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A Review of Fertilization Assessment Methods in Oil Palm Plantation

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Abstract
Rising in production cost due to labour shortage, low efficiency of farm operation, low yield, and increase in input cost of materials were among the key factors faced by Malaysian oil palm industry. Thus, significantly affect the overall upstream performance and the annual budget for the plantation operation. Input cost, especially fertilizer accounted for more than 50% of the production cost annually. Highly weathered tropical soil, intensive and mono-cropping farming activities caused nutrient depletion over the availability of the nutrient to the plant. Among the agronomic practices, fertilizer application and saving become a limitation due to its increasing share of production cost, thus effect the annual targeted yield. Prior to the fertilizer application and recommendation rate, a proper fertilizer assessment program should be conducted for achieving economic, social and environmental sustainability. In this paper, several methods of fertilizer assessment for oil palm plantation were identified and discussed based upon the agronomic practices. In addition, the several techniques under proximal sensing technology for Precision Agriculture (PA) program to quantify the fertility and crop response also were listed. The adaptation of the technology and a new approach in reducing the fertilizer used will lead the input cost reduction in oil palm plantation while improves overall farm efficiency.

Keywords: oil palm, sustainability, plant nutrition, fertilizer, precision agriculture, proximal sensing

Introduction

According to “The Forum for Sustainable Palm Oil”, oil palm (*Elaeis guineensis*) plantation had been criticized globally due to its cultivation activities, for instant, environmental destruction and human rights violations. Whilst Malaysian Palm Oil Council (MPOC), 2015 pointed out the local issues which are scarcity of competent manpower for plantation operation and scarcity of good arable land for oil palm plantation. Despite the challenges, we should not prejudge the worth of oil palm plantation by its negative reputation alone because it has the highest yield of any oil plant as all the palm oil and palm kernel oil are certified. In order to meet the scheme which designed by Roundtable on Sustainable Palm Oil (RSPO) economic, social and environmental sustainability criteria should be properly applied in the overall supply chain management especially upstream practices. But, there is no restriction for the expansion of the oil palm plantation due to the increasing world population.

United States Department of Agriculture (USDA) has reported that Malaysian palm oil companies have engineered a sustained long-term expansion of plantation area, increasing 3.85 million hectares since 1980 or 385%. Malaysian Palm Oil Board (MPOB) also estimate the maximum future oil palm area will be 5.6 Ha in year of 2020. This scenario had stretched the capability of the fertilizer manufacturing industry to meet the global demand. According to Shean (2011), the price volatility for rock phosphate was the highest, increased by 400% from 2007 to 2008. 90% of total imported fertilizer had been utilized in oil palm industry in Malaysia. The high price level had cost squeezed the industry as the share of fertilizer cost, including application in the overall field production cost increased from 30-35% in 2007 and even 50% in 2008 due to high dependency on imported fertilizer. Due to bad economic circumference and a number of factors have reportedly led to the sharply declining in average yields over the past 4 years (Simeh, 2010), including adverse weather also known as El Nino and La Nina, decreasing fertilizer use, and low replanting rates (Shean, 2011).

Therefore, judicious use of fertilizer is a must to achieve higher productivity, cost effective and at the same time maintain the sustainability in long-term management (Goh, 2003).

Oil Palm Nutrition Requirement and Recommendation

Generally, nutrient requirement of oil palm different which depend on target yield, type of planting material, planting density, palm age, soil type, ground cover conditions, as well as climate and other environmental factors. Referring to the Mulder’s chart of antagonistic elements, each of the fertilizer element can be affected by other excess antagonistic element. In addition, Justus von Liebig’s “Law of the Minimum” which emphasize the importance of nutrient balance by applying the optimum rate of macronutrient and micronutrient application should always bared in mind such as utilizing the nutrient from the biomass decomposition as mentioned by Tarmizi and Mohd Tayeb (2006).

The essential nutrients are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), Magnesium (Mg), Calcium (Ca), sulfur (S), chlorine (Cl), boron (B), copper (Cu), zinc (Zn) and

Manganese (Mn) (Fairhurst & Härdter, 2003). Basic nutrition of oil palm and its suggested application rates of macronutrient fertilizer which planters focus on are listed in Table 2. The cost of fertilizer mainly varies by its type of source, solubility and reaction ability. In terms of fertilizer application, N fertilizer application should be avoided from applying immediately before or during high rainfall periods to prevent leaching and volatilization losses.

