Determination of Variable Rate Fertilizing Amount in Small Size Fields Using Geographic Information System

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ABSTRACT

The feasibility of precision farming for small sized fields was studied by determining fertilizing amount of nitrogenous and calcareous to a cite specific region. A detailed soil survey at three experimental fields of 672m^2, 300m^2 and 140m^2 revealed a considerable spatial variation of the pH and organic matter(OM) levels. Soil organic matter was measured using Walkley-Black method and soil pH was measured with a pH sensor. Soil sample was obtained by Grid Node Sampling Method. The soil sampling depth was 10 ~ 20 cm from the soil surface.

To display soil nutrient variation, a soil map was made using Geographic Information System (GIS) software. In soil mapping, soil data between nodes was interpolated using Inverse Distance Weighting (IDW) method. The variation was about 1 ~ 1.8 in pH value and 1.4 ~ 7 % in OM content. Fertilizing Amount of nitrogenous and calcareous was determined by the fertilizing equation which was proposed by National Institute of Agricultural Science and Technology.(NIAST). The variation of fertilizing amount was about 3 ~ 11 kg/10a in nitrogenous and 70 ~ 140 kg/10a in calcareous. The results showed a feasibility of precision fertilizing for small size fields.

Key Words : Precision farming, VRT(Variable Rate Treatment), Soil pH, Soil organic matters, Precision fertilizing

INTRODUCTION

Soil and underground water have been contaminated continuously because of unreasonable overdosing with a chemical fertilizer. That is due to a custom fertilizing method without considering of variable biologic environmental variant in cultivated fields. There may be variability to some extent in soil nutrient level in small size fields, so a detailed soil survey in each field must be needed in Korea. In Japan's study, precision farming could be available for small scale farming as well as big scale farming (Shibusawa, 1999).

The purpose of this research was to determine N and Ca fertilizing amounts to a site specific region, and to show a feasibility for precision farming in small size field. Because N is the element of protein that forms a protoplasm of a vegetable sell which is the foundation of a vegetable structure. And the excessive N fertilizing brings about contamination of underground water through the nitrate effusion (Son, 1997). And Ca fertilizer is a role of soil pH control to neutralize the effects of acidity in soil. Therefore, the site specific N and Ca fertilizing amounts must be determined to prevent from contamination of soil and underground water.

MATERIALS AND METHODS

1. Survey of soil data

A detailed soil survey was executed for three test fields. Test fields were a rice field(106) and a radish field(502) on the university farm of Seoul National University, and a potato field in the Province of Kangwon. The rice and radish fields for test were flat and the potato field sloped by 15~18 degrees. Size of test fields was the rice field of $672m^2$, the radish field of $300m^2$ and the potato field of $140m^2$. A depth of soil acquisition was between 10 cm to 20 cm on surface soil. A grid node sampling method was used for soil survey is shown in fig.1.

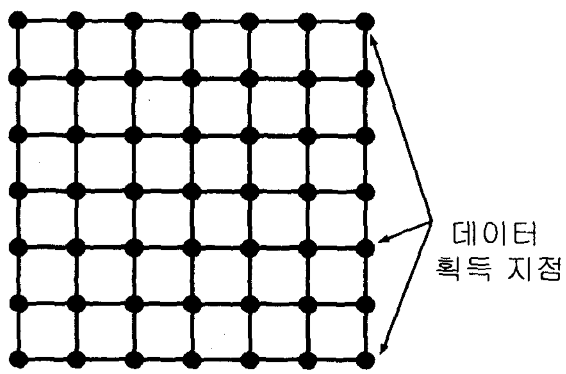

Fig. 1 Soil smapling point

The grid size was determined by considering of the agricultural vehicle's operation width, that is, the working width of a fertilizer. Therefore, the width of fertilize vehicle was 2~3m. Therefore, raw data were taken at 1m x 1.5m intervals in radish field, 1m x 1m in potato field, 2m x 2m in rice field.

