Designing an Environmentally Friendly Agricultural System: Agriculture and the Environment in Okinoerabu Island, Japan

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Some fact-findings of our "self-contained society" project in three research fields are presented as an introduction. Then, focusing on Okinoerabu Island, Japan, uses of land and water, and agrochemicals as stresses on the environment are examined based on the research at the town office and the surveys of 27 farms in Kunigami community in Wadomari Town. Policies for forming environmentally friendly agriculture at Wadomari Town are explained. Finally, one way of reducing environmental burden in agriculture is proposed and its gains and costs are estimated, followed by concluding remarks.

***Keywords**: Okinoerabu Island, Land and Water, Agrochemicals, Fertilizers, Policies for Environmentally Friendly Agriculture*

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I. Introduction

We have been conducting the research project, “Modeling a Self-contained Community with Social, Ecological and Material Balance in the Rural Environment” since 1997. The key concept is “self-contained society.” We define the self-contained society as society, where environmental burdens and throughput of matter and energy are as less as possible and the ecosystem is healthy. In our research fields, we examine the conditions for obtaining the self-contained society in rural areas. We specified three types of rural region: (1) the major agricultural (livestock) region, (2) the hilly and mountainous area, and (3) small islands. We selected one town or island from each type of region. Therefore, there are three research fields (Table 1).

We will present an outline of these fields and introduce some fact-findings of our project in sequence, and, then, focusing on Okinoerabu Island, assess the economic and ecological impacts of sustainable agriculture.

1.1 The Major Igricultural (Livestock) Region: Shihoro Town, Hokkaido

Livestock and field crop farming in Shihoro is one of the largest scales in Japan. There is also a large food-processing complex. They raise 15,000 dairy cows and 30,000 beef cattle, and produce 100,000 ton of potatoes annually. Animal manure and wastes from field crop make tremendous environmental burdens.

The construction of a biogas plant (anaerobic digestion facility) is under consideration in Shihoro to recycle these wastes. We applied the life cycle assessment analysis to activities in Shihoro for providing quantitative information on the environmental performance of prospective technology (e.g. anaerobic digestion). As a result, the impacts on the global warming could be halved if a part of fossil fuels used in food processing and incineration was replaced with generated biogas, though

Table 1 Overview of Three Research Field (1995)

	Shihoro, Hokkaido	%	Miharu, Fukushima	%	Okinoerabu Island, Kagoshima	%	source
Population	7,010		20,124		15,325		Population Census
Population density (per km^2)	27.1		276.6		163.7		
Area (km^2)	258.52	100.0	72.76	100.0	93.63	100.0	Population Census
Cultivated land (ha)	14,061	54.4	1,148	15.8	3,378	36.1	Census of Agriculture
Employed persons	3,822	100.0	10,505	100.0	7,461	100.0	Population Census
Agriculture	1,678	43.9	1,349	12.8	3,073	41.2	
Primary industry	1,698	44.4	1,351	12.9	3,109	41.7	
Secondary industry	605	15.8	4,109	39.1	1,034	13.9	
Tertiary industry	1,519	39.7	5,035	47.9	3,315	44.4	
Harvested area (ha)	14,073	100.0	870	100.0	3,126	100.0	Census of Agriculture
Rice	0	0.0	460	52.9	1	0.0	
Wheat and barley	2,168	15.4	3	0.3	0	0.0	
Potatoes and sweet potatoes	2,790	19.8	25	2.9	665	21.3	
Pulses	1,415	10.1	21	2.4	16	0.5	
Industrial crops	2,327	16.5	69	7.9	1,313	42.0	
Vegetables	542	3.9	92	10.6	258	8.3	
Flowers	0	0.0	2	0.2	404	12.9	
Feed and forage crops	4,763	33.8	88	10.1	343	11.0	
Gross agricultural output (million dollars)	147.1	100.0	18.1	100.0	75.8	100.0	Statistics of Agricultural Income
Crop cultivation	71.8	48.8	15.9	88.0	67.7	89.3	
Livestock and its products	75.3	51.2	1.9	10.6	8.1	10.7	
Rice	0.0	0.0	6.2	34.1	0.0	0.0	
Potatoes and sweet potatoes	24.8	16.8	0.5	2.8	13.5	17.8	
Vegetables	9.8	6.7	5.8	32.3	14.4	19.0	
Flowering plants	0.5	0.3	0.3	1.4	24.9	32.9	
Industrial crops	18.1	12.3	2.9	16.1	14.3	18.8	
Beef cattle	30.2	20.5	1.1	6.0	7.7	10.0	
Dairy cattle	44.8	30.5	0.8	4.6	0.2	0.2	
Commercial farm households	493	100.0	1,043	100.0	1,930	100.0	Census of Agriculture
Full-time	403	81.7	70	6.7	926	48.0	
Earned main income from farming	76	15.4	97	9.3	506	26.2	
Earned main income from other jobs	14	2.8	876	84.0	598	25.8	

