ISSN 1816-6075 (Print), 1818-0523 (Online)
Journal of System and Management Sciences
Vol. 13 (2023) No. 3, pp. 128-138
DOI:10.33168/JSMS.2023.0309

A Generic Fuzzy Decision Support Model based on Plant Computational Model for Agriculture Investment Decision

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Abstract. Farming investment decision is risky. Numerous constraints should be deliberated in such a purpose. One of considerations to invest is an economic opportunity of plant type. Thus, the model that can predict the investment opportunity based on one plant is required. Here, the study conducted aims to construct a virtual plant model operated to support making a decision of agricultural investment in the succeeding constructed model (decision support model, DSM). Virtual plant model itself is a plant computational model (PCM) can produces three functional, morphological, and statistical facets of plant. PCM is a computer based model illustrating the plant in such three features. The functional aspect talks about the biological process in the plant, the morphological aspect speaks regarding the plant physically in three dimensions (3D), and all data and information finally are released and provided statistically. Finally, a DSM based on PCM is final destination of the study. The constructed DSM is operated to suggest the investment decision ultimately, specifically in the hydroponic vegetable plant Bok Choy (*Brassica Chinensis L.*). The main methods operated are fuzzy logic (FL) and structural-functional plant modeling (FSPM) for developing DSM and PCM respectively. The best investing value that gives the best breakeven point (BEP) is suggested thru model simulation; where investor should plant 16,198 plants of hydroponic Bok Choy with total investing cost approximately IDR 17,790,285 (or US$ 1,148). The BEP calculated itself has accuracy value of 94.33%.

Keywords:

1. Introduction

Decision support model (DSM) is a computer based model functioned to assist decision makers in making a decision to resolve the problem. The problem confronted is structured-unstructured problem habitually by seeing a lot of decision parameters in various cases, including in agriculture area. On the other hand, plant computational model (PCM) is a computer model to point-out the plant physiologically, morphologically, and statistically. The PCM, practically in agriculture case, can deliver a number of processed information as an input for the DSM; and the DSM act toward to become an actionable decision then.

DSM itself has become a research domain that ever conducted by many researchers. Jung et al. (2022) conducted a DSM specifically for planning a new drug development. The model developed based on machine learning. Sitek et al. (2022) made a DSM for handling customer order by combines routing, allocation, and planning problems for restaurant chains. Then, Li et al. (2022) constructed a DSM as well for ship navigation in Arctic waters. The model constructed based on dynamic risk assessment; where the dynamic Bayesian network (DBN) analysis method was functioned to guess ship Arctic navigation risk, and acquire risk maps of the entire Arctic waters.

Furthermore, also, a lot of researchers conducted a study in PCM. Kurth and Ong, (2017) built a design of extensible language (XL) in implementing multiscale models. The experiment was performed via a fruit tree simulator. Utama et al. (2015) developed a virtual plant model consisting two sub-models: rice plant and skylight model. The conclusion said that the plant architecture and leaf shape affect the quantity of light capture. Merklein et al. (2018) created a dynamic model of xylem and phloem flux in an apple branch. By using the method of functional and structural plant modeling (FSPM), the constructed model clearly explained the water and sugar transportation in the apple (*Malus domestica (L.) Bartsch.*) branch. Chi et al. (2022) rebuilt the leaf model at the example of digitized red mangrove (*Rhizophora mangle*) and the created an application of simulation for light interference by single leaf. Fabrika et al. (2019) found the branching pattern of young spruce trees growing. The study results demonstrated the best frequency of growth units in the first and second order.

The gap discovered in the research is actually in a study space to blend a PCM and DSM, specifically in solving the agriculture investment problem. Here, the paper explains the study aiming to construct a DSM based on PCM to suggest the investment decision. The study itself is a further research of (Utama and Wibowo, 2021) and (Utama and Wibowo, 2022). It is a second year research project conducted in such a combination area. At this point, the DSM processes the information produced by the constructed PCM of Bok Choy plant, and then the constructed DSM can suggest the decision in agriculture investment by considering economic instruments; i.e. investment value and breakeven point (BEP). The study implication is very clear. The investment prediction can be easily managed here, and the business opportunities can be forecasted too. The paper itself delivered in the five sections; i.e. introduction, theoretical view, research methodology, result and discussion, and conclusion and further works.

2. Theoretical View

2.1. Decision Support Model (DSM)

DSM is a computer-based model developed by using intelligence methods to recommend the actionable decision in facing structured or unstructured problem. DSM supports a decision maker to make the best decision from several decision alternatives (Li and Ji, 2022). The model prepares the process of decision-making runs objectively and scientifically. Also with the decision produced. The model can create the proposed decision which is traceable and methodical (Utama, 2021).

