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OPTIMISING CATTLE BODY WEIGHT WITH *TERUBUK* WASTE FEED FOR SUSTAINABLE AGRICULTURE

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Purpose. This research aimed to predict the increase in cow weight through the use of *terubuk* (*Saccharum edule* Hassk) waste feed technology based on pH content, silage water content (KA), silage dry weight (BK), and silage fermentation value (NF) on daily increase in cow weight.
Results. The results showed that an optimal increase in cow weight by using *terubuk* waste silage is achievable when silage formula is at pH value of 4.15, KA 74.1, BK 36.6, NF 85.4, and protein 11.2. The values produced the most optimum weight increase during daily observations, namely 1.03 kg/day. These results show that the use of feed technology through *terubuk* waste silage as an alternative feed based on predictions proved to be very effective in increasing cow weight. Consequently, the development of cow farming businesses could be more efficient based on predictions of weight increase based on input variables contained in waste silage used as feed. The feasibility of implementing innovations in the field of using *terubuk* waste as an alternative feed is

substantiated.

Scientific novelty. Utilising *terubuk* waste feed technology as an alternative feed processed into silage, is a new sustainable solution in the livestock industry. A prediction model for increasing cow weight based on the content of crushed waste silage was created. Other scientific values obtained also show that based on predictions through its utilisation, it can increase production efficiency in the era of sustainable agricultural systems.

Practical value. Increasing optimal cattle weight is a goal that every farmer wants to achieve in running their livestock business. Use of *terubuk* waste as feed can be an alternative solution in overcoming the problem of food scarcity and increasing production efficiency in the era of sustainable agricultural systems.

Key words: feed, landfill waste, cow, prediction, efficiency, innovations, sustainable agriculture.

1. Introduction

The main focus of sustainable agriculture is to achieve a golden Indonesia by 2045, which is planned through four stages. These stages include transformation foundation, transformation acceleration, global expansion, and golden Indonesia. Transformation comprises economic, socio-cultural, and ecological transformation. The emphasis on economic transformation includes the downstream of natural resources, research, and innovation as well as a green economy (Bappenas, 2019), particularly the issue of food.

Food needs continue to increase along with a rise in population, which affects the level of nutritional adequacy of the community. One important food source that should be fulfilled is animal food as the main production of protein. As ruminant animal, cow produces food with high nutritional value and supply two major nutrients needed by humans, namely protein and lipids. Ruminant population is quite high in Indonesia and meat consumption is expected to continue to increase. According to Norra et al. (2021), to meet protein needs, a minimum of 1 g/kg body weight is needed, comprising a quarter of animal sources. In Indonesia, the backbone of beef supply is generally small and medium breeders. However, breeders are faced with various obstacles in running the businesses. The main obstacle in the livestock sector, including in cow beef business, is related to feed. As reported by Dwiprasetyo et al. (2023), feed in the livestock business is a major requirement that often experiences problems, specifically in terms of supply.

The majority of livestock farmers still depend on seasonal forages and the use of waste or by-products from crops. Although forage is the main feed for livestock, specifically ruminant, the availability is often not commensurate with the number of livestock available. Various efforts have been made to obtain different new feed sources that can be used as alternative ingredients. Innovation is needed to overcome the problem of the availability of feed sourced from green fodder. These include industrial and agricultural waste as a substitute for the main forage for ruminant livestock. According to Castaño-Sánchez et al. (2023), the success of livestock business is closely related to the availability of feed ingredients both in quantity and quality. In this context, various innovations are required to replace or supplement nutritious feed for ruminant livestock for sustainable growth and development,

including by utilising *terubuk* (*Saccharum edule* Hassk) waste.

To overcome problems related to this feed, breeders can use *terubuk* waste as an alternative feed. Apart from being consumed, *terubuk* can also be used as animal feed to overcome the main obstacles faced by breeders in increasing cow productivity. Based on previous research, in 1 ha of *terubuk* plants, an average wet biomass in the form of leaves is obtained at approximately 11,300 kg/ha to fulfill feed needs of 4 cows for 90 days (Chaniago, 2015). The results of Sukmawani et al. (2018) on industrial trees showed that all parts of *terubuk* plant could be used, including waste as alternative animal feed. Sukmawani et al. also supported the experiment on silage trials using *terubuk* waste as raw material carried out by (Putriyana, 2019). The results showed that *terubuk* waste increased the weight of cow. The use of reef waste as an alternative feed ingredient, specifically when applied during the dry season, has also been proven effective in overcoming limited forage availability. However, *terubuk* waste needs to be preserved and maintained, namely by making it into silage through fermentation. Silage is a fermented feed product from forage that is preserved using acids either added or naturally produced during storage in anaerobic conditions (Moran, 2005). The aim of fermenting forage for animal feed is to maximise the preservation of the nutrient content and extend storage time.

Terubuk (*Saccharum edule* Hassk) is an *indigenous* vegetable that can be processed into various types of dishes. Generally, it is processed from sauteed, steamed, vegetables, grilled, and fried to be eaten directly as fresh vegetables, with waste serving as animal feed (Sukmawani et al., 2017). The results of Sukmawani et al. (2021) showed that by using the basic ingredients of landfill waste as animal feed, the advantages obtained included savings in production costs and time with sustainable availability of feed.

Recent research has been conducted by Sukmawani et al. (2019) in Indonesia, specifically, Sukabumi Regency comprising 47 districts, 381 villages, and 5 sub-districts. Based on the results, approximately 50% of the districts were found to have coral reef plants. This has the potential for developing *terubuk* as a food ingredient that can be consumed and used as alternative animal feed.

