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An Estimation Method for the Emission Accounting Table of Global Agricultural Activities

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Approved by

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Foreword

This report describes the research carried out by the author during participation in the 2009 Young Scientists Summer Program (YSSP) with the Integrated Modeling Environment Project. The research documented in this report is part of a long-term study the author has been carrying out at the Kyoto University as part of her Ph.D. research. The objective of the author's research is to develop green-house gases emission accounting table of global agricultural activities. This activity is a part of a large activity coordinated by the Japan National Institute of Environmental Studies aimed at integrated analysis of diverse policies for reducing global emissions of green-house gases.

During the three-month YSSP period the author analysed data from various sources, including statistical data from different organizations, and results of various models. These data were inconsistent and incomplete. Therefore, it was necessary to develop methods that exploit all relevant knowledge for most plausible estimations of missed and/or inconsistent data.

The author succeeded to develop a new method for estimation of emission accounting table of global agricultural activities that includes both material and monetary flows of agricultural commodities.

The method was thoroughly tested on a large sample of data covering 94 countries and 12 world regions for the period of 1971 through 2000; the results of tests show that the developed method can be successfully applied to more commodities than it was possible during the short period of the YSSP.

Abstract

This paper describes an estimation method to develop an emission accounting table of global agricultural activities which consists of accounting tables including agricultural commodity flows from production to consumption, GHG emissions and agricultural waste etc.. Material and monetary flows related with agricultural commodities are estimated by using reported information such as production, trade and consumption from published statistics. In our calculation, the table covers 94 countries and 12 regions in the world from 1971 to 2000. These calculations are conducted to extract most plausible estimates which minimize differences between estimated data and reported data subjected to several constraints on the accounting systems. In our estimation, 47.4% and 72.2% of all estimated values are in 0.95-1.05% range and 0.80-1.20% range of reported value, respectively. We found a part of outliers in the existing data was modified. We clarified that total CH_4 and N_2O emission is estimated to have been 2450 $MtCO_2eq$ and 1310 $MtCO_2eq$ in 1971 and they are estimated to have increased to 3140 $MtCO_2eq$ and 2220 $MtCO_2eq$ in 2000.

Acknowledgments

This report describes all the research done during my participation in the Young Scientists Summer Program (YSSP) 2009 at the International Institute of Applied Systems Analysis in Laxenburg, Austria.

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About the Author

Tomoko Hasegawa was a participant of the 2009 Young Scientists Summer Program (YSSP) for the IME project at IIASA. She graduated from Kyoto University, Japan, in March 2008. She holds a master's degree in Environmental Engineering with a specialization in global integrated assessment modeling. She is currently a second-year Ph.D. student in a Department of Urban and Environmental Engineering, Graduate School of Engineering at Kyoto University, Japan. Her main fields of scientific interest include future estimation of greenhouse gas emission and reduction potential in agriculture.

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An Estimation Method for the Emission Accounting Table of Global Agricultural Activities

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Introduction

It is considered that agricultural model for long-term projections will play an important role to provide fundamental information to analyze the policy to reduce greenhouse gas emission from agriculture. Various institutions are currently developing agricultural models, making future projections of the world food supply and demand and evaluating the food trade system (Table 1).

Table 1 A list of agricultural models

Model	Institute	Parameters	Structure	Ref.
AGLINK	OECD	Synthetic	Partial, Dynamic	[1]
AT2030	FAO	Synthetic	Partial, Dynamic	[2]
ATPSM	UNCTAD	Synthetic	Partial, Static	[3]
BLS	IIASA	Synthetic	General, Dymanic	[4]
Country link systen	USDA	Synthetic/Econometric	Partial, Dynamic	[5]
FAPRI	FAPRI	Econometric	Partial, Dynamic	[6]
Grain model	World Bank	Synthetic	Partial, Dynamic	[7]
GTAP		Synthetic	General, Static	[8]
IFPSIM	JIRCAS	Synthetic	Partial, Dynamic	[9]
IMPACT	IFPRI	Expert judgement	Partial, Dynamic	[10]
MTM model	Huff et al.(1989)	Refer to national reports of each country. If national report is not available, parameters are calibrated from one-year data.	Partial, Dynamic	[11]
PEATSim	USDA	Synthetic	Partial, Dynamic	[12]
SWOPSIM	Roningen (1986) and Sullivan *et al.* (1992)	Synthetic	Partial, Static	[13], [14]
WATSIM	Kuhn *et al.* (2003)	Econometric (mostly)	Partial, Dynamic	[15]
WFM	FAO	Synthetic	Partial, Dynamic	[16]

Parameters are an important factor to decide the estimation result because a model's result depends on its parameters. However, the parameters used by many agricultural models are unsupported by econometrics. For example, parameters of IFPRI (Rosegrant et al., 2002) [10] are decided by expert judgment. Parameters of the other models except Huff et al. (1989) [11] are referred to the previous researches and they are adjusted by using only the base-year data under several economic conditions. Huff et al. (1989) [11]

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In case they are not available, parameters are adjusted by using only one-year data. Thus, parameters of many agricultural models are not estimated by using historical data.

It is necessary that accuracy of their parameters is improved by estimating them by using a long-term historical data, not one-year data. That is because realistic results are not estimated if the one-year data includes outlier or missing data. Parameters are needed to be estimated by using data with consistency. That is because realistic results are not obtained if the data includes outlier or missing data or lacking consistency. Not only quantitative data but also monetary data are necessary because agricultural model is an economic model. Considering these things, the data that satisfies the following conditions is necessary to estimate the parameters of the agricultural models.

1) Long-term historical data
2) Data with consistency
3) Not including outliers or missing data
4) Quantity data and monetary data of agricultural commodities

Consumer price of agricultural commodities which is used to calibrate consumption functions does not exist in the world. In addition to this, FAOSTAT (FAO, 2007) [17], which is the world's largest and most comprehensive statistical database on food and agriculture, includes some problems in the data before 1989. For example, total import and total export have imbalance. Trade price is not smooth due to food aid. Production value and consumption value do not exist in FAOSTAT (2007) [17].