The model constructed via operating one single or multi methods. The methods functioned depend on how the model is going to handle the data. As, in one case in advising the decision, model needs several parameters and data which have dissimilar characteristics. Such characteristic divergences encourage the model constructed based on multi methods (Wu et al. 2022).

2.2. Bok Choy Plant

Bok Choy (American English, Canadian English, and Australian English), Bak Choi, Pak Choi (British English) or Pok Choy (*Brassica rapa subsp. chinensis*) initially taken from Cantonese etymology ("baahk" means "white", and "choi" means "vegetables") is one of a Chinese cabbage species that comprise a large and diverse group of widely consumed vegetables. This *Chinensis* varieties are popular in Southern China, East Asia, and Southeast Asia, although it was natively grown and cultivated in China since the 5th century (Sanderson and Renfrew, 2005). This plant is also increasingly grown in Northern Europe due to its frost-resistant nature. Recently considered as a subspecies of *Brassica rapa*, this variety was originally classified as its own species under the name of *Brassica Chinensis* by Carl Linnaeus (Linné, 1753).

Bok Choy often has an eye-catching look based on its original type, with oval-shaped, green, ruffled leaves that can reach a height of 50 cm. The silky, juicy white stems that gave the veggies their Cantonese moniker of "bok", which means "white", contrast dramatically with the leaves of this vegetable. This vegetable's raw textures often have a crunchy, slightly fibrous firmness, a sweet, distinct cabbage flavor, and a moderate mustard-like taste if ingested. Bok Choy relatively has a simple morphology structure as a plant. Their main structure component consists of only 3 organs which are leaves, stem and root end.

Bok Choy grows until harvest time taking around 45-60 days. At start, the seed commonly germinates within five to seven days when planted around a one-quarter inch deep under moist soil and kept the temperature between 10°C to 26°C. The seed will end up with a sprout with a single stem containing two heart-shaped leaves. The stem continues to thicken and elongate as the Bok Choy continues to grow. The plant then produces multiple stems, or stalks, in a tight cluster. Weekly observation and irrigation are necessary to keep the soil moist. The plant then continues to produce leaves and elongate until they reached 6 inches tall for baby Bok Choy varieties, or up to 2 feet tall for large/standard Bok Choy varieties. The Bok Choy produces its full foliage as the heads are began to form. A mature head features multiple white stalks topped by large dark green leaves with white fibrous veins. At this final stage, Bok Choy plants are ready to harvest and to be served at best.

The originated *Brassicaceae* family is one of the top ten most economically important plant families in the world. Brassica itself consists of broccoli (calabrese and sprouting broccoli), cabbage, Chinese cabbage, kale, kohlrabi, mizuna, swede (rutabaga), turnips, and of course Bok Choy itself (Fahey, 2016). Modern-day Bok Choy has been cultivated by farmers into two distinct variations mostly according to its size even though these Bok Choy still is on the same *Brassica rapa subsp. chinensis* species.

3. Research Methodology

The research conducted is an extended work of (Utama and Wibowo, 2021) and (Utama and Wibowo, 2022). The stages of the research are similar with the previous studies. And here, the generic model is developed scientifically. It means, the design and construction stage are explained in more detail. Figure 1 clearly describes the research stages conducted in this research. Five main methods are benefited in the study: hydroponic system, daily observation, functional and structural plant modeling (FSPM), fuzzy logic, and object oriented.

The hydroponic system is a planting method selected to seed and plant the plant Bok Choy. Then, the daily observation functioned to collect the data of plant Bok Choy's daily morphological growth, around 10-20 plants monitored daily. The FSPM method itself used as a framework in designing a virtual plant by explaining three aspects morphology, physiology, and statistic. The fuzzy logic (Zadeh, 2015) operated to be fundamental method in the mathematic decision support model (DSM). All parameters considered in the model treated in the fuzzy logic world with three stages: fuzzification, fuzzy rules representation, and defuzzification. And then, the object oriented method (Booch, 2007) is one approaches used to design the constructed model. Four diagrams of unified modeling language (UML) are used here. They are usecase, class, activity, and statemachine diagrams.

The interconnection between actors and model application is described in the usecase diagram. All interconnected entities in the model in configured in the class diagram. The flow of model's processes executed was designed obviously via the activity diagram. Then, step by step status (state) of plant's growth process was clearly described by using the statemachine diagram. Both diagrams look similar, however the distinction can be met in mentioning the "rounded rectangle" notation. The activity diagram uses the noun in describing the "activity"; on the other hand, the statemachine diagram operates the adjective in declaring the "state".

