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Regional Diagnosis of Biomass Use in Thai My Village, Vietnam

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Ⅰ Introduction

Region-basis biomass use has been planned and implemented in many municipalities of Japan. The purposes of these projects are vitalization of rural area, formation of a recycle-basis society, mitigation of global warming and creation of new industries and so on. To ensure sustainable biomass use, appropriate planning and operations are needed. Previously authors have developed a diagnosis tool for regional biomass use[1]. This tool is worthy to apply more widely including foreign countries such as Vietnam to improve understanding of regional characteristics and for simplification.

Vietnam has been industrialized after *doi moi policy*, but agriculture still remains as the major sector with 70% of the population engaged in agricultural activities, and rice production for export has been increased. At the same time, rice consumption has been increased year by year due to continuous population increase. In addition, soil erosion and water shortage caused by deforestation as well as floods and droughts frequently occurred in recent years have led to decrease in yields for crop and large number of farmers who could not ensure subsistence crops. Under these circumstances, formulation of an appropriate agricultural production structure such as ensuring food security and promoting rice export is listed in government development policy.

Moreover, electricity demand has been increased in proportion to recent economic growth in Vietnam, which has led to the necessity of ensuring stable supply of power and primary energy. It is forecasted that annual growth rates would be 4.5-5.5% for energy supply and 5.5-7.5% for its demand, and Vietnam would be the net importer of energy. Despite this steady economic growth, regional disparity between urban area and rural one where 70% of the population live has been widened.

In order to cope with these issues which Vietnam has faced, the Government of Socialist Republic of Viet Nam requested support of the Government of Japan under the form of scientific technical cooperation with aiming to develop a model of "sustainable integration of local agriculture and biomass industries" enabling i) stable securement of food and energy, ii) prevention of global warming, iii) global environmental protection and improvement, and iv) livelihood improvement and poverty reduction of rural residents as well as demonstrate this model. Detail of this project is mentioned in sectionII.

In this paper, result of one assigned research task to diagnose regional biomass use is reported, followed by a general introduction of the Project. The task corresponds to the activities under Output (1) in the Master Plan as stated below. In this study, authors designed basic model structure to diagnosis the regional material flow for biomass use by modifying the existing tool. Methodology was developed as the first step analysis. Accuracy of the diagnosis will likely to be improved by future studies.

Ⅱ Outline of the Project

Japan Science and Technology Agency (hereinafter referred to as "JST") and Japan International Cooperation Agency (hereinafter referred to as "JICA") set up an international joint research project, called "Science and Technology Research Partnership for Sustainable Development (SATREPS)" [2]. SATREPS works through three to five-year projects to address global issues involving partnerships between researchers in Japan and researchers in developing countries.

Prof. Sakoda Akiyoshi, Institute of Industrial Science, The University of Tokyo (IIS-UT) submitted research titled "Sustainable Integrations of Local Agriculture and Biomass Industries" [3] (hereinafter referred to as "the Project") targeting southern Vietnam. In the Project, a biomass utilization system, in which the biofuels and bio-based materials are produced from byproducts and residues of combined primary industries in southern Vietnam, is designed, demonstrated and evaluated under a concept of local production for local consumption. Institute for Rural Engineering, National Agriculture and Food Research Organization (IRE-NARO) joined the Project as collaborator.

JICA, the responsible agency for the implementation of the technical cooperation program of the Government of Japan, and the Vietnamese authorities concerned agreed to implement the Project in accordance with the Master Plan on October 8, 2009 in Ho Chi Minh City. The record of discussion (R/D)[4] for this five-year technical cooperation project summarizes the Project as follows:

The Project period is for five years between October 2009 and October 2014.

Research institute for the Project implementation:

<Vietnamese side>

a. Hochiminh City University of Technology (HCMUT) (Representative)
b. Department of Science and Technology, Ho Chi Minh City (DOST-HCM)
c. Institute of Tropical Biology (ITB), Vietnam Academy of Science and Technology (VAST)
d. Hanoi University of Technology (HUT)

<Japanese side>

a. Institute of Industrial Science, The University of Tokyo (IIS-UT) (Representative)
b. Graduate School of Agriculture and Life Science, The University of Tokyo (GSALS-UT)
c. Institute for Rural Engineering, National Agriculture and Food Research Organization (IRE-NARO)

Department of Agriculture and Rural Development (DARD-HCM), People's Committee of Ho Chi Minh City and People's Committee of Thai My village are supporting institutes.

The Master Plan was designed as follows:

1. Project Title

"Sustainable Integration of Local Agriculture and Biomass Industries"

2. Project Purpose

A model of "Sustainable Integration of Local Agriculture and Biomass Industries" is developed and demonstrated in an area of Southern Vietnam, focusing on biomass conversions for the production of biofuels, such as bioethanol and biogas, and bio-based materials.

3. Project Outputs

(1) A methodology for designing "Sustainable Integration of Local Agriculture and Biomass Industries" is developed.
(2) Small-scale regional biorefinery processes based on the concept of local production of biofuels and bio-based materials for local consumption are developed and demonstrated.
(3) Key technologies for biorefinery processes, including production technologies of biofuels and bio-based materials, are studied and developed.

4. Project Activities

Activities under Output (1)

1-1. Analysis and design of material and energy flows in rural areas
1-2. Regional inventory analysis of rural areas
1-3. Estimation of the influences of biomass utilization on regional agriculture, energy balances, emissions of greenhouse gases and water environment
1-4. Comprehensive evaluation and compiling a database

Activities under Output (2)

2-1. Set-up and operation of "Biorefinery Experimental Process" at HCMUT
2-2. Set-up and operation of "Demonstration Plant for Sustainable Integration of Local Agriculture and Biomass Industries" at a village level
2-3. Design of practical processes

Activities under Output (3)

3-1. Development of novel pretreatment/saccharification of lingocellulosic biomass for bioethanol production

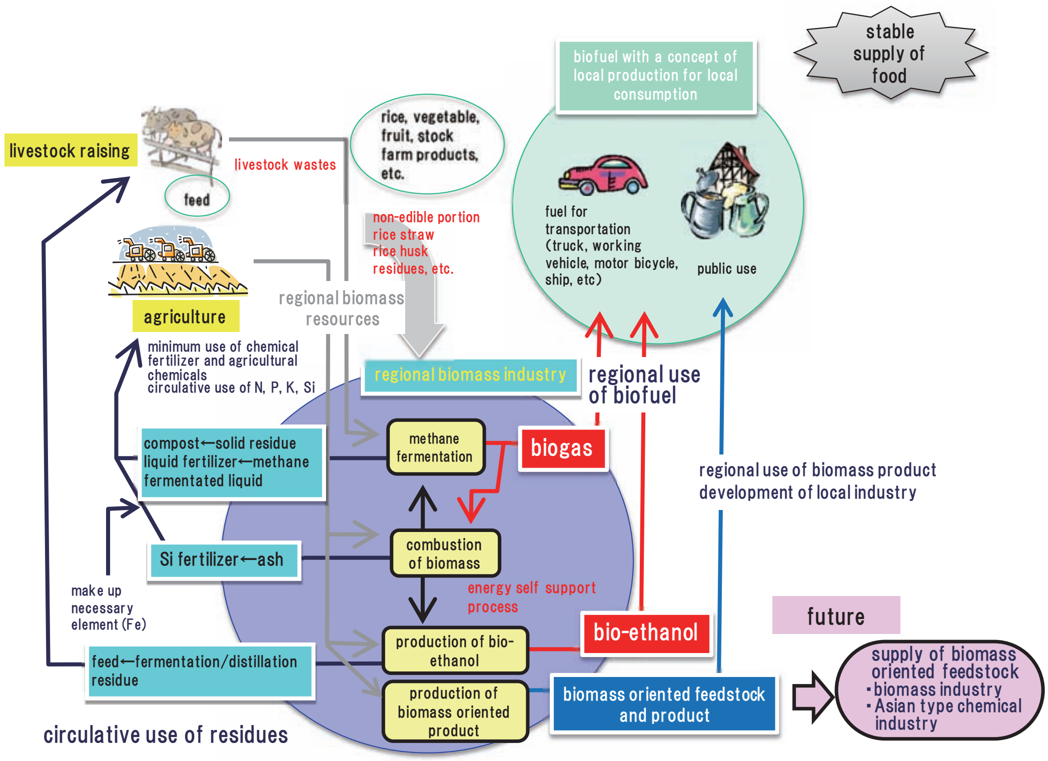


Fig.1　Outline of the Project[5)]

3-2. Production of biofuels, functional fertilizer, animal feed, and other valuables from local biomass resources

3-3. Development of novel separation technologies for biorefinery

3-4. Systemization of the developed key technologies

4. Project Site

- Hochiminh City University of Technology (HCMUT), Ho Chi Minh City
- Thai My village, Cu Chi District, Ho Chi Minh City

Fig.1. shows blueprint of this project by Prof. Akiyoshi Sakoda of IIS-UT. Biomass conversions for the production of biofuels such as bioethanol and biogas and bio-based materials are emphasized. Use of methane fermentated digested slurry in paddy fields and production of bioethanol from rice straw are challenging scenarios for the Project. These scenarios will make large impact on local agriculture, industries and the environment. Information for on-going activities can be accessed at the web site HCM-Biomass[6)].

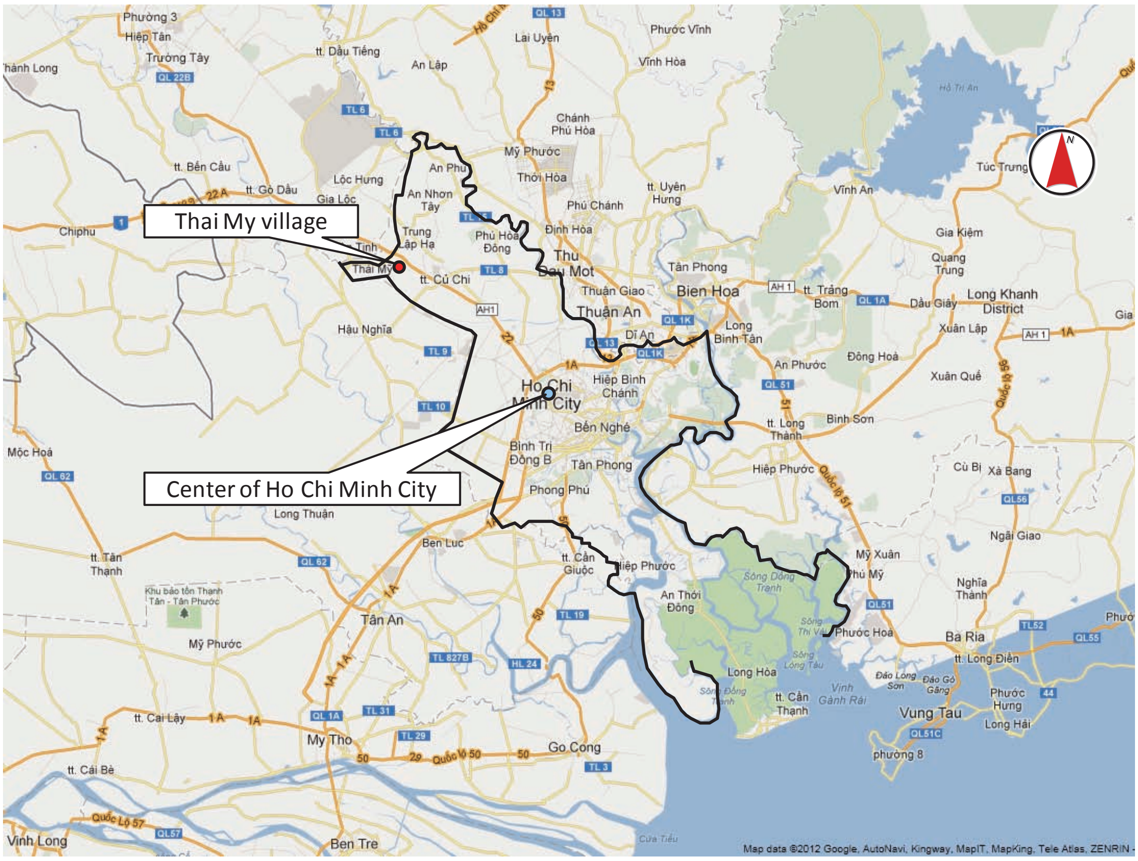
Ⅲ　Outline of study area

Thai My village was selected as one of the three target villages to promote activities as output (1). Thai My village is located in Cu Chi District of Ho Chi Minh City as shown in **Fig.2**. It is approximately 42km north-west from the center of Ho Chi Minh City.

According to information authors collected, the population of Thai My village is 10,849 with 2,873 households including 967 farmer households in 2010. Total land area is 2,415 ha composed of 1,861 ha of farmland, 113 ha of roads, 123 ha of river or canal and 159 ha for resident. The main agricultural land use is 544 ha for rice (total cultivation area in a year), 200 ha for corn and peanuts, 70-80 ha for vegetables, 146 ha for fruit trees such as dragon fruit, mango, and lemon. Melaleuca and bamboo trees are also grown in a wide area of the village.

Rice is cultivated 2 or 3 times per year depending on economical, water or soil conditions. About 50% of paddy fields cultivate 3 crops per year. Annual rainfall is 1880 mm. Irrigation water is supplied either by gravity or by pumps. Rice yield and fertilization rate are differ by season. Almost all the rice harvested is sold to merchants outside the village with little consumption by farmers. Farmers usually consume rice purchased outside the village. Rice straw is used for cow feed or burned in the field. Rice husks are sold or used as fuel for cooking. Bran is used for animal feed.

Livestock farming is popular than rice farming. Use of livestock excreta is variable by farmers, for example, feedstock of compost or biogas, or selling to fertilizer companies. 111 households have biogas digesters with capacities of 7.8±1.2 m^3 of fermentation tank volume. The main feedstock is pig and milk cow feces and urine mixed with the washing water of livestock farming shed. Biogas is mainly used for cooking in the homes. Most of the digested slurry is discharged to the infiltration pits, river or canal although a little of them is used as fertilizer for plants in yards or non-paddy fields. The reason that digested slurry is not used at paddy fields is that 1)



(a) Location of Thai My village and Ho Chi Minh City

(b) Satellite image of Thai My village

Fig.2 Geographical information of Thai My village

Vietnamese farmers have tendency to dislike working in the paddy field applied with compost or slurry for sanitary reason, 2) proper application method has not established yet and 3) cost and labor for application, environmental impact in case using digested slurry is not clear. Water pollution problems may become serious without adequate control of livestock excreta. Actually, water quality survey for two years show that nitrate nitrogen concentration in some rivers and canals are higher than 30mg・L^{-1}. Thus, there is a room to improve biogas and digested slurry use.