Table 1. Recommended application rates for macronutrients for immature and mature palm Year After Planting (YAP)

Nutrient Element	**Application rate (kg palm^{-1} year^{-1})**		**Particular details of recommendation**
	Immature palm (2-3 YAP)	**mature palm (>3 YAP)**	
Nitrogen, N	0.25 – 0.75	0.25 – 1.75	Range can be adjusted by taking into account palm age, planting density, soil analysis, leaf analysis and site yield potential.
Phosphorus, P	Soil type-based recommendation Coastal soil: 0.3 – 0.4 In-land soil: 0.4 – 0.7 Ultisols: 0.8		One time blanket application of 60 – 130 kg P for acidic and P deficient soil.
Potassium, K	0.3 – 3.0		Specific rate is depending on leaf and soil analysis
Magnesium, Mg	Maintenance application: 0.06 – 0.25 Corrective application: 0.30 – 0.75		Detection of Mg deficiency as the amount of Mg is <0.2 cmol kg^{-1}
Calcium, Ca	Peat soil: 100 – 150 (hectare basis)		In addition, 150 – 500 kg CaO can be applied to improve legume cover plants.
Sulfur, S	-	-	Generally applied with Ammonium Sulfate, Kieserite and Single Superphosphate

(Source: Fairhurst & Härdter, 2003)

Assessment of Oil Palm Fertilizer Requirement

Conventionally, there are four (4) approaches as shown in Table 2, including prediction based on permanent site properties such as climate, soil survey and initial soil analysis (Method I), evaluation of current soil nutritional status based on soil analysis (Method II), evaluation of current nutritional status of palm tissue analysis (Method III) and evaluation of current nutritional status of palm tissue analysis and fertilizer recovery efficiency from permanent site properties (Method IV) for assessing fertilizer requirement in oil palm plantation (Fairhurst & Härdter, 2003). Among the environmental factors, the most important climatic data is rainfall which will affect the timing of fertilizer application and equatorial conditions (1780–2280mm annual rainfall) for oil palm plantation. From soil survey data, parent material, slope, drainage conditions and soil consistency are the required key factors. Method I will be assessed by utilizing permanent and variable properties. While Method IV only focuses on permanent properties, for example, soil particle-size analysis, soil organic matter, soil buffering capacity and reserve nutrient levels and variable soil properties include the amount of extractable nutrient in soil. Meanwhile, Method II, which include only leaf nutrient analysis will be sufficient for correcting fertilizer rates in later years. Another element of Method II is analyzing fertilized soil which is not recommended because samples collected from areas where fertilizer had been broadcast give very high sampling errors. Evaluation of specific location required to establish important parameters and prediction equations before Method I, II and IV. But, Method III is also known as "Foliar analysis" which only relies on leaf nutrient analysis is important to assess nutrient deficiencies without any other local information. In order to select a better diagnostic tool for estimating the fertilizer application rate, variable factors, permanent factors and its functions should be encountered.

Since, fertilizer recommendation for oil palm is mainly based on calibrated soil or leaf test. The completed tests usually compare the soil and leaf nutrient concentration with a predetermined "critical" concentration and are used to make fertilizer application decision. Moreover, the sampling density is limited, and often used to predict the fertilizer recommendation, which may under or over fertilized. For those who have no appropriate trial information will thus depend on the basis of leaf analysis, infrequent soil analysis, nutrient content in the product, observable deficiency-symptom, past experience and opinion from experts of other farmers. All of these also called as field-by field basis which is not suitable to all smallholders (Webb *et al*., 2012). There is a significant variation in fertilizer recommendation preferences and options between large scale plantation and smallholder due to the gap of investment cost for upkeep management and fertilizer assessment. Large scale plantation tends to have higher allocation for soil analysis, leaf analysis, fertilizer trial block, equipment, manpower or combination of analysis, while, smallholder may depend on the fertilizer trial results for general application rate and observable nutrient deficiency symptoms. As a result, it causes delay in the effect of fertilizer on yield had been proven that additional return from the increased yield may be realized in full only after 8 months or even a few years (Goh & Teo, 2011). As mentioned in Goh *et al.* (1999), soil analysis results not taken into consideration of most fertilizer trials. The possible factors which affect the fertilizer recommendation preference are tedious workload and procedure, time consuming, and high cost consumption.

