Development of Cloud-Based Decision Support System for Fertilizer Management - A Case Study in Wilmar Oil Palm Plantation

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ABSTRACT

Indonesia is one of the largest palm oil-producing countries. The industrial management system in oil palm plantations is essential to realize the company's goals. On the other hand, many oil palm plantations in Indonesia still apply conventional data management. The deficiencies have an impact on decision-making that are slow, less accurate, and not on target. The application of precision agriculture can assist in the management of oil palm plantations, one of which is the provision of an information system as a Decision Support System (DSS). The DSS can accommodate fertilizer management needs. By using the DSS, fertilization can be controlled precisely and fast action. The purpose of this study was to develop a cloud-based Decision Support System (DSS) for fertilizer management. The DSS was developed using an expert system which the model can combine big data to provide advice or recommend a fertilization management in oil palm plantations. The implementation of this DSS can be in the form of an application or platform that becomes a database of plantation activities. The DSS will accommodate all inputs for fertilization activities such as the number of oil palm plants, age of oil palm, land area, etc. The data will be used to create an expert system related to fertilizer dosage recommendations and the amount of fertilizer needed at the time of planting. DSS related with fertilization management includes the dosage of fertilizers. In this study, in the model development phase, we examine the algorithm used in **Ferticalc** to know wheter it is suitable for fertilizer prediction for oil palm plantation. Algorithm used in Ferticalc suitable for development of DSS to predict fertilizer needs for oil plam plantation. This was indicated by determination coefficient value was 0,8494. With this Decision Support System, users can provide direct action to the production department of oil palm plantations according to system recommendations. This research is expected to be a reference for fertilizer management systems at Wilmar International Plantation that can be accessed by anyone and can help optimize oil palm production.

Keywords: *Decision Support System, Fertilizer, Management, Oil Palm Plantation*

1. INTRODUCTION

Palm oil is one of the leading commodities from the plantation sector in Indonesia. Indonesia is one of the largest palm oil producing countries in the world. According to Astrini (2015), palm oil is a non-oil and gas commodity with the largest foreign exchange contributor in Indonesia. Oil palm plantations are experiencing a fairly rapid development where the industry is getting more and more advanced. Upon the development of the palm oil industry, it needs to be supported by modern technology. According to Nugroho et. al. (2019), precision agriculture can support the management of the agricultural industry. The concept of precision agriculture is based on information systems to provide input regarding identification, data, action, and management of spatial/temporal information. Plantation management will be helped by the existence of a

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precision farming system so that variations in targeted actions can be determined. One of the applications of precision agriculture related to oil palm plantation management is an information system that can provide recommendations for actions regarding plantation management.

A cloud-based decision support system can be an alternative solution related to plantation management. With the DSS, all matters related to the plantation (on-farm and off-farm aspects) will be properly inventoried and monitored so that appropriate actions can be taken. One application of DSS in oil palm plantations is regarding fertilizer management. Fertilizer is an important part of plant growth. Proper fertilization will be useful for increasing soil fertility and optimizing plant productivity (Dong et. al., 2012). According to Goh (2005), fertilizer is an important component in oil palm cultivation. More than 85% of production costs are only used for the supply of fertilizers. This is because the price of fertilizer is quite expensive. Therefore, it is necessary to develop a DSS to support scientific fertilizer management that can calculate fertilizer needs accurately.

Research related to decision support systems has previously been developed by Sandea (2018) regarding the determination of fertilizer production, Dani (2021) regarding the selection of oil palm plantation locations using the Weighted Product (WP) method, and Widians et. al., (2019) related to land potential using the Promethee method. Research from Suroso and Ramadhan (2012) related to a decision support system using a web-based Policy Analysis Matrix (PAM) method called Decision Support Systems for Oil Palm Plantations (DSSOPP). Main research et al (2011) related to the decision-making system regarding the palm oil supply chain based on the Balance Score Card (BSC) and Supply Chain Operations Reference (SCOR) method combined with the ant colony optimization method. The developed model was able to show the optimum value processed from several supply chain perspectives. The novelty of this research is a decision support system with tools from smartagri.id regarding fertilizer management in oil palm plantations.