Terubuk is sugar cane eggs, which are widely cultivated by the community as a tumpang sari plant in gardens or on rice fields. This plant has promising economic value because *terubuk* flowers can be consumed and are widely favored. In Sukabumi, the stems and leaves are left as waste, with only a small portion being used as green fodder for livestock. *Terubuk* is a promising forage for livestock because it grows easily, both in the dry and rainy seasons. During the dry season, when little grass grows, reefs can be used as an alternative to provide green fodder for livestock. This is important for the sustainability of livestock businesses and sustainable agricultural development.

The application of technology for using *terubuk* waste as alternative feed is beneficial for small breeders in overcoming feed problems, positively impacting production efficiency in the livestock businesses. Therefore, this research aimed to

create a prediction model for increasing cow weight based on the content of crushed waste silage. Analysis was also carried out on the production efficiency in beef cow farming that used *terubuk* waste feed technology as an alternative.

2. Review of literature

Agricultural development should be directed towards a sustainable concept. This is important as an effort to fulfill current needs without reducing the ability of future generations to fulfill their needs. Sisworo (2006) said, that along with the increasing population, sustainable agriculture must be able to meet food needs. Therefore, sustainable agriculture must not only maintain the land's ability to produce food but must also be able to increase its productivity. To achieve this, according to Sisworo (2006) in implementing sustainable agriculture, it must be able to improve the quality of the environment and natural resources based on agricultural economic needs. Therefore, using natural resources must be efficient, including by utilising available resources in an integrated manner and utilising biological control and cycles if possible.

The importance of paying attention to the availability of food supply for future generations is the foundation for Indonesia in realising the golden Indonesia 2045 through sustainable agriculture as the main focus. Perlas (1993; 2000) succeeded in formulating seven dimensions of sustainable agriculture, namely: 1) ecologically sound; 2) associative economics; 3) socially just / equitable; 4) culturally appropriate; 5) holistic science; 6) appropriate technology; and 7) development of human potential. These seven dimensions, if applied, can produce a generic model of sustainable agriculture as shown in Figure 1.

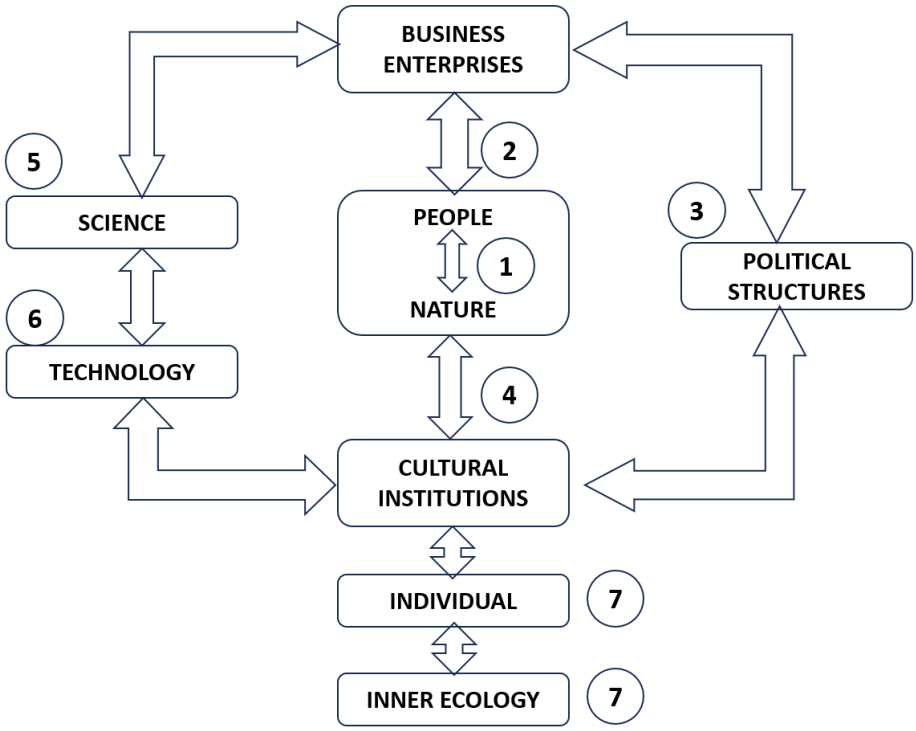


Figure 1. Generic model of sustainable agriculture

Source: Perlas (1993; 2000).

The generic model of sustainable agriculture as presented in Figure 1 can be applied to the concept of integrated farming, specifically an integrated system between plant and animal production practices in a location and the long-term function. Integrating this concept emphasises the principle of agriculture that it can maintain the balance of the ecosystem to increase high productivity. This also applies to *terubuk* farming and cattle farming, where *terubuk* farming can produce *terubuk* flowers for consumption and its waste can be used as cattle feed. The use of *terubuk* waste as an alternative feed is one solution to overcome the main obstacles in the livestock sector, including those related to feed. Feed is the main need that often experiences problems in livestock farming. Utami & Rangkuti (2021) stated that in an integrated farming system, plants will be a source of food for humans as well as a source of feed for livestock. Meanwhile, the livestock that is managed will produce the main product as a source of food for mammals and also produce by-products that can be processed to become a source of nutrients for plants. This concept is then applied to the use of *terubuk* waste as an alternative feed in this study which is applied to cattle.