Table 2: Summary of methods of fertilizer assessment indicating data required

Source	Fairhurst & Härdter, 2003			
Method	**I**	**II**	**III**	**IV**
Climatic data	√			√
Soil survey data	√			√
Unfertilized soil analysis results	√			√
Fertilized soil analysis results		√		
Leaf Analysis results			√	√
Comments	Initial fertilizer rate selection	Not suitable for oil palm	Often adequate for oil palm	Recommended method

Technology for Assessment of Oil Palm Fertilizer Requirement

To date, the advances made in geospatial information technologies, for example, Global Positioning System (GPS) and Geographic Information System (GIS) have lead oil palm plantation management toward computer support system in decision-making. Coupling the GPS and GIS technologies often is the practice in order to establish oil palm databases. Besides that, GPS and GIS also have been proven useful for land evaluation for oil palm plantation. (Nordiana, *et al.*, 2013). Planters able to use the collected data to generate digitized maps with geographic coordinate at relatively low to high accuracy GPS that could eventually generate the elevation. All of the data is useful for calculating slope and aspects relevant to landscape. This positioning method often known as "map-based approach" (Adamchuk *et al.* 2004).

Proximal Sensing Technology

Two different types of proximal sensing; (i) non-destructive and (ii) destructive method. Both can be can positioned on the ground or from the sky level. As mentioned previously, foliar analysis and application is the most important and preferred by the growers to tackle the crop nutrient deficiency (Method III and IV) using the non-destructive device. There are several proximal sensors for example Chlorophyll ContentMeter (CCM) for indirect chlorophyll estimation which result higher correlation with N detection for nursery oil palm. Unfortunately, the SPAD result might be different due to leaf age and restricted for mature palm. There was also poor responses between N applied and foliar N detection. Furthermore, SPAD also might be influenced by leaf thickness, varieties, chlorophyll and sampling season. Nevertheless, N estimation also can be done by palm Diameter and Green Model (Diyana *et al.*, 2014).

Remote sensing technology by utilizing the image from the sky either from Unmanned Aerial System (UAS, also known as a drone) integrated with either with camera sensor and/or payload had been explored for map-based oil palm plantation monitoring, including land cover classification, planting on terrace, automatic tree counting, deforestation detection, age estimation, pest and disease detection, and yield estimation. Yield estimation and palm age estimation are the essential database for targeting the production, forecasting and aiding in decision-making process. Technically, oil palm yield can be affected by several factors which are internal factors and external factors. Internal factors of fresh fruit bunch (FFB) production are palm age and its breeds. While, external factors are environmental factor, soil properties, soil fertility, pest and disease infection and many more.

Regarding to the recent research, vegetation indices derived from QuickBird satellite image are strongly correlated with FFB yield, with Ratio Vegetation Index (RVI) showing strongest relationship. From the information of leaf area index (LAI), palm age can be estimated while palm health and FFB yield production can be roughly estimated. Besides that, Normalized Difference Vegetation Index (NDVI) sensor which can be integrated with UAS has the potential to estimate palm health with certainly detecting and calculating the electromagnetic spectrum wavelength in real time condition (Webb *et al*., 2012).

From aspect of soil analysis, on-the-go sensor can be a part of “map-based” and “real time” approach. No matter electrical and electromagnetic sensors, both are rapid response, low cost operation and high durability. These instruments are being used to measure the ability of soil to conduct electricity which quantified as electrical resistivity (ER) or electrical conductivity (EC). This method had been correlated to soil texture, salinity, organic matter, moisture content, and other soil attributes.

Besides that, optical and radiometric sensors determine the amount of energy reflected from the soil surface in particular spectral range is the most popular approach in agriculture. Near- and mid-infrared spectrophotometer has potential organic carbon determination and total N. In addition, real-time portable spectrophotometer use soil reflectance data from 400nm to 2400nm to produce soil properties mapping. The result shows that spectral reflectance data at four single wavelength is correlated with soil moisture, soil pH, soil EC and soil OM. Lately, spectrophotometer had been integrated with a digital camera, EC electrode and a mechanical load sensor was applied for both spatial and temporal variability of soil OM and nitrate content. Furthermore, ground penetrating radar (GPR) which using principle of seismic and sonar method. GPR also represents another radiometric method that has great potential in geophysics in general and agriculture in particular, especially to assist water management.