impacts on eutrophication could scarcely be reduced (Oomura *et al*., 2000).

1.2 The Hilly and Mountainous Area: Miharu Town, Fukushima

The hilly and mountainous area is typical of rural area in Japan. Communities in Miharu are located among the hills, satoyama, from which they used to get wood for fuel and fallen leaves for fertilizer. The proportion of part time farmers to whole farmers is high. The land resources, such as croplands and forests, are not properly managed and abandoned/unplanted land is increasing. Major crops are rice, tobacco, and green peppers.

We think that use of forest products as energy sources and energy crop farming in abandoned/unused farmland and woodland can reduce the energy inflow from outside the region and the corresponding environmental emissions. We are examining material, environmental and economic feasibility of the system, which has energy crop cultivation in abandoned land and the combined heat and power plant as its components.

1.3 Small Island: Okinoerabu Island, Kagoshima

An island is a definite area, surrounded by sea, which implies its self-containedness has been or is supposed to be high. Agriculture, especially flower growing, is the major industrial sector in Okinoerabu Island. High-level input of chemical fertilizers and agrochemicals threatens the island's environment.

The flow of goods and energy in Okinoerabu Island from import through production and consumption to export was assessed in quantitative terms from a self-contained point of view (Figure 1). As a result, it was identified that self-sufficiency rate of food was not high, although Okinoerabu Island's major industry was agriculture, and almost all energy was imported from outside the island (Morozumi *et al*., 1998).

This paper focuses on Okinoerabu Island. First, the island and its agriculture are overviewed in Section II. Next, use of land, water, and agrochemicals as stresses on the environment are examined based on the research at the town office and the surveys of 27 farms in Kunigami community in Wadomari Town in Section III. Then, policies for forming environmentally friendly agriculture at Wadomari Town are explained in Section IV. Finally, one way of reducing environmental burden in agriculture is proposed and its gains and costs are estimated, followed by concluding remarks.