3. Methodology

This research was carried out in Sukabumi Regency, specifically at UPP (Breeding and Feed Unit) of Sukabumi Regency Livestock Service. Consideration in selecting the location was because at UPP there were reef plants available, deliberately developed as an alternative feed. This was based on research collaboration between Muhammadiyah University of Sukabumi and Sukabumi Regency Livestock Service. At UPP, there are also cow needed for research to facilitate field testing as well as groups of local breeders who were under the guidance of UPP Animal Husbandry Service as respondents.

This research applied a quantitative descriptive method using ANFIS (Adaptive Neuro-Fuzzy Inference System). ANFIS program is an adaptive neural network based on a fuzzy inference system (Mujiarto et al., 2019). Moreover, the system is often used due to the easy-to-understand nature, flexibility, consideration of inappropriate data, ability to model nonlinear data, as well as build and apply the experience of experts directly (Palupi et al., 2021). It also has the benefit of simulating human knowledge's qualitative aspect and the decision-making process' mechanism through created instructions (Faisal et al., 2012). The benefits of artificial neural networks include the ability to identify patterns, learn new things, and solve issues without the use of mathematical models (Ogunwolu et al., 2011). This is based on historical data that were entered to predict future events (Dahal et al., 2023).

The architecture of ANFIS program has similarities with artificial neural networks. A corresponding fuzzy inference system is created based on the input-output data set, and the parameters of the membership functions that modify the input data are calculated. The general structure of ANFIS program consists of five layers, as shown in Figure 2.

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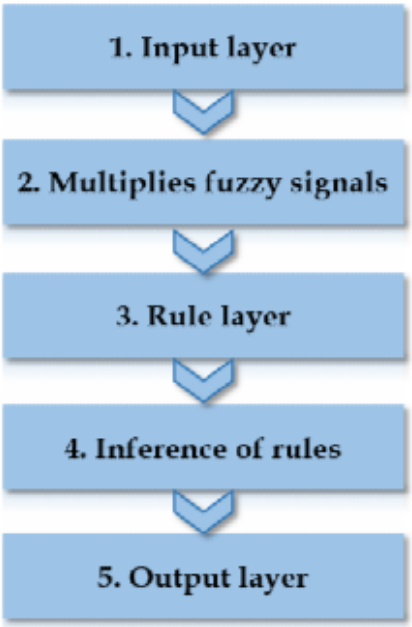


Figure 2. ANFIS layer

Source: primary data.

An inference system named ANFIS is based on fuzzy logic and artificial neural networks. With the assistance of this system, models that can adapt to data can be created by merging fuzzy logic with artificial intelligence (neuro). The ANFIS software in this study has five primary layers, the first of which is the layer 1 process (fuzzification), which is the first step. It is the stage of the data input process in the research, which consists of pH (potential of Hydrogen), silage water content (KA), silage dry weight (BK), and silage fermentation value (NF), on the daily increase in cow weight. Layer 2 (fuzzy logic operations), layer 3 (activation degree normalisation), layer 4 (defuzzyfication), layer 5 (output). Additionally, ANFIS uses a hybrid algorithm to adjust the parameters contained in the system. The hybrid algorithm is divided into 2, namely forward and backward learning. In forward learning, LSE Recursive algorithm is used, while Error Backpropagation (EBP) algorithm is applied in backward learning. To determine the error level of the predictions produced, the error measurement is carried out using RMSE, as shown in Figure 3.

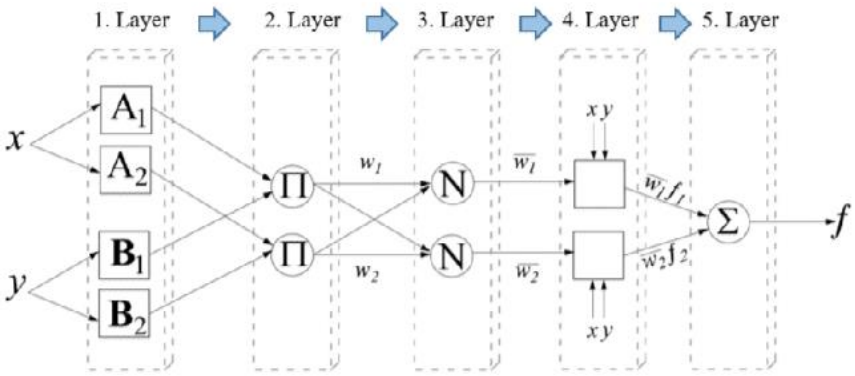


Figure 3. ANFIS model architecture

Source: Faisal et al., 2012.

Figure 3 shows that there are two types of nodes, namely adaptive with a square symbol and nodes with a circle symbol. The output of each layer is denoted by Oj, where is the number of rules and i is the number of layers. According to Kusumadewi & Hartati (2010), ANFIS network consists of five layers as follows:

Layer 1 (fuzzy layer)

Each node in layer 1 is an adaptive node, which indicates that parameter values can change with the node function as follows:

$O1{,}1t = \mu A1\ (Zt{-}1)$

$O1{,}2t = \mu A2\ (Zt{-}1)$

$O1{,}3t = \mu B1(Zt{-}2)$

$O1{,}4t = \mu B1(Zt{-}2)$

With "dan" is the input at the *i*-th node. Meanwhile, dan−2 are the membership functions of each node 1, which functions to express the degree of membership of each input to fuzzy sets A and B with 1, 2, 1, 2 being linguistic variables. In this research, the generalised bell membership function is used, which is expressed as follows:

$$\mu_A(x_t) = e^{\frac{-(x_t-c)^2}{2\sigma^2}}, \tag{1}$$

$$f\ x;\ a_i,\ b_i,\ c_i\ = \frac{1}{1+\frac{x-c_i{}^{2b_i}}{a_i}}, \tag{2}$$

where dan is a set of premise parameters. By taking the value = 1, only parameters will experience changes in the learning process. The generalised bell curve will change if the value of the parameter's changes.

