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Food Crop Rotation Decision Support System Using Fuzzy

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ABSTRACT

The purpose of this study is to develop a decision support system application that can provide advice in making decisions on the determination of types of food plants to be rotated. The case study was carried out in the Suka Hurip farmer group by using the fuzzy analytical hierarchy process method as a weighting in determining the priority of substitute plants as food crop rotation. The calculation of the fuzzy analytical hierarchy process begins with pairwise comparisons as the main criteria, namely pests, plant types, plant nutrition, harvest time, and season. Then pairwise comparisons are made for each alternative. The results of the analytical hierarchy process weight are measured by the consistency ratio. The results showed the application of food crop rotation decision support systems using the fuzzy analytical hierarchy process method obtained Consistency Ratio values for the main criteria were 0.088, meaning Consistency Ratio values < 0.1. Then it can be concluded that the plants that are ranked one to three can be used as a substitute plants in the process of crop rotation.

1. Introduction

Indonesia is an agrarian country with the majority of the population earning a living in agriculture or farming. According to the Central Statistics Agency, in 2017 the number of people engaged in agriculture was around 39.68 million people (Hamdani, 2017), this number decreased compared to 2018 which reached 38.7 million people in Indonesia who were engaged in agriculture (Sicca, 2018). Agricultural development and progress in Indonesia are considered very slow because Indonesia's fertile and extensive land is not well managed by farmers. In addition, technology in agriculture is still minimal, so that the government's efforts to make Indonesia capable of food self-sufficiency are impossible to realize. The use of chemicals in agricultural practices such as synthetic pesticides and non-organic fertilizers that is excessive and uncontrolled will cause concern from various parties regarding the impact.

The use of chemicals in agricultural processes that have been running for a long time carried out intensively and in excessive amounts results in chemicals being scattered and causing environmental damage. Environmental damage does not only occur in soil, air, water, but is very detrimental to the health of humans and living things in general. The use of synthetic pesticides in addition to polluting the environment will also affect the cycle of the food chain in the ecosystem in the agricultural area and even kill its predators, further from agricultural products contaminated with synthetic pesticides consumed by humans will cause various chronic diseases to cancer.

Various methods have been taken to minimize the use of chemical drugs in agriculture, by maximizing the use of medicines and natural fertilizers that have been provided by nature and using integrated pest control methods. If forced to use chemicals, then there is a need for control in their use and use wisely, right on target and efficiently, so that the creation of environmentally friendly agriculture. One of the integrated pest control methods is crop rotation. Crop rotation is the planting of various types of plants in rotation in one planting area. Rotational crop species selection is very important because errors in the selection of rotational plants can reduce the yield of the next crop. In carrying out crop rotation activities things that must be considered are, the type of plant to be planted is not a host plant (so pests cannot breed), land or land that will be used for planting, season, and time of harvest.

2. Method

This research was carried out in the Suka Hurip farmer group in Bojong Soang village, Mekar Baru Village, Kecamaan Petir, Serang Regency, Banten. In the system that runs in rotating food crops farmers still use the traditional system, where the analysis still refers to the season, if the dry season farmers plant *palawija* and if the rainy season will plant rice or corn as for the stages of the process can be seen in Figure 1.

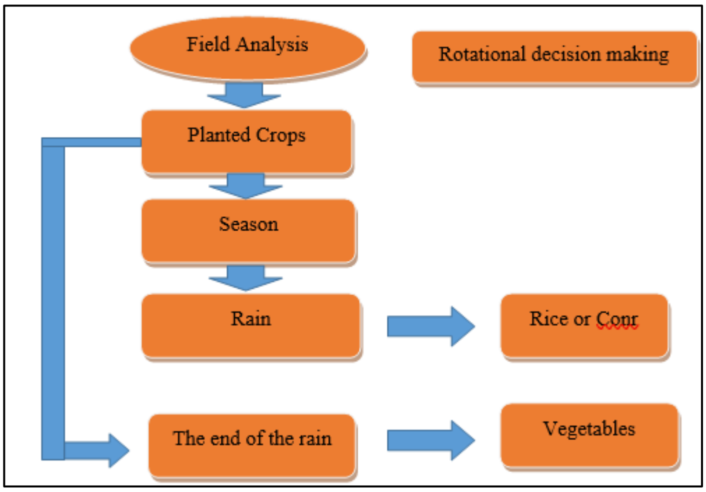

Fig. 1 Activity Diagram of the Current System

Based on the analysis that has been done and the analysis of the existing system, it can be seen what problems are faced by the Suka Hurip farmer group, the problems found are:

- Crop rotation is not in accordance with the rules of agriculture
- There is no system that helps the process of selecting plants to be rotated
- Excessive use of pesticides

Based on the analysis of the problems faced by the Suka Hurip group, we need a system that can solve that problem. This system, the Suka Hurip farmer group does not incur losses due to unfavorable crop rotation systems and human resources that are not friendly to the environment.

3. Results And Discussion

3.1 The New Procedure

Rotation support system for food crops is an application that will help Suka Hurip farmer groups, in terms of making crop changes so that yields are appropriate and maximum, so that the risk of crop loss can be minimized. Through this application the head of the farmer group and and its members can input criteria data and alternative data. For members who want to make crop changes after post-harvest can obtain information presented through the application. Because this application is web-based users do not need to install the application, simply by accessing the Web URL through a web browser. After the website has been opened in a web browser the admin can log into the application, change the criteria data and alternative data, to rotate using the Fuzzy AHP method based on the desired crop type. Here the system will display detailed plant information that is suitable based on the results of ranking for decision making to rotate. The procedure can be seen in Figure 2.

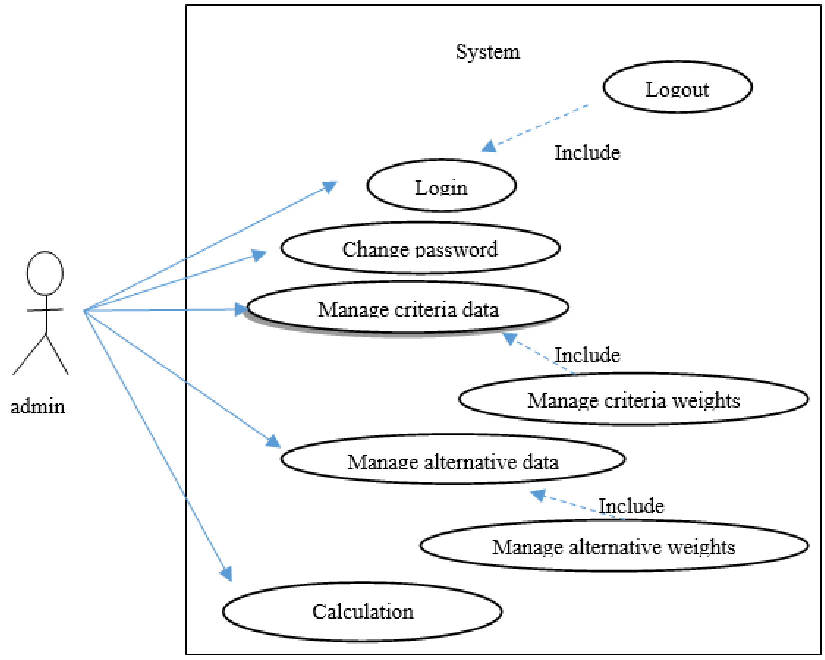

Fig. 2 Use Case Diagram System

Figure 2 is a Use case diagram of the system produced, to facilitate the admin in performing Fuzzy AHP process, while the relations between table can be seen in Figure 3