Fertilizer is the main energy ingredient in agroecosystems such as plants (Grassini and Cassman, 2012). Fertilizer management is important in an effort to increase the efficiency and effectiveness of crop production (Villalobos et.al., 2020). Plants have macro and micro nutrients. There are three macronutrients in plants, namely N (nitrogen), P (phosphorus), and K (potassium). These nutrients can be used as a reference for fertilizer requirements for each plant. Basically, the need for fertilizer can be predicted by the amount of NPK used during the production period. The balance of the NPK content in these plants is the reference for the concept of fertilizer needs. After knowing the value of fertilizer requirements, the selection of fertilizers can be determined further.

In this study, we develop a cloud-based fertilizer management DSS to support precision agriculture in oil palm plantations. The implementation of this DSS can be in the form of the smartagri.id application which becomes a database of garden activities. Smartagri.id will become an information system platform that can be accessed by users for the needs of garden management recommendations such as planning, maintenance, anticipation, and so on. The DSS will be integrated with the cloud so that it is easy to manage and supports appropriate garden actions, especially regarding fertilizer management.

The development of model in DSS refer to Ferticalc software which allow the fertilizer prediction based on some soil character information. The Ferticalc software can predict the amount of nitrogen, phosporus, potassium, potassium oxide, and phosphorus pentoxide. Therefore it is necessary to examine the algorithm used in Ferticlac, wheter it is suitable for fertilizer prediction for oil palm plantation.

In the other hand, the Ferticlac doesn't allow a real time usage. Therefore the future work for this study is innovation of a new model algorithm which enable cloud system support. From this research, it is expected that fertilizer management can be managed properly so that production costs can be effective and oil palm productivity can be optimal.

2. MATERIALS AND METHOD

The research was conducted with the main object, namely oil palm plantations. Development of a decision support system is focused on data management, in this study is fertilizer management in oil palm plantations. The framework of this research can be seen in Figure 1(a). Based on the picture, crop environment data will be delivered using the internet into a database or information system called as SmartAgri.id. The data will be managed online. From this data set, data from the fertilizer management division will be managed further. Fertilizer data will be modelled so that an expert system or expert knowledge can be obtained that can estimate fertilizer needs digitally and precisely. Then the interpretation of the data is carried out to obtain recommendations regarding correct and appropriate fertilizer management. That way, plantation workers can provide the best treatment according to system recommendations to increase oil palm productivity and minimize negative impacts such as wasted fertilizer, too much fertilizer, and can reduce fertilizer budget expenditures.

Decision Support System (DSS) is a software product specially designed to support management in decision making. This DSS acts as a second opinion that can be used for fertilizer management actions. The most common approach in developing DSS is to use interactive simulation techniques (Talari et. al., 2021). In general, a decision support system can be described as Figure 1(b). Users as DSS users can see supporting references to do something. DSS consists of three important elements, namely model management, database management, and user interface. From these three elements, the DSS will build an advise or reference that can be used to support a decision.

In general, the methodology in this research can be seen in Figure 2. The development of the SmartAgri.id information system will be made with a user interface that is easy to operate by the user. The DSS model in fertilizer management can be entered into the system to make it easier for farmers to manage their plantation. Broadly speaking, there are 4 stages, namely the first stage of preparation, the second stage of information system design, the third stage of model development, and the last stage of publication.

One of the company of PT. Wilmar is located in Sampit, East Kotawaringin Regency, Central Kalimantan. The company is engaged in the palm oil industry from palm oil plants to cooking oil. Wilmar International Plantation has a large area of oil palm land. The fertilizer management data used in this study was fertilizer data in 2021 with 39 data samples.

The determination of the amount of predicted fertilizer was carried out using FertiCalc software 3rd version. The FertiCalc software can be downloaded for free through the official Universidad de Cordoba webpage, which is https://www.uco.es/fitotecnia/fertilicalc.html. FertiCalc is an application developed by Villalobos et. al. in 2020, and to date already has version 3.4. FertiCalc is currently also available in the Indonesian version. FertiCalc covers 149 crops with one of them being oil palm.