Layer 2 (product layer)

All of the nodes in layer 2 are non-adaptive, and the parameter values are fixed. Each incoming input signal is multiplied by node function as follows:

$$O_{2,\,I}\ = wi = \mu_{Ai}\,(x).\,\mu_{Bi}\,(y);\ I = 1{,}2. \tag{3}$$

Each output node states the degree of activation for all fuzzy rules. The number of nodes in this layer determines the number of rules that are generated.

Layer 3 (normalisation layer)

Every non-adaptive node in this layer expresses a normalised degree function, which is the following ratio of the output of the *i*-th node in the preceding layer:

$$O_{3,1} = w_t \frac{wi}{w1+w2},\ dengan\ i = 1{,}2. \tag{4}$$

When there are more than two rules, the function can be enlarged by dividing by the total number of w for all rules.

Layer 4 (defuzzification layer)

Each node in this layer is an adaptive node with the following functions:

$$O_{4,1t} = w_{1t}^{*} Z_t^{(1)}\ = w_{1t}^{*}(a_1 Z_{t-1} + \beta_1 Z_{t-2} + \Upsilon_1, \tag{5}$$

$$O_{4,2t} = w_{2t}^{*} Z_t^{(2)}\ = w_{2t}^{*}(a_2 Z_{t-1} + \beta_2 Z_{t-2} + \Upsilon_2, \tag{6}$$

where αi, βi, γi are the set of parameters of the node, called consequent parameters.

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Total Output Layer (layer 5)

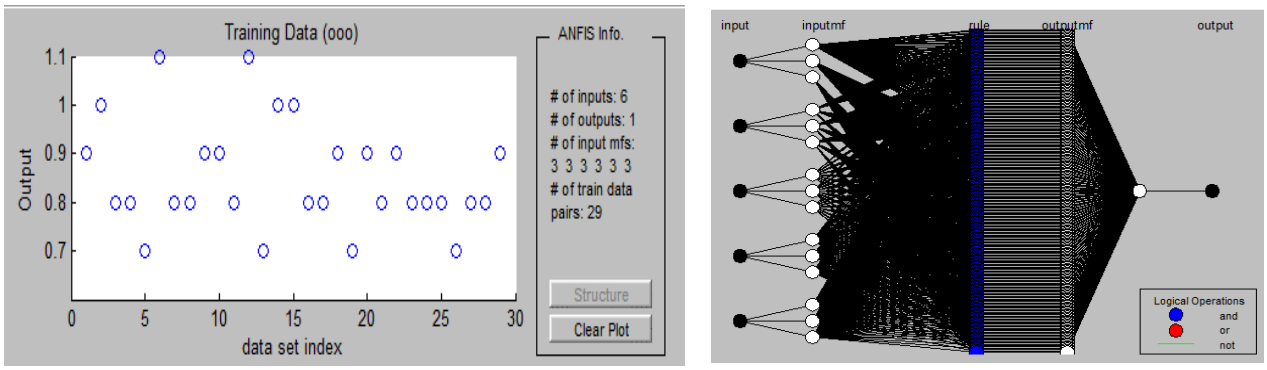
Total output layer functions to add up all input with the following node function:

$$O_{5t} = \hat{Z}_t = w_{1t}^* Z_t^{(1)} + w_{2t}^* Z_t^{(2)}. \quad (7)$$

4. Results and discussion

In this research, the design was built using primary data based on the collective results from routine observations of samples. These consisted of 5 input data as variables, namely pH (potential of Hydrogen), silage water content (KA), silage dry weight (BK), and silage fermentation value (NF), and protein into ANFIS program. Therefore, ANFIS automatically built an input data model that formed rules as a reference in building predictions of cow weight as output. Silage applied was the best formula according to Ratnasari et al. (2023), namely a mixture of 6% bran, 3% sugar, 0.02% water, and 0.0008 EM4, fermented for 21 days. Based on this formula, the best NF value was obtained, where Idukut et al. (2009) considered silage as good quality when NF value was 85–100.

Figure 4(a) shows the distribution of input data into ANFIS program with a total of 30 daily observations of weight gain based on the impact of providing silage. According to the distribution of input data, ANFIS will automatically build an initial model as a guide in building rules for predictions. The initial model built by ANFIS program is shown in Figure 4(a).



a b

Figure 4. ANFIS model architecture

Source: data analysis.

Determining training errors tested should be done to input data entered into ANFIS, where 0 serves as the tolerance value. In this research, the number of epochs used was 100. After that, ANFIS starts the training process until the specified number of epochs is reached. When the training process for each epoch has been completed, the error obtained on the main graph is shown. As presented in Figure 5, the value of ANFIS train error is 0.192. This shows that the input data can be used for training in building predictions in ANFIS program with an analysis requirement of RMSE < 0.5. Additionally, the results show that the input data will be read by ANFIS program accurately.

