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CALCULATION OF TRANSPORTATION ENERGY FOR BIOMASS COLLECTION

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ABSTRACT Assuming a bio-ethanol production facility using rice straw, characteristics of field-to-facility transportation were examined through simulation modeling and trial calculations. The conversion rate from straw to ethanol, the quantity of straw collected, and the ratio of the field area to that around the facility all affected the fuel consumption, the number of trucks needed, and other factors. Standard conditions were assumed based on reported data and actual observations: 15 ML/yr ethanol production, 0.3 kL output of ethanol from 1 t dry straw, 53.6 day/yr working days, 2.7 t truck load capacity, and 0.128 as the ratio of field to the area around the facility. The calculation results revealed that a quantity of 50 kt dry straw required the following: 2.78 L fuel consumption for transportation of 1 t of dry straw, 109.5 trucks, and a 19.1 km collection area radius. The fuel consumption for transportation was found to be proportional to the quantity of straw to the 0.5 power, but inversely proportional to the ratio of field to the 0.5 power. The study demonstrated that the rate of increase in the necessary number of trucks collecting straw increases with the decrease in the ratio of the field to area surface around the facility.

Keywords: biomass, rice straw, transportation, simulation

INTRODUCTION Assuming a bio-ethanol production facility using rice straw, characteristics of field-to-facility transportation were examined through simulation modeling and trial calculations. The conversion rate from straw to ethanol, the quantity of straw collected, and the ratio of the field area to that around the facility all affected the fuel consumption, the number of trucks needed, and other factors.

SIMULATION METHOD

The fuel consumption The quantity of fuel consumption for transportation of 1 t of dry and wet straw from field to facility were calculated based on the following equation.

For dry straw weight

$$E_{DS} = (4/3)\, Cf M_T^{-1} M_D^{0.5} (1 - w/100)^{-1.5} (\pi r Y_W)^{-0.5} \quad \text{-----(1)}$$

Where *C*f (L /km): fuel consumption of truck for 1 km travel, M_T (wet-t): straw capacity of truck, M_D (dry-t /year): quantity of straw to be collected in 1 year, *w* (% d.b.) : moisture content of straw, *r* : the ratio of the field area to that around the facility, Y_w(wet-t /km^2 year): yield of straw of 1 km^2 paddy field in 1 year.

For wet straw weight

$$E_{WS} = (4/3)\, Cf M_T^{-1} M_W^{0.5} (\pi r Y_W)^{-0.5} \quad \text{-----(2)}$$

Where M_W (t /year): quantity of straw to be collected in 1 year. (1) and (2) were introduced algebraically based on assumptions that field are scattered evenly in the area around the biomass conversion facility and that the road from field to the facility is straight.

Number of trucks needed The necessary number of trucks to transport straw was calculated based on the following equation.

For dry straw weight

$$N = (4/3)\, (H_d M_T P V_T)^{-1} M_D^{1.5} (1 - w/100)^{-1.5} (\pi r Y_W)^{-0.5} + H_b M_D (1 - w/100)^{-1} (H_d M_T P)^{-1} \quad \text{-----(3)}$$

Where H_d(hour): daily working hour of transportation, *P*(days): working days in 1 year, V_T (km /hour): average speed of the truck, H_b(hour): hours for loading and unloading of straw to the truck.

For wet straw weight

$$N = (4/3)\, (H_d M_T P V_T)^{-1} M_W^{1.5} (\pi r Y_W)^{-0.5} + H_b M_W (H_d M_T P)^{-1} \quad \text{-----(4)}$$

CALCULATION

Fixing the variables is as follows.

<u>*C*f (L /km): fuel consumption of truck for 1 km travel</u> 0.25L /km was used as Cf based on statistics of transportation vehicles by MLIT.

<u>M_T (wet-t): straw capacity of truck</u> How much straw bale role can be loaded to 3 t, 4 t and 10 t capacity truck was tested. As a result 3 t capacity truck can be loaded 14, 18, 32 bales. One bale weighs 150 kg(wet). 4 t truck was assumed to be used and MT was fixed as 2.7t because 4 t can access to the paddy field with narrow path but 10 t truck can not.

M_D (dry-t /year): quantity of straw to be collected in 1 year Based on the assumption of 15 ML/yr ethanol production and 0.3 kL output of ethanol from 1 t dry straw, M_D was fixed as 50 000 t.

w (% d.b.) : moisture content of straw Based on the field observation w was fixed as 15%.

r : the ratio of the field area to that around the facility The ratio of Ibaraki pref. of Japan, 0.128, was used.

Y_w(wet-t /km^2 year): yield of straw of 1 km^2 paddy field in 1 year Based on statistics of MAFF, 400 t /km2 (= 4t/ ha) was used.

H_d(hours): daily working hour of transportation Based on statistics of MHLW, 7.5hour was used.

P(days): working days in 1 year Ordinary farmers in Ibaraki pref. harvest rice from September. And they start conditioning the field January. So straw can be collected from September to December. But raining day and the next day at least the collection is impossible because of the high moisture content of the straw. Based on the statistics of weather 53.6(days) was used.

V_T (km /hour): average speed of the truck Based on our measurement result of the truck speed of straw collecting farmer by GPS logger, 25 km/h was used.

H_b(hours): hours for loading and unloading of straw to the truck Based on our measurement result of the loading and unloading efficiency, 18 roll bales of straw for 4t capacity truck, 1(hour)was used.