Figure 1 Decision support system: (a) DSS framework for palm fertilizer management; (b) conceptual DSS consists of model, database, and user interface

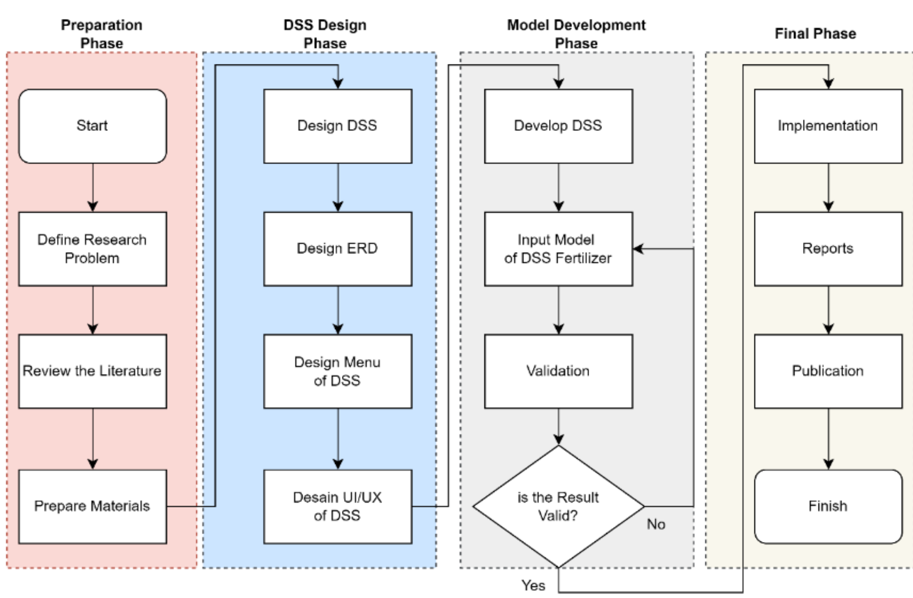

Figure 2 Flowchart design of DSS

3. RESULT AND DISCUSSION

3.1. Design of Decision Support System

DSS design is based on entity relationship diagram or Entity Relationship Diagram (ERD). Entity Relationship Diagram (ERD) is a model for compiling a database in order to describe data that has a relationship with the database to be designed. In an ERD there are three parts such as modules, entities, and attributes. The ERD design in Figure 3, can be the basis for the development of a fertilizer management DSS.

Several modules in the ERD design include user management, activity management, yield management, node management, inventory management, fertilizer management, and QnA management. User management contains user identity information. The user management module is used as the basis for managing or user access rights to the information system. The activity management module covers all activities carried out in oil palm plantations. The main module in this DSS, namely the fertilizer module, will contain output regarding fertilizer requirements with a case study in oil palm plantation. The fertilizer management module will combine with other modules such as node management related to soil moisture data. The fertilizer module will require input data such as the amount of NPK in soil and oil palm. This will allow the system to calculate the required dose of fertilizer to replace the lost or reduced NPK value of the plant.

The user management module is the user's access rights in managing and using the DSS. Each user will have different access rights on the system. User access rights such as admin, manager, gardener, and workers have different access. The access rights include four activities such as C (create), R (read), U (update), and D (delete). The activity management module functions as a provider of information data about all ongoing activities on oil palm plantations. The fertilizer management module serves to recommend the need for and provide fertilizer for oil palm plants.

The results of the ERD design can be continued to design the UI/UX (User Interface User Experience). Figure 4 is the UI/UX design of the DSS dashboard. Dashboard is a panel display in software to display information that is easy to read. The dashboard is used to display a summary of the DSS. Based on the image, through the dashboard interface, users can see the latest developments in real-time. Through the DSS dashboard, a collection of information can be presented so that the information becomes easily accessible, read, analysed, and understood by the user.