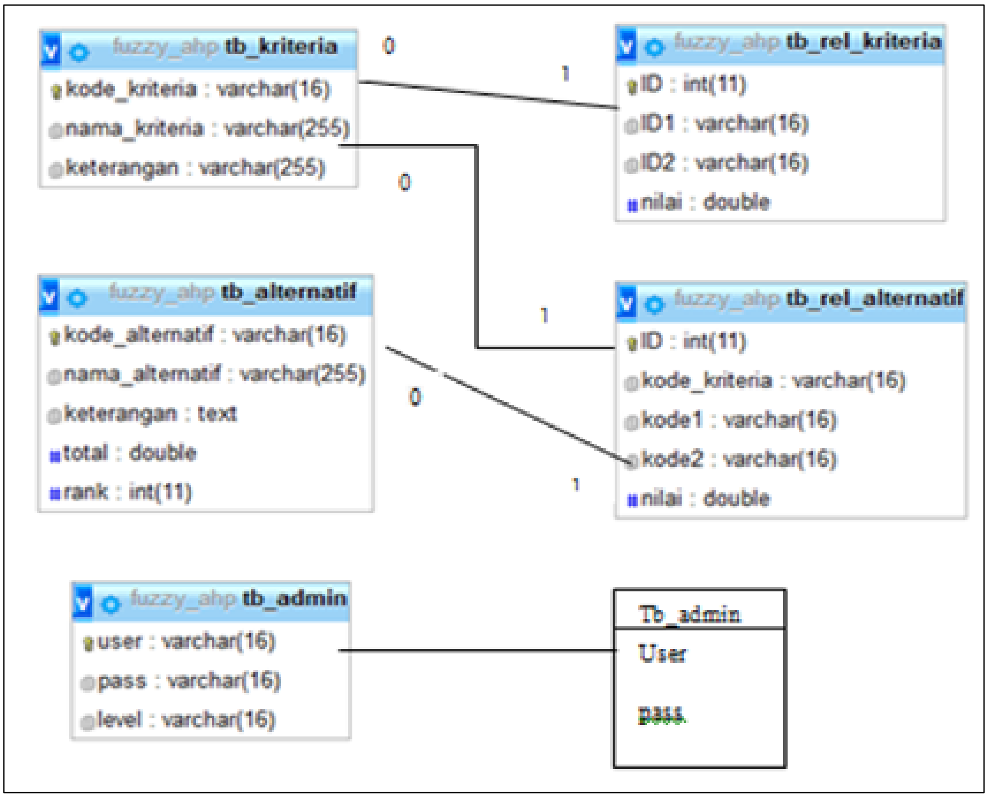

Fig. 3 Class diagram the relations between table

Class diagram the tables in Figure 3 are tables in the database, each table has its own relations so that data redundancy does not occur.

3.2 Process Fuzzy AHP

Determination of the degree of F-AHP membership developed by Aydin (Aydin & Kahraman, 2013), Using the Triangular Fuzzy Number function as in Figure 4.

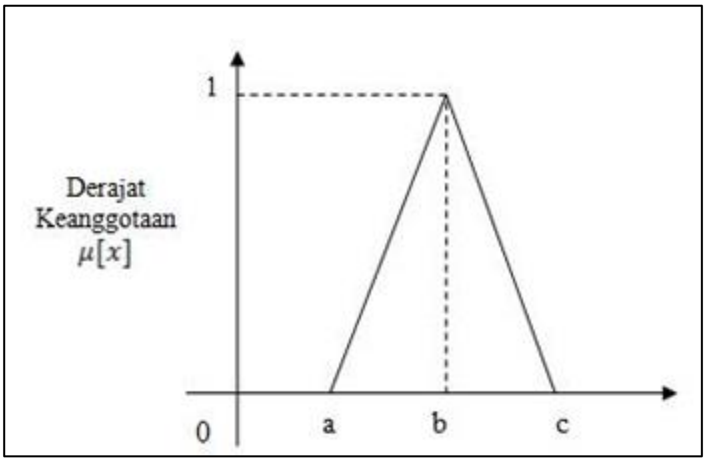

Fig. 4 Triangular Membership Function

Chang (Chang, 1996) defines the value of the AHP intensity into a triangle fuzzy scale that is dividing each fuzzy set by two, except for the intensity of importance one. Fuzzy triangle scale used by Chang can be seen in Table 1. Chang (Chang, 1996) defines the value of the AHP intensity into a triangle fuzzy scale that is dividing each fuzzy set by two, except for the intensity of importance one. Fuzzy triangle scale used by Chang can be seen in Table 1.

Table 1. Triangular Fuzzy Number (TFN) Chang (Chang, 1996)

Definition	Scale Chang	TFN
Equally important	1	(1, 1, 1)
Moderately more important	3	(1, 3/2, 2)
Strongly more important	5	(2, 5/2, 3)
Very strongly more important	7	(3, 7/2, 4)
Extremely more important	9	(4, 9/2, 9/2)
Intermediate Values	2, 4, 6, 8	(1/2, 1, 3/2), (3/2, 2, 5/2), (5/2, 3, 7/2) and (7/2, 4, 9/2)

Create a hierarchical structure of the problem to be solved and determine the comparison of paired matrices between criteria and alternatives with the TNF scale as in Figure 5, while the hierarchical structure is like Table 2.

