Is Japanese agriculture improving its eco-efficiency?

–An application of the System of Environmental and Economic Accounting (SEEA)–

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Abstract

The world is facing serious resource shortage and environmental problems. Eco-efficiency is more attention for sustainable development not only in manufacturing sector but also agricultural sector. This study investigates whether Japanese agriculture improves its eco-efficiency. To conduct the analysis, we, first, develop a System of Environmental and Economic Accounting (SEEA) for agriculture and forestry, and then estimate the eco-efficiencies and Factor values (FVs) of the agricultural sector, using a case study in Japan. Eco/energy-efficiencies and FVs are estimated based on greenhouse gas emission, acidification, eutrophication, air pollution, and energy and water use in every five year from 1985 to 2005. The results shows that although the absolute amounts of environmental impact and resource use have declined, eco/resource-efficiencies have worsened and FVs are less than 1 throughout the estimation period. Further governmental support for farmers is required to achieve improved eco-efficiency.

Keywords:

Eco-efficiency, Factor value, System of Environmental and Economic Accounting (SEEA), Agriculture, Japan

1. Introduction

Reduction of environmental impact and resource use is a critical global issue. In the manufacturing sector, efforts are being made to reduce the input of resources and environmental impact while trying to increase the value added. Research indicates that we should achieve Factor 4 and Factor 10, which means that eco/resource-efficiency must be improved by fourfold and tenfold, respectively (Weizsacker,1998).

The agricultural sector is also required to reduce its impact on the environment. However, farmers are not under the same level of pressure as manufacturers due to unique nature of agricultural production and the difficulty in monitoring pollutants from agriculture. Therefore, eco-efficiency and Factor values (FVs) are not always taken into consideration. We think that it is important even for the agricultural sector to introduce the concept of eco-efficiency to reduce

the environmental impact and resource input by/to its production.

In Japan, the agricultural sector is now facing severe competition with imported foodstuffs, and high quality of the products is one of the advantages of Japanese agriculture. However, in some cases, farmers use more resource input and its production emits more pollutant to produce higher quality and more value-added products. For sustainable and eco-friendly agriculture, farmers are required to reduce resource use and its impact on the environment, and to increase value-added at the same time. Therefore, it is important to introduce the concept of eco-efficiency in Japanese agriculture. Furthermore, it is also important for policy makers to understand eco-efficiency at national level to develop a new policy schemes to promote eco-efficiency.

To calculate eco-efficiency at national level, we think that the System of Environmental and Economic Accounting (SEEA) can be a support tool to clarify the relationship between economic activities and environmental impact. The SEEA was originally developed by the United Nations and some international organizations, and is a tool to organize both economic and environmental information on the same accounting matrices. It can deal with not only economic data such as GDP, final consumption, and intermediate input, but also environmental data such as greenhouse gas emission, water pollutant load, and amount of waste. The United Nations have also developed SEEA for specific issues such as water use, and fisheries. In light of this movement, the FAO joined with the United Nations in 2011 to compile an SEEA for agriculture (SEEA-Agri), which is scheduled for completion by 2013. These efforts imply the growing importance of the SEEA, including in the agricultural field.

Some studies addressed eco-efficiency or resource efficiency in agriculture such as Pelletier et al (2008), YuLin et al (2011), and Reith and Guidry (2003), and Keating et al (2011) explained the concept of eco-efficiency in agricultural sector. However, these studies are focused only on fertilizer input (Pelletier et al, 2008), energy use (YuLin et al, 2011), field analysis (Reith and Guidry, 2003) or specific faming (De Koeijer et al, 2002). To authors' knowledge, no studies addressed eco-efficiency of Japanese agriculture, particularly including whole agriculture at a national level.

This study investigates whether Japanese agriculture improves its eco/resource-efficiency. To conduct the analysis, we address following research questions;

i) to develop an SEEA for Japanese agriculture and forestry (SEEA-AF)

ii) to estimate eco/resource-efficiencies and FVs of the agricultural in Japan at national level

The organization of the paper is as follows. Section 2 explains the SEEA and develops a SEEA framework for Japanese agriculture and forestry, and also defines eco/resource-efficiency and FV. Section 3 describes estimation methods and data. Section 4 presents the results and discussion, then section 5 concludes.