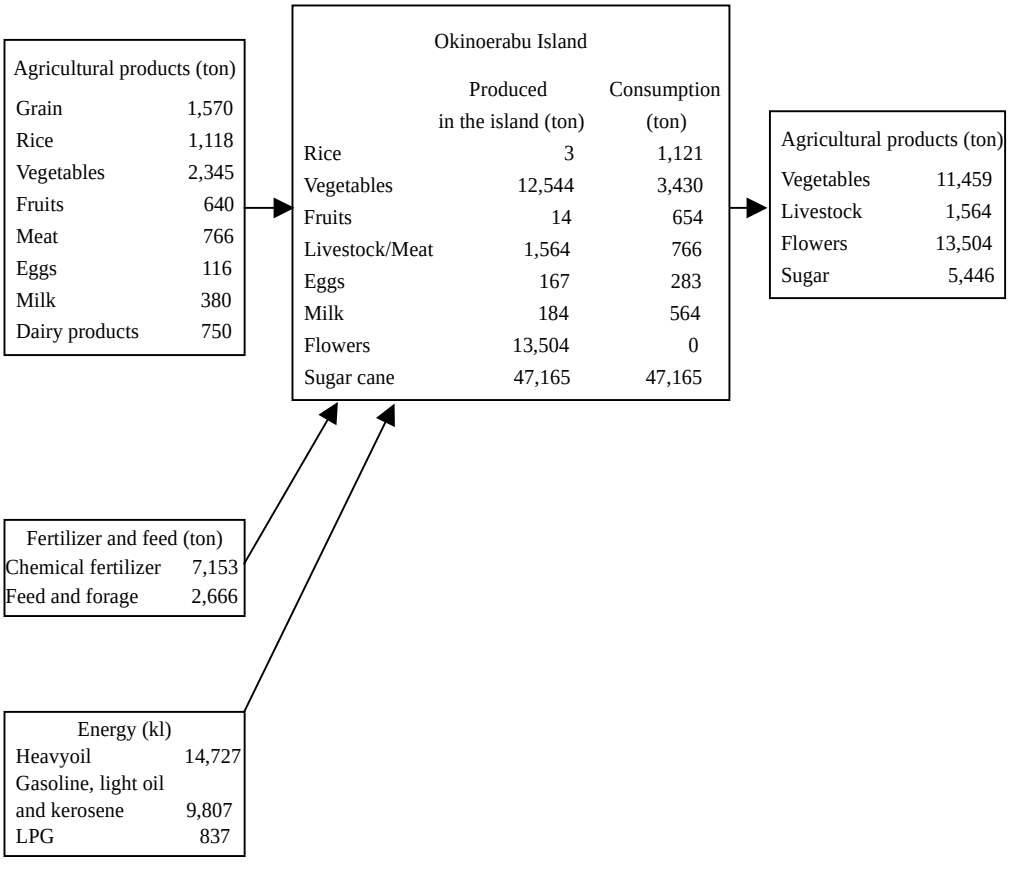

Figure 1 Flow of Agricultural Products and Energy in Okinoerabu Island (1996)

Source: Morozumi, *et al*., (1998)

II. Overview of Okinoerabu Island[1]

2.1 Okinoerabu Island

Okinoerabu Island is located in the Amami Islands, 537km to the southwest of Kagoshima City (Figure 2). The island area is 93.6 km^2, and farmland area is 4,360 hectare in 1996, which means the share of farmland in the whole island is 46.6%. There are two towns, Wadomari and China. There exist 15,000 inhabitants and 5,600 households in the island.

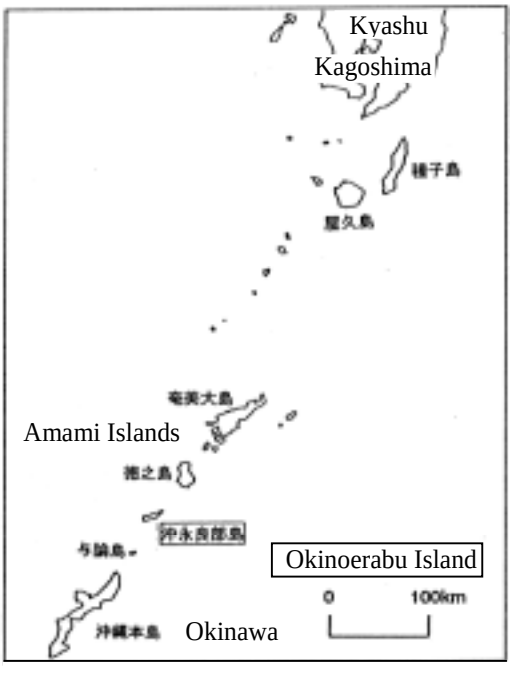

Figure 2 Location of Okinoerabu Island

Of all working population, 41.7% is engaged in the primary industries, 13.9% in the secondary industries, and 44.4% in the tertiary industries, according to the1995 Census. Of all people working, 41.2% is engaged in the agricultural sector, whose rate is higher than the average small islands. Net island product was 257.4 million dollars, 16.8 thousand dollars per capita in 1996.[2] The tertiary industries contributed to 62% of the product. The private and public service sector consists of 39% of the product, the construction sector 21%, and the agricultural sector 19%. Agriculture remains the important sector, although the share has been decreasing.