Completely, the model was constructed. The plant model itself was developed by utilizing GroIMP modelling platform and the implementation of fuzzy logic conception realized by applying Python programming language in Google Colaboratory (Google Colab) environment. The GroIMP itself is a modelling platform to model the plant's growth mechanically where the data of growth transferred from the Python.

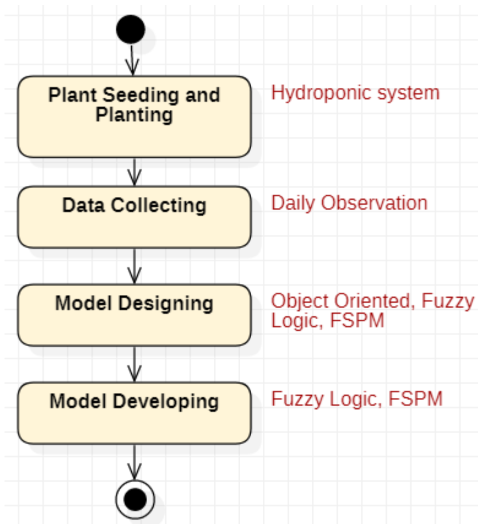


Fig 1. Research Stages with Methods Operated.

4. Result and Discussion

The constructed PCM explains the plant configuration in detail. Figure 2 displays a three dimension (3D) view of virtual single plant of Bok Choy with two viewpoints; with texture (A) and with detail-transparent organ (B) views. Furthermore, Figure 3 demonstrates the multi plant, in this case the view of 30 divergent virtual plants of Bok Choy. The texture view displays a more natural panorama of the Bok Choy plant; instead, the transparent organ view is able to expose the more detailed plant organ construction. Theoretically, the Figures 2 and 3 display the above-ground Bok Choy plant by implementing the growth-behavior model from (Utama and Wibowo, 2021) and (Utama and Wibowo, 2022).

Figure 4 shows the usecase diagram of the constructer model. The diagram presents the communication pattern between actors and model application. Here, there are four actors and four usecases being divided into two types of model block (i.e. virtual plant and decision support model). The actor researcher actually consists of two other actors, i.e. agronomist and computer researcher.

Moreover, Figure 5 exhibits the class diagram of the created model. All entities corresponded in the model mention in the diagram. All parts of plant and also method operated in the model are clearly showed. Root, Stem, and Leaf are plant's organs. The class FuzzyLogic is a method class, with other derivate classes. And finally, the class InvestmentDecision is representing the decision suggested by the model.

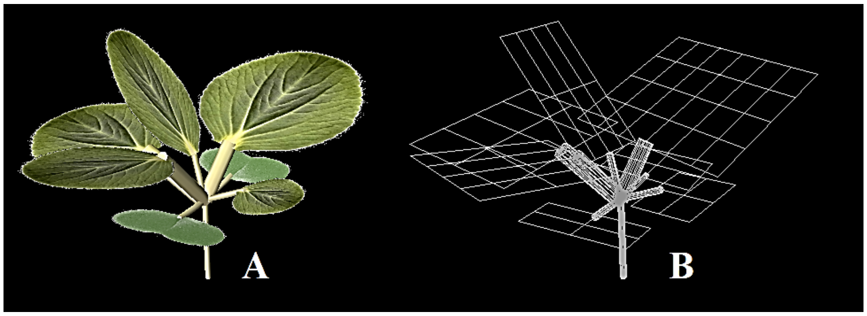


Fig 2. Virtual Single Plant of Bok Choy with Texture (A) and Virtual Single Plant of Bok Choy with Detail-Transparent Organ (B).

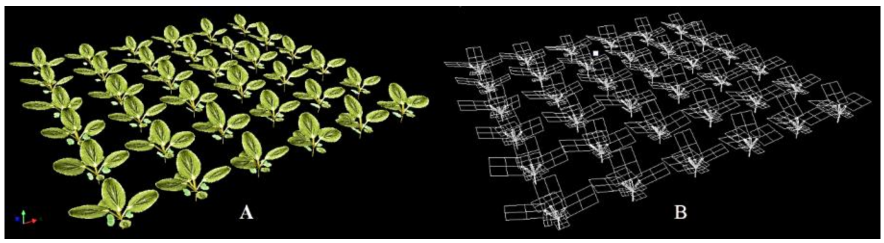


Fig 3. Virtual Multi Plant of Bok Choy with Texture (A) and Virtual Multi Plant of Bok Choy with Detail-Transparent Organ (B).

