Doctoral Dissertation
博士論文

A Study on a Regional Scale Agricultural Production System Based on Material Flow Analysis Methodology on Miyakojima Island
宮古島における物質フロー解析に基づく地域自立型農業生産システムの研究

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Summary of the Dissertation

This dissertation discusses the agriculture and stockbreeding on Miyakojima Island which is a part of Ryukyu Islands and tries to give a tool which solves problems and its relevant information. It tried to make the tool applicable to the agriculture and stockbreeding in the other areas. The agriculture on the island places its focuses on sugar cane whereas the stockbreeding focuses on breeding of beef cattle. But they deeply depend on the imported chemical fertilizer whereas stockbreeding depends on imported feeds. Because of its unique underground structure nitrogen contained in fertilizer used for agricultural plants and stockbreeding's manure and urine cause a serious pollution to the ground water. The sustainable agriculture and stockbreeding which reduce dependency to the imported resources and has less amount of nitrogen loading are highly desired. Now this dissertation examines the methodology to develop the system to solve the problems on the island by recycling the biomass resources based on the Material Flow Analysis, based on the Material Flow Analysis, in order to mitigate dependency on the imported resources and the ground water pollution while the current production level is maintained. It also tries to use biomass resources on the island efficiently, based on the Material Flow Analysis results. This dissertation is consisted of the following chapters.

Chapter 1 addresses the natural environment, the pollution to the ground water, sugar cane cultivation and beef cattle's breeding and raising on Miyakojima Island, based on topographical and statistical data and the previous studies for this research. Chapter 1 also clarifies the objective for this dissertation.

Chapter 2 clarified a material flow for a variety of stockbreeding such as beef cattle, dairy cattle, chickens and pigs on weight basis, using the investigation results for the amount of feeds, the amount of manure and urine, the degree of growth and the amount of exported products. In addition, it also clarifies the nitrogen, the carbon and phosphorus by element analysis. The material flow analysis results for element basis and weight basis is used as a basic unit for the discussion in Chapter 4 and 5. One of the deliverables from the discussion of this chapter is that dairy cattle and chicken only consume feeds imported from the outside of Miyakojima Island.

On the other hand, pigs primarily consume food wastes which are internally from the island.

Chapter 3 tries to investigate the agriculture in a quantitative manger by conducting Material Flow Analysis for a variety of agricultural plants and their production process, based on the information on cropping, fertilization management, sugar production. The target components are sugar cane, pasturage, leaf tobacco, squash, Chinese preserving melon, bitter melon, mango, green manure plants, as well as sugar mills and composting facilities. In addition to the information on growth and yield, generation and utilization of biomass resources were investigated. Also the reason why biomass resource is not utilized is clarified.

Chapter 4 tries to develop the methodology to increase productivity while reducing the dependency on the imported resources and the environmental loading by utilizing the result of discussion in Chapter 2 and Chapter 3. It put its focus on sugar cane and beef cattle breeding. By selecting sugar cane yield, calf's number, amount of imported feeds, and amount of imported fertilizer as evaluation indices, four scenarios were created. Basic units are values of one beef cattle and one hectare agricultural plants, based on the Material Flow Analysis results.

Chapter 5 simulates the imported amount of resources, yield, the amount of sugar cane production, the nitrate nitrogen pollution to the ground water for four scenarios set up in Chapter 4 when changing growing areas of sugar cane, recycled biomass resources like applied amount of manure and urine and the number of breeding cows. Based on the results, strategies to solve the problems on the island are discussed.

As a conclusion of the discussion, this dissertation tried to develop a recycling system for biomass resources which increase the production and which reduces the imported resources and environmental loading on the island in order to realize the regional scale less dependent agriculture and stockbreeding.

本論文では、南西諸島の一つである宮古島の農業と畜産業について取り扱っており、同島における問題解決を支援するツールと関連情報の提供を行うとともに、他地域でも一般的に利用が可能なツールとすることを目指している。宮古島はサトウキビの栽培を中心とした農業と繁殖牛を中心とした畜産業が盛んであるものの、サトウキビ栽培は島外からの移入化学肥料、畜産業は移入飼料に強く依存している。加えて、宮古島独特の地層に起因して、農地に施用された肥料中や、家畜の糞尿の窒素が、生活用水の供給を担う地下水の深刻な汚染をもたらしている。島外への依存と地下水等への環境負荷を低減しながら、島内で自立できる持続可能な農業、畜産業の実現が強く期待されている。

そこで本論文では、島内での物質フローの解析に基づいて、バイオマス資源の有効利用などによる地域自立型の農業、畜産業を実現するための手法を構築することによって、島内での生産性維持しながら島外への依存度と地下水汚染の低減を合わせて実現するために、島内での物質フロー解析に基づいて、バイオマス残滓の循環的利用促進を基盤として、問題解決のための手法を構築する検討が行われている。本論文は以下に示す全５章から構成されている。島外への依存と地下水等への環境負荷を低減しながら、島内で自立できる持続可能な農業、畜産業の実現が強く期待されている。

そこで本論文では、島内での物質フローの解析に基づいて、バイオマス資源の有効利用などによる地域自立型の農業、畜産業を実現するための手法を構築しようとしている。島内での生産性維持しながら島外への依存度と地下水汚染の低減を合わせて実現するために、島内での物質フロー解析に基づいて、バイオマス資源の循環的利用促進を基盤として、問題解決のための手法を構築する検討が行われている。本論文は以下に示す全５章から構成されている。

第 1 章では、現地調査、各種統計資料、既往の研究等による情報の収集と解析に基づいて、宮古島の自然環境、地下水汚染実態、サトウキビ栽培、肉牛の繁殖と肥育の状況についてまとめ、同島における課題を抽出するとともに、問題解決の方向性について論じ、本研究での目的を示した。

第 2 章では、肉牛、乳牛、鶏、豚等の家畜について、給餌量、畜糞尿量、成長と出荷量等に関する調査結果を基に、物質フローに加えて、元素組成の分析による窒素・炭素・

リンの元素フローを明らかにした。肉牛の繁殖、肥育等における物質フロー・元素フローを第 4 章、5 章の議論における原単位の基とした。合わせて、乳牛、肥育牛、老廃牛、鶏は島外の飼料のみに依存しているが、子牛と繁殖牛に島内の飼料作物、豚には食品残渣がそれぞれ給餌されている事などの実態が明らかにされた。

第 3 章では、宮古島における農作物の作付け、施肥管理、生産加工における物質フローの解析に基づいて、同島における農業の実態について定量的な把握が行われた。耕地面積当たりの作物栽培に伴う炭素・窒素・リンの元素を含む物質フローの原単位を明らかにされた。調査対象は、サトウキビ、飼料作物、葉タバコ、カボチャ、冬瓜、苦瓜、マンゴー、緑地作物等であり、製糖工場および堆肥化施設についても調査解析が行われた。農作物の生育・単収に加えて、バイオマス資源の発生と利用状況、利用を阻害する要因などが明らかにされた。

第 4 章では、第 2 章、第 3 章での成果を活用して、宮古島におけるサトウキビ栽培と肉牛繁殖に着目して、島外への依存と環境負荷の低減を実現しながら島内で生産性を向上するための方策を検討するための手法の構築が行われた。サトウキビ収量、子牛頭数、移入飼料量、化学肥料施用量（移入量）などの多寡を評価指標として、評価するための４シナリオが策定された。各シナリオにおける島内での物質フローの変化の予測には、第 2 章、第３章に示した物質フロー解析の結果に基づいて決定された 1ha の農作物収量や家畜一頭などの単位量当たりの情報が原単位に利用されている。

第 5 章では、第 4 章で設定された 4 つのシナリオについて、サトウキビおよび飼料作物の作付け面積、畜糞尿の農地施用量等のバイオマス資源循環利用、繁殖牛頭数等を変化した場合に、島外からの移入量、単収、砂糖生産量、子牛出荷頭数などへの影響、地下水への硝酸態窒素汚染の予測が行われ、各シナリオによる違いを明らかにしている。この結果に基づいて、宮古島で指摘されている問題の解決に向けた方策について議論がなされた。

以上、本論文は、地域自立型の農業・畜産業を実現するために、物質フローの解析に基づいて、地域外への依存と環境負荷の低減に加えて、地域内での生産性向上を合わせて実現することを目的としたバイオマス資源の循環利用システム構築に大きく貢献す

る手法と情報を提供するものである。

Contents

Chapter 1 Introduction

1.1 Objectives of the Dissertation

This subsection gives the objectives of the present dissertation. It discusses the agriculture and stockbreeding on Miyakojima Island. This dissertation discusses the agriculture and stockbreeding on Miyakojima Island which is a part of Ryukyu Islands. The agriculture and stockbreeding on the island are subject to the unstable and uncontrollable price of imported feeds and imported fertilizer.

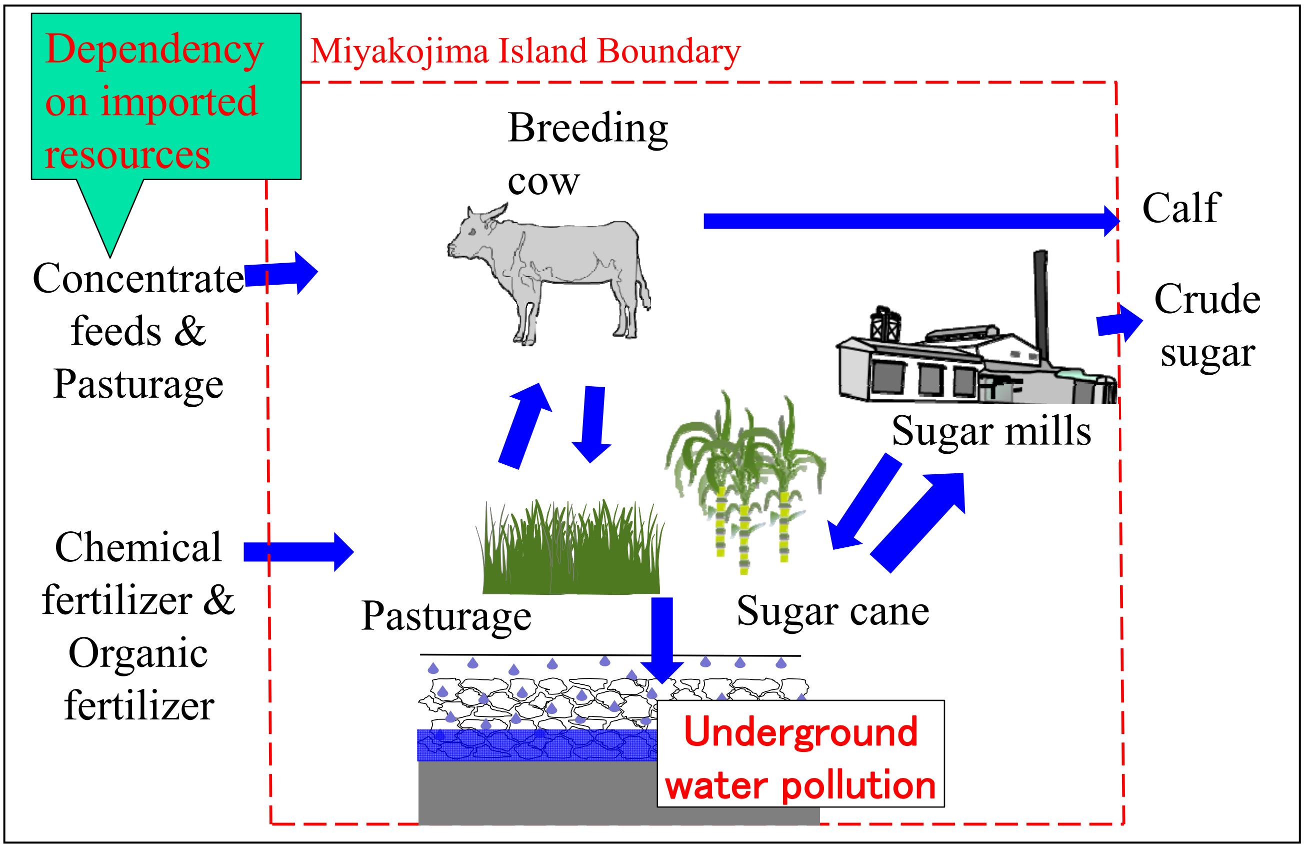

Fig. 1.1 The concept for this dissertation

For example, when BSE (bovine spongiform encephalopathy: mad cow disease) issues occurred, the price of beef cattle went down. A big beef cattle farmer on the island faced a financial issue because it kept adult cattle which only consume the imported feeds. In the same way, a dairy cattle's farmer went bankrupt maybe because dairy cattle only consume the imported cattle. On the other hand, farmers who kept calves and breeding cow were able to get revenues from the business even when BSE issue occurred.

Another issue is nitrate nitrogen pollution to the ground water. Nitrogen contained in fertilizer used for agricultural plants and stockbreeding's manure and urine is a source for pollution to the ground water. The objective of this dissertation is to discuss the way to obtain the agricultural production system which can reduce the risk arising from unstable price of imported fertilizer and imported feeds and which can mitigate the nitrate nitrogen pollution.

The objectives of the dissertation is to propose an agricultural production system which is able to make simulation to meet the following demands on Miyakojima Island: 1) Reduces the imported feeds for stockbreeding and imported fertilizer for agricultural plants, 2) Increases the export to the outside of Miyakojima Island and 3) Reduces the nitrogen loading to the underground water.

The dissertation is consisted of three parts: Part 1) Introduction to the dissertation, Part 2) Obtain the basic units with Material Flow Analysis (i.e. MFA) methodology in order to build up an agricultural production system. Part 3) Proposing an agricultural production system. Chapter 1 is corresponding to Part 1, Chapter 2 and 3 are corresponding to Part 2 and Chapter 4 and 5 are corresponding to Part 3.

1.2. Objectives of Chapter 1

Main tasks of Chapter 1 are: 1) Providing topographical and statistical data of Miyakojima Island. 2) Showing the underground structure of Miyakojima Island, 3) Explaining sugar cane cultivation on the island and 4) Explaining beef cattle breeding and raising on the island, 5) Providing examples of the environmental activities and projects on the island and 6) Showing the major previous research for the present dissertation.

1.3 Introduction to Miyakojima Island

Miyakojima Island is located 300 kilometers southwest of Okinawa Main Island as shown in Fig. 1.2. It takes approximately 45 minutes from Okinawa Main Island; it takes approximately 3 hours from Tokyo by airplane. The area of the island is 226 km^2. Compared with the area of Yokohama city 437.4 km^2, the island is approximately half size of it. From the urban area Hirara, which is located at the center of the island, it takes approximately 15 minutes to the north end or to the south end of the island by car.

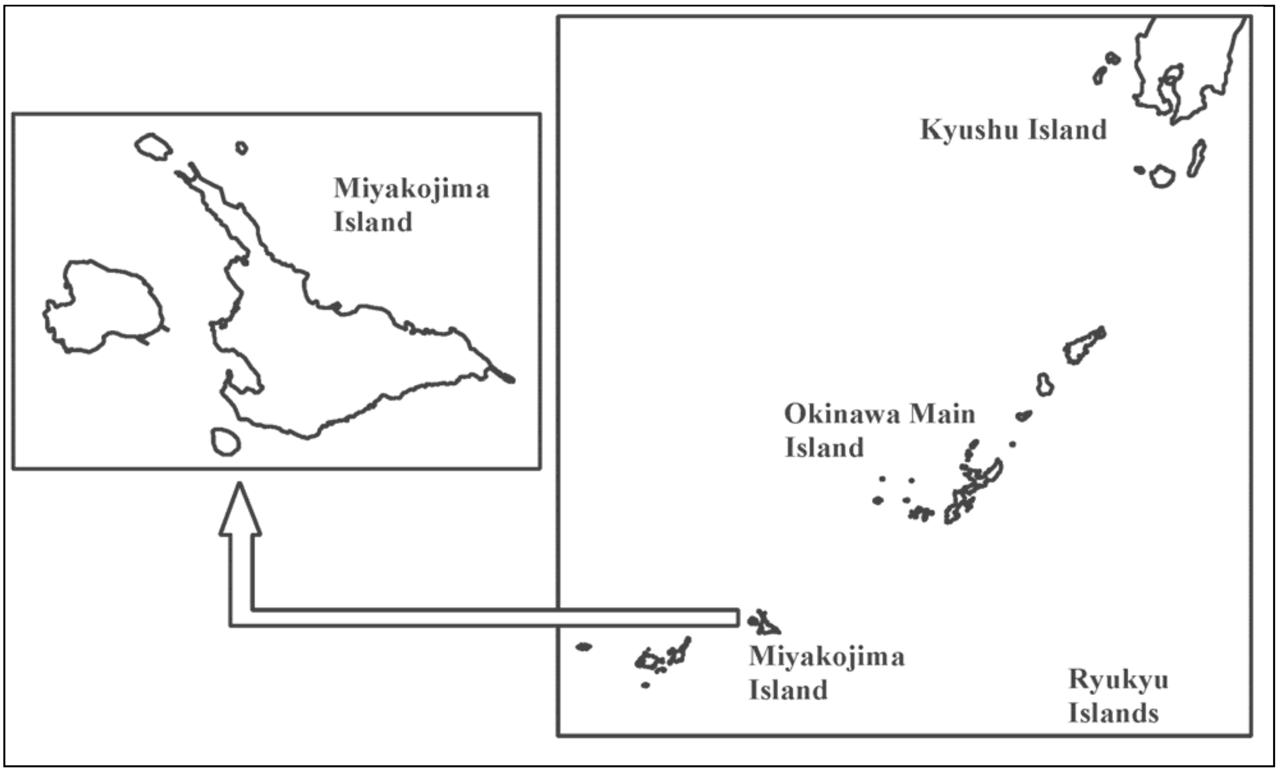

Fig. 1.2 Location of Miyakojima Island

The population of Miyakojima Island in Japanese Fiscal Year 2010 (i.e., from April of 2010 to March of 2011. Japanese Fiscal Year is shown as "FY" from here on) is 55,036[1]. Regarding "Regional Scale", the population on Miyakojima Island would determine the qualification as a unit of regions. According to "Thought of Regionalism[2], 2,000 - 3,000 residents are too small as a unit of regions where 20,000 – 30,000 residents are appropriate. 55,036 residents on Miyakojima Island can be bigger than that, but probably it would be acceptable as a unit of regions. Miyakojima Island has one administrative unit, Miyakojima City.

Here this research provides the information on the climate on the island. The temperature on Miyakojima Island is shown in Graph 1.1 and Table 1.1[3]:

Table 1.1 Temperature on Miyakojima Island (FY 2010)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Temperature (°C)	22.0	24.8	27.1	29.1	28.5	27.9	25.6	22.2	19.1	16.1	18.7	17.9

The average temperature in FY 2010 was 23.3°C. The climate of Miyakojima Island is subtropical. Therefore cultivation of the tropical agricultural plants like sugar cane, Rhodes grass (pasturage for beef cattle), tobacco (the type is Virginia), bitter melon, Chinese preserving melon and mango are widely found on the island.

The rainfall amount on Miyakojima Island(FY 2010) is shown in Table 1.2[3]. The total amount of rainfall in FY 2010 was 2,194 mm/year. The rainy season in FY 2010[4] started from May 6th and ended in June 19th, but it did not bring much rain fall. Three typhoons approached the island and they may partially contribute to the rainfall in August and September[5].

Table 1.2. Rainfall on Miyakojima Island (FY 2010)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Rainfall (mm)	191.5	134.5	127.5	284	319	156.5	289	230	102	216	105	39

From the experiences through the site investigation, it is assumed that the rainfall would be brought by squall like in the tropical zone.

Although this paper uses the data based on Japanese Fiscal Year, according to the statics of the temperature and the rainfall Calendar Year (hereafter, CY) 1981through 2010, the average temperature was 23.6 °C and the average annual rainfall amount was 2021 mm[6].

The temperature was 28.7°C in July while the bottom of the temperature was 18.0°C in January. More rainfall was observed in May, June, August and September.

1.4 The Underground Layer Structure of Miyakojima Island

The underground layer structure of Miyakojima Island is illustrated in Fig.1.3 and Fig.1.4 (Photo 1 and Photo 2 in Fig. 1.4 were provided by the Miyako Land Improvement District while Photo 3 in Fig.1.4 is mine). Fig. 1.3 shows the underground structure of Miyakojima Island.

Shimajiri Mudstone Layer was created in the Pliocene Epoch of the Tertiary (5,000,000-1,700,000 year ago): the layer was created by an accumulation of sand and mud in Shimajiri Sea (which is located in East China Sea as it is known today) which were brought by fluvial transport of rivers in China[7].

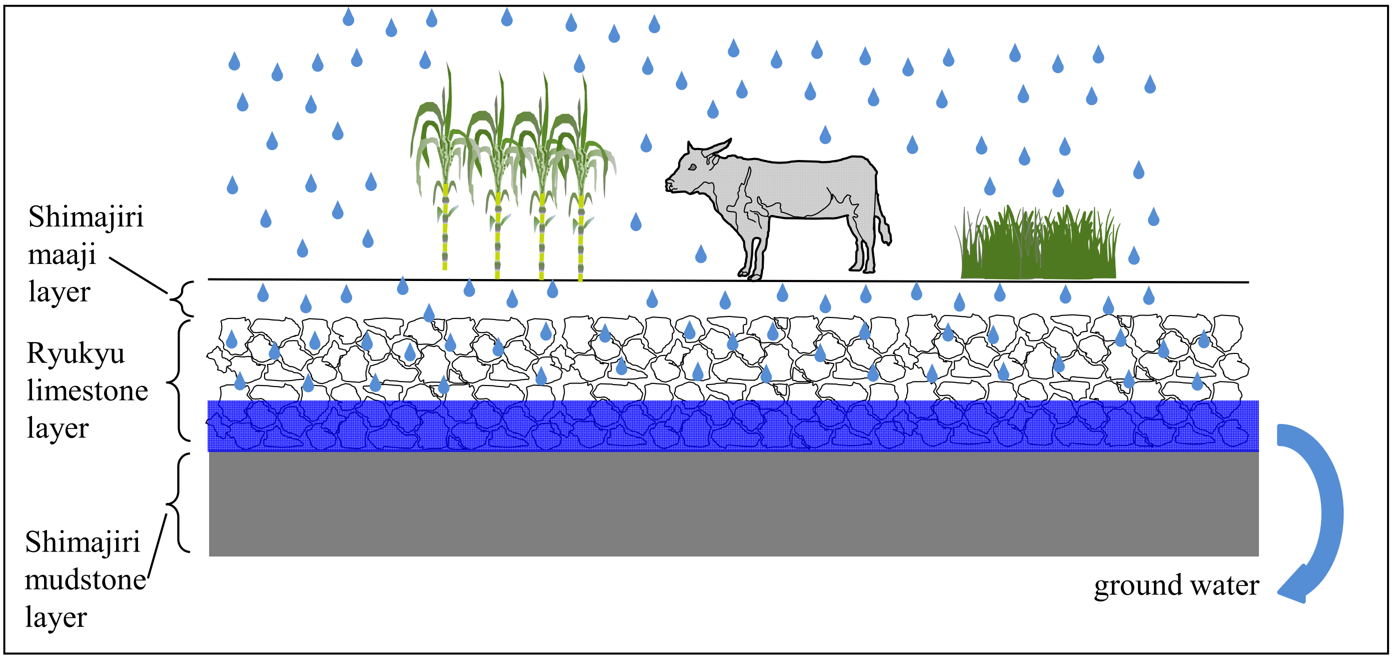

Fig. 1.3 Underground Layer Structures of Miyakojima Island

Ryukyu Lime Stone Layer was created in the late Pleistocene Epoch of the Quaternary

(1,000,000 - 200,000 years ago): It was created by the hermatypic coral growth in the Ryukyu Coral Sea which was located in Ryukyu Islands as it is known today[7].

Shimajiri Maaji Layer was said to be created after Ryukyu Lime Atone Layer was created. two theories for the creation of Shimajiri Maaji Layer are insisted: it is the weathered Shimajiri Maaji soil while it is a mixture of the weathered Shimajiri Maaji soil and Yellow Sand from China[7].

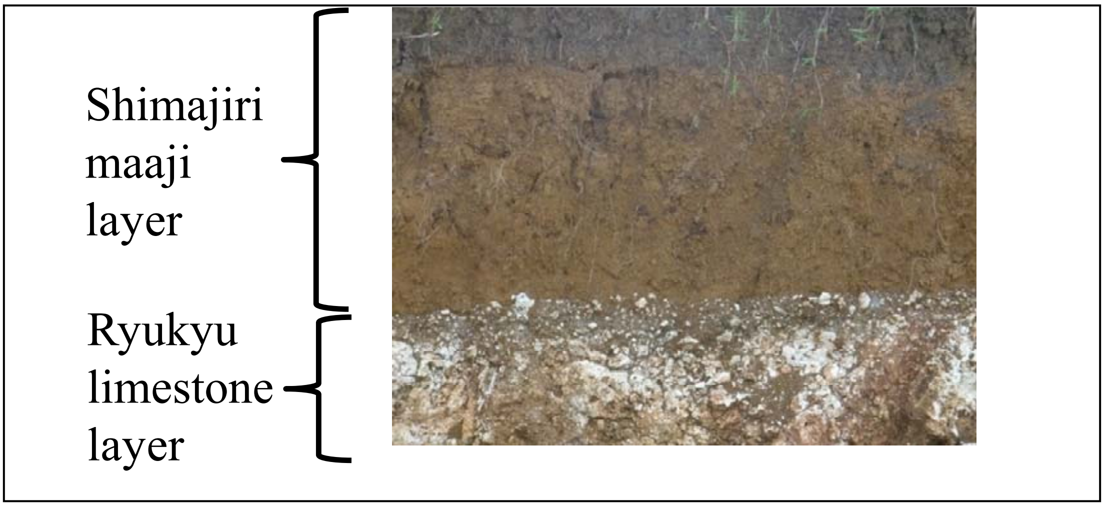

Fig. 1.4 Shimajiri maaji layer and Ryukyu limestone layer

Shimajiri Mud Stone Layer is the impermeable layer which does not allow water to penetrate. Fig.1.4, which is given by Miyako Land Improvement District, shows the Shimajiri Maaji Layer in which the agricultural plants are cultivated. The information on the thickness of the surface layer, Shimajiri Maaji Layer, was not obtained but probably it would be some dozen centimeters by my direct observation.

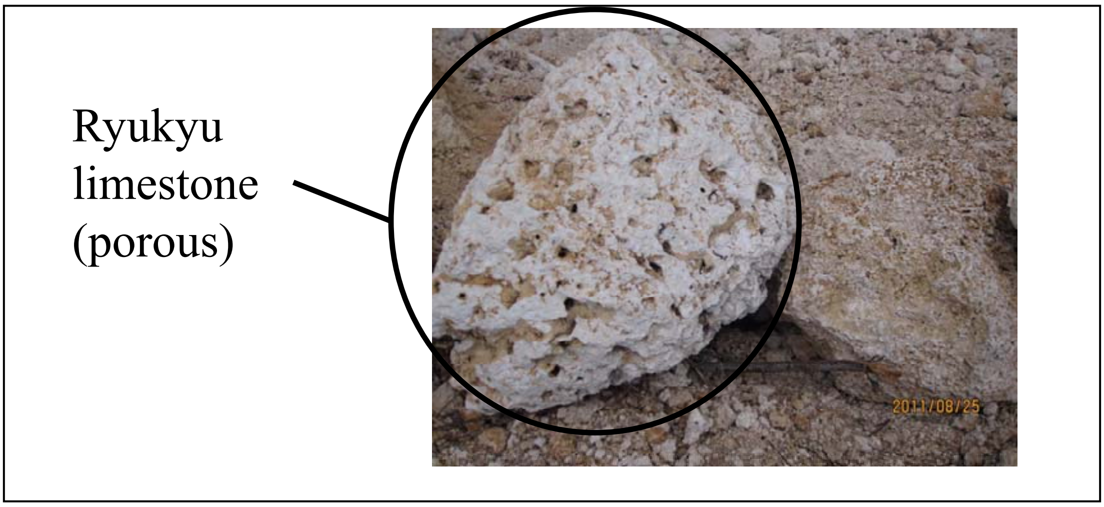

Fig. 1.5 Ryukyu limestone layer

The Ryukyu limestone is made of porous limestone as shown in Fig.1.5. According to the private communication with Miyakojima city hall, the void ratio of the Ryukyu limestone is 10%. The water is stored in the void structure of Ryukyu Limestone Layer. My direct observation in on-site investigation also finds that Shimajiri Maaji layer can allow the water to penetrate easily and seep into the void structure of Ryukyu Limestone Layer because no puddles were observed even immediately after it rained.

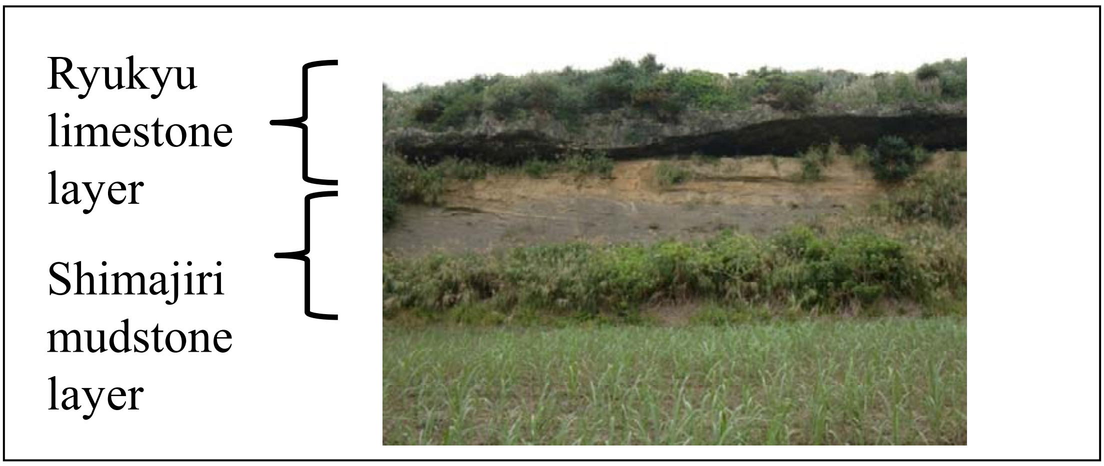

Fig. 1.6 Ryukyu limestone layer and Shimajiri mudstone layer

Miyakojima Island depends on ground water for all supply of the drinking water and for partial supply of agricultural water. Pollutants like nitrate nitrogen easily seep into the ground water.

Fig. 1.6, which is given by Miyako Land Improvement District, shows Ryukyu limestone layer and Shimajiri mudstone layer.

The high concentrated nitrate nitrogen in the water may cause cyanosis when it is drunken. An example of this pollution is known as “blue baby syndrome”, meaning babies who were caused by the concentrated nitrate nitrogen. For the ground water conservation, this research also needs to take the impact to the environment into consideration.

1.5 An Introduction to Agricultural Plants and Stockbreeding on Miyakojima Island

1.5.1 Harvested Areas or Growing Areas of Agricultural Plants on Miyakojima Island

Most of area is flat and that makes the island suitable for agriculture as shown in Fig.1.7.

Fig. 1.7 Photos Showing the Typical Flat Areas on Miyakojima Island

As shown in Table 1.3, the area of 58.4% is used for agricultural use. In Japan, rice fields get majority on the land utilization but on Miyakojima Island sugar cane fields get majority on the land utilization. As addressed above, because Shimajiri Maaji layer allows the water to penetrate easily, it is not suited for rice fields. Instead of rice, sweet potatoes were subsistence agricultural plants in the past. Growing area for sweet potatoes are now so small.

Table. 1.3 Table for Land Utilization

	Miyakojima Island (km^2)
Total Area	195
Farm Area for Rice	N/A
Farm Area for Agricultural Plants (Not Rice)	114(58.4%)
Mountain Forest Wilderness	N/A
Wilderness Area	35 (18.1%)
Housing Area	10 (5.09%)

Fig.1.8 is a satellite photograph of Miyakojima Island which shows the land utilization visually (the source is JAXA, Japan Aerospace Exploration Agency). By the colors, it is clear how it is used. The satellite photograph was taken on September 12 2009. The brownish yellow is considered as the farm area. The brownish yellow is the color of Shimajiri Maaji soil. At that time, the billet planting of the sugar cane was going on in the half area of sugar cane fields. Although the sugar cane were growing in the half area of the field, some area of the ground surface is supposed to be seen because the sugar cane have the vacant space when it is viewed from the upper side of the field.

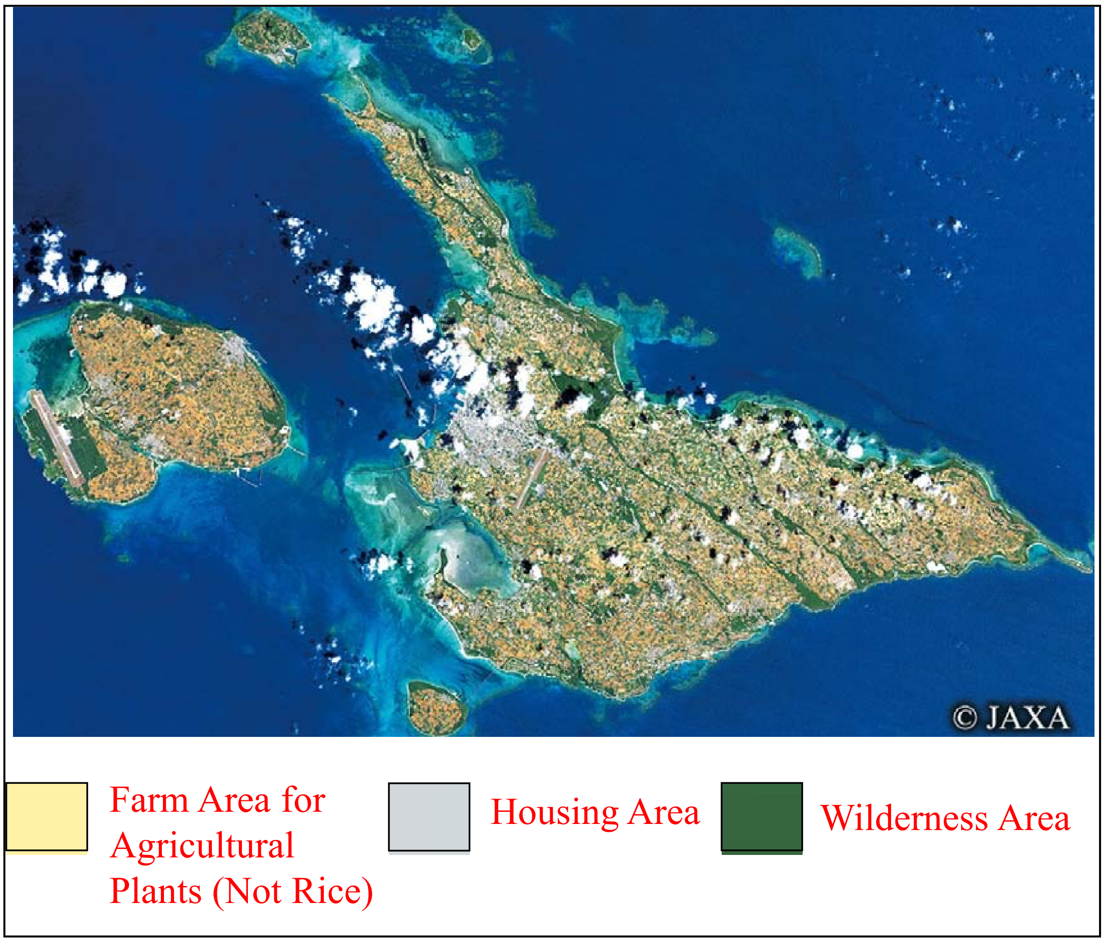

Fig. 1.8 A Satellite Photograph of Miyakojima Island

The light gray is considered as a housing area: it is the color of concrete roofs. Because Miyakojima Island has some of typhoons every year, almost all buildings are made of reinforced concretes. The light gray color is concentrated on Hirara area, the area where white clouds are. Hirara area is the only down town area on Miyakojima Island.

Although the areas colored green are considered as the wilderness area, weeds like beggar's tick(Bidens pilosa) and white lead trees (Leucaena leucocephala) are usually found.

The agricultural plants which this research targets are sugar cane, pasturage (for beef cattle), tobacco, squash, Chinese preserving melon, bitter melon and mango. Table 1.4 shows harvests and harvested areas/ growing areas of agricultural plants cultivated on Miyakojima Island. It is created based on the private communication with Miyakojima City Hall and “Statics

Miyakojima[1]" issued by the city hall.

Regarding sugar cane, harvested areas need to be used because the target term of this research is only one year. However the cultivation term of sugar cane is one year and half and its cycle is two years. Sugar cane are harvested every year. Farmers divide their own sugar cane fields into two and alternately conduct billet planting to one of the divided sugar cane field in summer. Growing area for sugar cane is assumed to be approximately double of the harvested area. This research uses the Material Flow Analysis (hereafter MFA) as a methodology of discussion based on one year data. The data obtained based on the harvested area also needs to be known. The discussion of an agricultural production system needs to use the values of areas for sugar cane and pasturage under one scale, therefore this research uses the value of growing areas.

Table. 1.4 Table for Harvests and Harvested Areas/ Growing Areas of Agricultural Plants on Miyakojima Island

	Agricultural Plants	Harvests(t/y)	Growing Areas (ha)	Harvested Areas (ha)
1	Sugar cane	300,300	7,706	3,853
2	Pasturage	11,255	943	943
3	Tobacco	2,138	621	621
4	Squash	1,595	334	334
5	Chinese preserving melon	920	9.5	9.5
6	Bitter melon	782	16.7	16.7
7	Mango	532	57	57

In this connection, this research will address the difference between billet planting and ratooning in the subsection 1.5.4 of "Billet Planting and Ratooning of Sugar cane".

1.5.2 The Number of Stockbreeding on Miyakojima Island

Table 1.4 shows the number of stockbreeding on Miyakojima Island. Chicken outnumber the others but the weight of chicken is so light that the biomass is exceeded by beef cattle.

Beef cattle is a major component for material flow of agriculture on the island. In this research the focus is placed on beef cattle's material flow for the discussion.

Table. 1.4 Table for Stockbreeding on Miyakojima Island

	Stockbreeding's Name	Number
1	Chicken	31,738
2	Beef Cattle	13,617
3	Breeding Cow	168
4	Pig	809

1.5.3 Beef Cattle Breeding and Raising

In cattle agricultural business, regional specialization is observed. What farmers who keep beef cattle on Miyakojima Island is basically different from what farmers who keep beef cattle in Matsuzaka city (Beef from Matsuzaka city is one of the three top brands in Japan).

Beef cattle farmers on Miyakojima Island keep breeding cows of beef cattle and have them a birth to calves, and calves are sold in the auction. By selling calves in the auction, the farmers are able to earn most of the revenue for the business. The breeding is conducted by the artificial insemination. The farmers raise the calves for 9 months. Calves are shown in Fig.1.9. The weight becomes 267kg when it is sold. They are sold to farmers in the areas like Matsuzaka city. The objective of this type to keep beef cattle is to increase the number of beef cattle and it is called "breeding".

Fig. 1.9 Calves

The breeding cows of beef cattle are kept for ten years to give a birth to calves for ten years and they are sold in the auction as well. Breeding cows of beef cattle are shown in Fig.1.8. The weight becomes more than 400 kg.

Fig. 1.10 Breeding Cows of Beef Cattle

Farmers in the areas like Matsuzaka city raise the purchased calves for 20 months. The farmers raise them until their weight reach more than 600kg. By then they got mature and they are ready to be slaughtered for human consumption. When they are purchased from the auction to the area like Miyakojima Island, roughages (such as pasturage or agricultural plant which contain the crude fibers) are still given. But the quantity of roughages are gradually decreased, instead the quantity of concentrate feeds are gradually increased. Fig. 1.11 shows the adult cattle. The weight becomes 625kg when it is sold.

Fig. 1.11 Adult Cattle

Next Fig. 1.12 shows the breeding cows which cannot give birth to calves. The weight becomes 550kg when it is sold. They are the same as breeding cows shown in Fig. 1.10 but the difference is that they cannot give birth to calves and the weight is increased by giving concentrate feeds.

Farmers in the areas like Matsuzaka city usually raise those breeding cow and the raising term is 6 months.

Fig. 1.12 Breeding Cow of Beef Cattle which cannot Give Birth to Calves

The objective of this type is to give weight to beef cattle for human consumption and called "raising".

One of the remarkable difference is that for "raising" of beef cattle the farmers only use imported feeds (pasturage) but not feeds created on the island. The reason why the farmers only use imported feeds to maintain the quality of meats. Because the humidity of the island is high, farmers cannot create sufficiently dried hay. Insufficiently dried hay may lower the quality of beef cattle's meat.

1.5.4 Billet Planting and Ratooning of Sugar cane

Billet planting is to plant a cut cane to the ground to grow it: it is the same as cottage. Fig. 1.13 shows "billet planting in summer". Billet planting is conducted in two seasons: it is in spring (March or April) or in summer (August or September). As addressed in subsection 1.5.1 "Harvests and Harvested Areas/ Growing Areas of Agricultural Plants on Miyakojima Island", the cultivation term of sugar cane is one year and half and its cycle is two years on the island.

Fig. 1.13 Billet Planting in Summer

Fig. 1.14 is given to illustrate the cycle of billet planting in summer. After sugar cane is harvested, dried leaves and sugar cane tops are left. The harvesting season is from January to March.They are plowed under for composting. For five month, they are decomposed by microbes in soil. Some farmers purchase the residues from sugar mills like bagasse, filter cake, trash or ashes to be plowed under. The timing for being plowed under is the same as dried leave and sugar cane tops.

In April some farmers like to plant green manure plants like crotalaria (juncea), mung beans and pigeon peas. Approximately one month before the billet planting (i.e. in early August) they are plowed under after they are grown for three or four month. Billet planting is conducted from late August to early September. Therefore this type of sugar cane cultivation is called “billet planting in Summer”. At the same time (one month prior to the billet planting), manure from stockbreeding is plowed under. These are basal fertilizer for sugar cane.

Additional fertilization by chemical fertilizer is conducted in October and December.

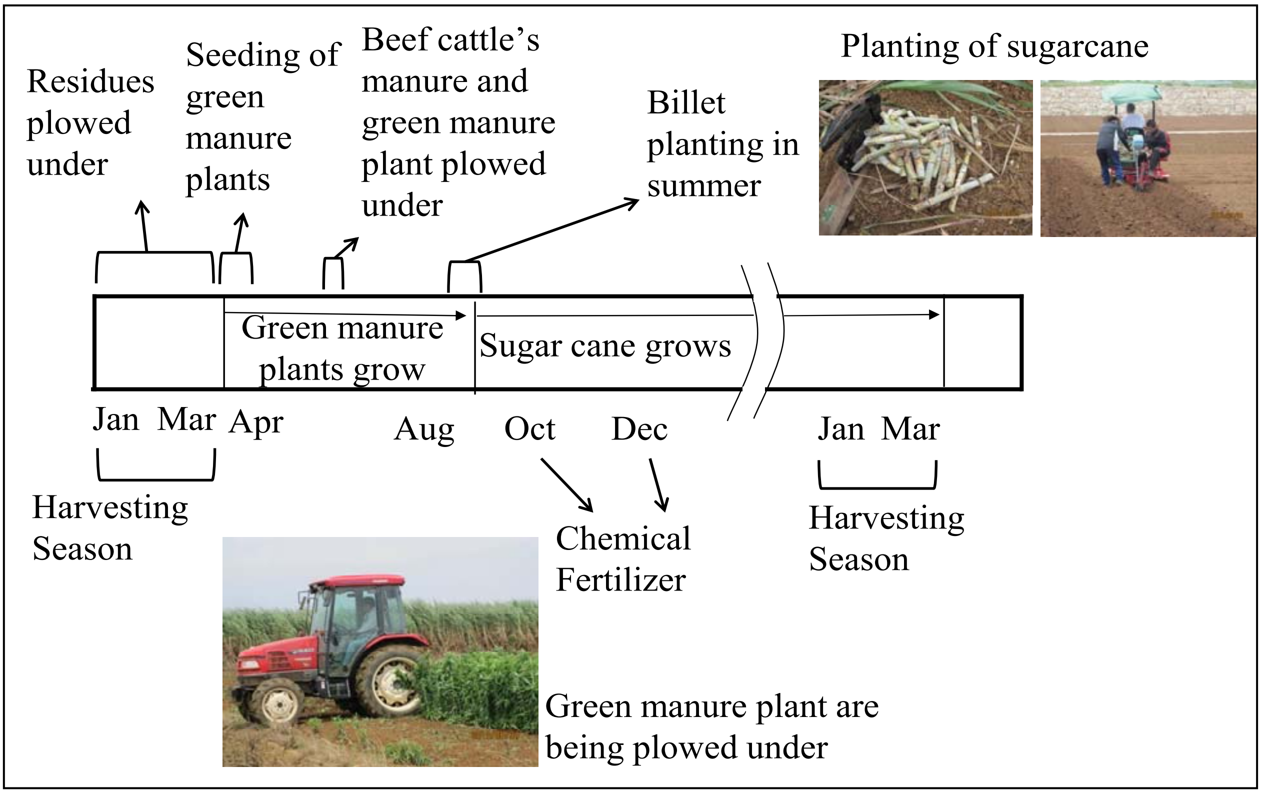

Fig. 1.14 Cycle of Billet Planting in Summer

This research also explains ratooning. Fig.1.15 shows ratooning. The lower parts of sugar cane are cut and some of shoots sprouted from them. In Okinawa Main Island, ratooning is conducted for three years or four years, billet planting in spring is usually conducted for one year. This cycle will be repeated when farmers choose ratooning. When ratooning is conducted, the harvests will be decreased. That is the reason why farmers need to do billet planting every four or five years.

However, ratooning was not conducted for a long time in the past on Miyakojima Island because of soil pest (especially, sugarcane wireworms are known). Because effective baits against the soil pest were developed, more farmers started ratooning from FY 2011. Therefore at this moment it is now clear whether the cycle of ratooning and billet planting in spring will be established on Miyakojima Island or not.

Ratooning is conducted in the areas enclosed by circles.

Fig. 1.15 Ratooning

The cycle of ratooning and billet planting in spring which is observed on Okinawa Mainland is shown in Fig. 1.16. This cycle is commonly found in other areas as well. In harvesting seasons from January to March, the residues from the sugar cane field and sugar mills and beef cattle's manure are plowed under. At the same time, chemical fertilizer is applied. Billet planting is conducted in late March. In the consecutive three years, instead of billet planting, ratooning is conducted. Green manure plants are not utilized. This is one cycle of the cycle of ratooning and billet planting in spring.

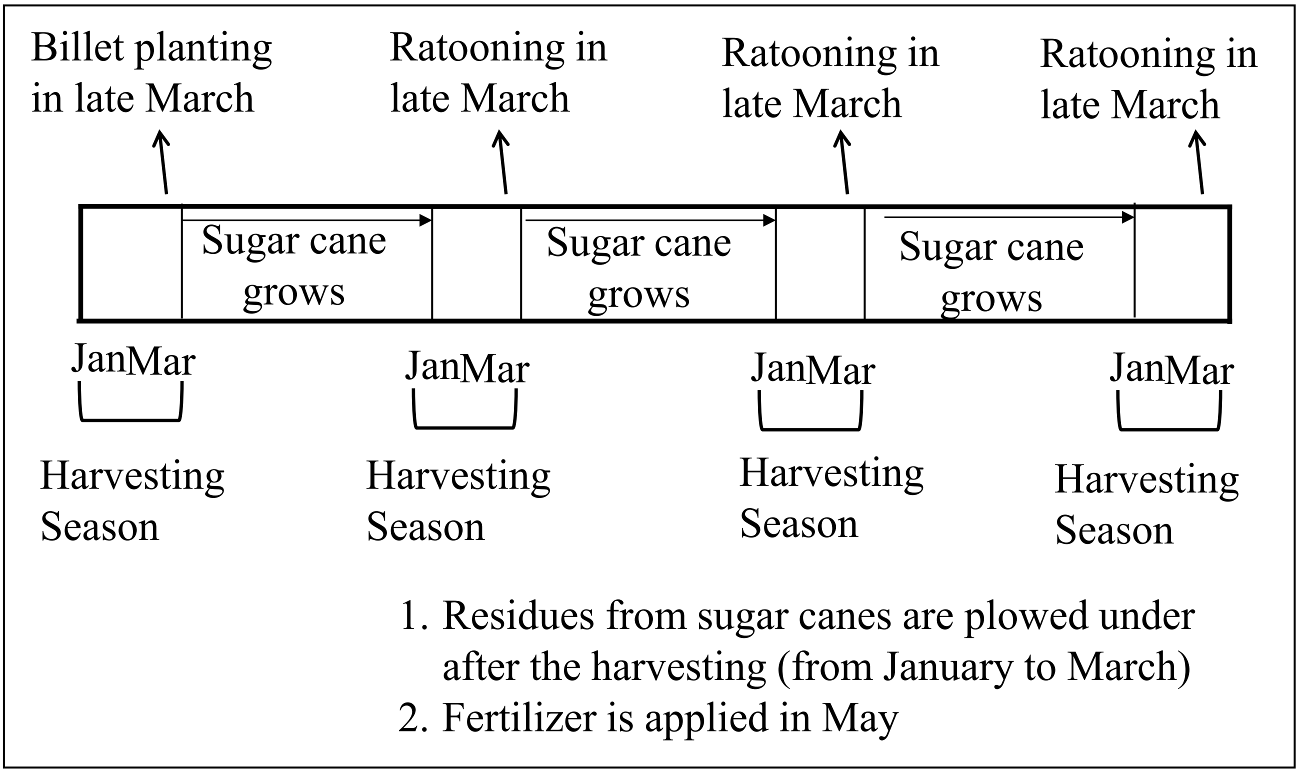

Fig. 1.16 One Cycle of "Billet Planting in Spring" and "Ratooning"

The merit with ratooning is that billet planting in summer usually requires bigger fields than the ratooning because only farmers need to depend on the revenues from the harvest of half sugar cane fields. In FY 2010, the ratooning is still negligible (Japanese FY, Fiscal Year, starts in April and ends in March).

1.5.5 Parts of Sugar Cane and Residue from Sugar Cane Fields or Sugar Mills

The object of this subsection is to introduce parts of sugar cane and residue from sugar cane fields or sugar mills. Fig. 1.17 shows the sugar cane top.

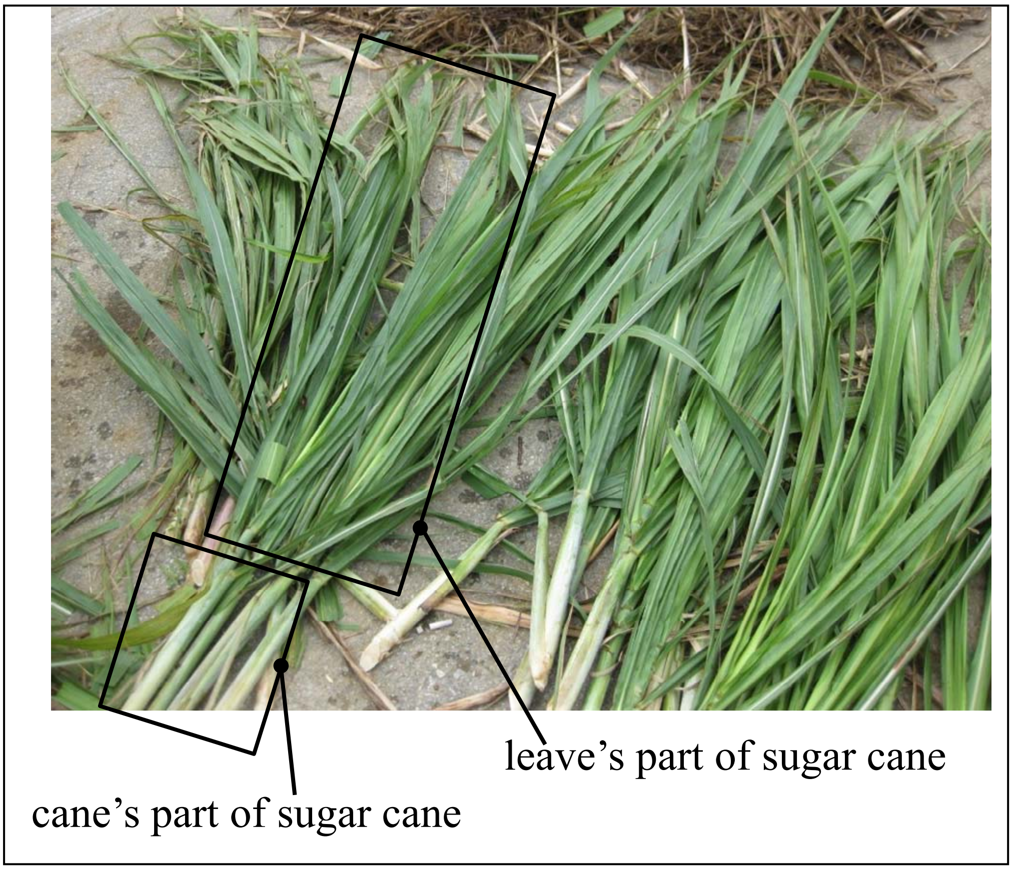

Fig. 1.17 Photo of Sugar Cane Top

It is consisted of two parts: cane's part and leave's part. Cane's part is the extended part of leaves and it contains sugar. When it is fed to beef cattle it must contain this part. But when sugar cane are harvested manually this part is left behind in the sugar cane fields. But when sugar cane are harvested by harvesters, this part is harvested as well. When harvesters are used, sugar cane tops are not left behind in the sugar cane fields. Farmers of beef cattle on Miyakojima Island usually cultivate the sugar cane as well. So farmers of beef cattle who would like to use the sugar cane tops as the feed for beef cattle cut the sugar cane tops before harvesting is conducted.