Situation of Thai My village is shown by pictures in **Fig.3**. Thai My village can be recognized relatively rich sub-urban rural area.

(a) Pig farming　(b) Pig farming and biogas digester

(c) Utilization of biogas in a kitchen　(d) Stream

(e) Paddy field　(f) Pasture area

Fig.3　Situation of Thai My village

Ⅳ Regional diagnosis

1 Purpose

Final goal of regional diagnosis is to clarify the sustainability and soundness of the biomass use plan based on accurate understanding of present condition. The regional diagnosis compares several ideas in terms of range of objective area, selection of feedstock biomass and biomass conversion processes, scale and disposition of biomass conversion plants. The balance of supply and demand in terms of quantity, time and space, is also confirmed. On the basis of this analysis, authors aim to propose a model for sustainable agriculture, where adequate quantities of N, P, K, C and Si exist in farmland so they are absorbed by crops not to be discharged into environment excessively.

Candidate evaluation indicators for agriculture include1) substitution of compost/bio-liquid fertilizer for chemical fertilizer per unit area, 2) soil fertility, 3) amount of final disposal of organic wastes, 4) reuse rate of organic wastes, 5) discharge load to water bodies from agriculture field and livestock farming shed, 6) emission rate of GHG, 7) input of fossil energy for agriculture and 8) self-sufficiency rate of food and feed in a region.

In this study, the basic model structure to diagnose regional material flow in biomass use (hereinafter referred to as “the Model”) was developed, and then the present condition and the plan of biomass use are compared and evaluated. The latter means widespread use of biogas digester which produces both biogas and digested slurry from livestock excreta with application of digested slurry to paddy field as liquid fertilizer.

2 Model structure

The Model is composed of “compartment (box)” that represents space to generate, convert or use biomass, and an “arrow” that represents material flow. The compartments involve livestock farming, agricultural fields, biogas digester, composting. Parameters for analysis are raw weight, water content, carbon content and nitrogen content of feedstock biomass and its converted products.

3 Procedure of analysis

First, data needed for regional diagnosis were collected by interview, field survey and literature reviews. Content and method of data collection is summarized in **Table 1**. Second, the present conditions of biomass use were represented as the “present” Model. Third, problems to be solved and the proposal from the Project were designed as the “plan” Model.

Interviewees were farmers and officers at public administration bodies such as DOST-HCM, DARD-HCM, People committee of Cu Chi district and People committee of Thai My village. Interviews were conducted from 11 to 29 January 2010 and 27 October 2010 by Mr. Akira Matsumoto, a short term expert of JICA and project members from HCMUT and IRE-NARO. Information collected by IIS-UT was also used.

Field surveys on water quality in the canal and river, and soil in fields were conducted 4 times per year from April 2010 to March 2012 by members from HCMUT and IRE-NARO. Field surveys in rice cultivation test field were conducted from 6 December 2011 to 24 March 2012 and from 11 May to 17 August 2012. Rice cultivation was conducted by contracts between a farmer and the Project in 1 hectare of paddy field. The farmer was requested to record a working diary to get data and information on application rate of fertilizer, irrigation and drainage water, yield and amount of by-product.

Basic information collected was mentioned in section III. Inventory of data and information collected and used for regional diagnosis and calculation process are shown in the Appendix. Bases of data for calculation of material balance in paddy field, no-paddy field and livestock excreta were arranged.

Ⅴ Results and discussions

1 Design of present material flow

Situation of present biomass use was reflected in the Model as much as possible based on data and information collected, although some data had to be assumed.

In terms of pig excreta, 11% (1263 heads) is put into the biogas digester, 10t/week of feces is shipped outside the village as feedstock for compost, and the remainder is discharged into the lower water bodies. In terms of milk cow excreta, 11% (7 heads) is put into the biogas digester and the rest discharged to the lower water bodies. In terms of beef cattle excreta, half of the feces is sold outside the village, the other half of the feces is put into the composting facility, and the urine is discharged to the lower water bodies. Condition of buffalo is as the same as beef cow.

Compost produced at composting facilities is used in agricultural field except paddy fields, In terms of digested slurry produced

Table 1　Data collection for regional diagnosis

Item	Method or data sources
a. Basic regional information (a) Land use (agricultural fields, settlement, road, river, irrigation and drainage canals, etc.) (b) Area of each land use (c) Population, agricultural population (population of farmers) (d) Kinds and amounts of fuels (energy) used at home (e) Current condition of water resources for drinking water (intake source, quantity, quality) (f) Environmental problem(s), if any	Interview to VPC, DOST , Cu Chi PC and Villager
b. Agriculture information (a) Main crop situation (cropping condition, crop yields, shipping destination of crops) (b) Kinds, amount and methods of fertilizer application (c) Agriculture machinery (variety, fuel expenses, man power needed)	Interview to VPC, DOST, Cu Chi PC , Villager and DARD
c. Information about rice cultivation	
(a) Application rate and variety of fertilizer	Interview to VPC and Villager
(b) Method of water management	Interview to VPC, Villager and DOST
(c) Water quality of canal and river, soil chemical property	Sampling survey conducted by HCMUT and NARO in Thai My village (April 2010-March 2012)
(d) Amount of irrigation water	1) Field survey conducted at test field in Thai My village (December 2011-March 2012) 2) Thoai N. L. Q (2012); Balance of water, nitrogen and phosphorus for rice crop at a paddy field in southern Vietnam, Society of Environmental Science, Japan, p.136-137
(e) Monthly average rainfall	Global Meteorological information CD edited by Japan meteorological business support center
(f) Ammonia volatilization	Takeshi Watanabe (2009); Measurement on ammonia volatilization from flooded paddy field in Vietnam,Soil science and plant nutrition 55, 793-799
(g) Nitrogen fixation	Giau Tran Quang (2012); Effects of rotational crops and water management on balance of N, P and K and characteristics of acidic alluvium soil, Doctoral Dissertation in Can Tho university, Vietnam
(h) Emission of carbon	Systemization Sub-team, Bio-recycle Project ed. (2006), Design and Evaluation of Biomass Use System, p.30-39
(i) Percolation	Thoai N. L. Q (2012); Balance of water, nitrogen and phosphorus for rice crop at a paddy field in southern Vietnam, Society of Environmental Science, Japan, p.136-137
(j) Methane gas release	NARO and Naigai Engineering (2010); Workshop on Development of Design and Evaluation Support Tool for Biomass Town Construction
(k) Yield and by-product	1) Interview to VPC, DOST, Cu Chi PC and Villager 2) Field survey conducted at test field in Thai My village (December 2011-March 2012, May-August 2012)
d. Information about cultivation except rice	
(a) Application rate and variety of fertilizer	1) Interview to VPC and Villager 2) http://www.maff.go.jp/j/seisan/kankyo/hozen_type/h_sehi_kizyun/
(f) Nitrogen fixation	Systemization Sub-team, Bio-recycle Project ed. (2006); Design and Evaluation of Biomass Use System, p.30-39
(g) Emission of carbon and nitrogen	Systemization Sub-team, Bio-recycle Project ed. (2006); Design and Evaluation of Biomass Use System, p.30-39
(h) Percolation	Thoai N. L. Q (2012); Balance of water, nitrogen and phosphorus for rice crop at a paddy field in southern Vietnam, Society of Environmental Science, Japan, p.136-137
(i) Yield	1) Interview to VPC and Villager 2) http://www.maff.go.jp/j/seisan/kankyo/hozen_type/h_sehi_kizyun/
e. Information about livestock	
(a) Kinds and numbers of livestock (cow, pig, chicken, etc.) (b) Method of livestock raising, variety of feed, way of disposal and use (c) Flows of livestock excreta (d) Set-up and operation of digesters (e) Case studies of digester (financial supports for construction and/or operation, construction period of time, size, use and/or disposal of biogas and digested slurry	1) Interview to VPC & Village Observation, Villager Interview
(f) Project institution and results of installation of biogas facility	Interview to DOST and DARD
(g) Generation of livestock excreta per head and its contents	Interview to DARD
(h) Yield of biogas by methane fermentation of cattle excrement	Interview to DARD

(Abbreviation) HCMUT: HoChiMinh City University of Technology, DOST-HCM: Department of Science and Technology, DARD-HCM: Department of Agriculture and Rural Development, VPC: Thai My Village People Committee, Cu Chi PC: People Committee of Cu Chi with a biogas digester, 10% is used in non-paddy fields and 90% is discharged to the lower water bodies without any treatment.

In terms of paddy fields, the inputs are chemical fertilizers, precipitation, irrigation water and carbon and nitrogen from the air by photosynthesis and nitrogen fixation. The outputs are products, gas emission, evapotranspiration, surface runoff and percolation. Flow direction of products and by-products is mentioned in section III.

In terms of non-paddy fields, the inputs are chemical fertilizer, compost, digested slurry, precipitation, carbon and nitrogen from the air by photosynthesis and nitrogen fixation. The outputs are product, gas emission, evapotranspiration and percolation. Products are shipped outside the village as same as for paddy fields.

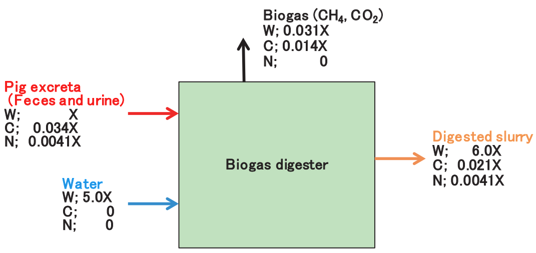
Based on the above data collected and treated, material balance at each compartment is designed as shown in **Fig.4-9**. They were arranged as specific values for easy understanding using the unit t･head^{-1}･y^{-1} or kg･ha^{-1}･y^{-1}.

2 Estimation of present condition of biomass use

Regional diagnosis was conducted using the above results and information in the Appendix. Present condition of target biomass use in Thai My village was calculated as shown in **Fig.10**. The following points are noticeable:

1) Out of a livestock excreta (including solid, slurry and liquid) total of 40,000 t・y^{-1}, 33% is brought outside the village as feedstock for compost, 21% is used in the village as feedstock for compost, and 41% is discharged into the lower water bodies without any treatment.

2) Nitrogen effluent load to water bodies comes from untreated livestock excreta, discharge from agricultural fields and other factors, which amounts to 122 t・y^{-1}. The loads from unused livestock excreta accounts for about 48% which would cause water pollution.

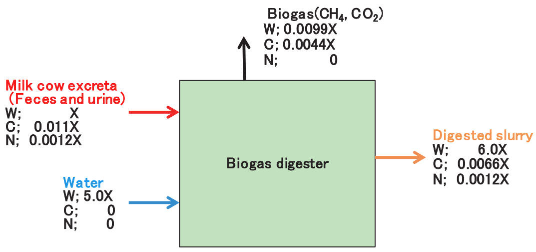


Input Unit (t･head･y^{-1})	W	C	N
Pig excreta (feces + urine) (feces : urine=0.73 : 0.49)	X	0.034X	0.0041X
Water	5.0X	0	0
Total	6.0X	0.034X	0.0041X

Output Unit (t･head･y^{-1})	W	C	N
Biogas (CH_4 : CO_2=6:4)	0.031X	0.014X	0
Digested slurry	6.0X	0.021X	0.0041X
Total	6.0X	0.034X	0.0041X

W ; Raw weight
C ; Carbon content
N ; Nitrogen content
X ; Specific raw weight of pig excreta

Fig.4 Designed material balance at biogas digester with the feedstock of pig excreta

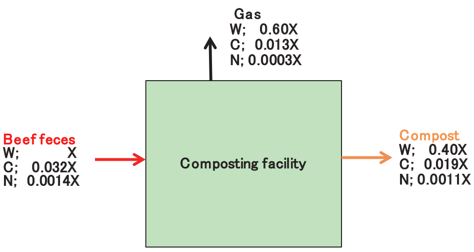


Input Unit (t･head･y^{-1})	W	C	N
milk cow excreta (feces + urine) (manure : urine=8.22 : 4.56)	X	0.011X	0.0012X
Water	5.0X	0	0
Total	6.0X	0.011X	0.0012X

Output Unit (t･head･y^{-1})	W	C	N
Biogas (CH_4 : CO_2=6:4)	0.0099X	0.0044X	0
Digested slurry	6.0X	0.0066X	0.0012X
Total	6.0X	0.011X	0.0012X

W ; Raw weight
C ; Carbon content
N ; Nitrogen content
X ; Specific raw weight of milk cow excreta

Fig.5 Designed material balance at biogas digester with the feedstock of milk cow excreta

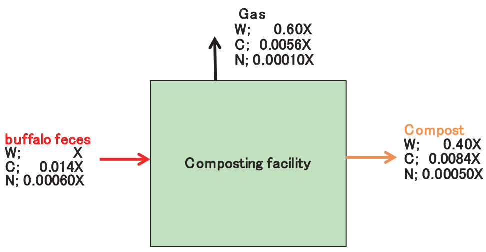


Input Unit (t･head･y^{-1})	W	C	N
Beef feces	X	0.032X	0.0014X
Total	X	0.032X	0.0014X

Output Unit (t･head･y^{-1})	W	C	N
Gas+H_2O	0.60X	0.013X	0.0003X
Compost	0.40X	0.019X	0.0011X
Total	X	0.032X	0.0014X

W ; Raw weight
C ; Carbon content
N ; Nitrogen content
X ; Specific raw weight of beef feces

Fig.6 Designed material balance at composting facility with the feedstock of beef feces

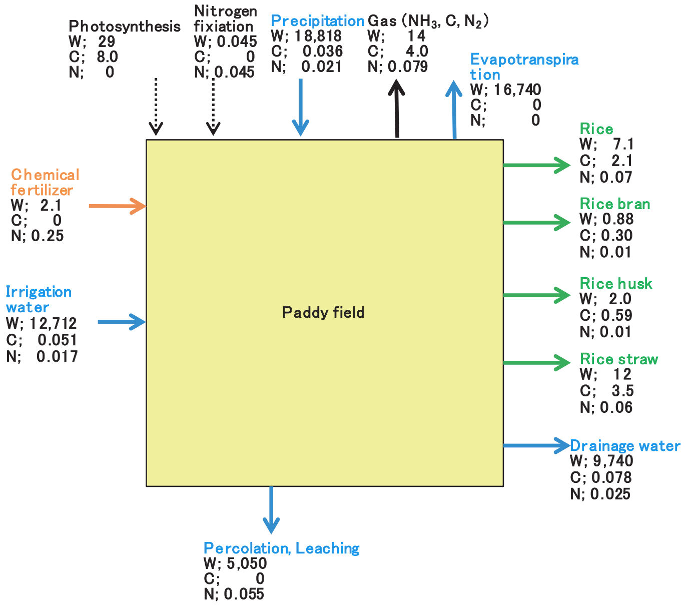


Input Unit (t･head･y^{-1})	W	C	N
buffalo feces	X	0.014X	0.00060X
Total	X	0.014X	0.00060X