2.2 Agriculture

The number of farm households is 1,998 (1,107 in Wadomari, 891 in China), according to the 1995 Census of Agriculture. The number of farm households exclusively engaged in farming is 956. The number of type I part-time farm households (farm households which have other jobs, but main source of income is farming) is 511. The number of type II part-time farm households (farm households which have other jobs, and main source of income is other jobs) is 531. Of all farmland, 95% is crop field, and about 5% is pastureland. Orchard area is small, and paddy field does not virtually exist.

The island's agriculture, especially flower growing, is successful. Agricultural product in Okinoerabu is 93.1 million dollars, next to Sado Island and Tanegashima Island, and 30.3 million dollars per farmers next to Ie and Ishigaki islands in Okinawa (Ministry of Agriculture, Forestry and Fisheries 1998). The level of agricultural productivity in Okinoerabu is one of the highest among small islands in Japan.

2.3 Kunigami Community

Kunigami Community is located in the northeast end of the island. Population is 1,185 (1997 Residents Register). Total farm households are 218 and 215 farms sell their products in 1995. Of 215 farms, 113 is exclusively engaged in farming, 60 is type I part-time farm households, and 42 is type II part-time farm households.

III. Stresses on the Environment

3.1 Farmland

Major use of farmland is twofold. One is flower growing in greenhouses or

chrysanthemum growing with lighting. The other is field farming, growing sugarcane, vegetables, bulbs, etc. In the latter system, crops can be rotated, while the former system does not allow other crops than flowers. The farm survey in Kunigami shows that farms growing some crops rotate more or less crops, while farms growing only flowers or growing flowers and one other crop do not rotate them.

Major change in land use is the decline of rice farming in paddy fields. The government control on the acreage of rice production extinguished rice farming in the island, even for own consumption. Paddy fields can grow rice without fallow and also rotate crops. Paddy field is also valuable from environmental point of view, such as providing water-storing function.

3.2 Problems with Land Improvement Projects

In Wadomari, 1,119 hectare crop field has been improved and 822 hectare in China by March 1999, which are 47.8% and 38.8% of the field supposed to need the improvement respectively. Land improvement projects, such as land consolidation, irrigation and drainage, cause environmental threats.

First, windbreak forests have been cut in order to make field as large as possible. There used to be cycad and *Pandanus tectorius* around the crop field. They started to replant *Rhaphiolepis umbellata* and *Casuarina equisetifolia*, which grow fast as well as cycad. Some farmers are, however, against planting these fast-growing species, since they are vulnerable to salt and their leaves have bad effects on crops.

Second, through concrete ditches constructed, water flows out from fields to the sea with much red clay washed by rainfall, which causes serious soil erosion. Agrochemicals and chemical fertilizers are also discharged through concrete ditches into the sea. Many farmers said that this caused marine pollution, and the stock of seaweeds and small fish has declined sharply. Sediment basin could be a remedy, but

some farmers said that it had little effect.

3.3 Water Use

Irrigation ponds, springs and ground waters are the sources of water to crop fields. There are 102 irrigation ponds (80 in Wadomari in 1997, 22 in China in 1996), including under construction, and 55 springs (25 in Wadomari, 30 in China).

Irrigation ponds are used less often these days. They are managed cooperatively through irrigation cooperatives. Collection and use of fees and cooperative work such as dredging the pond might make some troubles. Besides, each farm is allocated the amount of water it can use. Growing flowers, especially chrysanthemum, need large amount of water, but farms cannot use water beyond the limit from the irrigation pond.

Pumping up of ground water is on the increase instead. Farmers have bored 165 wells by July 1999 according to the Wadomari Town Office. Above all, pumps are very popular at Kunigami Community, where water is scarce and flower production is increasing, and there exist 77 pumps. Of 27 farms we surveyed, 11 farms use irrigation ponds, while 19 farms have pumps. One farm has as much as three pumps. Water pumped up is used for flower growing by all farms but one that have pumps. Even though both irrigation ponds and pumps are available to a farm, it is inclined to use pumps that it can use freely.

Each town has the ordinance that requires report or permission of boring wells. There seems to be no restriction on the site and number of wells, although farmers often take the location of the adjacent farmers' wells into account when they bore new ones. Some worry about groundwater shortage, and others argue that it does happen due to the increase in pumps.