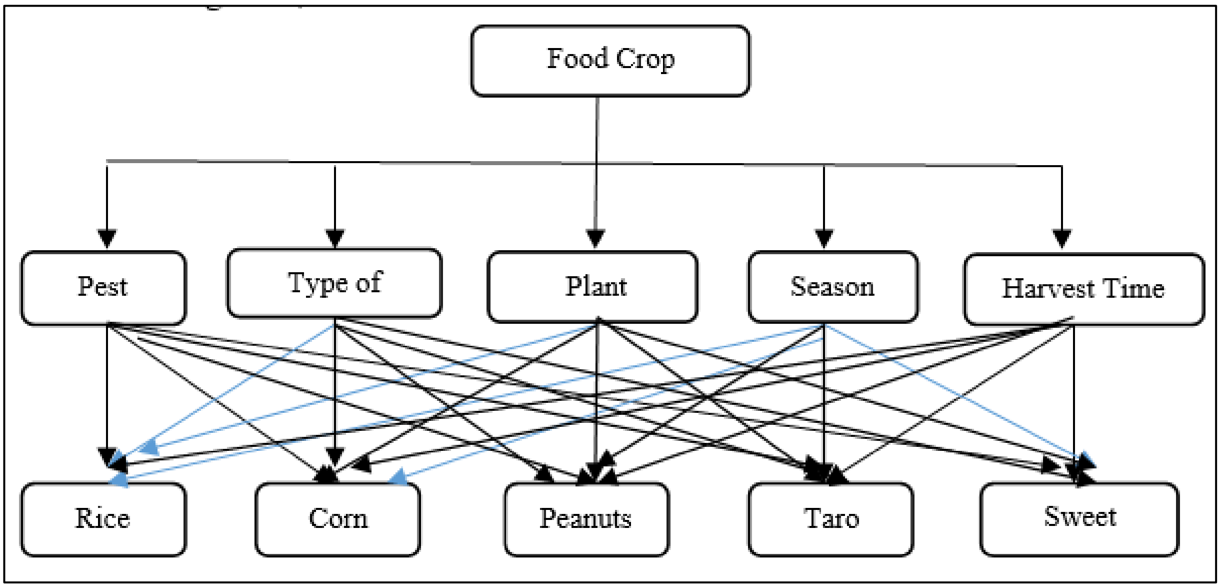

Fig. 5 Hierarchical Structure of the Problem

Table 2 Results F-AHP Criteria Comparison Matrix

	C1			**C2**			**C3**			**C4**			**C5**		
	L	**M**	**U**	**L**	**M**	**U**	**L**	**M**	**U**	**L**	**M**	**U**	**L**	**M**	**U**
C1	1	1	1	1.5	2	2	2	2.5	3	1	1.5	2	2	2.5	3
C2	0.5	0.6	1	1	1	1	0.5	0.6	1	0.3	0.4	0.5	0.5	1	1.5
C3	0.3	0.4	0.5	1	1.5	2	1	1	1	0.5	0.6	1	0.5	1	1.5
C4	0.5	0.6	1	2	2.5	3	1	1.5	2	1	1	1	2	2.5	3
C5	0.3	0.4	0.5	0.6	1	2	0.6	1	2	0.3	0.4	0.5	1	1	1

The results of the fuzzy synthesis value (Si) priority with the formula:

$$Si = \sum_{j=1}^{m} M_i^j x \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} M_i^j} \quad (1)$$

Where

$$\sum_{j=1}^{m} m_i^j = \sum_{j=1}^{m} lj . \sum_{j=1}^{m} mj . \sum_{j=1}^{m} uj \quad (2)$$

While

$$\frac{1}{\sum_{j=1}^{n}\sum_{j=1}^{m} M_i^j} = \frac{1}{\sum_{i=1}^{n} ui . \sum_{i=1}^{n} mi . \sum_{i=1}^{n} li} \quad (3)$$

The results of calculations with these formulas can be seen in table 3.