2. Determination of N-fertilizing amount

Recommend equation for N-fertilizing amount(Park, 1996) is equation (1) in rice field.

$$Y=12.74 - 1.52 \cdot A + 0.028 \cdot B \quad \text{------ equ. (1)}$$

Y = N-fertilizing amount(kg/10a)

A = Content of soil organic matter(%)

B = Content of soil silicic acid(ppm)

Prescription of N-fertilizing is different according to crops in field. N-fertilizing amount is determined as equation (2) in radish and potato field.

$$Y=26.169 - 1.564 \cdot A \quad \text{------ equ. (2)}$$

Y = N-fertilizing amount(kg/10a)

A = Content of soil organic matter(%)

3. Determination of Ca-fertilizing amount

Ca-fertilizing amount is determined with measured pH value according to equation (3). D was to 15cm, because soil samples were taken about 10cm to 20cm depth. The aiming pH value(X) was determined to 6.5 at rice and radish fields, and 5.5 at potato fields. And demanded amount of calcareous fertilizer (A) to raise pH 1.0 has different value in various soils 124 kg/10a was used in loamy soil.

$$Y=A \cdot (X-B) \cdot D/10 \quad \text{------ equ. (3)}$$

Y = Ca-fertilizing amount(kg/10a)

A = Ca-fertilizing amount for raising pH 1.0 (kg/10a)

X = Aiming pH value

B = Measured pH value

D = Depth from soil surface

4. Measurement of soil organic matter, pH, content of silicic acid

Content of soil organic matters was measured by the Walkley-Black Method(). The measurement is accurate but takes a long time. Soil pH was measured by a pH sensor(Jin-gu science).

After mixing dried soil 5g with distilled water 20ml, the samples were maintained stability during twenty minutes before the pH measurement. Content of soil silicic acid was estimated indirectly using a correlation equation(4) on pH.

$$Y=35 \cdot X-114 \quad \text{------ equ. (4)}$$

Y = Content of silicic acid(ppm)

X = Measured pH

5. Soil mapping

Soil distributed map was made using Arc View 3.1. In soil mapping, soil data between nodes were interpolated using the Inverse Distance Weighting (IDW) method. The IDW method estimates an interval value by assigning give weight proportion to distance difference.

RESULTS AND DISCUSSION

1. Distribution of soil pH

Figs. 2, 3 and 4 are a distribution map of pH at the rice field, the potato field and the radish field. A minimum pH was 5.552 and a maximum pH was 7.415 at fig. 2 of the rice field. It showed a weak acidity and neutrality from 5.8 to 6.6 at the most field. A minimum pH was 4.04 and a maximum pH is 5.74 at fig. 3 of potato field. Because it showed a strong acidity at the most field, a great deal of calcareous fertilizer was demanded. A minimum pH was 4.941 and a maximum pH was 5.925 at fig. 4 of the radish field. It also showed a strong acidity at the most field. Acidity of soil was ranges from 5.1 to 6.0 in the most cultivated fields of Korea. Therefore, the pH value of tested fields is close to the value of the common fields. However, potato fields acidified extremely more than the common fields.

2. Distribution of soil organic matters

Figs. 5, 6 and 7 are a distribution map of organic matters at the rice field, the potato field and the radish field. A minimum content of organic matter was 0.403% and a maximum content of organic matter was 2.552% at fig. 5 of the rice field. It showed organic matter from 1.2% to 1.6% at the most field. A minimum content of organic matter was 4.36% and a maximum content of organic matter was 11.55% at fig. 6 of the potato field. The potato field was sloped by degree. Because the surface soil was washed away by rain, the soil organic matter was varied according to the slope. A minimum content of organic matter was 1.478% and a maximum content of organic matter was 2.888% at fig. 7 of the radish field. The content of organic matter was evenly measured. The content of organic matter below 2% was 14.2%, and the content of organic matter above 2.5% was 16.6%.