Output Unit (t･head･y^{-1})	W	C	N
Gas+H_2O	0.60X	0.0056X	0.00010X
Compost	0.40X	0.0084X	0.00050X
Total	X	0.0014X	0.00060X

W ; Raw weight
C ; Carbon content
N ; Nitrogen content
X ; Specific raw weight of buffalo feces

Fig.7 Designed material balance at composting facility with the feedstock of buffalo feces

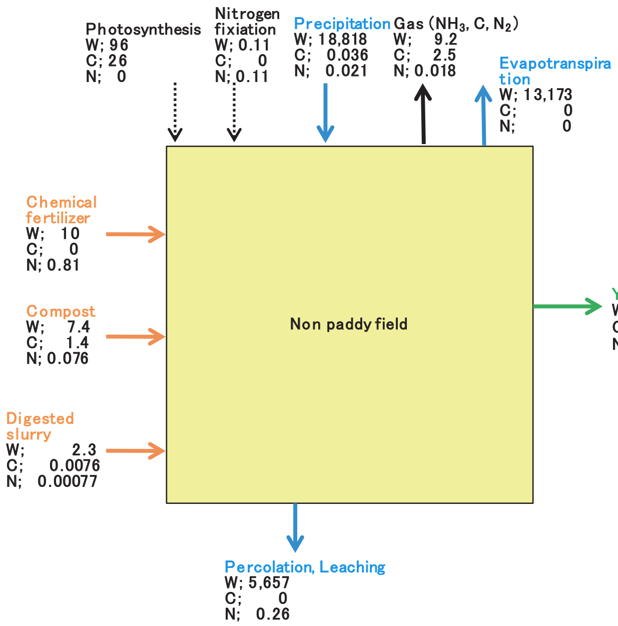


Input	W	C	N
	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$
Chemical fertilizer	2.1	0	0.25
Photosynthesis	29	8.0	0
Nitrogen fixation	0.045	0	0.045
Precipitation	18,818	0.036	0.021
Irrigation water	12,712	0.051	0.017
Total	31,561	8.1	0.33

Output	W	C	N
	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$
Polished rice (normal)	6.2	1.8	0.06
Polished rice (broken)	0.97	0.29	0.01
Rice bran	0.88	0.30	0.01
Rice husk	2.0	0.59	0.01
Rice straw	12	3.5	0.06
NH_3	0.0043	0	0.0043
C volitilization	14	4.0	0
Denitrification	0.075	0	0.075
Evapotranspiration	16,740	0	0
Drainage water	9,740	0.078	0.025
Percolation, Leaching	5,050	0	0.055
Total	31,566	11	0.31

W ; Raw weight
C ; Carbon content
N ; Nitrogen content

Fig.8 Designed material balance at paddy field



Input	W	C	N
	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$
Chemical fertilizer	10	0	0.81
Compost	24.9	4.6	0.25
Digested slurry	2.3	0.0076	0.00154
Photosynthesis	96	26	0
Nitrogen fixation	0.11	0	0.11
Precipitation	18,818	0.036	0.021
Total	18,951	31	1.2

Output	W	C	N
	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$
Yield	71	26	0.55
C volatilization	9.2	2.5	0
NH_3+Denitrification	0.018	0	0.018
Evapotranspiration	13,173	0	0
Percolation, Leaching	5,657	0	0.26
Total	18,910	29	0.83

W ; Raw weight
C ; Carbon content
N ; Nitrogen content

Fig.9 Designed material balance at non-paddy field

3) The number of biogas digester currently in use is 111 units, which collectively have a capacity to treat 4% of the livestock excreta generated in the village, namely 1,600 t・y^{-1}. Usage of digested slurry as liquid fertilizer is limited.

4) Amount of rice straw, rice husk and rice bran produced is 3,000 t・y^{-1} in total with 13% brought outside the village, 20% used as feed of livestock and 14% is used as feedstock for compost inside the village. The remaining 66%, 2,000 t・y^{-1} is burned or composted in paddy fields.

3　Design of the plan Model and result

To overcome water pollution and realize desirable biomass use, the “plan” model is designed as follows:

1) All unused livestock excreta are considered feedstock for biogas digester. By increasing the number of biogas digesters, excreta from 10,000 heads of pigs and 60 heads of milk cows becomes the target.

2) Digested slurry produced at the digesters is applied to paddy fields as liquid fertilizer, but many difficulties remain as mentioned in section III.

3) Half of the nitrogen contained in the slurry is considered effective for a crop uptake, because the ratio of ammonia nitrogen to total

nitrogen is approximately 50%. This portion is assumed to replace the chemical nitrogen fertilizer in paddy fields.

Following the above assumption (3), the material balance in paddy field was modified as shown in **Fig.11**.

Furthermore, following the above “plan” scenario, the material flow in a village was simulated as shown in **Fig.12**. Drastic changes might be expected. Results were summarized in **Tables 2-4**. Effluent nitrogen load decreased from 122 t・y^{-1} to 70 t・y^{-1}, by 43%. Application rate of nitrogen fertilizer decreased from 250 kg・ha^{-1}・y^{-1} to 130 kg・ha^{-1}・y^{-1} owing to application of digested slurry.

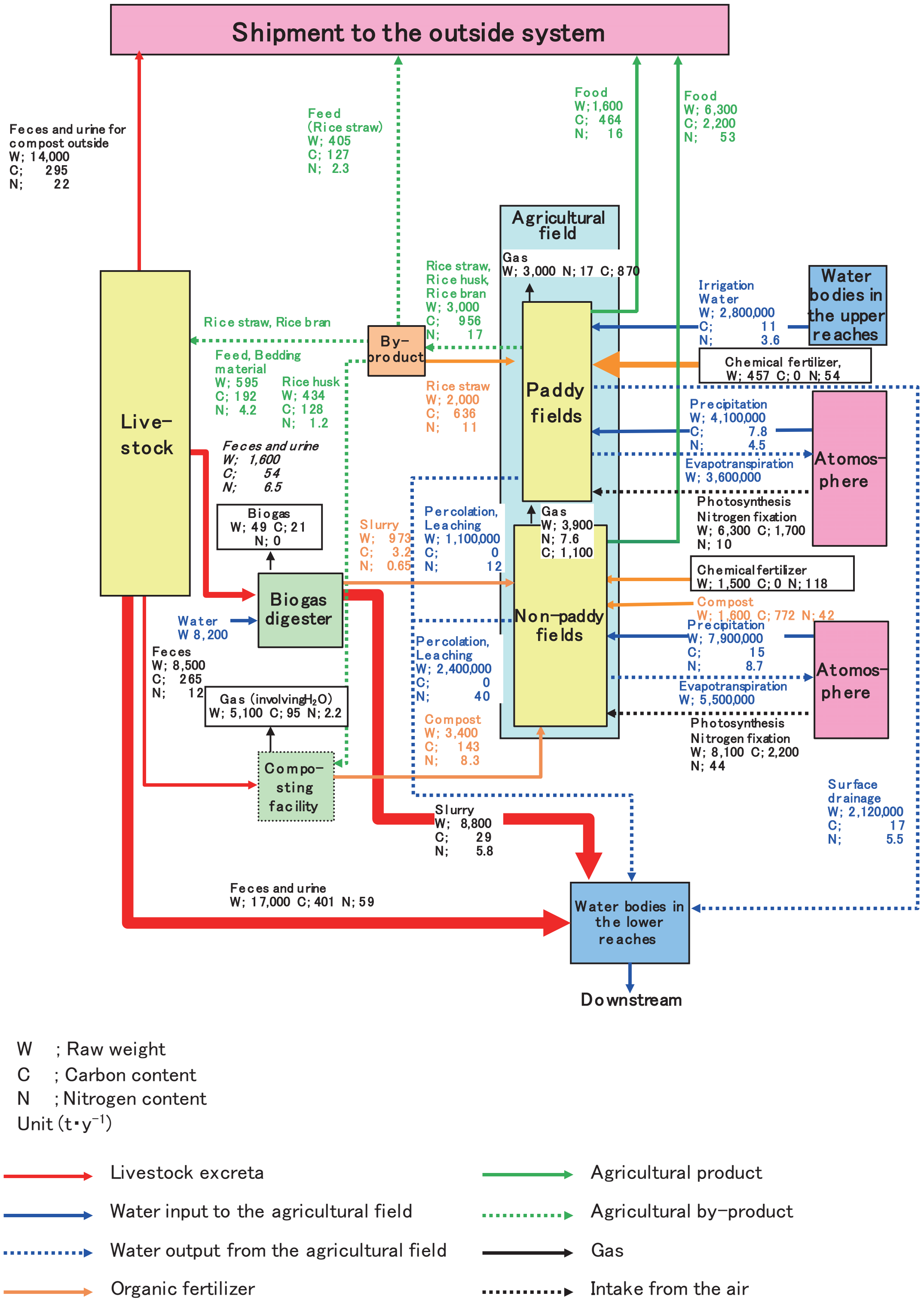
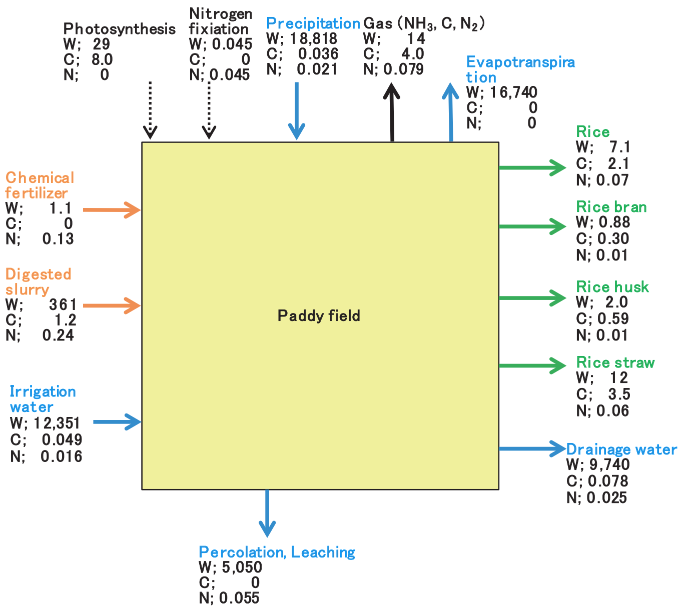


Fig.10 Result of regional diagnosis (present condition)



Input	W	C	N
	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$
Chemical fertilizer	1.1	0	0.13
Digested slurry	361	1.2	0.24
Photosynthesis	29	8.0	0
Nitrogen fixation	0.045	0	0.045
Precipitation	18,818	0.036	0.021
Irrigation water	12,351	0.049	0.016
Total	31,560	9.3	0.45

Output	W	C	N
	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$
Polished rice (normal)	6.2	1.8	0.06
Polished rice (broken)	0.97	0.29	0.01
Rice bran	0.88	0.30	0.01
Rice husk	2.0	0.59	0.01
Rice straw	12	3.5	0.06
NH_3	0.0043	0	0.0043
C volatilization	14	4.0	0
Denitrification	0.075	0	0.075
Evapotranspiration	16,740	0	0
Drainage water	9740	0.078	0.025
Percolation, Leaching	5,050	0	0.055
Total	31,566	11	0.31

W ; Raw weight
C ; Carbon content
N ; Nitrogen content

Fig.11 Designed material balance at paddy field (plan)

Biogas generation rate increased to 330,000 $Nm^3 \cdot y^{-1}$, 8 times larger than the present condition. These biomass uses contribute to local production for local consumption.

Ⅵ Conclusion

Authors have promoted the research titled “Sustainable integrations of local agriculture and biomass industry” in southern Vietnam under the international joint project called SATREPS.

In this study, basic model structure to diagnose regional material flow in biomass use was designed, and then the rational diffusion of a biogas digester in Thai My village was diagnosed as the first step.

Present condition of biomass use was investigated focusing on the treatment of livestock excreta, rice cultivation and conditions of water quality in canals. Necessary data and information were collected from a literature review, interviews of farmers and public administrators and field surveys, as well as rice cultivation trials. The Model that represents the present biomass use showed that unused livestock excreta may discharge excessive nitrogen to water bodies, accounting 48% of total load in a village and cause water pollution.

To solve environmental problems and seek rational biomass use to contribute to local production for local consumption, the “plan” model was proposed in which biogas digester system was diffused and produced digested slurry was applied as liquid fertilizer in paddy field. In this model, all the unused livestock excreta were considered feedstock. The model suggested 43% reduction of effluent nitrogen load to water bodies, 48% reduction of chemical fertilizer application rate and 8 times larger production of biogas.

The Model can be widely used to diagnose various biomass use plans, while increasing reliability. Moreover, this simplified model can spread the opportunity of existing tool use in Japan, because the person in change can concentrate on data collection and analysis for direct relation items. Field test and evaluation that authors have implemented to use digested slurry in paddy field is new challenge in Vietnam. If followings are clearly shown, the use of digested slurry in paddy fields would be adopted by many farmers; that is, 1) there is no bad environmental influence or sanitary problem for working people, 2) the digested slurry can substitute for chemical fertilizer, 3) proper application method of digested slurry is established and 4) cost and labor for application is acceptable. Achievements in Vietnam may also provide more economical methods to Japan.