Also the quantity of biomass resources which are left behind is different between harvesting manually and harvesting by harvesters.

Fig. 1.18 shows the dried leaves left behind in the sugar cane field and trash from sugar mills.

Fig. 1.18 Photo of Mixture of Dried Leaves

Trash from sugar mills is dried leaves collected by harvesters: they are basically identical. The only difference is that trash from sugar mills contains sand particle: sand particles are brown by harvesters and then they stick to dried leaves.

Fig. 1.19 shows filter cake from sugar mills.

Fig. 1.19 Photo of Filter Cake from Sugar Mills

Filter cake is a solid residue obtained from the sugar production. It contains more than 80% of water and more than 1% of sugar. It contains small pieces of bagasse, small amount of molasses and small pieces leaves. It is perishable in the short period of time.

Fig. 1.20 shows bagasse from sugar mills. It is a fiber of the cane part. It is plowed under or is used as a raw material for compost.

Fig. 1.20 Photo of Bagasse from Sugar Mills

Fig. 1.21 shows molasses in the container.

Fig. 1.21 Photo of Bagasse from Sugar Mills

Molasses is a liquid residue obtained from the sugar production. It is exported to the outside of Miyakojima Island and is used as a raw material for stockbreeding feed.

From here on this research deals with the biomass resource ratio against agricultural plant products. Table 1.4 shows percentage for each portion of sugar cane[8].

Table 1.4 Percentage for Each Portion of Sugar Cane

Name of Parts	Proportion (%)
Leave's part of sugar cane top	6
Cane's part of sugar cane top	3.4
Cane	54.6
Dried Leaves	30.2
Roots	5.8

As addressed above cane's part of sugar cane top is harvested by harvesters. This research collected the date from sugar companies on the percentage of manual-harvesting and mechanical-harvesting (harvesting by harvesters) by private communication. Manual harvesting percentage for sugar company A is 80% while the percentage for sugar company B is 75%. The sugar cane quantity which sugar company A accepted was 163,868t/y whereas the sugar cane quantity which sugar company B accepted was 136,432t/y. With these quantity and Table 1.4, this research is able to obtain the quantity of sugar cane tops and dried leaves. The quantity of residues from sugar mills was able to be obtained from the sugar companies. They sold all residues to farmers or composting facilities and they tracked the quantity of each residue. Note that the roots were not targeted for the convenience of this research.

Table 1.5 shows the proportion of the biomass resources against the harvested products[8].

Table 1.5 Proportion of the Biomass Resources against the Harvested Products

Name of Agricultural Plant	Proportion against Harvested Products (%)
Tobacco	33
Squash	150
Chinese preserving melon	150
Bitter melon	150
Mango	N/A (Different scale)

Biomass resources references by this research are stems and leaves. Regarding mango, the biomass resources are obtained by the harvested area[9]. The biomass resources are wastes from pruned trees (i.e. they are branches). The quantity of them ranges from $3g/m^2$ to $2036g/m^2$ and this research adopts the median as the target value.

1.6 Activities for Sustainability and the Independency on Miyakojima Island

1.6.1 Activities on Zero Emission and Environmental Projects on Miyakojima Island

Miyakojima City Hall got involved with the Zero Emission activities in the past[10]. It was initiated by United Nations University in 1994 as the Zero Emissions Research Initiative (ZERI). That it would like to promote is “that all industrial inputs can be completely converted into a final product and that waste products can be converted into value added inputs for another chain of production”. This means all products should be consumed and no wastes should be generated from them. “Another chain of production” leads to clustering of multiple industries. If one industry thinks of something as wastes, the other industry thinks of it as useful things.

In 1999, UNU/ZERI changed its name to the Zero Emissions Forum (ZEF). Scientist groups set three objectives: research, capacity–building, and networking. The forum’s activities are focused on the zero emissions concept from a "governance for local and regional sustainability" perspective. The forum is underpinned by the assumption that sustainable practices must be adopted at all levels of society and by all actors within a community such as local government, business, and civil society. This research also adopts “governance for local and regional sustainability” as the core concept.

Miyakojima Island hosts the Zero Emission Forum in 2008[11]. In that forum, efforts for composting and biodiesel project were discussed.

On Miyakojima Island, there are several environmental projects are going or were held as follows:

1). Biomass Town Initiative under Ministry of Agriculture, Forestry and Fisheries of Japan[12]

2). Bioethanol Experiments of Ministry of Environment and Ministry of Economy, Trade and Industry[13]

3). Smart Grid Experiment of Resources and Energy Agency [14]

4). Eco-Model City Project under Cabinet Office [15]

5). Next-Generation Energy Park of Ministry of Economy, Trade and Industry [16]

Biomass Town in 1) is the town in which generation of biomass generation points and utilization points efficiently connected under the close management of the relevant players and in which and stable and appropriate biomass utilization is conducted because the comprehensive management system is built up.

Regarding Bioethanol Experiments in 2), the bioethanol were created from molasses and sold in the gas stations. The experiment facility was built up first (with the implementation facility built up, it was torn down) and, based on the result, the implementation facility was built up. It was completed in 2011. The implementation facility is shown in Fig. 1.22. It was discussed in "Environmental and socio-economic assessment of local biomass projects: A case of a bioethanol project in Miyako Island" by Katsuyuki Kikuchi and Hiroki Hondo in 2010[17].

Fig. 1.22 Bioethanol Facility

Regarding "Smart Grid Experiment" in 3), photovoltaic generation by solar panels and wind-power generation by wind mills are working and the control system is experimented to control the unstable power generation by them. It seems that 30 % of power generation for the entire demand of the island would be possible[18].

As addressed above, Miyakojima Island seems to promote the activities in a positive manner. Regarding the biomass, it has created a public composting facility called "Miyakojima City

Resources Recycling Center" by the financial support from Ministry of Agriculture, Forestry and Fisheries of Japan. Its MFA will be shown and its role will be discussed later.

1.6.2 Independency on Miyakojima Island

One of the reasons why Miyakojima Island was targeted for this research was its potential for the sustainability. It has an independent history and culture from Okinawa Main Island. Considering the population, it has a large area for the agriculture which supports the human activities. One episode is found in "Okinawa not for Sightseeing" from Koubunken Co., Ltd[19]. The part for Miyakojima Island was written by Mr. Masaji Nakasone, the director of Miyakojima Multidiscipline Museum and a committee member of the local history study associate for Miyakojima Island.

After World War II, people on the island was forced to be independent without any support from the U.S. government and Japan. Sugar, pigs and dried bonito were exported for trade. According to elderly farmers, they cultivate sugar cane mainly in the past but they also cultivate more sweet potatoes than now instead of rice. Even now, people on the island cultivate various vegetables only for the self-support. The area is only approximately 0.5 are or so but they still try to make a living by themselves.

1.7 The Previous Major Researches

1.7.1 Researches by National Institute for Rural Engineering

This research has the previous researches. Researcher in National Institute for Rural Engineering conducted the research which put the focus on biomass utilization, environmental impact study, and environmental measure evaluations in the agricultural fields. Researches 2-5 deal with the agriculture on Miyakojima Island. This research refers to the carbon and nitrogen conversion factor from the reference 1. The reference 1 has the information on references which are related to biomass resources and it was referenced as well. The research 1 and 4 have the analysis results which this research was not able to and they are referenced as well. When the methodology used in those researches is adopted (except for the carbon conversion factor and the nitrogen conversion factor), the material balance is not able to be performed. Therefore this resarch tried to find the way to realize it.

1. Masato Nakamura and Yoshito Yuyama, "Data Base Streamlining on Various Biomas Compositions" 2005, Technical Report of National Institute for Rural Engineering Vol.203: pp.57-80

2. Yan Chen, Masahiko Taira, Yoshinobu Kawam and Yoshiyuki Shinogi, "A Study on Improving Crop of Sugarcane and Reducing Nitrate Nitrogen Losses-Utilization of biomass charcoal on Miyakojima Island-", 2005, Journal of the Japanese Society of Irrigation, Drainage and Rural Engineering, Vol. 251, pp. 501-506

3. Yutaka Kanri, Yoshiyuki Shinogi and Kiyotaka Tahara, "Development of Simulator for Assessing Environmental Impacts of Agriculture on Miyakojima Island", 2006, Journal of Life Cycle Assessment, Japan Vol. 2(4), pp. 386-394

4. Yutaka and Kanri and Yoshiyuki Shinogi, "Study of Cattle Manure Application on Miyakojima Island at Present", 2006, Technical Report of National Institute for Rural Engineering Vol. 204: pp.203-210

5. Yoshiyuki Shinogi and Koji Kameyama, "Case Study of Sustainable Agricultural and Rural Development at Miyakojima Island, Japan", 2007, Journal of the Japanese Society of Irrigation, Drainage and Rural Engineering, Vol. 75(7), pp. 603-607

6. Yoshiyuki Shinogi, Teruhito Miyamoto, Koji Kameyama and Yan Chen,
"Regional Vitalization with Biomass, Case Study at Miyakojima, Okinawa, Japan", 2009, Journal of the Japanese Society of Irrigation, Drainage and Rural Engineering Vol.77(8), pp.

623-626

1.7.2 Researches on Fertilization and Nitrate Nitrogen Pollution to the Ground Water on Miyakojima Island by Dr. Nakanishi

Associate Professor Nakanishi from Miyakojima Farm, Tokyo University of Agriculture made the researches on the nitrate nitrogen pollution to the ground water. He conducted the investigation about the fertilization by farmers on Miyakojima Island. He worked with the scholars in University of Tokyo and measured the nitrogen stable isotope ratios. As a result of the measurement, he argues that the fertilizers, stockbreeding manure and human wastes are the major sources of the nitrate nitrogen pollution to the ground water.

This research does not determine what the sources for the nitrate nitrogen pollution to the ground water are but this research can show what the potential sources for the pollution as a deliverable of the MFA are.

Regarding fertilization by farmers on the island, the result of the interviews conducted by this research is corresponding to his research result. The quantity of the stockbreeding manure which his research finds is larger than the quantity which this research finds.

1. Youji Yamamoto , Kwang-Lai Park, Yasuhiro Nakanishi and Shigeru Kato
"Nitrate Concentrations and σ15 N Values of Ground Water in the Miyakojima Island", 1995, Japanese Journal of Soil Science and Plant Nutrition, Vol.66(1), pp.18-26

2. Yasuhiro Nakanishi, Youji Yamamoto, Kwang-Lai Park, Shigeru Kato and Kikuo Kumazawa, "Estimation and Verification of Origins of Groundwater Nitrate by Using δ15 N Values", 2001, Japanese Journal of Soil Science and Plant Nutrition, Vol.66(5), pp.544-551

3. Yasuhiro Nakanishi, Kaneshi Takahira and Kuniki Shimoji, "Estimation of Nitrogen Loading Factors for Groundwater by Multiple Regression Analysis", Japanese Journal of Soil Science

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4. Yasuhiro Nakanishi, “Correlation between Actual Fertilizing to Sugarcane and Nitrate Concentration in Groundwater of Miyakojima Island, Okinawa”, 2001, Japanese Journal of Soil Science and Plant Nutrition, Vol.72(4), pp.499-504

1.7.3 Researches on Pasturage, Sugar Cane and Green Manure Plants by Okinawa Prefectural Government

Okinawa prefectural government has Okinawa Prefectural Agricultural Research Center for agricultural plants and has Livestock and Grassland Research Center for stockbreeding. Okinawa Prefectural Agricultural Research Center makes the researches on sugar cane growth, green manure and fertilizer application standard and this research is based on their achievements. From Livestock and Grassland Research Center, this research references the compositions and yield information on pasturage in the websites or through private communication.

1. Toshiyuki Zakimi, “Green Manure Plant Tests in Vacant Fields after Harvesting of Sugar Cane”, 2000, A Research Report of Okinawa Prefectural Agricultural Research Center, pp.322-333

2. Kazuhiko Tarora. Naoko Miyamaru, Moriya Ota, Masato Ishjmine, “Effects of Green Manure Crops on the Growth of Next Summer-Planted Sugarcane in Early Stages”, 2005, Report of the Kyushu Branch of the Crop Science Society of Japan, Vol. 71, pp.75-77

3. Mineko Kuba, “Fertilizer Reduction about Sugar Cane Cultivation”, 2011, Tokusan Shubyou Vol.12, pp.107-112

4. Akemi Higa, Yasushi Gima and Yasushi Gima, Influences of Long-Term Successive Application of Organic Matters on the Yield of Sugarcane and Soil chemical and Physical Properties, 2011, Bulletin of the Okinawa Prefectural Agricultural Research Center, Vol.(5), pp.11-15

1.7.4 Researches on Material Cycles by Professor Fujie

The researches of Zero Emission suggested that our society should move to the material cycle based society. Reference 1-3 discussed the ways to move to material cycle based society.

1. Naohiro Goto, Yukari Naito, Hong-Ying Hu and Koichi Fujie, "Analysis and Assessment of Material Flow in Aichi Prefecture for Zero Emission" , 2001, Environmental science Vol. 14(2), pp.211-219

2. Koichi Fujie, Naohiro Goto, Yuzuru Miyata, Akiyoshi Sakota, Keisuke Hanaki, Sachihiko Harashina, Shunsuke Mori, Kenichiro Yanagi, Shin Ikeda, Tadashi Hano, Hiroyuki Yoshida, "Establishment of regional material cycle network and methodology of scenario proposal for zero emission" 2001, Vol. 14(4), pp.391-401

3. Yakushima Project Working Group, "Zero Emission Yakushima Project – Scenarios Moving to Material Cycle Based Society" 2004, (Kaizosha Co., Ltd.)

The following remarkable points in reference 2 are useful for the discussion in this research[20]:

- Each production process should be closed on-site and should reduce the quantity of wastes.
- Hierarchical utilization of wastes based on the characteristics of unused materials should be realized; with the implementation of new technology, clustering of multiple industries should be made by utilizing unused materials as raw materials for products and by

changing them into valuables.

- To promote those measure, incentives for zero emission should be awarded to players.

This research interprets “each production process should be closed on-site” as the importance of material cycle and reduction of the imported materials. It can leads to the independency of the system, in this case, the agriculture on Miyakojima Island. This research interprets “clustering of multiple industries should be made” as the importance of the connection between the agriculture and other fields (industries).

Reference 3 is prepared based on researches of Zero Emission Yakushima Project and it shows the following 6 scenarios:

a. Scenario to reduce the imported materials from the outside of the island
b. Scenario to utilize unused materials
c. Scenario to independency of energy and hydrogen energy system society
d. Scenario to independency of economics
e. Scenario to sustainable tourism
e. Scenario to consensus building system

The focus of this research is placed on “Scenario to reduce the imported materials from the outside of the island” and “Scenario to utilize unused materials”.

1.7.5 Researches on Phosphorus Utilization by Mr. Maesato

Mr. Maesato from Miyako Technical High School conducts the research on the re-utilization of phosphate trapped in the soil. Phosphorus applied to the fields stays as calcium phosphate. Much of phosphorus is applied to the agricultural plants and stays in the soil. To re-utilize the phosphorus in the soil, composts and organic fertilizers needs to be applied to the field. By the activities of phosphate solubilizing bacteria and fungi, phosphorus in the soil as calcium phosphate is available to the agricultural plants. His researches suggest that the application of organic matters to the soil would increase the sugar content of sugar cane and the yield of agricultural plants. His research would give support to the basic position this research: utilization of biomass resources should be advanced more.

1. Kazuhiro Maesato, "Studies on the Utilization of the Accumulated Phosphate in Soil in Shimajiri-mahji" 1999, Journal of Okinawa agriculture, Vol.33, Issue 2, pp.2-8

2. Kazuhiro Maesato, Kawamitsu Yoshinobu, Masami Ueno, Yasuaki Komiya, Junichi Kugai, Junichi Kugai and Masaren Cho, "Studies on the Utilization of the Accumulated Phosphate in Dark-Red Soil (Shimajiri-mahji) : V. The Effect of Components of Bagasse Acid on the Growth and Quality of Sugarcane",2002, Japanese Journal of Crop Science Vol.71, Issue 2, pp.118-119

3. Kazuhiro Maesato, Kawamitsu Yoshinobu, Masami Ueno and Seiichi Murayama "Studies on the Utilization of the Accumulated Phosphate in Dark-Red Soil (Shimajiri-mahji) : IV. The Effect of Phosphorus on the Growth and Quality of the Continuous Cropping Sugarcane", Japanese Journal of Crop Science, 2002, Vol. 71. Issue 2, pp.116-117

4. Kazuhiro Maesato, Kawamitsu Yoshinobu, Masami Ueno, Naoko Uehara and Seiichi Murayama "Studies on the Utilization of the Accumulated Phosphate in Dark-Red Soil (Shimajiri-mahji): III. The effect of phosphorus on the growth of eggplant and green pepper", 2000, Japanese Journal of Crop Science, Vol. 69, Issue 2, pp.176-177

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2000, Japanese Journal of Crop Science, Vol. 69, Issue 2, pp.174-175

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1.8 Summary of the Discussion in Chapter 1

Topographical and statistical data of Miyakojima Island were provided in Section 1.2. The underground structure of Miyakojima Island was demonstrated in Section 1.3. Sugar cane cultivation on the island was explained in 1.5.1, 1.5.4 and 1.5.5. Parts of sugar cane were introduced and the differences between billet planting and ratooning were clarified. The differences between breeding and raising was explained. Beef cattle's raising only use imported feeds whereas beef cattle's breeding is able to use pasturage created on Miyakojima Island. Beef cattle's raising depends more on imported feed than beef cattle's breeding. Regarding environmental activities of Miyakojima Island, activities related to Zero Emission was addressed and an example showing the potential of the island was addressed. This research showed the major references of the present dissertation such as researched by National Institute for Rural Engineering, Dr. Nakanishi, Okinawa Prefectural Government, Professor Fujie and Mr. Maesato.

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8) *A Report for Biomass Unused Energy Business Survey*, 2006, Miyakojima City Hall

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11) Zero Emission Forum Website, Accessed December 26, 2013, http://archive.unu.edu/zef/events_j.html

12) Website of Miyakojima City "Miyakojima City Biomass Town Initiative" Accessed December 26, 2013, https://www.google.com/#q=%E5%AE%AE%E5%8F%A4%E5%B3%B6+%E3%83%90%E3%82%A4%E3%82%AA%E3%83%9E%E3%82%B9%E3%82%BF%E3%82%A6%E3%83%B3%E6%A7%8B%E6%83%B3

13) Okinawa General Bureau, Cabinet Office　Website "Miyakojima Island Bioethanol Island Initiative" , Accessed December 26, 2013,

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Chapter 2 Material Flow Analysis for Stockbreeding

2.1 Objectives for Chapter 2

Our tasks in this chapter are to performs the following two tasks with respect to agriculture and stockbreeding on Miyakojima Island: 1) Quantifies stockbreeding with material flow analysis methodology, 2) Establishes the base for values of basic units used to build up an agricultural production system which are discussed in Chapter 4 and 5.

2.2 Methodologies for Material Flow Analysis for Stockbreeding

2.2.1 Methodologies to Obtain the Information and the Composition

For the Material Flow Analysis(hereafter, MFA) for stockbreeding, we conducted the following tasks; (1)interviewing farmers or city hall officials who are involved in the stockbreeding; on-site investigations; (2)obtaining statistical data, government documents, and stockbreeding farmers' administrative documents; and lastly, (3) Newspaper articles available to the public are referenced. For the determination of water content, freeze dryer is utilized.

Many items are the targets for the MFA. This research confronted the following issues when it tries to figure out the compositions of the targets: The number of stockbreeding feeds on the market in FY 2010 is more than 50; the number of fertilizer on the market is more than 200; some of them such as the live bodies of stockbreeding are hard to be analyzed; some of concentrate feeds for stockbreeding are discontinued for manufacturing on the market; basically products need to be purchased for analysis.

This research obtained the nitrogen content of feeds from the crude protein content (hereafter, CP). Stockbreeding thinks of crude protein content information as one of the most important figures in the business. The CP content is the first reference to select their feed for stockbreeding. The information on CP content is readily accessible when we make the material flow for the stockbreeding. Note that the CP content is not obtained by analytical methods directly: After obtaining the nitrogen content by Kjeldahl method, CP content can be obtained by multiplying it with nitrogen-to-protein conversion factors (hereafter, NPCF). The Kjeldahl method can be given as follows: the oxidation decomposition is caused in the sample to generate ammonium ion; then it is possible to determine the quantity of the ion. Generally speaking, because the CP of foods contains 16% of the nitrogen, the NPCF is 6.25. Some foods like rice or meat have, different factor, 5.92. NPCFs for various materials can be obtained from the amino-acid composition[1 2 3].This research uses the factors shown in Table 2.1[1 2].

Table 2.1 Nitrogen-to-protein conversion factors

	meat (live cattle body)	dairy product (milk for calves)	the others
NPCF (nitrogen-to-protein conversion factor)	5.55	6.38	6.25

In the same way, to obtain the carbon concentration, we will use either (1), (2) or (3) factor from the following table. This is originated from the reference "Data Base Streamlining on Various Biomass Compositions"[3].

Table 2.2. Conversion factors to obtain carbon contents

(1)	total carbon＝(soluble sugar content starch + hemicellulose + cellulose) × 0.435 + lignin×0.65+crude protein×0.53+ crude fat×0.77
(2)	total carbon ＝ all carbohydrate×0.435 + crude protein×0.53 + crude fat×0.77
(3)	total carbon ＝ all carbohydrate×0.435 + protein×0.53 + fat×0.77
Note: 1) all carbohydrate ＝ crude fiber + NFE(nitrogen free extract) 2) soluble sugar content starch ＝ all carbohydrate － NDF (neutral detergent fiber) 3) hemicellulose ＝ NDF (neutral detergent Fiber) － ADF (acid detergent fiber) 4) cellulose ＝ crude fiber 5) lignin ＝ ADF －crude fiber	

Fig. 2.1 illustrates the feed bag. The composition information is shown on the left side of the bag while the mixture of the raw materials for the feed is shown on the right side. The venders

have the documents for the same information. With them, it is possible to estimate the carbon content.

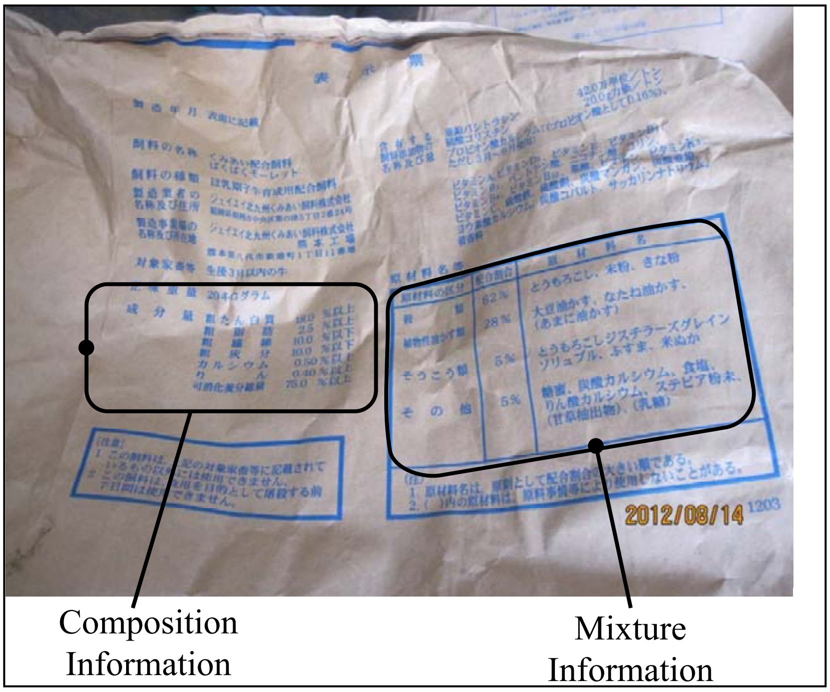

Fig. 2.1 Composition Information on a Feed Bag

Here this clarifies the sources for MFA of beef cattle and pasturage. All most all pasturage is consumed by beef cattle.

First we discuss the input to the beef cattle and the pasturage. We partially discuss residues from sugar mills and sugar cane fields. The information on CP of pasturage was obtained from the report on pasturage by Okinawa Prefectural Livestock Research Center or other prefectural governments, agricultural laboratories and the research paper on pasturage, etc. The weight of pasturage is obtained by the combination of pasturage yield per 10 are and areas for each pasturage cultivated on Miyakojima Island. The former information is obtained in the same way as the information on CP of pasturage whereas the latter information is obtained from Miyakojima city hall.

The information on the weight of cattle feeds imported from the outside of the Miyakojima

Island was obtained from Japan Agricultural Cooperatives (hereafter, JA) Miyakojima District, two stockbreeding feed dealers and two farmers for the beef cattle. Because we were not able to obtain detail information from two cattle feed dealers, we had to assume that they deal with the same products as JA Miyakojima District does for the convenience of the discussion. Two farmers provided the information on the weight. The information on CP of cattle feed products which JA Miyakojima District deals with is obtained in the website of cattle feed manufacturers, higher organizations of JA. For some products, we contacted manufacturers directly. Parts of the information of CP of cattle feed products are provided by JA Miyakojima District and JA Okinawa in Okinawa Main Island. The information on the quantity of the residues generated from sugar mills is provided by two sugar companies. The information on CP of bagasse, molasses and sugar cane tops are obtained from "Standard Tables of Feed Composition in Japan" and " Standard Tables of Food Composition 2010"[1 2]. We analyzed the filter cakes. The information on the content of trash and sugar cane tops are from "Feedipedia"[4] .

We next discuss the output from beef cattle. Regarding the weight information, we obtained the weight information from Miyako Meat Center and JA Miyakojima District. Because the information provided from Miyako Meat Center provided us with the weight of dressed carcass. The information on the average weight is obtained from the article on calf auction covered by the local newspaper[5]. The information on CP of living cattle or calves is obtained in the past study[6] and Miyako Meat Center. The information on the number of calves and cattle is obtained from Miyakojima city hall. Regarding the CP and weight of the diseased cattle, we employ the information on living calves and cattle. The information on the number of diseased calves and cattle was obtained from JA Miyakojima District. The nitrogen content of manure and urine from cattle is obtained from the past study[7]. The information on the number of calves and beef cattle is obtained from Miyakojima city hall. Regarding the CP and weight of the diseased cattle, we employ the information on living calves and beef cattle. The information on the number of diseased calved and beef cattle was obtained from JA Miyakojima District. The nitrogen content of manure and urine from cattle is obtained from the past study [7 23 24]. Gas like CO_2 or CH_4 is obtained the formula shown in the Table 2.3. Th e quantity of manure and urine is gained with the formula in Figure 2.4.

Table 2.3. Sources of Information for the MFA of Beef Cattle

The information sources for the MFA of beef cattle			
item	references	private communications	others
number of four t ypes of cattle	n/a	Miyakojima city hall	n/a
weight of fo ur types of cattle	5	Miyako Meat Center and JA Miyakojima District, beef cattle farmers	n/a
information for N, C and P content of live body of beef cattle	6	n/a	n/a
quantity of pasturage(yield per 10 are)	8, 9, 10,11,12, 13, 14, 15, 16, 17, 18	n/a	quantity of p asturage = yield per 10 are × areas
quantity of pasturage (areas)	n/a	Miyakojima city hall (areas)	quantity of pasturage = yield per 10 are × areas
information for N, C and P content of pasturage	4, 19 , ,20 21, 22	Okinawa Prefectural Livestock Research Center	n/a
quantity of residues from sugar mills	n/a	two sugar mills	n/a
quantity of consumed sugar cane tops	n/a	beef cattle farmers	n/a
quantity of consumed bagasse	n/a	two sugar mills	n/a
information for N content of residues from sugar mills	1(bagasse)	n/a	elemental analysis (filter cake and trash)
quantity of manure and urine	n/a	n/a	formula in Figure 2.3
information for N, C and P content of manure and urine	7, 23, 24	n/a	n/a
gas from beef cattle	n/a	n/a	=(all input of C) – (all other output of C)
quantity of imported feeds	n/a	JA Miyakojima District, two beef cattle feed deal ers, farmers for beef cattle	n/a
information for N content of imported feeds	1, 25, 26, 27 , 28 , 29, 30	JA Miyakojima District, JA Okinawa in Okinawa Main Island	n/a
information for C content of imported feeds	1	JA Okinawa in Okina wa Main Island	n/a

quantity and of milk for calves	31	n/a	n/a
information for N, C and P content of milk for calves	2, 29	n/a	n/a
number of beef cattle	n/a	Miyakojima city hall	n/a

Information sources for other stockbreeding ar e shown below. We briefly address su mmary of how the information was obtained.

We address the input to the stockbreeding. The information on feeds are obtained from JA Okinawa Mainland and the private co mmunications with far mers for each ty pe of stockbreeding.

We next address the output from the stockbreed ing. The infor mation on the weight o f stockbreeding was obtain ed from Miyako Meat Center and t he private communication with farmers. The inform ation on living body's c ontent is obtained fro m the past studies. The information on the Gas like CO_2 or CH_4 is obtained the formula shown in the Table 2.3. The quantity of manure and urine is gained with the formula in Fig. 2.4.

Table 2.4. Sources of Information for the MFA of the Other Stockbreeding

The information sources for the other stockbreeding			
weight of stockbreeding	n/a	the farmer(dairy cattle, chicken), Miyako Meat Center(pig)	n/a
information for N, C and P content of stockbreeding's live body	5, 32(pig P content only) 33(chicken P content only)	n/a	n/a
quantity of manure and urine of stockbreeding	n/a	n/a	formula in Figure 2.3
information for N, C and P content of manure and urine of stockbreeding	6, 23, 24	n/a	n/a
quantity of feeds for stockbreeding	n/a	Farmers for each type of stockbreeding	n/a
information on N, C and	1, 2	JA Okinawa Mainland	n/a

P content of feeds for stockbreeding		(about label of the product)	
gas from stockbreeding	n/a	n/a	=(all input of C) – (all other output of C)
quantity of residues from sugar mills/ from sugar cane field	34	two sugar companies, a composting facility	n/a
quantity of residues from fishery and its N, C and P contents	2	a composting facility	n/a
quantity of residues from pruned trees and its N, C and P contents	n/a	a composting facility, Miyakojima City Hall	elemental analysis
quantity of lees from Awamori Plants/ Residues from Methane Fermentation Plants	n/a	a composting facility, Miyakojima City Hall	n/a
N, C and P content of lees from Awamori plants/ residues from methane fermentation plants	1, 35	n/a	elemental analysis
quantity of food wastes and its N, C and P contents	2, 36	Miyakojima City Hall	n/a

2.3 Material Flow Analysis for Four Types of Beef Cattle

2.3.1 Material Flow Analysis for Calf of Beef Cattle

Now we are in a position to present the MFA results of 1) calves (younger than 10 months age), 2) adult cattle (raised for 20 months after 9 month raising as calf), 3) breeding cows (giving a birth to calves) and 4) breeding cows which cannot give a birth to calves (after 10 time calving)[37]. Discussions in subsection 2.3.1-2.3.5 are based on "An Evaluation of the Cattle Raising Business in Miyakojima Island: Material Flow Analysis about Four Types of Cattle Raising". Note that the mass balance of nitrogen, carbon and phosphorus are performed.

Firstly this research deals with a calf shown in Fig. 2.2 and Fig. 2.3. The target period for the MFA is 9 months. The target period is the life time on Miyakojima Island as a calf. At 9 months, they are sold in the auction and go to the outside of Miyakojima Island. When they are sold, its weight reaches 267kg[4]. The number of calves is 5,941 and it is the second largest cattle on Miyakojima Island. Manure generated by a calf is 11.7kg/day. The way how the amount of manure is obtained is given below. According to "Newly Edited Stockbreeding Great Encyclopedia"[24], cattle generates 15 kg manure per one day. The quantity of manure from a calf per 1day is close to it. Therefore this research finds that this can be considered as a supporting argument for the MFA. This research refers to it to check the validity of our MFA, regarding the other types of cattle as well. Regarding the input, "imported concentrate feed", "imported pasturage" and "pasturage" constitute the major portion of the input. Some of calves can be diseased accidentally and it is included in the MFA. This is tricky because the MFA has to show the quantity of materials is lost by the diseased calf. Some portion of carbon is lost by breathing or digestion as carbon dioxide or methane.

Table 2.5 is given to confirm the mass balance for calves.

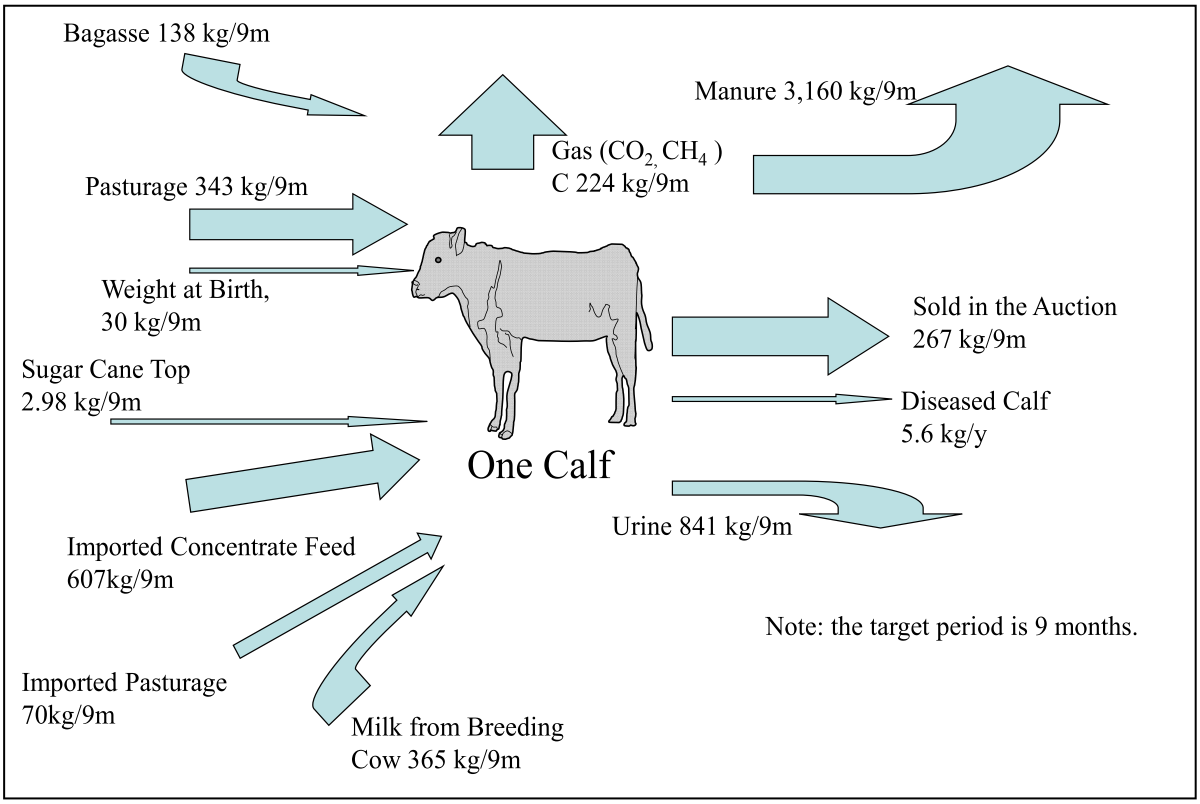

Fig. 2.2 MFA for Calves (Weight Basis)

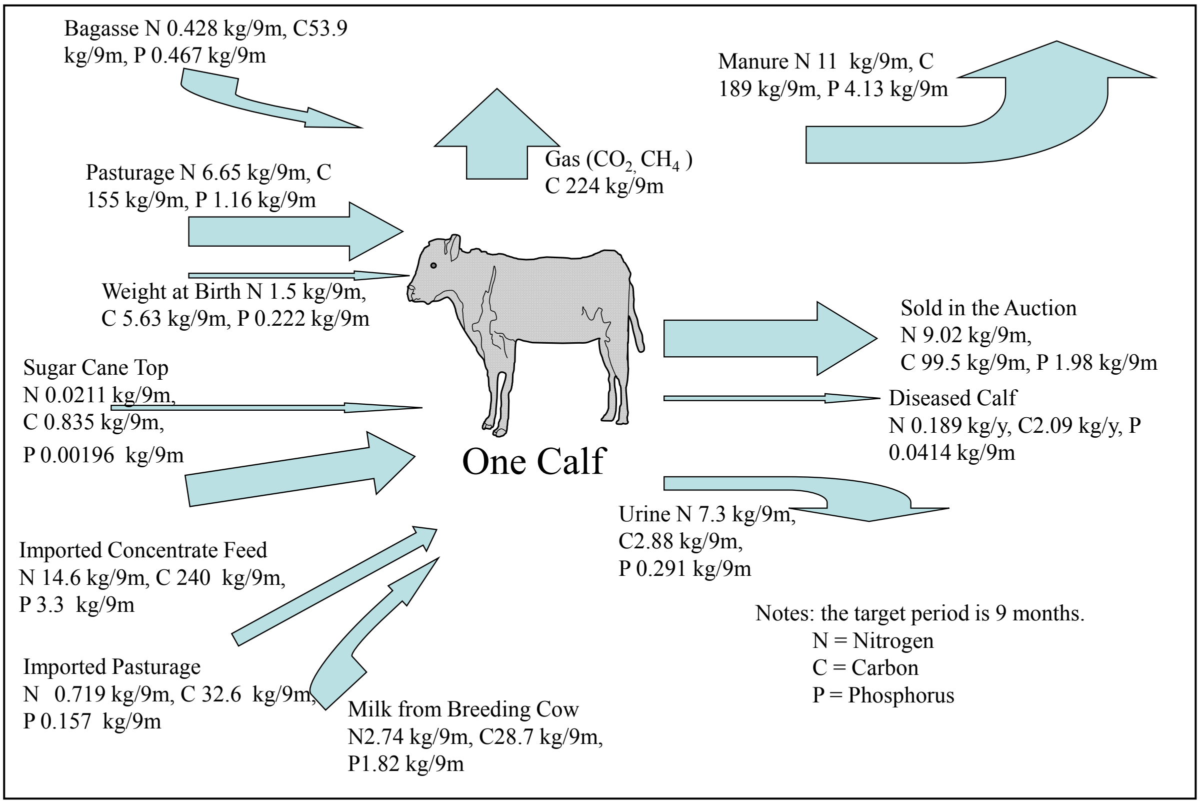

Fig. 2.3 MFA for Calves (Element Basis)

Table 2.5 Mass Balance for Calves

Unit = kg/9m	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Bagasse	0.428		53.9		0.0467	
Pasturage	6.65		155		1.16	
Weight at Birth	1.5		5.63		0.222	
Sugar Cane Top	0.0211		0.835		0.00196	
Imported Concentrate Feed	14.6		240		3.3	
Imported Pasturage	0.8		32.6		0.157	
Milk from Breeding Cow	2.74		28.7		1.82	

Gas (CO_2, CH_4)				224		
Manure		11		189		4.47
Sold in the Auction		9.02		99.5		1.98
Diseased Calf		0.189		2.09		0.0414
Urine		6.73		2.88		0.291
Total	26.7391	26.939	516.665	517.47	6.70766	6.7824

Here we are in a position to show "Formula to obtain the quantity of manure and urine of stockbreeding" in Table 2.6. This formula is designed not only to one of stockbreeding but to all of stockbreeding. In this research the mass balance of the nitrogen, carbon and phosphorus in the MFA for the present research should be performed. One of the benefits is that the formula allows us to perform the mass balance in the MFA. We are also able to get the quantity of manure and urine in accordance with the nitrogen quantity of the input into the stockbreeding when the mass balance of the nitrogen, carbon and phosphorus is performed. For example, adult cattle is given more feeds and nitrogen than calves: accordingly adult cattle generates more manure than calves. Formula in Table 2.6 allows us to obtain the quantity of stockbreeding's manure and urine from the quantity of the nitrogen assigned for manure and urine. The quantity of the nitrogen assigned for manure and urine is obtained from the equation in (1). Each quantity of manure and urine is obtained from the equations in (2) and (3). For example, variable X is 11kg/9m in Table 2.6 of manure and Y is 7.3 kg/9m of urine in Table 2.6. Variable V1 is the nitrogen quantity of "bagasse", which is 0.428 kg/9m. W1 is "Sold in the Market", 9.02kg/9m. The constants a, b, c and d are shown in Table 2.7. Regarding Table 2.6, the value 0.0035 for constant "a" and 0.008 for constant b is used. Therefore variable T is 3,160 kg /9m while variable U is 841 kg/9m.

We are also able to get the quantity of manure and urine in accordance with the nitrogen quantity of the input into the stockbreeding when the mass balance of the nitrogen, carbon and phosphorus is performed. For example, adult cattle is given more feeds and nitrogen than calves: accordingly adult cattle generates more manure than calves. The formula in Table 2.6, has another benefit. The quantity of manure obtained from stockbreeding farmers tends to be smaller than the quantity in the reference. ("Stockbreeding Great Encyclopedia" says the quantity of pig's manure is 3 kg/day but the actual quantity the farmers give 1 kg/ day). Stockbreeding farmers on Miyakojima Island keep a log when they sell manure to farmers of agricultural plants like sugar canes. But at that time, manure is stored for the certain period of times and the quantity got smaller than the fresh manure. Manure was dehydrated and decomposed if it was stored in the outside. Also in accordance with the weight of stockbreeding, the quantity of manure is different. Although it is not easy to measure how much the quantity of manure is (it is true of the quantity of urine as well), the formula gives us more probable quantity of the manure and urine: The values of the constant a, b, c and d are shown in Table 2.3[3, 4, 21]:

(1) X + Y = Z – (W1 + W2 + ... + Wn)

(2) X/a: Y/b= c:d

(3) T = X/a, U = Y/b

Where:

Z = V1 + V2 + ... + Vm

Variable X = Nitrogen Quantity contained in Manure

Variable Y = Nitrogen Quantity contained in Urine

Variable W = Items of Nitrogen Output except for Manure's an Urine's

Variable V = Items of Nitrogen Input

Variable T = Quantity of Each Stockbreeding's Manure

Variable U = Quantity of Each Stockbreeding's Urine

Constant a = Nitrogen Concentration of Each Stockbreeding's Manure

Constant b = Nitrogen Concentration of Each Stockbreeding's Urine

Constant c = Quantity Proportion of Each Stockbreeding's Manure against their Urine

Constant d = Quantity Proportion of Each Stockbreeding's Urine against their Manure

Table 2.6. Formula to obtain the quantity of manure and urine of stockbreeding

Table 2.7 Nitrogen Concentrations of Stockbreeding Manure and Urine and Quantity Proportion of Stockbreeding

	Nitrogen Concentration of Manure: Wet Matter	Nitrogen Concentratio n of Urine: Wet Matter	Proportion of Each Type of Stockbreeding's Manure against their Urine: Wet Matter	Proportion of Each Stockbreeding's Urine against their Manure: Wet Matter
Beef Cattle	0.0035	0.008	15	4
Chicken	0.0115	N/A	1	N/A
Dairy Cattle	0.0035	0.008	25	6
Pigs	0.0074	0.004	1	1

2.3.2 Material Flow Analysis for Adult Beef Cattle

Secondly we turn to adult beef cattle shown in Fig. 2.5 and Fig. 2.6. It is raised for 20 months after 9 month raising. In the other areas, calves are raised for 8 months, not 9 months. The raising term of 9 months for calves are commonly made only on Miyakojima Island. Accordingly the raising period, i.e. 20 months, is not usual in the other areas: it would be 21 months. Calves for adult cattle are purchased in the auction. Adult cattle is raised up to 20 months for the butchery purpose. When their weight reaches 625kg, it will be shipped from Miyakojima Island. This type of cattle raising is not common in the Miyakojima Island. One reason is that all feeds must be imported from the outside of Miyakojima Island and that it is unpopular in the island because of the expensive cost required for imported feeds. Farmers avoid feeding the pasturage available in the island to adult beef cattle because it gives a bad influence to the meat quality. Because Miyakojima Island is humid, the water content of the hay is higher than 10%. If farmers fed the pasturage with more than 10% water content to beef cattle, the color of the meat will become green. That is why they avoid feeding the pasturage available in the island to adult beef cattle.

The number of adult cattle in the island is only 694, which is the second from the lowest. The quantity of manure per 1 day is 18.9kg/day. The quantity is greater than that of a calf. Also it is greater than the quantity (15kg/day) in the reference given above. However, when we compare the final weight of both, that would be possible. Please note that this research is obliged to differentiate the phosphorus content of manure of adult cattle and a calf: Regarding the phosphorus content of manure, the content of the adult cattle is 0.124% while that of the calf is 0.131%; for your reference, the content of the adult cattle is 0.0385% while that of the calf is 0.0346% about the phosphorus content of urine.

Table 2.8 is given to confirm the mass balance for adult cattle.

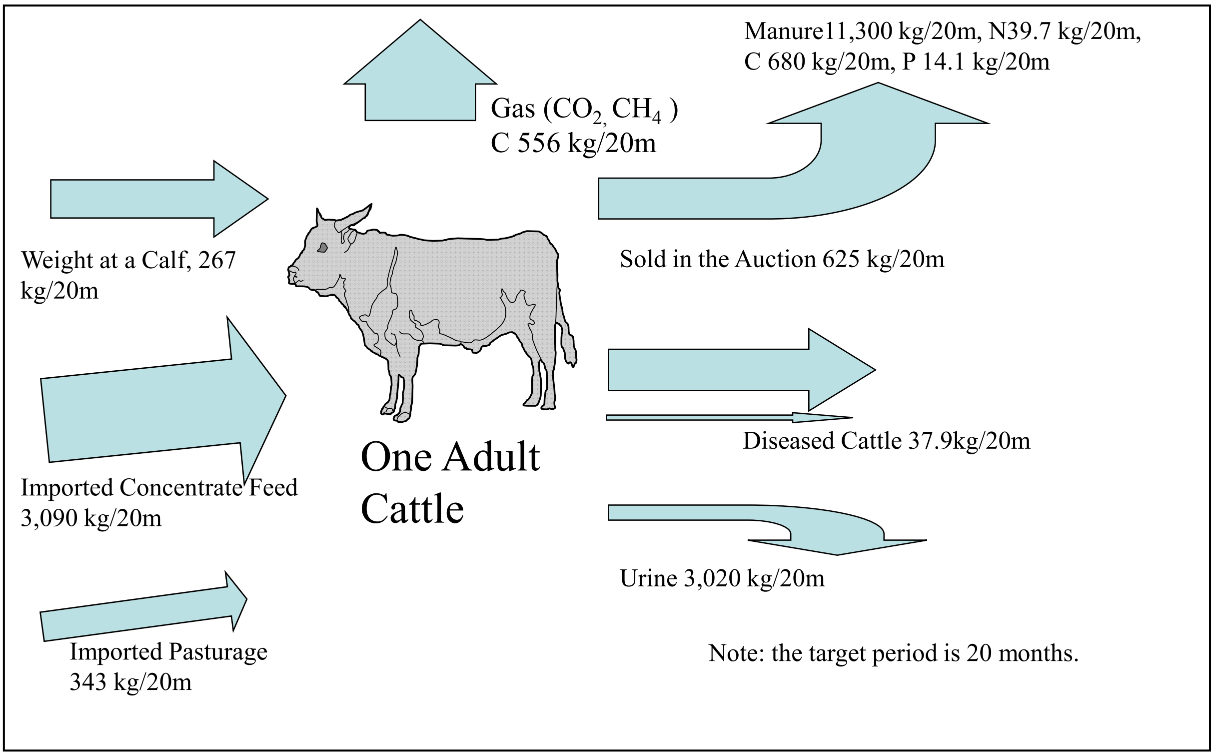

Fig. 2.5 MFA for Adult Beef Cattle (Weight Basis)

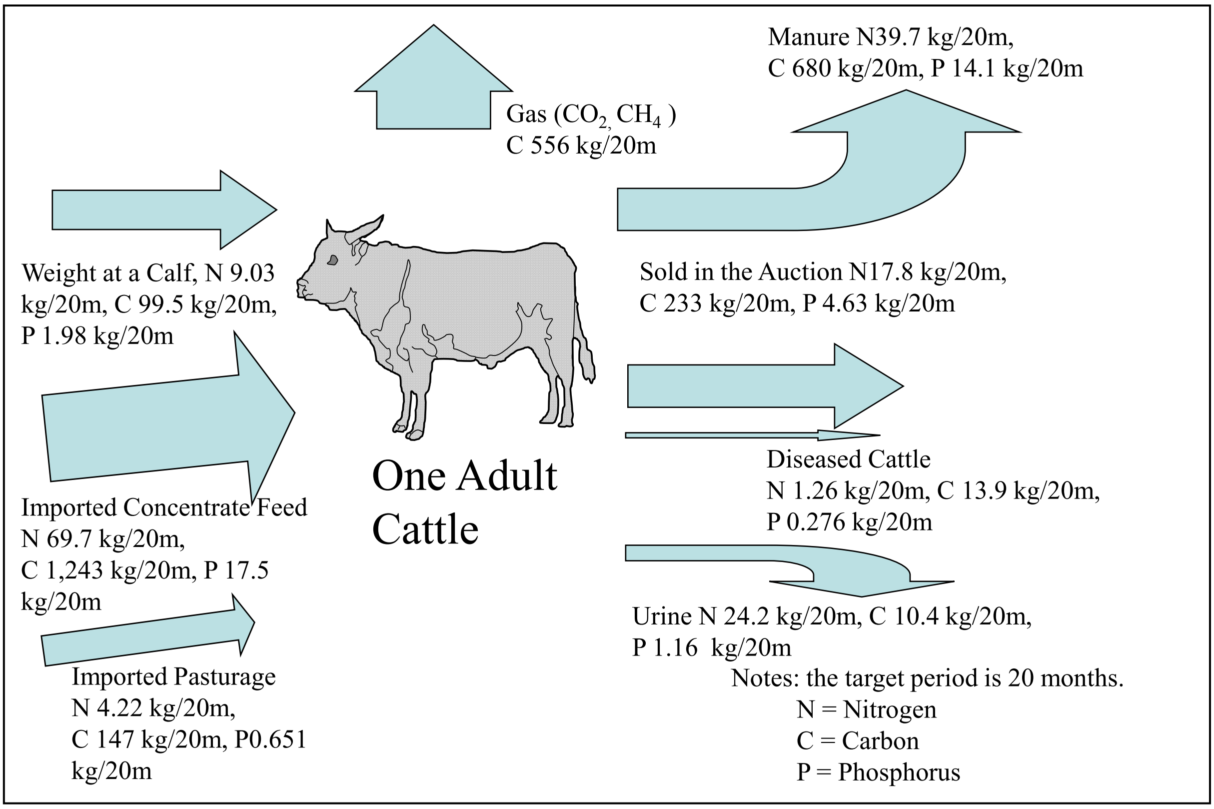

Fig. 2.6 MFA for Adult Beef Cattle (Element Basis)

Table 2.8 Mass Balance for Adult Cattle

Unit = kg/20m	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Weight at a Calf	9.03		99.5		1.98	
Imported Feed	73.9		1390		18.2	
Gas (CO_2, CH_4)				556		
Manure		39.7		680		14.1
Sold in the Auction		17.8		233		4.63
Diseased Cattle		1.26		13.9		0.276
Urine		24.2		10.4		1.16

Total	82.93	82.96	1489.5	1493.3	20.18	20.166

2.3.3 Material Flow Analysis for Breeding Cows of Beef Cattle

Thirdly we turn to breeding cows of beef cattle (giving a birth to calves) shown in Fig. 2.7 and Fig. 2.8. It is kept for 10 years after 9 month raising of calves. The target period for MFA is 10 years. Breeding cows are kept to have them give a birth to calves. After they are kept for ten years, they are sold in the auction. They will be sold for the butchery purpose or they are raised for 6 months to increase the weight. The average weight when they are sold is 404kg. The number of this type of breeding cows is 8,200, constituting 93.7% of beef cattle on Miyakojima Island. **The significant characteristics is that mainly they are fed pasturage.** Pasturage can be supplied in the island and it is important when we try to decrease the imported feeds for stockbreeding. The quantity of manure per 1 day is 14.7kg/day, which is close to the reference "Newly Edited Stockbreeding Great Ency clopedia". The quantity is greater than that of a calf. But it is lower than that of adult cattle.

Table 2.9 is given to confirm the mass balance for breeding cow.