2. SEEA-Agro Forestry (SEEA-AF), eco-efficiency, and Factor value

2.1 History of SEEA

Although the System of National Accounts (SNA) is one of the most important economic indicators, economists and ecologists have pointed out that its estimates such as Gross Domestic Product (GDP) and Gross National Product (GNP) do not necessarily reflect the well-being or happiness of people (Ahmad et al., 1989, Daly and Cobb, 1994, and Boyle and Simms, 2009). These criticisms turned into the “Beyond GDP” movement, and some economists developed alternative indicators for GDP and GNP. Therefore, the United Nations and some other international organizations such as the World Bank and the United Nations Environment Programme (UNEP) jointly developed the System of Environmental and Economic Accounting in 1993 (SEEA93) as a satellite accounting system of SNA.

SEEA is a macroeconomic accounting system that clarifies the relationship between economic activities and environmental impact in a specific nation and region. Its preliminary purpose is to supplement the SNA and provide additional information on environmental impact caused by economic activity. The environmental impact is evaluated in monetary terms as the costs of economic activities, and an alternative indicator of the GDP is defined by subtracting the environmental costs from the Net Domestic Product (NDP), which is called the eco-adjusted NDP (ea-NDP). In response to the publication of an SEEA explanatory paper and handbook (Bartelmus et al., 1991, United Nations, 1993), countries such as Australia, Canada, Denmark, and Germany, as well as Japan, developed and estimated their own SEEA.

The concept of ea-NDP is challenging because it internalizes the externalities of environmental damage caused by natural resource use, and this has drawn much criticism. One complaint is that there is no theoretical background with ea-NDP. Although the concept of GDP has a firm macroeconomic theory on its background, there are no theoretical reasons for why we must subtract the cost of environmental damage from the NDP. Therefore, the SEEA was drastically modified by its first revision in 2003, and this version is called SEEA2003 (United Nations, 2003). SEEA2003 is based on the National Accounting Matrix including Environmental Accounts (MANEA), which describes environmental impact in physical terms and economic statistics in monetary terms (Haan and Keuning, 1996). The use of physical terms helps provide a clearer understanding of the environmental impact, and avoids uncertainties. Composite indicators like ea-NDP were banned and a new framework which enables to calculate environmental impact in physical terms was introduced in SEEA2003. By using SEEA2003, we can understand how much environmental impact is generated by economic activities in physical terms instead of monetary values as well as economic activities measured in monetary term. Just like SEEA93, SEEA2003 has also been estimated in several countries including Japan (Economic and Social Research Institute, 2004), and even before SEEA2003 was published, the Japanese NAMEA was estimated by Ike (1999).

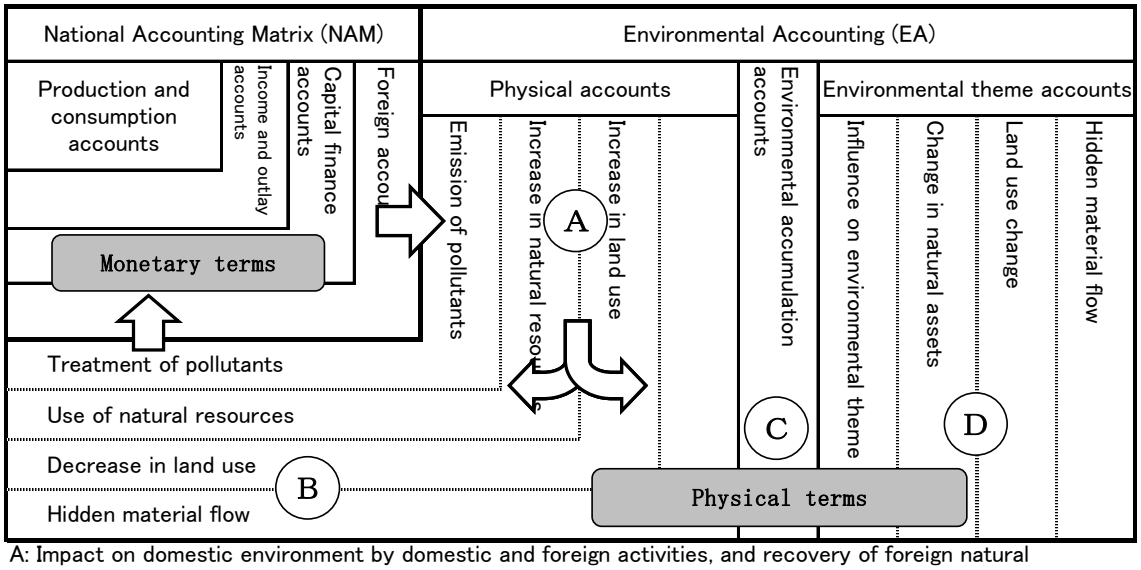
At the same time, the United Nations has developed SEEA frameworks for specific issues such as water use, and fisheries. SEEA for energy use is presently being developed and will be finished by 2012. In light of these efforts, the FAO joined with the United Nations in 2011 to compile an SEEA for agriculture (SEEA-Agri), which is scheduled for completion by 2013. These situations imply that the SEEA has become increasingly important, including in the agricultural field.