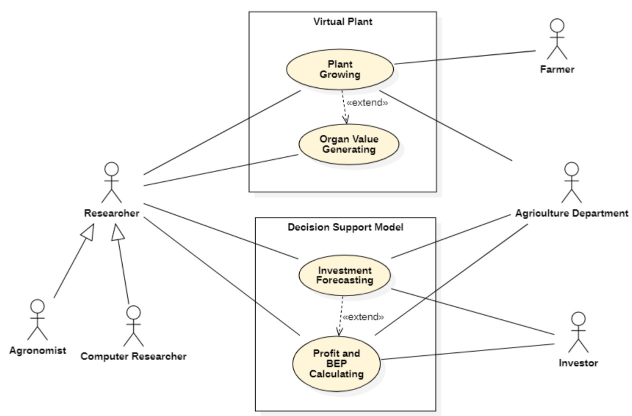


Fig 4. The Usecase Diagram for the Constructed Model Application.

The constructed model algorithm is given in Figure 6. Plant's mechanical growth process is modeled via the method of fuzzy logic. In this point, all increment values are converted to fuzzy value naturally. Based on specific fuzzy rules, the increment value is de-fuzzified then. The final absolute values are functioned to mechanically adjust the plant's growth. The part of the growing process called as "fuzzy mechanical growth". It is as a fundamental contribution and academic novelty of the research.

And then, the calculation of the green organ area and the organ weight operates such a final crisp value. The area and weight values are used for making an investment decision. In this case, the model is able to measure/predict the breakeven point (BEP) if the investors are going to invest in the business of hydroponic based Bok Choy plants. Such values also can be operated to calculate other financial instruments (e.g. return on investment, net present value, etc.).

All states of model machine determined in the constructed model are officially configured by statemachine diagram. It can be shown in Figure 7. The states are consequences of all activities performed in the assembled model. Here, in the plant model, the states settled are started from the state "Plant Growth

Increment Taken" until the state "Increment Value Defuzzified" for describing the plant's growth behavior; then, the state "Decision Generated" that means the model generates the decision.

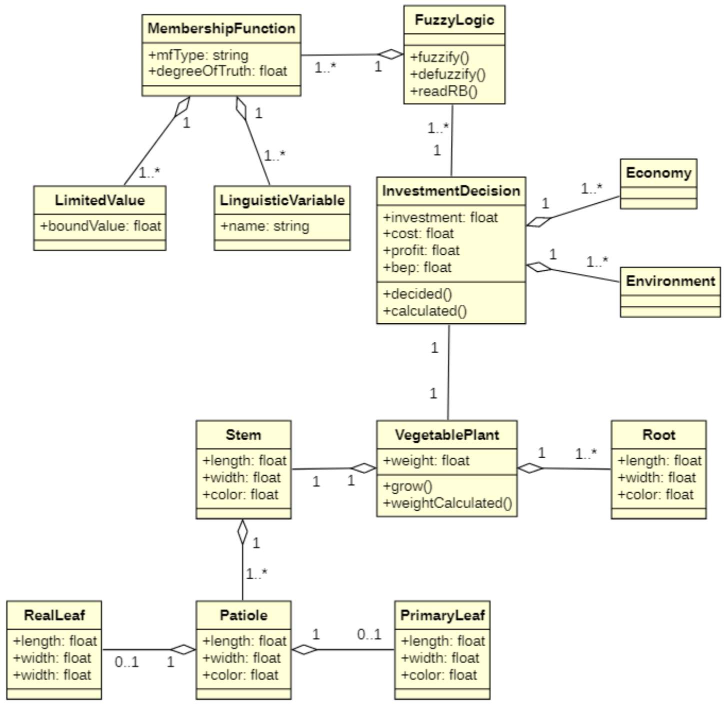


Fig 5. The Class Diagram for the Constructed Model Application.

As mentioned before that the created model is the future version of the (Utama and Wibowo, 2021) and (Utama and Wibowo, 2022). The model exposes the plant's growth mechanism in the fuzzy logic world. The incremental values of plant's growth processed via fuzzy logic method. The incremental crisp values pass-through three stages of fuzzy logic: fuzzification, fuzzy-rules read, and de-fuzzification. The final crisp value, produced by de-fuzzification process, could be used for other additional research purposes.