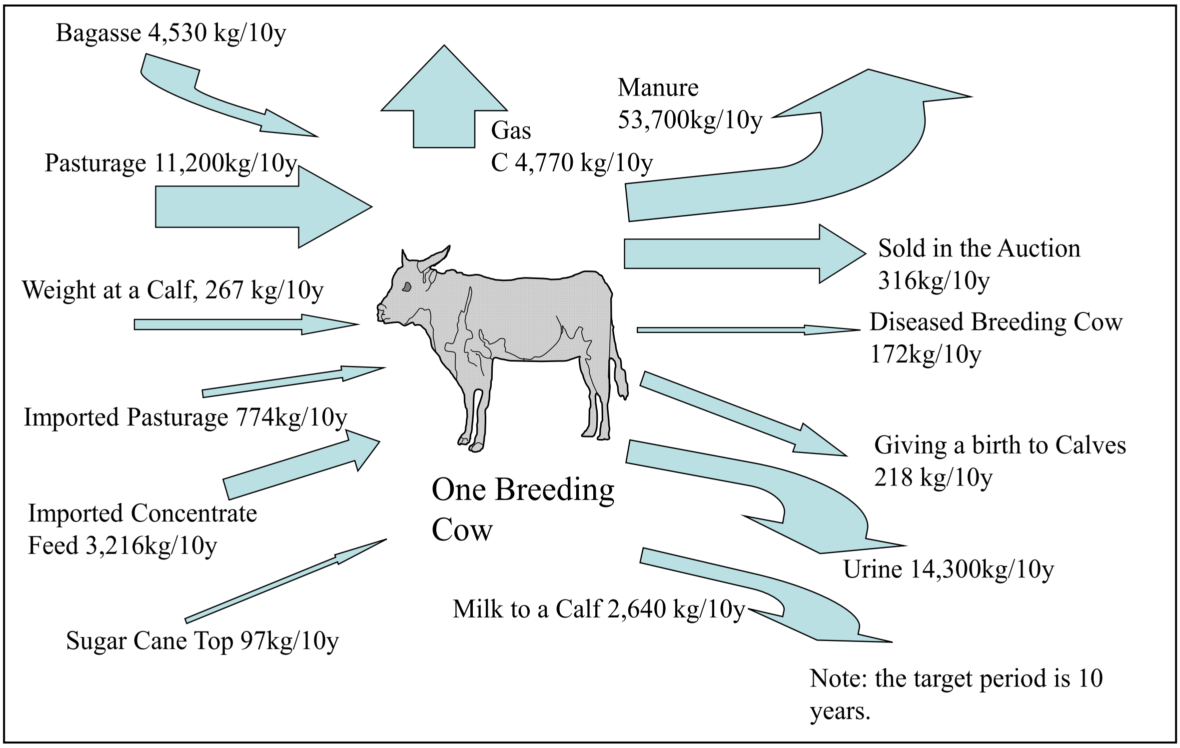

Fig. 2.7 MFA for Breeding Cow of Beef Cattle (Weight Basis)

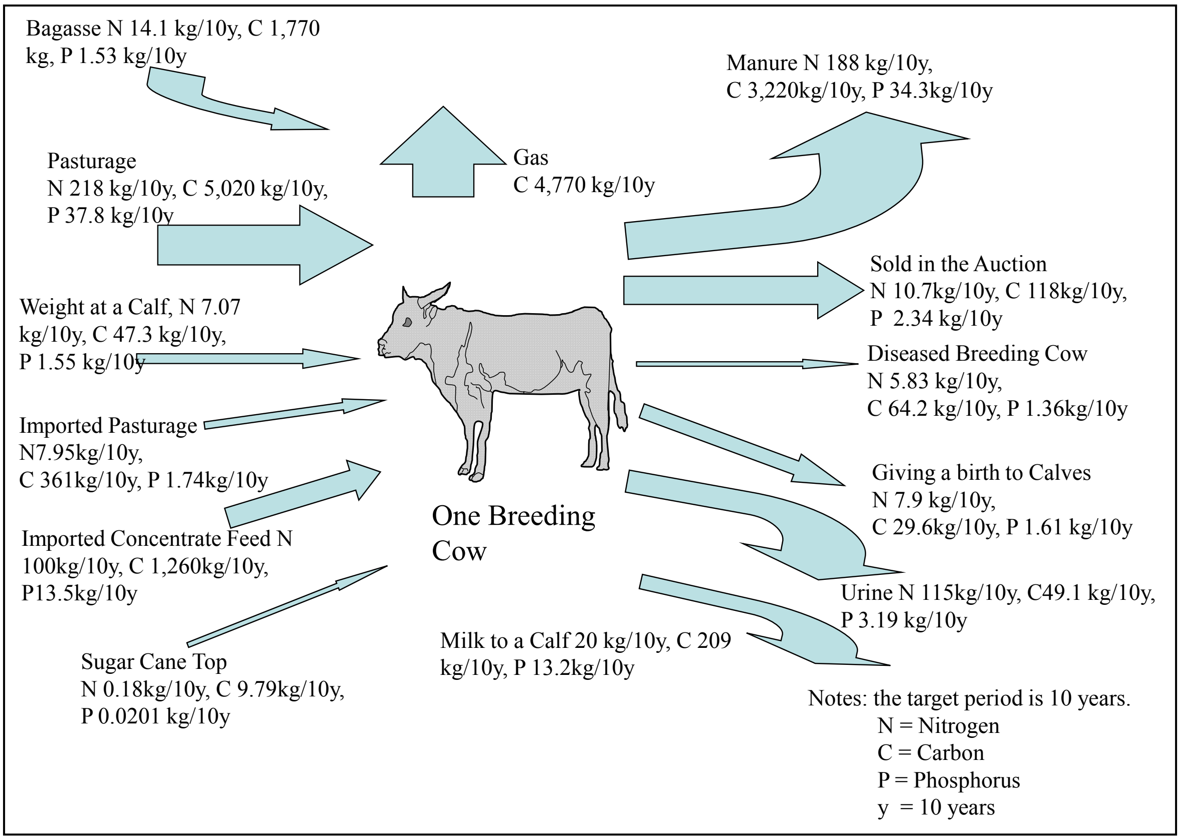

Fig. 2.8 MFA for Breeding Cow of Beef Cattle (Element Basis)

Table 2.9 Mass Balance for Breeding Cow

Unit = kg/10y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Bagasse	14.1		1,770		1.53	
Pasturage	218		5,020		37.8	
Weight at a Calf,	7.07		47.3		1.55	
Sugar Cane Top	0.18		9.79		0.0201	
Imported Concentrate Feed	100		1,260		13.5	
Imported Pasturage	7.95		361		1.74	
Gas (CO_2, CH_4)				4,770		
Manure		188		3,220		34.3

Sold in the Auction		10.7		118		2.34
Milk from Breeding Cow		20		209		13.2
Diseased Breeding Cow		6.21		68.4		1.36
Giving a birth to Calves		7.9		29.6		1.61
Urine		115		49.1		3.19
Total	347.3	347.81	8,468	8,464	56.1401	56.0

When we consider their weight (1. calf's weight is 267kg. 2. Adult cattle's weight is 625kg. 3. breeding cow's weight is 404kg), the MFA of breeding cows seems to be appropriately made. Regarding "Giving a birth to Calves", it is corresponding to "Weight at Birth" in Fig. 2.3. The weight of calves is 30kg at birth. The number of calves is 5,941 whereas that of breeding cows is 8,200. The target period of MFA for calves is 9 month whereas the target period of MFA for breeding cows is 10 years. Therefore, the calcula tion of the weight used f or giving birth to calves results in 218kg per 10 years.

The phosphorus content of manure and urine is lo wer than the others and that could be a challenging issue for the future research. The phosphorus content of the adult cattle's manure is 0.124% while that of the breeding cow is 0.0638%; the phosphorus content of the adult cattle's urine is 0.0385% while that of the breeding cow's is 0.0223%.

2.3.4 Material Flow Analysis for Breeding Cows of Beef Cattle which cannot Give a Birth to Calves

Fourthly this research deals with breeding cows which cannot give a birth to calves shown in Fig. 2.9 and Fig. 2.10. They are purchased in the auction and are rais ed for 6 m onths. The target period for MFA is 6 months. Breeding cows are raised for the butchery purpose after their weight is increased up to 550kg. The number of the breeding cows which cannot give a birth to calves is only 264, which is the lowest. As addressed above, all feeds must be imported from the outside of Miyakojima Island and that the cost required for imported feeds is expensive. Farmers who primarily raise breeding cows to give a birth to calves try to raise breeding cows for 6 months for the butchery purpose in a few cases. The quantity of manure per 1 day is 18.9kg/day. It is the same quantity as adult cattle. Regarding the phosphorus content of manure, the content of the adult cattle is 0.124% while that of the breeding cows raised for the butchery purpose is 0.145%. The phosphorus seems to be given to the breeding cows than the others.

Table 2.10 is given to confirm the mass balance for breeding cow which cannot give a birth to calves.

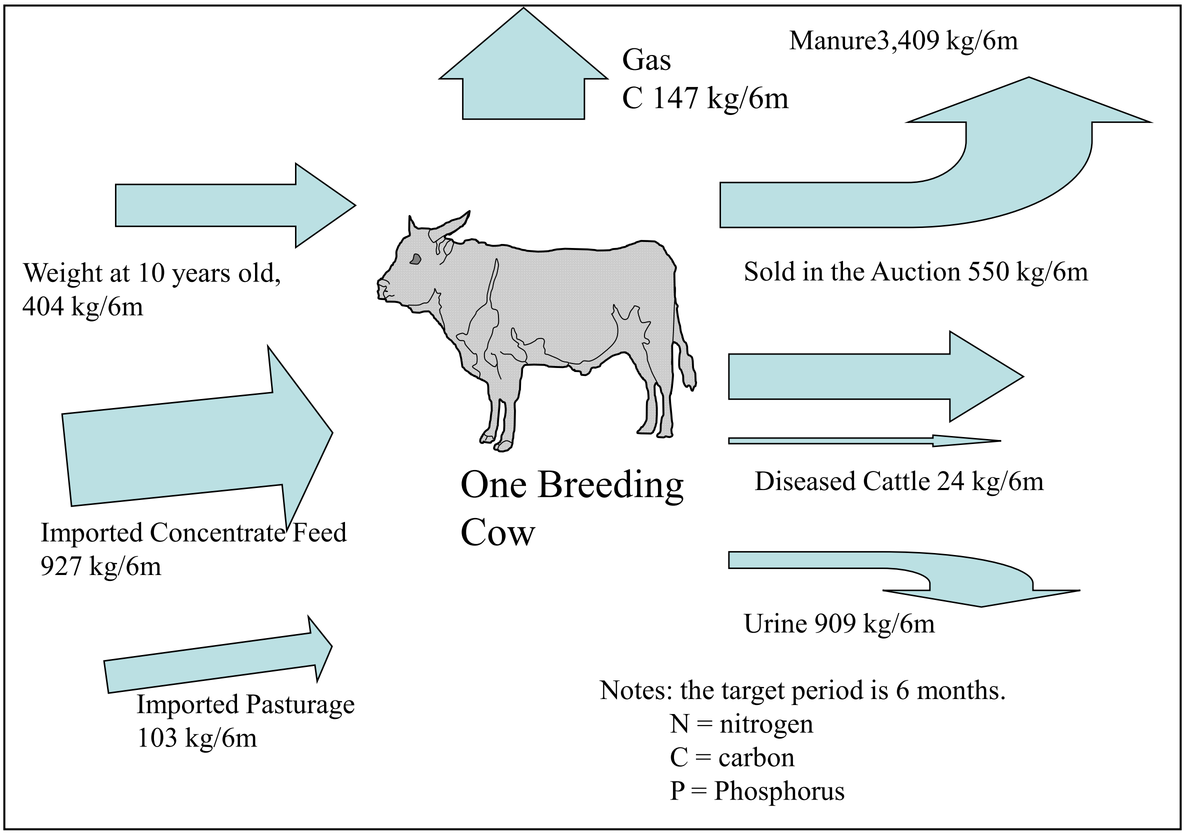

Fig. 2.9 MFA for Breeding Cows which cannot Give a Birth to Calves (Weight Basis)

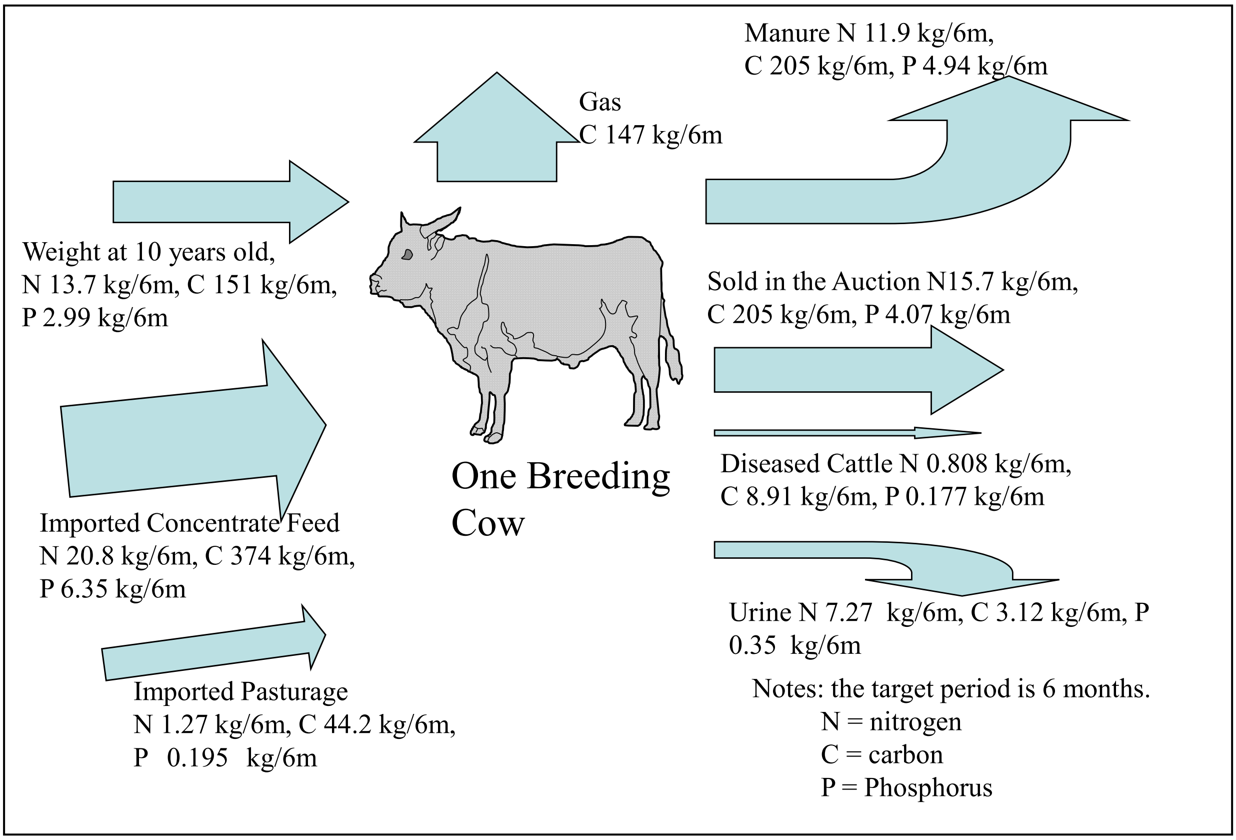

Fig. 2.10 MFA for Breeding Cows which cannot Give a Birth to Calves(Element Basis)

Table 2.10 Mass Balance for Breeding Cow which cannot Give a Birth to Calves

Unit = kg/6m	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Weight at 10 years old	13.7		151		2.99	
Imported Feed	22.1		418		6.55	
Gas (CO_2, CH_4)				147		
Manure		11.9		205		4.94
Sold in the		15.7		205		4.07

Auction						
Diseased Cattle		0.808		8.91		0.177
Urine		7.27		3.12		0.35
Total	35.8	35.678	569	569.03	9.54	9.537

Here we would like to state more on each substance flow. Regarding the input to the cattle, the content of each substance is given as follows. 1) the imported feeds: the nitrogen content of is 2.31%; the carbon content is 40.4%; the phosphorus content is 0.525%. 2) the pasturage: the nitrogen content is 1.94%; the carbon content is 45.1%; the phosphorus content is 0.337%. 3) Bagasse: the nitrogen content is 0.31%; the carbon content is 39.0%; the phosphorus content is0.0338%. 4) Sugar Cane Top : the nitrogen content is 0.708%; the carbon content is 28.1%; the phosphorus content is 0.0657%.

The nitrogen, carbon and phosphorus content of pasturage are not as low as expected , compared to the imported feeds because they are being used as hay.

Imported feeds are mainly consisted of concentrate feeds. Calves, adult cattle and breeding cows which cannot give a birth to calves are fed more than breeding cow which give a birth to calves. Because the rumen of calves is being developmental, concentrate feeds tend to be given more. The reason why adult cattle and breeding cows which cannot give a birth to calves are fed more concentrate feeds because they need to increase their weight more and to make the meat quality. Miyakojima Island has frequent precipitation and the hay tend to have more water content. The hay with more water content will affect the quality of the carcass meat.

Bagasse and sugar cane tops are fed to cattle for substitution of pasturage because the growth of the pasturage is slower in the winter. Sugar mills are operational in the January through March of the winter only because sugar cane get sweeter in the winter.

2.3.5 Material Flow Analysis for Dairy Cattle

This research will now provide MFAs for the other three kinds of stockbreeding. The present research first goes to the dairy cattle. Dairy cattle is kept by one farmer and the milk is provided to schools. It is fed the imported concentrate feeds and the imported pasturage. The reason why all feeds are imported is because dairy cattle (Holstein) eats pasturage grown in cold climates, such as Italian rye grass, alfalfa, and other grasses, few of which are cultivated on the island. Concentrate feeds are not cultivated on Miyakojima Island. This agricultural system may not be sustainable, as the farmer went bankrupt in September 2013, partially because procurement of all feed depended on the resources coming from the outside of the island. The MFA for dairy cattle is shown in Fig. 2.11 and Fig. 2.12.

Table 2.11 is given to confirm the mass balance for dairy cattle.

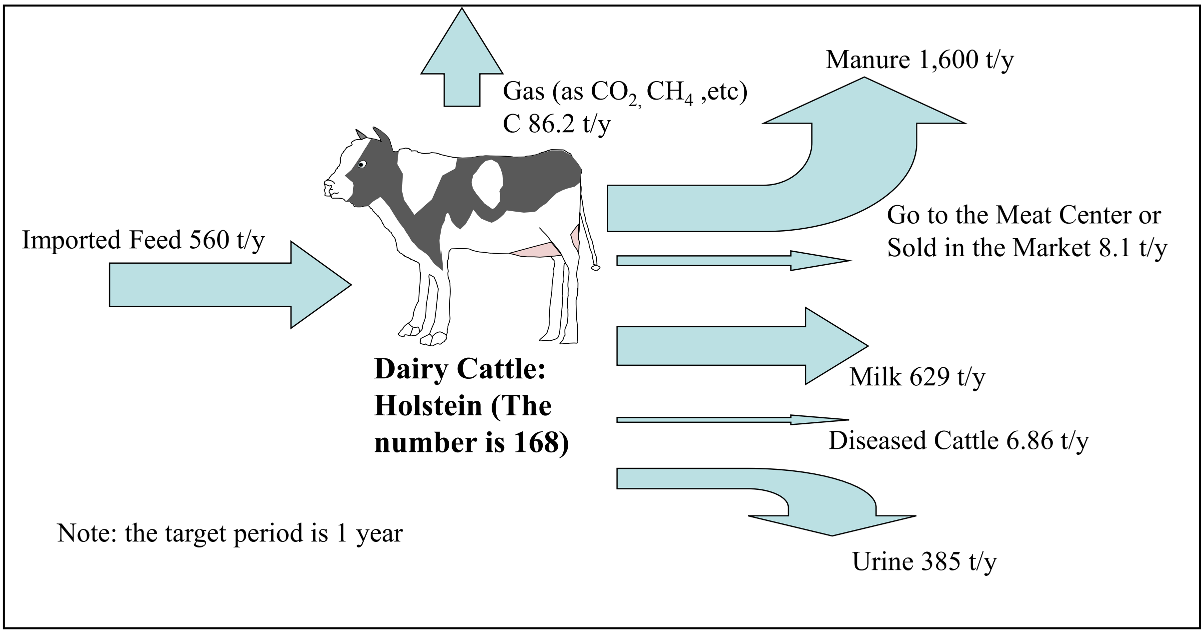

Fig. 2.11 MFA for Dairy Cattle (Weight Basis)

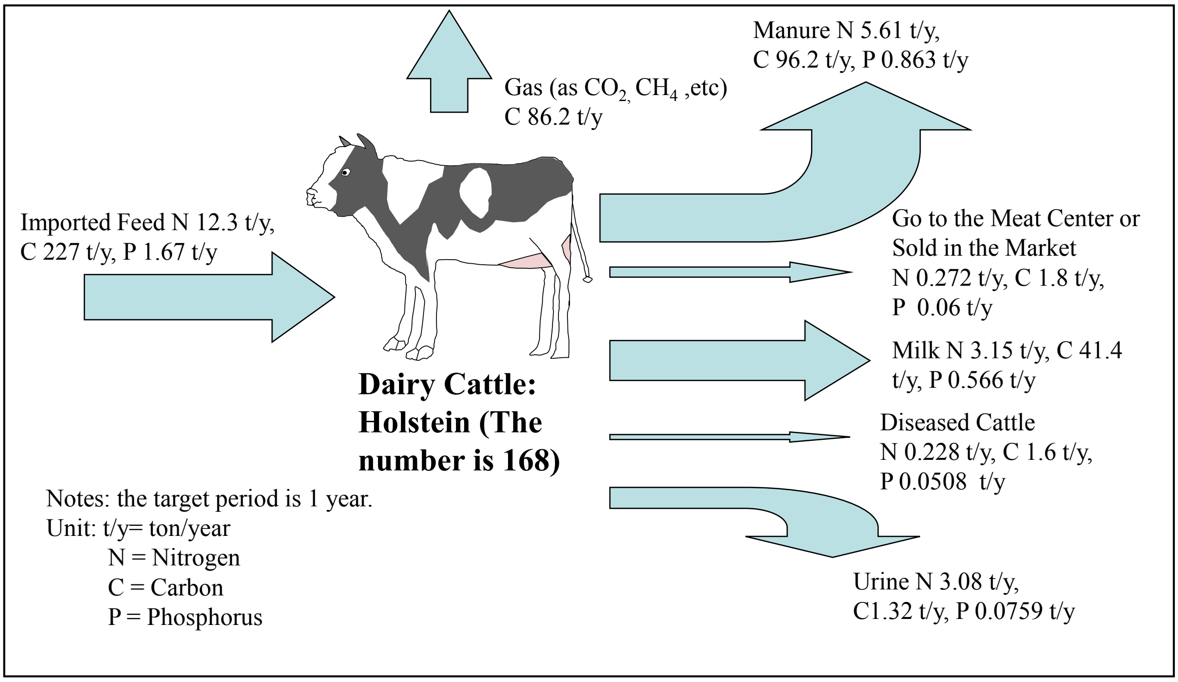

Fig. 2.12 MFA for Dairy Cattle (Element Basis)

Table 2.11 Mass Balance for the Dairy Cattle

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Imported Feed	12.3		227		1.67	
Gas (CO_2, CH_4)				86.2		
Manure		5.61		96.2		0.863
Go to the Meat Center or Sold in the Market		0.272		1.8		0.06
Milk		3.15		41.4		0.566
Diseased Cattle		0.228		1.6		0.0508
Urine		3.08		1.32		0.0759
Total	12.3	12.34	227	226.92	1.67	1.6157

To obtain the quantity of manure from dairy cattle, we use the formula to obtain the quantity of manure and urine production of Stockbreeding in Fig. 2.2. The quantity of manure production is 25 kg/day, according to “Stockbreeding Great Encyclopedia”. The quantity of manure for dairy cattle for this research is 20kg/day but it would be within acceptable range. The MFA includes manure production when dairy cattle are still calves. Therefore, the quantity of the manure is expected to be smaller. Feed is imported from outside the island, while meats and dairy cattle can be exported from the island.

2.3.6 Material Flow Analysis for Chicken

This research clarifies the MFA for poultry raising in Fig. 2.8. The majority of chickens, 30,598 out of a total of 31,738 chickens, are raised by one large farm. They are fed with imported concentrate feeds. Because chickens can only eat cereal, they are fed concentrate feeds, which consist primarily of cereals like corn. Miyakojima Island is not suitable for cultivation of cereals other than sweet potatoes.

This research does not discuss whether poultry breeding and raising with sweet potatoes is possible or not. Chickens are raised primarily for eggs, not meat. In FY 2010, farmers chose to dispose of half of the chickens as industrial waste rather than consuming them as meat. However, according to private communications with the large farmer, all chickens are currently consumed as meat. To sustain 31,738 chickens per year, the materials shown in Fig. 2.13 and Fig.2.14 Stockbreeding of an animal that has a life cycle longer than one year needs this type of substance output in the MFA.

Table 2.11 is given to confirm the mass balance for chickens.

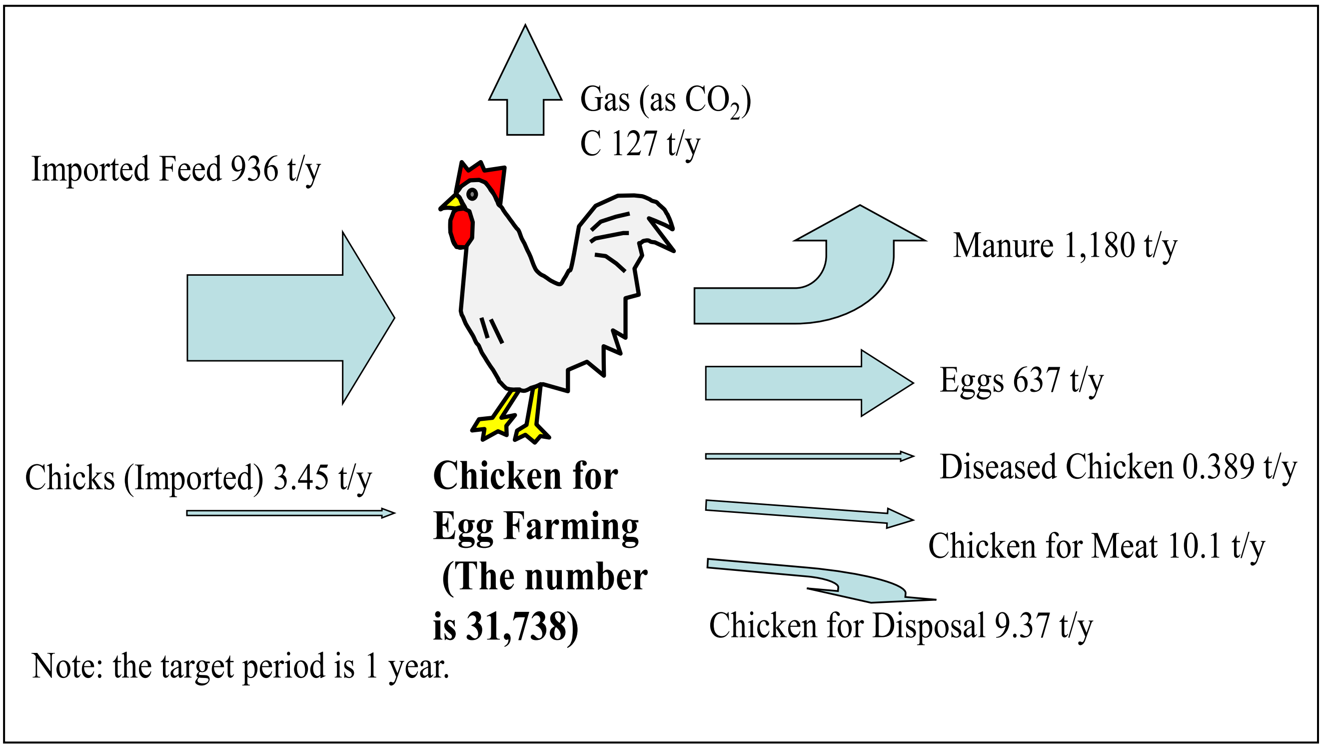

Fig. 2.13 MFA for Chickens (Weight Basis)

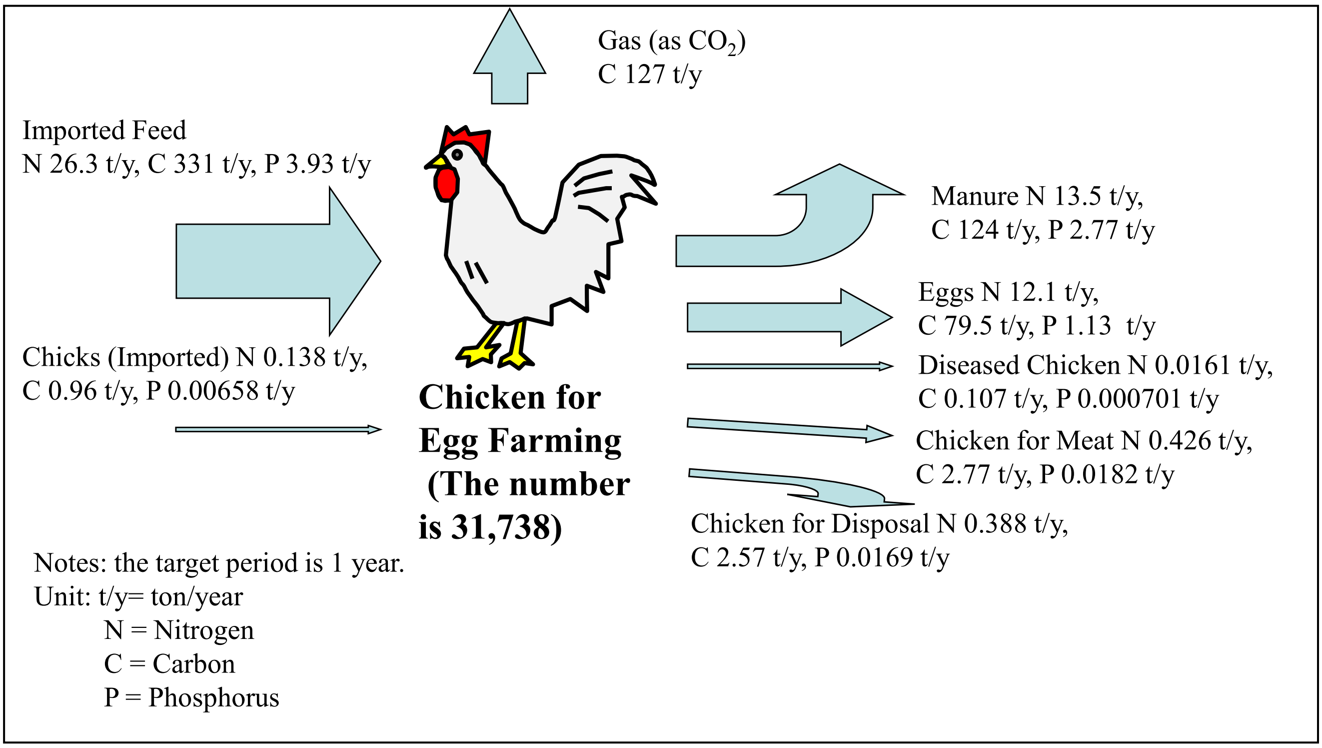

Fig. 2.14 MFA for Chickens (Element Basis)

Table 2.11 Mass Balance for the Chickens

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Imported Feed	26.3		331		3.93	
Chicks(Imported)	0.138		0.96		0.00658	
Gas (as CO_2)			127			
Manure		13.5		124		2.77
Eggs		12.1		79.7		1.13
Diseased Chicken		0.0161		0.107		0.000701
Chicken for Disposal		0.388		2.57		0.0169
Chicken for Meat		0.426		2.77		0.0182
Total	26.438	26.4301	331.96	336.147	3.93658	3.935801

2.3.7 Material Flow Analysis for Pigs

This research next shows the MFA for hog raising in Fig. 2.15 and Fig. 2.16. Pigs on Miyakojima Island are primarily fed food wastes from restaurants, supermarkets, hotels, and so on and do not need to be fed imported concentrate feeds. The way of raising follows the spirit of this research. However, lees from Awamori production which is done with imported broken rice from Thailand is given to them. Imported feeds are concentrate feeds created from corns, wheat bran, food oils, fish, pork, and so on. The purpose of the concentrate feed provision is assumed that it would make it leaner by reducing fats from pigs before they are shipped to the Miyako Meat Center. This can raise the price of pigs. The quantity of manure production is 2.08 kg/day. According to "Stockbreeding Great Encyclopedia", the quantity is 3kg/day but it would be within the acceptable range. The MFA includes manure production when pigs are piglets, so the quantity of the manure is expected to be smaller. The quantity after the storage process will become 1kg/day according to a farmer in Okinawa Main Island. If the quantity of raw manure is 3kg/day, the required quantity loss ratio of manure in the storage process would be 66.7%. We next show the MFA for hog breeding and raising in Fig.2.9. Pigs on Miyakojima Island are primarily fed food wastes from restaurants, supermarkets, hotels, and so on and do not need to be fed imported concentrate feeds. However, lees from Awamori production, which is done with imported broken rice from Thailand, is given to them. Imported feeds are concentrate feeds created from corn, wheat bran, food oils, fish, pork, and so on. The purpose of the concentrate feed provision is to reduce fats from pigs before they are shipped to the Miyako Meat Center. This can raise the price of pigs. The quantity of manure production is 2.08 kg/day. According to "Stockbreeding Great Encyclopedia", the quantity should be 3kg/day but it would be within the acceptable range. The MFA includes manure production when pigs are still piglets, so the quantity of the manure is expected to be smaller. The quantity after the storage process will become 1 kg/day according to a farmer in Okinawa Main Island. If the quantity of raw manure is 3 kg/day, the required quantity loss ratio quantity of manure in the storage process would be 66.7%.

Table 2.13 is given to confirm the mass balance for pigs.

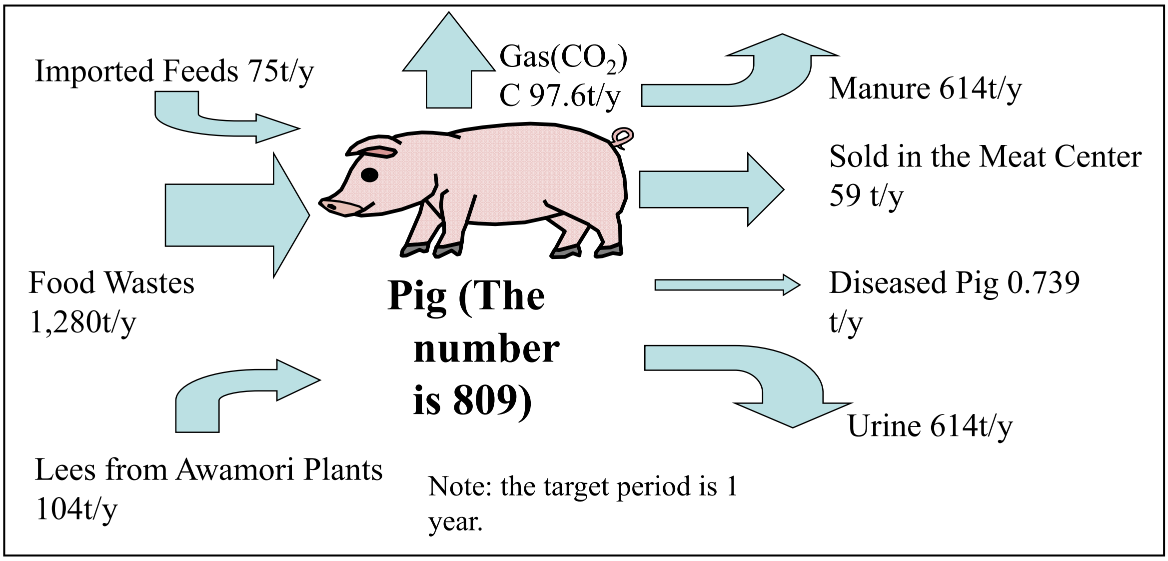

Fig. 2.15 MFA for Pigs (Weight Basis)

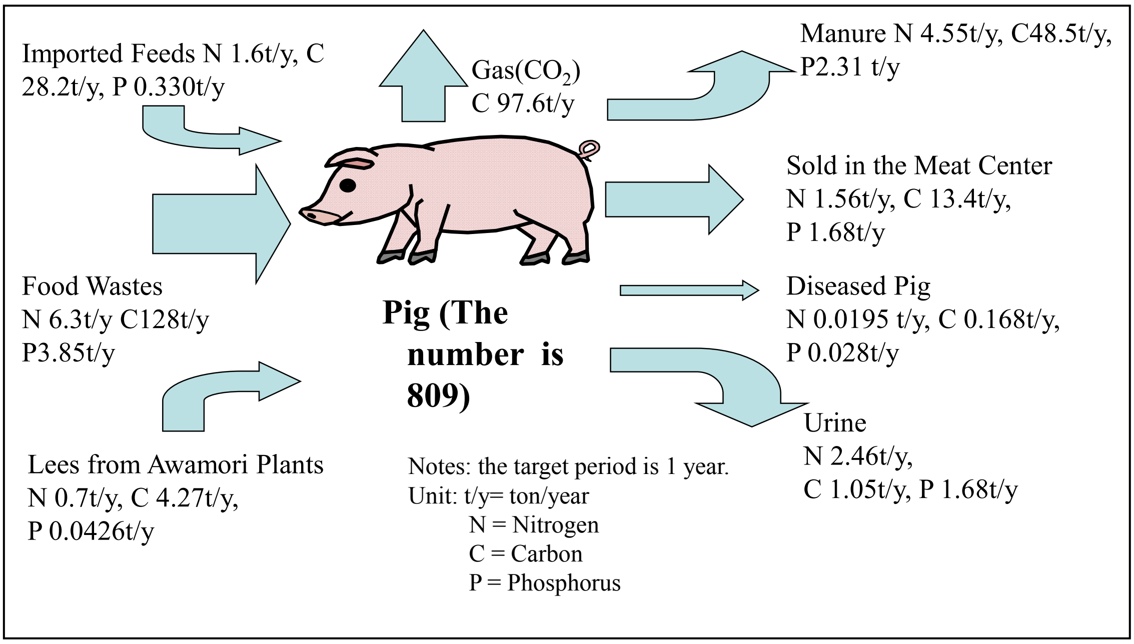

Fig. 2.16 MFA for Pigs (Element Basis)

Table 2.13 Mass Balance for the Pigs

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Imported Feed	1.6		28.2		0.33	
Food Wastes	6.3		128		3.85	
Lees from Awamori Plants	0.7		4.27		0.0426	
Gas (as CO_2)				97.6		
Manure		4.55		48.5		2.31
Sold in the Meat Center		1.56		13.4		0.224
Diseased Pig		0.0195		0.168		0.028
Urine		2.46		1.05		1.68
Total	8.6	8.5895	160.47	160.718	4.2226	4.242

2.3.8 Biomass Resources from Stock Breeding

The task in this subsection is to establish th e quantity of loss in the storage process. Not e that loss in the storage process is caused by decomposition of microbes: organic matters are decomposed and prim arily emit carbon, n itrogen, hydrogen and ox ygen gas. Private communication with the stockbreeding farmers revealed that mixing manure for co mposting is not conducted except in t he three composting f acilities. For exam ples, most of cattle raising farmers cultivate sugar cane at the same ti me as sugar cane cultivation and therefore they use manure as fertilizer for sugar cane cultivation. They place manure in the storage without mixing procedures for composting and plow under the manure for the sugar cane fields one month prior to planting sugar cane so that substances contained in the manure that are harmful to the sugar cane growth are decomposed by the bacteria in the soil. A few cattle raising farm ers and on e poultry raising farmer use two composting facilities with their manure for sale or for bagasse which is used as bedding material: one composting facility always keeps bagasse to exchange it for cattle manure. Another composting facility is not able to obtain any manure from stockbreeding farmers and so it uses the fishery residues instead.

First, we try to establish the quantity loss in the storage process. One farmer raises 200 calves and 300 breeding cows (beef cattle). Also the quantity of manure stored is kept in the administrative records of the farmer: the quantity of raw manure is 2,440 t/y while the quantity of stored manure is 1,500 t/y. Therefore we estimate that the loss ratio of quantity of beef cattle and dairy cattle is 38.7%. Since there are no reliable records on Miyakojima Island, we adopt the value from "Estimation of Flow Sheet and Load Unit to Farm Soils of Nitrogen Excreted by Animals on the Basis of the National Statistical Data" regarding the nitrogen loss ratio[38]. Note that we adopt the value of dairy cattle for the beef cattle i.e. 10.3% because the loss ratio of dairy cattle is greater than that of beef cattle and because the storage term of beef cattle is thought to be longer than any other type of stockbreeding according to personal communications with stockbreeding farmers.

Regarding the loss ratio for chickens, the quantity of raw manure of the large farmer is 1,100 t/y while the quantity of stored manure is 903 t/y: therefore the loss ratio for chicken manure production is 19.1%.

Regarding the loss ratio for pigs, we were not able to obtain the information on Miyakojima Island but obtained it from a farmer on Okinawa Main Island who raises hogs with food wastes and was able to provide the relevant information: The quantity of stored manure is 1 kg/day as addressed above, and the quantity of raw manure of hog raising is 2.09kg/day. Therefore the loss ratio for pigs is 52%.

Note that the storage period for chickens are considered to be 0.5 month. But the storage period of the beef cattle/dairy cattle and pigs is 5-6 month, and is primarily used as the basic fertilizer for sugar canes which are planted one time a year. Almost all manure from chicken goes to two composting facilities once per month. Therefore the loss ratio for chickens is relatively low when compared with other loss ratios in Table 2.14: however, because research studies for loss ratios of stockbreeding manure are few in number, we think further research will be necessary.

Table 2.14 Quantity and Substance Loss Ratio of Manure in the Storage Process

Unit = t/y	Quantity (%)	Nitrogen (%)	Carbon (%)	Phosphorus (%)
Beef Cattle / Dairy Cattle	38.7	10.3	13.1	0%
Chicken	18.1	8.4	10.7	0%
Pig	52	14.7	18.7	0%

Regarding the carbon loss ratio of composting process of manure and urine, this information is available in the research "Carbon, Nitrogen Balances and Greenhouse Gas Emission during Cattle Feedlot Manure Composting"[39]. The proportion between nitrogen loss and carbon loss in the research is applied to the quantity of carbon and nitrogen quantity for each type of stockbreeding. Although the result is obtained from cattle raising, it is applied to the other types of stockbreeding for the convenience of this discussion.

In this research, when the nitrogen loss is 8.3 kg, the carbon loss is 174kg. Accordingly the carbon loss ratios are obtained as shown in the Table 2.14.

Table 2.15 shows the nitrogen, carbon and phosphorus concentrations of stockbreeding manure after the storage process. Manure from each stockbreeding loses total quantity of nitrogen and carbon. However, concentrations themselves are increased by the storage process.

Table 2.15. Nitrogen, Carbon and Phosphorus Concentrations of Stockbreeding Manure after the Storage Process

	Nitrogen Concentration of	Carbon Concentration of	Phosphorus Concentration of

	Manure: Wet Matter (%)	Manure: Wet Matter (%)	Manure: Wet Matter (%)
Beef Cattle	0.51	8.51	0.183
Dairy Cattle	0.397	6.01	0.0667
Chicken	2.64	23.5	0.621
Pig	1.32	13.4	0.78

Next this research tries to clarify how much biomass resources are plowed under. Note that Table 2.14 is not applied to stockbreeding's manure in Table 2.16 yet. Regarding sewage plant sludge, nothing is applied because it does not have any storage process. There were two sewage plants in the island in FY 2010: one collects sludge from individual home septic tanks by tanker truck; the other collects sewage from sewage collection system lines. The present research adopts the C/N ratio from sludge processed from sewage collected from the sewage collection system lines because the analysis of sludge collected from home septic tanks was not made.

The information source for "residues from methane fermentation plants" and "sewage plant sludge" in Table 2.16 is Miyakojima city hall.

Table 2.16. Biomass Resource List which is Plowed under

	Total Quantity (t/y)	Nitrogen Quantity (t/y)	Carbon Quantity (t/y)	Phosphorus Quantity (t/y)
Beef Cattle's Manure	69,200	242	4,150	68
Chicken's Manure	42.37	0.489	4.47	0.106
Dairy Cattle's Manure	1,600	5.61	96.2	0.863
Pig's Manure	386	2.86	30.5	1.45

Sewage Plant Sludge	793	7.63	61.0	2.17
Residues from Methane Fermentation Plants	50	0.954	4.64	0.266

Table 2.17 shows biomass resources that are plowed under agricultural soil. When we use the values in Table 2.14 and Table 2.16 together, we are able to obtain quantities of biomass resources and quantities of nutrients (nitrogen, carbon and phosphorus) that are used to fertilize agricultural plants on Miyakojima Island.

The information source for "residues from fishery" is a composting facility which use it as a raw material for a compost. The information source for "pruned trees" and "food wastes" in Table 2.17 is Miyakojima city hall.

Table 2.17. Biomass Resource List for Composting Facilities

	Total Quantity (t/y)	Nitrogen Quantity (t/y)	Carbon Quantity (t/y)	Phosphorus Quantity (t/y)
Beef Cattle's Manure	3,770	40.2	791	4.59
Chicken's Manure	1,140	13.1	120	2.83
Residues from Fishery	101	3.89	17.2	0.26
Pruned Trees	4,360	18.9	1460	5.23
Food Wastes	189	0.93	18.9	0.134
Lees from Awamori Plants/ Residues from Methane	671	8.29	41.3	2.14

Fermentation Plants				

Table 2.18 shows a biomass resource from 300 pigs that is a slurry mixture of manure and urine used for vegetable cultivation:

Table 2.18. Pig's Slurry and Loss Ratios [39 38 40].

	Total Quantity and Loss Ratio	Nitrogen Quantity and Loss Ratio	Carbon Quantity and Loss Ratio	Phosphorus Quantity and Loss Ratio
Pig's Slurry	228 t/y	1.69 t/y	18 t/y	0.857 t/y
Loss Ratio	0%	25%	31.8%	0%

Note that urine from stockbreeding is the only biomass resource which is not used for any purposes.

Chapter 3 addresses other biomass resources like green manure, residues from sugar mills, residues from sugar cane fields, and also addresses quantities of imported chemical and organic fertilizers and composts.

2.4 Summary of the Discussion in Chapter 2

Chapter 2 conducted MFA of a variety of stockbreeding such as beef cattle, dairy cattle, chickens and pigs. Dairy cattle and chicken only consume feeds imported from the outside of Miyakojima Island. Pigs primarily consume foods wastes which are internally from the island. MFA for each type of beef cattle was clarified, a calf, adult cattle is conducted, a calf, adult cattle, a breeding cow and a breeding cow which cannot give a birth to calves. While adult cattle and a breeding cow which cannot give a birth to calves consume feeds imported from the outside of the island, a calf and a breeding cow also consume pasturage created on the island.

To confirm the mass balance, we created the tables for each MFA. We also clarified quantities of biomass resources generated by stockbreeding. When chapter 4 and 5 tries to discuss an agricultural production system, the MFA given in this chapter will be basis for the basic units.

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Chapter 3 Material Flow Analysis for Agricultural Plants

3.1 Objectives for Chapter 3

Our tasks in this chapter ar e to performs the following three task s with respect to agriculture on Miyakojima Island: 1) Quantifies agricultural plant with material flow analysis methodology, 2) Quantifies co mponents related to agricultura l plants such as sugar mills and composting facilities and 3)Establishes the base for values of basic units used to bu ild up an agricultural production system which are discussed in Chapter 4 and 5.

3.2 Methodologies for Material Flow Analysis for Agricultural Plants

3.2.1 Methodologies to Obtain the Information and the Composition

For the Mat erial Flow MFA for ag ricultural plants, we conducted the s ame tasks as stockbreeding; (1)interviewing farmers or city hall officials who are involved in he agricultural plants; on-site investigations; (2)obtaining statistical data, go vernment documents, and agricultural plant far mers' administrative documents; and lastly, (3) cond ucting elemental analysis of agricultural pl ant residues. Newspaper articles available to th e public are referenced as well. For the determination of water content, freeze dryer is utilized. For the determination of carbon and nitrogen, the elemental CHN analyzer, Vario EL III, was used. For the determination of phosphorus, the molybdenum blue method was conducted.

In the sam e way as Chapter 2, we used "Nitrogen-to-protein conversion factors" an d "Conversion factors to obtain carbon contents" to conduct the MFA for agricultural plants.

3.2. 2 Details on Sources for MFA of Agricultural Plants

Here this clarifies the sources for MFA of agri cultural plants. It is dealt with in this subsection.

First we address the infor mation source of the input to agricultural plants. Information on content of fertilizer was o btained from Miy akojima City Hall. Regarding carbon content for several chemical and organic fertilizers (which were widely used by farmers on Miyakojima Island) was analyzed. The information on content for residues of the sugar cane field and sugar mills are obtained from the past studies [1 2 3]. We analyzed the filter cakes. The information on the content of trash and sugar cane tops are from "Feedipedia"[4]. We analyzed the leaf tobacco. We also analyzed residues from tobacco, Chinese preserving melon, bitter melon, squash and mango. The content of other parts of those agricultural plants were obtained from the past study, "Standard Tables of Food Composition in Japan 2010"[2].Quantity of pasturage(yield per 10 are) were obtained from the past studies[5 6 7 8 9 10 11 12 13 14 15]. Area of pasturage was obtained from Miyakojima City Hall. The information on N, C and P content of pasturage was obtained from the past studies [4 16 17 18 19] and Okinawa Prefectural Livestock Research Center. The information on fertilization to each agricultural plants in this research is based on the comparison among the personal communication with farmers and administrative documents from Miyakojima city hall.

Next we address the information source of the output from agricultural plants. The information on the quantity of the residues generated from sugar mills is provided by two sugar companies. The information on the quantity of harvests and residues from each agricultural plant was from the investigation by Miyakojima City Hall[20 21],and the privation communication with tobacco farmers. Gas and humus from the soil of agricultural plants were obtained from the formula in Table 3.1.

Table 3.1. Sources of Information for the MFA of Agricultural Plants

The information sources for the MFA of beef cattle			
item	references	private communications	others
quantity of pasturage(yield per 10 are)	5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	n/a	quantity of pasturage = yield per 10 are × areas
area of pasturage	n/a	Miyakojima city hall (areas)	n/a
information for N, C and P content of pasturage	4, 16, 17, 18, 19	Okinawa Prefectural Livestock Research Center	n/a
quantity of residues from sugar mills	n/a	two sugar mills	n/a
information on content of	1, 2, 16	n/a	elemental analysis

agricultural plants			(filter cake leaf tobacco nd residues from tobacco, Chinese preserving melon, bitter melon, squash and mango)
quantity of harvest of agricultural plants	20	n/a	n/a
quantity of residues from agricultural plant fields	21, 22	Tobacco Farmers	n/a
quantity of green manure plants and its N, C and P contents	23, 24	Miyakojima City Hall	n/a
quantity of fertilization for agricultural plants	n/a	Farmers for each agricultural plant, Miyakojima City Hall	n/a
information on content of fertilizer	n/a	Miyakojima City Hall	elemental analysis (C content for several chemical and organic fertilizers)
gas and humus from the soil of agricultural plants	n/a	n/a	=(all input of C or N) – (all other output of C or N)

3.3.3Material Flow Analysis for Sugar Cane

3.3.3.1 Material Analysis for Sugar Mills

Now we will take a look at the MFA for sugar mills in Fig. 3.1 and Fig. 3.2. There are three sugar mills on Mi yakojima Island, which are run by two com panies. Table 3.2 is given to confirm the mass balance for sugar mills.

Sugar production generates crude sugars, molasses, bagasse, and filter cakes. Crude sugars go to sugar mills outside of the island which can create white sugar. Molasses is purchased as raw material for stockbreeding feeds by a buy er from the outside of the island because it has a sweet odor and useful minerals for stockbreeding feeds. Crude sugar and molasses are exported from the island.

Most of sugar cane is harvested manually but some farmers use harvesters. Harvesters also collect dried leaves in the sugar cane fiel ds but they are not processed in sugar production. They go out from the sugar mills as trash.