Table 3 Results of Synthesis Criteria Values

	Number of Row			**Synthesis Values**		
	L	**M**	**U**	**L**	**M**	**U**
C1	7	9	11	0.18	0.30	0.48
C2	2.8	3.7	5	0.07	0.12	0.22
C3	3.3	4.5	6	0.08	0.15	0.26
C4	6.5	8.1	10	0.17	0.27	0.44
C5	3	3.8	6	0.07	0.12	0.26
Total	**22.67**	**29.26**	**38**			

The results of the calculation of the vector value (V) and the Defuzzification ordinate value (d ') by using the formula below.

$$V(m2 \geq m1) \quad \begin{cases} 1, & \text{if } m2 \geq m1, \quad (4) \\ 0, & \text{if } l1 \geq \mu 2, \quad (5) \end{cases}$$

The results of the calculations can be seen in table 4.

Table 4 Vector and Defuzzification Ordinate

	a *l*1-*u2*	*b* *m2-u2*	*c* *m1-l1*	*d* b-c	e a/d	fuzzy *d*`	Min
C2 ≥C1	-0.03	-0.09	0.12	-0.21	0.16	0.16	0.168
C2 ≥C3	-0.13	-0.09	0.06	-0.16	0.82	0.82	
C2 ≥C4	-0.04	-0.09	0.10	-0.20	0.24	0.24	
C2 ≥C5	-0.14	-0.09	0.05	-0.14	0.98	0.24	

In mid 1990s, Heuvel (Heuvel, 1996) wrote about precision agriculture the big information upgrade in agriculture that was yet to arise. In his work he emphasized that the emerging technologies are driving the development of agriculture, which will be able to evolve to a more efficient level in terms of agricultural production and land stewardship. It seems that today we are in the era of making precision agriculture omnipresent, whilst trying to enrich it with computer assisted Decision Support Systems (DSS) for entire farm management (with the goal of optimizing returns on inputs while preserving resources) (Rupnik et al., 2018).

In the recent years, farm management information systems have evolved from simple farm record keeping into sophisticated and complex systems to support all aspects of production management (Fountas et al., 2015). The purpose of system is to manage demands to reduce production costs, comply with agricultural standards, and maintain high product quality and safety by ensuring access to timely information, elaborate estimation, simulation and decision making tools. Decision support system that integrates all of the above is therefore a crucial step in both day-to-day and strategic decision making(Rupnik et al., 2018) about food crop rotation.

That soil analysis process does not directly improve performance, but it maintains soil fertility and maintains the crop rotation growth rate as it is a walkway platform between soil nutrient and soil fertility(García-Sánchez et al., 2017). Rajput et al. (Rajput et al., 2016) and Wani et al. (Wani et al., 2017) reported that the crops are grown with long term soil analysis process has resulted in increased soil performance, soil organic carbon, soil nutrient and soil microorganisms which eventually culminates into increased benefit cost ratio by reducing the pollution and indirect cost.

Analytic Hierarchy Process (AHP), since its invention, has been a tool at the hands of decision makers and researchers; and it is one of the most widely used multiple criteria decision-making tools (Vaidya & Kumar, 2019). Analytical hierarchy process (AHP) was first developed by Thomas Saaty (Saaty, 1987) and has been modified by various researchers. Since its invention, AHP has been a tool in the hands of decision makers and researchers. It is one of the most widely used multiple criteria decision-making tools (Kazemi et al., 2016). This technique is based on ranking and the importance of factors affecting the goal by attributing relative weights to factors with respect to comments provided in the questionnaires. Many outstanding works have been published based on AHP, among which are: applications of AHP in different fields such as planning, selecting best alternative, resource allocations, resolving conflicts, optimization, and numerical extensions of AHP (Vaidya & Kumar, 2019).

Smart farming is about supporting the farmer and their professional network, about the management of production and about managing information related to production(Naud et al., 2020) . Decision support is about providing the user of a DSS (decision support system) means to make a decision. Evaluation of the environmental components and understanding of local biophysical restraints can help determine the areas suitable for agriculture. Topographic characteristics, climatic conditions and the soil quality of an area are the most important parameters to evaluate land suitability(Kahsay et al., 2018). Land suitability determination for a particular agricultural crop requires consideration of many criteria(Abushnaf et al., 2013). Crop rotation is one of the cropping patterns that is planting more than one type of plant that is not in one family in rotation on one land in one planting period in a certain time sequence aimed at breaking the life cycle of pests and plant diseases (Hadi et al., 2014).