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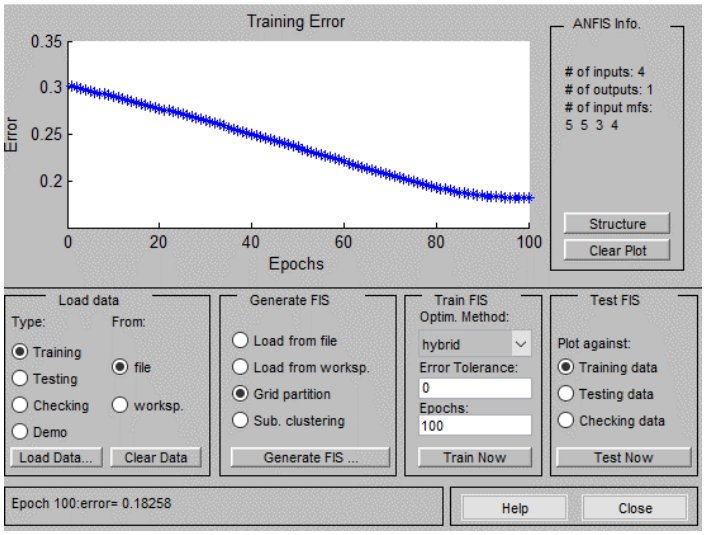


Figure 5. Training data and determination of error tolerance for ANFIS programming

Source: data analysis.

ANFIS shows the accuracy of training data on the editor graph. As shown in Figure 6, training data and results are symbolised by a blue circle and a red star, respectively. ANFIS trains the training data with increasing precision as indicated by the red star's location within the blue circle. In terms of accuracy in providing data output, the proposed system is of higher quality when the average training error is reduced, bringing it closer to the error tolerance. The testing data performance, however, deteriorates when the red star's position becomes farther from the blue star. When the test results are good and the average test error is getting close to the target error tolerance, which is 0, the new system can be deemed successful and ready to use.

Based on Figure 6, the red star is in the blue circle, showing that the input data has an error value close to 0. Therefore, the input data in the form of the variables pH, BK, KA, NF, and protein can build a cow weight prediction model that ANFIS program will issue.



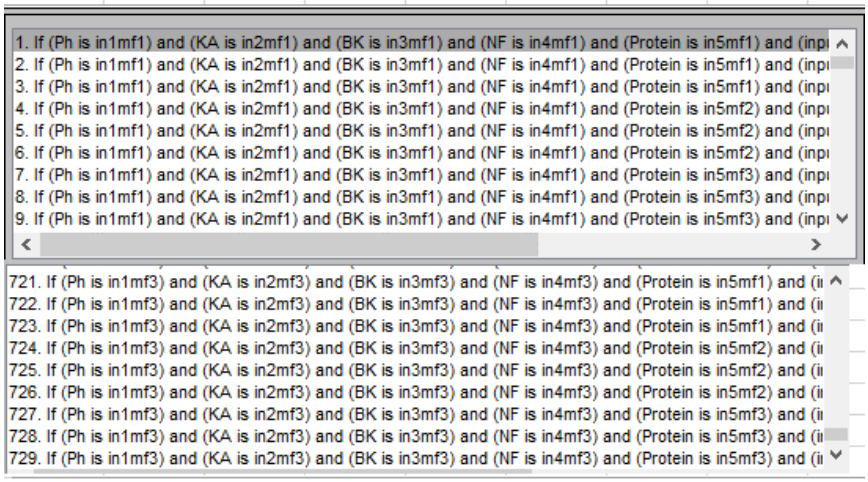
Figure 6. Training input data for ANFIS program

Source: data analysis.

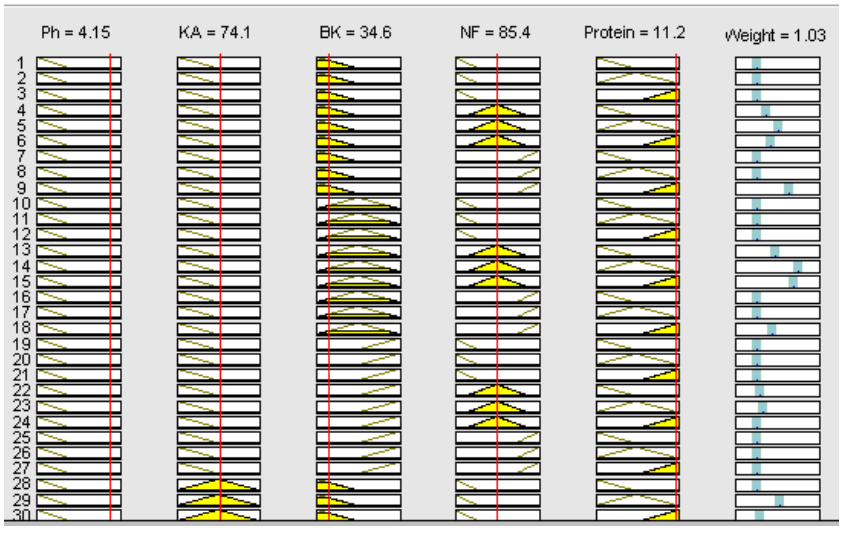
Based on the input data, ANFIS program automatically builds the rules. From the

