AGRIVITA VOLUME 33 No. 3 OCTOBER-2011 ISSN : 0126-0537

A STUDY OF USING QUEFTS MODEL FOR ESTABLISHING SITE SPECIFIC FERTILIZER RECOMMENDATION IN MAIZE ON THE BASIS OF FARMER FIELDS

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Received: February 2, 2010/ Accepted: June 17, 2011

ABSTRACT

Nutrient Use Efficiency (NUE) of Maize is considered low. There are two important factors responsible for this condition: (a) uniform fertilizer recommendation, (b) lack of consideration on soil variability, Indigenous Nutrient Supply and plant nutrient needs. A method for studying low NUE and the capability of studying these two factors are urgently required. This study used Quantitative Evaluation of Fertility on Tropical Soils (QUEFTS) model. The main aim of this study was to employ and evaluate QUEFTS model for establishing site specific fertilizer recommendation in maize on the basis of farmer fields. Due to a unique characteristic of farmer field, it may be interesting to observe the pattern of soil fertility in relation to yields. Six farmer's fields and thirty soil samples were taken and analysed in the laboratory. The results showed that QUEFTS model was a valuable tool to make fertilizer recommendation by using yields as an integrated indicator. The results also showed that QUEFTS model was a promising method for establishing fertilizer recommendation for maize. The merits of model for determining Indigenous Nutrient Supply, nutrient yield limiting factors, balanced fertilizer recommendation show that QUEFTS model is a valuable tool for site-specific fertilizer recommendation.

Keywords: QUEFTS, recommendation, site specific, yield

INTRODUCTION

Nutrient Use Efficiency in Maize in Indonesia and in almost countries in Asia is considered low which mainly relates to inappropriate management (Dobermann in http://www.fertilizer.org/IFA/publicat/PDF/2007_IFA_FBMP-part_1_dobermann.pdf). Two main factors responsible for this condiction are : (a) uniform fertilizer recommendation and (b) lack of consideration on Indigenous Nutrient Supply (INS) and plant nutrient needs. These factors caused overapplication and underapplication of fertilizers (Scharf *et al.,* 2005).

Large variability of factors determining plant performance has made this procedure impractical to be applied in real condition of field. Maiti*, et al* (2006), for example, claimed that there are significant differences amongst climate, soil and management, making it impossible to extrapolate the results of fertilizer recommendation from one site to others.

There are emerging technologies, particularly computer software which can contribute to the development of methodology for fertilizer recommendation, and one of these potential technologies is crop model. Maiti *et al (*2006) claimed that crop model can assist in real time application of fertilizers. In fact, there have been a quite number of crop models which can support the development of fertilizer recommendation as claimed by Hartkam *et al* (1999) and Segda *et al*, (2005). Hartkamp*, et al* (1999) described a number of crop models and their characteristics, two of them are DSSAT and WOFOST. These two models are called dynamic models. According to Hartkamp *et al.* (1999), the main weaknesses of dynamic model are: (a) significant amount of data are needed; (b) the limited data are most likely to be impediment for the calibration and validation of dynamic model. Therefore, for the purpose of fertilizer recommendation, a simple model is required.

Thus, a simple model for making fertilizer recommendation exists. This model is called QUEFTS (*Quantitative Evaluation of the Fertility in Tropical Soils*). The comprehensive description of this model was explained in previous studies (Maiti *et al,* 2006; Mulder, 2000; Mowo *et al* in http://www.africanhighlands.

org/pdfs/wps/ahiwp_18.pdf). In terms of proce-dure used to make recommendation, QUEFTS model has four main stages (Mulder, 2000):

(a) The actual fertility of soil is calculated on the basis of certain chemical soil properties. For three macro-nutrients: nitrogen, phosphorus and potassium, the maximum quantity that can be taken up from the soil by the plant is determined.
(b) The relationship between potential supply (step 1) and actual uptake of the three nutrients (UN, UP, UK) is established.
(c) For upper and lower nutrient bounds, yields are calculated on the basis of the actual uptake of each nutrient (UN, UP, UK). The upper bound yield refers to the yield attainable when, for instance, N is maximally diluted in the plant, the *Yield N maximally Diluted* (YND) is obtained.The lower bound yield refers to the *Yield N maximally Accumulated* (YNA), the yield that could be obtained when N is maximally accumulated in the plant.
(d) Finally the yield estimates are calculated in pairs on the basis of the actual uptake of each nutrient (UN, UP, UK) and the yield ranges are calculated in step 3 (YNA, YND, YPA, YPD,YKA, YKD). This will result in six paired estimations (YNP, YNK, YPN, YPK, YKN, YKP), which are averaged.