2.2 Framework of SEEA for Japanese agriculture and forestry (SEEA-AF)

In this study, we developed a new framework of the SEEA that is applicable to agriculture and forestry in Japan (SEEA-AF). The fundamental framework is based on a Japanese SEEA compiled by the Economic and Social Research Institute (ESRI) in 2004 (Economic and Social Research Institute, 2004), and we also referred to a previous study in which the SEEA was applied to German agriculture (Schmidt and Osterburg, 2010). We modified it to capture economic activities and environmental impact, resource use, and waste generation caused by production in agriculture and forestry.

Figure 1 shows the summary of the framework of SEEA-AF we have developed. The National Accounting Matrix (NAM), which describes economic indicators in monetary term such as GDP, is surrounded by the Environmental Accounting (EA), which illustrates the status of environmental impact caused by economic activities. Environmental impact (pollutants) from agriculture and forestry is indicated in the “A” part in EA, and if its environmental pollutants are treated or recycled in economic activities, it is recorded in the “B” part; if they are accumulated in the environment, they are described in the “C” part. Accumulated pollutants are categorized by environmental theme, and aggregated by appropriate weight such as global warming potential (GWP) in “D”. Use of energy, water and land is also addressed in EA.

Using the SEEA-AF, we can arrange various statistics that explain the relationship between agricultural and forestry production and the impact on the environment, and then we can calculate composite indicators for sustainable agriculture and forestry, for example, eco-efficiency, energy-efficiency, and water-efficiency as well as absolute amount of pollution. SEEA-AF is a very useful tool for capturing the environmental impact caused by agriculture and forestry at the national or regional level. With the time series estimation, we can also understand how the relationship between agriculture and environmental impact has changed over time.



A: Impact on domestic environment by domestic and foreign activities, and recovery of foreign natural resources by domestic activities
B: Flow from domestic environment to domestic and foreign activities, and decrease in foreign natural resources by import
C: Accumulation in domestic environment and change in foreign natural resources
D: Impact by environmental theme

Note: This figure is made by the authors based on the Economic and Social Research Institute (2004).

Figure 1. Framework of SEEA-AF

2.3 Definition of Eco/resource-efficiency and Factor value

Eco/resource-efficiency is introduced under the concept of maximizing value added while minimizing environmental impact and resource input. This is quite different from production efficiency, which seeks to maximize value added UNDER certain resource input. The concept of FV was originally introduced as "Factor Four" in Weizsacker (1998). The background of Factor Four is based on a warning in Meadows et al. (1972) that oil resources would be depleted by 1993, and Factor Four suggests earning double value-added with half resource input. Factor Four is one of the environmental indicators used in evaluating improvement of eco-efficiency.

In our study, eco/resource-efficiency is defined as the gross value added (GDP in SNA) per unit of amount of pollutants or resource input. A unit is one yen per pollutant emission, for example, yen/CO_2-eq. FV is defined as the ratio of eco/resource-efficiency to base year. In this study, the base year is set in 1985, and then FV of item *i* at time point *t* is formulated as follows:

$$FV_{it} = \frac{EE_{it}}{EE_{i85}} \qquad (1)$$

EE: Eco-efficiency

Using FV, we can determine if eco/resource-efficiencies have improved over time. If FV_{it} is

more than 1.0, eco-efficiency has improved, and if it is less than 1.0, it has worsened during the estimation period. Some researchers suggest that FV should be 4.0 and even 10.0, which means that eco-efficiency should be fourfold and tenfold, respectively.