3. Result of nitrogenous fertilizer prescription

Conventional standard fertilizing amount of nitrogenous fertilizer is 19kg/10a(Ministry of Agriculture and Forestry, 2000) for rice fields in Korea. Nitrogenous fertilizing amount was calculated using the equation(2). A grid size of the variant distribution map was determined by

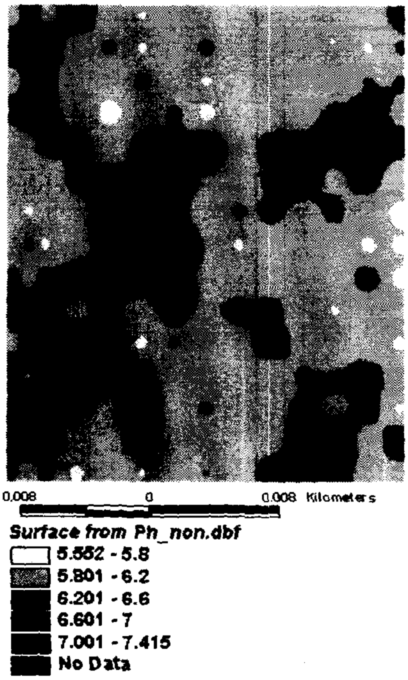

Fig. 2 Soil pH map of the rice field

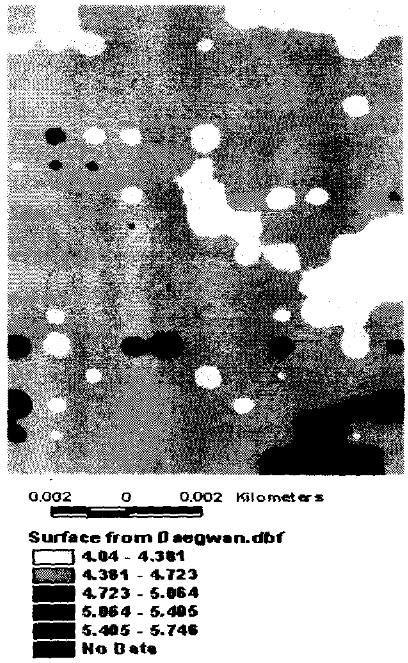

Fig. 3 Soil pH map of the potato field

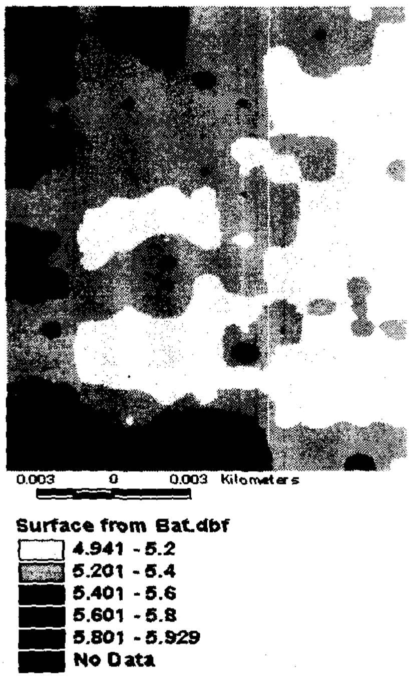

Fig. 4 Soil pH map of the radish field

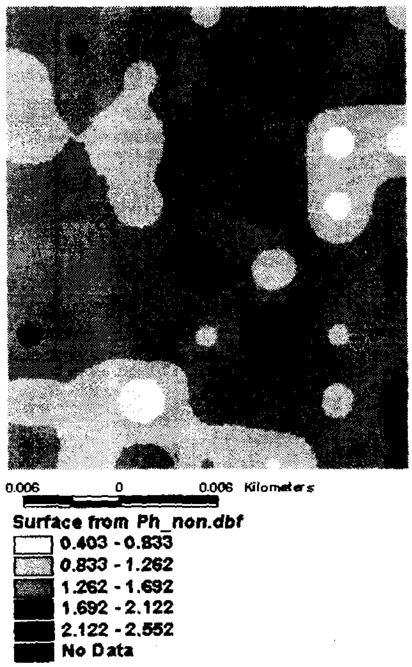

Fig. 5 Soil OM map of the rice field

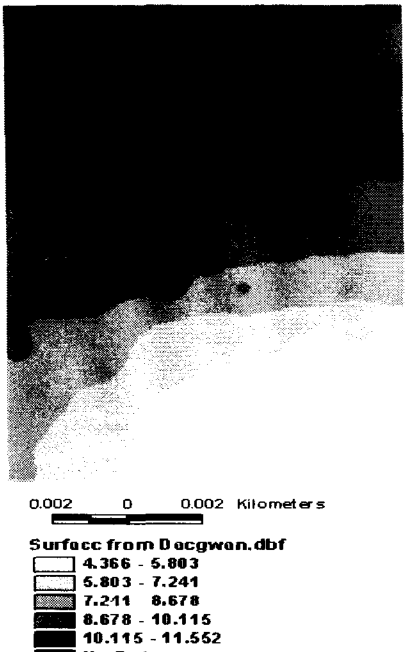

Fig. 6 Soil OM map of the potato field

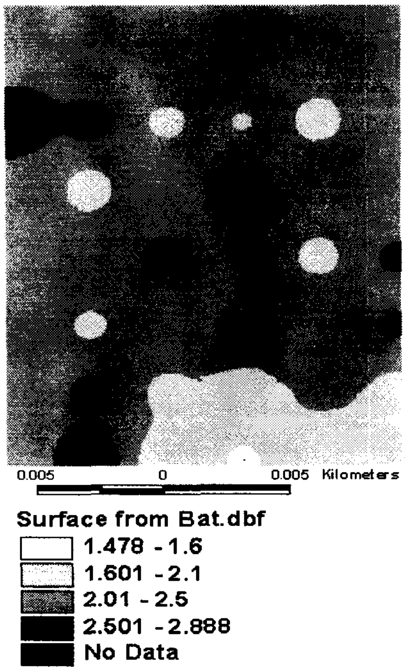

Fig. 7 Soil OM map of the radish field

considering the agricultural vehicle's operation width. The variation of nitrogenous fertilizing amount was about 12～15 kg/10a(fig. 8). Average amount of nitrogenous fertilizer was 13.45 kg/10a. Prescribed amount of nitrogenous fertilizer was 70.8% of the standard fertilizing amount 19kg/10a. Therefore, the N-fertilizer could be reduced by 29.2% on the whole field.