Britz (2007a [18], 2007b [19] and 2008 [20]) tried to address these issues, but they could not overcome these faults. Britz (2007a) [18] tried to construct the global accounting table, the Supply Utilization Accounts (SUA). He added the monetary and material balance equation of export and import. In the SUA, however, total import is not balanced with total export at the global level. In addition, monetary flows at production and consumption are not computed.

CAPRI (Britz, 2008) [20] constructed the accounting table in the EU. They use the Economic Accounts for Agriculture (EAA) as monetary information exogenously. However, they do not keep the relation among quantity, value and price in each country at every stage: production, consumption and trade. As for the monetary data, they develop only trade value and they did not develop the production value and consumption value.

Objectives

From these backgrounds, the aim of this report is to develop the estimation method of the emission accounting table of global agricultural activities and to construct the data set from 1971 to 2000 by referring several statistical data. The focus of this report is on the agricultural primary commodities including crops, livestock products, primary fish products and primary forest products. We tried to estimate consumer price of the agricultural commodities.

Structure of this documentation

Section 2 introduces a framework of the Emission Accounting Table of Global Agricultural activities (EATGA). Section 3 indicates our methodology to estimate the EATGA. Section 4 represents an application of the methodology by using several global statistics data. Section 5 represents our results. Finally, we will suggest the conclusion in Section 6.

Framework of EATGA

Emission Accounting Table of Global Agricultural Activities (EATGA) consists of monetary and material accounting tables which represents food material, money flows, and environmental load substances in one year in one country. This chapter shows contents and structure of EATGA. This database would be useful not only to analyze the agricultural impact on the environment, but also to calibrate the agriculture economic models.

Material table

Material table represents all food material flows related to agricultural activities from sellers to buyers. Columns and rows have the same headings. Columns represent buyers and rows represent sellers. These headings are categorized into “commodities”, “activities”, “final demand” and “rest of world”. These food material flows except wood and wood products are counted in calories. Wood and wood products are counted in metric tones.

“Commodities” include primary crops, livestock animals, primary fish products, primary forest product, meat, processed food and non-food. “Activites” are aggrigated into the same classification with commodities because it is assumed that one activity produces one corresponding commodity group. “Activities” include crop primary sectors, dairy farm, primary fishery sector, primary forestry sector, meat industry, other food industry and non-food industry. “Final demand” is classified by private household and government. “Rest of world” represents aggregated trade partners.

Table 2 shows the brief structure of material accounting table in one country in one year. In this table, agricultural commodities are aggregated into “Commodity (1,...,n) ”. Activities of primary crops are aggregated into “Crops (1,…,m)”. Activities of livestock animal are aggregated into “Livestocks (CTL) (1,…,l)”.

Agricultural commodities produced domestically or imported from rest of world are supposed to be consumed in the country or to be exported to rest of world.

This means total domestic supply should be equal to total demand. Demand is classified into i) intermediate input as feed, seed and other use, ii) final demand as food and saving, iii) export to rest of world and iv) waste.

“Waste“ includes lost at all stages between the level at which production is recorded and the household, i.e. losses during storage and transportation. Technical losses occurring during the transformation of the primary commodities into processed products are included. Losses occurring during the pre-harvest and harvesting stage are excluded. The waste of both edible and inedible parts of the commodity occurring in the household is also excluded and it is included in private household as final demand.

As the satellite data, i) per-capita calories, ii) harvested area of each crops, iii) land use data (i.e. agricultural land area, pasture land area and forest area), iv) stock number of livestock, v) fertilizer consumption and vi) greenhouse gas emission are written in the bottom of the table. Harvested area, fertilizer consumption and stock number of livestock are important factors.

Table 2.1 Material table

Supply \ Use		Commodity (1,・・・,n)	Activity (1,・・・,n)						Final demand		ROW
			Crops	CTL	FSH	FRS	OFI	waste collection	Private household	Governm ent	
Commodity (1,・・・,n)			Intermidiate input (Feed, Seed, Processing)				Other use	Waste	Food	Stock change	Export
Activity (1,・・・,n)	Crops	Production									
	Livestocks (CTL)										
	Fishery (FSH)										
	Forestry (FRS)										
	Other food industry (OFI)										
Rest of world (ROW)		Import									

Satellite

Food per capita		food per capita	
Landuse	Crops (1,・・・,m)	Harvested area	
	Crops	Agricultural land area	
	Livestocks	Pasture land area	
	Forestry	Forest area	
Livestocks’ stock number (1,・・・,l)		Stock animal number	
Fertilizer consumption		Fertilizer per area by commodity	
		Total fertilizer consumption	
GHG emission	Cropland		
	Livestocks		
	Agricutual waste		

Monetary table

Monetary accounting table represents all money flows related to agricultural commodities from buyers to sellers. Each cell shows the payment from a sector represented by the corresponding columns to an account represented by the corresponding row. A structure of this table is basically the same as that of social accounting table.

Table shows a brief structure of monetary accounting table in one country in one year. With regard to a structure of monetary accounting table, some features are noteworthy. Factors are: disaggregated labor, capital investment, and land. Domestic nongovernment institutions consist of households and regional household. Regional household receive factor incomes and incomes of household, government. Their income is used for direct taxes and transfers to other institutions.

“Government” is disaggregated into a core government and different tax accounts because the economic interpretation of some payments may be ambiguous. The tax types are divided into export tax, import tax, production tax, commodity sales tax and direct tax. Activity subsidies are represented by negative values.

“Transport margin” represents costs of to transporting commodities from producer to domestic consumer. For imports, it represents cost to transport commodities from the border to the domestic consumer (c.i.f price), while for exports, it shows cost to transport commodities from the producer to the border (f.o.b.price). Thus, total value of each commodity includes these transaction costs.