This work was supported by JST/JICA SATREPS, “Sustainable Integration of Local Agriculture and Biomass Industries”. We appreciate Dr. Phan Dinh Tuan, Project Leader for good management and necessary personnel assignment. Mr. Akira Matsumoto, JICA short time expert investigated present situation of society, economic and environment in Thai My village. His methods were very useful for data collection by project members. This report uses a lot of information provided by environment group and engineering group members who are not included as authors of this paper. Authors thank many organizations for their cooperation. Last but not least, authors thank adequate coordination by Mr. Ryuji Nakayama, Project Coordinator of JICA expert who promoted smooth field

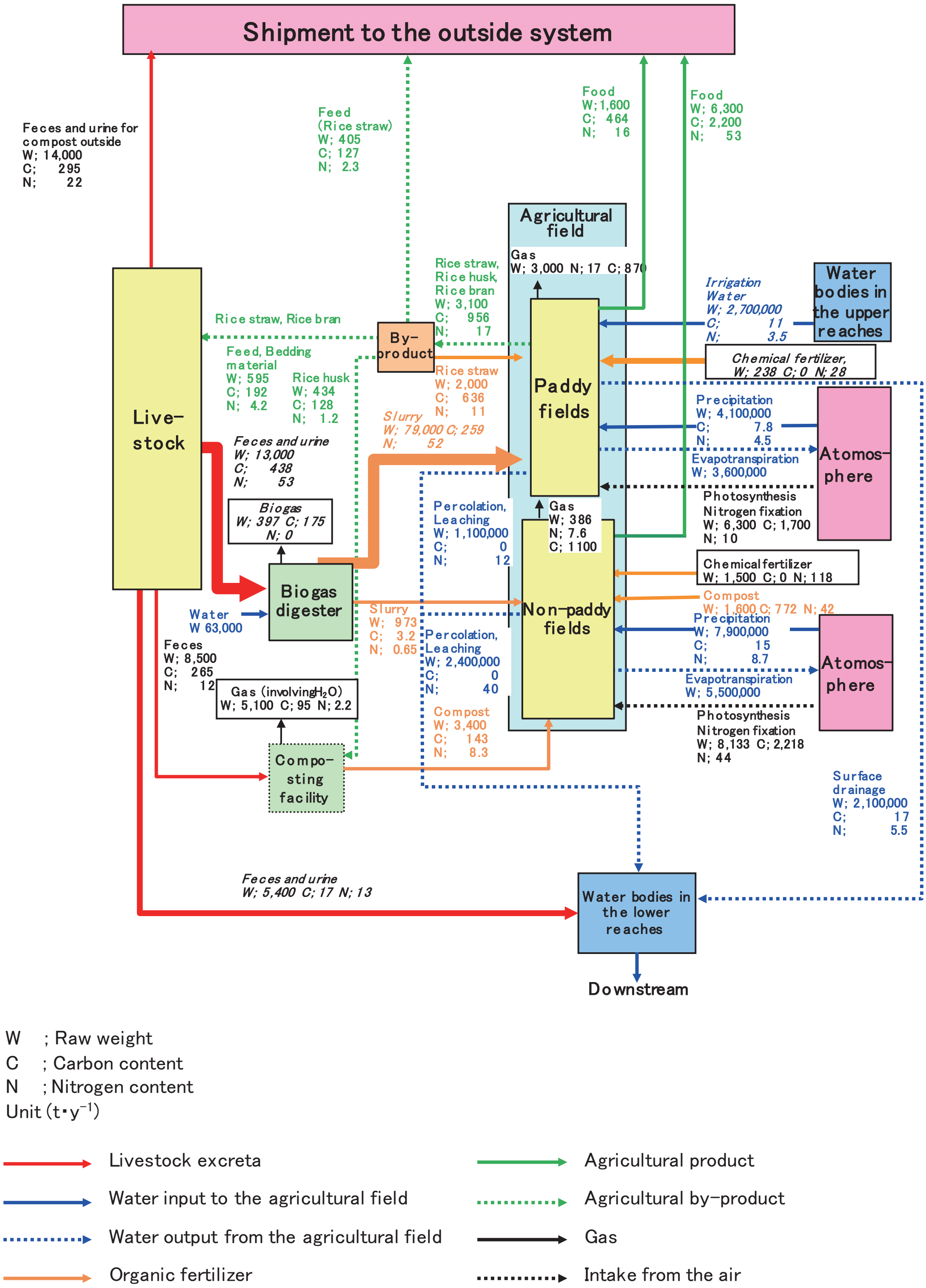


Fig.12 Result of regional diagnosis (plan)

investigation and analysis.

References

1) Yuyama, Y., Doi, K, Nakamura, M. and Shimizu, N. (2010) : Development of Diagnosis Tool on Regional Biomass Use, Transactions of the Japanese Society of Irrigation, *Drainage and Rural Engineering*, **78** (2), 57-62

2) SATREPS: Japan Science and Technology Agency
http://www.jst.go.jp/global/english/about.html

3) Sustainable Integrations of Local Agriculture and Biomass Industries, Japan Science and Technology Agency http://www.jst.go.jp/global/english/

Table 2 Change of nitrogen load to the lower water bodies from each source

Source of nitrogen load to the lower water bodies	Present		Plan		Change
	N	rate	N	rate	N
	$t \cdot y^{-1}$	%	$t \cdot y^{-1}$	%	$t \cdot y^{-1}$
Feces and urine of livestock	59.1	48.3	12.9	18.3	−46.2
Leaching from non-paddy fields	39.9	32.6	39.9	56.8	0.0
Leaching from paddy fields	12	9.8	12.0	17.1	0.0
Surface drainage from paddy field	5.5	4.5	5.5	7.8	0.0
Digested slurry	5.8	4.7	0.0	0.0	−5.8
Total	122.3	100	70.3	100	−52.0

N; Amount of nitrogen from each load source
Change; Value of "Plan"－"Present"

Table 3 Change of chemical fertilizer use rate at paddy fields

Present		Plan		Change	
W	N	W	N	W	N
$t \cdot y^{-1}$	$t \cdot y^{-1}$	$t \cdot y^{-1}$	$t \cdot y^{-1}$	$t \cdot y^{-1}$	$t \cdot y^{-1}$
457.0	54.4	238.1	28.4	−218.8	−26.0
W	N	W	N	W	N
$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$	$t \cdot ha^{-1} \cdot y^{-1}$
2.1	0.25	1.09	0.13	−1.01	−0.12

W; Raw weight of chemical fertilizer used for cultivation of rice
N; Nitrogen content in chemical fertilizer used for cultivation of rice
Change; Value of "Plan"－"Present"

Table 4 Change of biogas generation rate

Source of biogas digester	Present				Plan				Change		
	Biogas generation rate			Heads	Biogas generation rate			Heads	Biogas generation rate		
	W	C	V		W	C	V		W	C	V
	$t \cdot y^{-1}$	$t \cdot y^{-1}$	$Nm^3 \cdot y^{-1}$		$t \cdot y^{-1}$	$t \cdot y^{-1}$	$Nm^3 \cdot y^{-1}$		$t \cdot y^{-1}$	$t \cdot y^{-1}$	$Nm^3 \cdot y^{-1}$
Pig excreta	47.8	21.1	39340	1263	389.1	171.7	320452	10288	341.3	150.6	281112
Milk cow excreta	0.9	0.4	731	7	7.7	3.4	6370	61	6.8	3.0	5639
Total	48.7	21.5	40071		396.9	175.1	326822		348.2	153.6	286751

W; Weight of biogas
C; Carbon content in biogas
V; Volume of biogas
Heads; Heads of cattle
Change; Value of "Plan"－"Present"

kadai/h2106_vietnam.html
4) Record of Discussions between Japan International Cooperation Agency and The Authorities Concerned of The Government of Socialist Republic of Viet Nam on Japanese Technical Cooperation for The Project for Sustainable Integration of Local Agriculture and Biomass Industries, JICA and Vietnamese authorities concerned, Ho Chi Minh City, October 8, 2009
5) Sakoda A. (2012) : Science and Technology Research Partnership for Sustainable Development (SATREPS) Sustainable Integrations of Local Agriculture and Biomass Industries, proceeding of annual meeting 2012, *Society of Environmental Science*, Japan, 134,
6) HCM-Biomass, JST/JICA SATREPS http://hcmbiomass.cocolog-nifty.com/blog/
7) Thoai N.L.Q, Hanh D,V.B, Dan N.P., Tuan P.D., Oritate, F., Yuyama, Y., Nakumura, M., Yamaoka, M., Mochizuki, K. and Sakoda, A. (2012) : Balances of Water, Nitrogen and Phosphorus for rice crop at a paddy field in Southern Vietnam, Proceeding of Annual meeting 2012, *Society of Environmental Science*, Japan, 136-137,

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ベトナム国タイミー村におけるバイオマス利用の地域診断

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迫田章義***，望月和博***

要　旨

JST と JICA は，地球規模課題対応国際協力（SATREPS）を共同実施している。本報は東京大学生産技術研究所が代表機関の課題「持続可能な地域農業・バイオマス産業の融合」の一部である，バイオマス利用の地域診断に関わる中間成果をまとめたものである。

ベトナム国タイミー村を対象としてバイオマス利用に関する現状を調査した。タイミー村はホーチミン市中心街から北西へ42km の位置にあり，畜産と稲作が盛んな，人口約 11,000 人，面積約 2,400ha のモデル農村である。調査は，文献データの収集，農家や行政部局へのインタビュー，水質・土壌サンプリング，稲栽培試験によった。タイミー村では家畜ふん尿を原料とするバイオダイジェスターが導入され，バイオガスを回収し調理等の燃料として利用している。バイオガスダイジェスターから排出される消化液の大部分は，有効利用されることなく水域に放流されている。

収集したデータから農業生産及び家畜ふん尿処理における原材料，生産物及び副生成物の物質収支に着目した地域診断モデル（現状）を作成した。モデルの境界は，副生成物の行き先となる大気及び水域までとして，それらへの環境影響を把握できるようにした。解析項目は，生重量，窒素量、炭素量である。

現状診断の結果，水域への負荷の中では未処理の家畜ふん尿の垂れ流しが最も大きく，水域への負荷全体に対する割合は 48% であった。これまでの調査結果から，村の河川や水路の硝酸態窒素濃度は 30mg・L^{-1} をこえるところもあり，水域への窒素負荷削減及び資源の有効利用が課題と考えられた。

これらを踏まえ，現在未処理のまま水域へ垂れ流しとなっている家畜ふん尿の全量をバイオガスダイジェスターへ投入し，生成した消化液を全量液肥として水稲作に利用する計画を作成した。これによると，現状より水域への窒素負荷が 43% 削減，農地に施用される化学肥料が 48% 削減でき，地産地消型のエネルギーであるバイオガスの生産が 8 倍になるという結果になった。

診断モデルについては，今後精度を向上させた上で，様々なバイオマス利用の診断と評価に活用していく。

この診断モデルは日本国内用に開発してきたツールを基礎としたが単純化により取扱いやすくなったので日本国内での適用拡大が期待される。また，消化液の水田での液肥利用は，ベトナム国においては新たな試みであり，多くの課題があるが現地実証を進めていく。

キーワード：物質フロー，バイオガスダイジェスター，消化液，家畜ふん尿，水稲作，地産地消，環境影響

Appendix A　Bases of data used for regional diagnosis (paddy field compartment)

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
Paddy field area	―	―	―	217.6	ha	1) Paddy cropping area in a year is 544 (ha・y^{-1}). 2) Half area is 2 crops・y^{-1}, and another half area is 3 crops・y^{-1}. 3) Assuming that same size of area is used for each cultivation season, actual paddy field area is calculated as follows; Paddy field area (ha) = 544 (ha・y^{-1})/(1/2 (ha) * 2 (crops) + 1/2 (ha) * 3 (crops)) = 544 ((ha・y^{-1}) * 2/5 = 217.6 (ha)	Interview to VPC, DARD
(Input) Application of chemical fertilizer	W	840	kg・ha^{-1}・crop^{-1}	457	t・y^{-1}	1) Application rate of chemical fertilizer is 840 (kg・ha^{-1}・crop^{-1}). 2) Therefore, chemical fertilizer rate (t・y^{-1}) = Application rate of chemical fertilizer (kg・ha^{-1}・crop^{-1}) * Cropping area in a year (ha・y^{-1})/1000 = 840 (kg・ha^{-1}・crop^{-1}) * 544 (ha・y^{-1})/1000 ≒ 457 (t・y^{-1})	Interview to VPC and Villager
	C	0		0	t・y^{-1}	Carbon is not contained in chemical fertilizer	―
	N	100		54	t・y^{-1}	1) Application rate of nitrogen fertilizer is 100 (kg・ha^{-1}・crop^{-1}). 2) Therefore, application rate of nitrogen chemical fertilizer (t・y^{-1}) = Application rate of chemical fertilizer (kg・ha^{-1}・crop^{-1}) * Cropping area in a year (ha・y^{-1})/1000 = 100 (kg・ha・$^{-1}$・crop^{-1}) * 544 (ha・y^{-1})/1000 ≒ 54 (t・y^{-1})	Interview to VPC and Villager
(Input) Precipitation	W	1881.8	mm・y^{-1}	4,100,000	t・y^{-1}	1) Mean annual precipitation is 1881.8 (mm・y^{-1}). 2) Therefore, input from precipitation (t・y^{-1}) = Mean annual precipitation (mm・y^{-1}) * Area (ha) * 10 = 1881.8 (mm・y^{-1}) * 217.6 (ha) * 10 = 4094797 (t・y^{-1}) ≒ 4,100,000 (t・y^{-1})	Global Meteorological information CD edited by Japan meteorological business support center
	C	1.9	mg・L^{-1}	7.8	t・y^{-1}	1) Total carbon concentration of precipitation is 1.9 (mg・L^{-1}). 2) Therefore, input from precipitation (t・y^{-1}) = Total carbon concentration of precipitation (mg・L^{-1}) * Precipitation rate (t・y^{-1})/1000000 = 1.9 (mg・L^{-1}) * 4094797 (t・ha^{-1})/1000000 ≒ 7.8 (t・y^{-1})	1) Tabuchi T. and Takamura y. (1985) : Discharge of nitrogen and phosphorus from watetershed, p.19, University of Tokyo Press. 2) Hanya T. and Ogura N. (1985) : Water quality investigation method, p. 58, Maruzen.
	N	1.1	mg・L^{-1}	4.5	t・y^{-1}	1) Total nitrogen concentration of precipitation is 1.1 (mg・L^{-1}). 2) Therefore, nitrogen content of precipitation (t・y^{-1}) = Total nitrogen concentration of precipitation (mg・L^{-1}) * Precipitation rate (t・y^{-1})/1000000 = 1.1 (mg・L^{-1}) * 4094797 (t・ha^{-1})/1000000 ≒ 4.5 (t・y^{-1})	1) Tabuchi T. and Takamura y. (1985) : Discharge of nitrogen and phosphorus from watetershed, p.19, University of Tokyo Press. 2) Hanya T. and Ogura N. (1985) : Water quality investigation method, p. 58, Maruzen.
(Input) Irrigation water	W	12700	t・ha^{-1}・y^{-1}	2,800,000	t・y^{-1}	1) Irrigation water for cultivation in dry season (from December to March) was 8928.5 (t・ha^{-1}) and precipitation in this season was 1728 (t・ha^{-1}). 2) Therefore, necessary water for rice cultivation per crop is supposed to be 10656.5 (t・ha^{-1}). 3) Precipitation in spring-summer season (from April to August) is 17090 (t・ha^{-1})* and precipitation in summer-autumn season (from September to November) is 6873 (t・ha^{-1})*. (*Global metheorogical data CD-ROM), thus, necessary irrigation water for each season is 0 (t・ha^{-1}) and 3783.52 (t・ha^{-1}), respectively. 4) Therefore, quantity of irrigation water is 12712 (t・ha^{-1}・y^{-1}). 5) Quantity of irrigation water (t・y^{-1}) = 12712 (t・ha^{-1}・y^{-1}) * Area (ha) = 12712 (t・ha^{-1}・y^{-1}) * 217.6 (ha) ≒ 2766140 (t・y^{-1}) ≒ 2800000 (t・y^{-1})	1) Field survey at test field (December 2011-March 2012) 2) Thoai N. L. Q (2012); Balance of water, nitrogen and phosphorus for rice crop at a paddy field in southern Vietnam, Society of Environmental Science, Japan, p.136-137