3.4 Water Quality in Wadomari

Water quality in Wadomari is overviewed here based on the report by College of Biological Resources, Mie University, which analyzed nitrate nitrogen and agrochemicals in water in 1994 (Mie University, 1994).

First, the report examined the trend of nitrate nitrogen concentration in sources of water supply at Goran and Nagamine. The source at Nagamine has no problem because it is surrounded by forests, while nitrogen in the source at Goran, surrounded by crop fields, is on the increase and came to 2-3mg/l. As for the source at Azefu, which was the first source of water supply in the Town, the nitrate nitrogen exceeds 6mg/l. Therefore, the source is not used. In addition, Mie University examined the nitrate nitrogen level of 30 wells and 21 springs. The concentration exceeded 10mg/l at 8 sites and was between 5-10mg/l at 20 sites.

The report concluded that the main reason for high concentration of nitrate nitrogen was fertilizer applied to crop fields. The nitrate nitrogen level of drinking water is not at the critical level. If crop fields expand around the source of water and farming practices become more intensive, the level of concentration at some sources of water supply could increase to threaten inhabitants' health in this or next decade. The water supply at Nagamine, where the concentration level is low, is not so abundant that water supply would be restricted if the nitrate nitrogen concentration at Goran increases.

Mie University examined groundwater with respect to 6 agrochemicals whose application rates were high. At least one agrochemical was detected over 0.1ppb level from 16 samples at 9 sites out of 118 samples at 34 sites. A sample near Goran contains agrochemicals. The report pointed out that there is some possibility that source of water supply contains agrochemicals. Besides, at least one agrochemical was detected in 9 out of 13 samples collected at discharged water in ditch.

3.5 Use of Agrochemicals and Fertilizers

Mie University (1994) estimated the amount of agrochemicals applied per unit of crop field in Wadomari. According to the estimation, it is 62.6kg/hectare in 1991, comparable to national average (86.5kg/hectare) and Okinawa (54.4kg/hectare). The application per unit of total area is, however, 31.3kg/hectare in Wadomari, which is as 2.6 times much as the national average (12.2kg/hectare), due to the high proportion of crop field to total area. Agrochemicals used in flower growing are as ten times much as in sugarcane growing.

Only two farms out of 27 we surveyed responded that the application of agrochemicals had fallen. Flower growers are unlikely to reduce agrochemicals. Flowers are not food, and produced for ornamental and decorative use. That is why the appearance is the most important factor, which discourages the incentive to curb the application of agrochemicals. Costs of agrochemicals and their negative effects on farmers' health could reduce the agrochemical application.

On the one hand, only one out of surveyed farmers told us that he used as less chemical fertilizers as possible. Most farmers we surveyed applied compost on the other. If they increase the input of compost, total application of nitrogen might not decline even if they reduce chemical fertilizer. Some farmers were aware of negative effects of nitrogen application, since water in their wells turned out to be unable to drink due to high concentration of nitrate nitrogen. On the whole, however, they were aware less of over-application of nitrogen than of agrochemicals.

IV. Policies for Environmentally Friendly Agriculture in Wadomari Town

This section states the development of policies for environmentally friendly agriculture in Wadomari. Income from agriculture in this island has grown as flower growing develops. In the meanwhile, environmental costs of flower growing are substantial; flower growing requires large amount of water and agrochemicals. They worry about water shortage and decline in water quality. People in Wadomari have been conducting projects of forming new farming system since early 1990's. The basic idea is the input of organic matters into soil and rational crop rotation, aiming the reduction in the input of chemical fertilizers and agrochemicals.