Evidently, QUEFTS model has been applied in many developing countries and most applications relate QUEFTS model to Site Specific Nutrient Management (SSNM). Beside the fact that QUEFTS model is simple, another reason for using QUEFTS model is because this model takes into account (a) Indigenous Nutrient Supply (INS), nutrient interaction and nutrient use efficiency. Another advantage on using QUEFTS model is that the integrated indicator used, called crop yield for fertilizer recommendation.

The evidence on using QUEFTS to model the variability of soil fertility on yields on the scale of farmer field is limited. This kind of modeling would be important because : (a) the variability of soil properties is more likely to exist in farmer fields due to inherent variability or the history of management occurred in every field; (b) fertilizer input into farmer field is different. As a consequence, every field could have different yields and fertilizer recommendation. .Therefore, the main aim of this study was to employ QUEFTS model for fertilizer recommendation at farmer fields. The focus of this study was on making recommendation for macro-nutrient only (nitrogen, phosphorus and potassium).

MATERIALS AND METHODS

The study area was in Kertonegoro Village located in Jenggawah Sub-District in Jember Regency, East Java, Indonesia. The study area was about 40 Ha. The main reason of choosing this study was due to the existence of the variability of management conducted by farmers and the variability of soil properties in the area. Six farmer' fields were chosen as samples since they represented management and soil variability. Thirty soil samples were selected by grid sol sampling technique.

The analysis of soil samples was undertaken in the Laboratory of Soil Physical and Chemical in the Faculty of Agriculture, The University of Jember. The analysis was conducted for soil properties: Organic C, N, P Total, P Olsen, K, pK and Cation Exchange Capacity following standard procedure of soil analysis. The results of soil analysis were then entered into QUEFTS model. Table 1 shows the results of soil analysis indicating that other soil properties can be categorized as low to very low, except for soil P Total, K and pH (H2O).

The values shown in Table 1 were then used to estimate Indigenous Nutrient Supplies, such as Indigenous Nitrogen Supply (INS), Indigenous Phosphorus Supply (IPS) and Indigenous Potassium Supply (IKS). Original QUEFTS model were used to estimate Indigenous Nutrient Supply. The results of the calculation of QUEFTS model were then used for input in the modified QUEFTS model.

Model calibration was conducted by using data from Ommision plots to determine some important parameters required by QUEFTS. Besides, model calibration was conducted by using parameters used by previous studies (Maiti, 2006; Alxandrova and Donov, 2003). Model validation was conducted by using data obtained from the six farmer's fields. At first, the fertilizer dosage at each farmer's field was used as input for QUEFTS analysis. The results of analysis showed that there was a significant difference between the crop yields predicted and the actual yields. The only reason for this is that farmers had not applied balanced fertilizers, while QUEFTS model predicted crop yields on the basis on balanced fertilizer.

Table 1. The Results of laboratory analysis and the criteria of soil chemical for QUEFTS model

No	Farmer Name	C org (%)	N (%)	P Total mg/100 gr	P Olsen ppm	K me/ 100 gr	pH H_2O
1	Ahmad	0.91	0.12	32.58	3.88	0.39	6.91
2	H. Syairi	1.25	0.08	31.33	9.38	0.47	7.04
3	Hanifah	1.24	0.13	36.50	12.39	0.58	6.96
4	Kanan	1.12	0.16	37.07	12.99	0.60	6.87
5	Kasiyanto	1.12	0.14	31.79	6.13	0.46	6.98
6	Syamsudin	1.41	0.14	30.08	1.48	0.36	7.04
7	Toyib	1.24	0.19	32.87	6.72	0.38	6.87

Table 2.Recovery efficiency obtained from calculation at the ommision plots

Partition	N	P	K
	RE ($kg.kg^{-1}$)	RE ($kg.kg^{-1}$)	RE ($kg.kg^{-1}$)
Non NPK	-	-	-
NPK	0.51	0.19	0.31
NP	0.21	0.19	-
NK	0.44	-	0.95
PK	-	0.01	0.21
	0.39	0.13	0.27