“Waste sector” represents payment for waste collection. They are represented as negative value because they are the opposite direction as other monetary flows. “Trade balance” represents differences between export and import. Columns and rows are summed up to ensure accounting consistency, and total of each row equals to total of each corresponding column. Total import value of all countries should be equal to total export value of them.

Table 2.2 Monetary table

Supply \ Use		Commodity (1,･･･,n)	Activity (1,･･･,n)							Factor			Final demand			Tariff and Tax					ROW	Trade Balance
			Crops	CTL	FSH	FRS	OFI	OTH	WST	LAB	CAP	LAD	P	G	C	M	X	I	P	D		
Commodity (1,･･･,n)			Intermidiate input (feed, seed, processing)					Other use	Waste				Food	Stock change	Capital cost						Export	
Activity (1,･･･,n)	Crops	Production																				
	Livestocks (CTL)																					
	Fishery (FSH)																					
	Forestry (FRS)																					
	Other food industry (OFI)																					
	Other industry (OTH)		Input (i.e. energy)																			
Factor	Labor (LAB)		Labor																			
	Capital(CAP)		Capital											Capital investment								
	Land (LAD)		Land																			
Regional Household (RHO)													Wage									
Final demand	Private household																					
	Government										Capital wastage											
	Capital																					
Tariff and tax	Import tariff (M)																					
	Export tax (X)																					
	Indirect tax (I)																					
	Producton tax (P)																					
	Direct tax (D)																					
	Transport margin																					
Rest of the world (ROW)		Import																				

Estimation Methodology

Overview

The EATGA modeling system is given by several available statistical sources at country level. However, this data is not perfect because of missing data, outlier and lacking consistency. Using the available data we tried to make a complete and consistent time series data.

Both material tables and monetary tables are estimated by country and year using several statistical data. We tried to fill gaps in the domestic input output data under several constrains. Imports and exports are estimated under trade balance equation. We also tried to fill gaps in the trade data.

Initial value is determined by the conventional way. If data in the best source are unavailable, we looked for the second best source and filled the gaps using a conversion factor derived from the sources. If data in any other source is not available, fill the gaps using a conversion factor of the data about the country which is close geographically.

Model structure

Agricultural time series data, composed of elements of either the material table or the monetary table, are estimated by countries using several statistical data. The domestic supply must be equal to domestic demand by commodity and country. The sum of production and import is estimated in order to be equal to the sum of consumption, waste and export. At the same time, the domestic monetary flow must be balanced. Therefore, i) linkage among material elements, ii) linkage among monetary elements and iii) linkage between material elements and monetary elements are imposed. We tried to fill gaps in the input output data by these constraints.

Notation, Supplements and Variables

Table 3 summarizes the notational principles. A supplement is shown in Table 4. Parameter and variable names are chosen to facilitate interpretation; Conversion factor starts with α, total value with *TV*, unit value with *UV*, tax with *TAX*, and land area with *A*. Core model structure is shown by using only main variables for clarification. Exogeneous and endogeneous variables are shown in Table 6 and Table 7. Main exogeneous variables represent statistical information of each element in the accounting tables and conversion factors derived from statistical information. Main endogeneous variables represent elements in the accounting tables and the estimated conversion factors. A relation between main variables and sub-variables is represented by using supplement p which indicates elements of the accounting table shown in Table 5. For example (1), $Z_{i,r,"PRO",t} = PRO_{i,r,t}$ and (2) $\alpha pro_{i,r,t} = \alpha_{i,r,"PRO",t}$. $\bar{O}_{i,r,"PRO",t}$ represent statistical information of production.

Table 3 Notation principle

	Notation
Endogenous variables	letters without a bar
Exogenous variables	letters with a bar

Table 4 Supplement

Supplement	Notation
r	Country
p, pp	Elements of accounting table and price data
i	Commodity
t	Year
s	Type of statistical data
I	Commodity group
I_{crop}	Commodity group of crop
$I_{livestock}$	Commodity group of livestock
I_{wood}	Commodity group of wood

Table 5 Elements of the accounting table and unit value data represented by supplement p

	Elements	Notation
Material elements	PRO	Production
	C	Total consumption
	FOD	Food consumption
	FED	Feed consumption
	SED	Seed consumption
	OTH	Other use
	WST	Waste
	PROC	Processing
	STK	Stock change
	M	Import
	X	Export
Monetary elements	VPRO	Production value
	VM	Import value
	VC	Consumption value
	VX	Export value
	VFOD	Food consumption value
	VFED	Feed consumption value
	VSED	Seed consumption value
	VOTH	Other use value
	VWST	Waste value
	VPROC	Value for processing
	VSTK	Stock change value
Unit value	UVPRO	Production unit value
	UVC	Consumption unit value
	UVM	Import unit value
	UVX	Export unit value
	UVFOD	Food consumption value
	UVFED	Feed consumption value
	UVSED	Seed consumption value
	UVOTH	Other use value
	UVWST	Waste value
	UVPROC	Value for processing

	UVSTK	Stock change value
Land use	AHV	Harvested area
	APC	Agricultural area
	APP	Pasture land area
	AFR	Forest land area
Socio-economic indicator	POP	Population
	TVPRO	Total production value of agricultural commodities
	TVVM	Total import value of agricultural commodities
	TVX	Total export value of agricultural commodities
	TVC	Total consumption value of agricultural commodities