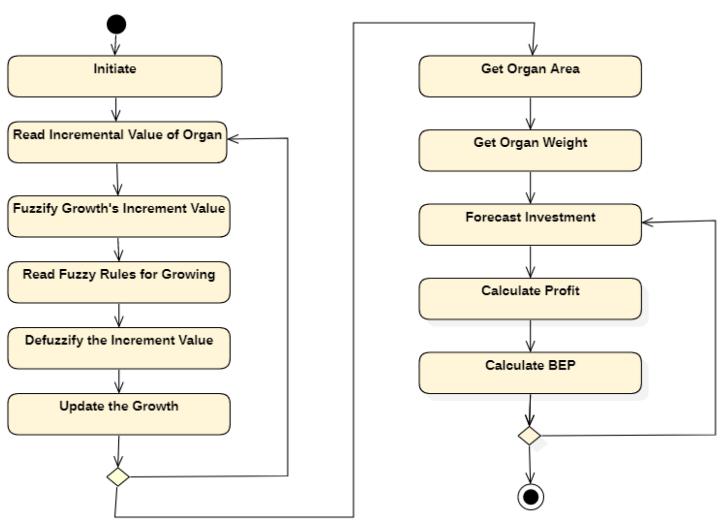


Fig 6. The Activity Diagram for the Constructed Model.

In the fuzzification process, the incremental values converted in to the triangular-trapezoidal membership functions with three human-linguistic variables. In this study, the fundamental plant organs deeply studied are leaf and stem (of each leaf); at this point, only plant organs that are above-land observed intensely. Each leaf and stem grow twelve days naturally. Thus, all incremental values in every day transformed in to the antecedent membership functions. For instances, the antecedent triangular-trapezoidal membership functions benefited in the model are imagined in the Figure 8.a, 8.b, 9.a, and 9.b. The figures respectively portray the length increment day 1 (LID1) for leaf, the width increment day 1 (WID1) for leaf, the LID1 for stem, and width increment day 2 (WID2) for stem; at this juncture, WIDI2 and the width increment day 6 were not considered in the model, as based on empirical data, in those days, the stem's width does not grow (means the incremental values are zero). Thus, conclusively, there are only 22 antecedent membership functions were successfully established.

The antecedent membership functions, operated in the model, are hypothetically established by the combination of triangular and trapezoidal forms. The trapezoidal forms worked for determining the lower and upper linguistic variables; oppositely, the triangular one utilized for controlling the middle variable. Let's say, in the Figure 8.a, the "short" and "long" verbal variables configured by the trapezoidal form; with value ranges respectively (0.00, 0.00, 0.05, 0.15) and (0.15, 0.25, 0.30, 0.30). Later, the "medium" variable shaped by triangular form via ranges (0.05, 0.15, 0.25).

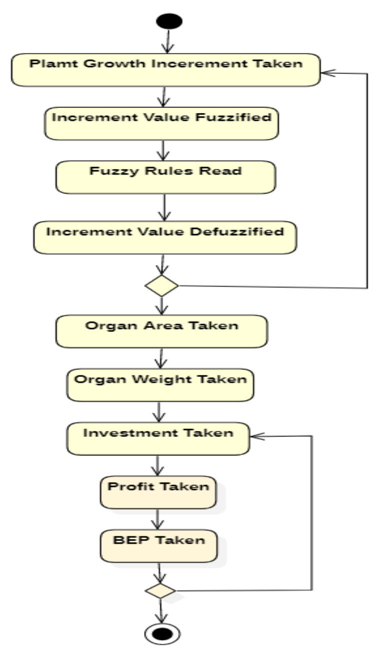
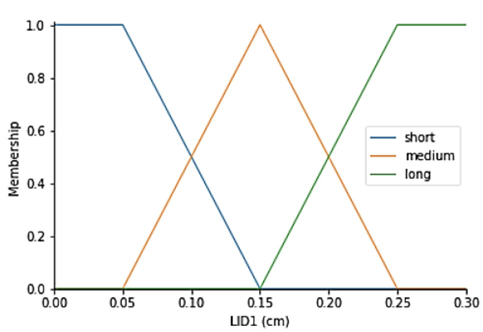
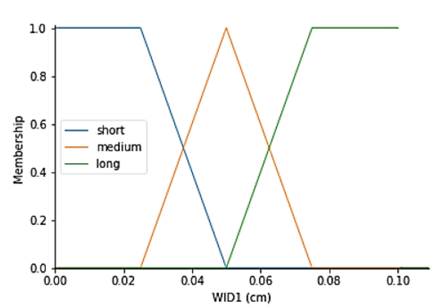