First, Wadomari Organic Farming Association was founded in 1991. Town of Wadomari asked for Mie University to assess the environmental impact of agrochemicals and chemical fertilizers in 1992. The study was conducted from July 1992 to May 1994. The Ordinance on Promoting Farming System Harmonious with the Regional Environment in Wadomari Town was passed in March 1994, which expressed the necessity for conserving the natural environment in the long run. This ordinance requires the Wadomari Town to register farmers engaged in environmentally friendly farming and to certificate their products. The ordinance also established the Committee for Promoting Farming System Harmonious with the Regional Environment in Wadomari, consisting of 15 members. The Committee replaced Wadomari Organic Farming Association. In December 1994, the Town Office published the Master Plan for Promoting Farming System Harmonious with the Regional Environment in Wadomari. The Master Plan set the target of 20% reduction in the input of chemical fertilizers and agrochemicals by 2000, taking the results of the study by Mie University into account.

Several facilities were built on the abovementioned line, subsidized by the national government. In March 1996, the treatment facility of waste agrochemicals was built. Bulbs of lilies and freesia, and seed potatoes are sterilized by being soaked in agrochemicals. Mie University (1994) pointed out that as much as one percent of national consumption of germicide captan (sold as Orthocide) was used in this island. The facility dehydrates and filtrates waste agrochemicals. In March 1997, the Erabu Compost Center was built. The Center produce compost from sugarcane leaves, human excretion (partly dehydrated), and half-fermented animal manure (transported from mainland Kyushu).

V. A Proposal: Replacing Chemical Fertilizer with Compost

The replacement of chemical fertilizer with compost is proposed as a step toward a farming system harmonious with the environment. Chemical fertilizers come from outside of the island. If the input of chemical fertilizers declines and compost, which is made from animal manure and agricultural wastes in the island, is used more instead, total input of nitrogen to the environment would decrease. The amount of nitrogen discharged to the environment and cost of the replacement are estimated to examine the economic and ecological impacts and feasibility of the replacement.[3]

Table 2 shows the results of the estimation. The total amount of nitrogen discharged to the environment is estimated at 933.6tN (nitrogen ton), consisting of chemical fertilizer (747.5tN), animal manure (177.5tN), sugarcane leaves (4.2tN), and manure of pig and chicken (4.4tN). Four fifth of nitrogen emitted to the environment comes from chemical fertilizers. While the rate of feed produced in the island is 77.4%, the share of fertilizer produced in the island is only 5.6%. Farming in this island is heavily dependent on the outside in terms of fertilizer.

Production cost of compost is estimated based on the balance sheet of Erabu Compost Center. The Center purchases cattle manure at 7,255 dollars per nitrogen ton, and procures sugarcane leaves at free. Production cost other than material cost is 15,813 dollars per nitrogen ton for compost of cattle manure, and 33,110 dollars per nitrogen ton for compost of sugarcane leaves. Cost of chemical fertilizer is calculated to be 5,581 dollars per nitrogen ton: sales of chemical fertilizers (4,172 thousand dollars) divided by content of nitrogen (747.5 ton).

Table 2　Estimated Environment Load and Self-sufficiency Rate of Fertilizer*

	fertilizer		feed and forage
Internal resources	compost of sugar cane leaves	4.2tN/yr	self-supplied forage 6447.6tTDN/yr
	compost of cattle manure	40.1tN/yr	
	subtotal	44.3tN/yr	
External resources	chemical fertilizer	747.5tN/yr	purchased forage 1883.1tTDN/yr
	compost of swine and poultry manure	4.4tN/yr	
	subtotal	751.9tN/yr	
Total		796.2tN/yr	8330.8tTDN/yr
Self-sufficiency rate		5.6%	77.4%

Source: Tagami, *et al*. (2000).

* Livestock feces and urine are estimated to be 177.5tN including compost of cattle manure. Calculated on the compost efficacy rate of 30%.

The case where fertilizer is reduced by 20% and the rate of fertilizer produced in the island is raised to 10% is examined here (Table 3). This case can be achieved by replacing 9 tN of chemical fertilizers with 1 tN of compost, or put another term, reducing chemical fertilizer by 24% and increasing compost by 44%. The increase in cost of using more compost would be from 447 (manure compost) to 642 (sugarcane leaves compost) thousand dollars, which could be offset by the reduction in cost of chemical fertilizer, 997 thousand dollars.