3. Application

3.1 Estimation of SEEA-AF

In this study, we estimate the Japanese SEEA-AF at national level. The estimated years are 1985, 1990, 1995, 2000, and 2005. Environmental pollutants and resource use we take into account are greenhouse gas (GHG) emission s (CO_2, CH_4, N_2O), acidification (NO_x, SO_2, NH_3), eutrophication (T-N, T-P), air pollution (SPM), and energy use (oil, gas, electricity) and water use.

To compile the SEEA-AF, we firstly estimate the amount of resource inputs such as oil, gas and electricity, and water use, and also estimate the amount of waste generated from agriculture and forestry, and then calculate the amount of environmental pollutants. In terms of GHG emissions, the amount is referenced from the Greenhouse Gas Inventory Office (2011). However, the report does not include the GHG emissions in 1985; therefore we estimated the GHG emissions in 1985 according to the methods applied in the report. Emission of NO_x, SO_2, and SPM is estimated from the amount of oil consumed in the agricultural sector, multiplying emission per unit of oil consumed. As the emission of T-N, T-P and NH_3 is mainly from animal excrement, the figures are estimated by multiplying the number of livestock raised and the amount of excrement per head per year, and then multiplying the intensities of T-N T-P and NH_3 per unit of excrement.

In terms of economic data, we referred to disaggregated figures for agriculture and forestry in a SNA report in Japan. However, we were unable to estimate some figures in 2005 due to the implementation of statistical reform in Japan around 2000, and we could not obtain some data for estimation of the year 2005. The estimated SEEA-AF for the year 1985 is illustrated at the end of the paper.

3.2 Calculation of eco/resource efficiency and Factor value

We estimated eco-efficiencies based on following four items GHG emissions, acidification, eutrophication, air pollution. In terms of resource efficiencies, we estimated using energy use and water use. All statistics needed for the estimation are referred to SEEA-AF. We calculated the eco/resource-efficiencies from environmental pollutants and energy and water use and the value added (GDP) in the agricultural sector, and then estimated the FVs for all items. Although the SEEA-AF covers both the agricultural and the forestry sectors, we focused only on the agricultural sector and did not look at forestry in the analysis. This is mainly two reasons. One it that in forestry sector, most of the statistics used for the SEEA-AF estimation are revised every

ten years and we originally estimate the value during the period. Therefore, the results for forestry sector are not reliable to draw conclusion. The other is that most of the environmental issues are caused by agricultural sector. Forestry sector in Japan is very minor as a cause of environmental concerns.

4. Results and discussion

The results of this study are illustrated in Figures 2-4. Figure 2 shows the absolute amount of environmental impact (GHG emission, acidification, air pollution, and eutrophication) and of energy and water use measured in appropriate physical terms. All items except energy use show a consistently slight decline, especially since 1990. The overall results show a declining trend for the absolute amount. On the other hand, only energy use shows a different trend; it increased sharply from 1985 to 2000 and then changed to a declining trend from 2000 to 2005. From this result, we learn that Japanese agriculture was more energy intensive until 2000. This is because oil prices were very low during the period, and horticultural farmers use more oil to increase their production.