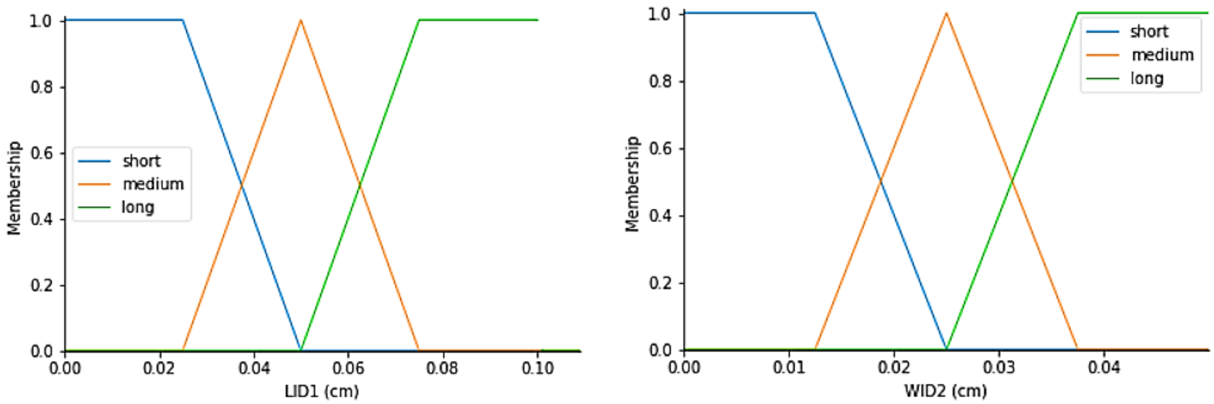
Fig 7. The Statemachine Diagram for the Constructed Model.





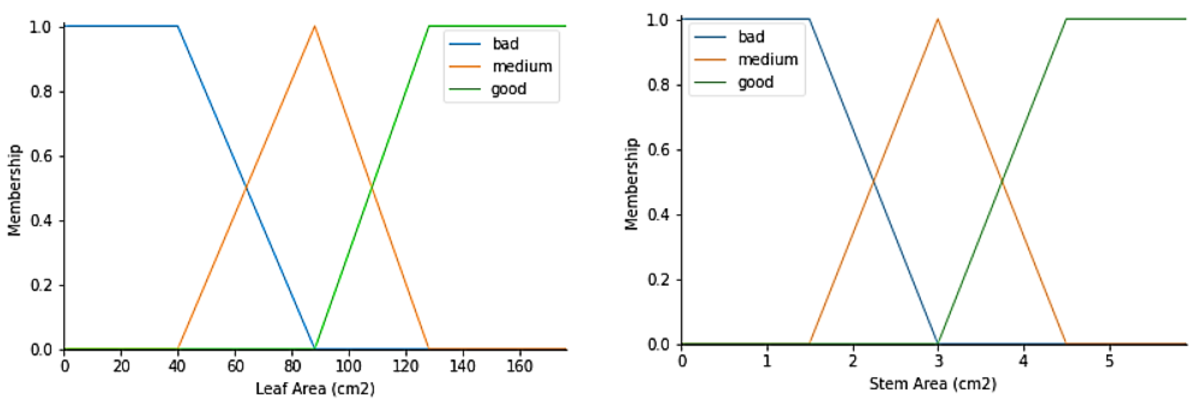
(a) (b)

Fig 8. (a) Membership Function for Variable LID1 for leaf; (b) Membership Function for Variable WID1 for leaf.



(a) (b)

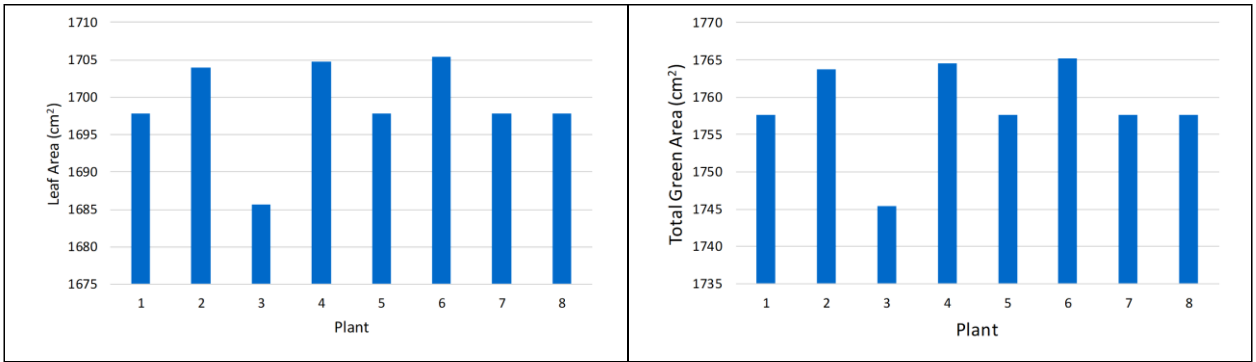
Fig 9. (a) Membership Function for Variable LID1 for Stem; (b) Membership Function for Variable WID2 for Stem.