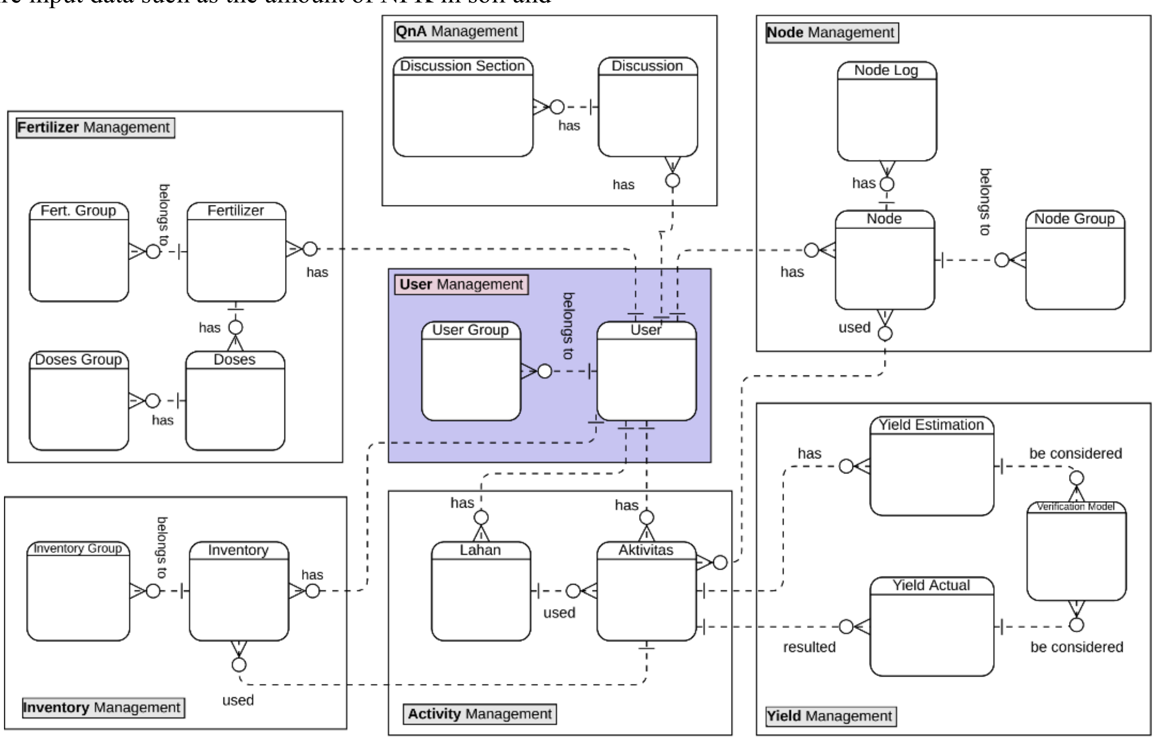

Figure 3 Entity Relationship Diagram (ERD) of DSS

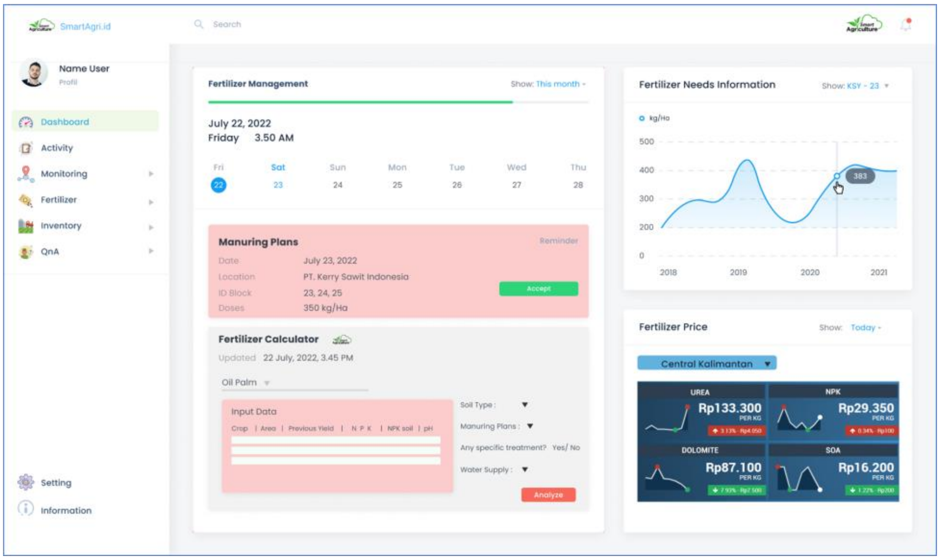

Figure 4 Design of DSS dashboard

3.2. Case Study of Oil Palm Plantation of Wilmar International Plantation Region Central Kalimantan

The appearance of the FertiCalc software can be seen in Figure 5a. Input data on FertiCalc used to predict fertilizer needs include crop yield data, CV yield, Harvest index, residues left in the field, and NPK content in plants. In addition, Ferticalc data inputs include soil NPK content, pH, soil organic matter, water supply, and soil type. In determining the need for predicted fertilizers in FertiCalc, fertilization strategies can be chosen such as sufficiency strategy (minimum fertilizer), build-up & maintenance (reduced fertilizer), build-up & maintenance (maximum yield), and maintenance (soil analysis not available). After the data has been entered, results will be obtained as shown in Figure 5b. The results of the prediction fertilizer needs are obtained from the FertiCalc algorithm with results such as kg N/ Ha, kg P/ Ha, kg K/ Ha, kg P2O5/ Ha, and kg K2O / Ha.