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input data of 5 variables, a total of 729 rules were formed by ANFIS, as shown in Figure 7(a). These rules could be visualised in the program to determine the real-time effect of each variable on the prediction output. Figure 7(b) shows that when the parameters in the rule viewer are moved manually, changes will be immediately visible in the model. Among the 729 rules created, one example of the rule in Figure 7(b) built by ANFIS was considered the best result. This showed that the best values for the variables pH, KA, BK, NF, and protein were 4.15, 74.1, 36.6, 85.4, and 11.2, respectively. The values produced the most optimum weight increase during daily observations, namely 1.03 kg/day. These results show that an optimal increase in cow weight by using terrestrial waste silage is achievable when silage formula is at pH value of 4.15, KA 74.1, BK 36.6, NF 85.4, and protein 11.2.



a



b

Figure 7. (a) Rules created by ANFIS program, (b) ANFIS rules viewer

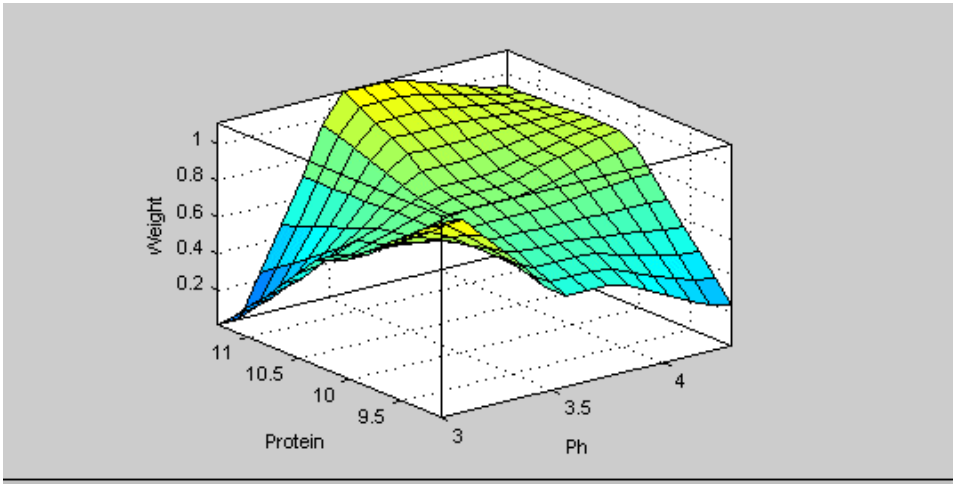
Source: data analysis.

Figure 8 is the result of the 3D surface visualisation built by ANFIS program. Specifically, Figure 8(a) is a visualisation of the variables pH and protein on the daily weight increase of cow. From the surface visualisation, pH values in the range 3–3.5 and protein in the value range 10–11 can increase cow weight by 0.8–1 kg every day.

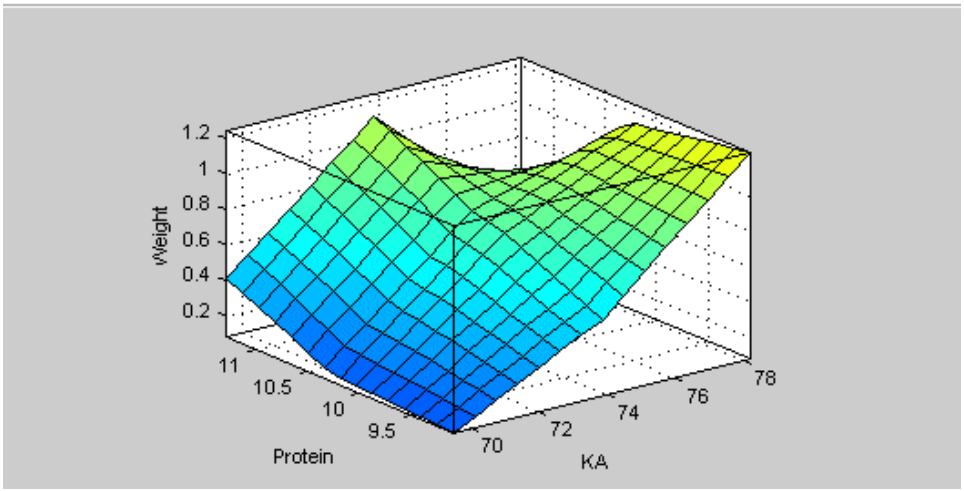
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These results show that to obtain good silage to increase the daily weight of cow, the quality of feed from pH and protein aspects requires significant consideration. pH is an important part of determining silage quality.

Apart from pH and protein, other variables are also included in determining the quality of silage for cow feed. As in Figure 8(b), it is a visualisation of KA and protein variables on the increase in cow weight. Based on the surface visualisation, a good KA value for weight is in the range of 72–74 and protein on a scale of 10–11.



a



b

Figure 8. Visualisation of surface images from ANFIS program results in (a) visualisation of pH and protein variables on increasing cow weight, (b) visualisation of KA and protein variables on increasing cow weight

Source: data analysis.

Each input variable has the influence on the output variable. From the results of ANFIS prediction analysis, it can be observed the pattern of influence of each variable on the increase in cow weight. Figure 9(a) indicates that protein is directly proportional to the increase in cow weight, while 9(b) shows direct proportionality between pH and cow weight. In Figure 9(c), KA is directly proportional to the increase in weight, while 9(d) shows the characteristics of weight increases based on the range of NF values. As presented in Figure 9(e), BK is inversely proportional to the increase in cow weight.