Prescribed amount of N-fertilizer in the potato field was calculated using the equation(2) and showed in fig. 9. The demanded amount of nitrogenous fertilizer was ranged from 8.91 kg/10a to 19.92 kg/10a, and the difference was 11 kg/10a. Average demanded amount of nitrogenous was 12.63 kg/10a, and increased by 26% compared with the standard amount 10kg/10a.

In a radish field, standard fertilizing amount is 28 kg/10a(Ministry of Agriculture and Forestry, 2000) in Korea. Prescribed amount of N-fertilizer in the radish field showed in fig. 10. A grid size was determined 3m×2m by considering of the cultivated field size. Average fertilizing amount of nitrogenous fertilizer was 27.53 kg/10a, and 98.3% of the standard fertilizing amount.

4. Results of Calcareous fertilizer prescription

Fig. 11 showed distribution of prescribed calcareous fertilizing amount calculated by the equation(3) in the rice field. The soil in this field was weakly acid, the demanded amount of calcium hydroxide was not much. The demanded amount of Ca-fertilizer was ranged from 0 kg/10a to 107 kg/10a. Average demanded amount of Ca-fertilizer was 65 kg/10a, and it differed greatly from 200 kg/10a(Ministry of Agriculture and Forestry, 2000) of the standard Ca-fertilizing amount.

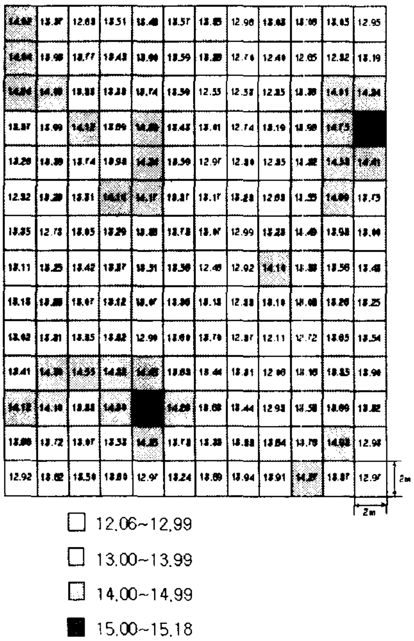

Fig. 8 Prescribed N-fertilizing of the rice field(kg/10a)