(a) (b)

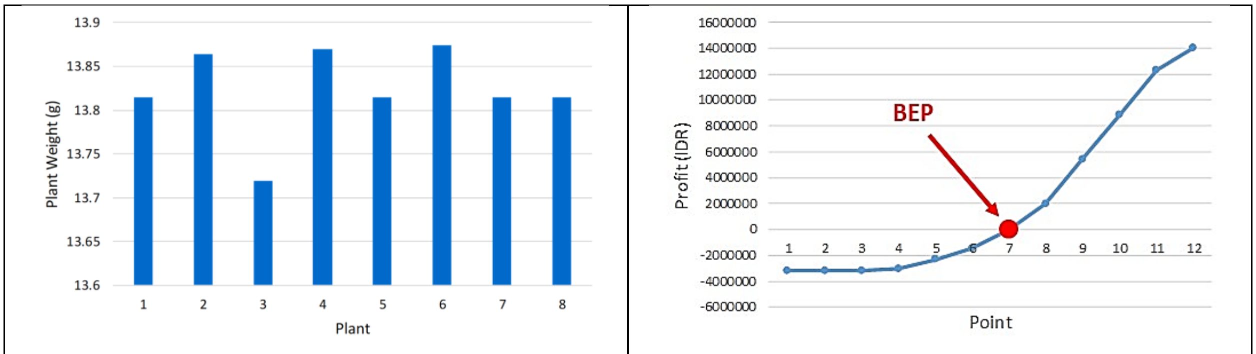
Fig 10. (a) Membership Function for Growth Decision Influencing the Leaf Area; (b) Membership Function for Growth Decision Influencing the Stem Area.

Therefore, all 22 antecedent membership functions employed for making a consequence growth decision influencing leaf and stem area via three kinds of fuzzy rule. It means that the wider area of plant's leaves and stems indicates better plant's performance. Now, the growth decision mentioned by three linguistic variables "bad", "medium", and "good" with still combination between trapezoidal and triangular forms. Figures 10.a and 10.b articulate the growth decision that representing leaf and stem areas individually. The linguistic variables and value scopes for leaf area are "bad" (0.00, 0.00, 40.00, 90.00), "medium" (40.00, 90.00, 130.00), and "good" (90.00, 130.00, 160.00, 160.00); and then for stem area are "bad" (0.00, 0.00, 1.50, 3.00), "medium" (1.50, 3.00, 4.50), and "good" (3.00, 4.50, 6.00, 6.00). And, the underlying judgements used to construct the fuzzy rules are that if one of the antecedent variables was "medium", the consequence growth decision was "medium" as well; if all antecedent variables were "short", the consequence was going to be "bad", and if all antecedent variables were "long", the consequence was "good".



(a) (b)

Fig 11. (a) Leaf Area for each Plant; (b) Total Green Area for each Plant.



(a) (b)

Fig 12. (a) Weight for each Plant; (b) Breakeven Point Graph.

Based on empirical data for eight plants, the simulation result for calculating total leaf area for each plant, total green area for each plant (green area is total leaf area added by total stem area), and weight for each plant presented separately in Figures 11.a, 11.b, and 12.a. Based on simulation result, the breakeven point (BEP) could be found as red dot in the Figure 12.b; where investor plants 16,198 plants (at seventh point) of hydroponic based Bok Choy with total investing cost approximately IDR 17,790,285 (or US$ 1,148). The BEP calculated with model accuracy 94.33%. The accuracy itself is coming from the comparison between real and model calculation results. It is clearly mentioned in equation (1).

$$Acc = \frac{Value_{real} - d(Value_{real} - Value_{model})}{Value_{real}} \quad (1)$$

5. Conclusion

The further model of plant Bok Choy was positively designed. It depicts the mechanical growth behavior of the plant Bok Choy. Then, it encourages the second constructed model (DSM) to see the opportunities of agricultural investment. The combination of both models is the academic and practice contribution from the study. The main method operated in developing the model is fuzzy logic approach in FSPM attention. The GroIMP and Python were functioned as modeling platform and programing language correspondingly. The statistical result was then treated to propose decision alternatives in agriculture investing by showing the BEP calculation. The constructed model shows the BEP in 16,198 plants with model accuracy 94.33%.