Table 6 Exogeneous variables

Type of variables	Variables	Notation
Main variables	$\overline{O}_{i,r,p,s,t}$	Statistical information of elements of commodity i, country r and year t in statistical data s
	$\overline{\zeta}_{i,r,p,s,t}$	Conversion factor for statistical information $\overline{O}_{i,r,p,s,t}$
	$\overline{w_{i,r,p,s,t}}$	Weight for statistical information s of elements of commodity i, country r and year t
	$\overline{wt_{i,r,p,t}}$	Weight for changes in time series of elements of commodity i, country r and year t in statistical data s
	$\overline{w\zeta_{i,r,p,s,t}}$	Weight for conversion factor of elements of commodity i, country r and year t in statistical data s
	$\overline{flag}_{i,r,p,s,t}$	Flag which represents data existences of commodity i, country r and year t in statistical data s
	$\overline{dataMap_{pp,p}}$	Matrix which represents relation among elements for interpolation
Sub variables		
Socio-economic indicator	$\overline{POP}_{r,t}$	Population in country r, year t
	$\overline{TVPRO_{r,t}}$	Total production value of agricultural commodities in country r, year t

Type of variables	Variables	Notation
	$\overline{TVM_{r,t}}$	Total import value of agricultural commodities in country r, year t
	$\overline{TVX_{r,t}}$	Total export value of agricultural commodities in country r, year t
	$\overline{TVC_{r,t}}$	Total consumption value of agricultural commodities in country r, year t
Land use	$\overline{APC_{r,t}}$	Agricultural area in country r, year t
	$\overline{APP_{r,t}}$	Pasture land area in country r, year t
	$\overline{AFR_{r,t}}$	Forest land area in country r, year t
Tax and tariff	$\overline{TAXX_{i,r,t}}$	Export tax of commodity i, country r and year t
	$\overline{TAXM_{i,r,t}}$	Import tax of commodity i, country r and year t
	$\overline{TAXP_{i,r,t}}$	Production tax of commodity i, country r and year t
	$\overline{TAXI_{i,r,t}}$	Indirect tax of commodity i, country r and year t
	$\overline{TAXD_{i,r,t}}$	Direct tax of commodity i, country r and year t
	$\overline{ITP_{i,r,t}}$	Import transport margin of commodity i, country r and year t
	$\overline{CGD_{i,r,t}}$	
Greenhouse gas emission factor	$\overline{e_{i,r,m}}$	Greenhouse gas emission factor per unit production activity of commodity i, country r and gas m
	$\overline{GWP_m}$	Global warming potential of gas m

Table 7 Endogeneous variables

Type of variables	Variables	Notation
Main variables	$Z_{i,r,p,t}$	Estimated value of an elements of commodity i, country r, year t
	$\alpha_{i,r,p,t}$	Estimated value of a conversion factor of $Z_{i,r,p,t}$
	Obj	Objective variable
Sub variables		
Material elements	$PRO_{i,r,t}$	Production of commodity i, country r, year t
	$C_{i,r,t}$	Total consumption of commodity i, country r, year t
	$FOD_{i,r,t}$	Food consumption of commodity i, country r, year t

Type of variables	Variables	Notation
	$FED_{i,r,t}$	Feed consumption of commodity i, country r, year t
	$SED_{i,r,t}$	Seed consumption of commodity i, country r, year t
	$OTH_{i,r,t}$	Other use of commodity i, country r, year t
	$WST_{i,r,t}$	Waste of commodity i, country r, year t
	$PROC_{i,r,t}$	Processing of commodity i, country r, year t
	$STK_{i,r,t}$	Stock change of commodity i, country r, year t
	$M_{i,r,t}$	Import of commodity i, country r, year t
	$X_{i,r,t}$	Export of commodity i, country r, year t
Monetary elements	$VPRO_{i,r,t}$	Production value of commodity i, country r, year t
	$VM_{i,r,t}$	Import value of commodity i, country r, year t
	$VC_{i,r,t}$	Consumption value of commodity i, country r, year t
	$VX_{i,r,t}$	Export value of commodity i, country r, year t
	$VFOD_{i,r,t}$	Food consumption value of commodity i, country r, year t
	$VFED_{i,r,t}$	Feed consumption value of commodity i, country r, year t
	$VSED_{i,r,t}$	Seed consumption value of commodity i, country r, year t
	$VOTH_{i,r,t}$	Other use value of commodity i, country r, year t
	$VWST_{i,r,t}$	Waste value of commodity i, country r, year t
	$VPROC_{i,r,t}$	Value for processing commodity i, country r, year t
	$VSTK_{i,r,t}$	Stock change value of commodity i, country r, year t
Unit value	$UVPRO_{i,r,t}$	Production unit value of commodity i, country r, year t
	$UVC_{i,r,t}$	Consumption unit value of commodity i, country r, year t
	$UVM_{i,r,t}$	Import unit value of commodity i, country r, year t
	$UVX_{i,r,t}$	Export unit value of commodity i, country r, year t
	$UVFOD_{i,r,t}$	Food consumption value of commodity i, country r, year t
	$UVFED_{i,r,t}$	Feed consumption value of commodity i, country r, year t

Type of variables	Variables	Notation
	$UVSED_{i,r,t}$	Seed consumption value of commodity i, country r, year t
	$UVOTH_{i,r,t}$	Other use value of commodity i, country r, year t
	$UVWST_{i,r,t}$	Waste value of commodity i, country r, year t
	$UVPROC_{i,r,t}$	Value for processing commodity i, country r, year t
	$UVSTK_{i,r,t}$	Stock change value of commodity i, country r, year t
Other variables	$AHV_{i,r,t}$	Harvested area of commodity i, country r, year t ($i \in I_{crop}$)
	$YLD_{i,r,t}$	Yield of crop i, country r, year t ($i \in I_{crop}$)
		Land intensity of pasture land($i \in I_{livestock}$) or forest land ($i \in I_{forest}$)
	$LST_{i,r,t}$	Stock animal's number of commodity i, country r, year t ($i \in I_{livestock}$)
	$NFR_{r,t}$	Total nitrous fertilizer consumption in country r, year t
	$NHA_{i,r,t}$	Nitrous fertilizer consumption per harvested area of commodity i, country r, year t ($i \in I_{crop}$)
	$GHG_{r,t}$	Greenhouse gas emission in country r, year t
Conversion factor	$\alpha fod_{i,r,t}$	Per-capita food consumption of commodity i, country r, year t
	$\alpha fed_{i,r,t}$	Unit animal feed consumption of commodity i, country r, year t
	$\alpha sed_{i,r,t}$	Per-area seed consumption of commodity i, country r, year t
	$\alpha wst_{i,r,t}$	Waste conversion factor of commodity i, country r, year t
	$\alpha proc_{i,r,t}$	Processing conversion factor of commodity i, country r, year t
	$\alpha stoc_{i,r,t}$	Stock change conversion factor of commodity i, country r, year t
	$\alpha pro_{i,r,t}$	Livestock production ratio of commodity i, country r, year t ($i \in I_{livestock}$)
	$\alpha vpro_{i,r,t}$	Conversion factor of production value of commodity i to total agricultural production value in country r, year t
	$\alpha vc_{i,r,t}$	Conversion factor of consumption value of commodity i to total agricultural consumption value in country r, year t