Mechanical sensor may help to measure soil strength and compaction level of soil. Meanwhile, acoustic and pneumatic sensors have been created as alternative of mechanical sensor which can measure soil texture and compaction separately. Last but not least, electrochemical sensors use ion-selective membranes that produce a voltage output in response to the activity of selected ions including H+, K+, NO3-, Na+, and soil pH measurement. (Adamchuk *et al.*, 2004).

Employment of either geospatial information technologies, remote sensors or proximal sensor is highly recommended for both smallholder and large scale oil palm plantation. Because technology advancement is not only contribute to national research and development also create a platform for smallholder to enhance their knowledge. Besides that, technology can also assist to minimize the gap between smallholder and large scale oil palm plantation. In addition, experts, technology advisors and service producers have been engaged in several research projects in order to improve the performance of the oil palm industry.

Conclusion

In the future oil palm plantation, precision agriculture play a crucial rule for production cost minimization, profit maximization and labour force dependency reduction. Further research and development of application technology is needed to achieve and maintain sustainable agricultural practices. Government and non-government sectors should emphasize dissemination and technology transfer in order to advance in mutual advantage.

References

Adamchuk, V. I., Hummel, J. W., Morgan, M. T., & Upadhyaya, S. K. (2004). On-the-go soil sensors for precision agriculture. Computers and Electronics in Agriculture, 44(1), 71–91. https://doi.org/https://doi.org/10.1016/j.compag.2004.03.002

Diyana, A., Muharam, F. M., & A Rahman, Z. (2014). Evaluation of Multiple Proximal Sensors for Estimating Nitrogen Nutritional Content of Matured Oil Palm. Asian Journal of Plant Sciences (Vol. 13). https://doi.org/10.3923/ajps.2014.136.146 Fairhurst, T., & Härdter, R. (2003). The Oil Palm. Management for Large and Sustainable Yields.

Goh, K. J. (2003). Fertilizing for maximum return. (R. Härdter, & T. F., Eds.) Oil palm: Management for large and sustainable yields, 279-306.

Goh, K. J. (2005). Fertilizer recommendation systems for oil palm: estimating the fertiliser rates. (P. S. Chew, & Y. P. Tan, Eds.) Proceedings of MOSTA Best Practices Workshops – Agronomy and Crop

Management. Malaysian Oil Scientists' and Technologists.
Goh, K., & Teo, C. B. (2011). Agronomic principles and practices of fertilizer management of oil palm. Agronomic Principles & Practices of Oil Palm Cultivation.
Goh, K., Teo, C., Chew, P., & Chiu, S. B. (1999, September). Fertiliser management in oil palm: Agronomic principles and field practices. Fertiliser management for oil palm plantations, 1-44.
Nordiana, A. A., Wahid, O., Esnan, A. G., Zaki, A., Tarmizi, A. M., Zulkifli, H., & Norman, K. (2013). Land Evaluation for Oil Palm Cultivation using Geospatial Information Technologies. Oil Palm Bulletin, 67, 17-29.
Ramme, O. (2015, November). Retrieved from Forum for Sustainable Palm Oil: https://www.forumpalmoel.org/en
Shean, M. (2011). Commodity Intelligence Report. United State Departement of Agriculture.
Shean, M. (2011). Foreign Agricultural Service-Commodity Intelligence Report. United States Department of Agriculture.
Simeh, M. A. (2010, May). Impact of increases in fertilizer prices on Long-term Economic Variability of Palm Oil Production. Oil Palm Bulletin 60, 1-16.
Tarmizi A.M and Mohd Tayeb D. (2006). Nutrient demands of Tenera oil palm planted on inland soils of Malaysia. Journal of Oil Palm Research, 18, 204-209.
Webb, M., Nelson, P., Gary Rogers, L., Curry, G., Pasuquin, J. M., & M Johnston, A. (2012). Site-Specific Fertilizer Recommendations for Oil Palm Smallholders Using Information from Large Plantations. Better crops (Vol. 94).