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
	C	4	$mg \cdot L^{-1}$	11	$t \cdot y^{-1}$	1) Total carbon concentration of irrigation water is 4.0 ($mg \cdot L^{-1}$). 2) Therefore, carbon content of irrigation water ($t \cdot y^{-1}$) = Quantity of irrigation water ($t \cdot y^{-1}$) * Carbon concentration of irrigation water ($mg \cdot L^{-1}$)/1000000 = 2766140 ($t \cdot y^{-1}$) * 4.0 ($mg \cdot L^{-1}$)/1000000 ≒ 11 ($t \cdot y^{-1}$)	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.79
	N	1.3	$mg \cdot L^{-1}$	3.6	$t \cdot y^{-1}$	1) Total nitrogen concentration of irrigation water is 1.3 ($mg \cdot L^{-1}$). 2) Therefore, nitrogen content of irrigation water ($t \cdot y^{-1}$) = Quantity of irrigation water ($t \cdot y^{-1}$) * Nitrogen concentration of irrigation water ($mg \cdot L^{-1}$)/1000000 = 2766140 ($t \cdot y^{-1}$) * 1.3 ($mg \cdot L^{-1}$)/1000000 ≒ 3.6 ($t \cdot y^{-1}$)	Tabuchi T. et al. (1998) : Science for clean water, The Japanese Society of irrigation, Drainage and Rural Engineering
(Input) Photothinthesis	W	7.95	$t \cdot ha^{-1} \cdot y^{-1}$	6,300	$t \cdot y^{-1}$	1) Carbon is taken from the air as carbon dioxide as shown in following formula of photothinthesis; 6CO2 + 12H2O → C6H12O6 + 6H2O + 6O2 2) Therefore, photothinthesis rate ($t \cdot y^{-1}$) = 44/12 * Carbon rate taken by photothinthesis ($t \cdot y^{-1}$) = 44/12 * 1730 ($t \cdot y^{-1}$) ≒ 6300 ($t \cdot y^{-1}$)	1) Calculated by carbon content of harvest (Unhulled rice+Rice straw) 2) Calculation on the basis of the molecular formula of carbon dioxide
	C	7.95		1,700	$t \cdot y^{-1}$	1) Assuming that carbon content taken by photothinthesis is equal to the carbon content of harvest, that is, total carbon content of unhulled rice and rice straw. 2) Total carbon content of unhulled rice and rice straw is 7.95 ($t \cdot ha^{-1} \cdot y^{-1}$). 3) Therefore, carbon content taken by photothinthesis ($t \cdot y^{-1}$) = 7.95 ($t \cdot ha^{-1} \cdot y^{-1}$) * Area (ha) = 7.95 ($t \cdot ha^{-1} \cdot y^{-1}$) * 217.6 (ha) ≒ 1730 ($t \cdot y^{-1}$) ≒ 1700 ($t \cdot y^{-1}$)	1) Field survey at test field (December 2011-March 2012)
	N	0		0	$t \cdot y^{-1}$	Nitrogen is not provided by photothinthesis.	—
(Input) Nitrogen fixation	W	0.0445	$t \cdot ha^{-1} \cdot y^{-1}$	10	$t \cdot y^{-1}$	Weight is as same as nitrogen.	—
	C	0		0	$t \cdot y^{-1}$	Carbon is not provided by nitrogen fixation.	—
	N	0.0445		10	$t \cdot y^{-1}$	1) Nitrogen fixation rate ($t \cdot ha^{-1}$) = 0.0445 ($t \cdot ha^{-1} \cdot y^{-1}$). 2) Nitrogen fixation rate ($t \cdot y^{-1}$) = Nitrogen fixation rate ($t \cdot ha^{-1} \cdot y^{-1}$) * Area (ha) = 0.0445 ($t \cdot ha^{-1} \cdot y^{-1}$) * 217.6 (ha) ≒ 10 ($t \cdot y^{-1}$)	Giau Tran Quang (2012) : Effects of rotational crops and water management on balance of N, P and K and characteristics of acidic alluvium soil, Doctoral dissertation in Can Tho university, Vietnam
(Output) Amount of evapo-transpiration	W	150	$mm \cdot month^{-1}$	3,600,000	$t \cdot y^{-1}$	1) Average of evaporation rate at Ho Chi Minh city is 150 $mm \cdot month^{-1}$, and the relationship between evapotranspiration and pan evaporation can be written as E = 0.93 * Pan evaporation. 2) Therefore, evapotranspiration rate ($t \cdot y^{-1}$) = Average of evaporation rate ($mm \cdot month^{-1}$) * 12 (month) * 0.93 * Area (ha) * 10 = 150 ($mm \cdot month^{-1}$) * 12 (month) * 0.93 * 217.6 (ha) * 10 ≒ 3600000 ($t \cdot y^{-1}$)	1) Hieu, T. V. (2011) : Assessment of status of rain water source in Ho Chi Minh City and proposal of its management. Report of DOST-HCMC project. 2) Yoshida S. (1978) : A simple evapotranspiration model of a paddy field in tropical Asia, Soil Sci. Plant Nutr., 25 (1), 81-91
(Output) Drainage	W	—	—	2,100,000	$t \cdot y^{-1}$	1) Assuming that, quantity of drainage water ($t \cdot ha^{-1} \cdot y^{-1}$) = (Quantity of irrigation water + Precipitation rate) - (Evapotranspiration rate + Percolation rate) 2) Therefore, quantity of drainage water ($t \cdot y^{-1}$) = (2766140 ($t \cdot y^{-1}$) + 4094797 ($t \cdot y^{-1}$)) - (3642624 ($t \cdot y^{-1}$) + 1098880 ($t \cdot y^{-1}$)) ≒ 2119424 ($t \cdot y^{-1}$) ≒ 2100000 ($t \cdot y^{-1}$)	Calculation

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
	C	8	mg·L^{-1}	17	t·y^{-1}	1) Total carbon concentration of drainage water is 8.0 (mg·L^{-1}). 2) Therefore, carbon content of drainage water (t·y^{-1}) = Quantity of drainage water (t·y^{-1}) * Total carbon concentration of drainage water (mg·L^{-1})/1000000 = 2119424 (t·y^{-1}) * 8.0 (mg·L^{-1})/1000000 ≒ 17 (t·y^{-1})	Assuming that carbon concentration of drainage water is 2 time larger as irrigation water
	N	2.6	mg·L^{-1}	5.5	t·y^{-1}	1) Nitrogen concentration of drainage water is 2.6 (mg·L^{-1}). 2) Therefore, nitrogen content of drainage water (t·y^{-1}) = Quantity of drainage water (t·y^{-1}) * Total nitrogen concentration of drainage water (mg·L^{-1})/1000000 = 2119424 (t·y^{-1}) * 2.6 (mg·L^{-1})/1000000 ≒ 5.5 (t·y^{-1})	Assuming that nitrogen concentration of drainage water is 2 time larger as irrigation water
(Output) Denitrification	W	30		16	t·y^{-1}	1) Denitrification rate is 30 % of nitrogen fertilization rate. 2) Therefore, denitrification rate (t·y^{-1}) = Nitrogen content of fertilizer (kg·ha^{-1}·crop^{-1}) * Cropping area in a year (ha·y^{-1}) * 0.3/1000 = 100 (kg·ha^{-1}·crop^{-1}) * 544 (ha·y^{-1}) * 0.3/1000 ≒ 16 (t·y^{-1})	Kyuma K. (2004) : Paddy soil science., Kyoto University Press. P.151
	C	0	%	0	t·y^{-1}	Carbon is not lost by denitrification.	—
	N	30		16	t·y^{-1}	1) Denitrification rate is 30 % of nitrogen fertilization rate. 2) Therefore, denitrification rate (t·y^{-1}) = Nitrogen content of fertilizer (kg·ha^{-1}·crop^{-1}) * Cropping area in a year (ha·y^{-1}) * 0.3/1000 = 100 (kg·ha^{-1}·crop^{-1}) * 544 (ha·y^{-1}) * 0.3/1000 ≒ 16 (t·y^{-1})	Kazutake Kyuma (2004) : Paddy soil science., Kyoto University Press. P.152
(Output) Ammonia volatilization	W	—		0.92	t·y^{-1}	Weight is as same as ammonia vitalization rate.	—
	C	0		0	t·y^{-1}	Carbon is not lost by ammonia volatilization.	—
	N	1.7	kg·ha^{-1}·crop^{-1}	0.92	t·y^{-1}	1) Ammonia volatilization rate (Nitrogen loss by ammonia volatilization) is 1.7 % of nitrogen fertilization rate per crop at paddy field with the pH range between 3.4 and 6.2. 2) Therefore, nitrogen loss by ammonia volatilization (t·y^{-1}) = Nitrogen content of fertilizer (kg·ha^{-1}·crop^{-1}) * Cropping area in a year (ha·y^{-1}) * 0.017/1000 = 100 (kg·ha^{-1}·crop^{-1}) * 544 (ha·y^{-1}) * 0.017/1000 ≒ 0.92 (t·y^{-1})	Takeshi Watanabe (2009) : Measurement of ammonia volatilization from flooded paddy fields in Vietnam, Soil science and plant nutrition (2009) 55, 793-799
(Output) Percolation	W	202	mm·ha^{-1}·crop^{-1}	1,100,000	t·y^{-1}	1) Percolation rate is 202 (mm·ha^{-1}·crop^{-1}). 2) Therefore, percolation rate (t·y^{-1}) = Percolation rate (mm·ha^{-1}·crop^{-1}) * 0.01 * Cropping area in a year (ha·y^{-1}) * 1000 = 202 (mm·ha^{-1}·crop^{-1}) * 0.01 * 544 (ha·y^{-1}) * 1000 ≒ 1100000 (t·y^{-1})	Thoai N. L. Q (2012); Balance of water, nitrogen and phosphorus for rice crop at a paddy field in southern Vietnam, Society of Environmental Science, Japan, p.136-137
	C	0	kg·ha^{-1}·crop^{-1}	0	t·y^{-1}	Carbon loss by percolation is assumed to be 0.	—
	N	22.06	kg·ha^{-1}·crop^{-1}	12	t·y^{-1}	1) Total amount of nitrogen loss by surface drainage and nitrate leaching is 47.6kgN·ha^{-1}·crop^{-1}. 2) Nitrogen loss by surface drainage is 25.54 (kg·ha^{-1}). 3) Therefore, loss by nitrate leaching is 22.06 (kg·ha^{-1}). 4) Loss by nitrate leaching (t·y^{-1}) = Nitrate Leaching rate (kg·ha^{-1}) * Cropping area in a year (ha·y^{-1})/1000 = 22.06 (kg·ha^{-1}) * 544 (ha)/1000 ≒ 12 (t·y^{-1})	Giau, Tran Quang (2012) : Effects of rotational crops and water management on balance of N, P and K and characteristics of acidic alluvium soil, Doctoral Dissertation in Can Tho University, Vietnam
(Output) Methane gas release	W	160	kg·ha^{-1}·crop^{-1}	87	t·y^{-1}	1) Methane gas generated at cultivation of rice at paddy field is 160 (kg·ha^{-1}·crop^{-1}). 2) Therefore, methane gas release rate (t·y^{-1}) = Methane gas release (kg·ha^{-1}·crop^{-1}) * Cropping area in a year (ha·y^{-1})/1000 = 160 (kg·ha^{-1}) * 544 (ha·y^{-1})/1000 ≒ 87 (t·y^{-1})	NARO and Naigai Engineering（2010）: Workshop on Development of Design and Evaluation Support Tool for Biomass Town Construction, p. 88
	C	—	—	65	t·y^{-1}	Carbon content in methane gas (t·y^{-1}) = Methane gas release (t·ha^{-1}) * 12/16 = 87 * 12/16 ≒ 65 (t·y^{-1})	Calculation on the basis of the molecular formula of methane
	N	0	kg·ha^{-1}	0	t·y^{-1}	Nitrogen is not lost by methane gas release.	—