Type of variables	Variables	Notation
	$\alpha vm_{i,r,t}$	Conversion factor of import value of commodity i to total agricultural import value in country r, year t
	$\alpha vx_{i,r,t}$	Conversion factor of export value of commodity i to total agricultural export value in country r, year t

Objective function

Each element in the accounting table is calculated by solving an optimization problem minimizing a gap between statistical data and estimated value. The objective function includes the following three differences. This method makes it possible that each variable is determined at a point where it is cloth to all available statistical data, and all variables have consistency without missing data and outliers.

(1) Differences between statistical information($\overline{O}_{i,r,p,s,t}$) and variables($Z_{i,r,p,t}$)
(2) Differences among endogenous conversion factors in every 3 consecutive years $\left(\alpha_{i,r,p,t-1}, \alpha_{i,r,p,t}, \alpha_{i,r,p,t+1}\right)$
(3) Differences between given conversion factor($\overline{\zeta}_{i,r,p,s,t}$) and conversion factor variables($\alpha_{i,r,p,t}$)

$$
\begin{aligned}
Obj = & \sum_{i,r,p,s,t} \overline{w_{i,r,p,s,t}} \cdot F\left(Z_{i,r,p,t}, \overline{O}_{i,r,p,s,t}\right) \\
& + \sum_{i,r,p,t} \overline{wt_{i,r,p,t}} \cdot G\left(\alpha_{i,r,p,t+1}, \alpha_{i,r,p,t}, \alpha_{i,r,p,t-1}\right) \\
& + \sum_{i,r,p,s,t} \overline{w\zeta_{i,r,p,s,t}} \cdot H\left(\alpha_{i,r,p,t}, \overline{\zeta}_{i,r,p,s,t}\right) \cdot \overline{flag}_{i,r,p,s,t}
\end{aligned}
\tag{1}
$$

where,

$$
F\left(V_{i,r,p,t}, \overline{O}_{i,r,p,s,t}\right) = \ln\left(\frac{Z_{i,r,p,t}}{\overline{O}_{i,r,p,s,t}}\right)^2 \tag{2}
$$

$$
G\left(\alpha_{i,r,p,t+1}, \alpha_{i,r,p,t}, \alpha_{i,r,p,t-1}\right) = \ln\left[\left(\frac{\alpha_{i,r,p,t+1}}{\alpha_{i,r,p,t}}\right)^2 \Bigg/ \left(\frac{\alpha_{i,r,p,t}}{\alpha_{i,r,p,t-1}}\right)^2\right] \tag{3}
$$

$$H\left(\alpha_{i,r,p,t},\overline{\zeta}_{i,r,p,s,t}\right)=\ln\left(\frac{\alpha_{i,r,p,t}}{\overline{\zeta}_{i,r,p,s,t}}\right)^2 \qquad (4)$$

The relation between statistical information $\overline{O}_{i,r,p,s,t}$ and variables $Z_{i,r,p,t}$ is defined with $F\left(Z_{i,r,p,t},\overline{O}_{i,r,p,s,t}\right)$. In case where statistical data is available, $Z_{i,r,p,t}$ is estimated in order to minimize difference between statistical data and variables. $F\left(Z_{i,r,p,t},\overline{O}_{i,r,p,s,t}\right)$ being close to 0 represents that the difference between statistical data and estimated value is small. $G\left(\alpha_{i,r,p,t+1},\alpha_{i,r,p,t},\alpha_{i,r,p,t-1}\right)$ represents two change ratios of endogenous conversion factors in the three-year period. $G\left(\alpha_{i,r,p,t+1},\alpha_{i,r,p,t},\alpha_{i,r,p,t-1}\right)$ being close to 0 means the change ratio between the two differences become small. $H\left(\alpha_{i,r,p,t},\overline{\zeta}_{i,r,p,s,t}\right)$ represents a difference between endogenous conversion factor ($\alpha_{i,r,p,t}$) and an exogenous conversion factor ($\overline{\zeta}_{i,r,p,s,t}$).

Interpolation methodology of missing data by using conversion factors

As defined with the following function, "estimated conversion factor ($\alpha_{i,r,p,t}$)" is a ratio of one element ($Z_{i,r,p,t}$) from the other element ($Z_{i,r,pp,t}$). $\overline{dataMap_{pp,p}}$ is a matching matrix to represent a relation between each two elements.

$$Z_{i,r,p,t}=\alpha_{i,r,p,t}\cdot\sum_{pp}\overline{dataMap_{pp,p}}\cdot Z_{i,r,pp,t} \qquad (5)$$

Missing data in $Z_{i,r,p,t}$ is interpolated by using an estimated conversion factor ($\alpha_{i,r,p,t}$) from the other data ($Z_{i,r,pp,t}$). At the same time, the estimated conversion factor ($\alpha_{i,r,p,t}$) is close to the given conversion factor ($\overline{\zeta}_{i,r,p,s,t}$) As represented by a term $H\left(\alpha_{i,r,p,t},\overline{\zeta}_{i,r,p,s,t}\right)$ of objective function, the sum of differences between estimated conversion factors and given conversion factors is minimized. At the same time, as represented by a term $G\left(\alpha_{i,r,p,t+1},\alpha_{i,r,p,t},\alpha_{i,r,p,t-1}\right)$ of objective function, $\alpha_{i,r,p,t}$ is made smooth in time series.