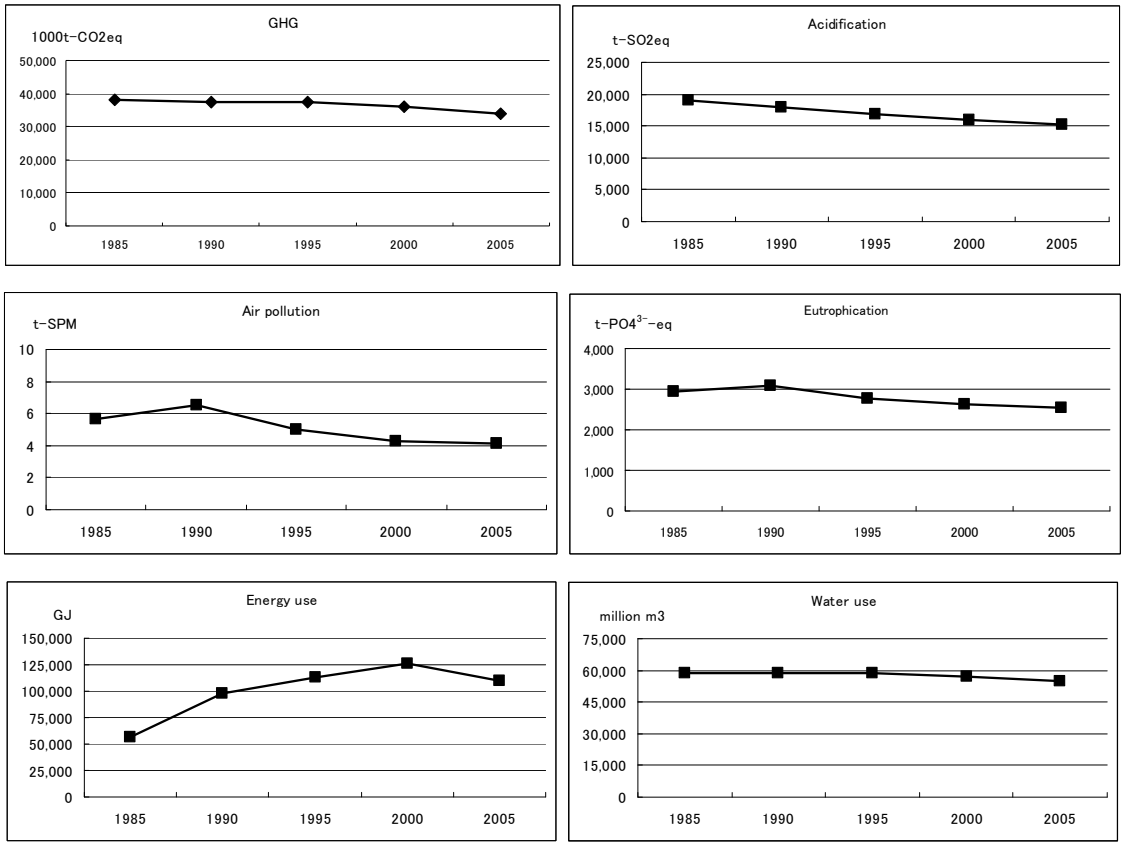


Figure 2. Absolute amount of environmental impact, and energy and water use

However, as production in Japan's agricultural sector has also consistently declined since 1994, the results may stem not from improvement of eco/resource-efficiencies but from

shrinking of agricultural production. Therefore, to avoid any misunderstanding by looking only at the absolute amount, it would be necessary to determine if the decrease in environmental impact exceeded the decline in production. To understand this, we should analyze eco/resource-efficiencies.

Figure 3 illustrates the eco/resource-efficiency of each item. Note that as eco/resource-efficiencies are defined by the GDP per amount of environmental impact, a decline in the figures means worsening performance, and an increase means improved performance. The results show a declining trend in eco/resource-efficiency of all items. Among them, the trend in energy-efficiency is very unique. It declined sharply from 1985 to 2000 and then stabilized until 2005.

These results mean that the reduction in environmental impact is not sufficient compared with the decline in production. From the viewpoint of eco-efficiency, Japanese agriculture did not achieve environmental improvement. In particular, energy-efficiency performed very poorly, and it is necessary save energy input for agricultural production.