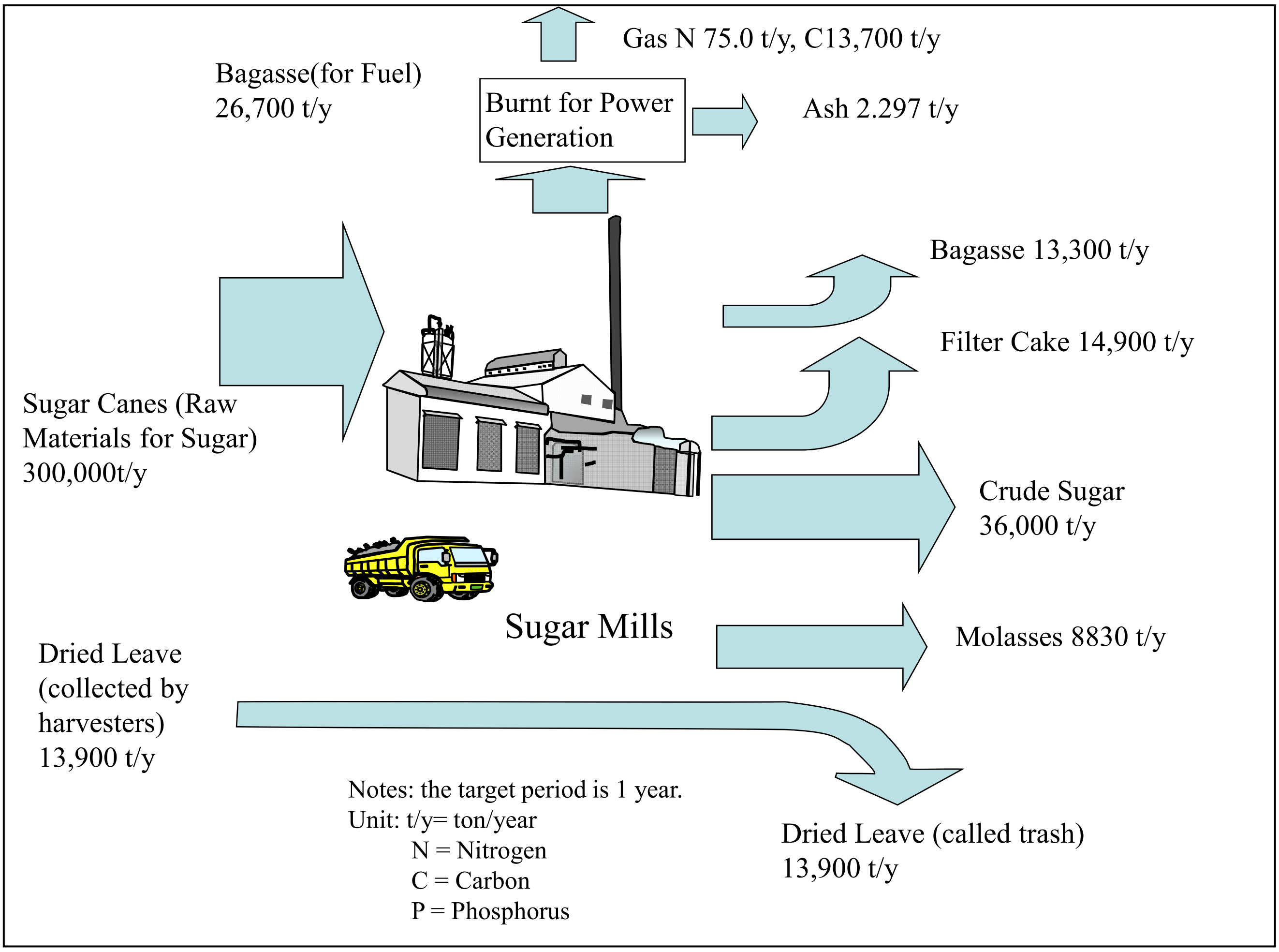

Fig. 3.1 MFA for Sugar Mills (Weight Basis)

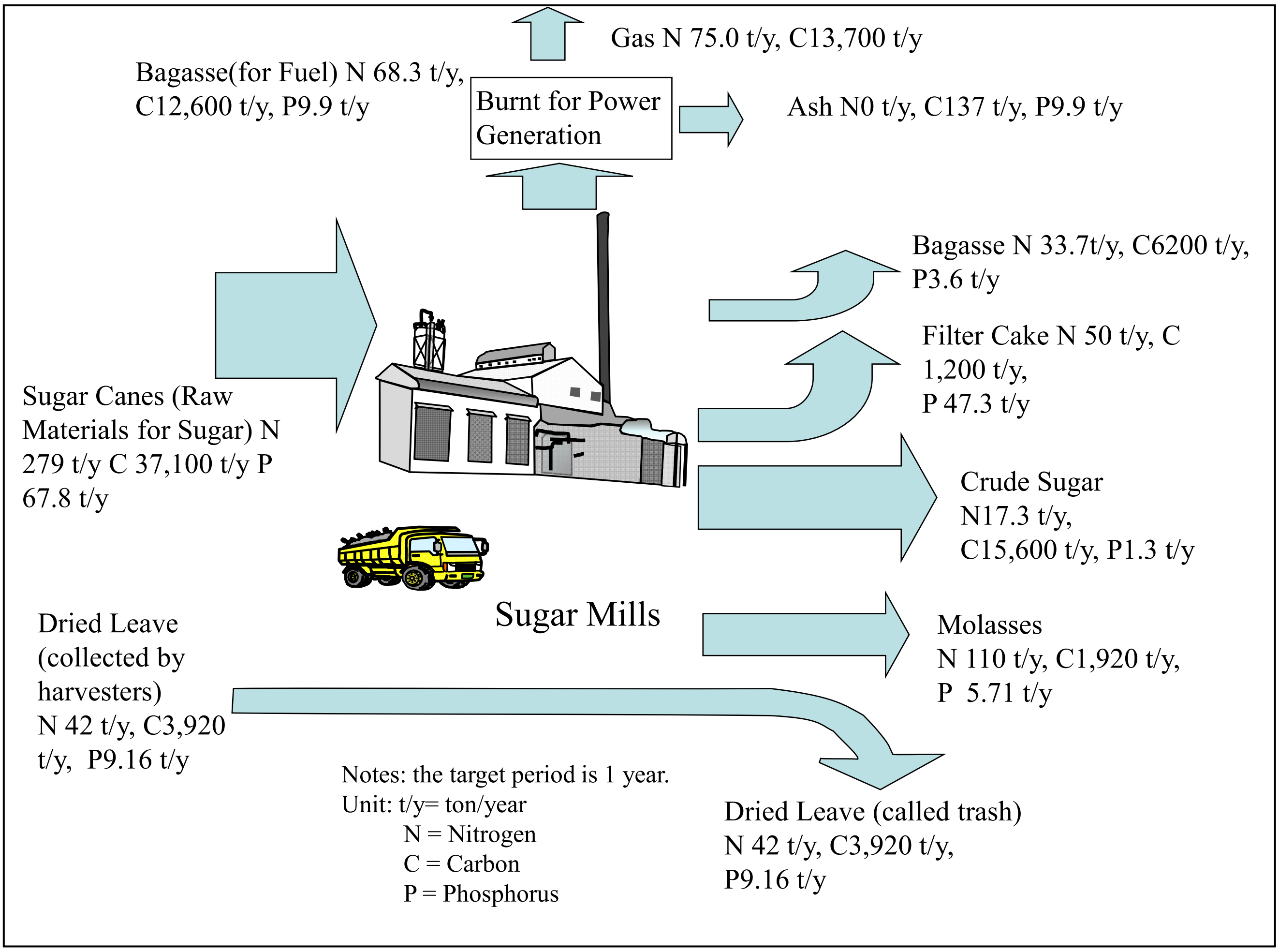

Fig. 3.2 MFA for Sugar Mills (Element Basis)

Table 3.2 Mass Balance for Sugar Mills

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Sugar Canes (Raw Materials for Sugar)	279		37,100		67.8	
Dried Leave (collected by harvesters)	42		3,920		9.16	
Trash		42		3920		9.16
Bagasse(for Fuel)		68.3		12,600		9.9

Bagasse		33.7		6,200		3.6
Filter Cake		50		1,200		47.3
Crude Sugar		17.3		15,600		1.3
Molasses		110		1,920		5.71
Total	321	321.3	41020	41440	76.96	76.97

Much of bagasse is used as fuel for power generation and meets almost all electricity needs for sugar production operations. Because ashes generated from the power generation contain useful minerals for agriculture, they are plowed under by farmers or are used as raw materials for composting. A part of the rest of bagasse is consumed as a cattle feed but most of it is plowed under or is used as raw material for composting. Trash and filter cakes are plowed under or are used as raw materials for composting. Note that "composting" in this subordinate section means composting in three composting facilities: mixing process is conducted to promote microbe's decomposition. Table 3.2 shows the information on biomass resource and product quantity from sugar mills, and the way of utilization for a quick reference.

Table 3.4 Biomass Resource and Product Quantity from Sugar Mills and the Way of Utilization

Unit = t/y	Total Quantity (t/y)	Nitrogen Quantity (t/y)	Carbon Quantity (t/y)	Phosphorus Quantity (t/y)	Way of Utilization
Filter Cake	14,900	50	1,200	47.3	Raw Materials for compost, fertilizer plowed under (organic amendment)
Bagasse	13,300	33.7	6,200	3.6	Same as filter cake

Ash	2,297	0	137	9.9	Same as filter cake
Trash	139,000	42	3,920	9.16	Same as filter cake
Crude Sugar	36,000	17.3	15,600	1.3	Raw materials for white sugar (going to the outside of the island)
Molasses	8,830	110	1,920	5.71	Raw materials for stockbreeding feeds (going to the outside of the island)

3.3.3.2 Material Flow Analysis for Sugar Cane in the Field

The task in this subordinate section is to clarify the material flow for sugar cane in the field. See Fig. 3.3 and Fig. 3.4 for the MFA for sugar cane in the field. Fertilizer and biomass resources which are applied to sugar cane goes to soil first and some of nitrogen and phosphorus are absorbed by the target agricultural plant, in this case, sugar cane. Carbon is not absorbed by the sugar cane; it stays as humus or it is consumed by microbes. All carbon required for sugar cane is produced by sugar cane with photonic synthesis. It applies to the other agricultural plants. Sugar cane is an agricultural plant which does C_4 carbon fixation and it is suited for the subtropical island like Miyakojima Island.

Unused nitrogen may stay with microbes, is emitted by denitrification or seep into the ground water as ammonium ion. Unused phosphorus might seep into ground water but according to the personal communication with Miyakojima City Hall which monitors the water quality of ground water. This research assumes that most of the phosphorus stay as calcium phosphate. As addressed in the subsection 1. 3 "The Underground Layer Structure of Miyakojima Island", Shimajiri Maaji layer and Ryukyu Lime Stone Layer are originated from the coral. They contain much of calcium which is united with phosphorus. Regarding the environmental issue with calcium phosphate, Mr. Kazuhiro Maesato from continuously is making research[25]. The point for his research is to be placed on the re-utilization of phosphate trapped in the soil. Much of phosphorus is applied to the agricultural plants and stays in the soil. To re-utilize the phosphorus in the soil, composts and organic fertilizers would work. His research would give support to the basic position this research: utilization of biomass resources should be advanced more.

More advantages for sugar cane are that it is used to improve the soil condition. When we interview elderly farmers, many farmers state that their field had sugar cane cultivated more than 60 year – 70 years. It means that replant failure is not observed. Other advantages are that when other plants like squash and pasturage face replant failure the farmers change the fields to sugar cane fields (the type of billet planting in summer). In the sugar cane fields, a large quantity of residues is plowed under. Farmers are aware of the advantage for soil improvement. See appendices as well. Also the quantity of fertilizer applied on Miyakojima Island is smaller than the standard determined by Okinawa prefectural government. Generally speaking, residues have an effect on reduction of the fertilization. That can be another benefit.

Regarding fertilization, farmers tend to apply chemical fertilizer as additional fertilization in October and December. Some of farmers apply beef cattle's manure as basal fertilizer and the others use green manure plants as basal fertilizer. A few farmers apply imported organic fertilizer as basal fertilizer. Many farmers do not apply any as basal fertilizer. Residues from sugar mills (like filter cake) and the sugar cane field (like sugar cane tops) can be considered as basal fertilizer.

Table 3.3 and 3.4 are given to confirm the mass balance for sugar cane in the field. Table 3.3 stands for mass balance of the soil for sugar cane whereas Table 3.4 stands for mass balance of sugar cane.

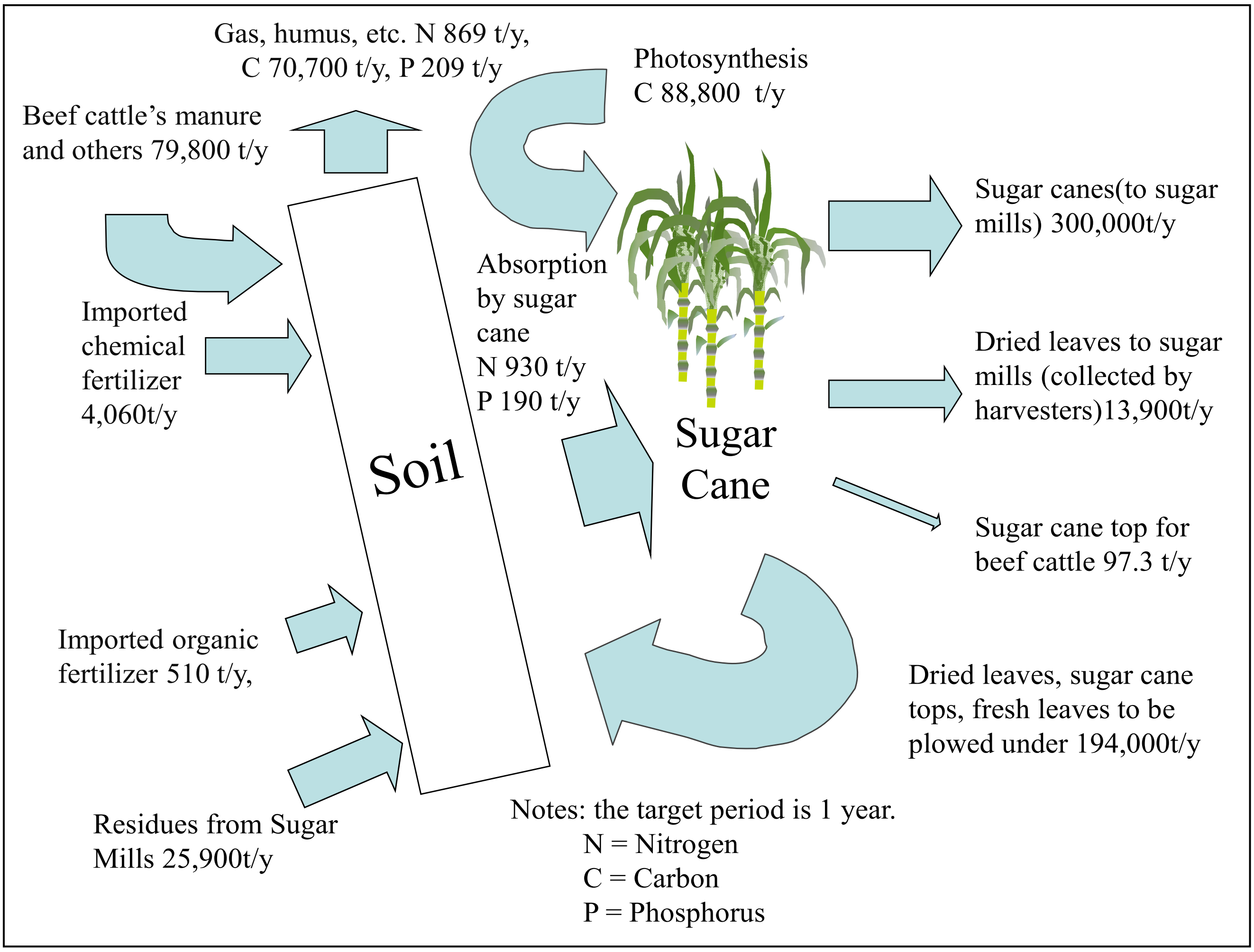

Fig. 3.3 MFA for Sugar Cane in the Field (Weight Basis)

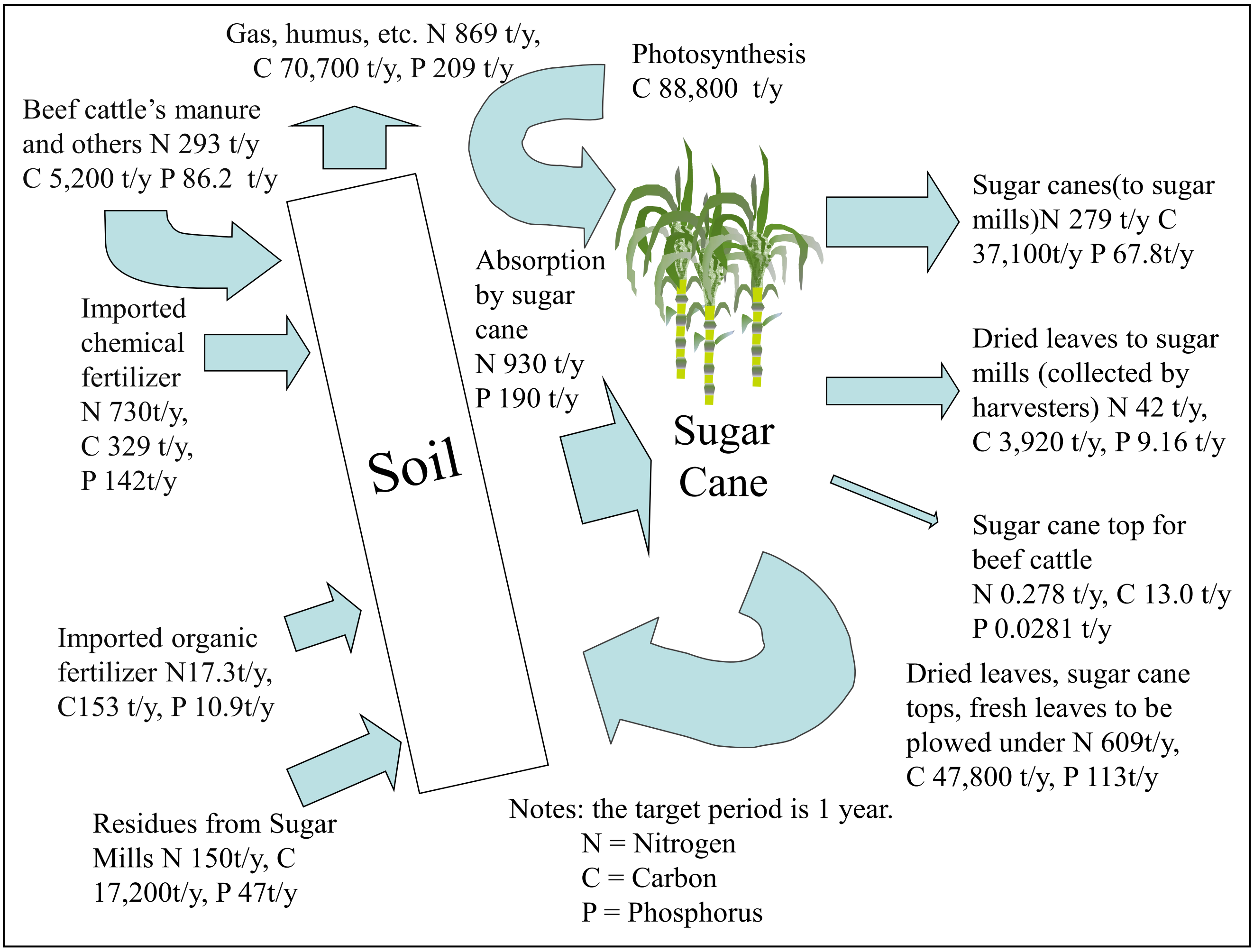

Fig. 3.4 MFA for Sugar Cane in the Field (Element Basis)

Table 3.3 Mass Balance for Input and Output of the Soil for Sugar Cane

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Beef cattle's manure and others	293		5,200		86.2	
Imported chemical fertilizer	730		329		142	
Imported organic	17.3		153		10.9	

fertilizer						
Residues from Sugar Mills	150		17,200		47	
Dried leaves	409		38,200		89.3	
Sugar cane tops	146		6,800		14.8	
Fresh leaves	53.4		2,750		8.59	
Absorption by sugar cane		930				190
Gas, humus, etc.		869		70,700		209
Total	1798.7	1799	70632	70700	398.79	399

Table 3.4 Mass Balance for Input and Output of the Sugar Cane

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Absorption by sugar cane	930				190	
Photosynthesis			88,800			
Sugar canes(to sugar mills)		279		37,100		67.8
Dried Leave (collected by harvesters)		42		3920		9.16
Dried leaves		409		38200		89.3
Sugar cane tops		146		6800		14.8
Fresh leaves		53.4		2,750		8.59
Sugar cane top for beef cattle		0.278		13		0.0281
Total	930	929.678	88800	88783	190	189.6781

3.4 Material Flow Analysis for Pasturage

Fig. 3.5 and Fig. 3.6 for the MFA for pasturage in the field. It is partially based on the discussion in subsection 3.3.3.2 Material Flow Analysis for Sugar Cane in the Field. Pasturage is cultivated by the farmers of beef cattle, not farmers of the other stockbreeding. Most of pasturage is consumed by the breeding cow of the beef cattle. Calves also consume it but the quantity of the pasturage consumed by breeding cow is much larger than the pasturage consumed by calves. Breeding cow consumes it per one day more than calves and the number of breeding outnumbers that of calves. Farmers basically apply chemical fertilizer and some farmers apply beef cattle's manure as well.

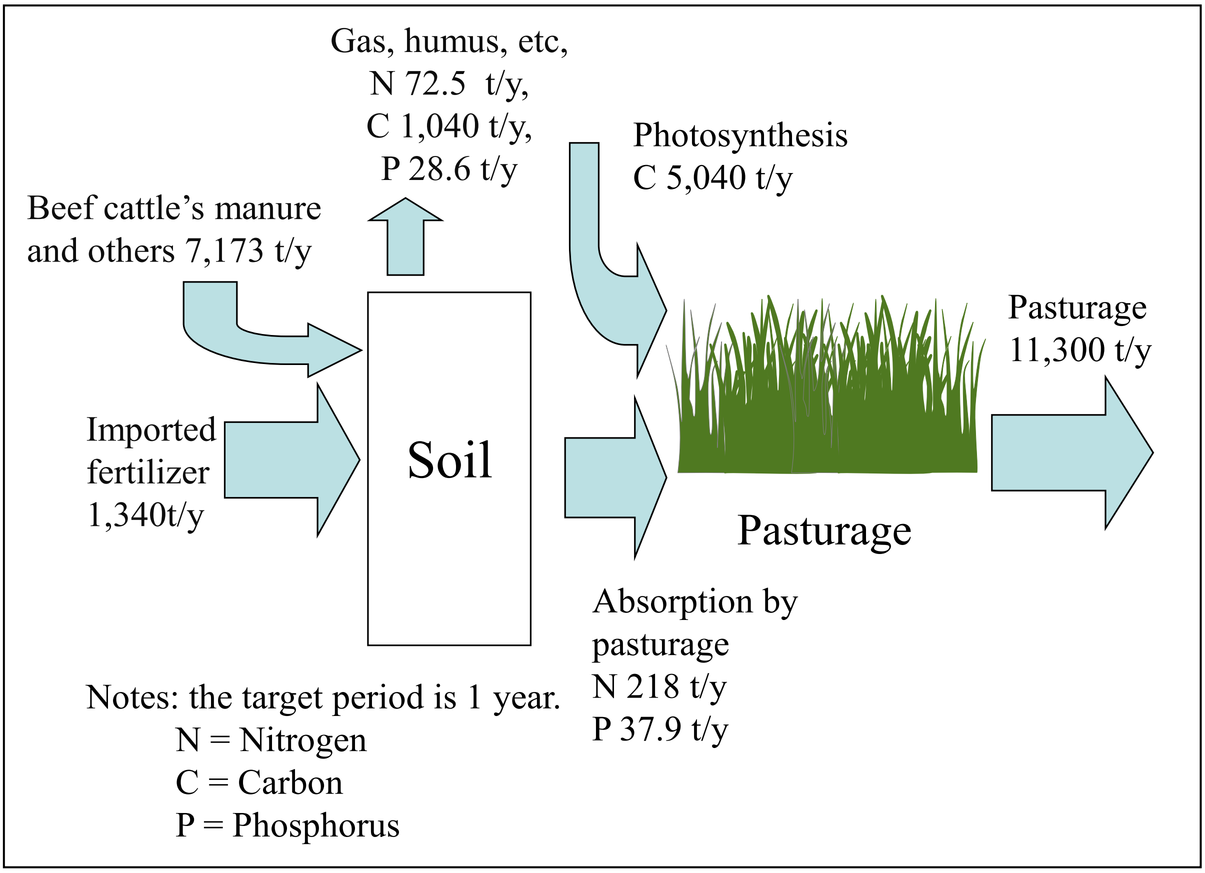

Fig.3.5 MFA for Pasturage (Weight Basis)

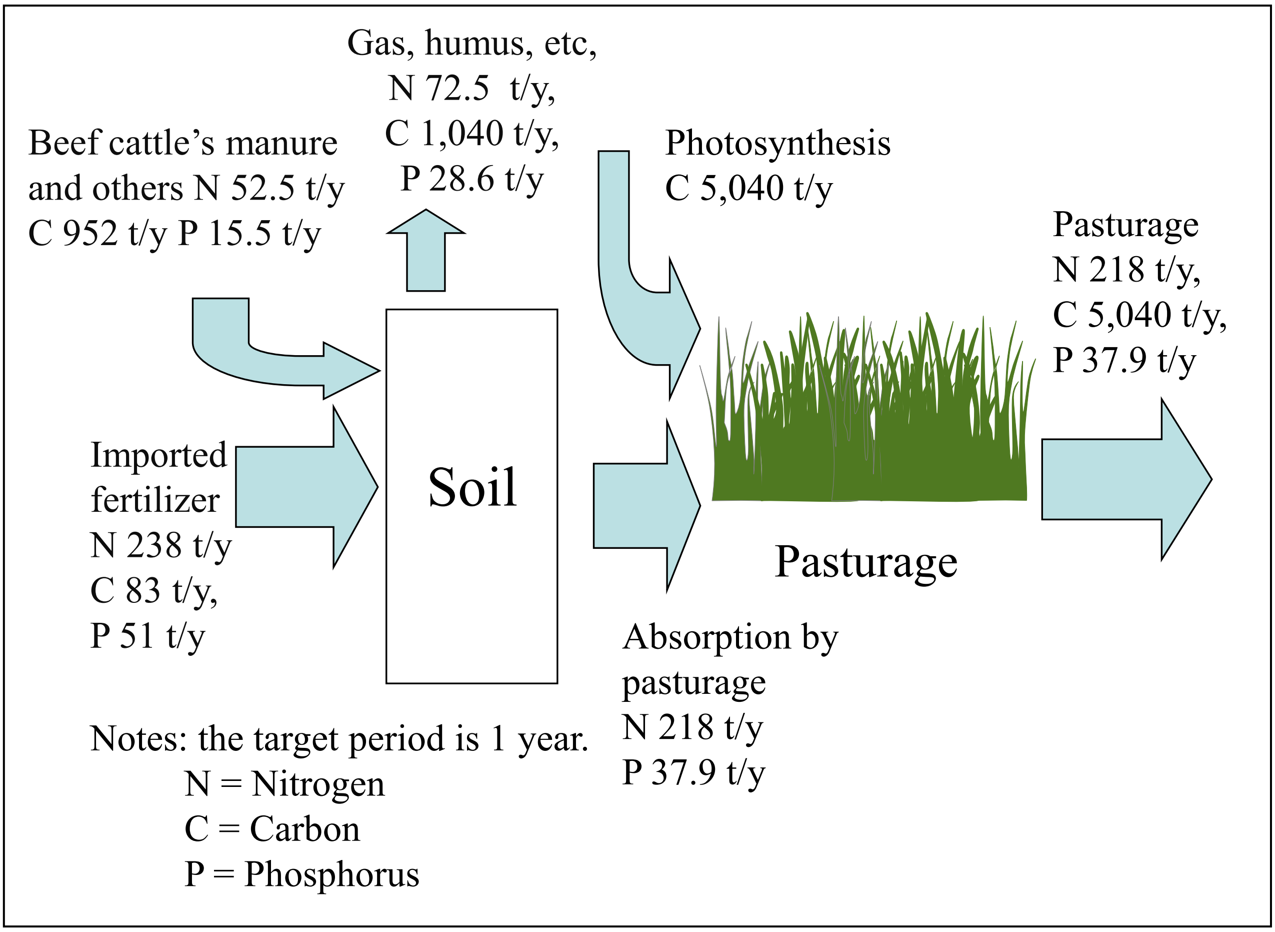

Fig.3.6 MFA for Pasturage (Element Basis)

Table 3.5 and 3.6 are giv en to confirm the mass balance for pasturage. Table 3.5 stands fo r mass balance of the soil for pasturage whereas Table 3.6 stands for mass balance of pasturage.

Table 3.5 Mass Balance for Input and Output of the Soil for Pasturage

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Beef cattle's manure and others	52.5		952		15.5	
Imported fertilizer	238		83		51	

Absorption by pasturage		218				37.9
Gas, humus, etc.		72.5		1,040		28.6
Total	290.5	290.5	1,035	1,040	66.5	66.5

Table 3.6 Mass Balance for Input and Output of Pasturage

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Absorption by pasturage	218				37.9	
Photosynthesis			5,040			
Pasturage		218		5,040		37.9
Total	218	218	5,040	5,040	37.9	37.9

3.5 Material Flow Analysis for Leaf Tobacco

Fig. 3.7 and Fig. 3.8 for the MFA for leaf t obacco. It is partially based on the discussion in subsection 3.3.3.2 Material Flow Analy sis for Sugar Cane in t he Field. Re sidues from leaf tobacco are left behind in the field for a while and it is burnt after harvesting. To avoid bacteria wilt, they are burnt.

Many farmers appl y imported organic fertilizer to the field m ainly. They seem to use chemical and organic m ixture created by specific manufacturers. Some of farmers apply beef cattle's manure only when they are able to pur chase them from beef cattle's farmers. However because beef cattle's farmers apply the manure to th eir own field, they are usually not able to purchase it. So many farmers are forced to purchase imported organic fertilizer.

Because many man hours are r equired to keep beef cattle and to cultivate leaf tobacco, farmers do not usually do both at the same time.

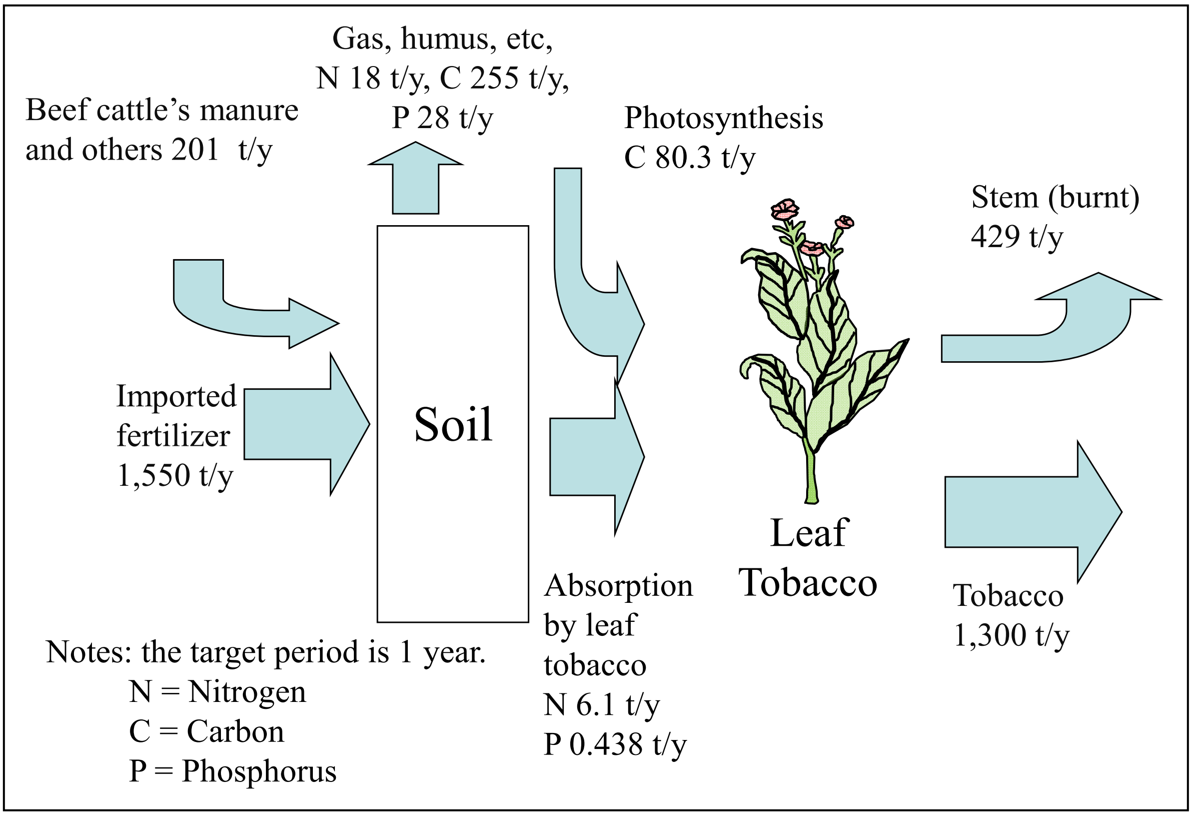

Fig. 3.7 MFA for Leaf Tobacco

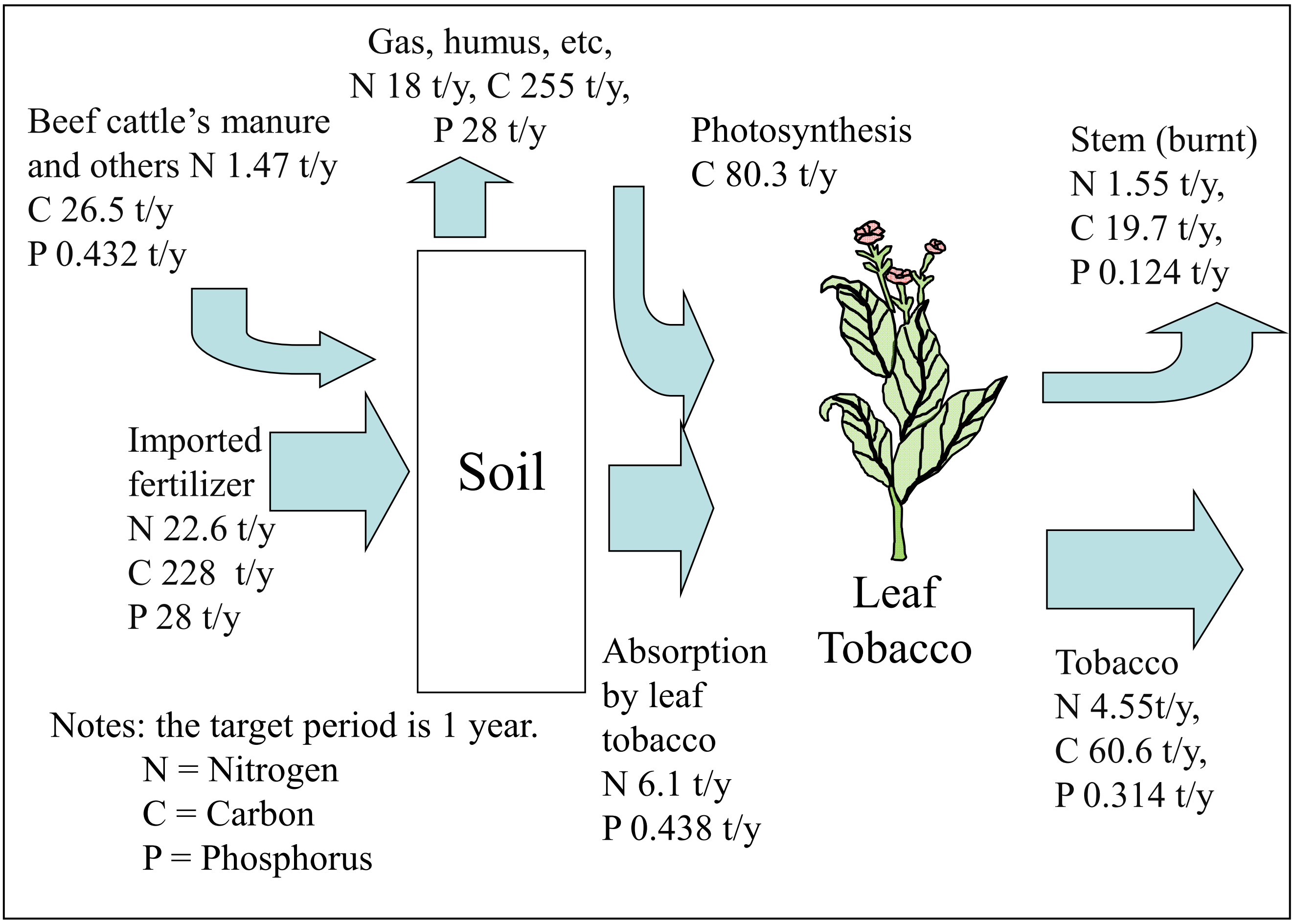

Fig. 3.8 MFA for Leaf Tobacco

Table 3.7 and 3.8 are given to confirm the mass balance for leaf tobacco. Table 3.7 stands for mass balance of the soil for tobacco whereas Table 3.8 stands for mass balance of tobacco.

Table 3.7 Mass Balance for Input and Output of the Soil for Leaf Tobacco

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Beef cattle's manure and others	1.47		26.5		0.432	
Imported fertilizer	22.6		228		28	

Absorption by leaf tobacco		6.1				0.438
Gas, humus, etc.		18		255		28
Total	24.07	24.1	254.5	255	28.432	28.438

Table 3.8 Mass Balance for Input and Output of Leaf Tobacco

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Absorption by leaf tobacco	6.1				0.438	
Photosynthesis			80.3			
Stem (burnt)		1.55		19.7		0.124
Tobacco		4.55		60.6		0.314
Total	6.1	6.1	80.3	80.3	0.438	0.438

3.6 Material Flow Analysis for Squash

Fig. 3.9 and Fig. 3.10 shows the MFA for squash. It is partially based on the discussion in subsection 3.3.3.2 Material Flow Analysis for Sugar Cane in the Field. Residues from squash are left behind in the field for a while and it is burnt after harvesting. To avoid disease like anthracnose, the residues (vine and leaves) are burnt. A few of squash are cultivated in green house and most of them are cultivated outdoors. In Okinawa Prefecture including Miyakojima Island, farmers who cultivate agricultural plants in green house receive the financial support from the local government.

They apply chemical and organic fertilizer to the field. Some of farmers apply beef cattle's manure only when they are able to purchase them from beef cattle's farmers. However because beef cattle's farmers apply the manure to their own field, they are usually not able to purchase it. Because many man hours are required to keep beef cattle and to cultivate squash, farmers do not usually do both at the same time. So many farmers are forced to purchase imported organic fertilizer.

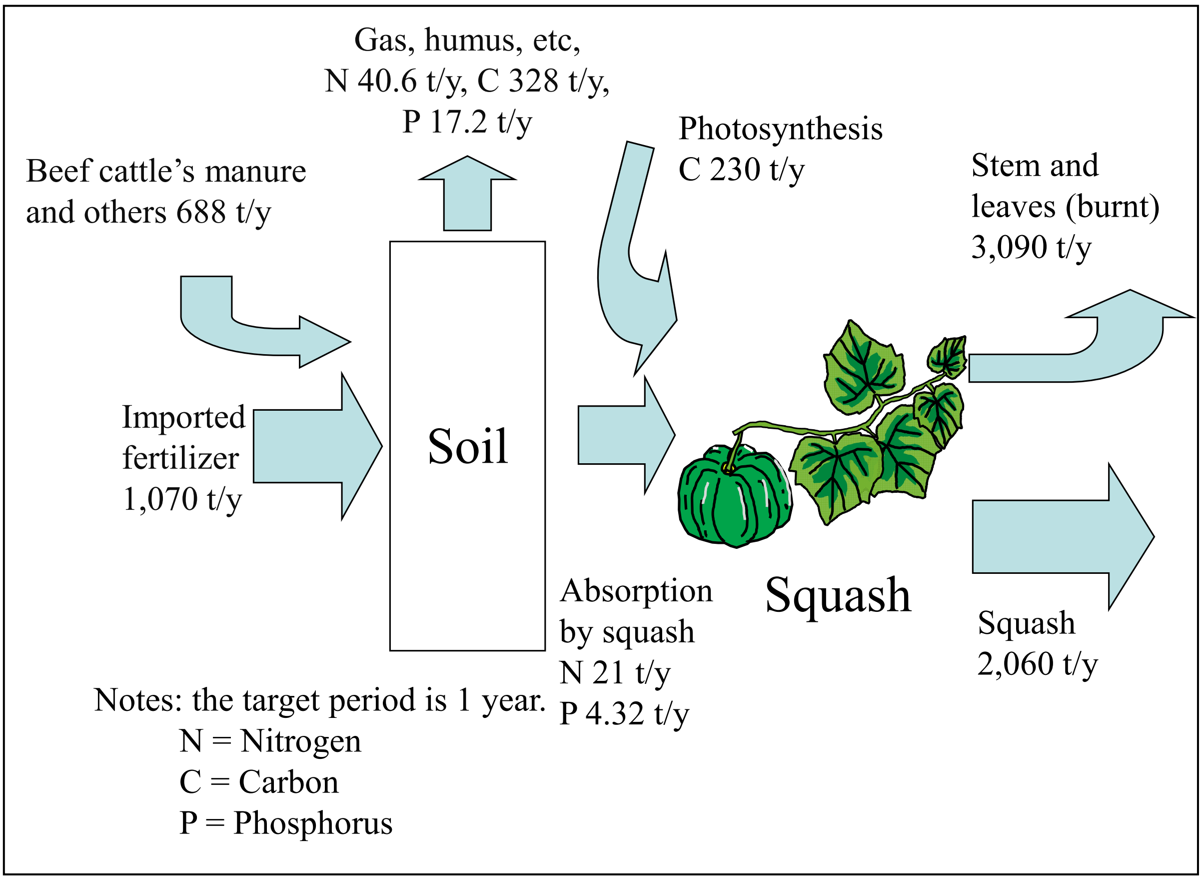

Fig. 3.9 MFA for Squash (Weight Basis)

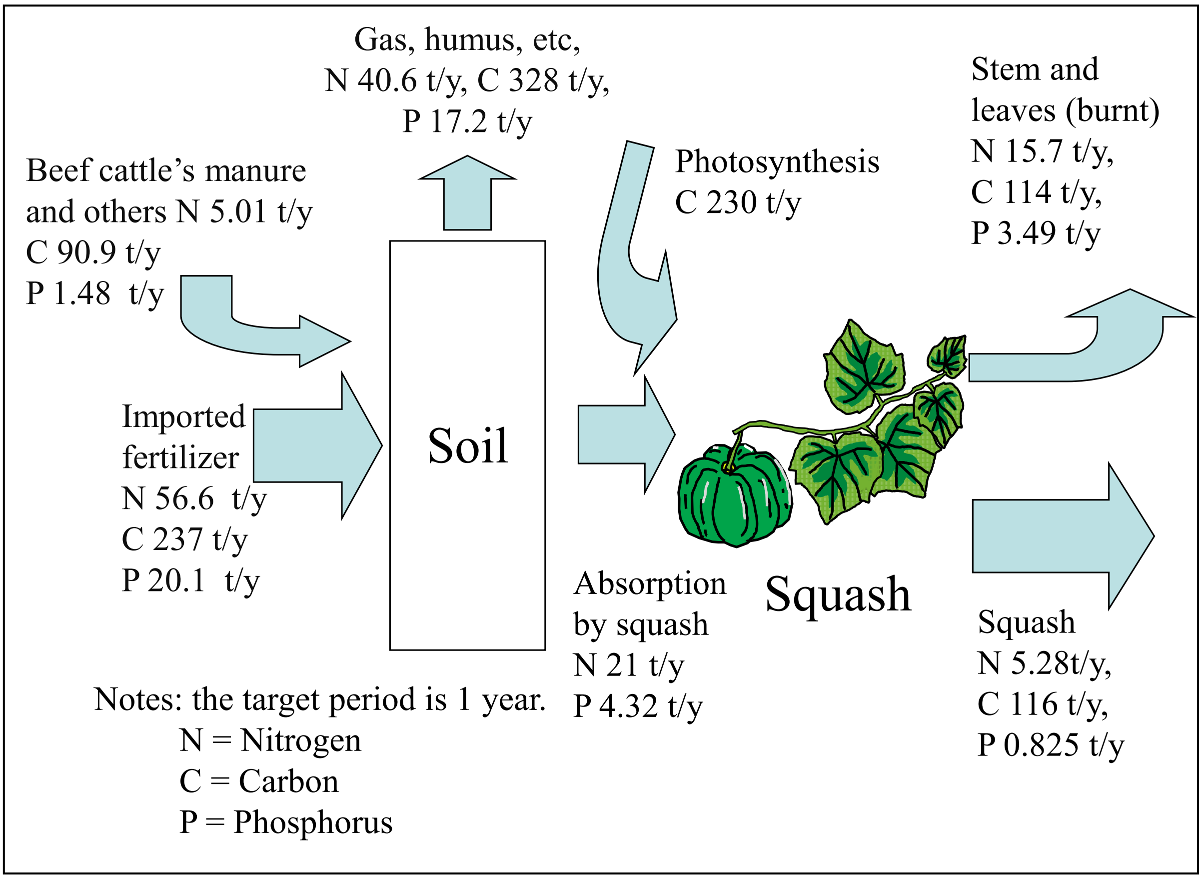

Fig. 3.10 MFA for Squash (Element Basis)

Table 3.9 and 3.10 are given to confirm the mass balance for squash. Table 3.9 stands for mass balance of the soil for squash whereas Table 3.10 stands for mass balance of squash.

Table 3.9 Mass Balance for Input and Output of the Soil for Squash

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Beef cattle's manure and others	5.01		90.9		1.48	
Imported fertilizer	56.6		237		20.1	
Absorption by		21				4.32

squash						
Gas, humus, etc.		40.6		328		17.2
Total	61.61	61.6	327.9	328	21.58	21.52

Table 3.10 Mass Balance for Input and Output of the Squash

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Absorption by squash	21				4.32	
Photosynthesis			230			
Stem and leaves (burnt)		15.7		114		3.49
Squash		5.28		116		0.825
Total	21	20.98	230	230	4.32	4.315

3.7 Material Flow Analysis for Chinese Preserving Melon

Fig. 3.11 and Fig. 3.12 shows the MFA for Chinese preserving melon. It is partially based on the discussion in subsection 3.3.3.2 Material Flow Analysis for Sugar Cane in the Field. Residues from Chinese preserving melon are left behind in the field for a while and it is burnt after harvesting. To avoid disease like anthracnose, the residues (vine and leaves) are burnt. They are cultivated in green house. In Okinawa Prefecture including Miyakojima Island, farmers who cultivate agricultural plants in green house receive the financial support from the local government.

They apply chemical and organic fertilizer to the field. Some of farmers apply beef cattle's manure only when they are able to purchase them from beef cattle's farmers. However because beef cattle's farmers apply the manure to their own field, they are usually not able to purchase it.

Because many man hours are required to keep beef cattle and to cultivate Chinese Preserving Melon, farmers do not usually do both at the same time. So many farmers are forced to purchase imported organic fertilizer.

Table 3.11 and 3.12 are given to confirm the mass balance for Chinese preserving melon. Table 3.11 stands for mass balance of the soil for Chinese preserving melon whereas Table 3.12 stands for mass balance of Chinese preserving melon.

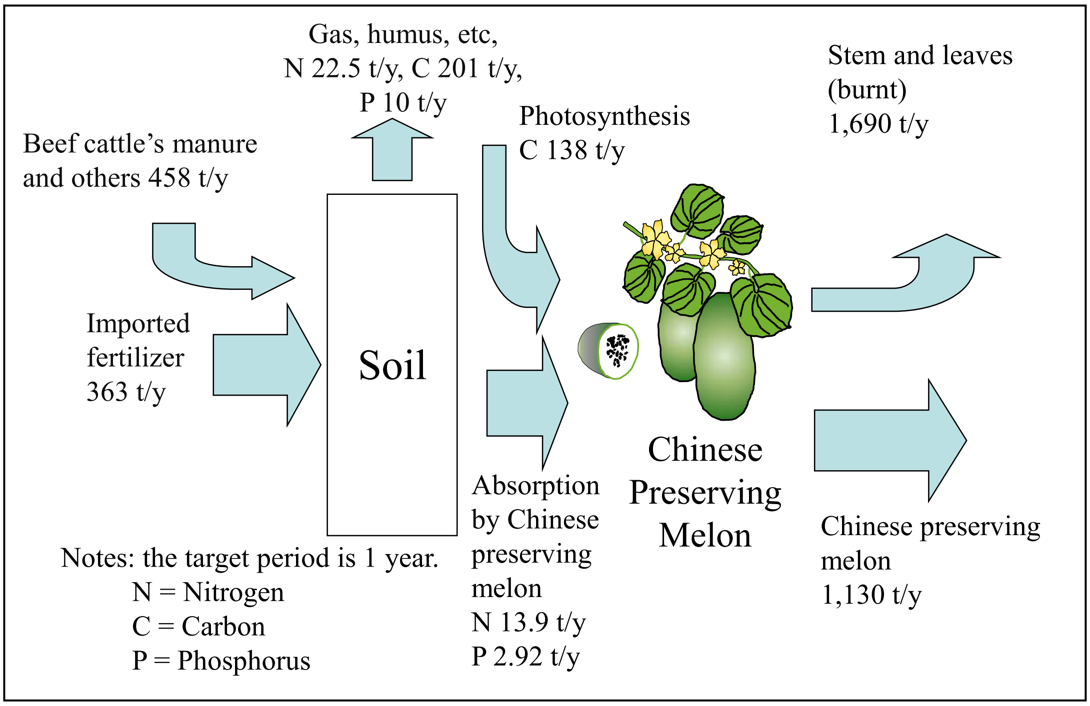

Fig. 3.11 MFA for Chinese Preserving Melon(Weight Basis)

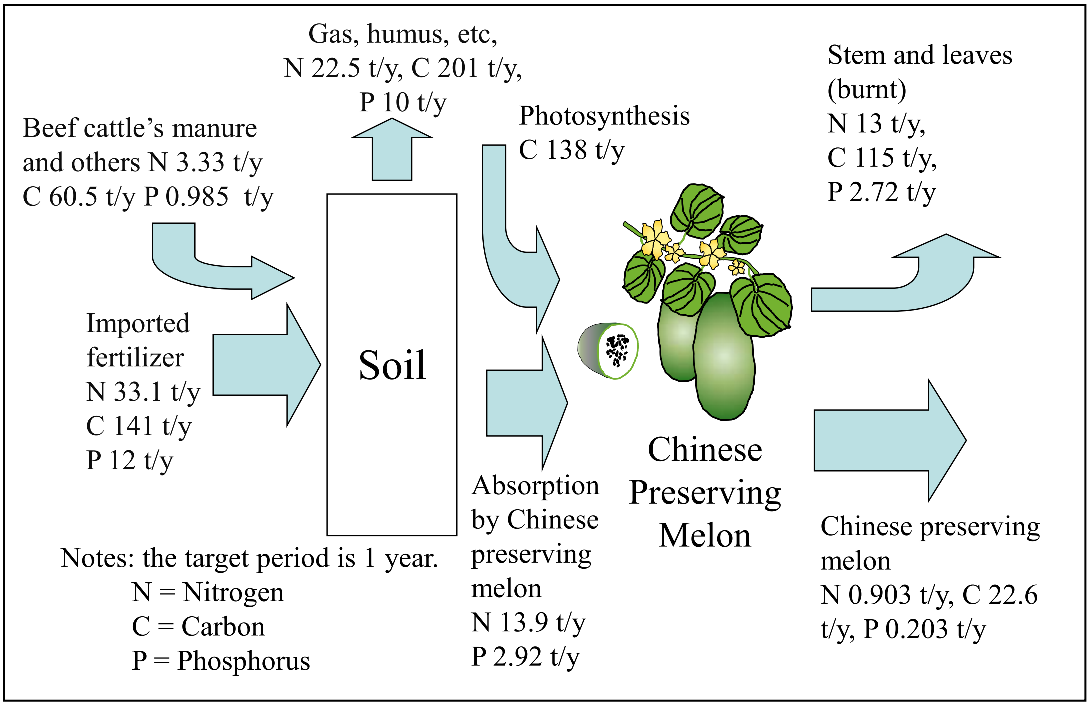

Fig. 3.12 MFA for Chinese Preserving Melon (Element Basis)

Table 3.11 Mass Balance for Input and Output of the Soil for Chinese Preserving Melon

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Beef cattle's manure and others	3.34		60.5		0.991	
Imported fertilizer	33.1		141		12	
Absorption by Chinese preserving melon		13.9				2.92
Gas, humus, etc.		22.5		202		10

Total	36.44	36.4	201.5	202	12.991	12.92

Table 3.12 Mass Balance for Input and Output of the Chinese Preserving Melon

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Absorption by Chinese preserving melon	13.9				2.92	
Photosynthesis			138			
Stem and leaves (burnt)		13		115		2.72
Chinese preserving melon		0.903		22.6		0.203
Total	13.9	13.903	138	137.6	2.92	2.923

3.8 Material Flow Analysis for Bitter Melon

Fig. 3.13 and Fig. 3.14 shows the MFA for bitter melon in the field. It is partially based on the discussion in subsection 3.3.3.2 Material Flow Analysis for Sugar Cane in the Field. Residues from bitter melon are left behind in the field for a while and it is burnt after harvesting. To avoid disease like anthracnose, the residues (vine and leaves) are burnt. They are cultivated in green house. In Okinawa Prefecture including Miyakojima Island, farmers who cultivate agricultural plants in green house seem to receive the financial support from the local government.