Constraints

This section shows constraints in the model. Elements of accounting tables can be inter-related in a number of balancing equations. The most important requirement is a domestic balance for each commodity and world trade balance in each year.

(1) Domestic balance equation

・ Material balance equation

$$PRO_{i,r,t} + M_{i,r,t} = C_{i,r,t} + X_{i,r,t} \qquad (i \in I) \tag{6}$$

where,

$$C_{i,r,t} = FOD_{i,r,t} + FED_{i,r,t} + SED_{i,r,t} + OTH_{i,r,t} + WST_{i,r,t} + PROC_{i,r,t} + STK_{i,r,t} \quad (i \in I)$$

・ Monetary balance equation

$$VPRO_{i,r,t} + VM_{i,r,t} + \overline{TAXM_{i,r,t}} + \overline{ITP_{i,r,t}} = VC_{i,r,t} + VX_{i,r,t} + \overline{TAXX_{i,r,t}} \qquad (i \in I) \tag{7}$$

(2) World trade balance equation

World total import should be equal to world total export. It is assumed that a sum of exports is equal to a sum of imports by commodity. Import and export are estimated with taking into account world trade balance.

・Material balance equation

$$\sum_r X_{i,r,t} = \sum_r M_{i,r,t} \qquad (i \in I) \tag{8}$$

・ Monetary balance equation

$$\sum_r X_{i,r,t} \cdot UVX_{i,r,t} = \sum_r M_{i,r,t} \cdot UVM_{i,r,t} \cdot (1\text{-}\overline{ITP_{i,r}}) \qquad (i \in I) \tag{9}$$

(3) Crop production related to harvested area

A relation of crop production, yield and harvested area is defined by the following equation. Crop production should be equal to yield multiplied by harvested area.

$$PRO_{i,r,t} = YLD_{i,r,t} \cdot AHV_{i,r,t} \qquad (i \in Icrop)$$

(4) Linkage between material elements and monetary elements

Amounts of agricultural commodity and amounts of money are related each other via unit value at all stages. We define the linkage between these two types of elements as the following equations.

$$VPRO_{i,r,t} = PRO_{i,r,t} \cdot UVPRO_{i,r,t} \qquad (i \in I) \tag{10}$$

$$VC_{i,r,t} = C_{i,r,t} \cdot UVC_{i,r,t} \qquad (i \in I) \tag{11}$$

$$VX_{i,r,t} = X_{i,r,t} \cdot UVX_{i,r,t} \cdot (1 - \overline{TAXX}_{i,r,t}) \qquad (i \in I) \tag{12}$$

$$VM_{i,r,t} = M_{i,r,t} \cdot UVM_{i,r,t} \cdot (1 + \overline{TAXM}_{i,r,t}) \qquad (i \in I) \tag{13}$$

Linkage accounting data with satellite data

In material accounting table and monetary accounting table, population, total agricultural value, harvested area of each crop and land use data, livestock stock number are satellite data.

Population and total agricultural value play a role as socio-economic indicators. Harvested area, permanent meadows and pastures area and forest area are production factor of primary crops, livestock animals and wood products respectively.

(1) Land intensity

Livestock animals are linked with permanent meadows and pastures area. Animal number per pasture land area indicates a pasture land intensity. In the same way, wood production is linked with forest area. Production per forest area indicates a forest land intensity.

$$\alpha pro_{i,r,t} = PRO_{i,r,t} / \overline{APP_{i,r,t}} \qquad \left(i \in I_{livestock}\right) \tag{14}$$

$$\alpha pro_{i,r,t} = PRO_{i,r,t} / \overline{AFR_{i,r,t}} \qquad \left(i \in I_{forestry}\right) \tag{15}$$

(2) Per capita food consumption

Food consumption is linked with population and food consumption per person.

$$\alpha fod_{i,r,t} = FOD_{i,r,t} / \overline{POP_{i,r,t}} \qquad \left(i \in I\right) \tag{16}$$

(3) Monetary flow related to total agricultural value

Monetary element is linked with total agricultural added value at the corresponding stage.

$$\alpha vpro_{i,r,t} = VPRO_{i,r,t} / \overline{TVPRO_{i,r,t}} \qquad \left(i \in I\right) \tag{17}$$

$$\alpha vc_{i,r,t} = VC_{i,r,t} / \overline{TVC_{i,r,t}} \qquad \left(i \in I\right) \tag{18}$$

$$\alpha vm_{i,r,t} = VM_{i,r,t} / \overline{TVM_{i,r,t}} \qquad \left(i \in I\right) \tag{19}$$

$$\alpha vx_{i,r,t} = VX_{i,r,t} / \overline{TVX_{i,r,t}} \qquad \left(i \in I\right) \tag{20}$$

(4) Relation of stock animal's number and slaughtered animal's number

Stock animal's number (LST) of livestock indicates the number of animals of the species present in the country. It includes animals raised either for draft purposes or for meat and dairy production or kept for breeding. On the other hand, a slaughtered animal's number (PRO) indicates the number of animals of the species slaughtered within national boundaries, irrespective of their origin. It includes both commercial and farm slaughtered animals. A relation of stock animal's number and slaughtered animal's number is defined by the following equation: $\alpha pro_{i,r,t}$ indicates production cycle ratio of livestock in one year in the country.

$$LST_{i,r,t} = \alpha pro_{i,r,t} \cdot PRO_{i,r,t} \qquad \left(i \in I_{livestock}\right) \tag{21}$$