Calculation result for standard conditions Standard conditions were assumed based on reported data and actual observations: 15 ML/yr ethanol production, 0.3 kL output of ethanol from 1 t dry straw, 53.6 day/yr working days, 2.7 t truck load capacity, and 0.128 as the ratio of field to the area around the facility. The calculation results revealed that a quantity of 50 kt dry straw necessitated the following: 2.78 L fuel consumption for transportation of 1 t of dry straw, 109.5 trucks, and a 19.1 km collection area radius.

RESULTS AND DISCUSSION

The fuel consumption for transportation Fig.1 shows how the quantity of straw collected and the field ratio effects on the fuel consumption per 1t dry straw. According to eq.(1) the fuel consumption for transportation was found to be proportional to the quantity of straw to the 0.5 power, but inversely proportional to the ratio of field to the 0.5 power

The necessary number of trucks collecting straw Fig.2 shows how the quantity of straw collected and the field ratio effects on the necessary number of trucks collecting straw. According to eq.(3) the rate of increase in the necessary number of trucks collecting straw increases with the decrease in the ratio of the field to the area around the facility.

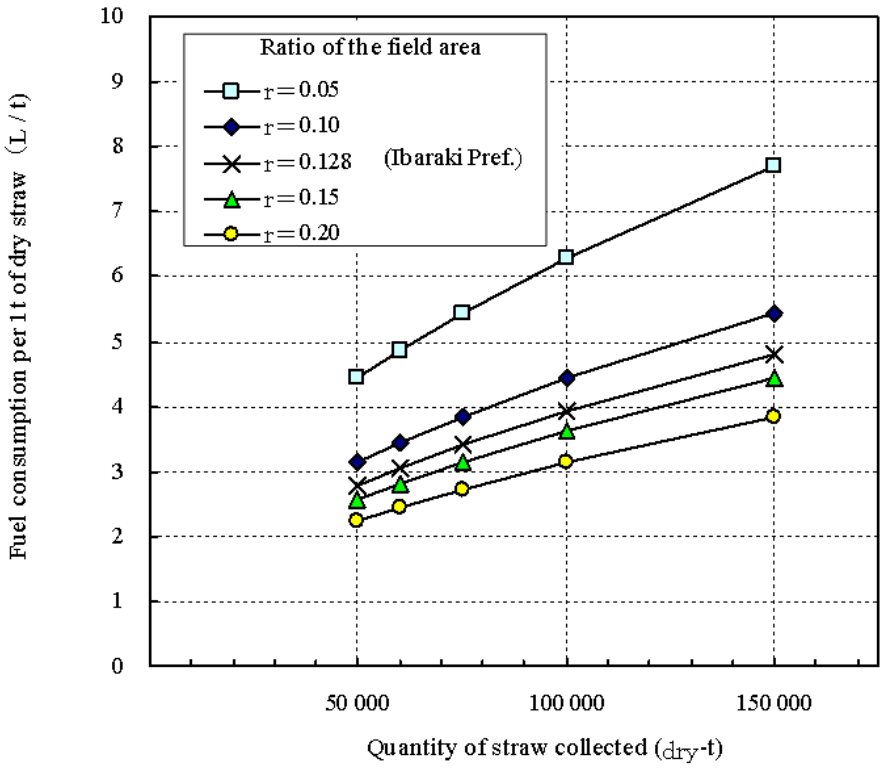

Fig.1 Fuel consumption per straw changes along with conditions

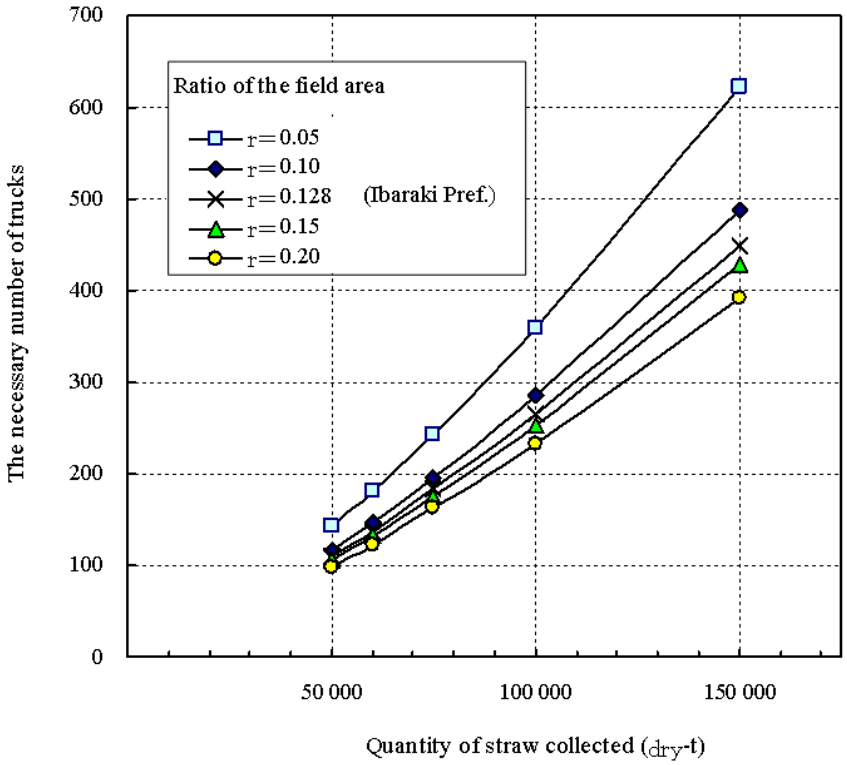

Fig.2 The necessary number of trucks changes along with conditions

CONCLUSION How the fuel consumption for transportation and the necessary number of trucks would react against the quantity of straw collected and the field ratio were explained with some variables. As next step we need to compare the results with straw collecting farmer's cost structure.

REFERENCES

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