They apply chemical and organic fertilizer to the field. Some of farmers apply beef cattle's manure only when they are able to purchase them from beef cattle's farmers. However because beef cattle's farmers apply the manure to their own field, they are usually not able to purchase it. Because many man hours are required to keep beef cattle and to cultivate Bitter Melon, farmers do not usually do both at the same time. So many farmers are forced to purchase imported organic fertilizer.

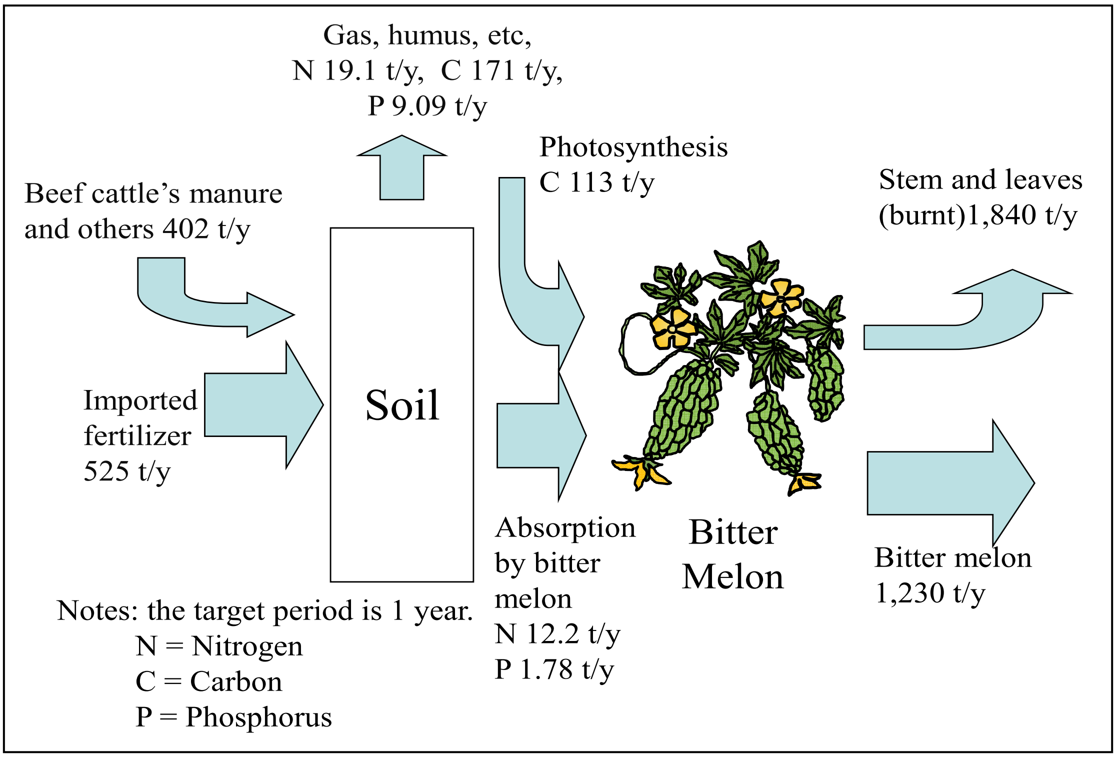

Fig. 3.13 MFA for Bitter Melon (Weight Basis)

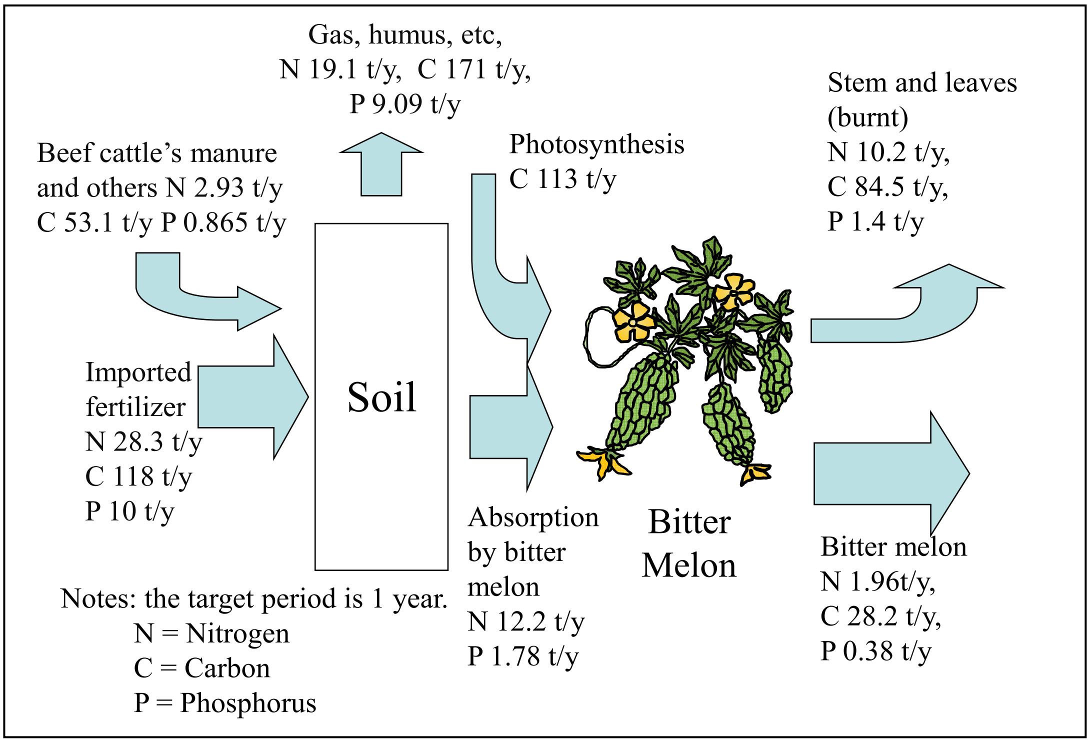

Fig. 3.14 MFA for Bitter Melon (Element Basis)

Table 3.13 and 3.14 are given to confirm the mass balance for bitter melon. Table 3.13 stands for mass balance of the soil for bitter melon wh ereas Table 3.14 stands for mass balance of bitter melon.

Table 3.13 Mass Balance for Input and Output of the Soil for the Bitter Melon

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Beef cattle's manure and others	2.93	53.1			0.865	
Imported fertilizer	28.3		118		10	

Absorption by bitter melon		12.2				1.78
Gas, humus, etc.		19		171		9.09
Total	31.23	31.2	171.1	171	10.865	10.87

Table 3.14 Mass Balance for Input and Output of the Bitter Melon

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Absorption by bitter melon	13.9				2.92	
Photosynthesis			138			
Stem and leaves (burnt)		13		115		2.72
Bitter melon		0.903		22.6		0.203
Total	13.9	13.903	138	137.6	2.92	2.923

3.9 Material Flow Analysis for Mango

Fig. 3.15 and Fig. 3.16 for the MFA for mango in the field. It is partially based on the discussion in subsection 3.3.3.2 Material Flow Analysis for Sugar Cane in the Field. Residues from mango are left behind in the field for a while and it is burnt after harvesting. To avoid disease like anthracnose, most of wastes from pruned trees (branches) are burnt. But some of leaves are used as mulch. Mango has the part of trees but it is not replanted. According to the personal communication with the farmers on Miyakojima Island, the start of the mango cultivation is not that old (at oldest, approximately 20 years ago). Every year branches of mango are pruned and the wastes are not that much. The quantity of the biomass resources are not that large. Mango is cultivated in green house. Its height is not higher than that of vegetables.

In Okinawa Prefecture including Mi yakojima Island, farmers who cultivate agricultural pl ants in green house receive the financial support from the local government.

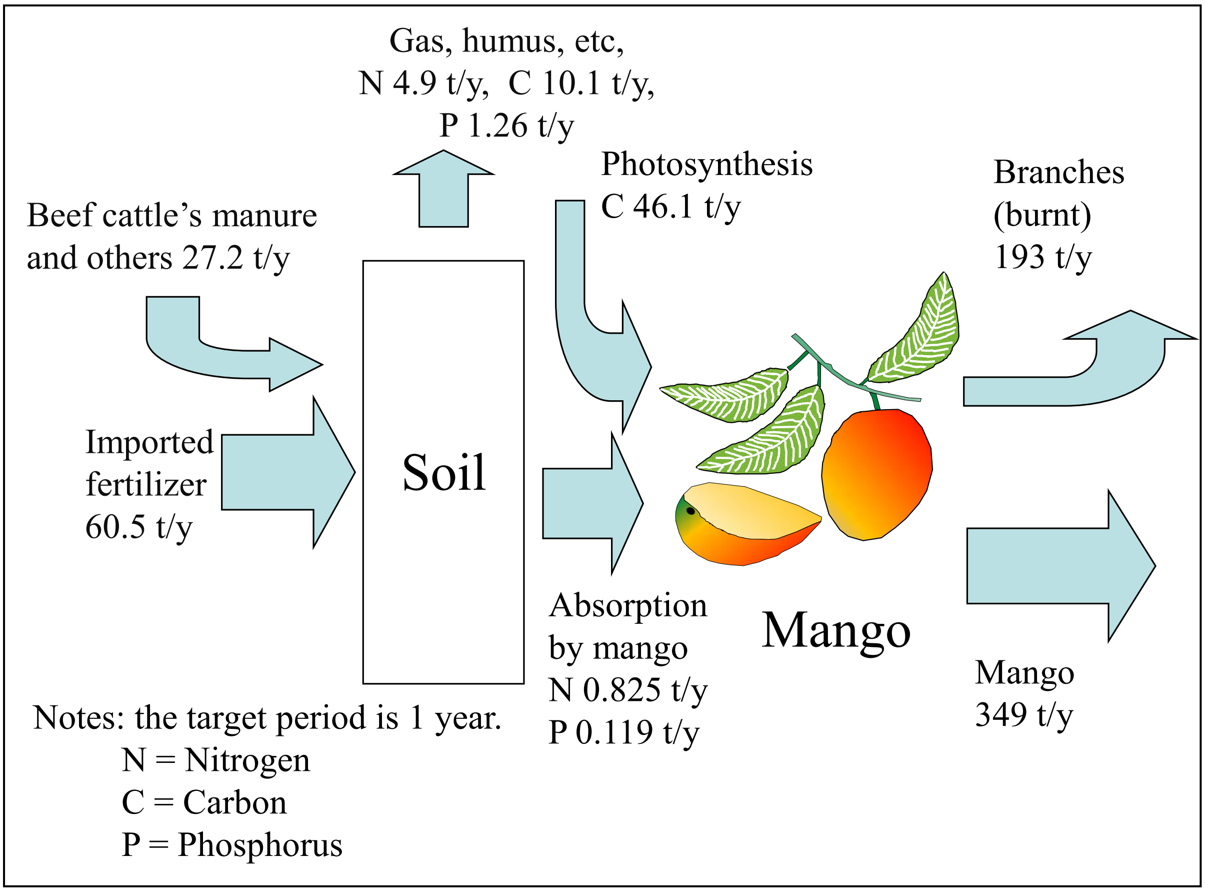

Fig. 3.15 MFA for Mango (Weight Basis)

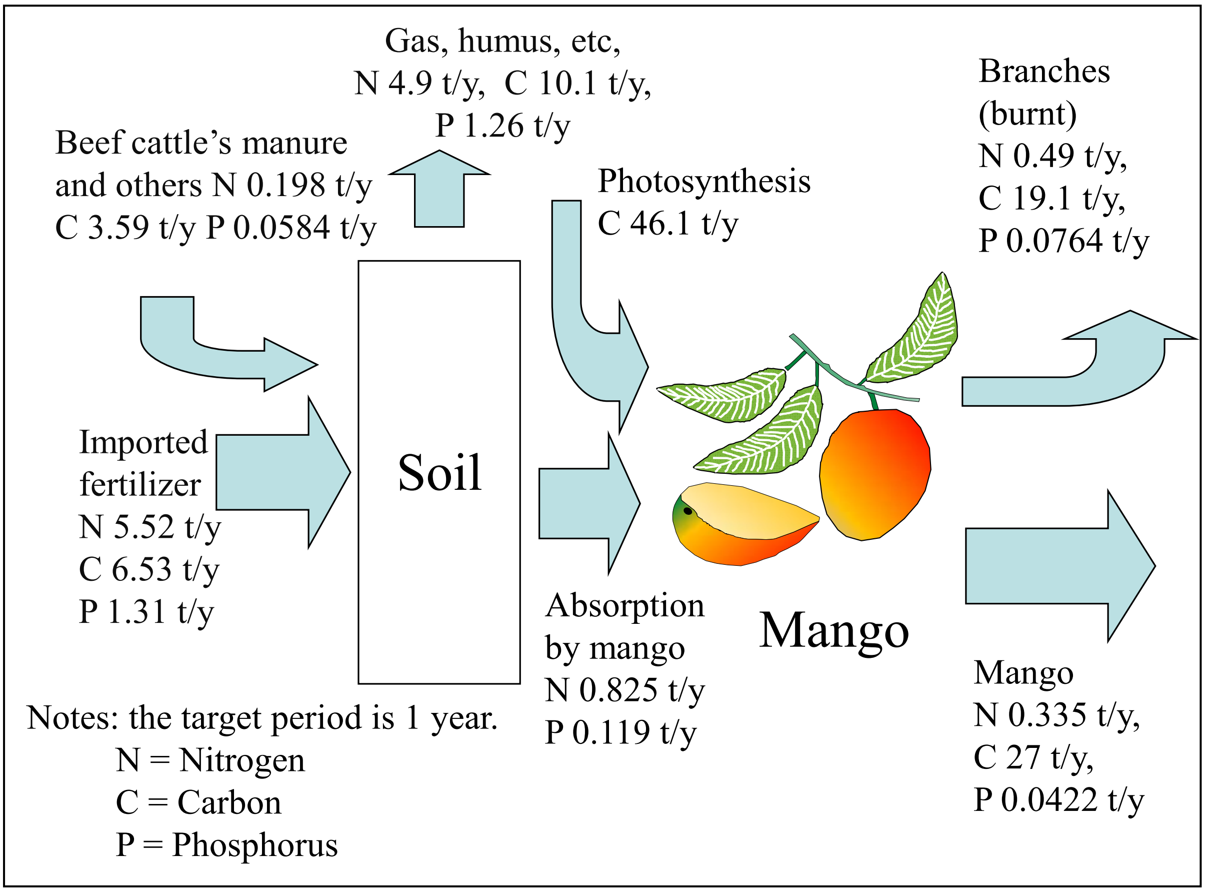

Fig. 3.16 MFA for Mango (Element Basis)

Many farmers apply imported organic fertilizer to the field mainly. They do not use chemical fertilizer to mango. Some of farmers apply beef cattle's manure only when they are able to purchase them from beef cattle's farmers. A few farmers mix beef cattle's manure with branches, put them in the hole and cover the surface with the soil to create compost. However the quantity of branches used for composting would be negligible. In the same way as other agricultural plants, because beef cattle's farmers apply the manure to their own field, they are usually not able to purchase it. So many farmers are forced to purchase imported organic fertilizer. Because many man hours are required to keep beef cattle and to cultivate mango, farmers do not usually do both at the same time.

Table 3.15 and 3.16 are given to confirm the mass balance for mango. Table 3.15 stands for mass balance of the soil for mango whereas Table 3.16 stands for mass balance of mango.

Table 3.15 Mass Balance for Input and Output of the Mango

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Beef cattle's manure and others	0.198		3.6		0.0584	
Imported fertilizer	5.52	6.53			1.31	
Absorption by mango		0.825				0.119
Gas, humus, etc.		4.9		10.1		1.26
Total	5.718	5.725	10.12	10.1	1.3684	1.379

Table 3.16 Mass Balance for Input and Output of the Mango

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Absorption by mango	0.825				0.119	
Photosynthesis			46			
Branches (burnt)		0.49		19		0.0764
Mango		0.335		27		0.0422
Total	0.825	0.825	46.1	46.1	0.119	0.1186

3.10 Material Flow Analysis for Green Manure Plants

Four green manure plants are cultivated in the fields of Miyakojima Island,: that is, crotalaria (juncea), pigeon pea, moong bean and sorghum . The MFA for the green manur e plants is shown in Fig. 3.17.

Green manure plants can obtain the nitrogen necessary for growth by nitrogen fixation. So the fertilizer is not given. After three or four month cultivation, they are plowed under.

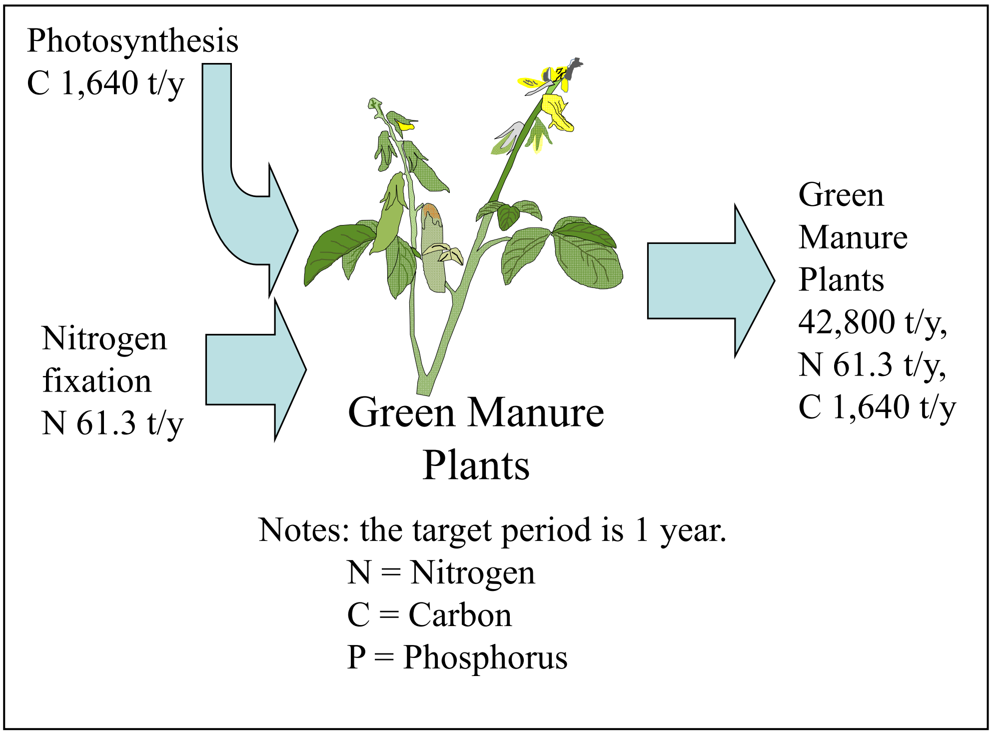

Fig. 3.17 MFA for Green Manure

We do not give the tables to confirm the mass balance table for green manure plants because we can tell the mass balance without it.

The area for each green manure plant is: crotalaria (juncea) is 210ha; pigeon pea is 26.9 ha; moong bean is 114ha; sorghum is 73.6 ha.

For the discussion of Chapter 4 and 5, we also show MFA for pigeon pea in Fig 3.18.

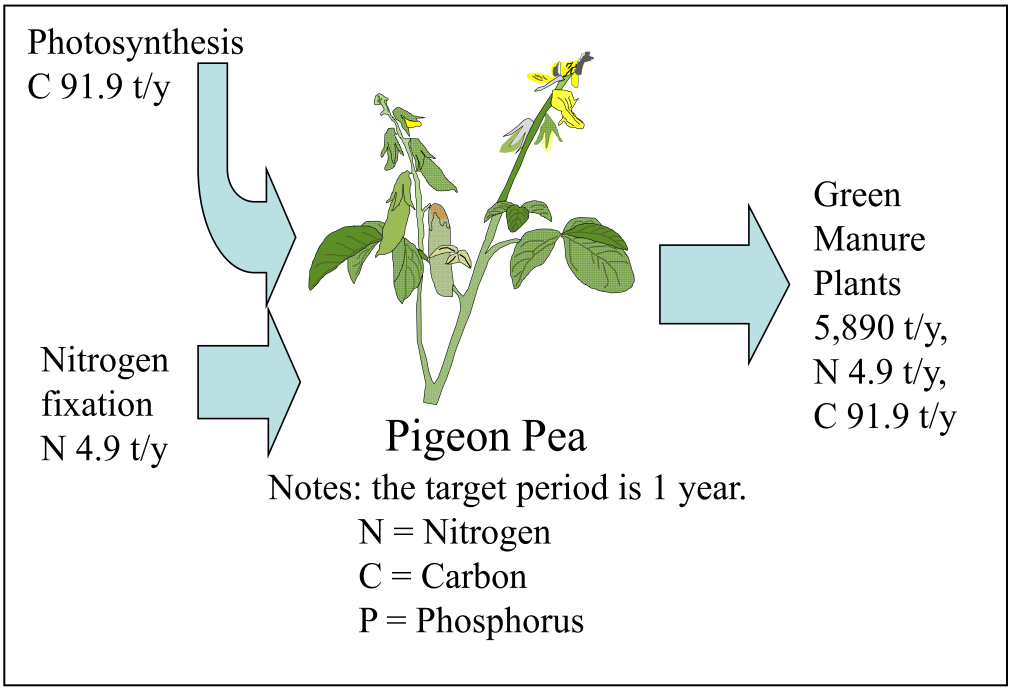

Fig. 3.18 MFA for Pigeon Pea

3.11 Biomass Resources from Agricultural Plants and Imported Fertilizer

This section discusses biomass resources from agricultural plants and imported fertilizer. Note that we already discussed biomass resources from stockbreeding in Chapter 2. Table 3.17 shows biomass resources from sugar mills and sugar cane fields. Also it includes the information on green manure plants. All of biomass resources in Table 3.17 are plowed under.

Table 3.18 shows biomass resources which go to composting facilities. Note that as addressed above biomass resource from leaf tobacco, squash, Chinese preserving melon, bitter melon and mango are burnt so those biomass resources cannot be available.

Now this research clarified all biomass resources available for stockbreeding and agricultural plants.

Table 3.17 Biomass Resource List which are Plowed under

	Total Quantity (t/y)	Nitrogen Quantity (t/y)	Carbon Quantity (t/y)	Phosphorus Quantity (t/y)
Residues from Sugar Mills	25,900	150	17,200	47
Residues from Sugar Cane Fields	201,000	812	56,500	133
Green Manure Plants	42,800	61.3	1640	N/A

Table 3.18 Biomass Resource List for Composting Facilities

	Total Quantity (t/y)	Nitrogen Quantity (t/y)	Carbon Quantity (t/y)	Phosphorus Quantity (t/y)
Residues from Sugar Mills	11,200	32	2,920	19.3

We next discuss the fertilizer imported from the outside of Miyakojima Island. Table 3.19 shows the quantity of chemical and organic fertilizers and composts. It is created, based on the administrative data provided by Miyakojima city hall. As you can see, chemical fertilizers contain much nitrogen. On the other hand, organic fertilizer tends to contain more carbon (Organic fertilizers are different from composts: They are usually created with machines while compost is created with microbe's decomposition. Therefore most of "Organic Fertilizer and Compost" in Table 3.19 is occupied by one product: it is chicken's manure dried by machines. So the composition of "Organic Fertilizer and Compost" in Table 3.19 is relatively high when we compare it with the composition of compost). Regarding the carbon concentration of chemical fertilizers (not organic fertilizer and compost), manufacturers did not make any analysis to them because there are no regulatory requirements in Japan. So we rely on two methods: when we know the active ingredients such as urea, we presume the concentration from its chemical formula; we also made elemental analysis to several fertilizers. On the quantity scale, we are able to presume and analyze the carbon concentration from 86.4% of fertilizers. For the carbon concentration of fertilizers which are not included in this analysis and presumption, this research assumes that they have the same concentration as the analyzed and presumed fertilizers.

Table 3.19 Imported Fertilizer Quantity

	Total Quantity (t/y)	Nitrogen Quantity (t/y)	Carbon Quantity (t/y)	Phosphorus Quantity (t/y)
Chemical Fertilizer	5,940	1,000	217	202
Organic Fertilizer and Compost	3,870	96.7	1,090	59.1
Total	9,810	1040	1310	262

Before we close this section, as a deliverable of MFA for all agricultural plants, we give fertilizer and biomass resource distribution ratio in Table 3.20.

Table 3.20 Fertilizer and Biomass Resource Distribution Ratio

Agricultural Plant Name	Stockbreeding Manure's and other Biomass (excluding sugar cane residues) Distribution Ratio (%)	Sugar Cane Residue's Distribution Ratio (%)	Fertilizer Distribution Ratio (%)
Sugar Cane	80.6	100%	66
Pasturage	15.6	0%	21
Squash	1.49%	0% (negligible)	5

Leaf Tobacco	0.435%	0% (negligible)	2
Chinese Preserving Melon	0.991%	0% (negligible)	3
Bitter Melon	0.87%	0% (negligible)	2.5
Mango	0.0588%	0% (negligible)	0.5

3.12 Material Flow Analysis for Miyakojima City Resources Recycling Center

We next turn to the MFA of Miy akojima City Resources Recycling Center. The purpose of this MFA is to establish the, nitrogen and carbon loss ratios of the raw materials which are processed in the three co mposting facilities: we think that the result from Miyakojima City Resources Recycling Center can be applied to other composting facilites. The target period of the MFA of Miy akojima City Resources Recycling Center is five years because the loss rati os among years are variable. The reasons for variability of the loss rat ios would be 1) co mposting processes take a few months. 2) the period of hi gh demands are August or Septem ber, i.e. the application timing of base fertilization to sugar cane. 3) Com posts are competitive with other composts and organic fertilizers from the inside and the outside of the island. Note that "organic fertilizers" on this contest are manure from stockbreeding but di d not go t hrough composting processes. It is usually a pellet dried by mach ines. To enhance the accura cy, this resear ch sets the target period as five years.

Now we are in a position to show the MFA for Miyakojima City Resources Recycling Center, as in Fig. 3.19:

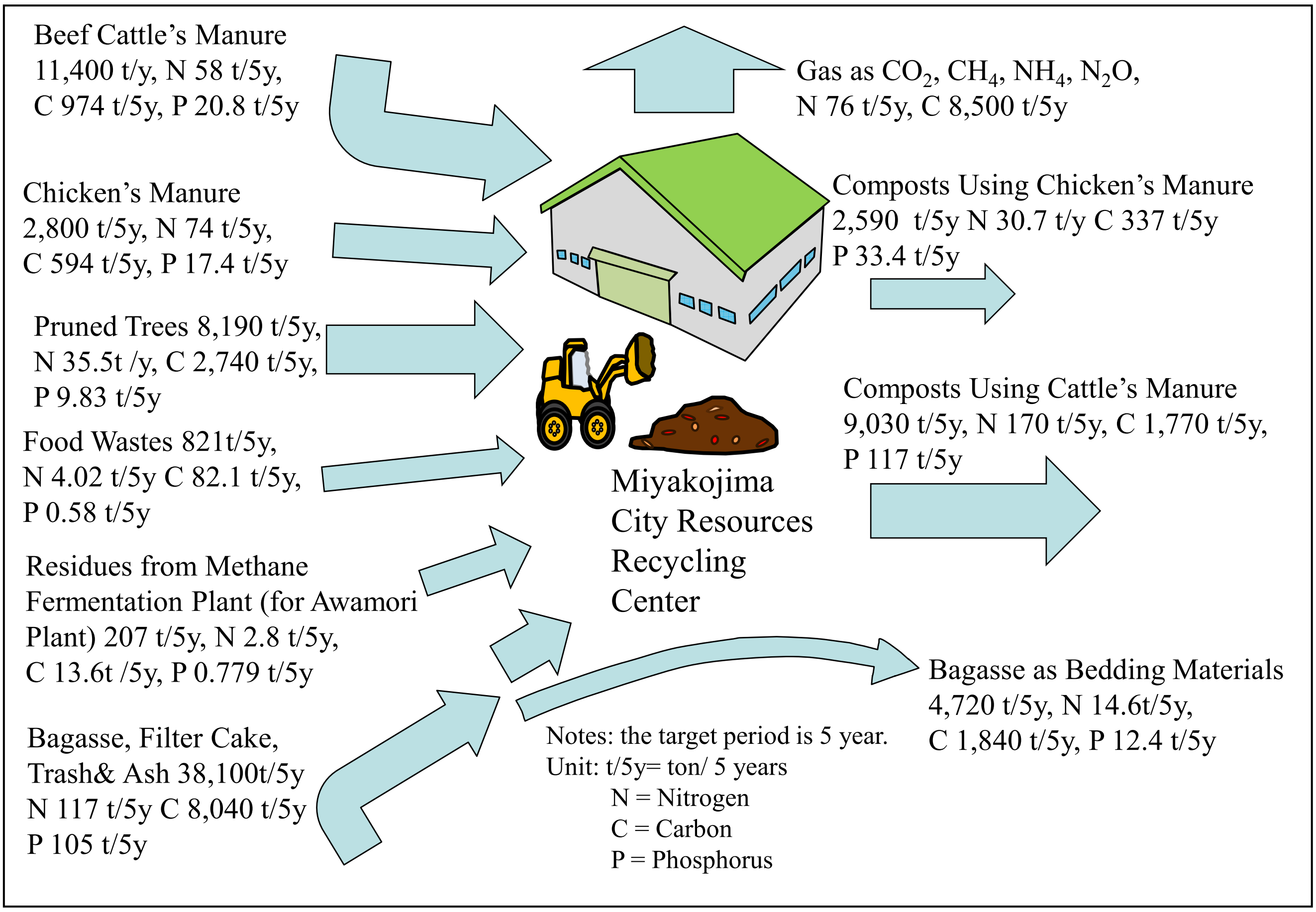

Fig. 3.19 MFA for Miyakojima City Resources Recycling Center

Table 3.21 Mass Balance for Miyakojima City Resources Recycling Center

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Beef Cattle's Manure	58		974		20.8	
Chicken's Manure	74		594		17.4	
Pruned Trees	35.5		2,740		9.83	
Food Wastes	4.02		82.1		0.58	

Residues from Methane Fermentation Plant (for Awamori Plant)	2.8		13.6		0.779	
Bagasse, Filter Cake, Trash& Ash	117		8,040		113	
Composts Using Chicken's Manure		30.7		337		33.4
Composts Using Cattle's Manure		170		1,770		117
Bagasse as Bedding Materials		14.6		1,840		12.4
Gas as CO_2, CH_4, NH_4, N_2O,		76		8,500		
Total	291.32	291.3	12,444	12,447	162.389	162.8

As addressed above, one composting facility always keeps bagasse to exchange it for beef cattle manure and it is this composting facility. Two types of the composts are created in the facility: i.e. composts using chicken manure and composts using cattle manure. Another composting facility purchases manure from the biggest poultry raising farmer when the MFA of the poultry raising was conducted. Food waste is collected by the city together with other wastes from homes and businesses. The difference between the food wastes for the composting facility and the food wastes for hog raising is that the food wastes for the composting facility are usually decayed because they are stored home or in companies until they are collected by the city whereas the ones for hog raising are collected daily from restaurants, hotels and supermarkets as addressed above. The food wastes are not fully used but they will be discussed in the future research.

Wastes from pruned trees are also collected by the city hall and are shredded into wood chips for composting. Residues from sugar mills are purchased by the facility. Even if the public composting facility like Miyakojima City Resources Recycling Center does not need to compost them, they are fully utilized by farmers to plow under. This topic will be discussed in the future research as well. Regarding the residues from a methane fermentation plant, two Awamori plants own them and one of them has the composting facility use it as raw material for composting.

This research adopts the analysis results for the nitrogen and carbon concentrations provided by the composting facility. However the analysis results for the phosphorus concentrations are not adopted for the convenience of the discussion: The phosphorus quantity of the input should be the same quantity of the output within the framework of the present research. Because Miyakojima City Resources Recycling Center has the concrete floor, phosphorus in the input will not be lost

Now we are able to obtain the quantity, nitrogen and carbon loss ratio of the raw materials which are processed in the three composting facilities, as shown in Table 3.22:

Table 3.22 Loss Ratio Establishment of All Materials for Composting in the Facility

	Quantity (%)	Nitrogen (%)	Carbon (%)	Phosphorus (%)
Composting in the Facility	79.5	27.4	80.3	0

This research thinks about another composting system used widely on Miyakojima Island: residues from sugar mills and sugar cane fields for your reference only. We do not need to establish these loss ratio for this research,. The carbon-to-nitrogen ratio (hereafter, C/N ratio) of the residues from sugar mills and sugar cane fields are high. No past research was done regarding loss ration of the residues from sugar mills and sugar cane fields. But there was a study which determined the residual ratio of plants with the relatively high C/N ratio are when they are plowed under. In the research of "Studies on Soil Science and Fertilizer in the Paddy Field Applied Rice and Barley Straw"[26], how much barley and rice straw remain when they are plowed under. The residual ratios for residues from sugar mills and sugar cane field use would be close to the result of that study. The residues are decomposed relatively slowly and a nitrogen deficiency occurs. The nitrogen quantity in the residues increase because the residues absorb the nitrogen in the soil: 138 for barley and 95 for rice show the maximum values of nitrogen when 9.5 months elapses for barley and when 6 months elapses for rice. The nitrogen values 84 and 89 are the lowest values until 9.5 months for barley and 6 months for rice. Those are judged to show the nitrogen quantity which barley's and rice's residues lost. Because residues from sugar mills and residues from sugar cane are assumed to cause a nitrogen deficiency, they are plowed under 5 months prior to the billet planting. On the island the planting is usually made in late August or early September.

Table 3.23 Residual Ratio (of the Residues from Sugar Cane) for Composting when Plowed Under

	Quantity (%)	Nitrogen (%)	Carbon (%)	Phosphorus (%)
Barley (9.5 Months Elapsed)	34.3	84 (138)	55	100
Rice (6 Months Elapsed)	54.8	89 (95)	39.6	100

3.13 Summary of the Discussion in Chapter 3

Chapter 3 conducted MFA of a variety of agricultural plants and its related facilities such as sugar cane, pasturage, leaf tobacco, squash, Chinese preserving melon, bitter melon, mango, green manure plants, sugar mills and Miyakojima City Resources Recycling Center. To confirm the mass balance, we created the tables for each MFA. We found that residues from most of agricultural plants were not utilized and were burnt to prevent disease except for sugar cane. We also clarified quantities of biomass resources generated by agricultural plants. The discussion in this chapter and the previous chapter we were able to clarify all of the biomass resources on Miyakojima Island. The discussion in this chapter reveals that the quantity of imported fertilizer and biomass resources applied to each agricultural plant. We found that residues from sugar mills and sugar cane field were plowed under in the sugar cane field and that much of beef cattle's manure was applied to sugar cane. We also found that imported chemical and organice fertilizer were applied to sugar cane as well. Regarding pasturage, it made clear that beef cattle's manure and chemical fertilizer only were applied. When chapter 4 and 5 tries to discuss an agricultural production system, the MFA given in this chapter will be basis for the basic units.

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Chapter 4 Development of a Regional Scale Agricultural Production System on Miyakojima Island

4.1 Objectives for Chapter 4

The tasks in this chapter are to performs the following for a regional scale agricultural production system: 1) Demonstrates basic units for scenario building based on MFAs shown in Chapter 2 and Chapter 3, 2) Establishes the basic form for scenario building, 3) Creates evaluation functions for scenario building, 4) Exemplifies “evaluation index”, “operational factor” and “scenario” and 5) Shows the objectives for four scenarios.

4.2 Basic Units for Scenario Building

This section clarifies the basic units for scenario building. Basic units are the basis for calculation with evaluation functions. Valuables in evaluation functions use basic units. Basic units are obtained from the results of MFAs in Chapter 2 and Chapter 3. Basic units are values in the results of MFAs (in other words, “components” for scenarios) .

This research does not use all results of MFAs. The following is a list of components (MFAs) which this research uses to develop a regional scale agricultural production system on Miyakojima Island:

In addition to these, “composting facilities” appears in the scenarios. However values for composting facilities are used only for the basic form not for scenarios. Therefore basic units from the MFA for compositing facilities are not needed.

Table 4.1 Basic units for a regional scale agricultural production system

	Names of MFAs
1	Calf (beef cattle)
2	Breeding cow (beef cattle)
3	Adult cattle (beef cattle)
4	Breeding cow which cannot give a birth to calves (beef cattle)
5	Sugar cane in the field
6	Sugar mills
7	Pasturage
8	Green manure plants

One of the important things when this research proposes the system is that the focus is placed on the network among sugar cane, pasturage and beef cattle. The reason is that they occupy major portion of the material flow for the agriculture and stockbreeding on Miyakojima Island.

This research does not use the results of MFAs as they are. Regarding stockbreeding's MFAs, this research uses one stockbreeding animal as a basic unit. On the other hand, this research uses one ha (hectare) area of agricultural plants as a basic unit.

Figure 3.1 though Figure 3.7 show MFAs which are used as basic units for scenario building. Table 4.2 through Table 4.11 show their mass balance for confirmation as in Chapter 2 and 3.

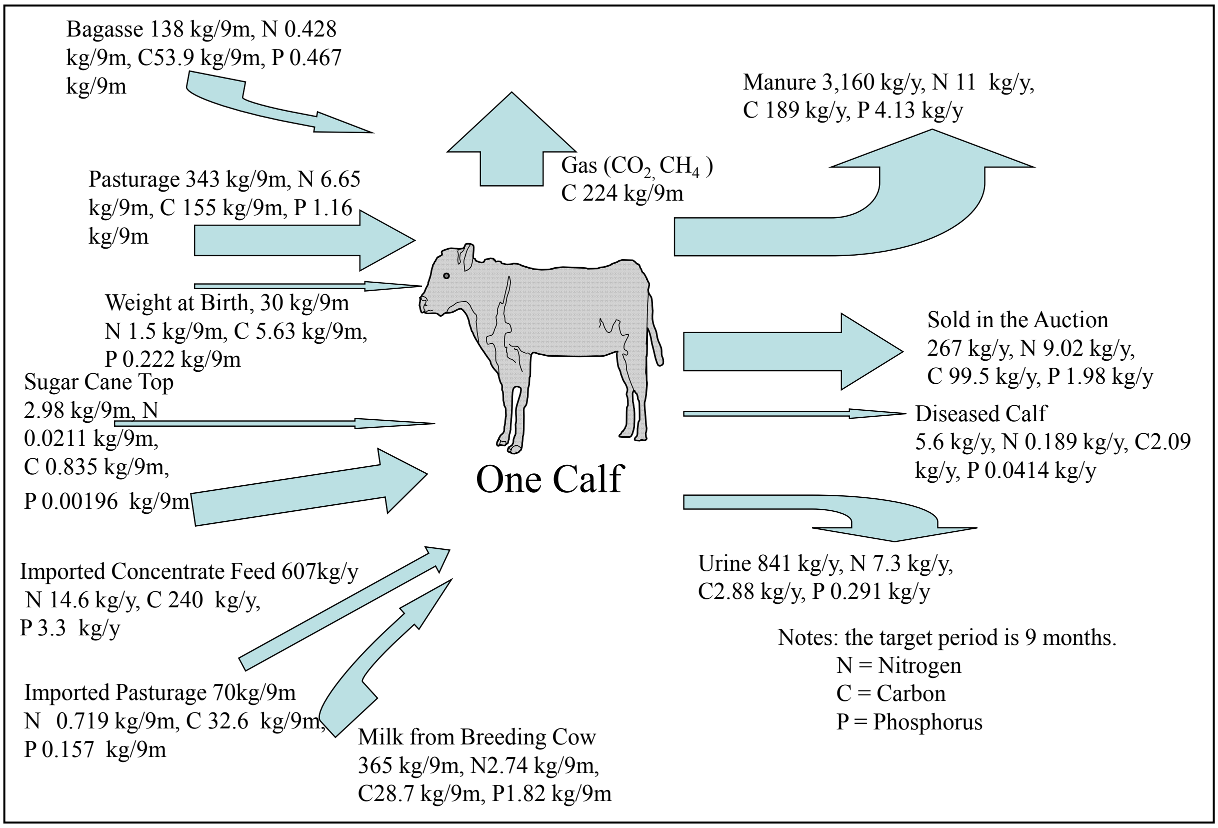

Fig. 4.1 MFA for one calf as a basic unit

Table 4.2 Mass balance for one calf as a basic unit

Unit = kg/9m	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Bagasse	0.428		53.9		0.0467	
Pasturage	6.65		155		1.16	
Weight at Birth	1.5		5.63		0.222	
Sugar Cane Top	0.0211		0.835		0.00196	
Imported Concentrate Feed	14.6		240		3.3	
Imported Pasturage	0.8		32.6		0.157	

Milk from Breeding Cow	2.74		28.7		1.82	
Gas (CO_2, CH_4)				224		
Manure		11		189		4.47
Sold in the Auction		9.02		99.5		1.98
Diseased Calf		0.189		2.09		0.0414
Urine		6.73		2.88		0.291
Total	26.7391	26.939	516.665	517.47	6.70766	6.7824

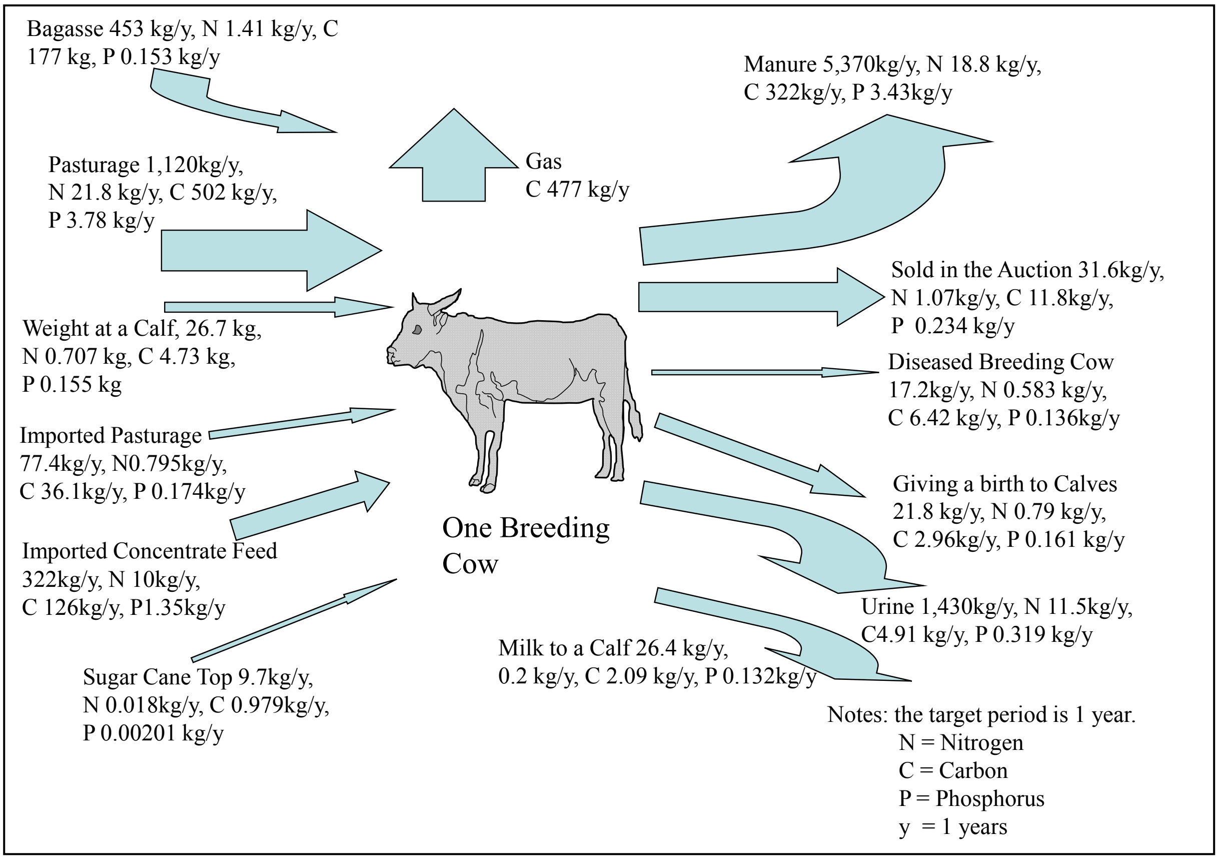

Fig. 4.2 MFA for one breeding cow as a basic unit

Table 4.3 Mass balance for one breeding cow as a basic unit

Unit = kg/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Bagasse	1.41		177		0.153	
Pasturage	21.8		502		3.78	
Weight at a Calf	0.707		4.73		0.155	
Sugar Cane Top	0.0180		0.979		0.00201	
Imported Concentrate Feed	10		126		1.35	
Imported Pasturage	0.795		36.1		0.174	

Gas (CO_2, CH_4)				477		
Manure		18.8		322		3.43
Sold in the Auction		1.07		11.8		0.234
Milk from Breeding Cow		2		20.9		1.32
Diseased Breeding Cow		0.621		6.84		0.136
Giving a birth to Calves		0.79		2.96		0.161
Urine		11.5		4.91		0.319
Total	34.73	34.781	847	846	5.61401	5.6

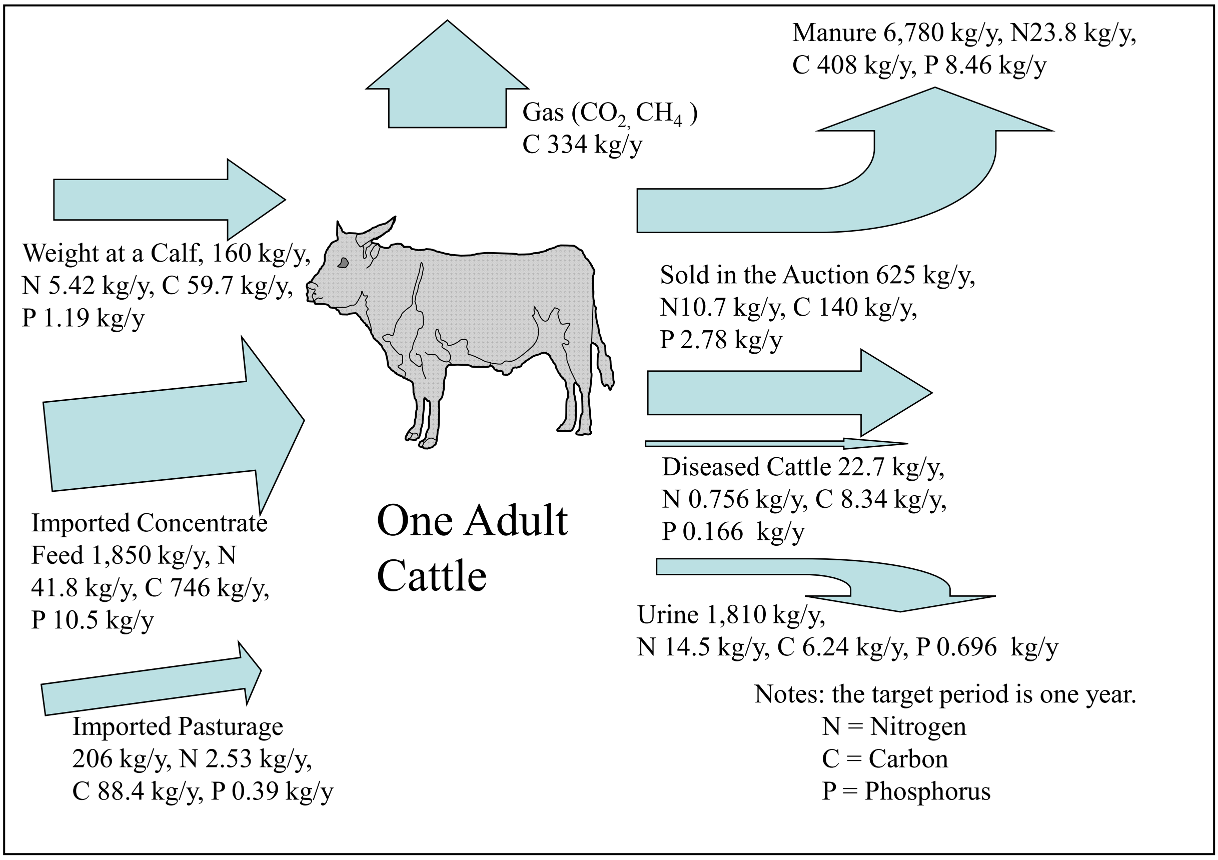

Fig. 4.3 MFA for one adult cattle as a basic unit

Table 4.4 Mass balance for one adult cattle as a basic unit

unit = kg/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Weight at a Calf	5.42		59.7		1.19	
Imported Concentrate Feed	41.8		746		10.5	
Imported Pasturage	2.53		88.4		0.39	
Gas (CO_2, CH_4)				334		

Manure		23.8		408		8.46
Sold in the Auction		10.7		140		2.78
Diseased Cattle		0.756		8.34		0.166
Urine		14.5		6.24		0.696
Total	49.75	49.756	894.1	896.58	12.08	12.102

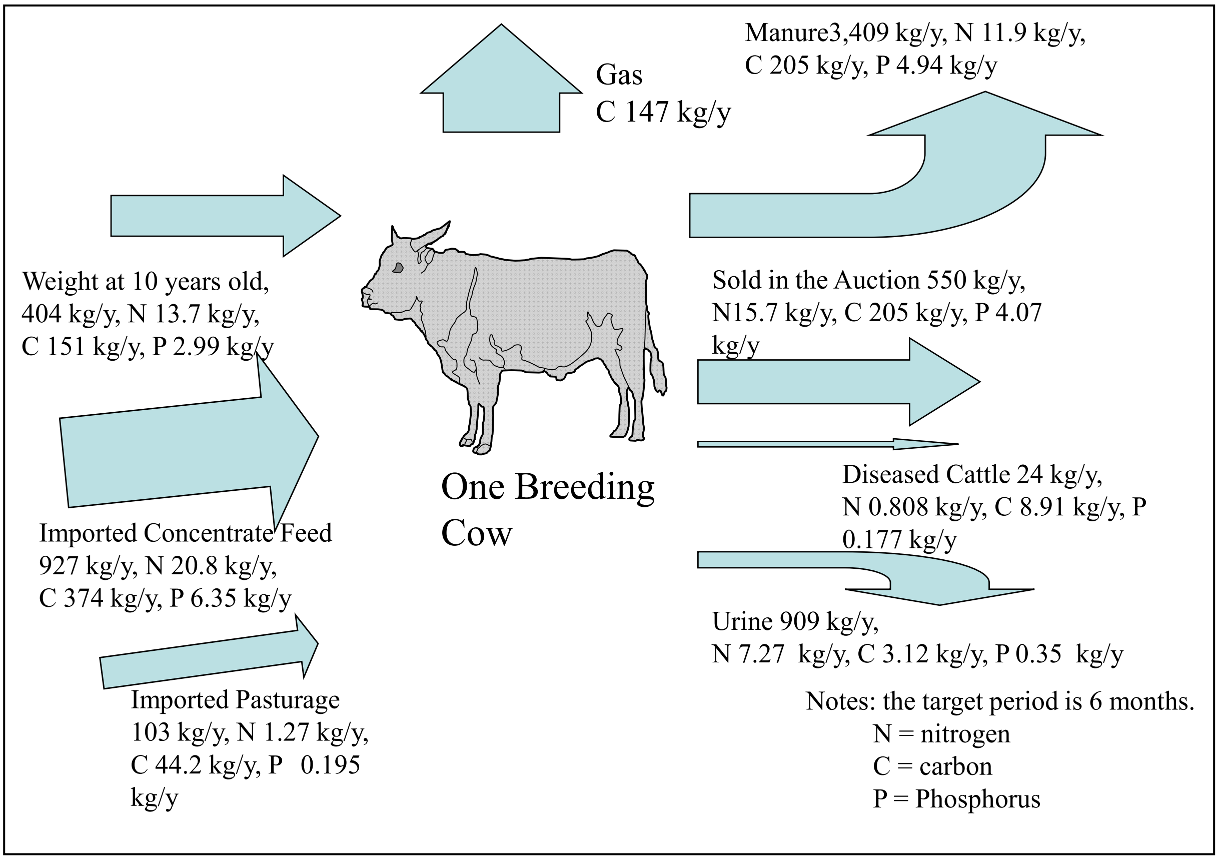

Fig. 4.4 MFA for one breeding cow which cannot give a birth to calves as a basic unit

Table 4.5 Mass balance for one breeding cow which cannot give a birth to calves as a basic unit

Unit = kg/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Weight at 10 years old	13.7		151		2.99	
Imported Concentrate Feed	20.8		374		6.35	
Imported Pasturage	1.27		44.2		0.195	
Gas (CO2, CH4)				147		
Manure		11.9		205		4.94
Sold in the Auction		15.7		205		4.07
Diseased Cattle		0.808		8.91		0.177
Urine		7.27		3.12		0.35
Total	35.8	35.678	569	569.03	9.54	9.537