(5) Fertilizer balance equation

A relation of total nitrous fertilizer consumption, per-area fertilizer consumption and harvested area is defined by the following equation. Total nitrous fertilizer consumption should be equal to per-area fertilizer consumption multiplied by harvested area.

$$NFR_{r,t} = NHA_{i,r,t} \cdot AHV_{i,r,t} \qquad \left(i \in I_{crop}\right) \tag{22}$$

(6) Greenhouse gas emission related to agricultural activities

This study focuses exclusively on anthropogenic sources of CH_4 and N_2O from agricultural production activities: livestock's enteric fermentation, livestock's manure management, cropland and soils and rice paddy. Greenhouse gas (GHG) emissions are calculated from activity data (Table 8), emission factor and global warming potential (GWP). The relation is defined by the following equation.

$$GHG_{r,t} = \sum_i \left(NFR_{i,r,t} \cdot \overline{e_{i,r,m}} \cdot \overline{GWP_m} \right) + \sum_i \left(LST_{i,r,t} \cdot \overline{e_{i,r,m}} \cdot \overline{GWP_m} \right) \tag{23}$$

Table 8 Activity data

Emission sources	Activity data
Cropland and soils	Crop's harvested area
	Nitrous fertilizer consumption per area
Livestock manure management	Livestock animals
Livestock enteric fermentation	Livestock animals
Rice paddy	Rice paddy area

Application: Data sources

The EATGA modeling system is given by several statistical sources available at country level. Data used in this study is listed at Table 9. FAOSTAT (2007, 2005)[17] covers more over 600 food and agricultural commodities by over 100 countries on annual basis. Food Balance Sheets (FAO, 2001, 2005)[21, [22] and FAO core data (FAO, 2007)[17], which are also FAO data, are not used to be referred because their primary commodity data include not only primary commodity but also processed commodities converted into primary equivalent (e.g., "bread" is converted back to "wheat"). We use them to calculate the conversion factor from total domestic consumption to a classified domestic consumption because they have a classified domestic consumption data such as food and feed etc.

(1) Production and trade data

Production and trade is basically referred to FAOSTAT (2007) [17] and PSD (USDA, 2007)[23]. For a commodity group in which the number of aggregated commodity is different between FAOSTAT and PSD (USDA, 2007) [23], it referred only to FAOSTAT because usually FAOSTAT covers more types of commodities than that of PSD. In this way, wheat and other grains are referred to both data, and the other commodity groups are referred only to FAOSTAT.

Production value is basically referred to National Accounts Database (UN, 2006) [24] and FAOSTAT (FAO, 2007). Production value is derived from producer price (FAO, 2007) and production quantity (FAO, 2007) [17]. In the case that both data are not available, production value is referred to GTAP6 (Hertel, 2005) [8]. Trade value is basically referred to FAOSTAT (2007) and COMTRADE (UN, 2006) [24].

(2) Livestock animal data

The number of livestock animals for production and trade is referred to as both FAOSTAT (FAO, 2007) and PSD. We put a priority on FAOSTAT because PSD has only the number of cattle and swine, not including other animals. Only for a country in which FAOSTAT data is not available, the number of livestock animals is referred to PSD. FAOSTAT uses calendar year which begins in January and PSD uses market year which begins in July. The time lag is not taken account.

(3) Price data

Producer price is referred to FAOSTAT (FAO, 2007). Trade price is derived from trade quantity data and trade monetary data. International price is calculated as a world average trade price by using trade quantity data and trade monetary data.

(4) Fertilizer data

Total nitrous fertilizer consumption is referred to FAOSTAT (FAO, 2007). Per-area fertilizer consumption by commodity is referred to IFA/FAO/IFDC (1999 [25], 2002 [26]) which is only one-year data in each country. These two dataset are not consistent, which means total fertilizer consumption derived from per-area fertilizer consumption and harvest area (FAO, 2007) are far from total nitrous fertilizer consumption from FAOSTAT (FAO, 2007).

(5) Greenhouse gas emission factor and GWP

GHG emissions are estimated by using IPCC Tier 1 methodology (IPCC, 2006) [27]. In order to compare this study with other results, the GWP value is referred to IPCC (1996) [28] whose value is used by GHGs national inventory reports.

(6) Initial value of domestic supply and demand

Domestic supply is calculated by production plus import. Total domestic consumption is calculated by subtracting import from domestic supply. Total domestic consumption value is derived from production value data, trade value data and tax.

(7) Conversion factor of classified domestic demand

Conversion factor from total domestic consumption to waste is derived by using Food Balance Sheets. Conversion factors from total domestic consumption to other domestic consumption (food, feed, seed, other use, stock change) are calculated by using GTAP6. For livestock animals, conversion factors from total domestic consumption to stock, other use and waste is derived from PSD.

Table 9 Data sources

	Elements	Data sources
Economic indicator	Population	UN(2006)
	Agricultural total added value	Fujimori *et al.*(2009)
	Agricultural total trade value	Fujimori *et al.*(2009)
Land use	Agricultural land area, pasture land area and forest land area	FAOSTAT (FAO, 2005)
Material data	Production	FAOSTAT(FAO, 2007), PSD(USDA, 2007)
	Harvested area	FAOSTAT(FAO, 2007)
	Livestock slaughter number	FAOSTAT(FAO, 2007),
		PSD(USDA, 2007)
	Livestock stock animal number	FAOSTAT(FAO, 2007)
	Import and export	FAOSTAT(FAO, 2007, 2005), PSD(USDA, 2007)
Monetary data	Production value	National Accounts Database (UN, 2006), FAO(2007), GTAP (Hertel, 2005)
	Import and export value	COMTRADE(UN, 2006), FAOSTAT(FAO, 2007, 2005)
	GDP deflator	National Accounts Database (UN, 2006)
Price	Production price	FAOSTAT (FAO, 2007)
Conversion factor	Domestic consumption	Food Balance Sheets (FAO, 2005)
Tax data	Export tax, import tax, production tax, indirect tax, direct tax and	GTAP (Hertel, 2005)

	Elements	Data sources
	import transport margin	
Fertilizer	Total nitrous fertilizer consumption	FAOSTAT (FAO, 2007)
	Per-area nitrous fertilizer consumption by commodity	IFA/FAO/IFDC (1999, 2002)

Classification

Countries and Regions

We disaggregated the world into 94 countries and 12 regions. Total GDP of these 94 countries represents 99 percent of total world GDP. The rest are merged into 12 regions geographically and geopolitically. The country codes are shown in Table 11.

