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Fluctuation of Environmental Burden Induced by Uncertainty of Biomass Production

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Abstract: Biomass is expected as renewable energy resources or materials to contribute for reduction of greenhouse gas emission. Carbon neutrality is applied only for its combustion stage but not for other stages such as production, transportation, etc. The authors analyse lifecycle environmental impacts of biomass utilization system especially from the point of impact on global warming. For the analysis, Life Cycle Inventory (LCI) data are indispensable but its production data have large variation and the effects caused by the variation should be evaluated to interpret the results rightly. In this report, some results of the analysis for the variation of the production data and simulation based on the results are reported.

Keywords: Biomass, LCA, LCI, Uncertainty, Palm Oil, Rice, Sugarcane.

Introduction

Life Cycle Assessment (LCA) is supposed to be one of the powerful assessment methods to evaluate environmental aspects of product system. This method is expected to be applied not only for the products and service but also activities taken by many sectors. Actually, many expanded applications are tried and reported by its many implementers in the world.

For the implementation of LCA, LCI data are indispensable and they usually contain uncertainties. Obtained LCA results are based on the uncertainties and their effects must be evaluated to avoid misunderstanding of the results. According to ISO 14040 series (LCA standards) [1], they request interpretation of the results of LCA or LCI study (Fig. 1), and one of the main elements of the interpretation is sensitivity check.

In case of biomass utilization, many factors such as climate, soil, geography, etc influence the biomass resources production and LCI data contain large uncertainties. LCA based on those LCI data may bring wrong results and the results may provide wrong decisions. Hence, the uncertainties of the production data should be evaluated and we should understand the possibilities of the errors.

This paper reports the possible errors caused by uncertainties of biomass resources production estimated from our LCI study.

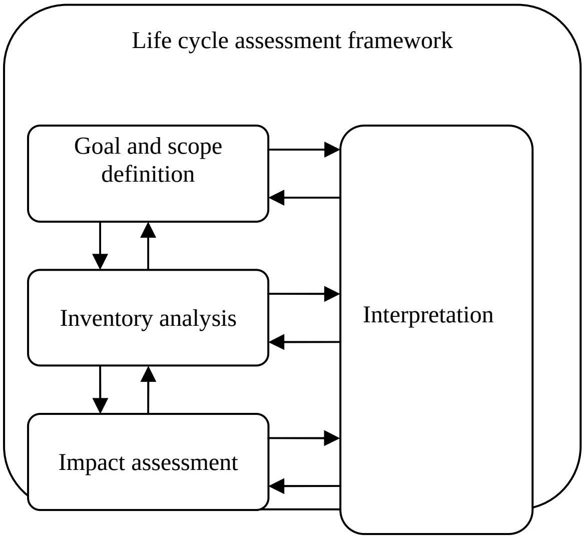

Figure 1. Phases of an LCA [1].

Biomass resources production

1. Data sources

This investigation is based upon literatures. The authors summarised published papers, reports, handbooks, etc. on the input/output of cultivation of rice, oil palm and sugarcane, though only few of them explained detailed data especially focused on Asian countries. From the reported inputs for the cultivation, the authors calculated Nitrogen, Phosphorus and Potassium intensity for unit yield of the crops and analysed dispersion of the intensities and its effect.

2. Rice cultivation

Fig. 2 shows fertiliser input against crop for one year [2]. We can find that rough tendency exists between them, i.e. high fertiliser input gives high crop. If we fit a curve for them, however, the deviation from the curve is large. Since the sample number is limited, the distribution pattern cannot be decided. If we apply to fit the existing distribution types for the samples, the results depend on the statistical test method.

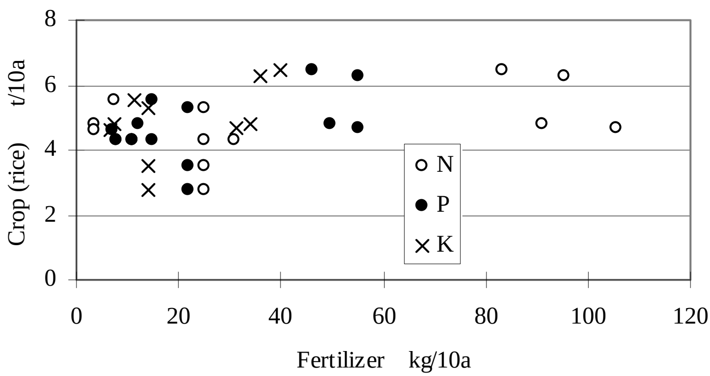

Figure 2. Fertiliser input vs. Rice crop.