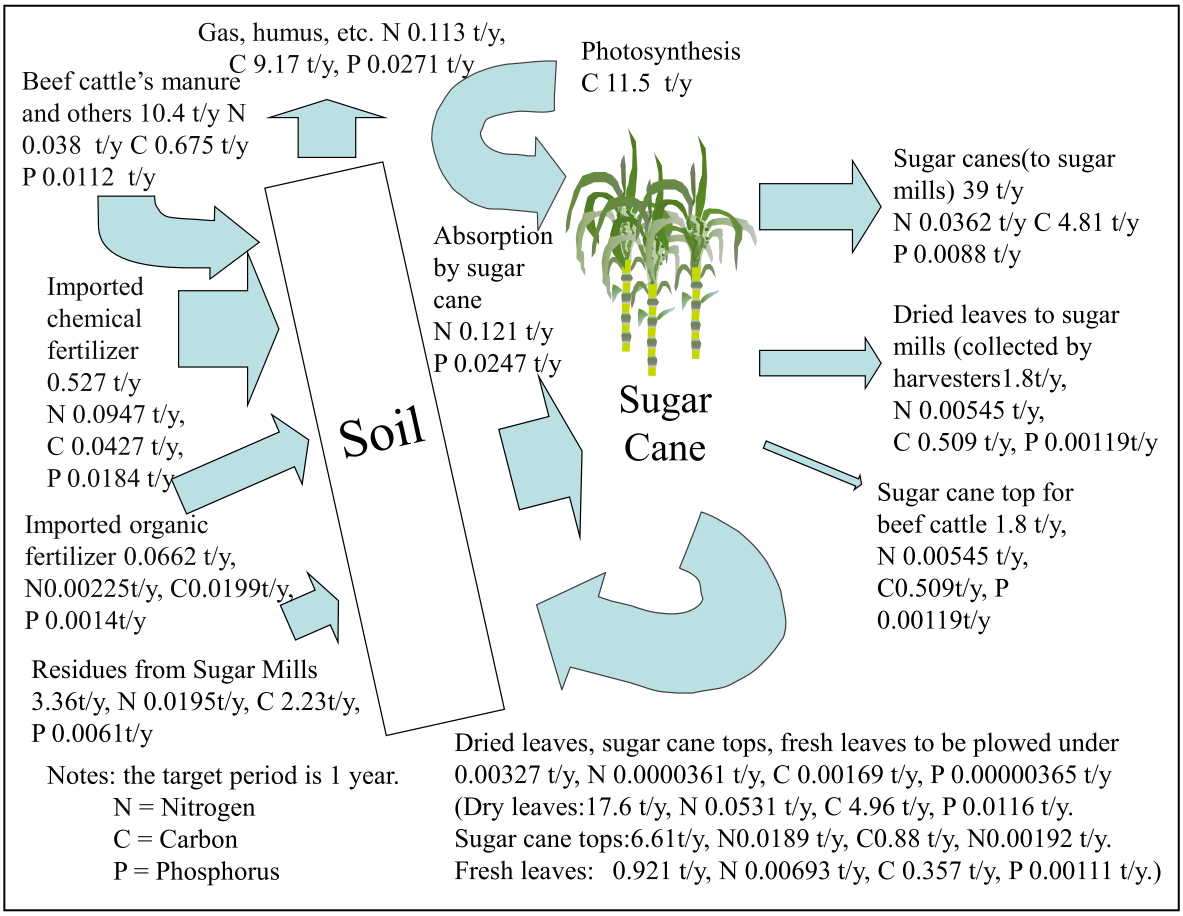

Fig. 4.5 MFA for sugar cane as a basic unit

Table 4.6 Mass balance for sugar cane as a basic unit

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Beef cattle's manure and others	0.038		0.675		0.0112	
Imported chemical fertilizer	0.0947		0.0427		0.0184	
Imported organic	0.00225		0.0199		0.0014	

fertilizer						
Residues from Sugar Mills	0.0195		2.23		0.00610	
Dried leaves	0.0531		4.96		0.01160	
Sugar cane tops	0.0189		0.88		0.00192	
Fresh leaves	0.00693		0.357		0.00111	
Absorption by sugar cane		0.121				0.0247
Gas, humus, etc.		0.113		9.17		0.0271
Total	0.23338	0.234	9.1666	9.17	0.05174	0.0518

Table 4.7 Mass balance for input and output of sugar cane as a base unit

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Absorption by sugar cane	0.121				0.0247	
Photonic synthesis			11.5			
Sugar canes(to sugar mills)		0.0362		4.81		0.0088
Dried Leave (collected by harvesters)		0.00545		0.509		0.00119
Dried leaves		0.0531		4.96		0.0116
Sugar cane tops		0.0189		0.882		0.00192
Fresh leaves		0.00693		0		0.00111
Sugar cane top for beef cattle		0.0000361		0.00169		0.00000365

Total	0.121	0.1206161	11.5	11.51969	0.0247	0.02462365

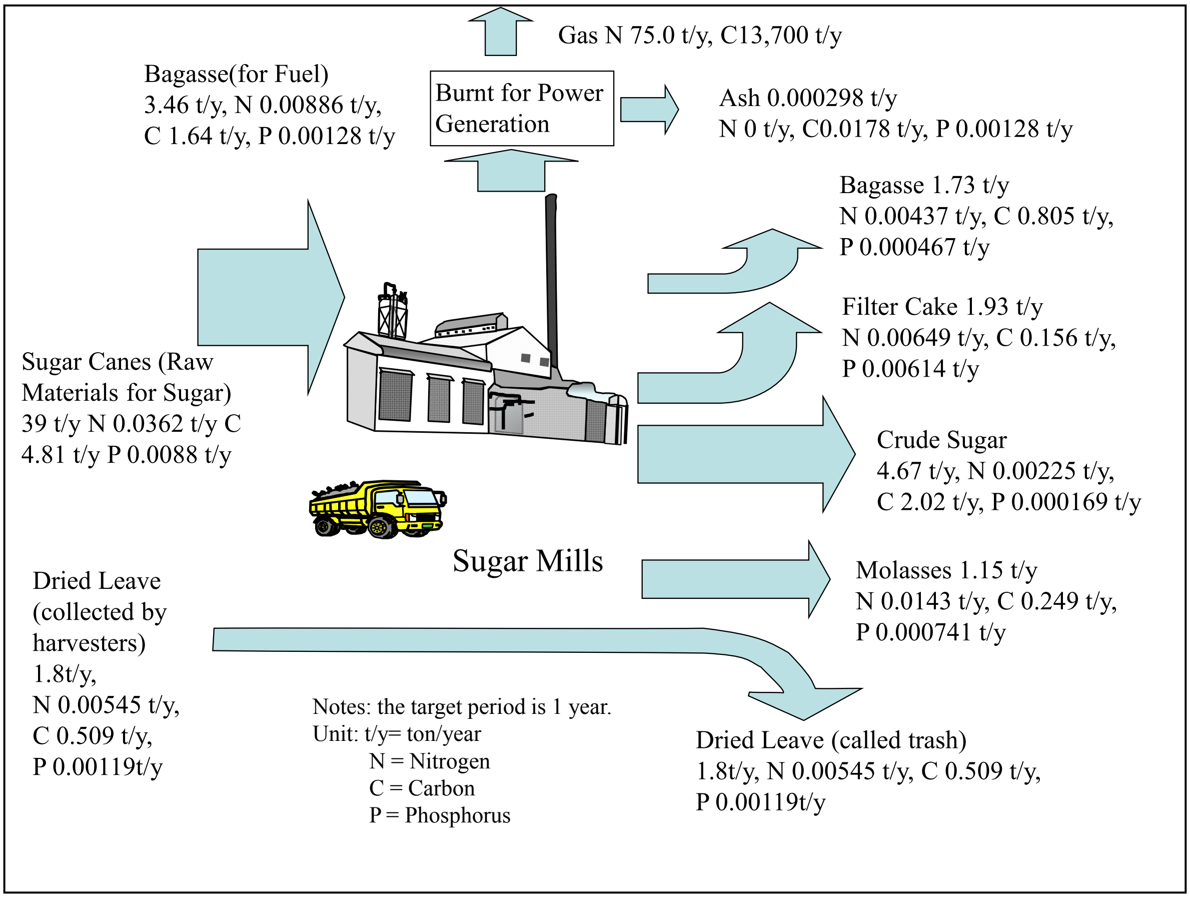

Fig. 4.6 MFA for sugar mill as a basic unit

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Sugar Canes (Raw Materials for Sugar)	0.0362		4.81		0.00880	
Dried Leave (collected by	0.00545		0.509		0.00119	

harvesters)						
Trash		0.00545		0.509		0.00119
Bagasse(for Fuel)		0.00886		1.64		0.00128
Bagasse		0.00437		0.805		0.000467
Filter Cake		0.00649		0.156		0.00614
Crude Sugar		0.00225		2.02		0.000169
Molasses		0.0143		0.249		0.000741
Total	0.04165	0.04172	5.319	5.379	0.00999	0.009987

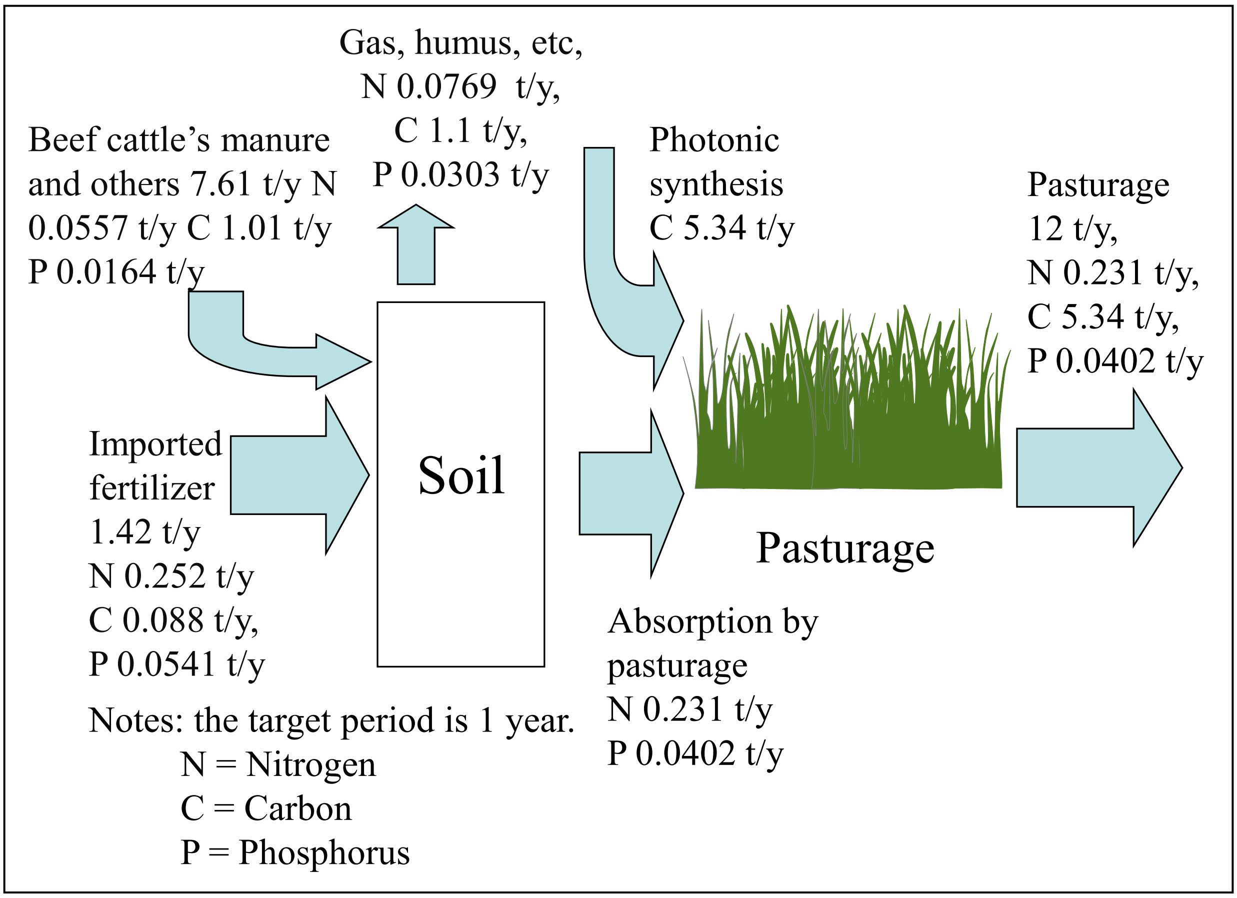

Fig. 4.7 MFA for pasturage as a basic unit

Table 4.9 Mass balance for input and output of the soil for sugar cane as a basic unit

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Beef cattle's manure and others	0.0557		1.01		0.0164	
Imported fertilizer	0.252		0.088		0.0541	
Absorption by pasturage		0.231				0.0402
Gas, humus, etc.		0.0769		1.1		0.0303
Total	0.3077	0.3079	1.098	1.1	0.0705	0.0705

Table 4.10 Mass balance for input and output of sugar cane as a base unit

Unit = t/y	input(N)	output(N)	input(C)	output(C)	input(P)	output(P)
Absorption by pasturage	0.231				0.0402	
Photonic synthesis			5.34			
Pasturage		0.231		5.34		0.0402
Total	0.231	0.231	5.34	5.34	0.0402	0.0402

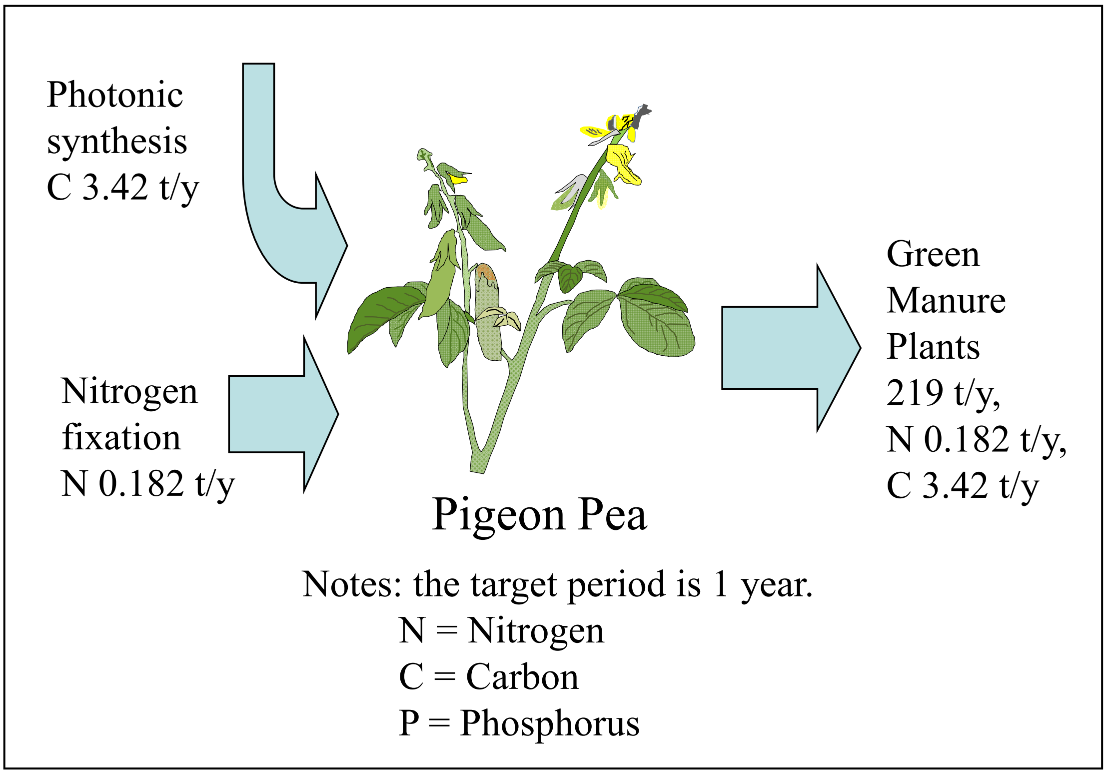

Fig. 4.8 MFA for pigeon pea as a basic unit

MFAs for stockbreeding like a calf and a breeding cow which cannot give a birth to calves are the same as the MFAs in Chapter 2 because the target term for them was shorter than one year and the number of stockbreeding is one. They are sold to the outside of the island within a year. Regarding MFA for pigeon pea, this research does not provide the table for mass balance because it is clear that the mass balance is performed.

4.3 Concept of Basic Form, Evaluation Function, Operational Factor, Evaluation Index and Scenario

4.3.1 Exemplification of Evaluation Function, Operational Factor, Evaluation Index and Scenario Using Basic Form

4.3.1.1 Basic Form

This research introduces several concepts to this research: Basic form, evaluation function, operational factor, evaluation index and scenario. This subsection explains basic forms. The following subsections exemplify the other concepts with basic form.

Fig. 4.9 shows the "basic form".

The definition of "basic form" is that it is the basis to create scenarios. It is based on the actual MFA's results. The MFAs which the basic form is based on is given in Table 4.1. However it has some minor differences from the actual material flows:

First, sugar cane receives manure from the other stockbreeding but it is ignored in the basic form because it is assumed to be less than 2,000 t/y when the magnitude of the entire material flow is considered.

Second, sugar cane receives compost from other biomass resources by way of composting facilities but it is ignored in the basic form because it is assumed to be less than 2,000 t/y when the magnitude of the entire material flow is considered.

Third, less than 2,000 t/y manure from beef cattle goes to other agricultural plants but it is ignored in the basic form because the quantity can be ignored when the magnitude of the entire material flow is considered.

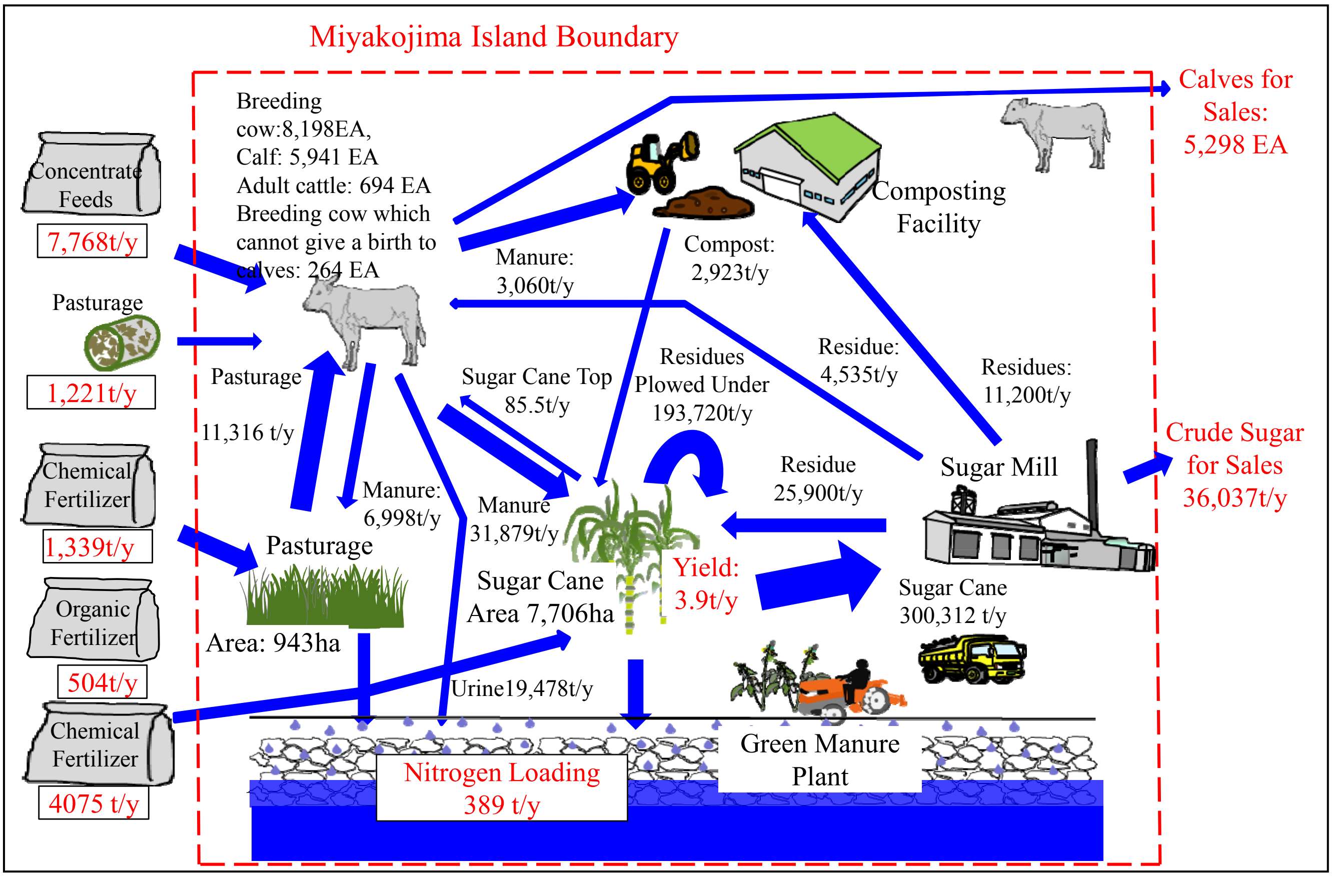

Fig. 4.10 The basic form for scenario building

Fourth, green manure plants has the effect of reducing fertilizer by 30% with the same level or higher level of yield [1]. In most cases, farmers plant green manure plants with the different purpose. They do it because they mean to increase the yield. Therefore they do not reduce the fertilization when they plant green manure plants in most cases. A few cases, it is possible to find the effect of increasing yield. However no previous studies prove that green manure plants increased the yield. Anyway this research would like to think that the growing area of green manure plants is 0 ha for the convenience of the discussion.

In addition, the effect of composts and imported organic fertilizer to the growth of sugar cane are not clear. The effect of beef cattle’s manure to the growth of sugar cane is known. It increases yield per 10 are by 10.5%[2]. For the convenience of the discussion, this research thinks the effect of composts and imported organic fertilizer would have the same effect as beer cattle's manure regarding the yield.

4.3.1 Evaluation Function

This subsection tries to explain the evaluation functions. They are are used to obtain the values in the algorithms. Evaluation functions which are used for the basic form is shown by Fig.4.10:

Evaluation Functions for Each Evaluation Factor

1. Amount of imported concentrate feed (t/y) = N2 = $b1 \times Z + b3 \times V1 + b5 \times W + b7 \times L$

2. Amount of imported pasturage (t/y) = N3 = $b2 \times Z + b4 \times V1 + b6 \times W + b8 \times L$

3. Total amount of imported fertilizer for sugar cane and pasturage (t/y) = O1 = $((d1 + d2) \times Y + d3 \times X - (d1 + d2) \times g \times U \times 2$

4. Yield of 10 are of growing area for sugar cane (t/y) = R = $((a1 \times Z + a2 \times V1 + a3 \times W + a4 \times L - A2\text{-}A3 + (A2+B1+B2+B3+B4) \times m + d2 \times Y) \div f \times (1+c) \times e + (Y - (a1 \times Z + a2 \times V1 + a3 \times W + a4 \times L - A2\text{-}A3 + (A2+B1+B2+B3+B4) \times m + d2 \times Y) \div f) \times e) \div Y \div 10$

5. Amount of Crude Sugar(t/y)= C = $u \times M = u \times P = u \times 10 \times R \times Y$

6. Nitrogen loading to ground water (t/y) = T = $((Y \times (i1 \times E \times (1 -(o1 \times Z + o2 \times V1) \div (n1 \times Y)) + i2 \times E + i3 \times E + i4 \times E \times (n2 \times Y - B1) \div (n2 \times Y) + i5 \times E \times (n3 \times Y - B2) \div (n3 \times Y) + i6 \times E \times (1 - (o3 \times Z + o4 \times V1 + B3 - D) \div (n4 \times E \times Y)) + i8 \times (1 - g \times U \div Y)) \times Y + p \times (i4 \times E \times Y \times B1 \div (n2 \times Y) + i5 \times E \times Y \times B2 \div (n3 \times Y) + i6 \times E \times Y \times B3 \div (n4 \times Y) + i10 \times A2) + i10 \times S1 + i7 \times U \times 2) \times (1- k) + (i9 \times X + i10 \times S2 + i11 \times q \times S3)) \times (1-l)) + i11 \times q \times (r1 \times Z + r2 \times V1 + r3 \times W + r4 \times L)) \times j$

Subject to (Constraint)

Fig. 4.10 Evaluation function for scenario building

$X+Y = s$

$Z = t \times V1$

$C = u \times M$

$V1 = v \times X$

$O1 = O2 + O3 + O4$

$A1 = A2+A3+A4$

$E = R \div w$

$0 \leq Q1 - (o1 \times E \times Z + o2 \times E \times V1)$, $0 \leq Q4 - (o3 \times E \times Z + o4 \times E \times V1)$,

$0 \leq$ X, Y, Z, V1,V2, W, L, M, N1,N2,N3,O1,O2, O3,O4, P,Q, R, S, T, U, V,A1,A2, A3, A4, B1, B2, B3, B4, a1, a2, a3, a4, b1, b2, b3, b4, c, d1, d2, d3, e, f, g, h, i1, i2, i3,i4, i5, i6, i7, i8, i9, i10, i11, j, k, l, m, n1, n2, n3, n4,o1,o2, o3,o4, p, q, r1, r2, r3, r4, s, t, u, v and w

where,

(Variables)

X = Growing area of pasturage (ha)

Y = Growing area of sugar cane (ha)

Z = Number of breeding cows (EA)

V1 = Number of calves (EA)

V2 = Number of sold calves(EA)

W = Number of adult cattle (EA)

L = Number of breeding cows which cannot give birth to calves (EA)

M = Harvested amount of sugar cane (t/y)

N1 = Total amount of imported feed (t/y)

N2 = Amount of imported concentrate feed (t/y)

N3 = Amount of imported pasturage (t/y)

O1 = Total amount of imported fertilizer for sugar cane and pasturage (t/y)

O2 = Amount of imported chemical fertilizer for sugar cane (t/y)

O3 = Amount of imported organic fertilizer for sugar cane (t/y)

Fig. 4.10 Evaluation function for scenario building

O4 = Amount of imported fertilizer for pasturage (t/y)

P = Harvested amount of sugar cane (ha)

Q1= Amount of sugar cane top (t/y)

Q2= Amount of filter cake (t/y)

Q3= Amount of trash (t/y)

Q4= Amount of bagasse (t/y)

R = Yield of 10 are growing area for sugar cane (t/y)

S1 = Amount of beef cattle's manure which are applied to sugar cane (t/y)

S2 = Amount of beef cattle's manure which are applied to pasturage (t/y)

S3 = Amount of beef cattle's urine which are applied to any agricultural plants (t/y)

T = Nitrogen loading to ground water (t/y)

U = Growing area of green manure plant (ha)

A1 = Total amount of beef cattle's manure

A2 = beef cattle's manure which goes to the composting facility

A3 = beef cattle's manure which is applied to sugar cane

A4= beef cattle's manure which is applied to pasturage

B1 = Amount of filter cake which goes to the composting facility

B2 = Amount of trash which goes to the composting facility

B3 = Amount of bagasse which goes to the composting facility

B4 = Amount of ash which goes to the composting facility

C = Amount of crude sugar (t/y)

D = bagasse which are used for fuel (t/y)

E = The change ratio of yield of 10 are growing area for sugar cane from the basic form to other scenarios

(Constant)

a1 = Amount of manure generated by one breeding cow =3.29 t/y

Fig. 4.10 Evaluation function for scenario building

a2 = Amount of manure generated by one calf == 1.94 t/y

a3 = Amount of manure generated by adult cattle =4.16 t/y

a4 = Amount of manure generated by one breeding cow which cannot give a birth to calves =2.09 t/y

b1 = Imported concentrate feeds for one breeding cow = 0.322 t/y

b2 = Imported pasturage for one breeding cow = 0.0774 t/y

b3 = Imported concentrate feeds for one calf =0.607 t/y

b4 = Imported pasturage for one calf = 0.07 t/y

b5 = Imported concentrate feeds for one adult cattle = 1.85 t/y

b6 = Imported pasturage for one adult cattle= 0.206 t/y

b7 = Imported concentrate feeds for one breeding cow which cannot give a birth to calves = 0.927 t/y

b8 = Imported pasturage for ne breeding cow which cannot give a birth to calves = 0.103 t/y

c = Sugar cane's yield increase ratio per one hectare of area when 30t/y of beef cattle's manure is applied to = 0.105

d1 = Amount of imported chemical fertilizer per one hectare of area for sugar cane = 0.527 t/y

d2 = Amount of imported organic fertilizer per one hectare of area for sugar cane = 0.0662 t/y

d3 = Amount of imported organic fertilizer per one hectare of area for pasturage = 1.42 t/y

e = Sugar cane's yield per 1 hectare of growing area (for one year) when only chemical fertilizer is applied =37.76t/y

f = The least amount of manure for one hectare of growing area to increase the yield= 15t/y

g = The effect of fertilizer reduction ratio by green manure plants for sugar cane cultivation= 0.3

h = Ratio of sold calves out of the entire calves= 0.892

Fig. 4.10 Evaluation function for scenario building

i1 = Nitrogen amount of sugar cane top obtained from one hectare of growing area of sugar cane= 0.0189 t/y

i2 = Nitrogen amount of fresh leaves obtained from one hectare of growing area of sugar cane= 0.00693t/y

i3 = Nitrogen amount of dried leaves obtained from one hectare of growing area of sugar cane= 0.0531 t/y

i4 = Nitrogen amount of filter cake obtained from one hectare of growing area of sugar cane= 0.00649 t/y

i5 = Nitrogen amount of trash obtained from one hectare of growing area of sugar cane= 0.00545 t/y

i6 = Nitrogen amount of bagasse obtained from one hectare of growing area of sugar cane= 0.00886 t/y

i7 = Nitrogen amount of green manure plants obtained from one hectare of growing area of green manure plants= 0.182 t/y

i8 = Nitrogen amount of imported fertilizer applied to one hectare of growing area of sugar cane= 0.0969 t/y

i9 = Nitrogen amount of imported fertilizer applied to one hectare of growing area of pasturage = 0.252 t/y

i10 = Nitrogen ratio of beef cattle's manure= 0.00511

i11 = Nitrogen residual ratio of beef cattle's urine until when it is used or seeps into the ground water = 0.89

j = Overall penetration ratio of nitrogen loading to the ground water=0.4

k = Absorption ratio by sugar cane = 0.517

l = Absorption ratio by pasturage = 0.75

m = Residual ratio of compost from raw materials =0.205

n1= Amount of sugar cane top per one hectare of area for sugar cane = 0.662 t/y

n2= Amount of filter cake per one hectare of area for sugar cane =1.93 t/y

Fig. 4.10 Evaluation function for scenario building

n3= Amount of trash per one hectare of area for sugar cane = 1.8 t/y

n4= Amount of bagasse per one hectare of area for sugar cane = 5.19 t/y

o1= Amount of sugar cane top which is consumed by one breeding cow = 0.0097 t/y

o2= Amount of sugar cane top which is consumed by one calf = 0.00298 t/y

o3= Amount of bagasse which is consumed by one breeding cow = 0.453t/y

o4= Amount of bagasse which is consumed by one calf = 0.138 t/y

p = Nitrogen residual ratio for composting process = 0.726

q = Concentration of nitrogen in beef cattle's urine=0.08

r1=Amount of urine per one breeding cow=1.43t/y

r2= Amount of urine per one calf=0.841t/y

r3= Amount of urine per one adult cattle=1.81t/y

r4= Amount of urine per one breeding cow which cannot give a birth to calves=0.909t/y

s = Total growing areas of sugar cane and pasturage =8,649

t = Ratio of the number of breeding cows to calves = 1.38

u = Ratio of the amount of crude sugar to sugar cane = 0.12

v = Ratio of growing area of pasturage to the number of calves = 4.73

w = The change ratio of yield of 10 are growing area for sugar cane from the basic form = 3.9

Fig. 4.10 Evaluation function for scenario building

Regarding the quantity of beef cattle, the basic unit shown above cannot be used. The amount of manure from a1 to a4 is obtained after the loss ratio shown in Table 2.13 of Chapter 2 is taken into consideration.

Regarding "h = Ratio of sold calves out of the entire calves= 0.892", it is based on the information from Miyakojima City Hall, which investigated how many calves are used for the new breeding cows per one year.

Regarding “ c = Sugar cane’s yield increase ratio per one hectare of area when 60t/y of beef cattle’s manure is applied to = 0.105”, “e = Sugar cane’s yield per 1hectare of growing area (for one year) when only chemical fertilizer is applied =37.76t/y”, “f = The least amount of manure for one hectare of growing area to increase the yield= 15t/y” as addressed, the effect of beef cattle’s manure to the growth of sugar cane is known[2]. It increases yield per 10 are by 10.5% . It is also said in 4.3.1.1 that it would be possible to think the effect of composts and imported organic fertilizer had the same effect as beer cattle’s manure regarding the yield. So when 30t/y of beef cattle’s manure, composts or organic fertilizer are applied, it is possible to think it increases yield per 10 are by 10.5%.

Regarding “g = The effect of fertilizer reduction ratio by green manure plants for sugar cane cultivation= 0.3”

Regarding allocated beef cattle’s manure, the way of obtaining “A3” and “A4” needs to be explained. “A3,” which is “beef cattle’s manure which is applied to sugar cane”, is given by the equation “(A1 - A2) × 0.82”. On the other hand, “A4,” which is “beef cattle’s manure which is applied to pasturage”, is given by the equation “(A1 - A2) × 0.18”. The constants, “0.82” and “0.18” are given based on Table 3.20 of Chapter 3. The beef cattle allocated to agricultural plants excluding sugar cane and pasturage such as squash, leaf tobacco, bitter melon and mango are given approximately equal to sugar cane and pasturage.

Regarding urine of beef cattle, because it is not used on Miyakojima Island, it is not clear how much the quantity of the urine is lost until when it is used or seeps into the ground water. This research sets the nitrogen residual ratio 0.89 to cope with the nitrogen loading to the ground water as in “ i11 = Nitrogen residual ratio of beef cattle’s urine until when it is used or seeps into the ground water = 0.89” of Fig. 4.10, based on the previous study[3]. This research does not set up any loss ratio on the weight of urine, carbon and phosphorus.

Regarding “Amount of imported concentrate feed (t/y)”, basically it is obtained by the number of each kind of beef cattle and its corresponding amount of feeds.

Regarding “Amount of imported pasturage (t/y)”, in the same way as “Amount of imported concentrate feed (t/y)” it is obtained by the number of each kind of beef cattle and its corresponding amount of feeds.

Regarding “Total amount of imported fertilizer for sugar cane and pasturage”, it is obtained by subtracting the fertilizer reduction effect of green manure plants from the amount of applied fertilizer for sugar cane and pasturage.

Regarding “Amount of Crude Sugar(t/y)”, this research thinks that the relationship between the amount of harvested sugar cane and the amount of crude sugar can be described as a fixed ratio because the crude sugar production processes would be the same.

Regarding “Yield of 10 are of growing area for sugar cane (t/y)” see Table 4.11.

Table 4.11 Yield of 10 are of growing area for sugar cane (t/y)

Part of Functions	Meaning which Functions Try to Mean
((a1 × Z + a2 × V1 + a3 × W + a4 × L – A2-A3 +	“a1 × Z + a2 × V1 + a3 × W + a4 × L” means the amount of beef cattle’s manure and “– A2-A3” means “beef cattle’s manure which goes to the composting facility” and “beef cattle’s manure which is applied to sugar cane”
(A2+B1+B2+B3+B4) × m + d2× Y)	“(A2+B1+B2+B3+B4) × m” means the amount of compost which composting facility can create and “d2× Y” means the amount of imported amount of organic fertilizer
÷ f	“f” means the least amount of manure for one hectare of growing area to increase the yield. Together with the functions “((a1 × Z + a2 × V1 + a3 × W + a4 × L – A2-A3

	+(A2+B1+B2+B3+B4) × m + d2× Y)", the area which receives yield increase by beef cattle, compost or organic fertilizer is shown.
×(1+c) × e	"×(1+c) × e" means yield increase by beef cattle
+ (Y - (a1 × Z + a2 × V1 + a3 × W + a4 × L – A2-A3 +(A2+B1+B2+B3+B4) × m + d2× Y) ÷ f)	"(Y - (a1 × Z + a2 × V1 + a3 × W + a4 × L – A2-A3 +(A2+B1+B2+B3+B4) × m + d2× Y)" means growing area of sugar cane subtracted by the area which receives yield increase by beef cattle, compost or organic fertilizer.
× e)	"× e)" means sugar cane's yield per one hectare of growing area (for one year) when only chemical fertilizer is applied
÷ Y	"÷ Y" changes its unit from the amount of yield to the yield per one hectare of areas
÷ 10	"÷ 10" changes its unit from hectare to 10 are

First the function for "Yield of 10 are of growing area for sugar cane (t/y)" tries to obtain the area which receives yield increase by beef cattle, compost or organic fertilizer. Next it tries to obtain the area which does not receives yield increase by beef cattle, compost or organic fertilizer. Next the former function is added to the latter function. Next it is divided by the growing area for sugar cane. The yield per one hectare of the area is obtained. Finally one hectare area is converted to 10 are of areas.

Next "Nitrogen loading to ground water" is discussed. See Table 4.12

Table 4.12 Nitrogen loading to ground water (t/y)

Part of Functions	Meaning which Functions Try to Mean
((Y× (i1× E × (1 -(o1 × Z+ o2 × V1) ÷ (n1 × Y))+ i2 × E + i3 × E + i4 × E ×(n2 × Y- B1) ÷(n2 × Y)+i5 × E ×(n3× Y- B2) ÷(n3 × Y)+i6 × E ×(1 - (o3 × Z+ o4× V1+ B3-D) ÷(n4 × E × Y))	Nitrogen loading of sugar cane residues which is plowed under in the sugarcane field
+ i8 × (1-g × U ÷ Y)) × Y	Nitrogen loading of imported fertilizer applied to sugar cane field
+ p ×(i4 × E × Y× B1÷ (n2 × Y) + i5× E × Y× B2 ÷ (n3 × Y)+ i6 × E × Y × B3÷ (n4 × Y) + i10 × A2)	Nitrogen loading of compost which is applied to sugar cane
+ i10 × S1+	Nitrogen loading of beef cattle's manure which is applied to sugar cane
i7 × U × 2)	Nitrogen loading of green manure plants
× (1- k)	Penetration ratio of nitrogen loading which goes to the ground water by way of sugar cane field
+ (i9 ×X+	Nitrogen loading of imported fertilizer applied to pasturage
i10 × S2	Nitrogen loading of beef cattle's manure which is applied to pasturage
+ i11×q×S3))	Nitrogen loading of beef cattle's urine which is applied to pasturage
× (1-l))	Penetration ratio of nitrogen loading which goes to the ground water by way of

	pasturage field
+ i11×q× (r1×Z + r2×V1+ r3×W + r4×L)) × j	Nitrogen loading of beef cattle's urine which is not applied to any agricultural plants

Only beef cattle's urine seep into the ground water. The others are absorbed by the sugar cane or the pasturage, then it seeps into the ground water, evaporated into the air or stays in the soil. Regarding the residues from the sugar mills or residues in the sugar cane fields, most of them are plowed under. Regarding the residues from the sugar mills, some of them goes to composting facility. Regarding bagasse, a part of it is consumed by beef cattle. Regarding the residues in the sugar cane field, a part of sugar cane tops are consumed by beef cattle. Most of them are plowed under. Nitrogen which are contained by those residues are absorbed by sugar cane. Regarding manure from beef cattle, most of them are plowed under in sugar cane field. Some of them goes to composting facilities and the others are used for pasturage. The amount of the materials which go to composting facilities must be determined first for each scenario's requirements. For the basic form, it is based on the documents given by the composting facilities. However for the convenience of the discussion, this research determined the amount of materials which go to the composting facilities.The amount of materials for beef cattle is based on the sugar mill's information, personal communication with beef cattle's farmers for the basic form. But The amount of materials for beef cattle can be determined for each scenario's requirements. Nitrogen which seeps into the ground water is calculated by "j = Overall penetration ratio of nitrogen loading to the ground water=0.4". This is bases on the previous research[4]. Nitrogen which is not absorbed by agricultural plants may seep into the ground water.

Regarding "X+Y = s", it limits the target areas to the growing area of sugar cane and pasturage.

Regarding “Z = t ×V1”, the ratio of calves to breeding cows is determined, based on the statistics in FY 2010.

Regarding “C= u ×M”, the ratio of sugar cane to crude is determined, based on the MFA result for sugar mills for the convenience of discussion.

Regarding “V1 = v×X”, the ratio of calves to the growing area of pasturage is determined, based on the MFA results for calves and pasturage for the convenience of discussion.

Regarding “O1 = O2+ O3+ O4”, “total amount of imported fertilizer for sugar cane and pasturage” is obtained when “amount of imported chemical fertilizer for sugar cane” is added to and “Amount of imported organic fertilizer for sugar cane” and “ Amount of imported organic fertilizer for sugar cane”.

Regarding “A1= A2+A3+A4”, “total amount of beef cattle’s manure” is obtained when “ beef cattle’s manure which goes to the composting facility” is added to “ beef cattle’s manure which is applied to sugar cane” and “beef cattle’s manure which is applied to pasturage”.

Regarding “E = R ÷ w”, “Yield of 10 are growing area for sugar cane” can be changed when beef cattle’s manure, compost or organic fertilizer is applied. To incorporate it into functions, this function is created.

Regarding “$0 \leq Q1- (o1\times E\times Z + o2\times E\times V1)$, $0 \leq Q4- (o3\times E\times Z + o4\times E\times V1)$”, the amount of bagasse or sugar cane tops consumed by beef cattle cannot exceed the actual amount of bagasse or sugar cane tops. These functions prohibit beef cattle from exceeding the actual amount of them.

4.3.1.3 Evaluation Index

This subsection exemplifies the concept of “evaluation index”. The following is a list o evaluation indices which this research uses to evaluate the proposed regional scale agricultural production system on Miyakojima Island:

Table 4.11 Evaluation indices for a regional scale agricultural production system

	Names of evaluation indices
1	the amount of imported concentrate feeds
2	the amount of imported pasturage
3	the amount of chemical fertilizer
4	the amount of organic fertilizer
5	the amount of chemical fertilizer
6	nitrogen loading to the ground water
7	yield per one hector of sugar cane
8	the number of calves sold to the outside of the island
9	the amount of crude sugar sold to the outside of the island

Evaluation indices "the amount of imported concentrate feeds", "the amount of imported pasturage", "the amount of chemical fertilizer", "the amount of organic fertilizer" and "the amount of chemical fertilizer" are used to evaluation "independency" of the agricultural production system. Miyakojima Island is a remote island and transportation costs for imported materials like fertilizer and feeds affects the agriculture and stockbreeding. Dairy cattle's bankruptcy can be ascribed to the costs of imported feeds. As the MFA for dairy cattle has shown, all of the feeds for dairy cattle are imported from the outside to the island.

Evaluation index "nitrogen loading to the ground water" is used to evaluate "environmental impact" of the agricultural production system. On Miyakojima Island, all of drinking water depends on ground water. Therefore minimizing pollution to the ground water should be included in the list.

Evaluation indices "yield per one hector of sugar cane", "the number of calves sold to the outside of the island" and "the amount of crude sugar sold to the outside of the island" are used to evaluate “producer’s ability” which the agricultural production system has. Farmers can obtain the revenues by selling calves (by way of the auction) and crude sugar (by way of sugar mills) to the outside of the island.

In “Fig. 4.10 The basic form for scenario building”, evaluation indices are highlighted in a red letters.

Evaluation indices “the amount of imported concentrate feeds”, “the amount of imported pasturage”, “the amount of chemical fertilizer”, “the amount of organic fertilizer” and “the amount of chemical fertilizer” are located on the left side of Fig. 4.10.

Evaluation index “nitrogen loading to the ground water” is located on the bottom of Fig. 4.10.

Evaluation index “yield per one hector of sugar cane” is located on right above the “nitrogen loading to the ground water” in Fig. 4.10.

Evaluation indices “the number of calves sold to the outside of the island” and “the amount of crude sugar sold to the outside of the island” are located on the right side of Fig. 4.10.

The values of “Operational Factor” in the following subsection will be changed in order to find the directions which the agriculture and stockbreeding on Miyakojima Island need to move forward.

4.3.1.4 Operational Factor

This subsection exemplifies the concept of “operational factor”. To simulate an agricultural production system, it is necessary to change some portion of the basic form. The portions which are subject to changes are “operational factors”.

If this research changes the value of some components of agriculture or stockbreeding on Miyakojima Island, it would be possible to have better values for the evaluation indices listed in Table 4.11. Therefore the concept of “operational factor” is that for better values related to evaluation indices some components of agriculture or stockbreeding on Miyakojima Island are changed to realize the objective of the agricultural production system.

Take a look at Fig. 4.10 The basic form for scenario building and Fig. 4.11 Causal-loop diagram for Scenario 1.

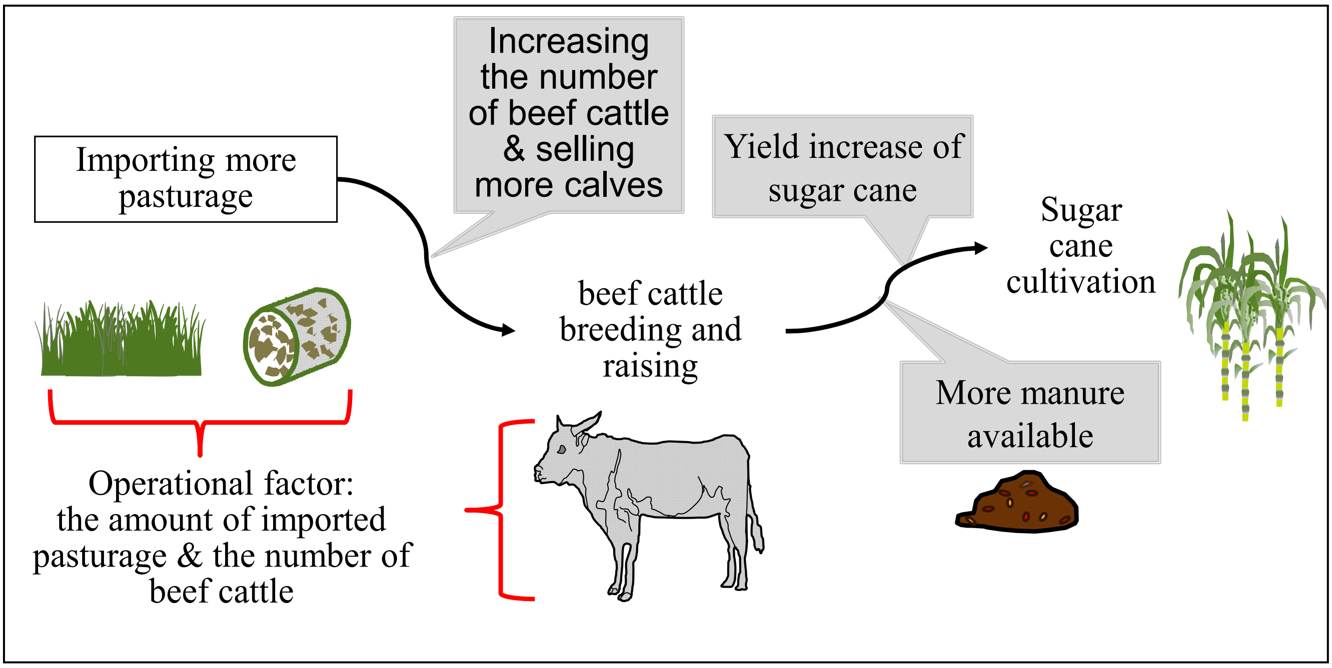

Fig. 4.11 Causal-loop diagram for scenario 1

This research tries to change some components in Fig. 4.10. It is known that application of beef cattle's manure to sugar cane is able to increase its yield up to 10.5%[2]. By using constants "c = Sugar cane's yield increase ratio per one hectare of area when 30t/y of beef cattle's manure is applied to = 0.105" and "f = The least amount of manure for one hectare of harvested area to increase the yield= 30t/y" in Fig. 4.10 Evaluation function for scenario building this research is able to realize good changes to the basic form.

Fig. 4.11 Causal-loop diagram for scenario 1 demonstrates how and why yield increase of sugar cane will be realized. As said on the right side of Fig. 4.11, this research tries to have more manure to increase the yield. In order to do that, it is possible to increase the number of beef cattle. To increase the beef cattle, it is necessary to procure more pasturage by importing more pasturage or by allocating more areas for pasturage cultivation. In this case, “importing more pasturage” is chosen. This research will change “the number for beef cattle” and “the amount of imported pasturage”.

Components “the number for beef cattle” and “the amount of imported pasturage” are operational factor.

In passing, as the title of this figure says, the basic form with these changes will be “scenario 1”.

Table 4.12 Operational factor for a regional scale agricultural production system

	Names of evaluation indices
1	growing area of pasturage,
2	growing area of sugar cane
3	growing area of green manure plants
4	Residues from sugar mills
5	the amount of imported feeds
6	manure of beef cattle
7	urine of beef cattle
8	sugar cane top
9	the amount of imported feeds
10	manure of beef cattle

Table 4.12 Operational factor for a regional scale agricultural production system shows a list of operational factor used by this research.

4.3.1.5 Scenario

This subsection explains the concept of "scenario" briefly. When this research exemplifies the concepts of "the basic form", "evaluation index" and "operational factor", the concept of scenario was already addressed.

Scenario is derived from the basic form. **Scenario is the basic form in which some components, i.e. operational factor received changes.** some components should be changed because this research tries to have a better result. What is better in this research is judged by some standards, i.e. evaluation indices. Calculation to realize the changes are made with evaluation functions.

4.4 Scenario Building

4.4.1 Objectives for Scenario 1 "Increasing Yield of Sugar Cane"

This subsection and the following subsections brief the objectives for each scenario. The main objectives were already addressed in 4.3.1.4 Operational Factor.

Scenario 1 tries to increase the yield of sugar cane by applying beef cattle's manure to sugar cane. To Scenario 1 tries to increase the yield of sugar cane by applying beef cattle's manure to sugar cane.

For that purpose, this research will increase the number of beef cattle.

It is also necessary to decide whether more areas will be allocated to pasturage or more pasturage will be imported. This research chose the latter option. It is expected that more crude sugar will be generated and more calves will be obtained to sell them to the outside of the island. Instead, it is necessary to import more feeds. Note that concentrate feeds cannot be replaced with feeds created on the island. So when the number of beef cattle increases, it is necessary to import more concentrate feeds.

Also any adult cattle and breeding cow which does not give a birth to calves will not be kept because they only consume imported feeds.

4.4.2 Objectives for Scenario 2 "Decreasing Imported Fertilizer and Increasing Sugar Cane Yield Amount"

This subsection addresses the objectives for scenario 2.

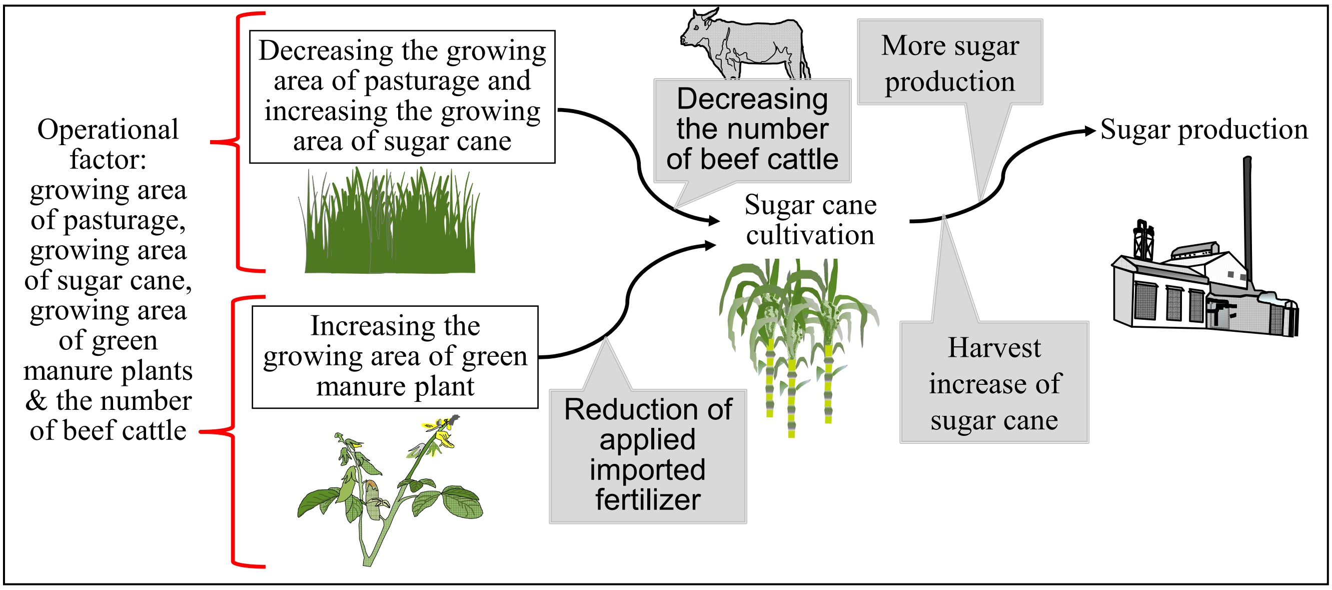

Fig. 4.12 Causal-loop diagram for scenario 2

Scenario 2 tries to decrease imported fertilizer and increase sugar cane yield amount. any beef cattle are not kept and all resources for sugar cane are used.