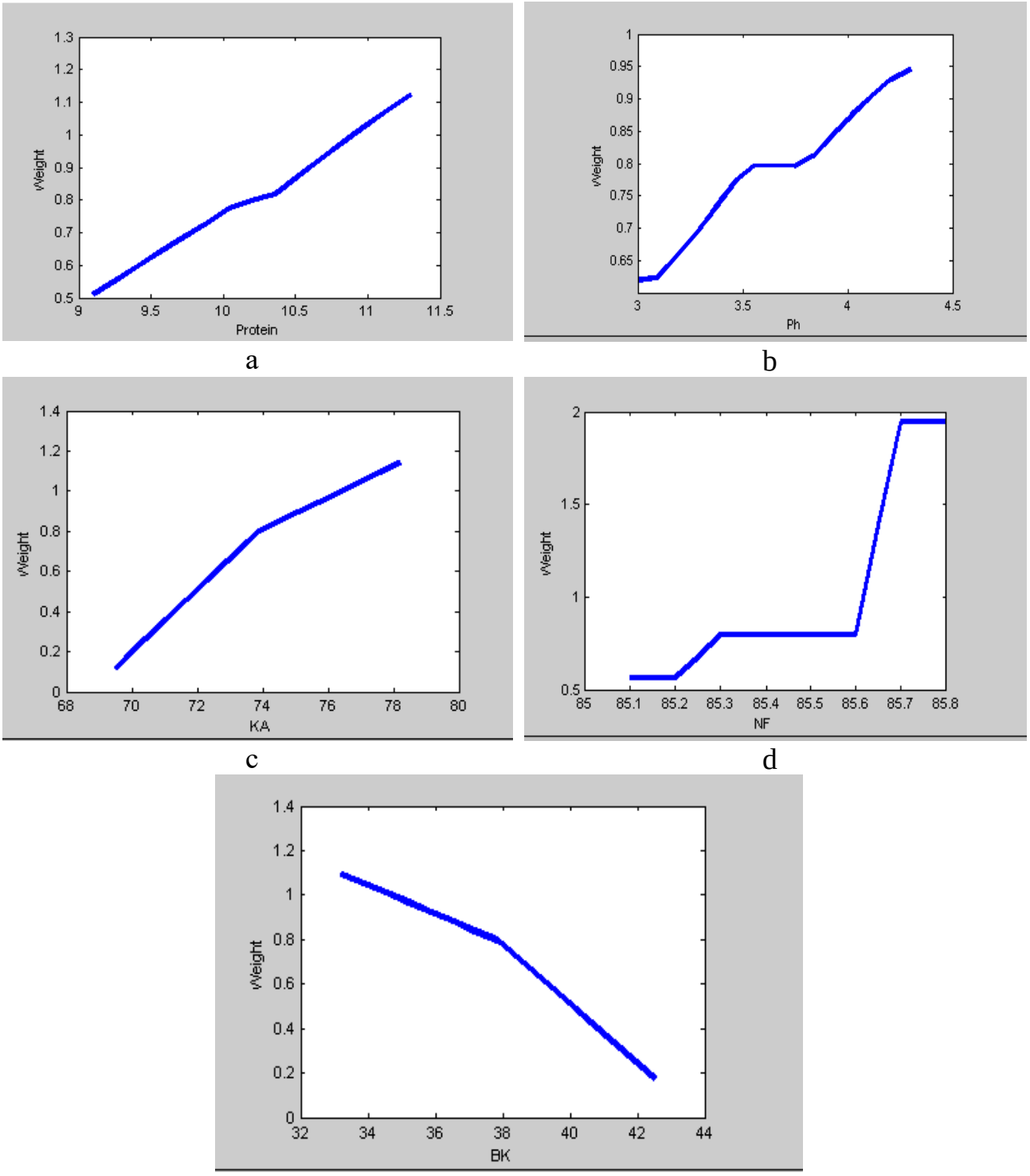


Figure 9. ANFIS prediction based on each input variable against the output variable

Source: data analysis.

This ANFIS prediction model can be assessed from the accuracy by comparing the input training data to observational or actual data. In this research, an accuracy of 99.6% was obtained, as shown in Figure 10, indicating that the input data in the model could represent real data in the field.

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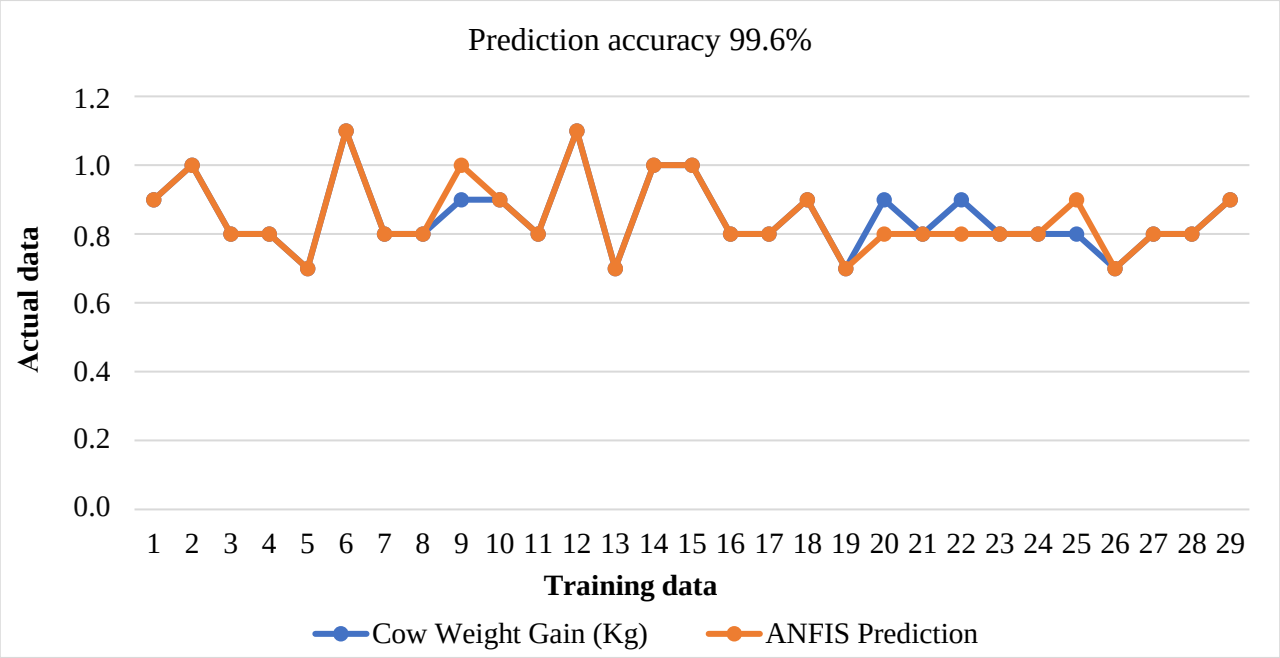