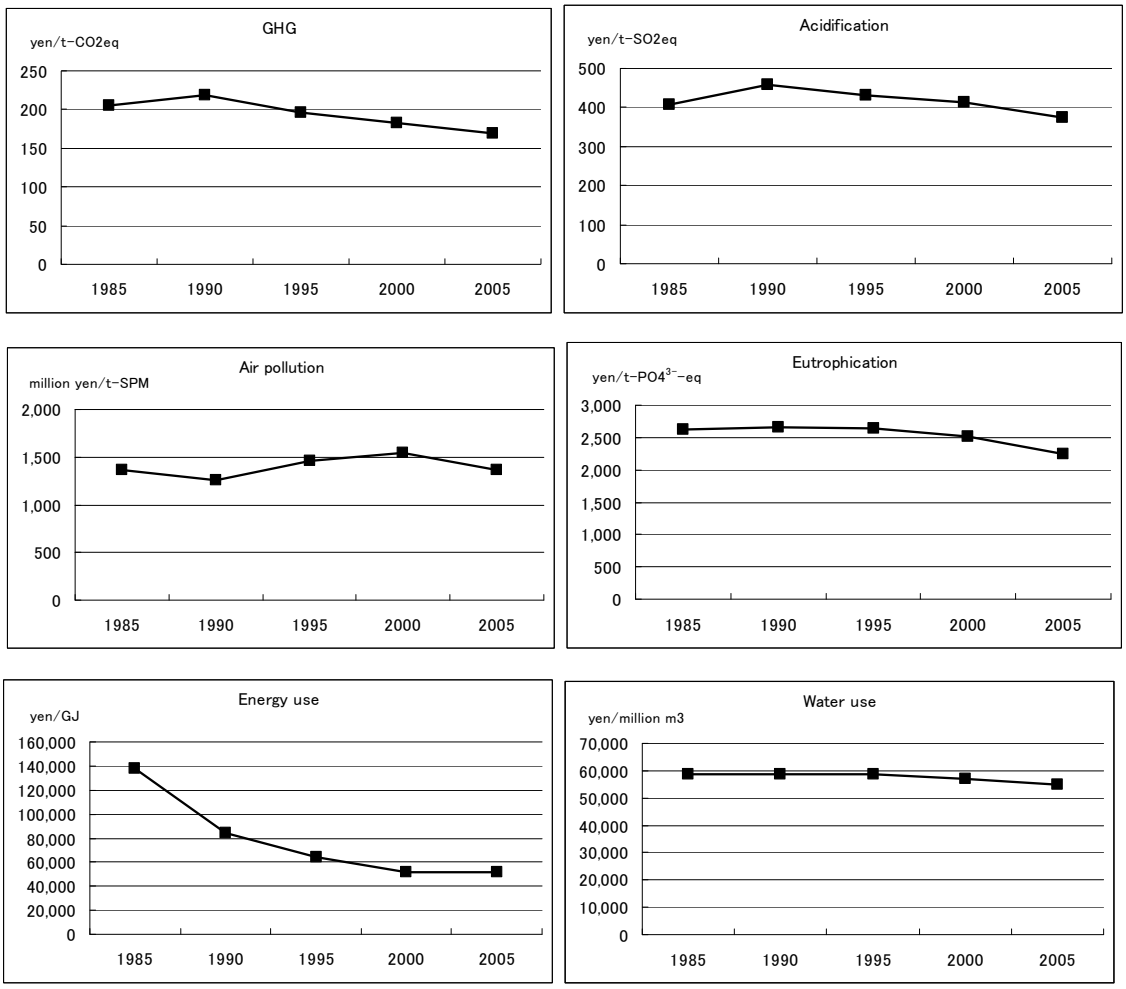


Figure 3. Eco-efficiencies, and energy and water efficiencies

Figure 4 illustrates the FV of each item placing the baseline in 1985 (1985 = 1.00). These graphs show how the eco/resource-efficiency has changed over time. As energy-efficiency declined steeply over time, the value of FV is less than 0.40 in 2005. This means that energy-efficiency declined by more than 60% in 2005. FVs of other items also worsened over time. Only air pollution remained unchanged in 2005 although it declined and increased during the period.

In the manufacturing and service sectors, Factor 4 and even Factor 10, which means resource and eco-efficiency should be fourfold and tenfold, respectively, is suggested by researchers to reduce environmental impact and improve eco/resource-efficiency. However, in the agricultural sector, FVs are less than 1.0, far from 4 or 10.

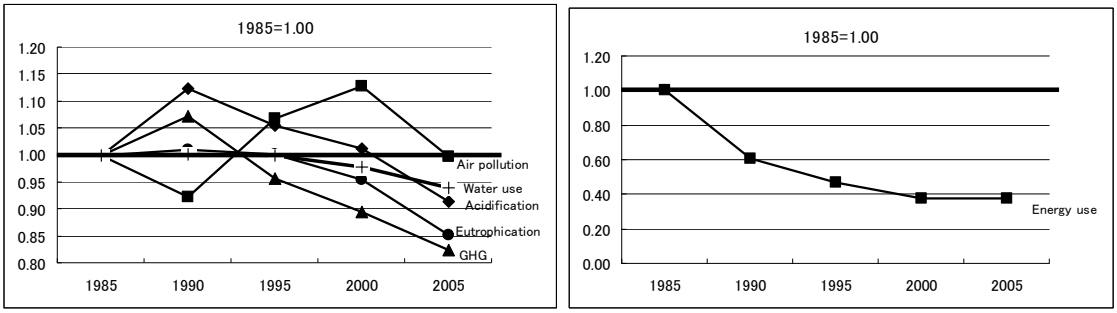


Figure 4. FVs of Japanese agriculture

These results imply there is a strong need to promote more eco-friendly agriculture. Most farmers in Japan are small-scale household farmers, many of whom have limited access to knowledge about the latest technologies for eco-friendly and energy-saving agriculture. Thus, official support for them is inevitable in order to achieve improved eco/resource-efficiencies, for instance, disseminating eco-friendly and energy-saving technology, and R&D for new technologies. Another option for improving eco/resource-efficiency is to increase value added (GDP). Although this is a difficult option in Japan due to the declining agricultural production, some farmers are trying to put more value added to their products by stressing good taste and consciousness of eco-friendliness.