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
	W	—	—	3,000	$t \cdot y^{-1}$	Carbon dioxide emission rate ($t \cdot y^{-1}$) = 44/12 * Carbon loss rate in the form of carbon dioxide ($t \cdot y^{-1}$) ≒ 2952 ($t \cdot y^{-1}$) ≒ 3000 ($t \cdot y^{-1}$)	Calculation on the basis of the molecular formula of carbon dioxide
(Output) Carbon dioxide release	C	87	$t \cdot y^{-1}$	805	$t \cdot y^{-1}$	1) Total carbon loss from paddy field is 4000 ($kgC \cdot ha^{-1} \cdot y^{-1}$), that is, 87 ($t \cdot y^{-1}$). 2) Assuming that carbon loss from the paddy field is in the form of methane and carbon dioxide. 3) Therefore, carbon loss in the form of carbon dioxide ($t \cdot y^{-1}$) = Total carbon loss rate ($t \cdot y^{-1}$) - Carbon loss rate in the form of methane ($t \cdot y^{-1}$) = 870 ($t \cdot y^{-1}$) - 65 ($t \cdot y^{-1}$) ≒ 805 ($t \cdot y^{-1}$).	Systemization Sub-team, Bio-recycle Project ed.（2006）：Design and Evaluation of Biomass Use System, p.30-39
	N	0	$t \cdot y^{-1}$	0	$t \cdot y^{-1}$	Nitrogen is not lost by carbon dioxide emission	—
	W	0.6161	—	1,341	$t \cdot y^{-1}$	1) Average yield of unhulled rice is 4 ($t \cdot ha^{-1} \cdot crop^{-1}$) with the water content of 15 %. 2) Generation rate of polished rice (normal) to yield of unhulled rice is 0.6161 with the water content is 15 %. 3) Therefore, the amount of polished rice (normal) with the water content of 15 % ($t \cdot y^{-1}$) = Yield of unhulled rice with the water content is 15 % ($t \cdot ha^{-1} \cdot crop^{-1}$) * Cropping area in a year ($ha \cdot y^{-1}$) * Generation rate = 4 ($t \cdot ha^{-1} \cdot crop^{-1}$) * 544 ($ha \cdot y^{-1}$) * 0.6161 ≒ 1341 ($t \cdot y^{-1}$)	1) Field survey at test field (from December 2011 to March 2012, from May to August 2012) 2) Interview to VPC and villagers
(Output) Yield of polished rice (normal)	C	35.2	%	401	$t \cdot y^{-1}$	1) Carbon concentration of polished rice with dry condition is about 35.2 (%). 2) Therefore, carbon content of polished rice (normal) = The amount of polished rice (normal) with the water content of 15 % ($t \cdot y^{-1}$) * (1-water content (%)) * Carbon concentration of polished rice with dried condition (%) = 1341 ($t \cdot y^{-1}$) * (1-15/100) * 35.2/100 ≒ 401 ($t \cdot y^{-1}$)	NARO and Naigai Engineering（2010）：Workshop on Development of Design and Evaluation Support Tool for Biomass Town Construction, p.137
	N	1.18	%	13	$t \cdot y^{-1}$	1) Nitrogen concentration of polished rice under dry condition is 1.18 (%). 2) Therefore, nitrogen content of polished rice (normal) = The amount of polished rice (normal) with the water content of 15 % ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration of polished rice (normal) under dry condition (%) = 1341 ($t \cdot y^{-1}$) * (1-15/100) * 1.18/100 ≒ 13 ($t \cdot y^{-1}$)	Nakamura M. et al.（2005）：Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.68
	W	0.0967	—	210	$t \cdot y^{-1}$	1) Generation rate of polished rice (broken) to yield of unhulled rice is 0.0967 with the water content of 15 %. 2) Therefore, the amount of polished rice (broken) with the water content of 15 % ($t \cdot y^{-1}$) = Yield ($t \cdot ha^{-1} \cdot crop^{-1}$) * Cropping area in a year ($ha \cdot y^{-1}$) * Generation rate = 4 ($t \cdot ha^{-1} \cdot crop^{-1}$) * 544 ($ha \cdot y^{-1}$) * 0.0967 ≒ 210 ($t \cdot y^{-1}$)	Field survey at test field (from December 2011 to March 2012, from May to August 2012)
(Output) Yield of polished rice (broken)	C	35.2	%	63	$t \cdot y^{-1}$	1) Carbon concentration of polished rice under dry condition is 35.2 (%). 2) Therefore, carbon content of polished rice (broken) = The amount of polished rice (broken) with the water content of 15 % ($t \cdot y^{-1}$) * (1-water content (%)) * Carbon concentration of polished rice (broken) under dry condition (%) = 210 ($t \cdot y^{-1}$) * (1-15/100) * 35.2/100 ≒ 63 ($t \cdot y^{-1}$)	NARO and Naigai Engineering（2010）：Workshop on Development of Design and Evaluation Support Tool for Biomass Town Construction
	N	1.18	%	2.1	$t \cdot y^{-1}$	1) Nitrogen concentration of polished rice under dry condition is 1.18 (%). 2) Therefore, Nitrogen content of polished rice (broken) = The amount of polished rice (broken) ($t \cdot y^{-1}$) with the water content of 15 % * (1-water content (%)) * Nitrogen concentration of polished rice (broken) under dry condition (%) = 210 ($t \cdot y^{-1}$) * (1-15/100) * 1.18/100 ≒ 2.1 ($t \cdot y^{-1}$)	Nakamura M. et al.（2005）：Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.68

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
(Output) Yield of rice husk	W	0.1995	—	434	$t \cdot y^{-1}$	1) Generation rate of rice husk to yield of unhulled rice is 0.1995 with the water content of 15 %. 2) Therefore, the amount of rice husk with the water content of 15 % ($t \cdot y^{-1}$) = Yield ($t \cdot ha^{-1} \cdot crop^{-1}$) * Cropping area in a year ($ha \cdot y^{-1}$) * Ggeneration rate = 4 ($t \cdot ha^{-1} \cdot crop^{-1}$) * 544 ($ha \cdot y^{-1}$) * 0.1995 ≒ 434 ($t \cdot y^{-1}$)	Field survey at test field (from December 2011 to March 2012, from May to August 2012)
	C	34.6	%	128	$t \cdot y^{-1}$	1) Carbon concentration of rice husk under dry condition is 34.6 (%). 2) Therefore, carbon content of rice husk ($t \cdot y^{-1}$) = The amount of rice husk with the water content of 15 % ($t \cdot y^{-1}$) * (1-water content (%)) * Carbon concentration of rice husk with dried condition (%) = 434 ($t \cdot y^{-1}$) * (1-15/100) * 34.6/100 ≒ 128 ($t \cdot y^{-1}$)	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.69
	N	0.32	%	1.2	$t \cdot y^{-1}$	1) Nitrogen concentration of rice husk is 0.32 (%). 2) Therefore, nitrogen content of rice husk ($t \cdot y^{-1}$) = The amount of rice husk with the water content of 15 % ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration of rice husk with dried condition (%) = 434 ($t \cdot y^{-1}$) * (1-15/100) * 0.32/100 ≒ 1.2 ($t \cdot y^{-1}$)	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.69
(Output) Yield of rice bran	W	0.0877	—	191	$t \cdot y^{-1}$	1) Generation rate of rice bran to yield of unhulled rice with the water content of 15 % is 0.0877. 2) Therefore, the amount of rice bran with the water content of 15 % ($t \cdot y^{-1}$) = Yield with the water content of 15 % ($t \cdot ha^{-1} \cdot crop^{-1}$) * Cropping area in a year ($ha \cdot y^{-1}$) * Generation rate = 4 ($t \cdot ha^{-1} \cdot crop^{-1}$) * 544 ($ha \cdot y^{-1}$) * 0.0877 ≒ 191 ($t \cdot y^{-1}$)	Field survey at test field (from December 2011 to March 2012, from May to August 2012)
	C	40.2	%	65	$t \cdot y^{-1}$	1) Carbon concentration of rice bran under dry condition is 40.2 (%). 2) Therefore, carbon content of rice bran = The amount of rice bran with the water content of 15 % ($t \cdot y^{-1}$) * (1-water content (%)) * Carbon concentration of rice bran with dried condition (%) = 191 ($t \cdot y^{-1}$) * (1-15/100) * 40.2/100 ≒ 65 ($t \cdot y^{-1}$)	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.69
	N	1.18	%	1.9	$t \cdot y^{-1}$	1) Nitrogen concentration of rice bran under dry condition is 1.18 (%). 2) Therefore, nitrogen content of rice bran = The amount of rice bran with the water content of 15 % ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration of rice bran with dried condition (%) = 191 ($t \cdot y^{-1}$) * (1-15/100) * 1.18/100 ≒ 1.9 ($t \cdot y^{-1}$)	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.69
(Output) Yield of rice straw (taken out)	W	1.1154	—	2,427	$t \cdot y^{-1}$	1) Generation rate of rice straw (taken out) to yield of unhulled rice is 1.1154. 2) Therefore, the amount of rice straw (taken out) ($t \cdot y^{-1}$) = Yield ($t \cdot ha^{-1} \cdot crop^{-1}$) * Cropping area in a year ($ha \cdot y^{-1}$) * Generation rate = 4 ($t \cdot ha^{-1} \cdot crop^{-1}$) * 544 ($ha \cdot y^{-1}$) * 1.1154 ≒ 2427 ($t \cdot y^{-1}$)	Field survey at test field (from December 2011 to March 2012, from May to August 2012)
	C	37	%	764	$t \cdot y^{-1}$	1) Carbon concentration of rice straw under dry condition is 37 (%). 2) Therefore, carbon content of rice straw (taken out) = The amount of rice straw (taken out) with the water content of 15 % ($t \cdot y^{-1}$) * (1-water content (%)) * Carbon concentration of rice straw under dry condition (%) = 2427 ($t \cdot y^{-1}$) * (1-15/100) * 37/100 ≒ 764 ($t \cdot y^{-1}$)	Field survey at test field (from December 2011 to March 2012, from May to August 2012)

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
	N	0.66	%	14	$t \cdot y^{-1}$	1) Nitrogen concentration of rice straw under dry condition is 0.66 (%). 2) Therefore, nitrogen content of rice straw = The amount of rice straw (removed) ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration of rice straw under dry condition (%) = 2427 ($t \cdot y^{-1}$) * (1-15/100) * 0.66/100 ≒ 14 ($t \cdot y^{-1}$)	Field survey at test field (from December 2011 to March 2012, from May to August 2012)
(Output) Yield of rice straw (remained at field)	W	0.2676	—	582	$t \cdot y^{-1}$	1) Generation rate of rice straw (remained at field) to yield of unhulled rice is 0.2676. 2) Therefore, the amount of rice straw (remained at field) ($t \cdot y^{-1}$) = Yield ($t \cdot ha^{-1} \cdot crop^{-1}$) * Cropping area in a year ($ha \cdot y^{-1}$) * Ggeneration rate = 4 ($t \cdot ha^{-1} \cdot crop^{-1}$) * 544 ($ha \cdot y^{-1}$) * 0.2676 ≒ 582 ($t \cdot y^{-1}$)	Field survey at test field (from December 2011 to March 2012, from May to August 2012)
	C	37	%	183	$t \cdot y^{-1}$	1) Carbon concentration of rice straw under dry condition is 37 (%). 2) Therefore, carbon content of rice straw (remained at field) = The amount of rice straw (remained at field) ($t \cdot y^{-1}$) * (1-water content (%)) * Carbon concentration of rice straw under dry condition (%) = 582 ($t \cdot y^{-1}$) * (1-15/100) * 37/100 ≒ 183 ($t \cdot y^{-1}$)	Field survey at test field (from December 2011 to March 2012, from May to August 2012)
	N	0.66	%	3.3	$t \cdot y^{-1}$	1) Nitrogen concentration of rice straw under dry condition is 0.66 (%). 2) Therefore, nitrogen content of rice straw = The amount of rice straw (residue) ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration of rice straw under dry condition (%) = 582 ($t \cdot y^{-1}$) * (1-15/100) * 0.66/100 ≒ 3.3 ($t \cdot y^{-1}$)	Field survey at test field (from December 2011 to March 2012, from May to August 2012)

Appendix B　Bases of data used for regional diagnosis (non-paddy field compartment)

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
Total area	—	—	—	421	ha	—	Interview to VPC, DARD
Corn cultivation area	—	—	—	200	ha	—	Interview to VPC, DARD
(Input) Application of chemical fertilizer for corn	W	3500	kg･ha^{-1}	700	t･y^{-1}	Chemical fertilization rate is 10 times of nitrogen fertilization rate.	—
	C	0	kg･ha^{-1}	0	t･y^{-1}	Carbon is not contained in chemical fertilizer.	—
	N	350	kg･ha^{-1}	70	t･y^{-1}	1) Fertilization standard on corn in Okinawa prefecture is referred here because standard about corn in Vietnam is not clear. 2) The fertilization rate is as follows; fertilization by chemical fertilizer is "N : P_2O_5 : K_2O = 35 : 19 : 20 (Unit: kg･10a^{-1})" and fertilization by compost is 2500 kg･10a^{-1}. 3) Nitrogen fertilization rate by chemical fertilizer (t･y^{-1}) = 350 (kg･ha^{-1}) * 200 (ha)/1000 ≒ 70 (t･y^{-1})	Guideline for vegetable cultivation in Okinawa prefecture (2006) : Department of Agriculture, Forestry and Fisheries, Okinawa prefecture, p.7
(Input) Application of compost for corn	W	25	t･ha^{-1}	5,000	t･y^{-1}	1) Fertilization standard on corn in Okinawa prefecture is referred here because standard on corn in Vietnam is not clear. 2) The fertilization rate is as follows, fertilization of chemical fertilizer is "N : P_2O_5 : K_2O = 35 : 19 : 20 (Unit: kg･10a^{-1})" and fertilization by compost is 2500 kg･10a^{-1}. 3) Therefore, the application rate of compost (t･y^{-1}) = Fertilization rate by compost (t･ha^{-1}) * Area (ha) = 25 (t･ha^{-1}) * 200 ≒ 5000 (t･y^{-1}) * In case using digested slurry as fertilizer, the application rate of compost would be decreased.	1) Guideline for vegetable cultivation in Okinawa prefecture (2006) : Department of Agriculture, Forestry and Fisheries, Okinawa prefecture, p.7 2) Systemization Sub-team, Bio-recycle Project ed.（2006）：Design and Evaluation of Biomass Use System, p.31
	C	18.36	%	918	t･y^{-1}	1) Carbon concentration in dry compost is 18.36 (%). 2) Therefore, application rate (t･y^{-1}) = Application rate (t･y^{-1}) * Carbon concentration of compost (%) = 5000 (t･y^{-1}) * 18.36/100 ≒ 918 (t･y^{-1}) * In case using digested slurry as fertilizer, the application rate of compost would be decreased.	http://kin-taihi.jp/product.html
	N	1.02	%	51	t･y^{-1}	1) Nitrogen concentration in dry compost is 1.02 (%). 2) Therefore, application rate of nitrogen by compost (t･y^{-1}) = Application rate of compost (t･y^{-1}) * Nitrogen concentration of compost (%) = 5000 (t･y^{-1}) * 1.02/100 ≒ 51 (t･y^{-1}) * In case using digested slurry as fertilizer, the application rate of compost would be decreased.	http://kin-taihi.jp/product.html
Vegetable cultivation area	—	—	—	75	ha	—	—
(Input) Application of chemical fertilizer for vegetable (in case of sugar cane)	W	2560	kg･ha^{-1}	192	t･y^{-1}	Chemical fertilization rate is 10 times of nitrogen fertilization rate.	—
	C	0	kg･ha^{-1}	0	t･y^{-1}	Carbon is not contained in chemical fertilizer.	—
	N	256	kg･ha^{-1}	19.2	t･y^{-1}	1) Vegetable variety cultivated at Thai My village is not clear because vegetable variety is decided according to the price year by year. 2) Sugar cane is one of the main vegetable cultivated in Vietnam and also in Thai My village, therefore, assuming in case sugar cane is the main here. 3) Fertilization standard about sugar cane in Okinawa prefecture is referred here because standard about sugar cane in Vietnam is not clear. 4) The fertilization rate is as follows, fertilization by chemical fertilizer is "N : P_2O_5 : K_2O = 25.6 : 23.2 : 10.9 (Unit: kg･10a^{-1}) in average". 5) Therefore, Nitrogen fertilization rate by chemical fertilizer (t･y^{-1}) = 25.6 (kg･10a^{-1}) * 10 * Area (ha)/1000 ≒ 19.2 (t･y^{-1})	1) Interview to VPC and Villager 2) Statistical year book 2011（2011）：General statistical office in Vietnam, 322-324 3) Guideline for sugar cane cultivation（2006）：Department of Agriculture, Forestry and Fisheries, Okinawa prefecture
Fruit cultivation area	—	—	—	146	ha	—	—