Figure 10. Accuracy of ANFIS program prediction

Source: data analysis.

The backbone of providing beef as a source of protein food in Indonesia is small and medium breeders. Despite playing a major role, breeders are faced with obstacles related to feed in running the livestock businesses. The results of this study indicate that input data in the form of variables Ph, BK, KA, NF, and protein can build a prediction model for cattle weight that will be issued by the ANFIS program. This showed that the best values for the variables pH, KA, BK, NF, and protein were 4.15, 74.1, 36.6, 85.4, and 11.2, respectively. The values produced the most optimum weight increase during daily observations, namely 1.03 kg/day. These results indicate that the optimum increase in cattle weight by utilising *terubuk* waste silage will be achieved when the silage formula is at the pH value of 4.15, KA 74.1, BK 36.6, NF 85.4 and Protein 11.2. Moreover, the increased optimal weight of cow is the main objective of all breeders when running their livestock business. This is to significantly support the achievement of sustainable agricultural development goals. Specifically, SDG goal number 2 aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture (Deaton, 2020).

Based on the result of the 3D surface visualisation develop by analysis ANFIS known that the increase in cow weight will reach 0.8–1 kg per day if the silage pH is between 3–3.5 and the protein value is 10–11. A good KA value for weight is in the range of 72–74. This shows that in order to obtain the best quality silage so that it can increase the weight of cattle, it is necessary to pay attention to the elements of pH, protein and water content. According to (McDonald et al., 2022), the quality of silage can be observed based on its OH value, which is around 4.50–3.50. This is supported by the results of Sadarman et al. (2023), where acidic or low pH silage indicates that the material ensilage process is going well, resulting in good silage. Quality silage also contains good protein, which is needed by livestock for antibodies to maintain the

immune system (Santoso, 2022). Meanwhile, the amount of KA in silage will influence the composition of the overall percentage of nutrients because it can determine BK (Zuliansyah et al., 2023).

Of the five input variables, only BK is inversely proportional to the increase in cattle weight, while the other input variables show a direct proportionality to the increase in cattle weight. This result is proven to be accurate (99.6%) which means it represents real data in the field. Therefore, decision-making in developing cow business could be more efficient based on prediction of weight increase according to the input variables contained in silage used as cow feed. Efficiency is important in business, particularly in agriculture which has the characteristic of a longer waiting time in trying to produce results. This efficiency is closely related to the amount of input used in business activities. Either farming or livestock, inefficiency can occur when business actor is unable to allocate the use of existing input to produce maximum output (Baihaqi et al., 2022). This research proves that using production input such as feed from *terubuk* waste is very efficient in increasing optimal output in the form of increasing cow weight.

5. Conclusions

In this study, the prediction of the increase in cow weight through the use of *terubuk* (*Saccharum edule* Hassk) waste feed technology was carried out based on pH content, silage water content, silage dry weight, and silage fermentation value on daily increase in cow weight. The use of *terubuk* waste feed technology as an alternative feed processed into silage is a new sustainable solution in the livestock industry. The use of *terubuk* waste as feed could be an important alternative solution to overcome food shortages and improve production efficiency in the sustainable agricultural systems.

This research showed that the use of *terubuk* waste silage as an alternative feed based on predictions proved to be very effective in increasing cow weight. An optimum increase in weight was achieved when the formula was at pH value of 4.15, KA 74.1, BK 36.6, NF 85.4, and protein 11.2. These results represented real data in the field, therefore, the development of cow farming businesses could be more efficient based on predictions of weight increase according to input variables contained in waste silage. The implementation of innovation in utilising *terubuk* waste as alternative feed is not only beneficial for small farmers in overcoming feed problems but will also have a positive impact on increasing production.

6. Limitations and future research

Terubuk is also not the main commodity cultivated by farmers. Although it is found in almost all regions, the development of its farming is only limited to intercropping or hedge plants and intercropping. Based on this, to support the use of *terubuk* waste as alternative feed, further studies are needed on the development model of *terubuk* integrated with livestock, especially ruminant livestock.

Conflicts of interest: the authors declare no conflict of interest in relation to this study.

Use of artificial intelligence: the authors confirm that they did not use artificial

intelligence technologies during the creation of this work.

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