An important component of the analysis using QUEFTS model is the determination of Ymax (maximum yield) and GY (Grain Yield Target). In this study, Ymax was set at10000 kg/Ha, while GY Target was 70% Ymax and 80% of Ymax respectively. These Values of GY Target was considered realistic considering the yield obtained by farmers in the study area. Model Validation was conducted by running model at farmers' fields using established parameters obtained from calibration. The yields predicted by QUEFTS model were then compared to those obtained in farmers' fields in order to assess the accuracy using U-Theil. The values of U-Theil is interpreted as follow: if the value of U is equal to zero, then the model is perfect, and if the value of U = 1, then the model is poor for prediction:

$$U = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^s - Y_t^a)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^s)^2} + \sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^a)^2}}$$

In which :

T = the number of samples; Y_t^s = the predicted values of model Y_t^a = the real values

(Source : http://www.damandiri.or.id/file/elinu-ripbbab4.pdf)

RESULTS AND DISCUSSION

Results of Model Calibration

The calculation of Recovery Efficiency (RE) is an important parameter of QUEFTS model because this will be employed for fertilizer recommendation. The values of RE can be seen in Table 2. The values of RE shown in Table 2 seem to agree with those found in Dobermann in http://www.fertilizer.org/IFA/publicat/PDF/2007_IFA_FBMP-part_1_dobermann.pdf) stating that the values of RE for maize in Indonesia are 0.32 kg/kg for Nitrogen, 0.1—0.35 for Phosphorus and 0.4-0.5 for Potassium. The values of RE for Potassium do not agree with those found in Dobernmann. Lower value of average RE was found in the study area than that in the range, showing that less potassium was taken by plant. These values show that uptake of nutrient of maize in the study area was 39% N, 13% P and 27%K of fertilizer. The values of RE in Table 2 indicates that there is a need to improve the fertilizer efficiency.

An important stage in the use of QUEFTS model is the calculation of two important parameters: (a) accumulation and (b) dilution, which are called “a” and ”d” respectively. The values of “a” and “d” can be seen in Table 3.

Table 3. *Parameters for QUEFTS Model*

	a	d
N	35	90
P	350	876
K	15	105

Table 4 shows the comparison between the yields at Ommision plots and the predicted yields at Ommision plots. These values show that QUEFTS model predicted the yields quite accurately at Ommision plots, especially when the balanced fertilizer was applied, as shown in plot NPK and NonNPK. For other plots, there seems to be a quite large difference. This difference is probably due to the nature of QUEFTS model for predicting yields in balanced fertilizer.

Table 4. The comparison of grain yield at ommision plots and those from simulated QUEFTS model

Ommision plot	Actual Yields (kg/ha)	Predicted Yields by QUEFTS (kg/ha)
Non NPK	7528	7305
NPK	9169	9209
NP	9569	7008
NK	9594	7968
PK	5558	6562

Model Validation

Table 5 shows the result of model validation. U-Theil statistic technique was used for calibrating model between the yields obtained from farmers' fields and the predicted yields by QUEFTS model. The calculated U-Theil was 0.14 showing that the model can be used for predicting yields.

The same values (7000 kg/Ha) in column 3 (Table 5) show the targeted yield which was set to be 7000 kg/Ha. The same values show that the yields could potentially be increased if balanced fertilizer was applied in farmers' fields. Moreover, yield gap existed in most fields (Table 5). The results clearly indicate that there is still an opportunity to increase yields larger than the current yields by using balanced fertilizer

Table 5 . The comparison of yields at farmer's field and simulated QUEFTS model

NO	Farmers' Fields	Actual Yields (kg/ha)	*Gy Target* (kg/ha)
1	Ahmad	6000	7000
2	H. Syairi	6000	7000
3	Hanifah	5000	7000
4	Kanan	7000	7000
5	Kasiyanto	4850	7000
7	Syamsudin	5000	7000
8	Thoyib	5000	7000

Table 6 shows the comparison of fertilizer dosage at farmers' field and those resulting from the calculation of QUEFTS model. The results show that by considering Indigenous Nutrient Supply (INS), the dosage of fertilizer N and P was lower compared to those provided by farmers at Yield Target 7000 kg/Ha, whereas the recommended fertilizer dosage by QUEFTS model was higher for fertilizer K. However, some points need take into account:

a. there were differences in the values of Indigenous Nutrient Supply for every farmer's field which proved that site specific condition seems to dictate the differences;
b. imbalanced fertilizer inputs are most likely to be the common practices by farmers;
c. over dosage of N was the common phenomenon in the study area.