Based on the results of the development of a decision support system application in carrying out crop rotation that the application system is effective according to the results of field trials that that the system can help farmers regulate crop turnover, facilitate planting time so as to increase productivity. The results of this study were supported by researchers Nassary (Nassary et al., 2020) that rotation with one of these crops significantly improved grain yields and hence provided promising grounds of the options for sustainable food production on smallholder farms. The decision support tool is envisaged to identify potential strategies which systems in a cost effective manner(Newton et al., 2014). The decision support system application can help in improving service and accurate in arranging schedules(Meesang et al., 2016). Decision making systems have sensitivity (Balusa & Gorai, 2019) in selecting crop rotation (Bowles et al., 2020). Crop rotations reduce the general environmental pressure of agricultural activities and affect a large part of the arable land (Cortignani & Dono, 2020).

4. Conclusions

Based on the results of research, analysis, design, and discussion of food crop rotation decision support systems using the Fuzzy AHP method in the Suka Hurip farmer group, it can be concluded as follows:

1) The system that is still running is based on habits, so it needs a system that helps in the selection of replacement plants.
2) The crop rotation decision support system using the Fuzzy AHP method was built using the PHP programming language, mySql database and using bootstarp. The main criteria for crop rotation using the Fuzzy AHP method include pests, plant types, plant nutrition, harvest time and season.
3) AHP calculation on the main criteria of crop rotation has a CR value of 0.088, alternatives based on pests have a CR value of 0.074, alternatives based on plant type have a CR value of 0.061, alternatives based on plant nutrition have a CR value of 0.082, alternatives based on harvest time have a CR value of 0.092, and alternatives based on seasons have a CR value of 0.093. Overall CR value obtained < 0.1, then the degree of consistency is satisfactory.
4) From the results of weighting the criteria and alternative values, plants that are ranked 1 to 3 from the system output, can be used as a substitute crop chosen by farmers to rotate the plants because they provide good crop yields.

REFERENCES

Abushnaf, F. F., Spence, K. J., & Rotherham, I. D. (2013). Developing a Land Evaluation Model for the Benghazi Region in Northeast Libya using a Geographic Information System and Multi-criteria Analysis Farag F Abushnaf. *APCBEE Procedia*, *5*, 69–75. https://doi.org/10.1016/j.apcbee.2013.05.013

Aydin, S., & Kahraman, C. (2013). A New Fuzzy Analytic Hierarchy Process and Its A New Fuzzy Analytic Hierarchy Process and Its Application to Vendor Selection Problem. *J. of Mult.-Valued Logic & Soft Computing*, *20*, 353–371.

Balusa, B. C., & Gorai, A. K. (2019). Sensitivity analysis of fuzzy-analytic hierarchical process (FAHP) decision- making model in selection of underground metal mining method. *Journal of Sustainable Mining*, *18*(1), 8–17. https://doi.org/10.1016/j.jsm.2018.10.003

Bowles, T. M., Mooshammer, M., Socolar, Y., Schmer, M. R., Strock, J., & Grandy, A. S. (2020). Long-Term Evidence Shows that Crop-Rotation Diversification Increases Agricultural

Resilience to Adverse Growing Conditions in North America. *One Earth*, *2*, 284–293. https://doi.org/10.1016/j.oneear.2020.02.007

Chang, D. (1996). Applications of the extent analysis method on fuzzy AHP. *Chang, D.-Y., 1996. Applications of the Extent Analysis Method on Fuzzy AHP. European Journal of Operational Research, 95, 649-655*, *95*, 649–655.

Cortignani, R., & Dono, G. (2020). Greening and legume-supported crop rotations: An impacts assessment on Italian arable farms. *Science of the Total Environment*, 139464. https://doi.org/10.1016/j.scitotenv.2020.139464

Fountas, S., Carli, G., Sørensen, C. G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A., Liakos, B., Canavari, M., Wiebensohn, J., & Tisserye, B. (2015). Farm management information systems : Current situation and future perspectives. *COMPUTERS AND ELECTRONICS IN AGRICULTURE*, *115*, 40–50. https://doi.org/10.1016/j.compag.2015.05.011

García-Sánchez, F., Martínez-Nicolás, J. J., Muelas-Domingo, R., & Nieves, M. (2017). Using Near-Infrared Spectroscopy in Agricultural Systems. *Intech Open Science*, *March*. https://doi.org/10.5772/67236

Hadi, M., Soesilohad, R. H., Wagiman, F., & Rahayuningsih, Y. (2014). Organic farming is an alternative management of healthy, natural, and environmentally friendly paddy ecosystems. *Buletin Anatomi Dan Fisiologi*, *12*(1), 72–77.