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
(Input) Application of chemical fertilizer for fruit (in case of mango)	W	4000	$kg \cdot ha^{-1}$	584	$t \cdot y^{-1}$	1) Fruits variety cultivated at Thai My village is not clear because that is decided according to the price year by year. 2) Mango is one of the main fruits cultivated in Vietnam and also in Thai My village, therefore, assuming in case mango is the main here. 3) Fertilization standard about mango (five years after starting cultivation) in Okinawa prefecture is referred here because standard on mango in Vietnam is not clear. 4) The fertilization rate is as follows, fertilization by chemical fertilizer is total fertilization rate in a year is 400 ($kg \cdot 10a^{-1}$), and nitrogen fertilization rate is 20 ($kg \cdot 10a^{-1}$) in a year. 5) Therefore, chemical fertilization rate ($t \cdot y^{-1}$) = Fertilization rate ($kg \cdot ha^{-1}$) * 10 * Area (ha)/1000 = 4000 ($kg \cdot ha^{-1}$) * 146 (ha)/1000 ≒ 584 ($t \cdot y^{-1}$)	1) Interview to VPC and Villager 2) Statistical year book 2011（2011）:General statistical office in Vietnam, 372-374 3) Guideline for fruits cultivation,（2003）: Department of Agriculture, Forestry and Fisheries, Okinawa prefecture, p.10
	C	0	$kg \cdot ha^{-1}$	0	$t \cdot y^{-1}$	Carbon is not contained in chemical fertilizer.	—
	N	200	$kg \cdot ha^{-1}$	29	$t \cdot y^{-1}$	1) Fruits variety cultivated at Thai My village is not clear because that is decided according to the price year by year. 2) Mango is one of the main fruits cultivated in Vietnam and also in Thai My village, therefore, assuming in case mango is the main here. 3) Fertilization standard about mango (five years after starting cultivation) in Okinawa prefecture is referred here because standard about mango in Vietnam is not clear. 4) The fertilization rate is as follows, fertilization by chemical fertilizer is Total fertilization rate in a year is 400 ($kg \cdot 10a^{-1}$), and nitrogen fertilization rate is 20 ($kg \cdot 10a^{-1}$) in a year. 5) Therefore, nitrogen fertilization rate of chemical fertilizer ($t \cdot y^{-1}$) = Nitrogen fertilization rate ($kg \cdot ha^{-1}$) * Area (ha)/1000 = 200 ($kg \cdot ha^{-1}$) * 146 (ha)/1000 ≒ 29 ($t \cdot y^{-1}$)	1) Interview to VPC and Villager 2) Statistical year book 2011（2011）:General statistical office in Vietnam, 372-374 3) Guideline for fruits cultivation,（2003）: Department of Agriculture, Forestry and Fisheries, Okinawa prefecture, p.10
(Output) Yield of corn	W	7.5	$t \cdot ha^{-1}$	1,500	$t \cdot y^{-1}$	1) Yield of corn per crop is 6-9 $t \cdot ha^{-1}$. Therefore, average is 7.5 ($t \cdot ha^{-1}$), and the water content in this condition is supposed to be 39.2 (%). 2) Therefore, yield with the water content of 39.2 (%) ($t \cdot y^{-1}$) = yield ($t \cdot ha^{-1}$) * Area (ha) = 7.5 ($t \cdot ha^{-1}$) * 200 (ha) ≒ 1500 ($t \cdot y^{-1}$)	1) Interview to VPC and Villager 2) Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.70
	C	43.8	%	399	$t \cdot y^{-1}$	1) Carbon concentration of corn under dry condition is 43.8%. 2) Therefore, carbon content with the water content of 39.2% ($t \cdot y^{-1}$) = Yield the water content of 39.2% ($t \cdot y^{-1}$) * (1-water content (%)) * Carbon concentration under dry condition (%) = 1500 ($t \cdot y^{-1}$) * (1-39.2/100) * 43.8/100 ≒ 399 ($t \cdot y^{-1}$)	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.70
	N	2.12	%	19	$t \cdot y^{-1}$	1) Nitrogen concentration under dry condition is 2.12%. 2) Therefore, nitrogen content with the water content of 39.2% ($t \cdot y^{-1}$) = Yield of corn with the water content is 39.2% ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration under dry condition (%) = 1500 ($t \cdot y^{-1}$) * (1-39.2/100) * 2.12/100 ≒19 ($t \cdot y^{-1}$)	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.70
(Output) Yield of sugar cane	W	62.95	$t \cdot ha^{-1}$	4,700	$t \cdot y^{-1}$	1) Yield of sugar cane in Ho Chi Minh city is 132200 (t) in case the cultivation area is 2100 (ha), and the water content in this condition is supposed to be 9.8 (%). 2) Therefore, calculating as 133200 (t)/2100 (ha) = 62.95 ($t \cdot ha^{-1}$). 3) Yield of sugar cane with the water content is 9.8 % ($t \cdot y^{-1}$) = Yield ($t \cdot ha^{-1}$) * Area (ha) = 62.95 ($t \cdot ha^{-1}$) * 75 (ha) ≒ 4721 ($t \cdot y^{-1}$) ≒ 4700 ($t \cdot y^{-1}$)	1) Statistical year book 2011（2011）:General statistical office in Vietnam, p.366-367 2) Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.70

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
	C	42.5	%	1,800	t･y^{-1}	1) Carbon concentration under dry condition is 42.5 %. 2) Therefore, carbon content with the water content of 9.8 % (t･y^{-1}) = Yield of sugar cane (t･y^{-1}) * (1-water content (%)) * Carbon concentration under dry condition (%) = 4721 (t･y^{-1}) * (1-9.8/100) * 42.5/100 ≒ 1810 (t･y^{-1}) ≒ 1800 (t･y^{-1})	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.70
	N	0.8	%	34	t･y^{-1}	1) Nitrogen concentration of sugar cane under dry condition is 0.8 %. 2) Therefore, nitrogen content of sugar cane with the water content of 9.8 % (t･y^{-1}) = Yield of sugar cane (t･y^{-1}) * (1-water content (%)) * Nitrogen concentration of sugar cane (%) = 4721 (t･y^{-1}) * (1-9.8/100) * 0.8/100 ≒ 34 (t･y^{-1})	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.70
(Output) Yield of mango	W	0.824	t･ha^{-1}	120	t･y^{-1}	1) Yield of mango in Vietnam is 71200 (t) in case the cultivation area is 86400 (ha). 2) Therefore, calculating as 71200 (t)/86400 (ha) = 0.824 (t･ha^{-1}). 3) Yield (t･y^{-1}) = Yield (t･ha^{-1}) * Area (ha) = 0.824 (t･ha^{-1}) * 146 (ha) ≒ 120.3 ≒ 120 (t･y^{-1}), and the water content is supposed to be 82 %.	1) Statistical year book 2011（2011）:General statistical office in Vietnam. 372-373 2) Kagawa Y. ed (2003) : Food component table, Kagawa Education Institute of Nutrition Press, p.118
	C	40	%	8.7	t･y^{-1}	1) Assuming that carbon concentration is 40 %, because carbon concentration of other plants under dry condition is about 40 %. 2) Therefore, carbon content (t･y^{-1}) = Yield of mango with the water content of 82 % (t･y^{-1}) * (1-water content (%)) * Carbon concentration of mango (%) = 120.3 (t･y^{-1}) * (1-82/100) * 40/100 ≒ 8.7 (t･y^{-1})	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.69-70
	N	0.096	%	0.02	t･y^{-1}	1) Nitrogen concentration of mango under dry condition is 0.096 %. 2) Therefore, nitrogen content of mango with the water content of 82 % (t･y^{-1}) = Yield of mango (t･y^{-1}) * (1-water content (%)) * Nitrogen concentration of mango (%) = 120.3 (t･y^{-1}) * (1-82/100) * 0.096/100 (%) ≒ 0.02 (t･y^{-1})	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.68
(Input) Precipitation	W	1881.8	mm･y^{-1}	7,900,000	t･y^{-1}	1) Mean annual precipitation is 1881.8 (mm･y^{-1}). 2) Therefore, input from precipitation (t･y^{-1}) = Mean annual precipitation (mm･y^{-1}) * Area (ha) * 10 = 1881.8 (mm･y^{-1}) * 421 (ha) * 10 ≒ 7922378 (t･y^{-1}) ≒ 7900000 (t･y^{-1})	Global Meteorological information CD edited by Japan meteorological business support center
	C	1.9	mg･L^{-1}	15	t･y^{-1}	1) Total carbon concentration of precipitation is 1.9 (mg･L^{-1}). 2) Therefore, input from precipitation (t･y^{-1}) = Total carbon concentration of precipitation (mg･L^{-1}) * Precipitation rate (t･y^{-1})/1000000 = 1.9 (mg･L^{-1}) * 7922378 (t･ha^{-1})/1000000 ≒ 15 (t･y^{-1})	1) Tabuchi T. and Takamura y. (1985) : Discharge of nitrogen and phosphorus from watetershed, p.19, University of Tokyo Press. 2) Hanya T. and Ogura N. (1985) : Water quality investigation method, p. 58, Maruzen.
	N	1.1	mg･L^{-1}	8.7	t･y^{-1}	1) Total nitrogen concentration of precipitation is 1.1 (mg･L^{-1}). 2) Therefore, input from precipitation (t･y^{-1}) = Total nitrogen concentration of precipitation (mg･L^{-1}) * Precipitation rate (t･y^{-1})/1000000 = 1.1 (mg･L^{-1}) * 7922378 (t･ha^{-1})/1000000 ≒ 8.7 (t･y^{-1})	1) Tabuchi T. and Takamura y. (1985) : Discharge of nitrogen and phosphorus from watetershed, p.19, University of Tokyo Press. 2) Hanya T. and Ogura N. (1985) : Water quality investigation method, p. 58 , Maruzen.

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
(Input) Photothinthesis	W	—	—	8,100	$t \cdot y^{-1}$	1) Carbon is provided from the air as carbon dioxide by following formula of photothinthesis; $6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$ 2) Therefore, photothinthesis rate ($t \cdot y^{-1}$) = 44/12 * Carbon rate taken by photothinthesis ($t \cdot y^{-1}$) ≒ 8133 ($t \cdot y^{-1}$) ≒ 8100 ($t \cdot y^{-1}$)	Calculation on the basis of the molecular formula of carbon dioxide
	C	2218	$t \cdot y^{-1}$	2,200	$t \cdot y^{-1}$	Assuming that carbon content provided by photothinthesis is equal to the carbon content of harvest Therefore, 2218 ($t \cdot y^{-1}$) ≒ 2200 ($t \cdot y^{-1}$)	1) Interview to VPC and Villager 2) Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, p.68-70 3) Statistical year book 2011（2011）:General statistical office in Vietnam, p.366-367, 372-373 4) Kagawa Y. ed (2003) : Food component table, Kagawa Education Institute of Nutrition Press, p.118
	N	0	$t \cdot y^{-1}$	0	$t \cdot y^{-1}$	Nitrogen is not provided by photothinthesis.	—
(Input) Nitrogen fixation	W	—	—	44	$t \cdot y^{-1}$	Weight is as same as nitrogen fixation rate.	Systemization Sub-team, Bio-recycle Project ed.（2006）:Design and Evaluation of Biomass Use System, p.30-39
	C	0	$t \cdot y^{-1}$	0	$t \cdot y^{-1}$	Carbon is not provided by nitrogen fixation.	—
	N	—	—	44	$t \cdot y^{-1}$	1) Nitrogen fixation rate is 10-200 ($kgN \cdot ha^{-1} \cdot y^{-1}$), the average value is 105 ($kgN \cdot ha^{-1} \cdot y^{-1}$). 2) Therefore, nitrogen fixation rate ($t \cdot y^{-1}$) = Nitrogen fixation rate ($kgN \cdot ha^{-1} \cdot y^{-1}$) * Area (ha)/1000 = 105 ($kgN \cdot ha^{-1} \cdot y^{-1}$) * 421 (ha)/1000 ≒ 44 ($t \cdot y^{-1}$)	Systemization Sub-team, Bio-recycle Project ed.（2006）:Design and Evaluation of Biomass Use System,, p.30-39
(Output) Denitrification	W	18	$kg \cdot ha^{-1} \cdot y^{-1}$	7.6	$t \cdot y^{-1}$	Weight is as same as denitrification rate.	Systemization Sub-team, Bio-recycle Project ed.（2006）:Design and Evaluation of Biomass Use System,, p.30-39
	C	0	$t \cdot y^{-1}$	0	$t \cdot y^{-1}$	Carbon is not provided by photothinthesis.	—
	N	18	$kgN \cdot ha^{-1} \cdot y^{-1}$	7.6	$t \cdot y^{-1}$	1) Denitrification rate is 5-30 ($kgN \cdot ha^{-1} \cdot y^{-1}$), the average value is 18 ($kgN \cdot ha^{-1} \cdot y^{-1}$). 2) Therefore, denitrification rate ($t \cdot y^{-1}$) = Denitrification rate ($kgN \cdot ha^{-1} \cdot y^{-1}$) * Area (ha)/1000 = 18 ($kgN \cdot ha^{-1} \cdot y^{-1}$) * 421 (ha)/1000 ≒ 7.6 ($t \cdot y^{-1}$)	Systemization Sub-team, Bio-recycle Project ed.（2006）:Design and Evaluation of Biomass Use System, p.30-39
(Output) Carbon dioxide release	W	—	—	3,900	$t \cdot y^{-1}$	Assuming that carbon loss is in the form of carbon dioxide. Therefore, carbon dioxide emission ($t \cdot y^{-1}$) = 44/12 * Carbon loss ($t \cdot y^{-1}$) ≒ 3859 ($t \cdot y^{-1}$) ≒ 3900 ($t \cdot y^{-1}$)	Calculation on the basis of the molecular formula of carbon dioxide
	C	2500	$kgC \cdot ha^{-1} \cdot crop^{-1}$	1,100	$t \cdot y^{-1}$	1) Carbon loss is 1500-3500 ($kgC \cdot ha^{-1} \cdot y^{-1}$), the average value is 2500 ($kgC \cdot ha^{-1} \cdot y^{-1}$). 2) Therefore, carbon loss ($t \cdot y^{-1}$) = Carbon loss ($kgC \cdot ha^{-1} \cdot y^{-1}$) * Area (ha)/1000 = 2500 ($kgC \cdot ha^{-1} \cdot y^{-1}$) * 421 (ha)/1000 ≒ 1053 ($t \cdot y^{-1}$) ≒ 1100 ($t \cdot y^{-1}$)	Systemization Sub-team, Bio-recycle Project ed.（2006）:Design and Evaluation of Biomass Use System, p.30-39
	N	0	$t \cdot y^{-1}$	0	$t \cdot y^{-1}$	Nitrogen is not lost by carbon dioxide emission.	—