Table 3 A Plan for Reducing Fertilizer: An Example
(in case of 20% reduction of fertilizer and up to 10% improvement of the self-sufficiency rate)

	Present (A)	Target (B)	B/A (%)	B-A
Compost from inside the island (tN)	44.3	63.7	143.8	19.4
Fertilizer from outside the island (tN)	751.9	573.3	76.2	-178.6
Total	796.2	637.0	**80.0**	-159.2
Self-sufficiency rate (%)	5.6	**10.0**		

Source: Tagami, *et al*. (2000).

VI. Concluding Remarks

Okinoerabu Island started to shift to flower growing in 1980's, leading to one of the most profitable agricultural island in Japan. It is true that the island is viable in economic terms, but the environmental sustainability is in question. This paper pointed out some problems, namely the increase in water use, high-level input of agrochemicals and fertilizers, monoculture of farming system, decline in windbreak forests, and marine pollution. It is also revealed that chemical fertilizer is one of the major causes of environmental burdens, and the island is heavily dependent on the outside in terms of the supply of chemical fertilizers.

Town of Wadomari set the target of 20% cut in chemical fertilizer and agrochemicals by 2000. The target does not seem to be achieved, however. Besides, total nitrogen input including organic materials should be reduced if nitrate concentration in groundwater is to be taken seriously. It takes long time for the nitrate concentration to decline after the input level of nitrogen decreases. The prompt action on nitrogen should be taken.

We proposed the replacement of chemical fertilizer with compost and showed that

it could be economically feasible, which implies farmers could reduce environmental burdens as well as economic costs.

Notes

1. Much of the following is drawn from Nishizawa, *et al*., (2000).
2. Prices, costs etc. are converted on the rate of 120 Japanese yen per US dollar.
3. For more detail on the estimation method, see Tagami, *et al*., (2000).

References

Mie University, 1994. *Report on the Environmental Impact of Agrochemicals and Chemical Fertilizers Application in Wadomari Town, Okinoerabu Island.* Mie University, Tsu, Japan. (in Japanese).

Ministry of Agriculture, Forestry and Fisheries, 1998. *Statistics of Agricultural Output 1996*. Ministry of Agriculture, Forestry and Fisheries, Tokyo, Japan. (in Japanese).

Morozumi, K., M. Goda, E. Nishizawa, T. Tagami, and M. Uno, 1998. "Small Island as a "Self-contained Society": A Socio-economic Study of Okinoerabu Island, Kagoshima," *Quarterly Journal of Agricultural Economy*. 52(4): 63-112. (in Japanese).

Nishizawa, E., T. Tagami, M. Goda, K. Morozumi, and M. Uno, 2000. "Water, Land Use, and Food on Okinoerabu Island, Kagoshima Prefecture: A Preliminary Investigation toward Establishing a "Self-contained Society"," *Island Studies.* 1: 99-108. (in Japanese).

Oomura, M., K. Morozumi, M. Goda, T. Tagami, and E. Nishizawa, 2000. "A life Cycle Assessment of Agricultural Activity for Designing a Self-contained Society," *Proceedings of The Fourth International Conference on EcoBalance*. p. 427-428.

Tagami, T., M. Goda, K. Morozumi, E. Nishizawa, and M. Uno, 2000. "Designing an Environmentally Friendly System in an Island: Estimation of the Environmental Load from the Agricultural Production and the Economic Cost of the System," *Proceedings of The Fourth International Conference on EcoBalance*. p. 425-426.

一個與環境互助之農業系統的設計：日本的 Okinoerabu 島之農業與環境

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本文介紹一個在日本施行之「獨立自足社區」計畫的一些成果，介紹重點主要為 Okinoerabu 島在土地、水及農用化學物之使用對環境所造成之壓力的分析，而分析之資料是來自 Wadomari 鄉鎮及針對鄉鎮中之 Kunigami 社區的 27 個農戶所完成之調查研究。藉由此一結果則解釋了與 Wadomari 鄉鎮具有環境互助型農業政策之形成。最後亦提出了一種得以減輕環境負擔之農業生產方式，文中亦估算了此種方式之利得與成本。

關鍵詞：Okinoerabu 島、土地與水、農用化學物、肥料、與環境互助型之農業政策

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