Hamdani, T. (2017, May). 31 , 86 % Penduduk Kerja Indonesia Ada di Sektor Pertanian. *Okecone.Com*, 1–9.

Heuvel, R. M. V. (1996). The promise of precision agriculture. *Journal Soil Water Conservation*, *51*, 38–40.

Kahsay, A., Haile, M., Gebresamuel, G., Mohammed, M., & Moral, M. T. (2018). Land suitability analysis for sorghum crop production in northern semi-arid Ethiopia : Application of GIS-based fuzzy AHP approach. *Cogent Food & Agriculture*, *4*(00), 1–24. https://doi.org/10.1080/23311932.2018.1507184

Kazemi, H., Sadeghi, S., & Akinci, H. (2016). Developing a land evaluation model for faba bean cultivation using geographic information system and multi-criteria analysis (A case study : Gonbad-Kavous region , Iran). *Ecological Indicators*, *63*, 37–47. https://doi.org/10.1016/j.ecolind.2015.11.021

Meesang, J., Soontornpipit, P., Vivatwongkasem, C., Kitidamrogsuk, P., & Sillabutra, J. (2016). Data flow diagram for developing decision support system of acute myocardial infarction screening. *Procedia Computer Science*, *86*, 248–251. https://doi.org/10.1016/j.procs.2016.05.111

Nassary, K. E., Baijukya, F., & Alois, P. (2020). Intensi fi cation of common bean and maize production through rotations to improve food security for smallholder farmers. *Journal of Agriculture and Food Research*, *2*(November 2019), 100040. https://doi.org/10.1016/j.jafr.2020.100040

Naud, O., Taylor, J., Colizzi, L., Giroudeau, R., Guillaume, S., Bourreau, E., Crestey, T., & Tisseyre, B. (2020). Support to decision-making. In *Agricultural Internet of Things and Decision Support for Precision Smart Farming*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-818373-1.00004-4

Newton, C., Jarman, D., Memon, F. A., Andoh, R., & Butler, D. (2014). Developing a decision support tool for the positioning and sizing of vortex flow controls in existing sewer systems. *Procedia Engineering*, *70*(2009), 1231–1240. https://doi.org/10.1016/j.proeng.2014.02.136

Rajput, P. S., Srivastava S., S. B. L., Sachidanand, B., Pradip, D., & Aher, S. B. (2016). Effect of soil-test-based long-term fertilization on soil health and performance of rice crop in Vertisols of central India. *International Journal of Agriculture, Environment and Biotechnology*, *9*(5), 801–806. https://doi.org/10.5958/2230-732X.2016.00102.9 (http://dx.doi.org/10.5958/2230-732X.2016.00102.9)

Rupnik, R., Kukar, M., Vra, P., Ko, D., Pevec, D., & Bosni, Z. (2018). AgroDSS : A decision support system for agriculture and farming. *Computers and Electronics in Agriculture*, *12*(November 2017), 1–12. https://doi.org/10.1016/j.compag.2018.04.001

Saaty, R. W. (1987). The analytic hierarchy pocess what it is and how it is used. *Mathd Modelling*, *9*(3–5), 161–176.

Sicca, S. P. (2018, May). BPS : Jumlah Penduduk Bekerja Triwulan I. *Tirto.Id*, 1–21.

Vaidya, O. S., & Kumar, S. (2019). Analytic Hierarchy Process : An Overview of Applications Analytic hierarchy process : An overview of applications. *European Journal of Operational Research*, *169*, 1–29. https://doi.org/10.1016/j.ejor.2004.04.028

Wani, S. P., Anantha, K. H., & Garg, K. K. (2017). Soil Properties , Crop Yield , and Economics Under Integrated Crop Practices in Karnataka , Southern India. *World Development*, *93*(January 2018), 43–61. https://doi.org/10.1016/j.worlddev.2016.12.012