No imported feeds are necessary. Imported fertilizer for pasturage is not necessary either. All resources for sugar cane cultivation can be used: in other words, all areas for pasturage cultivation can be used for sugar cane cultivation.

An effort to minimize the imported fertilizer is to utilize green manure plants[1]. Fertilization can be saved up to 30%. Constant in Fig. 4.10 "g = The effect of fertilizer reduction ratio by green manure plants for sugar cane cultivation= 0.3" can be available for this purpose.

Operational factors used for scenario 2 are growing area of pasturage, growing area of sugar cane, growing area of green manure plants and the number of beef cattle.

4.4.3 Objectives for Scenario 3 "Decreasing Imported Feed and Imported Fertilizer for Beef Cattle"

This subsection addresses the objectives for scenario 3.

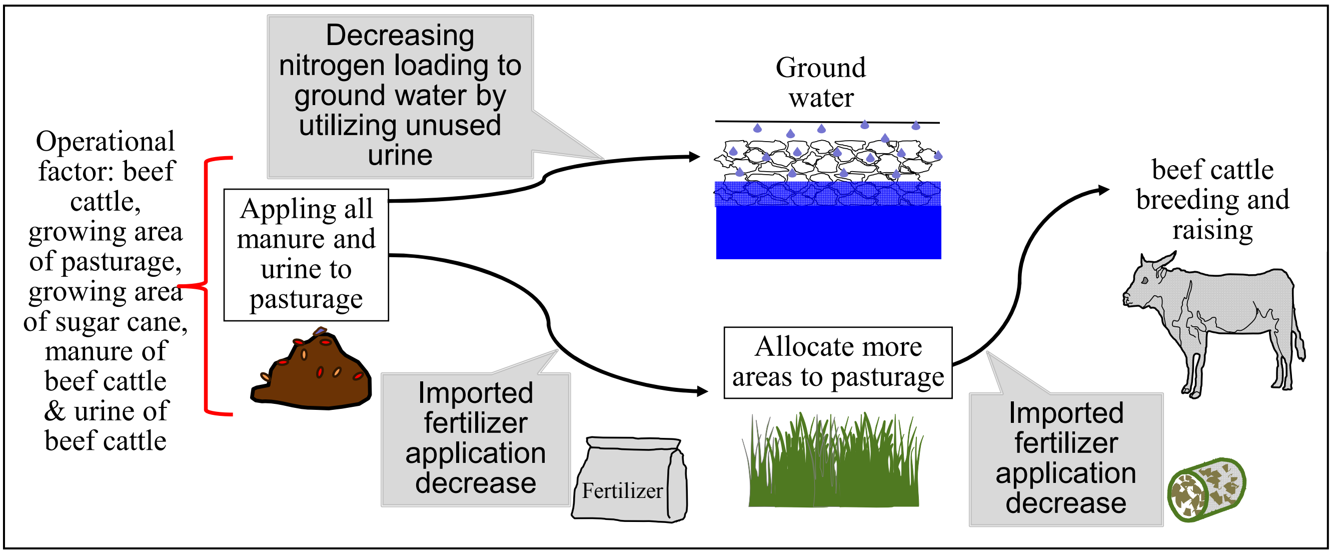

Fig. 4.13 Causal-loop diagram for scenario 3

Scenario 3 tries to decrease imported feed and imported fertilizer for beef cattle. All manure and urine of beef cattle are applied to pasturage only.

In the basic form, manure of beef cattle is used for sugar cane, pasturage and composting. It is not be used for sugar cane and composting. The expected results are : 1) imported fertilizer can be saved, 2)although manure has an effect to increase the yield per one hector of area up to 10.5% scenario 3 cannot utilize it.

Regarding urine of beef cattle, it is not used at all and becomes a source for pollution to the ground water. Pasturage will be allowed to use nitrogen and phosphorus.

Operational factors used for scenario 3 are beef cattle, growing area of pasturage, growing area of sugar cane, manure of beef cattle and urine of beef cattle.

Any adult cattle and breeding cow which does not give a birth to calves will not be kept because they only consume imported feeds.

4.4.4 Objectives for Scenario 4 "Using Sugar Cane Top Instead of Pasturage"

This subsection addresses the objectives for scenario 4.

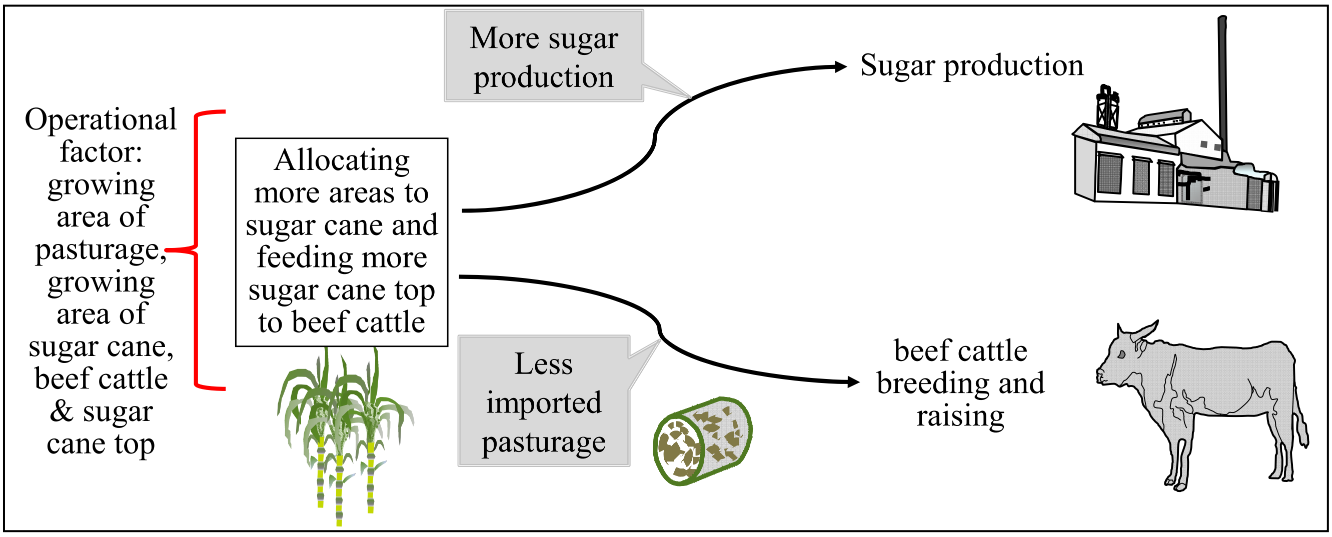

Fig. 4.14 Causal-loop diagram for scenario 4

Scenario 4 tries to utilize sugar cane tops for beef cattle instead of pasturage which may be grown on the island or may be imported from the outside of the island.

In the basic form, beef cattle are fed pasturage grown on the island. A certain amount of sugar cane tops are given to beef cattle. Sugar cane tops are plowed under and have sufficient amount instead of pasturage. Sugar cane tops will be given to beef cattle but this research has to decide how much of them is given to beef cattle.

No past studies were available for this purpose. So this research thinks that the quantity contained in the sugar cane tops which will be given to beef cattle should be the same as the quantity of nitrogen contained in the pasturage. However this is only for this research and need to be examined in the future researches.

Sugar cane tops which are plowed under may work as fertilizer. The effect of the sugar cane tops which are plowed under is not clarified. But this research utilizes green manure plants but do not reduce the quantity of imported fertilizer. Sugar cane tops are available only harvesting season from January to March. They will be used after they are changed to silage feeds.

Experiments were conducted to create silage feeds from sugar cane tops[5]. For the convenience of the discussion, no ingredient is reduced in the process of silage feeds. Also there are no examples that farmers keep beef cattle without pasturage grown on Miyakojima Island. Therefore the issue on whether silage sugar cane tops are available or not is not discussed in this research and it is open to the future researches.

No areas are used for pasturage cultivation. Instead of that, this research uses those areas for sugar cane cultivation. So it is expected that more yield amount for sugar cane will be obtained.

Nitrogen amount contained in sugar cane tops is smaller than the one contained in the pasturage. The number of beef cattle is reduced.

Also any adult cattle and breeding cow which does not give a birth to calves will not be kept because they only consume imported feeds and they are not fed sugar cane tops to keep the quality of meat.

Operational factors used for scenario 4 are beef cattle, growing area of pasturage, growing area of sugar cane, manure of beef cattle and urine of beef cattle.

4.5 Summary of the Discussion in Chapter 4

Chapter 4 first demonstrates basic units for scenario building based on MFAs shown in Chapter 2 and Chapter 3 such as a calf (beef cattle), a breeding cow (beef cattle), an adult cattle (beef cattle), a breeding cow which cannot give a birth to calves (beef cattle), sugar cane in the field, sugar mills, pasturage, green manure plants.

This research showed the basic form for scenario building. The basic form is the basis to forge four scenarios.

This research explained the evaluation indices with the basic form. Nine evaluation indices are available and they are used to evaluate three things: that is, the quantity of materials which are imported from the outside of the island, the environmental impact and an ability to create the products which are sold to the outside of the island.

To explain operational factor, the causal-loop diagram was used for scenario 1. The portions in the basic form which are subject to changes are "operational factors"

Evaluations functions were created for scenario building. Evaluation functions are used to calculate the values when this research would like to change the basic form to obtain better results.

It was revealed that it was possible to create scenarios, using evaluation indices, evaluation functions and operational factors.

This research discussed the objectives for four scenarios: i.e., scenario 1 "increasing yield of sugar cane", scenario 2 "decreasing imported fertilizer and increasing sugar cane yield amount", scenario 3 "decreasing imported feed and imported fertilizer for beef cattle" and scenario 4 "using sugar cane top for pasturage."

This research utilized causal-loop diagrams to show the objectives for each scenario. Scenario 1 tries to increase the yield of sugar cane by applying beef cattle's manure to sugar cane. Scenario 2 tries to decrease imported fertilizer and increase sugar cane yield amount. No beef cattle is kept and all areas are used for sugar cane. Scenario 3 tries to decrease imported feed and imported fertilizer for beef cattle. All manure and urine of beef cattle are applied to pasturage only and unused urine which is a pollution source of to the ground water will be used for fertilization. Scenario 4 tries to utilize sugar cane tops for beef cattle instead of pasturage which may be grown on the island.

Chapter 5 will show the result of calculation for each scenario and will also make evaluations for each scenario.

References for Chapter 4

1 Sumisu Sakiyama, Kazuhiko Tarora, Kazumi Uehara and Masahiko Taira, "The Effect of Green Manure Plants to Sugar Cane in Miyako Area", 2008, Summary of Technique for Diffusion in C Y 2007, pp. 67-68

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3) Masayuki Hojito, Atsuo Ikeguchi, Kazunori Kohyama, Kazuhiro Shimada , Akifumi Ogino, Shinichiro Mishima, Koichi Kaku, "Estimation of Nitrogen Loading in Japanese Prefectures and Scenario Testing of Abatement Strategies", Journal of the science of soil and manure, 2003, Volume 74 Issue 4, pp.467-474.

4 Yasuhiro Nakanishi, Kaneshi Takahira and Kuniki Shimoji, "Estimation of Nitrogen Loading Factors for Groundwater by Multiple Regression Analysis", Japanese Journal of Soil Science and Plant Nutrition, 2001, Japanese Journal of Soil Science and Plant Nutrition, Vol. 72(3), pp.365-371

5 Shuichi Tamura, and Koichi Fujie. "Material Cycle of Agriculture on Miyakojima Island: Material Flow Analysis for Sugar Cane, Pasturage and Beef Cattle". 2014, Switzerland, Basel: MDPI, Sustainability, 6(2), pp812-835. www.mdpi.com/journal/sustainability/10.3390/su6020812

Chapter 5 Evaluations and Discussions of Scenarios

5.1 Objectives for Chapter 5

The tasks in this chapter are to perform the following to evaluate and discuss a regional scale agricultural production system: 1) Demonstrates the results of calculation for each scenario, 2) Makes the overall evaluation by cobweb chart and discuss the desirable system for the agriculture and stockbreeding on Miyakojima Island and 3) Evaluate each scenario by tracing nitrogen flow.

5.2 Calculation Result for Scenario 1 "Increasing Yield of Sugar Cane"

This section shows the result of calculation for scenario 1. To make the calculation, basic units are used as shown in section 4.2 and evaluation function in subsection 4.3.1. When additional evaluation function is required, this research addresses it.

This research turns to the calculation result of scenario 1 shown in Fig. 5.1. Table 5.1 shows the basic form and the calculation result of scenario 1.

Scenario 1 is set up to increase the yield per one hector area of sugar cane. For that purpose, this research uses the beef cattle's manure as discussed in Chapter 4. This research does not keep adult cattle and breeding cow which cannot give a birth to calves because they only consume imported feeds. This research would like to have the agricultural production system which needs the minimum amount of imported materials. They are not oriented for the system which this research is trying to build up

Also this research does not utilize the composting facilities because the composting process has us loose almost 80% of materials.

For the calculation, this research needed to obtain how much beef cattle's manure is required. For pasturage, this research needs 6998t/y of manure. For sugar cane, this research needs 15 t/y of manure per one hector of sugar cane's growing area. Because the growing area for sugar cane is 7,706 ha, this research needs 115,080 t/y of manure. The total amount of beef cattle's manure required for this scenario is 122,078t/y.

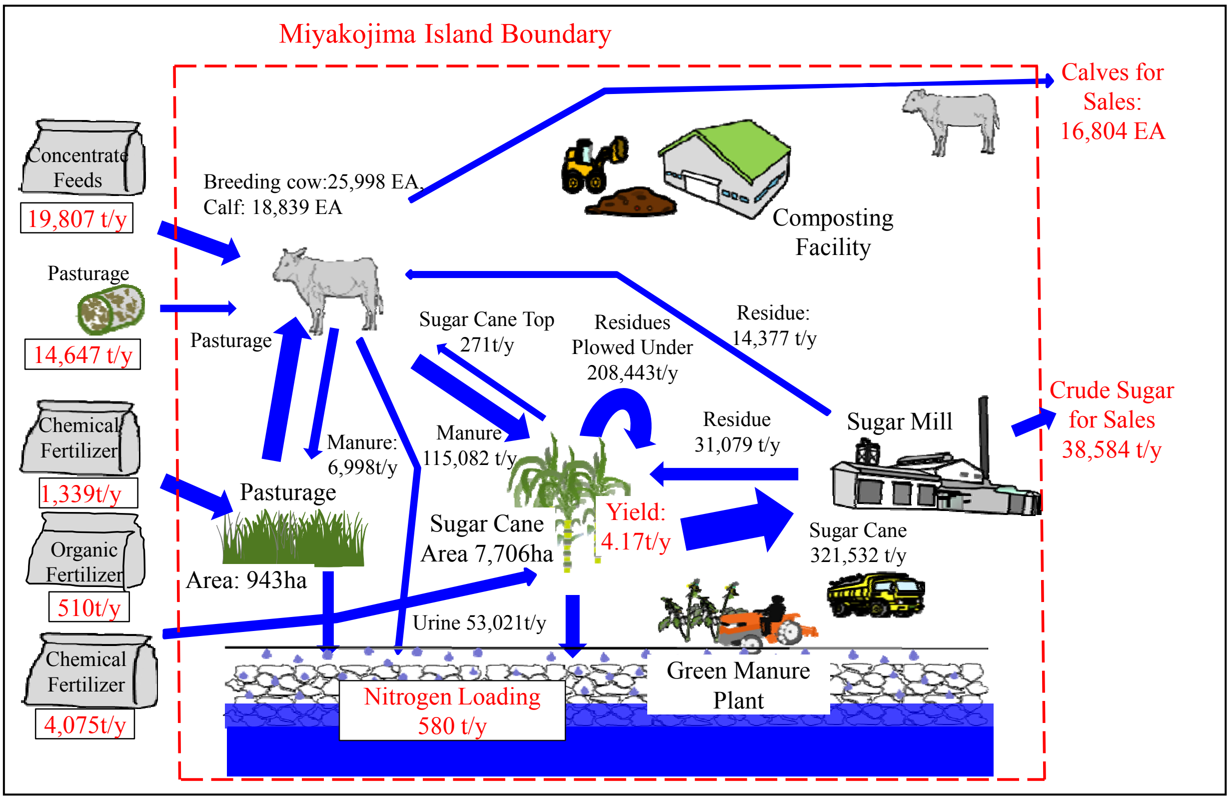

Fig. 5.1 Calculation Result for Scenario 1

Table 5.1 |The Basic Form and the Calculation Result of Scenario 1

Unit = EA for "Calves for Sales", t/y for the others	**Calves for Sales**	**Yield of sugar cane per 10 are area**	**Crude Sugar**	**Nitrogen Loading to Ground Water**	**Imported fertilizer**	**Imported concentrate feed**	**Imported pasturage**
Basic Form	5,299	3.9	36,037	389	5,910	7,775	1,221
Scenario 1	16,804	4.17	38,584	580	5,910	19,807	14,647

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Next it is necessary to obtain the required number of breeding cows and calves. Note that breeding cows and calves are always be together. The proportion of them is that 1 calf needs to be with 1.38 breeding cows. 1 calf generates 1.94 t/y of manure while 1.38 breeding cows generate 4.5402 t/y of manure. So the total amount of manure for this pair is 6.4802 t/y. When 122,078 t/y are divided by that number, 18,839 EA can be obtained for the number of calves and 25,997 EA for the number of breeding cows.

The other values found in Fig. 5.1 are automatically obtained by the evaluation function shown in Fig. 4.10.

5.3 Calculation Result or Scenario 2 "Decreasing Imported Fertilizer and Increasing Sugar Cane's Yield Amount"

Scenario 2 is set up to decrease imported fertilizer and to increase sugar cane's yield amount. This scenario does not have any beef cattle. Also this research does not utilize the composting facilities because the composting process has us loose almost 80% of materials. This is the same reason as scenario 1.

This research turns to the calculation result of scenario 2 shown in Fig. 5.2. Table 5.2 shows the basic form and the calculation result of scenario 2.

The growing area for pasturage is also set to be 0 ha. No fertilizer and no manure is required for that pasturage. Because no beef cattle is kept, urine which is a pollution source for ground water does not exist. The yield per one hectare of sugar cane's growing area stays the lowest level. But the area available for the scenario is only used for sugar cane cultivation. The yield amount of sugar cane the amount of crude sugar for sales are kept at the high level.

When the growing area for pasturage is set to 0ha and the number of beef cattle is set to 0EA, the values are obtained by the evaluation function shown in Fig. 4.10.

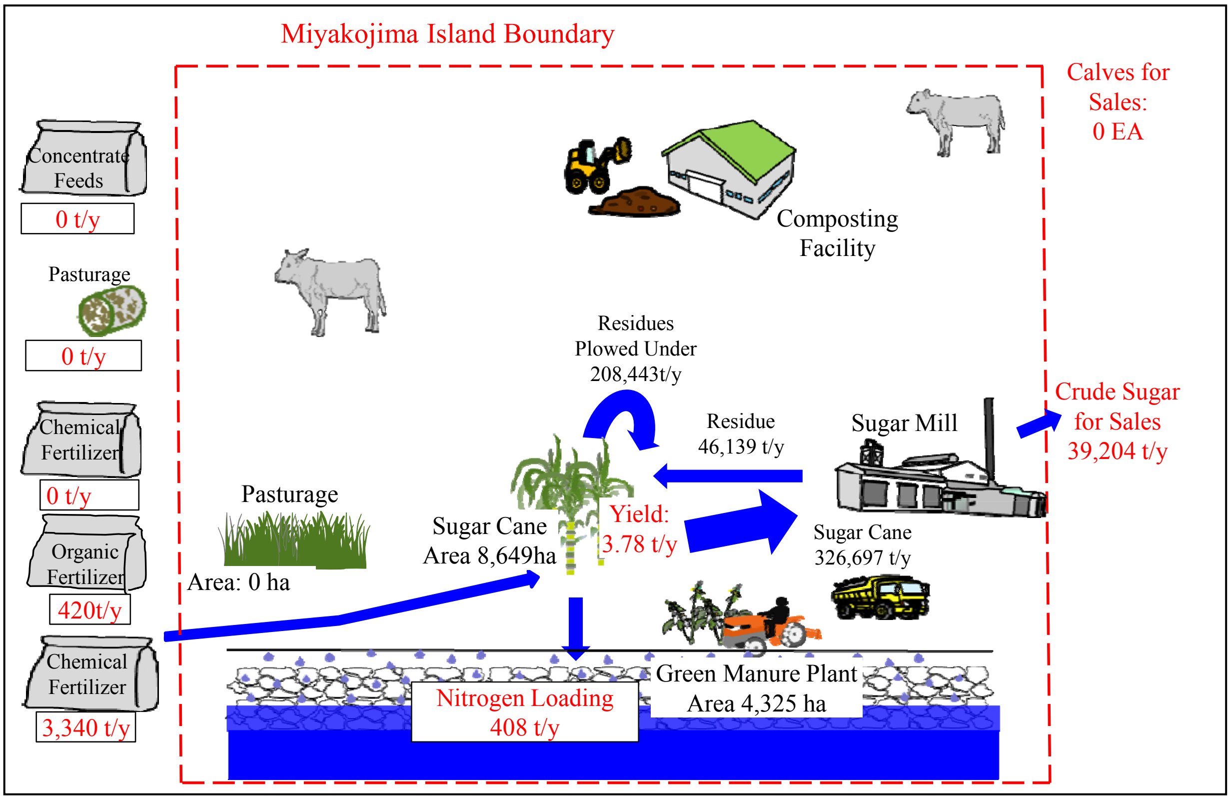

Fig. 5.2 Calculation Result for Scenario 2

Table 5.2 |The Basic Form and the Calculation Result of Scenario 2

Unit = EA for "Calves for Sales", t/y for the others	**Calves for Sales**	**Yield of sugar cane per 10 are area**	**Crude Sugar**	**Nitrogen Loading to Ground Water**	**Imported fertilizer**	**Imported concentrate feed**	**Imported pasturage**
Basic Form	5,299	3.9	36,037	389	5,910	7,775	1,221
Scenario 2	0	3.78	39,204	408	3,209	0	0

5.4 Calculation Result for Scenario 3 "Decreasing Imported Feeds and Imported Fertilizer for Beef Cattle"

Scenario 3 is set up to decrease imported fertilizer and to decrease imported fertilizer for beef cattle. Beef cattle itself does not need any fertilizer to sustain it live body. It indirectly need fertilizer: it needs pasturage and for pasturage cultivation fertilizer is required.

This research turns to the calculation result of scenario 3 shown in Fig. 5.3. Table 5.3 shows the basic form and the calculation result of scenario 3.

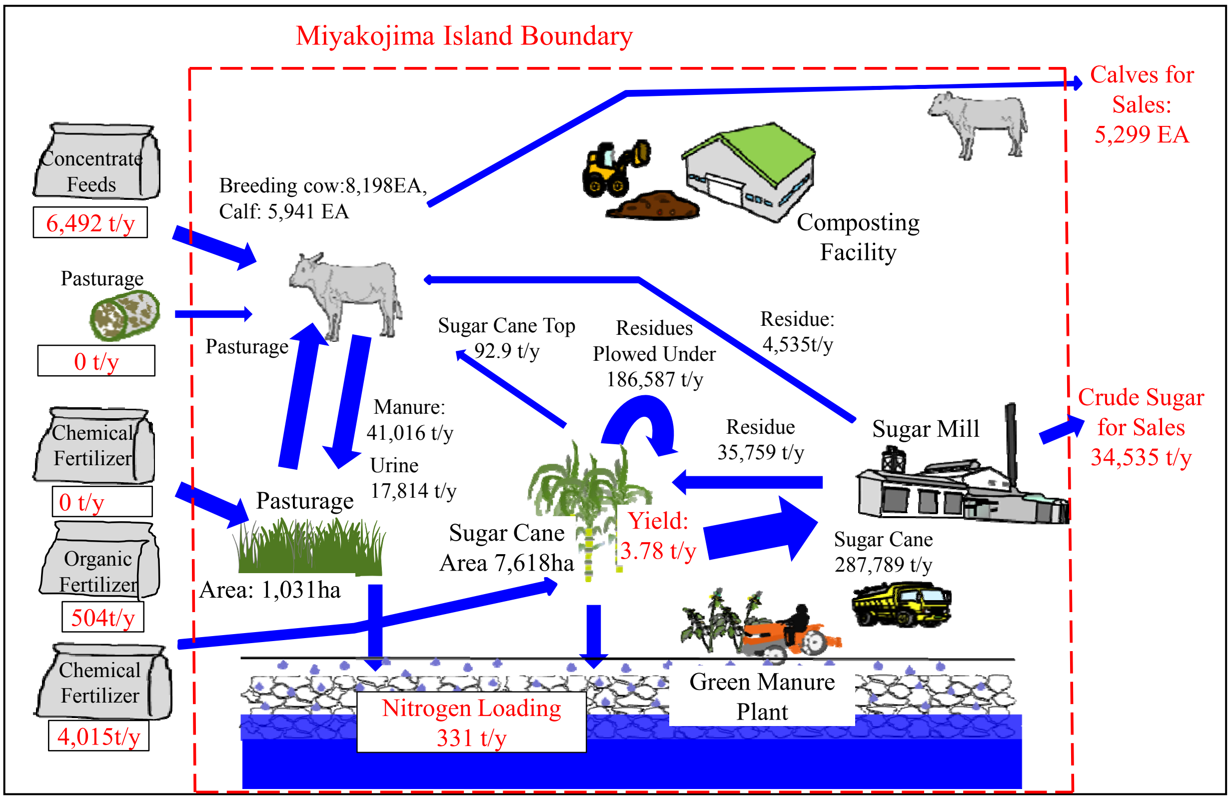

Fig. 5.3 Calculation Result for Scenario 3

Table 5.3 |The Basic Form and the Calculation Result of Scenario 3

Unit = EA for "Calves for Sales", t/y for the others	**Calves for Sales**	**Yield of sugar cane per 10 are area**	**Crude Sugar**	**Nitrogen Loading to Ground Water**	**Imported fertilizer**	**Imported concentrate feed**	**Imported pasturage**
Basic Form	5,299	3.9	36,037	389	5,910	7,775	1,221
Scenario 3	5299	3.78	34,535	331	4,215	6,492	0

The concept for this scenario is that instead of using imported fertilizer this research uses manure and urine from beef cattle for pasturage. Compare Table 5.4 with Table 5.5. The amount of nitrogen and phosphorus generated by beef cattle are exceeding the required amount of pasturage cultivation. For the convenience of the discussion, it supposes that when the same amount of nitrogen and phosphorus is contained by manure and urine they can be replaced with the same amount of nitrogen and phosphorus contained by fertilizer. Scenario 3 use all manure and urine for pasturage cultivation.

Table 5.4 Fertilization Requirements for Pasturage of Scenario 3

Unit = t/y	**Amount of beef cattle's manure required for pasturage**	**Nitrogen Amount required for pasturage**	**Phosphorus Amount required for pasturage**
Breeding cow's manure	26,971	137.8	5299
Calf's Manure	12,476	63.8	3.78
Fertilizer	1,464	260	55.7
Total	N/A	317.	72.2

Table 5.5 Manure and Urine Quantity Generated by Beef Cattle of Scenario 3

Unit = t/y	**Amount of beef cattle's manure or urine**	**Nitrogen Amount**	**Phosphorus Amount**
Breeding cow and Calf 's Manure	41,016	210	65.6
Breeding cow and Calf 's Urine	26,971	127	55.3
Total	N/A	336	121

Another difference between scenario 3 and the basic form is that the number of breeding cow and calves are the same but that growing area for pasturage cultivation for scenario is larger than the basic form. It means that more feeds are generated on Miyakojima Island and the amount of imported pasturage is decreased. Evaluation function for imported fertilizer and imported pasturage in Fig. 4.10 cannot be used. Because the other evaluation functions work and other values can be obtained automatically. Lastly in the same way as scenario 1, this research does not keep adult cattle and breeding cow which cannot give a birth to calves because they only consume imported feeds. Also this research does not utilize the composting facilities because the composting process has us loose almost 80% of materials.

5.5 Calculation Result for Scenario 4 "Using Sugar Cane Top Instead of Pasturage"

Scenario 4 is set up to use sugar cane top instead of pasturage. To keep breeding cows and calves, pasturage is needed. As shown in Chapter 2, beef cattle consume sugar cane tops and bagasse. They are used instead of the pasturage.

This research turns to the calculation result of scenario 4 shown in Fig. 5.4. Table 5.6 shows the basic form and the calculation result of scenario 4.

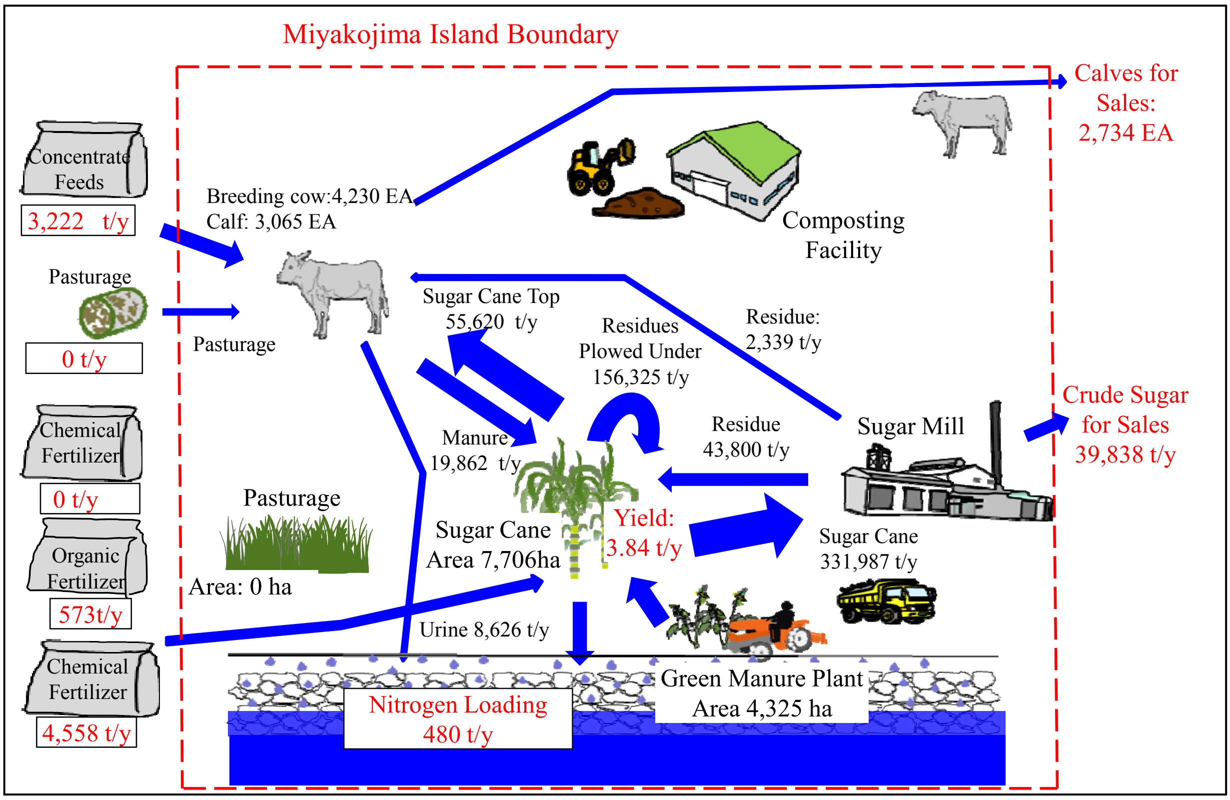

Fig. 5.4 Calculation Result for Scenario 4

Table 5.6 The Basic Form and the Calculation Result of Scenario 4

Unit = EA for "Calves for Sales", t/y for the others	**Calves for Sales**	**Yield of sugar cane per 10 are area**	**Crude Sugar**	**Nitrogen Loading to Ground Water**	**Imported fertilizer**	**Imported concentrate feed**	**Imported pasturage**
Basic Form	5,299	3.9	36,037	389	5,910	7,775	1,221
Scenario 4	2,734	3.84	39,838	480	5,131	3,222	0

The concept for this scenario is that, instead of using sugar cane tops as being plowed under, all sugar cane tops are given to beef cattle. Also this scenario does not cultivate the pasturage and the areas for pasturage will be used for sugar cane. The issue with that approach is that the nitrogen and phosphorus contained in sugar cane tops which may reduce the amount of fertilization. Nakanishi (2000) [1] Indicates that fertilization for sugar cane cultivation is smaller than the one guided by the fertilization standard determined by Okinawa Prefectural Government. This research thinks that there is a possibility that residues plowed under allow farmer to reduce the fertilization. This issue is beyond the scope of this research. So it is open to the future research.

Instead of sugar cane tops which are given to beef cattle, this scenario utilizes green manure plants. Scenario 2 used it for fertilization reduction. But because green manure plants are used instead sugar cane tops which are supposed to be plowed under, this scenario does not reduce the fertilization for sugar cane for this scenario.

Now it is necessary to find out how many number of beef cattle can be kept by the sugar cane tops.

The nitrogen quantity which one calf needs from “pasturage” “imported pasturage” and “sugar cane tops” are 0.719kg/y, 6.65 kg/y and 0.0211kg/y respectively. On the other hand, the nitrogen quantity which one breeding cow needs from “pasturage” “imported pasturage” and “sugar cane tops” are 21.8 kg/y, 0.795 kg/y and 9.7 respectively. As discuss above 1.38 breeding cows are pair with one calf. The total quantity of nitrogen 1.38 breeding cows and one calf is 0.052t/y. Variable “E”, see Fig. 4.10. When value “3,065” is assigned to “F”, all values are compatible. The number of calves is 3,065EA and that of breeding cows is 4,230EA.

Regarding “3. Total amount of imported fertilizer for sugar cane and pasturage (t/y) = O1 = ((d1 + d2)×Y + d3×X - (d1 + d2)×g×U×2”, it needs to be changed to “3. Total amount of imported fertilizer for sugar cane and pasturage (t/y) = O1 = ((d1 + d2)×Y + d3×X” because the fertilization reduction with green manure plants are not conducted.

Lastly in the same way as scenario 1 and 3, this scenario does not keep adult cattle and breeding cow which cannot give a birth to calves because they only consume imported feeds.

Also this research does not utilize the composting facilities because the composting process has us loose almost 80% of materials.

Function

aF = (b × Y × E)

Subject to

0 ≤ F, Y and Z

where,

F = Number of breeding cow and calf's pair

Y = Growing area of sugar cane

E = The change ratio of yield of 10 are growing area for sugar cane from the basic form

a = nitrogen quantity of beef cattle's pair = 0.0052t/y

b = nitrogen quantity of sugar cane top per one hector of sugar cane = 0.0189t/y

Fig. 5.5 Evaluation Function for Scenario 5

5.6 Evaluations for Scenarios

5.6.1 Comparative Assessment

For evaluations, this research utilizes the following two functions as shown in Fig. 5.6:

The functions enable us to convert evaluations indices into certain values between 1 and 5. For example regarding "Sold calf", the maximum value is "16,804" of "Scenario 1" from evaluation indices of the basic form and scenarios while the minimum value is "0" of "Scenario 2" from evaluation indices of the basic form and scenarios. When the target value from evaluation indices is "2.3" of "Basic Form", first "0" of "Scenario 2" is subtract from "2.3" of

"Basic Form". At this moment, the value standing for the distance between 'the maximum value from evaluation indices of the basic form and scenarios' and 'the target value' can be obtained. That value is divided by a certain value from the following equation: fist 'the minimum value from evaluation indices of the basic form and scenarios' is subtracted from 'the minimum value from evaluation indices of the basic form and scenarios', and then divide the obtained value by '4'. The intention of this equation is to obtain the constant for "sold calf" by which the value between 0 and 4 can be obtained. Because the values ranged from 1 to 5 needs bo be obtained, 1 is added to that equation.

Functions

$W = 1 \times (Z - Y) \div ((X - Y) \div 4)+1$

$V = -1 \times (Z - X) \div ((X - Y)) \div 4)+1$

Subject to

$0 \leq X, Y, Z$ and W

$1 \leq W \leq 5,\ 1 \leq V \leq 5$

where,

X = The maximum value from evaluation indices of the basic form and scenarios

Y = The minimum value from evaluation indices of the basic form and scenarios

Z = The target value from evaluation indices of the basic form and scenarios

W = The function calculation result for "Sold calf", "Yield of sugar cane per 1 ha area" and "Crude Sugar"

V = The function calculation result for "Nitrogen Loading to Ground Water", "Imported fertilizer", "Imported concentrate feed" and "Imported pasturage"

Fig. 5.6 Functions for Conversions of Evaluation Indices

In the same spirit, the function “V” is set up. Because the function “V” is used for “Nitrogen Loading to Ground Water”, “Imported fertilizer”, “Imported concentrate feed” and “Imported pasturage”, the maximum value is supposed to be the lowest value ‘1.’ Therefore, the function has “-1×” to convert the high value into the low value. Table 5.8 shows original values before they are converted by the function in Fig. 5.6 while Table 5.9 shows resultant values after they are converted by the function.

Table 5.7 Original values before they are converted by the function

Unit = EA for "Calves for Sales", t/y for the others	**Basic Form**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Calves for Sales	5,299	16,804	0	5299	2,734
Yield of sugar cane per 10 are area	3.9	4.17	3.78	3.78	3.84
Crude Sugar	36,037	38,584	39,204	34,535	39,838
Nitrogen Loading to Ground Water	389	580	408	331	480
Imported fertilizer	5,910	5,910	3,209	4,215	5,131
Imported concentrate feed	7,775	19,807	0	6,492	3,222
Imported pasturage	1,221	14,647	0	0	0

Table 5.8 Resultant values after they are converted by the function

	Basic Form	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Calves for Sales	2.3	5.0	1.0	2.3	1.7
Yield of sugar cane per 10 are area	2.2	5.0	1.0	1.0	1.6
Crude Sugar	2.1	4.1	4.5	1.0	5.0
Nitrogen Loading to Ground Water	4.1	1.0	3.8	5.0	2.6
Imported fertilizer	1.0	1.0	5.0	3.5	2.2
Imported concentrate feed	3.4	1.0	5.0	3.7	4.3
Imported pasturage	4.7	1.0	5.0	5.0	5.0

Now this research thinks about the evaluation of each scenario. Fig. 5.7 is the cobweb chart for the basic form. Each value appears, in comparison with the maximum value and the minimum value of the other scenarios.

This research turn to the basic form first. Regarding "Calves for Sales", the value is not high. The maximum value is given by scenario 1 as shown by Table 5.8. Scenario 1 increases the number of beef cattle like calves and breeding cattle, in accordance with that, the calves for sales is higher than the basic scenario

Regarding "Yield of sugar cane per 10 are area", the value is not that high because the value for that evaluation index can be increased when the amount of beef cattle is greater.

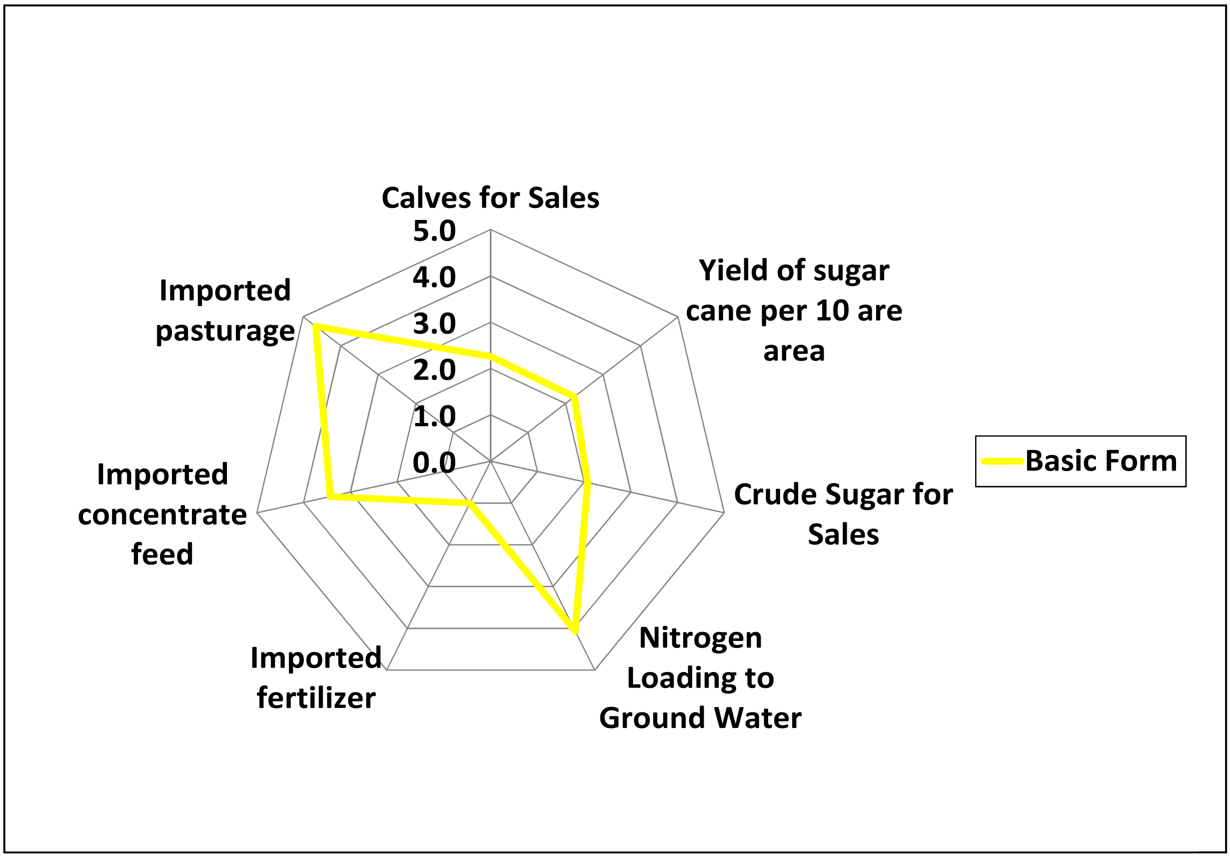

Fig. 5.7 Cobweb Chart for the Basic Form

Regarding "Crude Sugar for Sales", the value is not that high because the growing area is smaller than the other scenario.

Regarding "Nitrogen Loading to Ground Water", the value is quite good because it does not have much of beef cattle and green manure plants are not grown.

Regarding "Imported fertilizer", the value is the worst. The basic form did not take any action to reduce the amount of the fertilizer used for sugar and pasturage.

Regarding "Imported pasturage", the difference between the value of the basic form and the maximum value is not that great because scenario 1 imported much of pasturage.

Regarding "Imported concentrate feed" the value is the mid of the maximum value and the minimum value. The maximum value is given by scenario 1 which has many beef cattle, on the other hand, the minimum value is given by scenario 2 which does not have any number of beef cattle.

This research next turns to scenario 1 shown by Fig. 5.8.

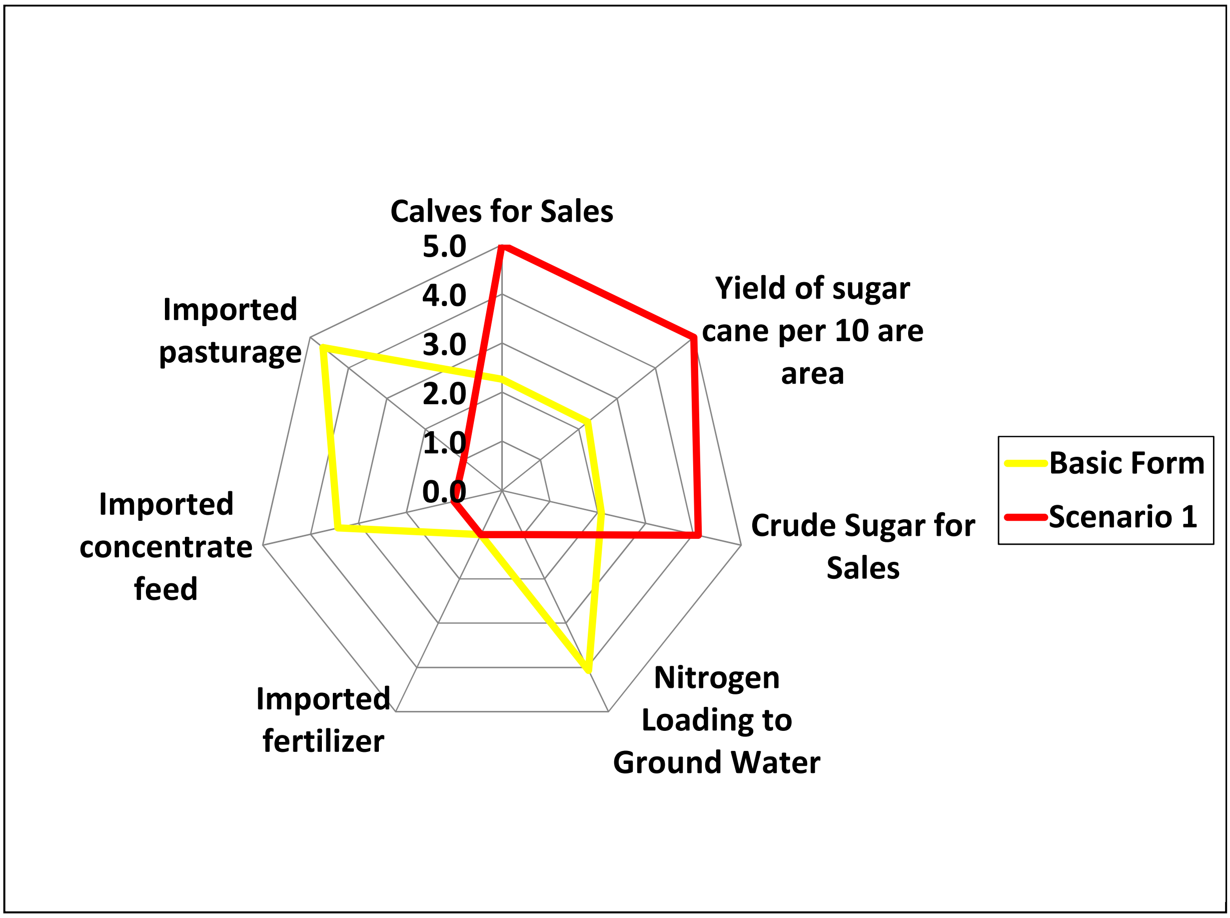

Fig. 5.8 Cobweb Chart for Scenario 1 and the Basic Form

Regarding "Calves for Sales" and "Yield of sugar cane per 10 are area", the value is the highest. The reason is that the beef cattle of this scenario outnumbers that of the other scenario and the basic form.

Regarding "Crude Sugar for Sales", the value is not that high because scenario 2 and 4 uses all areas for sugar cane cultivation.

Regarding “Nitrogen Loading to Ground Water”, the value is lowest because this scenario has many numbers of beef cattle. Also although the nitrogen applied to pasturage is relatively high compared to sugar cane, but no measures were not taken.

Regarding “Imported fertilizer”, the value is the worst. In the same say as the basic form , scenario 1 did not take any action to reduce the amount of the fertilizer used for sugar and pasturage.

Regarding “Imported pasturage” and “Imported concentrate feed” the value is the worst and the values are away from the values of the others. No measures were taken and the number of beef cattle is the greatest.

This research next turns to scenario 2 shown by Fig. 5.9.

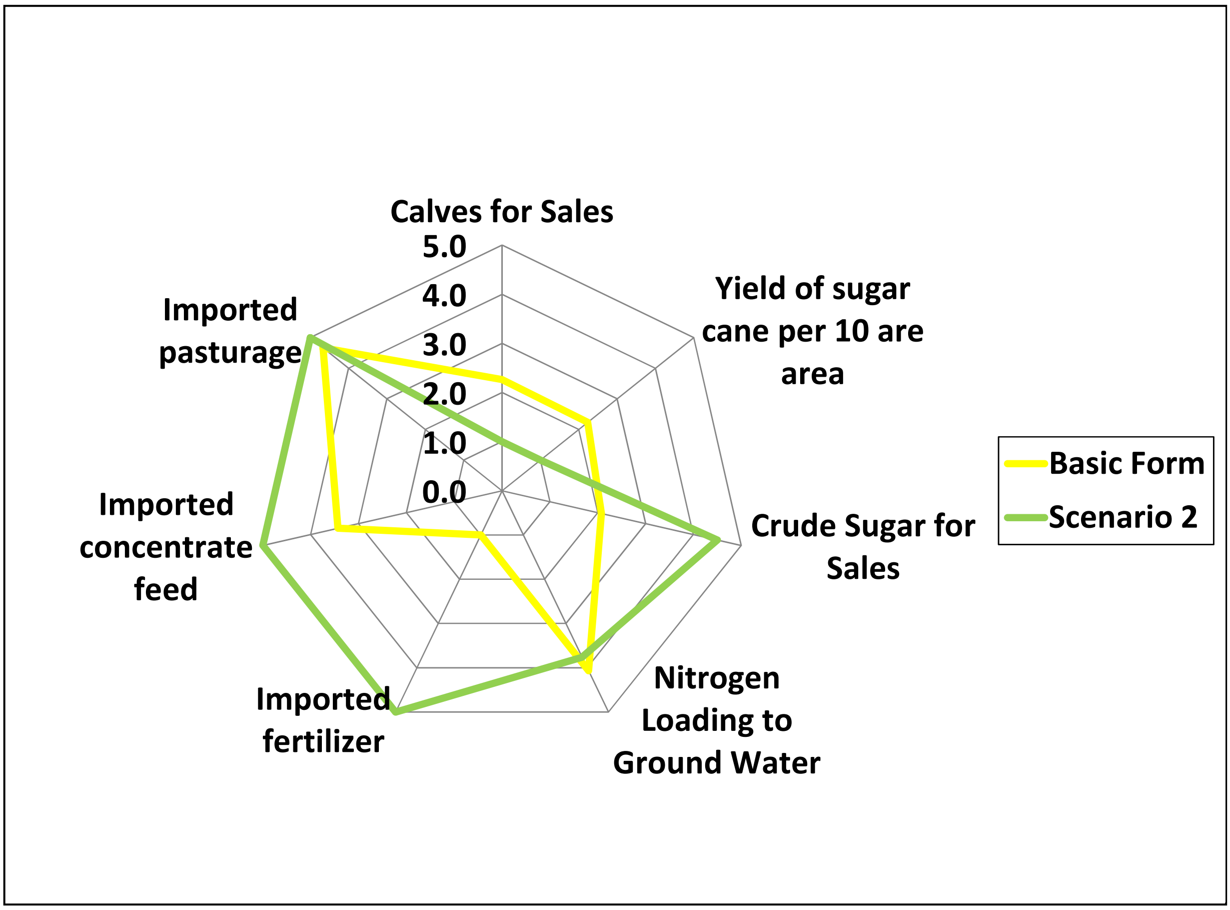

Fig. 5.9 Cobweb Chart for Scenario 2

Regarding “Calves for Sales” and “Yield of sugar cane per 10 are area”, the value is the lowest. This scenario does not have any beef cattle. Because evaluation “Yield of sugar cane per 10 are area” requires the collaboration between beef cattle and sugar cane, the value sits in the lowest.

Regarding “Crude Sugar for Sales”, the value is close to the highest. Because this scenario not the collaboration between beef cattle and sugar cane, the value is exceeded by scenario 4.

Regarding “Nitrogen Loading to Ground Water”, the value is close to the highest. Because it has green manure plants it did not reach the highest.

Regarding “Imported fertilizer”, the value is the highest. Because sugar cane uses less amount of fertilizer, the total amount of fertilizer will be smaller when the growing area of pasturage is changed into the sugar cane. Green manure plants also reduced the amount of fertilizer.

Regarding “Imported pasturage” and “Imported concentrate feed,” the value is highest because this scenario does not have any beef cattle.

This research next turn to scenario 3 shown by Fig. 5.10. The shape of this scenario is similar to the basic form. When the other scenarios are compared with this scenario it is relatively similar to the basic form.

Regarding “Calves for Sales”, it takes the same value as the basic for because the number of calves is not changed.

Regarding “Yield of sugar cane per 10 are area”, the value is the lowest. All biomass resources generated by beef cattle goes only to the pasturage.

Regarding “Crude Sugar for Sales”, the value is the lowest. To allocate more areas to each beef cattle, the growing area for pasturage was enlarged. Accordingly the yield amount of sugar cane was decreased.