Reijnders (1998) also insists that it is necessary to introduce government-driven technology to achieve higher FVs in practical terms. Besides that, we also think it is important to provide farmers with incentives to reduce environmental impact, such as direct payment for eco-farmers and higher energy tax.

5. Conclusion

The purpose of our study was to investigate whether Japanese agriculture improves its

eco/resource-efficiency and to develop an SEEA for agriculture and forestry (SEEA-AF). We estimated eco/resource-efficiencies and FVs of the agricultural sector in Japan, based on greenhouse gas emission, acidification, eutrophication, air pollution, and energy and water use from statistical data organized by SEEA-AF.

The results showed that although the absolute amount of environmental impact is declining in Japanese agriculture, eco/resource-efficiencies are worsening and FVs are less than 1 throughout the estimated period: 1985-2005, which is far from the recommended FV: 4 or 10. It is important for the local or national government to support farmers' efforts to reduce environmental impact, particularly in view of their limited access to the latest eco-friendly production technologies. It is also important to provide farmers with incentives to reduce environmental impact, such as direct payment and higher energy tax.

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1985 The SEEA Agro-Forestry for Japan 1/2

			Goods and services	Production			Final consumption	Income and expenditure accounts			Capital finance accounts				Rest of the world		Material								Natural resources		
												Non-financial assets					Pollutant										
																	Wastes								Energy		
																	Plastic		Excrement		Rice straw		Corpse				
				Agriculture	Forestry	Other sector	Agricultural and forestry products	Income generation	Income distribution	Tax	Accumulation	Environmental protection assets	Infrastructure	Others	Current transaction	Transaction of assets	Treated in Agricultur	Treated in other	Treated in Agricultur	Treated in other	Treated in Agricultur	Treated in other	Treated in Agricultur	Treated in other	Gas	Petroleum	Electricity
Unit			(million yen)	(million yen)	(million yen)	(million yen)	(million yen)	(million yen)	(million yen)	(million yen)	(million yen)	(million yen)	(million yen)	(million yen)	(million yen)	(million yen)	(1000t)	(1000t)	(1000t)	(1000t)	(1000t)	(1000t)	(1000t)	(1000t)	(TJ)	(TJ)	(TJ)
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Opening assets		OA										333,716	61,025,427	200,941,800													
Goods and services		1		6,313	548	****	3,305					26	608	3,363	41													
Production	Agriculture	2	14,189														0	154	100,549	12,828	15,868	213	0	96	242	52,603	3,420
	Forestry	3	1,232																								
Final consumption	Agricultural and forestry products	4							3,305																		
Income generation		5		7,773	675	****						0	369	1,195	0												
Distribution of income		6						6,884		5,710,864					0												
Tax		7	−56	103	9				5,710,808																		
Capital		8	−4,285						3,635							0											
Non-financial assets	Environmental protection assets	9									26																
	Infrastructure	10									239																
	Others	11									2,168																
Out of Japan	Current transaction	12	3,124					0	0																		
	Transaction of assets	13									−3,083				3,083												
Materials / Pollutants / Air	Global warming	CO2 (t)	14																								
		N2O (t)	15																								
		CH4 (t)	16																								
	Acidification	NOx (t)	17																								
		SO2 (t)	18																								
		NH3 (t)	19																								
	Air pollution	SPM (t)	20																								
Quality of water		T-N (t)	21		0	0																					
		T-P (t)	22		0	0																					
Wastes		Plastic (1000t)	23		0	0	154																				
		Excrements (1000t)	24		50,944	0	12,828																				
		Rice straw (1000t)	25		15,132	0	213																				
		Corpse (1000t)	26		0	0	96																				
Forest resources (1000m3)			27				35,374																				
Water resources (million m3)			28																								
Land use	Agricultural land (1000ha)		29																								
	Forest land (1000ha)		30																								
Adjustment/Environmental accounting		R										Other change: 5,810	1,957,484	9,862,832													
Closing assets		CA										Closing assets: 339,551	62,983,151	210,806,800													