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
(Output) Evapotranspiration	W	—	—	5,500,000	t･y^{-1}	Assuming that 70 % of precipitation is evapotranspiration, Evapotranspiration rate (t･y^{-1}) = 0.7 * Precipitation rate (t･y^{-1}) = 0.7 * 7922378 ≒ 5545665 (t･y^{-1}) ≒ 5500000 (t･y^{-1})	Rough assumption
(Output) Percolation	W	—	—	2,400,000	t･y^{-1}	1) Assuming that percolation rate (t･y^{-1}) = Precipitation rate (t･y^{-1}) + (Application rate of digested slurry (in case using digested slurry because of the water content of digested slurry is more than 98%)) - Evapotranspiration rate (t･y^{-1}) ≒ 2381747 (t･y^{-1}) ≒ 2400000 (t･y^{-1}) (This is the case that 973 (t･y^{-1}) of digested slurry is used)	Rough assumption
	C	0	t･y^{-1}	0	t･y^{-1}	Carbon is not lost by denitrification.	—
	N	134	t･y^{-1}	40	t･y^{-1}	1) Nitrate leaching rate is 30% of nitrogen fertilization rate. 2) Therefore, nitrate leaching rate (t･y^{-1}) = Nitrate fertilization rate (t･y^{-1}) * 0.3 = 134 (t･y^{-1}) * 0.3 ≒ 40 (t･y^{-1})	Systemization Sub-team, Bio-recycle Project ed.（2006）：Design and Evaluation of Biomass Use System, p.30-39

Appendix C Bases of data used for regional diagnosis (livestock wastes compartment)

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
Number of pig	—	—	—	11000	heads		Interview to VPC and Villager
Generation rate of feces (pig)	W	0.73	$t \cdot head^{-1} \cdot y^{-1}$	8,000	$t \cdot y^{-1}$	1) Generation rate is 0.73 ($t \cdot head^{-1} \cdot y^{-1}$). 2) Therefore, raw weight ($t \cdot y^{-1}$) = Generation rate ($t \cdot head^{-1} \cdot y^{-1}$) * The numbers (heads) = 0.73 * 11000 ≒ 8030 ($t \cdot y^{-1}$) ≒ 8000 ($t \cdot y^{-1}$)	Nguyen Thi Hoa Ly, 1994
	C	18.7	%	459	$t \cdot y^{-1}$	1) Carbon concentration under dry condition is 18.7 %, and water content of raw feces is 69.4 %. 2) Therefore, carbon content = Raw weight ($t \cdot y^{-1}$) * (1-water content (%)) * Carbon concentration under dry condition (%) = 8030($t \cdot y^{-1}$) * (1-69.4/100) * 18.7/100 ≒ 459($t \cdot y^{-1}$)	1) Ngo Ke Suong_Nguyen Lan Dung, 1997 2) Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80
	N	0.83	%	20	$t \cdot y^{-1}$	1) Nitrogen concentration under dry condition is 0.83 %, and water content of raw feces is 69.4 %. 2) Therefore, nitrogen content = Raw weight ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration under dry condition (%) = 8030 ($t \cdot y^{-1}$) * (1-69.4/100) * 0.83/100 ≒ 20 ($t \cdot y^{-1}$)	Ngo Ke Suong_Nguyen Lan Dung, 1997 2) Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80
Generation rate of urine (pig)	W	0.49	$t \cdot head^{-1} \cdot y^{-1}$	5,400	$t \cdot y^{-1}$	1) Generation rate is 0.49 ($t \cdot head^{-1} \cdot y^{-1}$). 2) Therefore, raw weight ($t \cdot y^{-1}$) = Generation rate ($t \cdot head^{-1} \cdot y^{-1}$) * The numbers (heads) = 0.49 * 11000 ≒ 5390 ($t \cdot y^{-1}$) ≒ 5400 ($t \cdot y^{-1}$)	Nguyen Thi Hoa Ly, 1994
	C	0	$t \cdot head^{-1} \cdot y^{-1}$	0	$t \cdot y^{-1}$	Carbon is not contained in urine.	—
	N	32.5	%	35	$t \cdot y^{-1}$	1) Nitrogen concentration under dry condition is 32.5 %, and water content of raw urine is 98.0 %. 2) Therefore, nitrogen content = Raw weight ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration under dry condition (%) = 5390 ($t \cdot y^{-1}$) * (1-98.0/100) * 32.5/100 ≒ 35 ($t \cdot y^{-1}$)	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80
Number of beef cow	—	—	—	1,659	heads	—	Interview to VPC and Villager
Generation rate of feces (beef cow)	W	8.22	$t \cdot head^{-1} \cdot y^{-1}$	14,000	$t \cdot y^{-1}$	1) Generation rate is 8.22 ($t \cdot head^{-1} \cdot y^{-1}$). 2) Therefore, raw weight ($t \cdot y^{-1}$) = Generation rate ($t \cdot head^{-1} \cdot y^{-1}$) * The numbers (heads) = 8.22 * 1659 ≒ 13637 ($t \cdot y^{-1}$) ≒ 14000 ($t \cdot y^{-1}$)	Nguyen Thi Hoa Ly, 1994
	C	15.75	%	427	$t \cdot y^{-1}$	1) Carbon concentration under dry condition is 15.75 %, and water content of raw feces is 80.1 %. 2) Therefore, carbon content = Raw weight ($t \cdot y^{-1}$) * (1-water content (%)) * Carbon concentration under dry condition (%) = 13637 ($t \cdot y^{-1}$) * (1-80.1/100) * 15.75/100 ≒ 427 ($t \cdot y^{-1}$)	1) Ngo Ke Suong_Nguyen Lan Dung, 1997 2) Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
	N	0.7	%	19	$t \cdot y^{-1}$	1) Nitrogen concentration under dry condition is 0.70 %, and water content of raw feces is 80.1 %. 2) Therefore, nitrogen content = Raw weight ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration under dry condition (%) = 13637 ($t \cdot y^{-1}$) * (1-80.1/100) * 0.70/100 ≒ 19 ($t \cdot y^{-1}$)	Ngo Ke Suong_Nguyen Lan Dung, 1997 2) Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80
Generation rate of urine (beef cow)	W	4.56	$t \cdot head^{-1} \cdot y^{-1}$	7,600	$t \cdot y^{-1}$	1) Generation rate is 4.56 ($t \cdot head^{-1} \cdot y^{-1}$). 2) Therefore, raw weight ($t \cdot y^{-1}$) = Generation rate ($t \cdot head^{-1} \cdot y^{-1}$) * The numbers (heads) = 4.56 * 1659 ≒ 7565 ($t \cdot y^{-1}$) ≒ 7600 ($t \cdot y^{-1}$)	Nguyen Thi Hoa Ly, 1994
	C	0	$t \cdot head^{-1} \cdot y^{-1}$	0	$t \cdot y^{-1}$	Carbon is not contained in urine.	
	N	27.1	%	14	$t \cdot y^{-1}$	1) Nitrogen concentration under dry condition is 27.1 %, and water content of raw urine is 98.0 %. 2) Therefore, nitrogen content = Raw weight ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration under dry condition (%) = 7565 ($t \cdot y^{-1}$) * (1-99.3/100) * 27.1/100 ≒ 14 ($t \cdot y^{-1}$)	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80
Number of milk cow	—	—	—	61	heads	—	Interview to VPC and Villager
Generation rate of feces (milk cow)	W	8.22	$t \cdot head^{-1} \cdot y^{-1}$	501	$t \cdot y^{-1}$	1) Generation rate is 8.22 ($t \cdot head^{-1} \cdot y^{-1}$). 2) Therefore, raw weight ($t \cdot y^{-1}$) = Generation rate ($t \cdot head^{-1} \cdot y^{-1}$) * The numbers (heads) = 8.22 * 61 ≒ 501 ($t \cdot y^{-1}$)	Nguyen Thi Hoa Ly, 1994
	C	8.55	%	8.5	$t \cdot y^{-1}$	1) Carbon concentration under dry condition is 8.55 %, and water content of raw feces is 80.1 %. 2) Therefore, carbon content = Raw weight ($t \cdot y^{-1}$) * (1-water content (%)) * Carbon concentration under dry condition (%) = 501 ($t \cdot y^{-1}$) * (1-80.1/100) * 8.55/100 ≒ 8.5 ($t \cdot y^{-1}$)	1) Ngo Ke Suong_Nguyen Lan Dung, 1997 2) Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80
	N	0.38	%	0.38	$t \cdot y^{-1}$	1) Nitrogen concentration under dry condition is 0.38 %, and water content of raw feces is 80.1 %. 2) Therefore, nitrogen content = Raw weight ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration under dry condition (%) = 501 ($t \cdot y^{-1}$) * (1-80.1/100) * 0.38/100 ≒ 0.38 ($t \cdot y^{-1}$)	Ngo Ke Suong_Nguyen Lan Dung, 1997 2) Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80
Generation rate of urine (milk cow)	W	4.56	$t \cdot head^{-1} \cdot y^{-1}$	278	$t \cdot y^{-1}$	1) Generation rate is 4.56 ($t \cdot head^{-1} \cdot y^{-1}$). 2) Therefore, raw weight ($t \cdot y^{-1}$) = Generation rate ($t \cdot head^{-1} \cdot y^{-1}$) * The numbers (heads) = 4.56 * 61 ≒ 278 ($t \cdot y^{-1}$)	Nguyen Thi Hoa Ly, 1994
	C	0	$t \cdot head^{-1} \cdot y^{-1}$	0	$t \cdot y^{-1}$	Carbon is not contained in urine.	—
	N	27.1	%	0.53	$t \cdot y^{-1}$	1) Nitrogen concentration under dry condition is 27.1 %, and water content of raw urine is 98.0 %. 2) Therefore, nitrogen content = Raw weight ($t \cdot y^{-1}$) * (1-water content (%)) * Nitrogen concentration under dry condition (%) = 278 ($t \cdot y^{-1}$) * (1-99.3/100) * 27.1/100 ≒ 0.53 ($t \cdot y^{-1}$)	Nakamura M. et al. (2005) : Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80
Number of poultry	—	—	—	8,000	heads	—	Interview to VPC and Villager

Data required	Component	Specific value		Total amount		Process of calculation	Data/information sources
		Value	Unit	Value	Unit		
Generation rate of feces（poultry)	W	0.0435	t･head^{-1}･y^{-1}	348	t･y^{-1}	1) Generation rate is 0.0435 (t･head^{-1}･y^{-1}). 2) Therefore, raw weight (t･y^{-1}) = Generation rate (t･head^{-1}･y^{-1}) * The numbers (heads) = 0.0435 * 8000 = 348 (t･y^{-1})	http://www.naro.affrc.go.jp/nkk/introduction/files/basic_data.pdf
	C	13.2	%	17	t･y^{-1}	1) Carbon concentration under dry condition is 13.2 %, and water content of raw feces is 63.7 %. 2) Therefore, carbon content = Raw weight (t･y^{-1}) * (1-water content (%)) * Carbon concentration under dry condition (%) = 348 (t･y^{-1}) * (1-63.7/100) * 13.2/100 ≒ 17 (t･y^{-1})	http://www.naro.affrc.go.jp/nkk/introduction/files/basic_data.pdf
	N	1.2	%	1.5	t･y^{-1}	1) Nitrogen concentration under dry condition is 1.20 %, and water content of raw feces is 63.7 %. 2) Therefore, nitrogen content = Raw weight (t･y^{-1}) * (1-water content (%)) * Nitrogen concentration under dry condition (%) = 348 (t･y^{-1}) * (1-63.7/100) * 1.20/100 ≒ 1.5 (t･y^{-1})	http://www.naro.affrc.go.jp/nkk/introduction/files/basic_data.pdf
Number of buffalo	—	—	—	400	heads	—	Interview to VPC and Villager
Generation rate of feces (buffalo)	W	8.22	t･head^{-1}･y^{-1}	3,300	t･y^{-1}	1) Generation rate is 8.22 (t･head^{-1}･y^{-1}). 2) Therefore, raw weight (t･y^{-1}) = Generation rate (t･head^{-1}･y^{-1}) * The numbers (heads) = 8.22 * 400 = 3288 (t･y^{-1}) ≒ 3300 (t･y^{-1})	Nguyen Thi Hoa Ly, 1994
	C	6.98	%	46	t･y^{-1}	1) Carbon concentration under dry condition is 6.98 %, and water content of raw feces is 80.1 %. 2) Therefore, carbon content = Raw weight (t･y^{-1}) * (1-water content (%)) * Carbon concentration under dry condition (%) = 3288 (t･y^{-1}) * (1-80.1/100) * 6.98/100 ≒ 46 (t･y^{-1})	1) Ngo Ke Suong_Nguyen Lan Dung, 1997 2) Nakamura M. et al. (2005)： Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80
	N	0.31	%	2.0	t･y^{-1}	1) Nitrogen concentration under dry condition is 0.31 %, and water content of raw feces is 80.1 %. 2) Therefore, nitrogen content = Raw weight (t･y^{-1}) * (1-water content (%)) * Nitrogen concentration und condition (%) = 3288 (t･y^{-1}) * (1-80.1/100) * 0.31/100 ≒ 2.0 (t･y^{-1})	Ngo Ke Suong_Nguyen Lan Dung, 1997 2) Nakamura M. et al. (2005)： Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80
Generation rate of urine (buffalo)	W	4.56	t･head^{-1}･y^{-1}	1,800	t･y^{-1}	1) Generation rate is 4.56 (t･head^{-1}･y^{-1}). 2) Therefore, raw weight (t･y^{-1}) = Generation rate (t･head^{-1}･y^{-1}) * The numbers (heads) = 4.56 * 400 = 1824 (t･y^{-1}) ≒ 1800 (t･y^{-1})	Nguyen Thi Hoa Ly, 1994
	C	0	t･head^{-1}･y^{-1}	0	t･y^{-1}	Carbon is not contained in urine.	—
	N	27.1	%	3.4	t･y^{-1}	1) Nitrogen concentration under dry condition is 27.1 %, and water content of raw urine is 98.0 %. 2) Therefore, nitrogen content = Raw weight (t･y^{-1}) * (1-water content (%)) * Nitrogen concentration under dry condition (%) = 1824 (t･y^{-1}) * (1-99.3/100) * 27.1/100 ≒ 3.4 (t･y^{-1})	Nakamura M. et al. (2005)： Development of a composition database for various types of biomass, technical report of the national institute for rural engineering, 57-80