The prediction results from FertiCalc need to be validated so that the model on the FertiCalc algorithm will be suited with the realization of fertilization in oil plam plantation. Yield data, crop NPK, and soil NPK in 2020 were collected to predict fertilizer needs next year or 2021. There were 39 datas obtained, 19 of them used for validation meanwhile the 20 rest data used for implementation. The data as shown in Table 1. This is real data for validate the FertiCalc result. Table 1 show the data from fertilizer management in 2020 at PT. Wilmar is located in Sampit, East Kotawaringin Regency and data result of fertilizer management with FertiCalc.

The results of FertiCalc's predictions can be shown in Figure 6. Validation was carried out with a plot of N fertilizer needs versus Wilmar fertilizer data. Based on this validation, the validation equation was obtained, namely $y = 0.7199x - 25.28$. The validation results can be seen in Figure 6a. After obtaining the validation equation, another 20 data are used for implementation by entering into the validation equation. The results in Figure 6b, can be seen in the plot of the FertiCalc fertilizer demand prediction chart corrected versus the field fertilizer needs with an R Square of 0.8494. Based on these results, it can be assumed that FertiCalc can predict fertilizer needs well.

(a) (b)

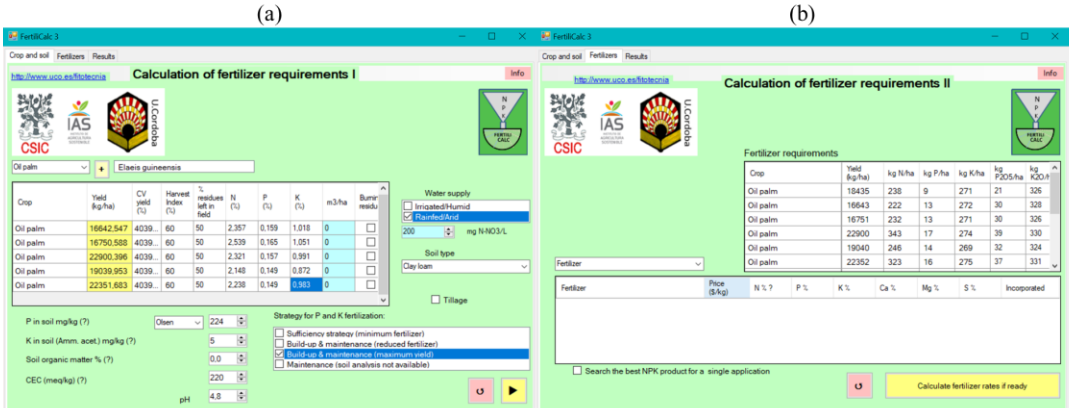

Figure 5 FertiCalc to determine the dose of oil palm fertilizer: (a) input data; (b) prediction for fertilizer requirements.

