related to seaweed supply chain management.

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