National Accounting Matrix

Environmental Accounting

Not**** Not estimated due to data availability

1985 The SEEA Agro-Forestry for Japan 2/2

			Material				Material									Accumulation	
			Natural resources		Land use		Pollutant										
			Forest resources	Water	Agricultural land	Forest land	Air							Water quality		Accumulation	Change in natural resources out of Japan
							Global warming			Acidification			Air pollutant				
			Use	Use			CO2	N2O	CH4	NOx	SO2	NH3	SPM	T-N	T-P		
							Emission	Emission	Emission	Emission	Emission	Emission	Emission	Emission	Emission		
Unit			(1000m3)	million m3	(1000ha)	(1000ha)	(t-CO2)	(t-N2O)	(t-CH4)	(t)	(t)	(t)	(t)	(t)	(t)	****	****
			26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Opening assets		OA															
Goods and services		1															
Production	Agriculture	2		58,500			4,921,373	45,877	897,313	5,270	8,966	101,324	6	1,854,716	711,305		
	Forestry	3	42,067				****										
Final consumption	Agricultural and forestry products	4					17,495,880	862	755	16,600	5,605	****		35,032	2,910		
Income generation		5															
Distribution of income		6															
Tax		7															
Capital		8			-21	-12											
Non-financial assets	Environmental protection assets	9															
	Infrastructure	10															
	Other assets	11															
Out of Japan	Current transaction	12	****	****						****	****	****					
	Transaction of assets	13															
Materials / Pollutants / Air / Global warming	CO2 (t)	14														4,921,373	
	N2O (t)	15														45,877	
	CH4 (t)	16														897,313	
Air / Acidification	NOx (t)	17														5,270	
	SO2 (t)	18														8,966	
	NH3 (t)	19														101,324	
Air / Air pollution	SPM (t)	20														6	
Quality of water	T-N (t)	21														1,854,716	
	T-P (t)	22														711,305	
Wastes	Plastic (1000t)	25														0	
	Excrements (1000t)	26														49,605	
	Rice straw (1000t)	27														736	
	Corpse (1000t)	28														0	
Forest resources (1000m3)		29														-42,067	
Water resources (million m3)		30														-58,500	
Land use / Agricultural land (1000ha)		31														-21	
Land use / Forest land (1000ha)		32														-12	
Adjustment/Environmental accounting		R															
Closing assets		CA															

Environmental Accounting

	Environmental issues								
	Global envi. issues	Regional environmental issues				Resource use		Land use	
		Acidification	Air pollution	Water pollution	Wastes	Forest resources	Water	Agricultural land	Woody land
	Greenhouse gas emission	Emission		Eutrophication		Use	Use		
Unit	(t-CO2eq)	(t-SO2eq)	(t)	(t-$PO4^{3-}$eq)	(t)	(1000m3)	million m3	(1000ha)	(1000ha)
	41	42	43	44	45	46	47	48	49
Opening assets									
	****	****	****	****	****	****	****	5,379,840	25,265,500
Goods and services									
Production / Agriculture									
Production / Forestry									
Final consumption / Agricultural and forestry products									
Income generation									
Distribution of income									
Tax									
Capital									
Non-financial assets / Environmental protection assets									
Non-financial assets / Infrastructure									
Non-financial assets / Other assets									
Out of Japan / Current transaction									
Out of Japan / Transaction of assets									
Air / Global warming / CO2 (t)	37,986,841								
Air / Global warming / N2O (t)									
Air / Global warming / CH4 (t)									
Air / Acidification / NOx (t)		19,061,596							
Air / Acidification / SO2 (t)									
Air / Acidification / NH3 (t)									
Air / Air pollution / SPM (t)			6						
Quality of water / T-N (t)				2,955,573					
Quality of water / T-P (t)									
Wastes / Plastic (1000t)					****				
Wastes / Excrements (1000t)					****				
Wastes / Rice straw (1000t)					****				
Wastes / Corpse (1000t)					****				
Forest resources (1000m3)						42,067			
Water resources (million m3)							58,500		
Land use / Agricultural land (1000ha)								-21	
Land use / Forest land (1000ha)									-12
Net change									
	37,986,841	19,061,596	6	2,955,573	****	42,067	58,500	-21	-12
Closing assets									
	****	****	****	****	****	****	****	5,359,330	25,254,000

Not**** Not estimated due to data availability