Table 1. Data of Fertilizer in 2020 at PT. Wilmar is located in Sampit, East Kotawaringin Regency and Data of Fertilizer Management with FertiCalc

No	ID	Yield (kg/Ha)	Leaf Analysis (%)			Soil Analysis				Fert. Observation	FertiCalc Results (kg/Ha)				
			N	P	K	N	P	K	pH		N	P	K	P_2O_5	K_2O
1	24	16642.55	2.54	0.17	1.05	599.32	223.50	5.40	4.79	230.45	393	13	271	30	326
2	25	16750.59	2.32	0.16	0.99	599.32	223.50	5.40	4.79	226.64	368	13	270	30	325
3	32	22498.92	2.32	0.16	106	599.32	223.50	5.40	4.79	347.07	500	17	275	39	331
4	33	23260.87	2.38	0.16	1.09	599.32	223.50	5.40	4.79	340.14	536	18	275	41	331
5	36	25600.34	2.26	0.15	0.94	599.32	223.50	5.40	4.79	361.73	537	19	275	44	331
6	37	23497.48	2.35	0.15	0.92	599.32	223.50	5.40	4.79	366.65	519	17	274	39	330
7	45	24585.99	2.39	0.16	1.10	599.32	223.50	5.40	4.79	358.80	553	19	278	44	335
8	51	24285.55	2.33	0.15	0.92	599.32	223.50	5.40	4.79	359.93	534	18	274	41	330
9	55	24319.08	2.42	0.16	0.98	599.32	223.50	5.40	4.79	366.39	564	18	275	41	331
10	58	24067.05	2.29	0.16	1.03	599.32	223.50	5.40	4.79	355.73	554	18	275	41	331
11	60	24717.81	2.25	0.16	0.98	599.32	223.50	5.40	4.79	353.27	523	18	275	41	331
12	64	18220.56	2.28	0.15	0.97	599.32	223.50	5.40	4.79	266.44	379	13	271	30	326
13	65	19638.98	2.19	0.15	1.01	599.32	223.50	5.40	4.79	287.67	423	14	272	32	328
14	66	22662.09	2.30	0.16	1.00	599.32	223.50	5.40	4.79	357.22	523	17	275	39	331
15	67	25826.95	2.20	0.15	0.94	599.32	223.50	5.40	4.79	369.65	545	19	275	44	331
16	69	21189.62	2.43	0.16	0.99	599.32	223.50	5.40	4.79	329.55	473	16	274	37	330
17	72	22582.92	2.32	0.16	0.89	599.32	223.50	5.40	4.79	352.08	508	17	275	39	331
18	73	23684.91	2.28	0.16	0.97	599.32	223.50	5.40	4.79	355.15	525	18	275	41	331
19	75	23567.01	2.40	0.16	0.93	599.32	223.50	5.40	4.79	353.49	522	18	275	41	331
20	76	22033.86	2.27	0.15	0.95	599.32	223.50	5.40	4.79	358.95	467	16	274	37	330
21	80	24199.78	2.32	0.16	0.95	599.32	223.50	5.40	4.79	360.44	519	18	275	41	331
22	81	24564.73	2.37	0.16	1.05	599.32	223.50	5.40	4.79	373.97	561	18	275	41	331
23	83	23255.35	2.41	0.16	1.02	599.32	223.50	5.40	4.79	346.27	525	18	275	41	331
24	85	23320.41	2.31	0.15	1.02	599.32	22350	5.40	4.79	346.30	513	17	275	39	331
25	88	24565.82	2.33	0.16	1.09	599.32	223.50	5.40	4.79	346.89	543	18	276	41	332
26	89	24357.54	2.28	0.15	0.91	599.32	223.50	5.40	4.79	363.75	532	18	275	41	331
27	93	20122.28	2.19	0.15	0.95	599.32	223.50	5.40	4.79	232.97	427	14	274	32	330
28	95	20810.58	2.40	0.16	0.99	599.32	223.50	5.40	4.79	326.81	488	16	274	37	330
29	97	20712.15	2.30	0.15	0.85	599.32	223.50	5.40	4.79	316.27	436	15	272	34	328
30	101	23245.36	2.28	0.15	1.01	599.32	223.50	5.40	4.79	340.25	476	17	275	39	331
31	102	22946.14	2.39	0.16	0.84	599.32	223.50	5.40	4.79	338.86	526	18	273	41	329
32	104	21226.63	2.30	0.15	0.95	599.32	223.50	5.40	4.79	246.98	439	16	273	37	329
33	105	19112.83	2.41	0.16	0.95	599.32	223.50	5.40	4.79	291.03	430	14	272	32	328
34	108	22227.12	2.29	0.15	0.81	599.32	223.50	5.40	4.79	363.01	488	16	274	37	330
35	111	21362.50	2.10	0.14	0.94	599.32	223.50	5.40	4.79	246.53	412	15	273	34	329
36	112	21272.40	2.30	0.15	0.90	599.32	223.50	5.40	4.79	292.34	477	16	275	37	331
37	116	21352.68	2.33	0.16	1.00	599.32	223.50	5.40	4.79	331.54	488	16	274	37	330
38	120	19355.91	2.39	0.15	0.98	599.32	223.50	5.40	4.79	244.06	428	14	271	32	326
39	123	20921.82	2.14	0.15	0.86	599.32	223.50	5.40	4.79	237.92	423	15	272	34	328