Regarding “Nitrogen Loading to Ground Water”, the value is the highest. Nitrogen loading to the ground water, i.e. urine of beef cattle, is absorbed by the pasturage.

Regarding “Imported fertilizer”, the value came to the highest. To reduce the amount of fertilization for pasturage, this scenario utilized manure and urine of beef cattle. It actually reduced the amount of the imported fertilizer.

Regarding “Imported concentrate feed”, it is the mid of the highest and lowest. The number of the beef cattle determines its value.

Regarding “Imported pasturage”,” the value is highest because this scenario enlarged the growing area for pasturage. No pasturage is needed to be imported.

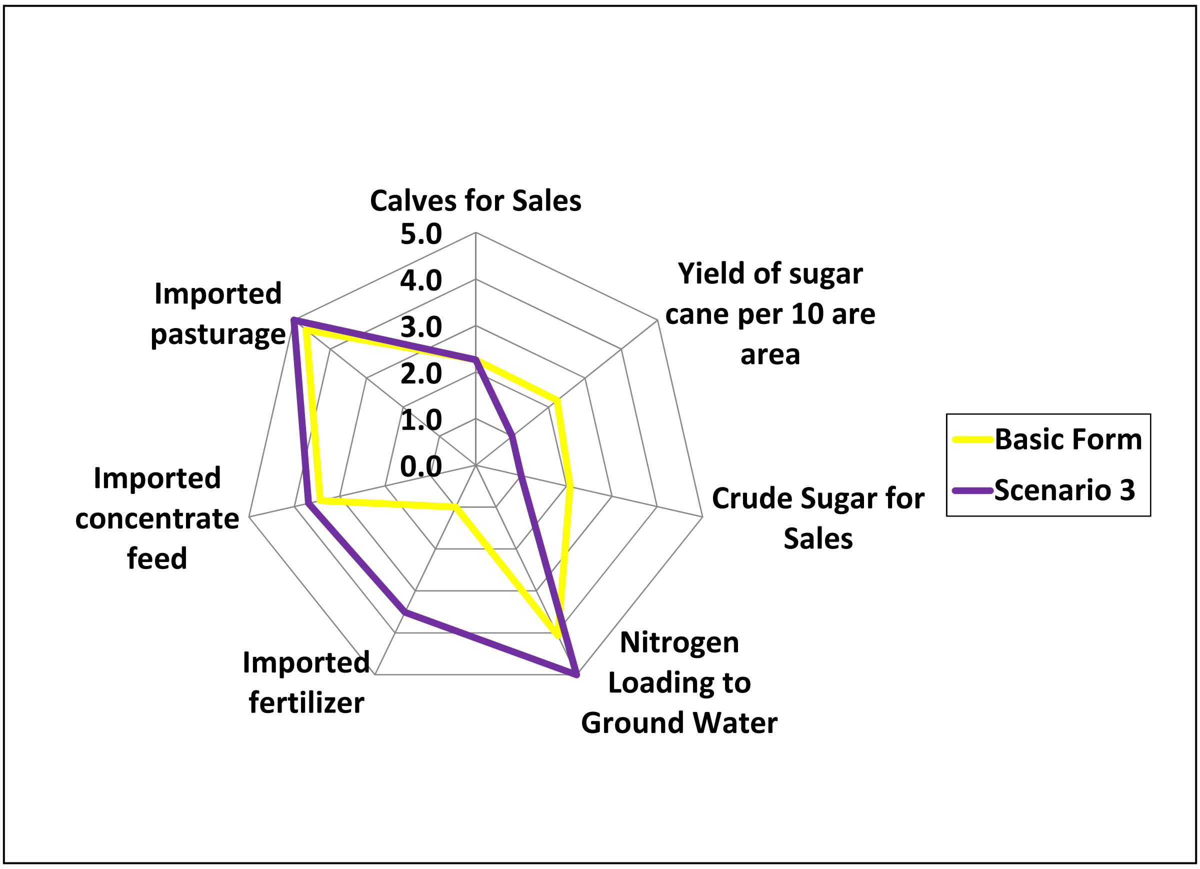

Fig. 5.10 Cobweb Chart for Scenario 3

This research next turns to scenario 4 shown by Fig. 5.10.

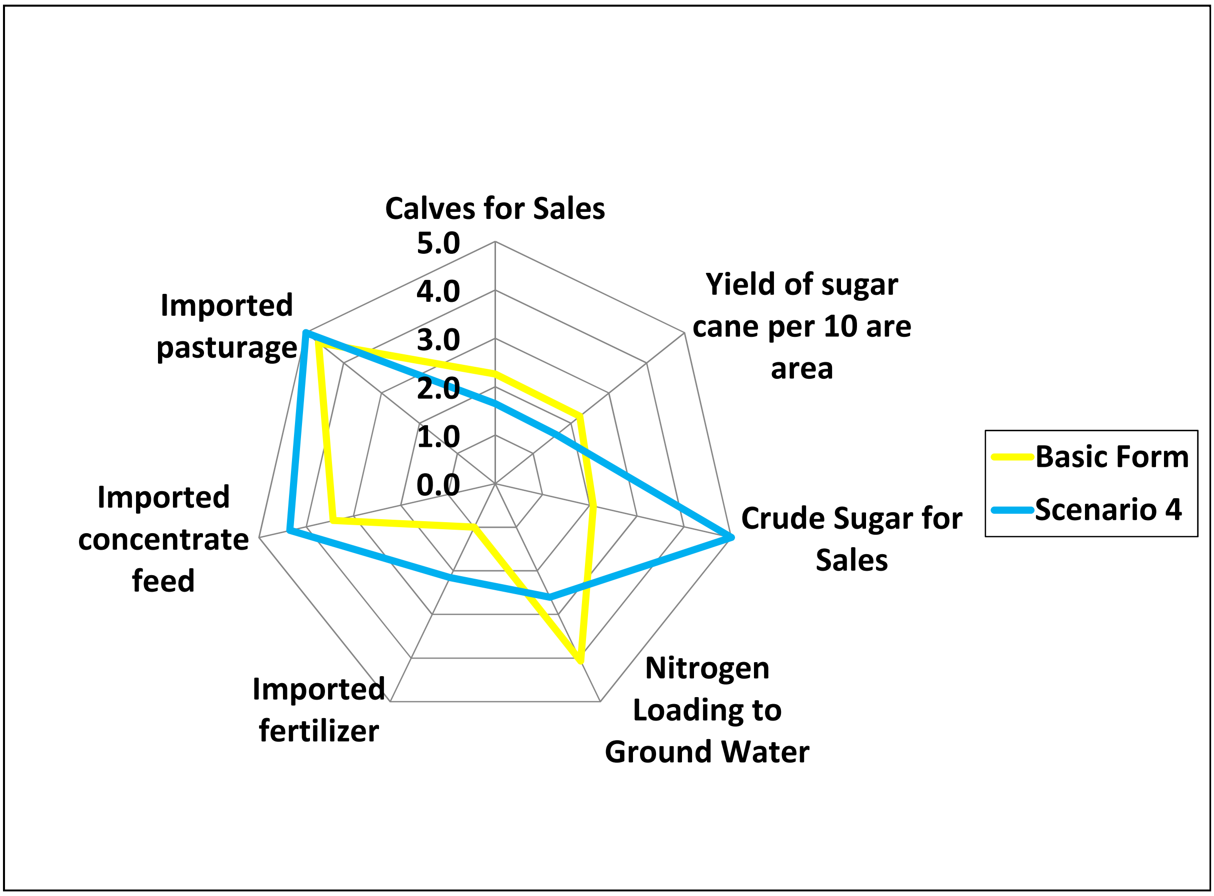

Fig. 5.11 Cobweb Chart for Scenario 4

Regarding “Calves for Sales” and “Yield of sugar cane per 10 are area”,, the number of calves are the second lowest. Therefore the evaluation is the second lowest.

Regarding “Crude Sugar for Sales”, the value is the highest. In the same as scenario 2, the growing area for sugar cane is largest and it is able to get beef cattle’s manure from beef cattle which are fed sugar cane tops instead of pasturage.

Regarding “Nitrogen Loading to Ground Water”, the value came to the second lowest. The measure to reduce the pollution from beef cattle’s urine was not taken. Also green manure plants also contain the nitrogen and it increased the nitrogen loading to the ground water.

Regarding “Imported fertilizer”, the value comes to the next to the lowest. No measures were taken. But sugar cane do not much fertilization compared to pasturage. So it was not the lowest.

Regarding “Imported concentrate feed” and “Imported pasturage”, the number of beef cattle is not that many and beef cattle consumes sugar cane tops. So the values are quit high.

This research next thinks about all scenarios and the basic form shown by Fig. 5.12.

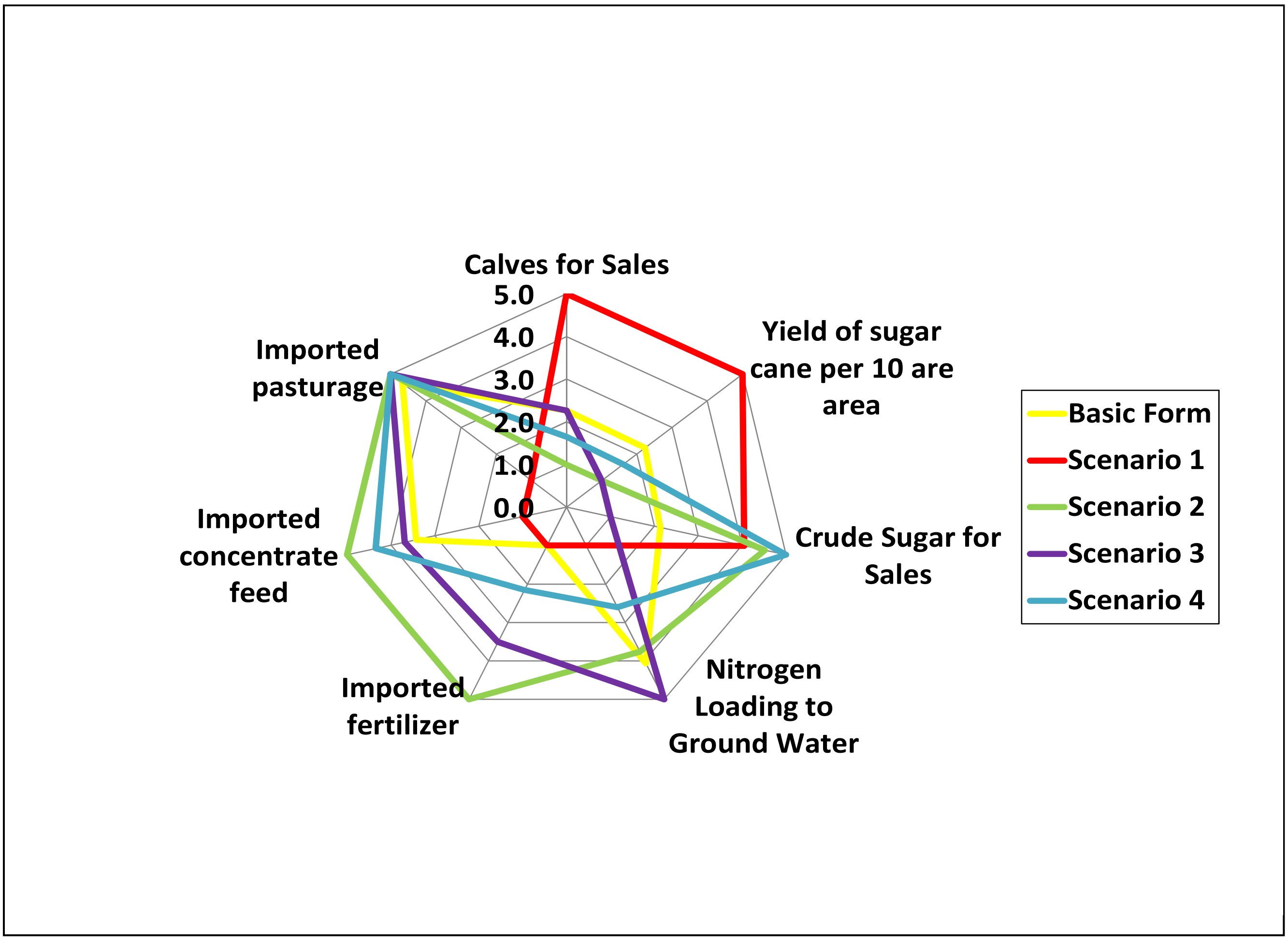

Fig. 5.12 Cobweb Chart for the Basic Form and All Scenarios

The shapes of scenario 1 and scenario 2 are at extreme opposite. Scenario 1 thinks that beef cattle is important. On the other hand, scenario 2 thinks that sugarcane is important.

The other scenarios and the basic form tried to have beef cattle and sugar cane collaborate. Therefore the shape of the other scenarios and the basic form look similar.

To promote the beef cattle, the scenario like scenario 1 would be better. To increase the number of calves and breeding cows would be effective. However the effort to minimize the pollution to the ground water would be required. Reducing more imported feeds are not easy. The reason would be that as shown by the basic form, stockbreeding on Miyakojima Island already tried to minimize the amount of imported feeds.

To promote the sugar cane, scenario like scenario 1 an scenario 4 would be better. The growing area for sugar cane must be acquired. To some extent, collaboration between beef cattle and sugar cane would work.

Regarding reduction of imported fertilizer and nitrogen, both can be dealt with one approach. Utilizing beef cattle's urine would reduce the pollution and reduce the imported fertilizer.

Green manure plants can be useful for reduction of imported fertilizer. But it may increase the nitrogen pollution. However, because it is used effectively, it is not necessary to put too much focus on it.

5.6.2 Evaluation with N-Foot Print

This section will evaluate each scenario to clarify unused resources and to find the way to reduce the nitrogen loading to the ground water. N-foot print is able to trace and to visualize nitrogen movement. Fig. 5.13 shows the N-foot print for the basic form. Nitrogen contained by cattle's urine seeps directly into the ground water and become a pollution source to the ground water. Nitrogen contained by other sources are divided into two groups: one group goes to sugar cane first, 51.7% of nitrogen are absorbed by sugar cane and 40% of the rest of nitrogen seeps into the ground water; the other group goes to pasturage first and 75% of nitrogen are absorbed by pasturage and 40% of the rest of nitrogen seeps into the ground water.

Three points this research would like to look at are: 1) what components have much nitrogen loading 2) whether nitrogen is efficiently utilized by agricultural plants and 3) when the nitrogen loading to the ground water is high what components contributes to it.

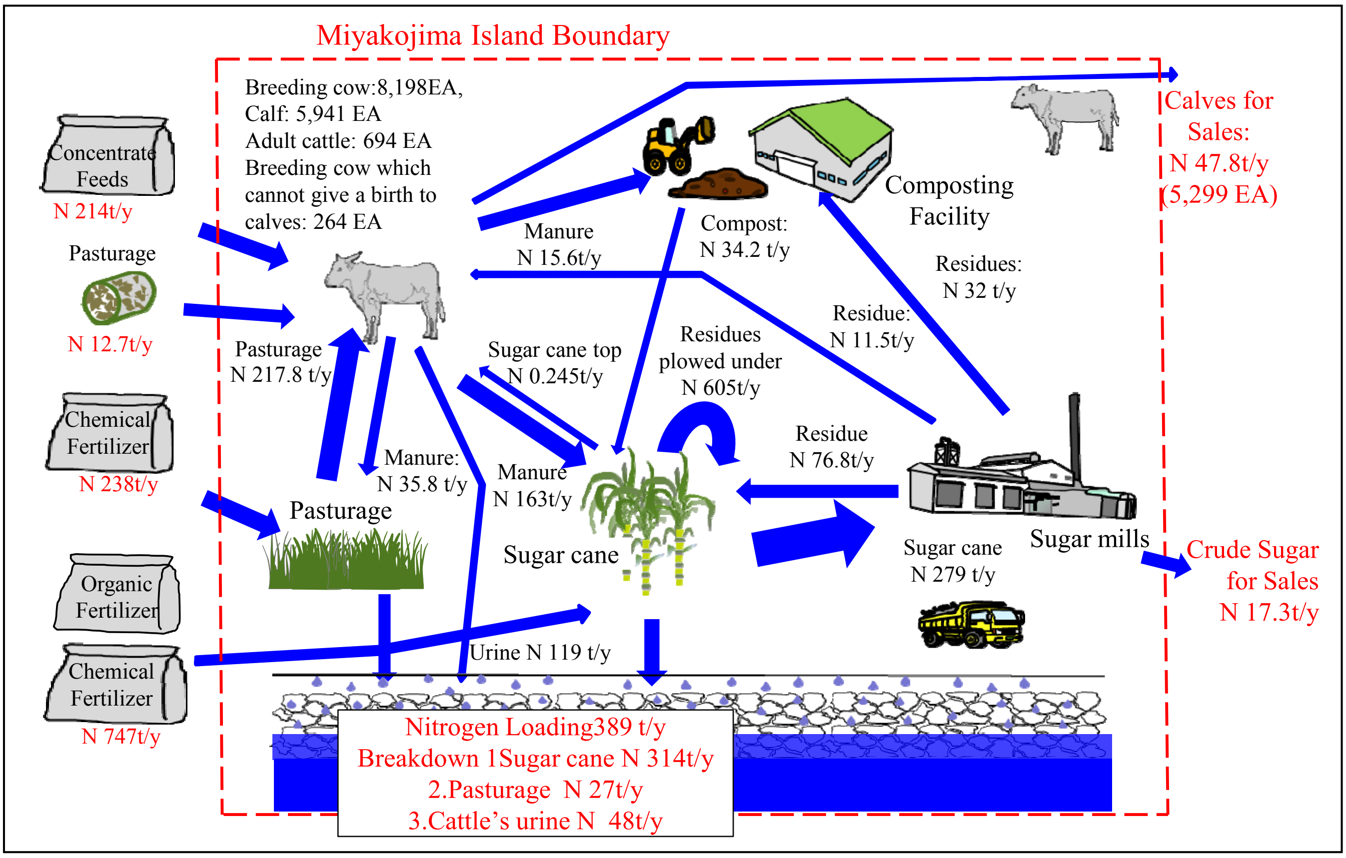

Fig. 5.13 N-Foot Print for the Basic Form

Now this research turns to N-foot print result for the basic form. Components which have much nitrogen loading are imported chemical fertilizer and residues for sugar cane while they are imported fertilizer for pasturage. However all of them are efficiently utilized. Cattle's urine is not efficiently used by any agricultural plants. The nitrogen loading to the ground water is not that high according to the evaluation made in the previous section.

Now this research next discusses N-foot print result for scenario 1.

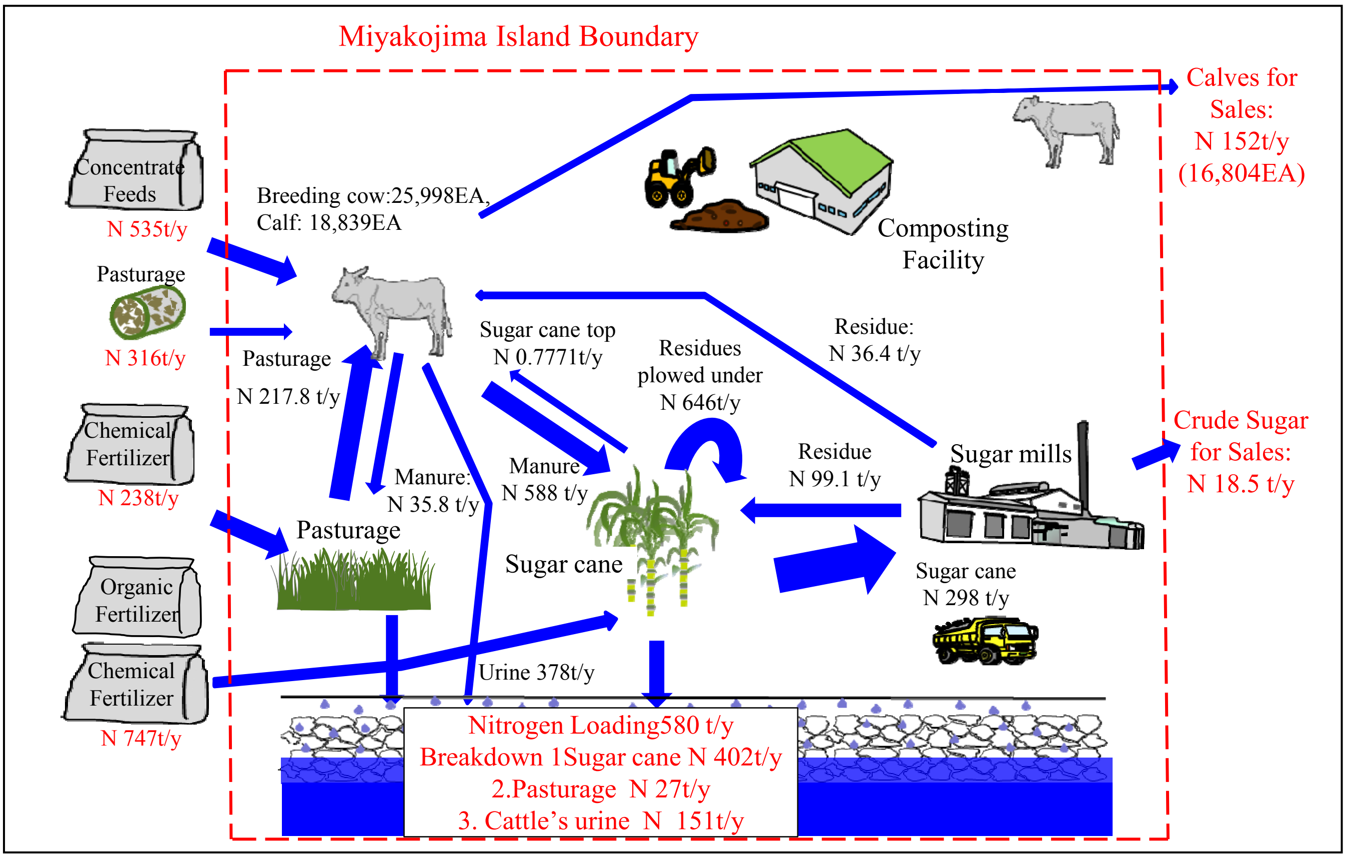

Fig. 5.14 N-Foot Print for Scenario 1

This scenario has the greatest number of beef cattle among all scenarios and the basic form. Urine of the beef cattle goes directly to the ground water without any absorption by sugar cane or pasturage. This was expected prior to N-foot print result but it is clearly shown. Also much manure from beef cattle is plowed under for sugar cane and the nitrogen burden from manure is much. However that could be acceptable; because nitrogen is used efficiently for sugar cane cultivation. The nitrogen imported for sugar cane is the same as the basic form whereas More amount of the nitrogen are imported for beef cattle as feeds than the basic form and the nitrogen for manure is used for sugar cane cultivation as the secondary use of nitrogen contained in the imported feeds. In this sense, urine of the beef cattle needs to be used secondarily like the nitrogen contained in the manure.

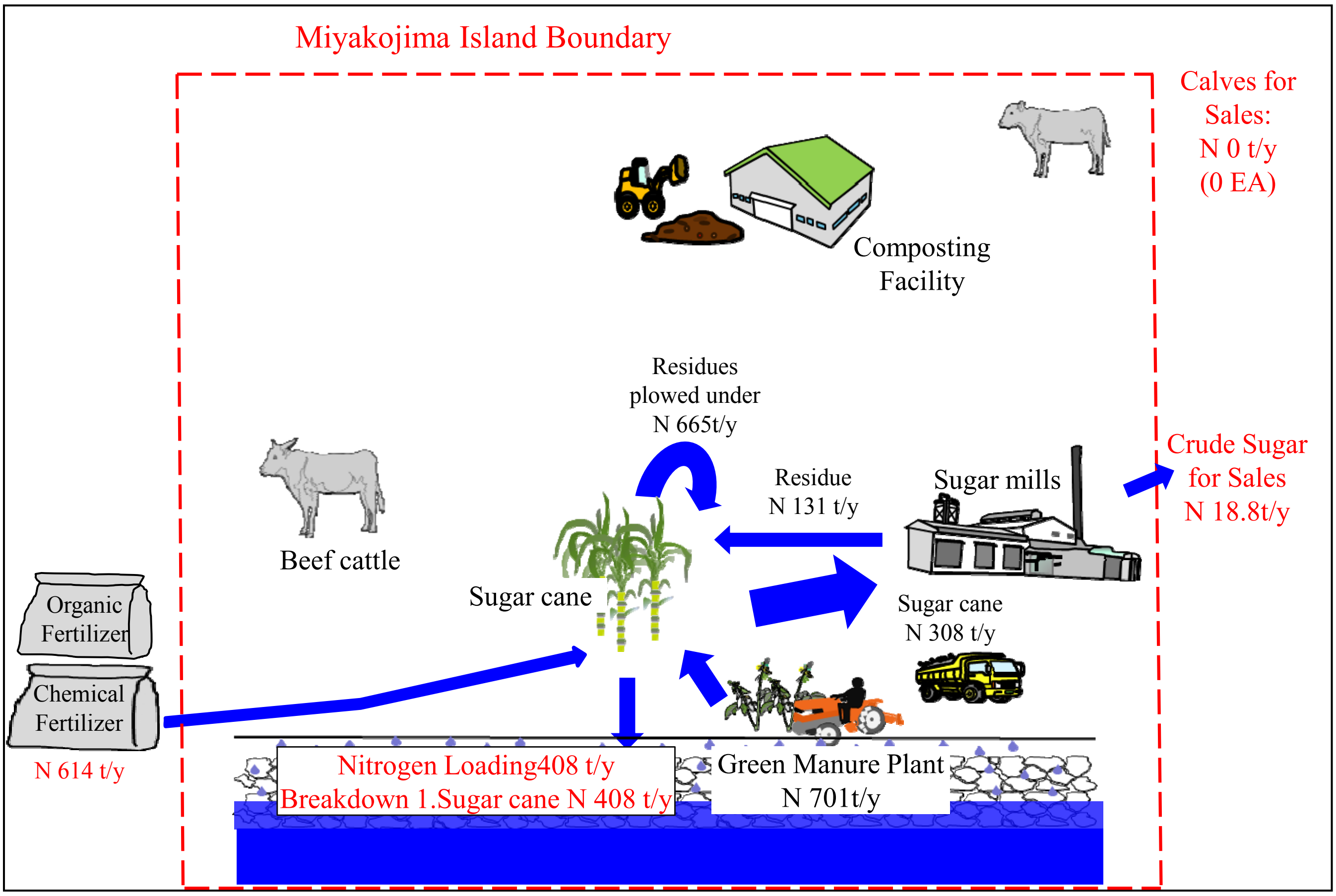

Fig. 5.15 N-Foot Print for Scenario 2

This scenario does not have beef cattle. No feeds nor fertilizer for pasturage are imported. Therefore nitrogen along with beef cattle and fertilizer for pasturage does not exist. Green manure plants which are plowed under grow in the same field as sugar cane. The single path which goes to the ground water would be the one from sugar cane. The nitrogen generated by green manure plants are relatively high. Nitrogen loading for the ground water is higher than the basic form. Nitrogen imported is lowest among all scenarios and the basic form but the nitrogen is generated much and is consumed much on the island internally. Note that it can be possible to think that nitrogen generated by green manure plants is utilized efficiently by sugar cane.

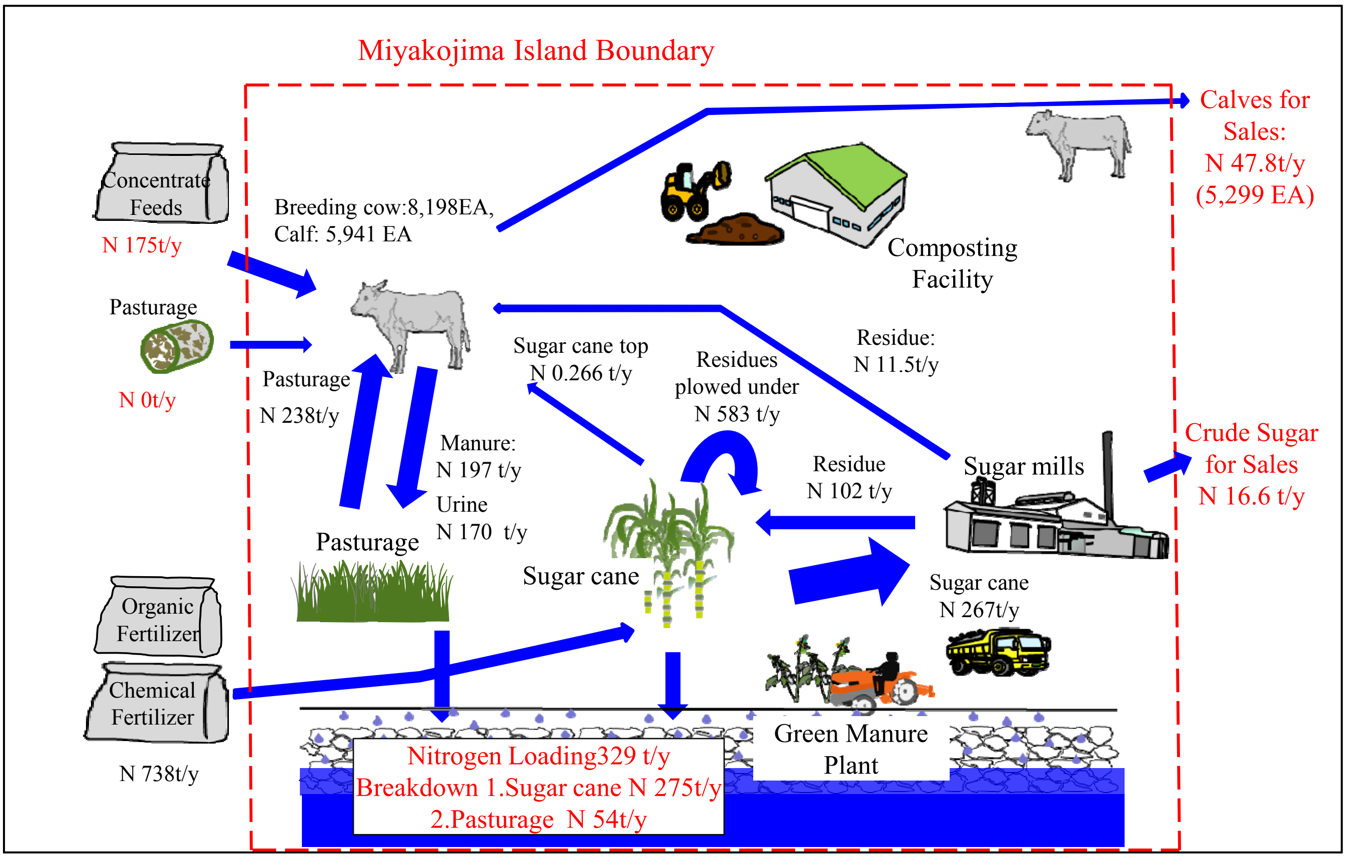

Fig. 5.16 N-Foot Print for Scenario 3

The nitrogen loading of this scenario is the lowest. Urine of the beef cattle goes to pasturage and indirectly to the ground water. The effectiveness of urine utilization by pasturage could be expected prior to N-foot print result but it is clearly shown. Also all manure from beef cattle is used by pasturage. The nitrogen imported for sugar cane is slightly smaller than the basic form because the growing area for sugar cane is smaller to obtain more pasturage than the basic form by allocating more areas to pasturage. Because green manure plants are not cultivated in this scenario, the nitrogen loading going by way of sugar cane field is slightly smaller than the basic form.

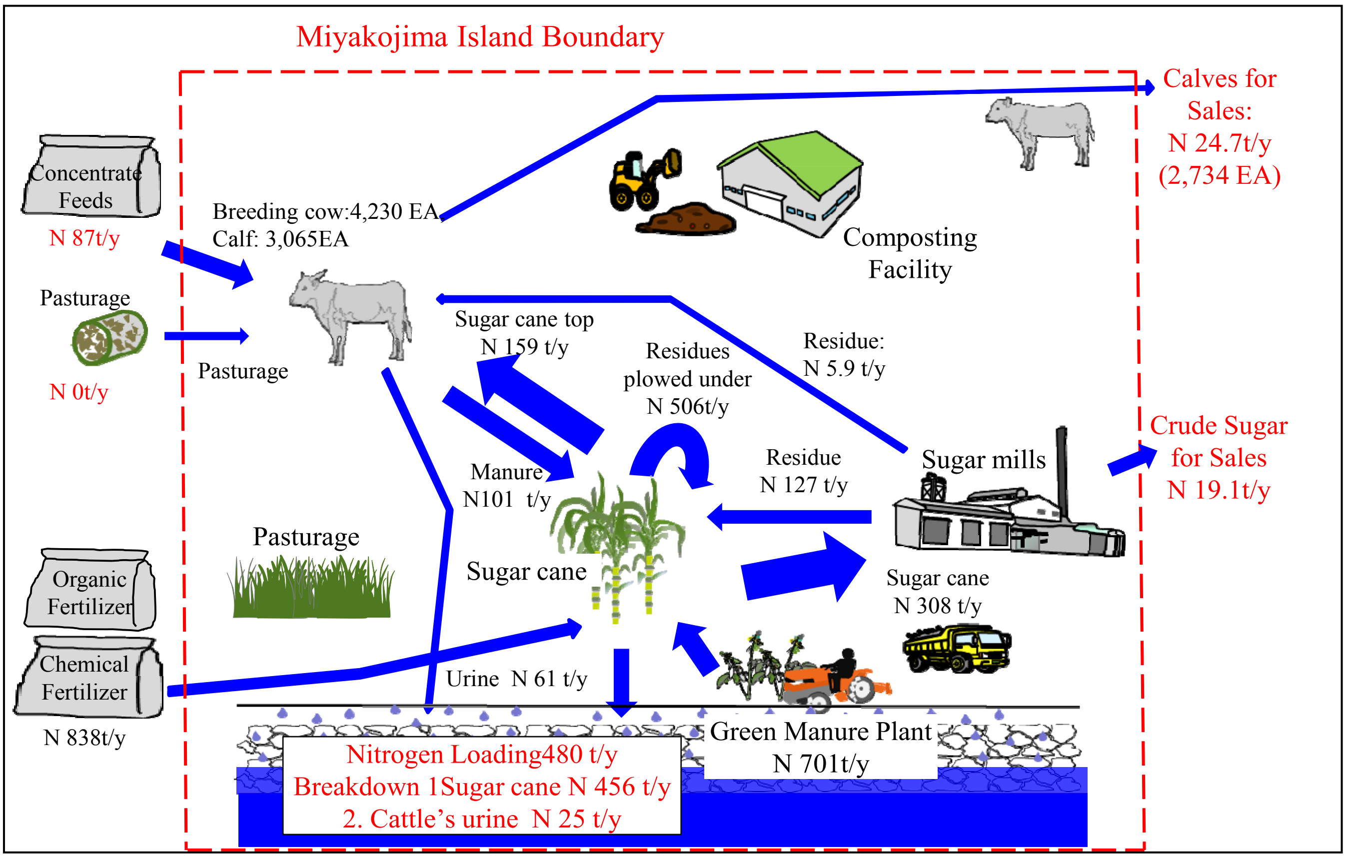

Fig. 5.17 N-Foot Print for Scenario 4

This scenario does not have growing areas for pasturage. No fertilizer for pasturage is imported. Instead because all areas are used for sugar cane, more nitrogen contained by the imported fertilizer for sugar cane than the basic form are applied to sugar cane. Green manure plants which are plowed under grow in the same field as sugar cane. The nitrogen generated by green manure plants is relatively high. Nitrogen loading for the ground water is higher than the basic form. Urine of the beef cattle goes directly to the ground water without any absorption by sugar cane or pasturage. As it is revealed by the result of N-foot print for scenario 1, urine without any absorption process increases the nitrogen loading to the ground water.

A deliverable from the discussion with N-foot print finds the following: nitrogen loading of cattle's urine is large because it seeps into the ground water directly; other nitrogen loading like fertilization for sugar cane and pasturage is being absorbed by agricultural plants; Although beef cattle's urine is a pollution source to the ground water, at the same time it can be a tool to reduce the amount of imported fertilizer when it is applied to pasturage.

Now tentatively this research tries to assume the relationship between nitrogen loading and average nitrate nitrogen concentration of ground water.

The overall average concentration of nitrate nitrogen in the ground water during FY 2010 is **4.86mgL^{-1}**[2]. This research assumes that the current level of nitrogen loading shown by the basic form would make the overall average concentration of nitrate nitrogen in the ground water at 4.86mgL^{-1}. Simulation for each scenario will be conducted from here on. The nitrogen loading of the agricultural plants and stockbreeding for the basic form is **389t/y**. It is necessary to find the nitrogen loading from other sources. One of the other sources is **domestic water**. It is discharged directly to the ground water. Nakanishi (2001)[1] suggested 4.75kg/y per one resident on Miyakojima Island and this research adopts that value. Because the population on Miyakojima Island is 55,036, this research is able to obtain 261t/y. Chapter 4 sets up "overall penetration ratio of nitrogen loading to the ground water" as 0.4. Therefore the nitrogen loading of domestic water is **104t/y**. The other source would be nitrogen oxide in the air. Nitrogen oxide in the air would fall down to the ground with the rainfall. Nakanishi (2001)[1] suggested it would be obtained when 1.4 mgL^{-1} is multiplied by the total annual amount of rainfall, i.e. 430,779,250,000L. Therefore that source would have 603t/y as the potential nitrogen loading to the ground water. Because "overall penetration ratio of nitrogen loading to the ground water" is 0.4, the nitrogen loading from the nitrogen oxide in the air would be **241t/y**. Now it is clear that the entire nitrogen loading is **734t/y** which makes the overall average concentration of nitrate nitrogen in the ground water during FY 2010 as 4.86mgL^{-1}. This research thinks that the overall average concentration of nitrate nitrogen in the ground water increases or decreases in direct proportion to the amount of nitrogen loading.

The following table shows the results of this calculation:

Table 5.9 Nitrate nitrogen concentration in the ground water

Unit = mgL^{-1}	**Basic Form**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
nitrate nitrogen concentration	4.86	6.12	4.99	4.46	5.46

The environmental standard for water quality which Government of Japan sets is 10 mgL^{-1}. Note that local nitrate nitrogen concentration of ground water varies from 0.68 to 9.16 10 mgL^{-1}. Therefore a local nitrate nitrogen concentration of ground water like 9.16 10 mgL^{-1} could be expected to exceed the environmental standard in scenario 1, scenario 2 and scenario 4. Therefore the effort to minimize the nitrogen loading would be required.

5.7 Summary of the Discussion in Chapter 5

This chapter first discussed the results of calculation for each scenario. For calculation of each scenario, this research stated the flow of calculation. Calculation can be made automatically based on the evaluation function shown in Chapter. But scenario 4 requires additional evaluation function. Second, each scenario is evaluated using cobweb chart. The discussion was made, comparing each scenario with the basic form. Third, the use of nitrogen is discussed by tracing its flow with N-foot print. Also the relationship between nitrogen loading and nitrate nitrogen concentration in the ground water was examined.

References for Chapter 5

1 Yasuhiro Nakanishi, "Correlation between Actual Fertilizing to Sugarcane and Nitrate Concentration in Groundwater of Miyakojima Island, Okinawa", 2001, Japanese Journal of Soil Science and Plant Nutrition, Vol.72(4), pp.499-504

2 "FY 2010 Miyakojima City Hall's Research Report for Ground Water Quality and Conservation", 2011, Miyakojima City Hall

Conclusion

This dissertation discussed the agriculture and stockbreeding on Miyakojima Island which is a part of Ryukyu Islands. The agriculture and stockbreeding on the island are subject to the effect from the unstable and uncontrollable price of imported feeds and imported fertilizer. Another issue is nitrate nitrogen pollution to the ground water. Nitrogen contained in fertilizer used for agricultural plants and stockbreeding's manure and urine is a source for pollution to the ground water. The objective of this dissertation is to discuss the way to obtain the agricultural production system which can reduce the risk arising from unstable price of imported fertilizer and imported feeds and which can mitigate the nitrate nitrogen pollution.

Chapter 1 addressed topographical and statistical data of Miyakojima Island, the underground structure, sugar cane cultivation and beef cattle's breeding and raising. Chapter 1 also addresses the previous studies for this research.

Chapter 2 conducted MFA of a variety of stockbreeding such as beef cattle, dairy cattle, chickens and pigs. Dairy cattle and chicken only consume feeds imported from the outside of Miyakojima Island. Pigs primarily consume food wastes which are internally from the island. While adult cattle and a breeding cow which cannot give a birth to calves consume feeds imported from the outside of the island, a calf and a breeding cow also consume pasturage created on the island. Quantities of biomass resources generated by stockbreeding are clarified.

Chapter 3 conducted MFA of a variety of agricultural plants and its related facilities such as sugar cane, pasturage, leaf tobacco, squash, Chinese preserving melon, bitter melon, mango, green manure plants, sugar mills and Miyakojima City Resources Recycling Center. Quantities of biomass resources generated by agricultural plants are clarified. It finds that residues from most of agricultural plants are not utilized and are burnt to prevent disease except for sugar cane.

When chapter 4 and 5 discusses an agricultural production system, the MFA given in chapter 2 and 3 will be basis for the basic units.

Chapter 4 first demonstrated basic units for scenario building such as beef cattle, sugar cane in the field, sugar mills, pasturage and green manure plants. Next "the basic form" which is the basis to forge four scenarios is shown. The evaluation indices are explained with the basic form. Next concept of operational factor is introduced and evaluations functions for scenario building are shown. Then objectives for each scenario are given.

Chapter 5 showed the results of calculation for each scenario using evaluation function and made evaluation for each scenario. Utilizing cobweb chart, comparison and evaluation for each scenario were made. Scenario 1 would be a scenario which promotes the beef cattle. Scenario 2 would be a scenario which promotes the

The knowledge and information obtained by the MFA can be readily available to study stockbreeding and agricultural plants in other areas. The feeds for stockbreeding and fertilizers for agricultural plants can be different form the ones in other areas. But the MFAs of this research included the information for nitrogen, carbon and phosphorus as well. Therefore even if the different feeds are given to stockbreeding or the different fertilizer are given to agricultural plants, the information on the nitrogen, carbon and phosphorus would be useful.

Parts of this system is considered to be applicable to the agriculture and the stockbreeding on the other areas, especially, the area which has beef cattle and sugar cane fields at the same time, such as Ryukyu Islands. In those islands, sugar cane is widely cultivated and beef cattle is also kept.

The methodology used in this research would be useful: i.e. using MFA methodology to obtain the basic units, evaluation function, evaluation index, operational factor and scenario building.

The vulnerability for nitrate nitrogen pollution would be different according to the underground structure. The way to minimize the nitrogen pollution would be referential.

In Ryukyu Islands, Miyakojima Island have larger areas for agriculture and stockbreeding. So using the areas available, the strategy to create as much agricultural plants as farmers can would be the optimal form. When people would like to promote the sugar cane, the strategy like scenario 2 would be required. When people would like to promote beef cattle more, the strategy like scenario 1 would be required. However the areas which is sensitive to the pollution to the ground water the strategy like scenario 3 would be required.

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Even though this paper is prepared in cooperation from many people given above but the responsibility of possible mistakes is mine alone.

Appendices

Appendix 1 Balance of Payment for Stockbreeding and Agricultural Plants on Miyakojima Island

This section addresses balance of payment for stockbreeding and agricultural plants as shown in the following tables. Note that the target number of breeding cows on Table a1 would be 1.38. Pasturage is included in Table a1. The area for pasturage for the table a1 is 15.9 are.

Table a1. Balance of Payment for a Breeding Cow and a Calf

Unit = ¥	Spend	Income	Profit
Stud fee	25,000		
Imported feeds	100,000		
Cost to cultivate pasturage	25,000		
Manpower expense	100,000		
Cost depreciation	50,000		
Tax	18,000		
Total	318,000	360,000	42,000

Table a2. Balance of Payment for an Adult Cattle

Unit = ¥	Spend	Income	profit
Spend to purchase a "calf"	360,000		
Imported feeds	300,000		
Cost depreciation	50,000		
Manpower expense	50,000		
Tax	30,500		
Total	790,500	610000	-180,500

Table a3. Balance of Payment for a Breeding Cow which cannot Give a Birth to Calves

Unit = ¥	Spend	Income	profit
Spend to purchase "a breeding cow which cannot give a birth calves"	60,000		
Imported feeds	100,000		
Tax	11,500		
Total	171,500	230000	58,500

Table a4. Balance of Payment for a Pig

Unit = ¥	Spend	Income	Profit
Fuel cost (Vehicle)	10,000		
energy bill	2,500		
Imported feeds	3,000		
Cost depreciation	1,500		
Tax	1,000		
Total	8,000	20,000	12,000

Table a4. Balance of Payment for a Chicken

Unit = ¥	Spend	Income	Profit
Cost of original livestock	267		
Labor cost	381		
Cost depreciation	381		
Imported feeds	2,517		
Tax	191		
Total	3,737	3,813	76

Table a5. Balance of Payment for Sugar Cane

Area =10 are, Unit = ¥	Spend	Income	Profit
Cost for plow	9,000		
Chemical fertilizer	12,600		
Agricultural chemical	15,000		
Tax	4,400		
Total	41,000	88,000	47,000

Table a6. Balance of Payment for Leaf Tobacco

Area =10 are, Unit = ¥	Spend	Income	Profit
Cost for mulch	27,417		
Cost for plow	7,000		
Fertilizer	12,600		
Outsourcing expenses for seedling cultivation	1,465		
Cost depreciation for green house	8,977		
agricultural chemical	18,000		
Dryer Utilization Cost	15,000		
Cost depreciation for equipment	50,000		
Manpower Expense	50,000		
Tax	23,250		
Total	190,459	465,000	274,541

Table a7. Balance of Payment for Squash

Area =10 are, Unit = ¥	Spend	Income	Profit
Cost for Plow	3,000		
Organic and chemical fertilizer	19,000		
Agricultural chemical	15,000		
Tax	15,000		
Total	52,000	88,000	36,000

Table a8. Balance of Payment for Squash

Area =10 are, Unit = ¥	Spend	Income	Profit
Cost for Plow	3,000		
Organic and chemical fertilizer	19,000		
Agricultural chemical	15,000		
Tax	15,000		
Total	52,000	88,000	36,000

Table a9. Balance of Payment for Squash

Area =10 are, Unit = ¥	Spend	Income	Profit
Spend to purchase beef cattle's manure	144,000		
Organic and chemical fertilizer	149,200		
Cost for plow	18,000		
Outsourcing expenses for seedling cultivation	1,465		
Cost depreciation for green house	8,977		
agricultural chemical	9,000		
Tax	23,750		
Total	354,392	475,000	120,608

Table a10. Balance of Payment for Bitter Melon

Area =10 are, Unit = ¥	Spend	Income	Profit
Spend to purchase beef cattle's manure	144,000		
Organic and chemical fertilizer	142,000		
Cost for plow	6,000		
Cost depreciation for green house	8,977		
agricultural chemical	9,000		
Tax	25,000		
Total	334,977	475,000	140,023

Table a11. Balance of Payment for Mango

Area =10 are, Unit = ¥	Spend	Income	Profit
Organic fertilizer	30,000		
Cost depreciation for green house	400,000		
agricultural chemical	205,000		
Cost for boxes	140,000		
Tax	131,250		
Total	906,250	2,625,000	1,718,750

Profit gained by mango is big. But note that when farmers start to cultivate mango they cannot gain any mango for the first 5 years. Farmers of mango do not have any revenues for the first 5 years and Table a 11 does not incorporate it.

Appendix 2 Quality Assurance for Meat

The quality and tastes of the carcass meats is dependent on breeding, so cattle semen are sought out the outside of the island. In the same way as purebred dogs, breeding determines the price of calf partially. In Okinawa Mainland, beer mill residues which use barley as raw materials are used for concentrate feeds. But Awamori (Okinawa traditional spirit) mill residues which use rice in Thailand have not been used, they are used only for hog raising (or for raw materials of composts), but not for cattle raising.

Because the water content of pasturage is high, the meat of the cattle became slightly green, the water content is should be low enough, desirably 15%. If we dry the pasturage in the sun, it will take 7 days. If the precipitation during 7 days drying period occurs, the pasturage should be dried again or it should be disposed of. On Miyakojima Island, there are frequent precipitations. The unrealistic scenario would be drying in the greenhouse but another extra place should be used.

Pasturage fed to adult beef cattle (at over 10 month age) must be dry in the low moisture content, targeting the 15% moisture content. The reason why the hay in the low moisture content is fed to the cattle at over 10 month age is to assure the quality of meats: the pasturage which is not in the low moisture content, in other words hay, may change the meat color to a slight green. Creating hay in in the low moisture content takes seven days and it needs to be prevented from the rain completely during that time. One unrealistic method is to use the greenhouse for the hay in the low moisture content.

Appendix 3 Information on Residues from Sugar Cane

Farmers raising beef cattle usually top-dress the chemical fertilizer to the field of pasturage (grassland). However they may top-dress the beef cattle manure to it as well shown below:

Fig. a1 Photo of Top-Dressing to Pasturage with Beef Cattle Manure

Appendix 4 Supplemental Information on Stockbreeding on Miyakojima Island

In Chapter 1, the information on beef cattle was given but that on the other stockbreeding was not. Here this research gives supplement information on it.

Most of chicken are kept in the birdhouse like the following. White color chicken on the right side is call ed "Boris Bro wn". White color chic ken on the rig ht side is called "Julia Light". Because some of manure's odor is confined to the inside of the bird house, that was an issue for raising chicken.

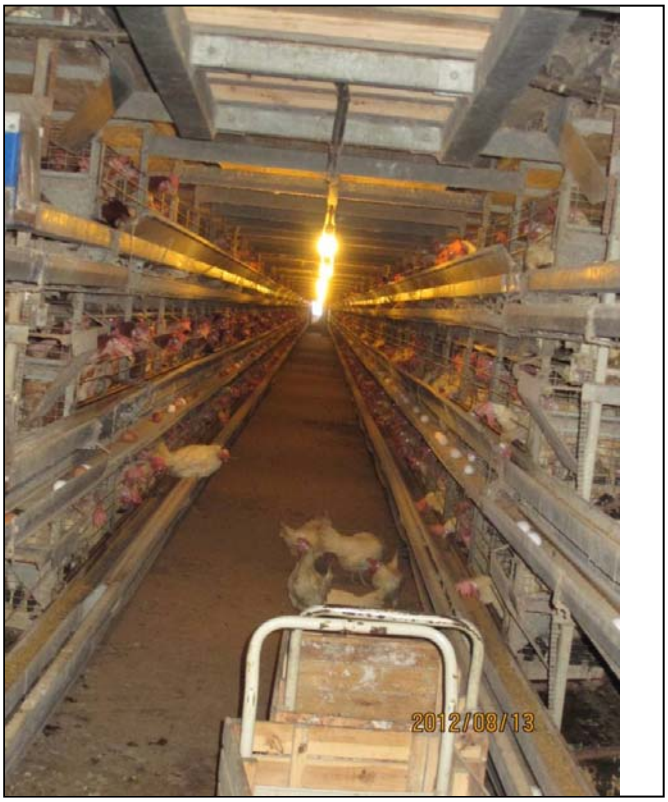

Fig. a2 Photo of Poultry Raising

Next this research shows hog raising. Pigs are kept in the pig hut shown in Fig.a3.

The slurry addressed in Chapter 2 is shown in Fig. a.4. That was the only example for the utilization of stockbreeding's urine.

Fig. a3 Photo of Hog Raising

Fig. a3 Photo of Hog Raising

Appendix 5 Information on Residues from Sugar Cane

Residues from sugar cane left behind are assu med to be plowed under. It is endorsed b y the interviews to farmers and the following picture:

Fig. a5 Photo of Residues in the Sugar Cane Field

Residues plowed under are observed. The time was August 12th of 2012, which was 1 month prior to billet planting in summer. According to the personnel communication with Miyakojima City Hall, burning of residues in suga r cane fields is steadily decreased. the following ta ble show the number of response by fire department on Miyakojima Island from January to April, i.e. the harvesting term for sugar cane:

Table a2. The number of response by fire department

	The Number of Response by Fire Department
FY 2013	8
FY 2012	7
FY 2011	15
FY 2010(Target Year)	**17**
FY 2009	21

Burning of r esidues in sugar cane fields was widely conducted on Miyakojima Island and other areas in Okinawa Prefecture but it is not conducted that much because of implementation of tillers. In Okinawa Main Island as well it is not conducted widely any more. This research does not regard it as a major issue on Miyakojima Island.

Appendix 6 Supplemental Information on Agricultural Plants on Miyakojima Island

Visual information for each agricultural plant is limited. Mango and vegetables are cultivated in green house as shown in Fig. a6 - Fig.a8. Because the climate on Miyakojima Island is warm, those vegetable can be harvested and sold to cons umers in the different sea sons. So the price is higher than usual.

Fig. a6 Photo of Mango

Fig. a7 Photo of Chinese preserving melon

Fig. a8 Photo of bitter melon

Fig. a9 Photo of Squash

Only squash and leaf tobacco are cultivated outdoors.

Fig. a8 Photo of Leaf Tobacco