Table 7 and 8 show the recommended fertilizer dosage calculated by QUEFTS model at Grain Yield (GY) Target of 7000 and 8000 kg/Ha respectively. These two tables clearly show that for every GY Target, the recommended fertilizer was different by using the same values of Indigenous Nutrient Supplies. These two tables show that for a larger GY Target, recommended fertilizer was not always larger than that in smaller GY Target. In Thoyib's and Samsudin's fields, for example, the Fertilizer KCl was smaller at target GY Target 8000 kg/Ha than that in 7000 kg/Ha.

Overall, QUEFTS model is an empirical model which potentially has a significant contribution for fertilizer recommendation. The capabilities of QUEFTS for calculating the Indigenous Nutrient Supply (INS) and crop yields provide significant benefits to Site Specific Nutrient Management.

Table 6 .The Yield and fertilizer rates at farmer's field and simulated QUEFTS model

No	Farmers' Fields	Farmer's Fertilization Practices				Recommended dosages by QUEFTS at *GY Target* 7000 (kg/ha)			
		Yields (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Yields (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
1	Ahmad	6000	260	30	30	7000	213	48	15
2	H. Syairi	6000	318	0	0	7000	244	31	25
3	Hanifah	5000	329	30	30	7000	98	16	50
4	Kanan	7000	348	120	30	7000	63	11	50
5	Kasiyanto	4850	245	15	15	7000	109	42	50
7	Syamsudin	5000	276	0	0	7000	184	64	69
8	Thoyib	5000	280	40	40	7000	80	39	35

Table 7. The Results of Fertilizer Recommendation Modelled by QUEFTS at the Target Yield of 7000 kg/Ha

No	Farmers' Fields	Results of QUEFTS *GY Target* 7000 (kg/ha)	Fertilizers (kg/ha)			Fertilizers (kg/ha)		
			N	P	K	Urea	SP36	KCl
1	Ahmad	7000	213	48	15	464	132	24
2	H. Syairi	7000	244	31	25	531	87	40
3	Hanifah	7000	98	16	50	214	45	79
4	Kanan	7000	63	11	50	137	31	79
5	Kasiyanto	7000	109	42	50	238	118	79
6	Syamsudin	7000	184	64	69	400	177	110
7	Toyib	7000	80	39	35	175	109	56

Table 8. The results of fertilizer recommendation modelled by quefts at the target yield of 7000 kg/Ha

No	**Farmers**	**Results of QUEFTS GY Target 8000 (kg/ha)**	**Fertilizer (Kg/ha)**			**Fertilizer (Kg/ha)**		
			N	**P**	**K**	**Urea**	**SP36**	**KCl**
1	Ahmad	8000	221	77	21	480	215	33
2	H. Syairi	8000	254	68	145	552	188	231
3	Hanifah	8000	156	48	50	339	134	79
4	Kanan	8000	92	43	50	200	119	79
5	Kasiyanto	8000	162	70	50	352	194	79
6	Syamsudin	8000	243	67	150	529	185	238
7	Toyib	8000	221	57	19	481	158	30

CONCLUSIONS

This study has shown the merits provided by QUEFTS for fertilizer recommendation for farmers' fields. The soil condition and the management in farmers' fields are different from one to the others, leading to the differences in yields and recommended fertilizer as modelled by QUEFTS. Although this study is considered as preliminary one, it has proven that QUEFTS model is a valuable tool for evaluating the farmer practices and provides the best management practices at field scale for improving fertilizer use efficiency, which is the main aim of Site Specific Nutrient Management.

ACKNOWLDEGEMENTS

Gratitude is addressed to Dikti for supporting this study through Competitive Funding 2007 and 2008. Thanks are also addressed to Dr. Christian Witt from IPNI who provided ideas and software for this study.

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