Study of the Mathematical Models for Operation of Liquid Fertilizer Application

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Abstract: Biogas from methane fermentation is anticipated for use as an alternative energy resource to fossil fuel. However, a problem persists related to treatment of wastewater generated in methane fermenters. Consequently, the wastewater must be processed additionally to reduce environmental load when released. The most important problem is the treatment raises the total running cost of fermenters. To lower this cost, application of the wastewater as liquid fertilizer in paddy fields without the treatment has been studied. However, in rice cropping, the suitable periods for application are limited. This study is intended to produce models for estimating working hours in each paddy field to construct an effective operation plan of a slurry injector for liquid fertilizer. Working times in the paddy fields were investigated for two cases of liquid fertilizer application: Nantan and Yamaga. Two simple models can be constructed; which model should be used can be determined according to the paddy field shape.

Keywords: methane fermentation, liquid fertilizer, working hours, modeling, statistics

1. INTRODUCTION

Biogas generated by methane fermentation is an energy resource that is anticipated for use as an alternative to fossil fuels. Nevertheless, a problem exists with additional treatment for the wastewater generated from fermenters in methane fermentation. Many nutrient-rich solids come from decayed organic matter. Therefore, wastewater must be processed to reduce its environmental load before it is discharged to drains or rivers. That wastewater treatment cost raises the total cost of digesters (Zenmyo et al. 2009).

Direct application of the wastewater as liquid fertilizer for rice cropping has been studied to mitigate this problem (Iida et al. 2009). Optimization using genetic algorithms was proposed to make an efficient schedule of a slurry injector for fertilizer application (Mori et al. 2009). Using that method, by arranging the working sequence of paddy fields, the "down" time of not-working was reduced. For optimization, working hours in every paddy field are necessary. Therefore, modeling of estimating working hours is important.

Moreover, the conceptual model of fleet management in agriculture was recently proposed. Sørensen and Bochtis (2010) reported that agricultural fleet management was viewed as farmers' or machine contractors' decision-making related to resource allocation, scheduling, routing, and real-time monitoring of vehicles and materials. Scheduling was related to working hours at each field. Therefore, estimating working hours might be valuable for this conceptual model.

This study produces such a model for estimating working hours in a paddy field based on *in situ* investigation of two areas of liquid fertilizer application: Nantan and Yamaga. Wastewater is produced constantly, increasing every day. Furthermore, suitable periods for applications are limited for paddy fields. Consequently, fertilizer is applicable only twice a year as a basal applications and supplement applications in rice cropping. In addition, there should be a limit to the amount of present storage for the fertilizer. For these reasons, the fertilizer must be used efficiently and regularly.

2. FIELD SURVEY

2.1 Investigation in Nantan City

Field surveys investigating applications with irrigation water were conducted in Nantan City, Kyoto Prefecture. Mixed application with irrigation water is one method used to apply the liquid fertilizer for paddy fields. In this method, a vacuum truck carries the liquid fertilizer from a storage area and applies it with irrigation water from the water inlet of a paddy field. Figure 1 portrays a typical basal application with irrigation water.

The correlation between the supply time to a vacuum truck and the amount of supplied liquid fertilizer was investigated. Results are presented in Fig. 2. A clear correlation exists between the supply time and the liquid fertilizer amount.

Fig. 1. Basal application with irrigation water in the field of Nantan City.

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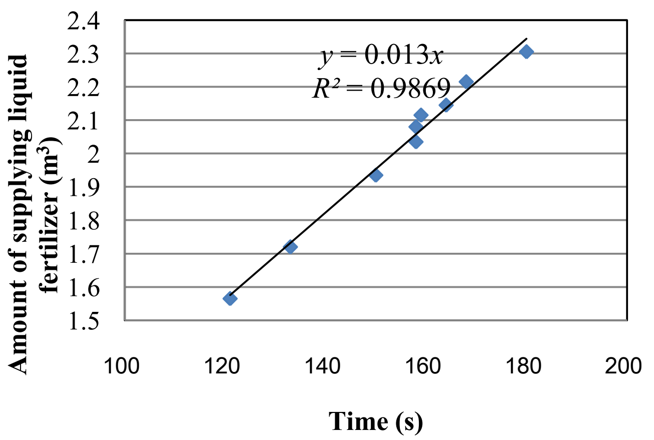

Fig. 2. Correlation between the supply time to a vacuum truck and the amount of supplied liquid fertilizer.

The time for application of one ton of liquid fertilizer was recorded with the car number and date. Basal and supplement applications with irrigation water were investigated. The paddy field area must be known to estimate the liquid fertilizer amount and paddy field irrigation time. Results of basal application and supplement application with irrigation water are presented respectively in Tables 1 and 2.

The time for basal application differs considerably from that for supplement application. The time for supplement application is apparently longer because the rice stubble disturbs the diffusion of liquid fertilizer.

An investigation of machine application was conducted. Surveys of two kinds were applied with a vehicle called a slurry injector. First, the correlation between the supply time from the vacuum truck to the slurry injector and the amount of supplied liquid fertilizer were examined. Second, the working path of the slurry injector was investigated. The slurry injector has disks at the rear of its body. The slurry injector can dig ditches with those disks and apply slurry along these ditches. Figure 3 shows the supply of liquid fertilizer from the vacuum truck to the slurry injector.

Fig. 3. Supplying liquid fertilizer from the vacuum truck to the slurry injector at the field in Nantan City.

A new machine is used in such cases; therefore the data for motion are not useful. However, the data for the correlation between the supply time and the amount of liquid fertilizer are useful because the tanks for fertilizer of the previous and the present machine are identical. The result of this investigation is depicted in Fig. 4. High correlation exists between the supplying time to the slurry injector and the amount of liquid fertilizer.

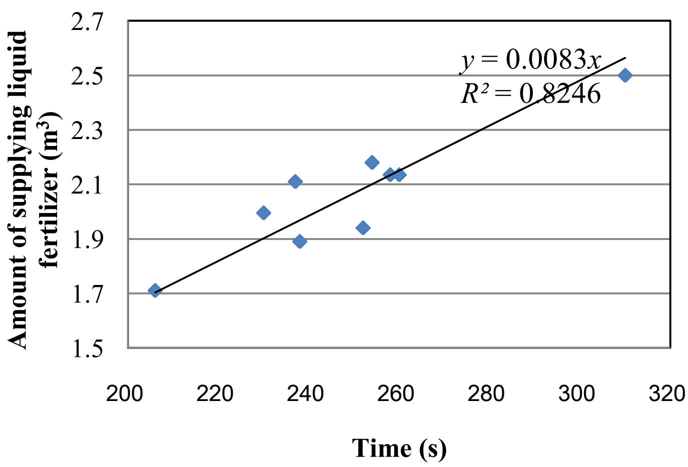

Fig. 4. Correlation between the supply time to the slurry injector and the amount of supplied liquid fertilizer.