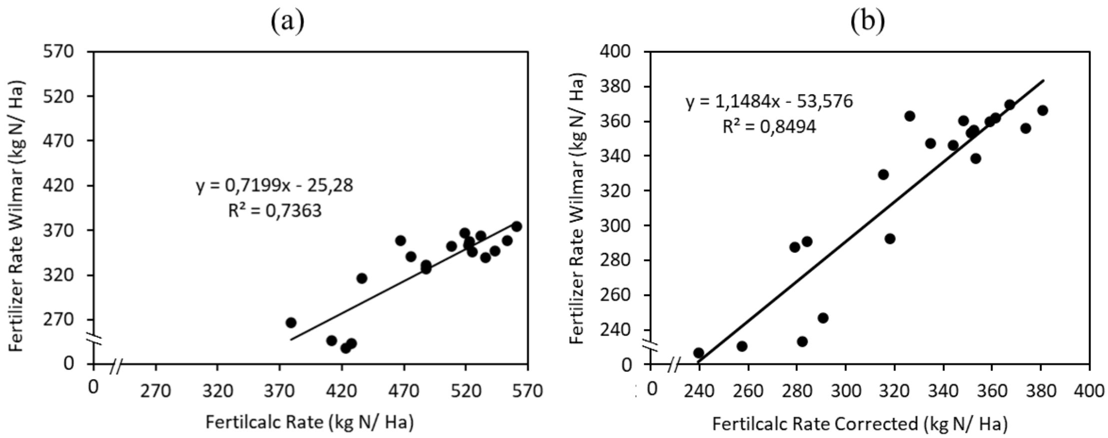

Figure 6 Fertilizer management result: (a) plots of N oil palm fertilizer rates observation versus the fertilizer rates recommended by FertiCalc; (b) oil palm fertilizer rates observation real data at wilmar versus ferticalc rate corrected

4. CURRENT CONCLUSION

Based on the research that has been done can be concluded that DSS is one of the technologies that is very helpful in data management, in this study is fertilizer management in oil palm plantations. Algorithm used in Ferticalc suitable for development of DSS to predict fertilizer needs for oil plam plantation. This was indicated by determination coefficient value was 0,8494. The future works of this study is development of model DSS supporting cloud system. Cloud-based decision support system for fertilizer management can be accesed realtime. The developed system has the potential to provide recommendations for oil palm fertilization plans appropriately and according to plant needs.

AUTHORS' CONTRIBUTIONS

Wiratmoko and Nugroho conceived of the presented idea about DSS of Fertilizer Management. Muna, Suwardi, Sukarman, and Sutiarso developed the theory of fertilizer management in oil palm plantation. All of authors was discussed the results and contributed to the final manuscript.

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