3. Oil palm cultivation

Fig. 3 shows aggregated result of fertiliser usage for unit field (ha). The data are based on FAO report [3] and those data are the average fertiliser usage of each member country. Crop is not considered for these data. Even if we ignore the outputs from the fields, the fertiliser inputs have large dispersion. In this case, largest difference between two countries which use smallest and largest amount of fertiliser becomes around six times. Not only soil condition, but economic situation of each country and many other factors affect the fertiliser consumption.

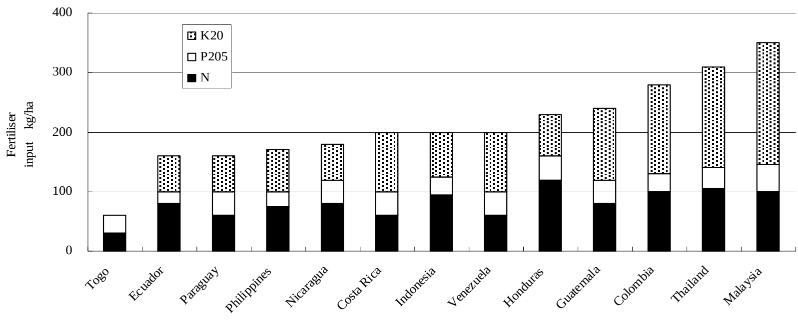

Figure 3. Fertiliser input for oil palm cultivation per one ha.

4. Sugarcane cultivation

Fertiliser usage for sugarcane cultivation by FAO member countries [3] are also shown in Fig. 4. We can find that the distribution features do not show typical patterns because they depend on soil, weather, climate, geographic and economic conditions, policy, environmental restriction, etc. as we can also observe in other farm products. If we assume that normal distribution can be applied for those, the standard deviations of each fertiliser are 51, 28 and 49 for N, P_2O_5 and K_2O respectively. And also the percentages of them against the averages are 99%, 43% and 23% respectively. They mean that there might be difficulties to apply normal distribution pattern for them or actually high dispersions exist because of many highly dispersed factors to affect them.

Discussions

1. Case study

Taking all those dispersions as uncertainties of the inputs for biomass utilisation, the authors estimated the effect for the total LCA results. Since inventory data for sugarcane utilisation are well prepared, this estimation is conducted for the case of sugarcane utilisation to produce ethanol (95 vol.%). The ethanol can be used for a source of transportation fuel or chemical material.

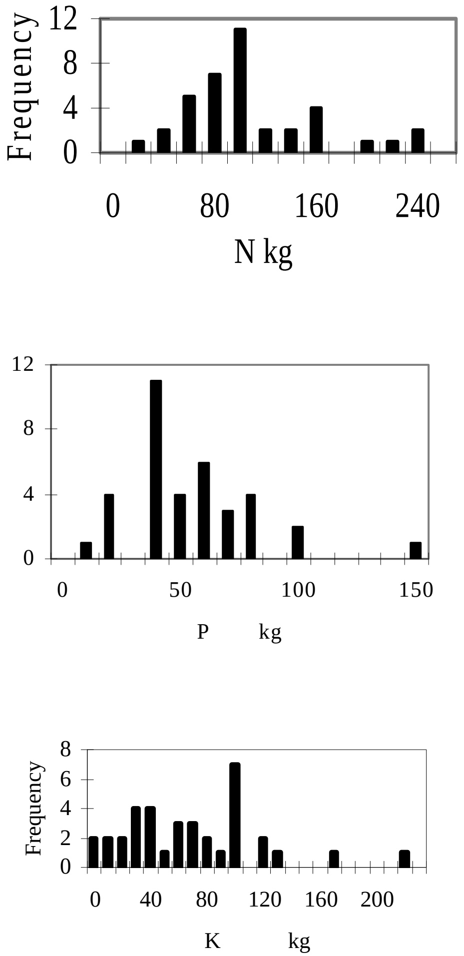

Figure 4. Distribution patterns of fertilization usage for sugarcane cultivation (kg/ha).