Bending and flexible moving, as other natural occurrences of plant's growth behavior, can be precisely explored in more detail. Such occurrences can be observed in the next study. Then also, the whole part of plant Bok Choy (including root part) is a potential study in the future. On the other hand, the investment view is partial, only the investment value and BEP considered in the model. It is the model limitation. Thus, the enrichment of investment parameters is also potentially explored more detail in the further works.

References

Booch, G., Maksimchuk, R., Engle, M., Conallen, J., Houston, K. and Young, B. (2007). *Object-Oriented Analysis and Design with Applications*. Pearson Education.

Chi, F., Streit, K., Tavkhelidze, A. and Kurth, W. (2022). Reconstruction of phyllotaxis at the example of digitized red mangrove (Rhizophora mangle) and application to light interception simulation. *Silico Plants*, 4(1).

Fabrika, F., Scheer, L., Sedmák, R., Kurth, W., and Schön, M. (2019). Crown architecture and structural development of young Norway spruce trees (Picea abies Karst.): A basis for more realistic growth modelling. *BioResources*, 14, no. 1, pp. 908-921.

Fahey, J. W. (2016). Brassica: Characteristics and properties. *Encyclopedia of Food and Health*, 469–477.

Jung, Y. L., Yoo, H. S. and Hwang, J. N. (2022). Artificial intelligence-based decision support model for new drug planning. *Expert Systems with Applications*, 198.

Kurth W. and Ong, Y. (2017). A design pattern in XL for implementing multiscale models, demonstrated at a fruit tree simulator. *Proceedings X Int. Symp. on Modelling in Fruit Research and Orchard Management, Acta Horticulturae*, 1160 (2017), pp. 35-41 (2017).

Linné, C. von. (1753). Species plantarum, exhibentes plantas rite cognitas, ad genera relatas, cum differentiis specificis, nominibus trivialibus, synonymis selectis, locis natalibus, secundum systema sexuale digestas. *Holmae: Impensis Laurentii Salvi*.

Li, L. and Ji, C. (2022). A new multi attribute group decision making approach based on fermatean fuzzy power hamy mean operator and novel score function. *Journal of System and Management Sciences*, 12(4), pp. 1-26.

Li, Z., Yao, C., Zhu, X., Gao, G. and Hu, S. (2022). A decision support model for ship navigation in arctic waters based on dynamic risk assessment. *Ocean Engineering*, 244.

Merklein, J., Poirier-Pocovi, M., Buck-Sorlin, G., Kurth, W. and Long, Q. (2018). A dynamic model of xylem and phloem flux in an apple branch. *Proceedings of International Symposium on Plant Growth Modeling, Simulation, Visualization and Applications PMA 2018*.

Sanderson, H. and Renfrew, J. (2005). *The Cultural History of Plants* (First). Routledge.

Sitek, P., Wikarek, J., Bocewicz, G. and Nielsen, I. (2022). A Decision Support Model for Handling Customer Order in Business Chain. *Neurocomputing*, 482, pp. 298-309.

Utama, D. N. (2021). *Logika Fuzzy untuk Model Penunjang Keputusan, Dilengkapi dengan Penerapan Contoh Kasus*. Yogyakarta: Garudhawaca.

Utama, D. N., Ong, Y., Streit, K., and Kurth, W. (2015). Determining the influence of plant architecture on light interception of virtual rice plants on the simulation platform GroIMP. *Proceedings of the International Conference on Plant Physiology*, pp. 92-101 (2015).

Utama, D. N., and Wibowo, A. (2021). Fuzzy decision support model based on virtual plant for Green-Leaf vegetable investment. *International Journal of Engineering Trends and Technology*, 69(11), pp. 180-186.

Utama, D. N., and A. Wibowo, A. (2022). Virtual plant computational model of Green-leaf vegetable plant Bok Choy (*Brassica chinensis L.*) for investment decision. *Proceedings of 5th International Conference on Eco Engineering Development, IOP Conf. Series: Earth and Environmental Science*, 998.

Wu, Z., Khalilpour, K., Hämäläinen, R. P. (2022). A decision support tool for multi-attribute evaluation of demand-side commercial battery storage products. *Sustainable Energy Technologies and Assessments*, 50.

Zadeh, L. A. (2015). Fuzzy logic – a personal perspective. *Fuzzy sets and systems*, 281, pp. 4–20.