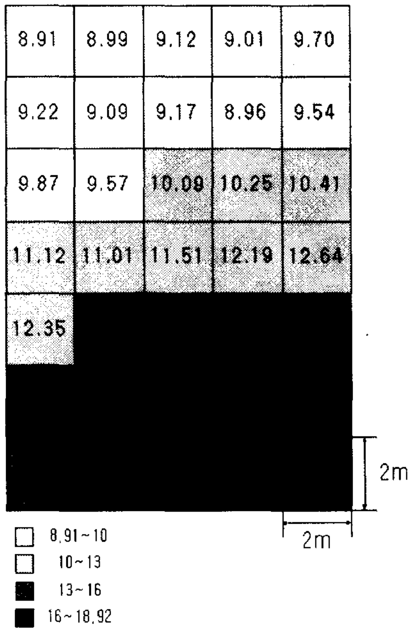

Fig. 9 Prescribed N-fertilizing of the potato field(kg/10a)

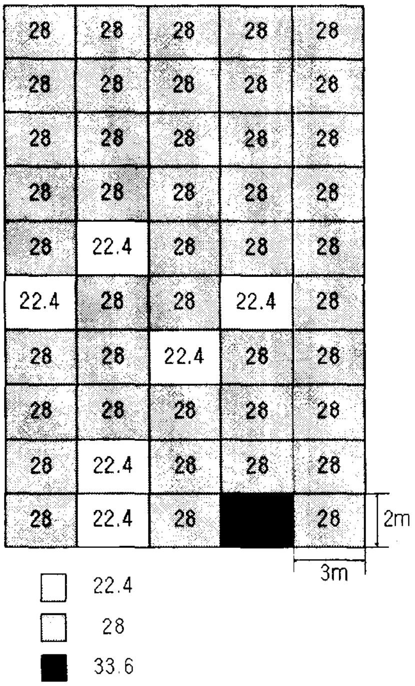

Fig. 10 Prescribed N-fertilizing of the radish field(kg/10a)

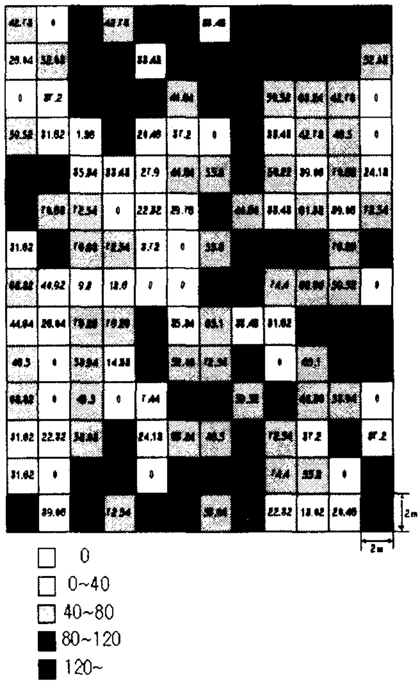

Fig. 11 Prescribed Ca-fertilizing of the rice field(kg/10a)

Fig. 12 showed distribution of prescribed Ca-fertilizing of the potato field. Soil in this field was strongly acid, calcareous fertilizer was demanded lots of amount than the standard Ca-fertilizing amount. The demanded amount of Ca- fertilizer was minimum 50 kg/10a to maximum 224 kg/10a. Average demanded amount of Ca-fertilizer was 180 kg/10a.

Fig. 13 showed distribution of prescribed Ca-fertilizing of the radish field. The demanded amount of Ca-fertilizer was the same distribution with the standard fertilizing amount. The demanded amount of Ca-fertilizer was minimum 133 kg/10a to maximum 272 kg/10a. Average demanded amount of Ca-fertilizer was 220 kg/10a.