2. Inventory data

The process chart for the production of ethanol from sugarcane considered in this case study is shown in Fig. 5. In this study, the inventory data shown in the literatures [4-5] are used. Basic statistical information of the inventory data is shown in Table 1. Though dispersion the data because of the uncertainty of them are unpredictable yet, the authors assumed the dispersions are based on the types listed in Table 1.

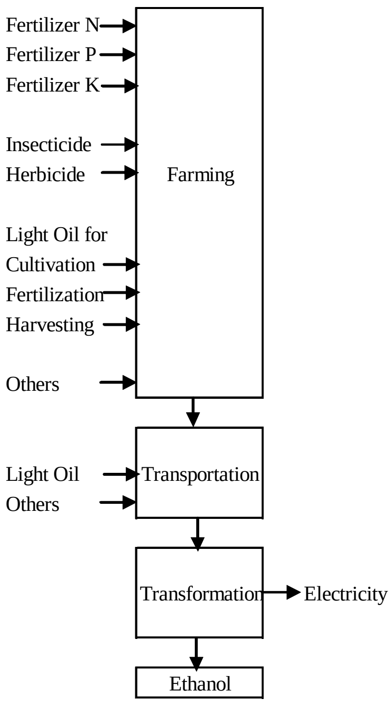

Figure 5. Input/output and flow of ethanol production from sugarcane.

Table 1. Summary of input data [product: ethanol 1 ton].

	unit	Average	Minimum	Maximum	Distribution (anticipation)
Fertilizer N	kg	6.1E+01	5.4E+01	6.9E+01	normal
Fertilizer P	kg	6.4E+01	2.4E+01	1.0E+02	normal
Fertilizer K	kg	3.0E+01	-	-	normal
Insecticide	kg	1.0E-01	-	-	constant
Herbicide	kg	8.5E-01	-	-	constant
Light Oil for					
Cultivation	littre	6.3E+00	6.3E-01	6.4E+00	normal
Fertilization	littre	1.2E+02	8.9E+01	1.5E+02	normal
Harvesting	littre	2.4E+01	6.4E+00	4.2E+01	normal
Transportation	km	7.5E+00	1.0E+00	1.0E+01	user
Electricity (generation)	kWh	510	170	850	uniform

3. Analysis

These case study analyses are done by changing the inventory data according to the statistical possibility and the effects are obtained. This methodology is a sort of Monte-Carlo simulation method. The obtained results from the calculation by 10,000 random data are shown in Fig. 6. The 95% confidence interval of the obtained results is between 812 and 1518 kg-CO_2-eq.

Estimated results of CO_2 emission by fertiliser (N) production is shown in Fig. 7. According to the results, the

95% confidence interval is between 536 and 894 kg-CO_2-eq. We can find the effect by the fertiliser (N) is almost more than half of the total emission.

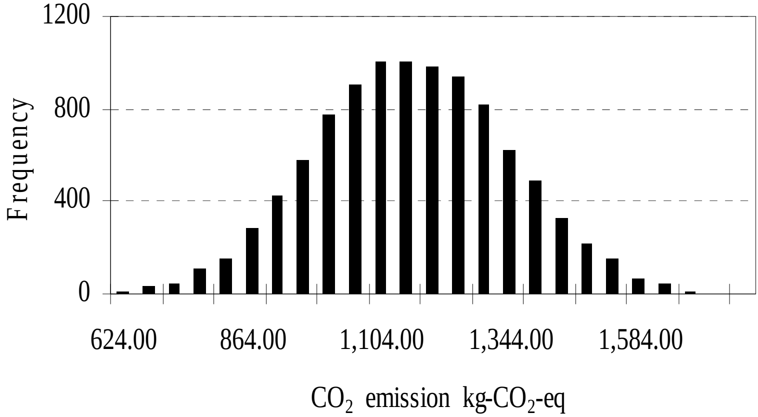

Figure 6. Distribution of CO_2 emission by ethanol production (95%, 1 ton) from sugarcane.