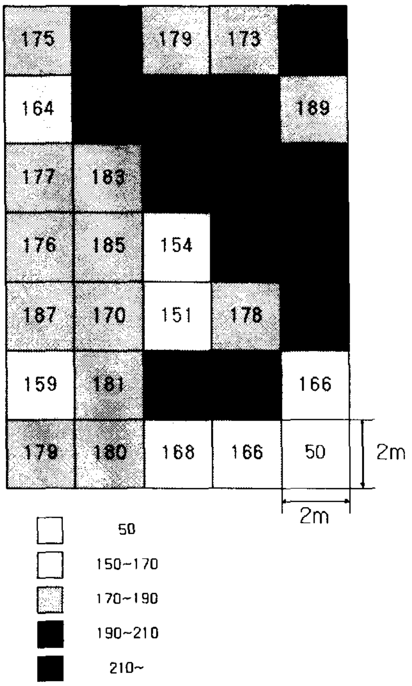

Fig. 12 Prescribed Ca-fertilizing of the potato field(kg/10a)

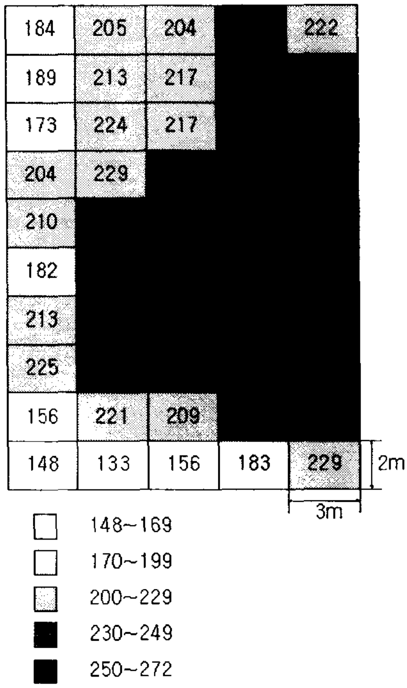

Fig. 13 Prescribed Ca-fertilizing of the radish field(kg/10a)

CONCLUSIONS

Distributions of soil pH and organic matter were shown in table 1. And the prescribed amount of nitrogenous and calcareous fertilizer were shown in table 2 and 3.

Distribution of organic matter showed around 2% in the rice and the radish fields and around 4%~11% in the potato field. Difference of it in one field was minimum 1.4% to maximum 7.2%. The pH values of tested fields showed acidity on the whole, but the radish field showed a various distribution of a weak acidity, a neutrality and a alkalinity. Therefore, a various distribution of pH was possible to be appeared on one field. The distribution of pH showed a difference of minimum 1.0 to maximum 1,9.

Table 1 Distribution of soil pH and OM

Field	Distribution of Soil OM(%)			Distribution Soil pH		
	Min	Max	Ave	Min	Max	Ave
Rice	0.40	2.55	1.39	5.55	7.41	6.18
Potato	4.36	11.55	8.59	4.04	5.75	4.51
Radish	1.47	2.88	2.26	4.94	5.93	5.29

Table 2 Distribution of N-fertilizing

Field	N fertilizing amount (kg/10a)			
	Min	Max	Ave	With conventional fertilizing
Rice	12.06	16.07	13.49	-29.%
Potato	8.91	19.92	12.63	+26.3%
Radish	22.4	33.6	27.53	-1.7%

Table 3 Distribution of Ca-fertilizing

Field	Ca fertilizing amount (kg/10a)			
	Min	Max	Ave	With conventional fertilizing
Rice	0	177	66.5	-66.8%
Potato	50	224	180	-10%
Radish	133	272	220	+10%

Fertilizing amounts were calculated by the recommended equations for precision farming. The demanded amounts of nitrogenous fertilizer showed a difference of minimum 3 kg/10a to maximum 11 kg/10a in the fields. It was possible to reduce the fertilizing amount up to 29%. However, the demanded amount of nitrogenous fertilizer in the potato field was more than the standard fertilizing amount. The demanded amounts of calcareous fertilizer were minimum 107 kg/10a to maximum 174 kg/10a in the field.

Variance of pH and organic matters was distributed, demanded amount of fertilization was fairly different in small size fields. Therefore, manage optimally a soil of cultivated fields, prescription of fertilization is demanded. The results showed that precision farming was feasible in small fields in Korea.

Survey of soil data and measurements of soil organic matters and pH required lots of labor and time. Therefore, measurement with a DGPS receiver and a GIS loaded on a agricultural vehicle could reduce the labor and time for the soil mapping.

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