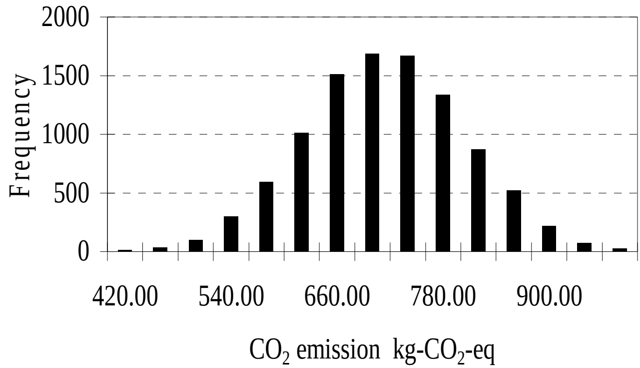

Figure 7. Estimation CO_2 emission by fertiliser (N) production and utilization.

Fig. 8 shows the results of sensitivity analysis for this emission from the process shown in Fig. 5. This figure shows that sensitivity by the usage of fertilisers, mainly Nitrogen and Phosphorous, are relatively high for the dispersion of the total CO_2 emission. Next large factors are light oil consumption for fertilisation and power generation by surplus of bagasse. Generated electricity by the bagasse is evaluated as avoided emission by this utilization. The generation efficiency depends on generator and it is estimated between 8% and 40% against lower heating value of bagasse used as fuel for the power generation. Light oil consumption for fertilisation must depend on the amount to provide the fertiliser and the dispersion is also high like fertiliser usage.

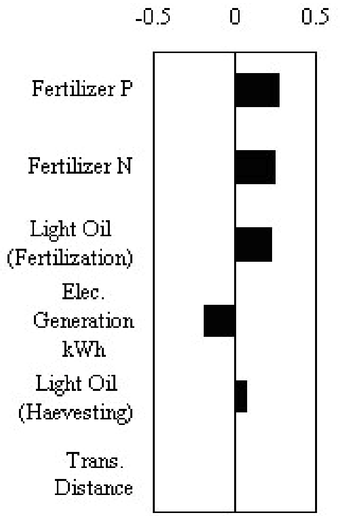

Figure 8. Sensitivity against total CO_2 emission variation.

The emission by transportation stage does not affect significantly for the results. Transportation is assumed to correct sugarcane from the equally distributed firms within 7.5 km radius from the transformation factory.

4. Discussion

Effect of the uncertainties gives almost 190% variation for the total CO_2 emission in this case study. Because this simulation adopts LCI data obtained from different farms in different countries, the results must be affected by the differences between the conditions where the data were obtained. Required accuracy depends on the purpose of the analysis. In case of LCA, the purpose has to be clearly decided at the first step, i.e. “goal and scope definition”. To satisfy the goal requirements, uncertainties of the using input data should be carefully evaluated and quantitative possibility to disprove the results should be cleared. If the possibility is quite high, we should improve data acquisition and adoption.

If we try to get to know the advantage or disadvantage of this biomass utilisation by LCA, we need to compare with comparison system. If the ethanol is used for transportation fuel instead of gasoline, the impact should be assessed against gasoline. According to our original inventory database, CO_2 emission from gasoline production and consumption is 3.3 ton for one ton of gasoline. Even if the high estimate of CO_2 emission for the ethanol production stage, it is around half of the total. For transportation fuels, dehydration or ETBE process is required as well as transportation of the ethanol. And also functional unit has to be appropriately decided. However, the variation of CO_2 emission by N-fertiliser usage is relatively large anyway and the data should be reconsidered for the case.

The results suggest that CO_2 emission by production of biomass resources is impossible to neglect and transformation process must be required to be efficient.

Conclusion

LCA is an adequate tool to investigate environmental aspects of product system such as biomass utilisation. Since obtained data are limited, the data usually contain large uncertainties. The authors analysed the effect of uncertainty for the results of LCI of bio ethanol production.

Uncertainty for biomass resources cultivation is relatively large because many factors affect for it. Since capacity of waste biomass is limited, opportunities to include emissions through the cultivation stages will increase. As ISO standards require us interpretation of LCA results, this step is important to bring right supports for decision making.

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