Commodities and Activities

Table 10 shows classification of agriculturla commodites. Agricultural commodities are aggregated into seven primary crops, one primary livestock, one primary fishery, one primary forestry and other food industry commodity group. The coding of the commodities is based on the codes of the International Standard Industrial Classification of All Economic Activities (ISIC) Revision 3 [29], the Central Product Classification (CPC) version 1.1 (CPC) [30] and GTAP6.

Table 10 Classification of agriculturla commodites

	Description	Code	CPC code	ISIC rev3 code
Crops primary	Paddy rice	PDR	0113, 0114	
	Wheat	WHT	111	
	Cereal grains nec	GRO	011, 0115, 0116, 0119	
	Vegetables fruit nuts	V_F	012, 013	
	Oil seeds	OSD	014	
	Sugar cane sugar beet	C_B	018	
	Plant-based fibers	PFB	0192	
	Crops nec	OCR	015, 016, 017, 0191, 0193, 0194, 0199	
Livestock	bovine, horses	CTL	0211, 0299	

	Description	Code	CPC code	ISIC rev3 code
Primary				
	other animal nec	OAP	0212, 0292, 0293, 0294, 0295, 0296, 0297, 0298	
Wood primary	Forestry	FRS	03	
Fish primary	Fishery	FSH		015, 05

Table 11 Country code

Code	Name of the countries
DZA	Algeria
ARG	Argentina
AUS	Australia
AUT	Austria
BGD	Bangladesh
BLR	Belarus
58	Belgium-Luxembourg
BRA	Brazil
BRN	Brunei Darussalam
BGR	Bulgaria
CAN	Canada
CHL	Chile
CHN	China
HKG	China, Hong Kong SAR
COL	Colombia
CRI	Costa Rica
HRV	Croatia
CUB	Cuba
CZE	Czech Rep.
CSHH	Czechoslovakia
CIV	Cote d'Ivoire
PRK	Dem. People's Rep. of Korea
DNK	Denmark
DOM	Dominican Rep.
ECU	Ecuador
EGY	Egypt
SLV	El Salvador
FIN	Finland
DDDE	Fmr Dem. Rep. of Germany
280	Fmr Fed. Rep. of Germany
SUHH	Fmr USSR
890	Fmr Yugoslavia
FRA	France
DEU	Germany
GRC	Greece
GTM	Guatemala
HUN	Hungary
IND	India
IDN	Indonesia
IRN	Iran
IRQ	Iraq
IRL	Ireland
ISR	Israel
ITA	Italy
JPN	Japan
KAZ	Kazakhstan
KEN	Kenya
KWT	Kuwait
LBN	Lebanon
LBY	Libya
MYS	Malaysia
MEX	Mexico
MNG	Mongolia
MAR	Morocco
NLD	Netherlands

Code	Name of the countries
NZL	New Zealand
NGA	Nigeria
NOR	Norway
OMN	Oman
PAK	Pakistan
PAN	Panama
PER	Peru
PHL	Philippines
POL	Poland
PRT	Portugal
QAT	Qatar
KOR	Rep. of Korea
ROU	Romania
RUS	Russian Federation
SAU	Saudi Arabia
CSXX	Serbia and Montenegro
SGP	Singapore
SVK	Slovakia
SVN	Slovenia
ZAF	South Africa
ESP	Spain
LKA	Sri Lanka
SDN	Sudan
SWE	Sweden
CHE	Switzerland
SYR	Syria
THA	Thailand
TUN	Tunisia
TUR	Turkey
USA	USA
UKR	Ukraine
ARE	United Arab Emirates
GBR	United Kingdom
URY	Uruguay
UZB	Uzbekistan
VEN	Venezuela
VNM	Viet Nam
YEM	Yemen
TWN	Chinese Taipei

Code	Name of the countries
XOC	Rest of Oceania
XSA	Rest of South Asia
XSE	Rest of Southeast Asia
XBT	Baltic countries
XE10	Rest of EU10
XER	Rest of Europe
XCI	Rest of CIS countries
XCA	Rest of central America
XSM	Rest of South America
XME	Rest of East Middle
XSS	Rest of Africa
XYU	Rest of former Yugoslavia

Results and Discussions: Accuracy of the results

In this Section, we show how estimated value is close to statistical values. Figure 1 to Figure 6 are histograms of absolute differences between the estimated value $Z_{i,r,p,t}$ and the reported value $O_{i,r,p,s,t}$.

$$Difference_{i,r,p,s,t} = \frac{Z_{i,r,p,t}}{\overline{O}_{i,r,p,s,t}}$$

In these histograms, there are high frequencies in the ranges around “1”. 47.4% and 72.2% of all estimated value is in 0.95-1.05% and 0.80-1.20% range of reported value respectively. 12.4% of estimated values are more than 50% far from reported value. From this, it can be said that most estimated values are close to the reported values.

Especially, estimated production values are close to reported production data. On the other hand, estimated trade values are far from reported values. As one of the reasons, it can be said that only one statistical data is refereed for production, on the other hand, three statistical data are referred for trade data. In addition to this, these trade statistical data report different values each other. It makes wide range among them. Therefore, estimated trade value is far from each reported data because all differences between these reported data and estimated value are minimized in this methodology.

As for production, 88.4% of estimated value is in 0.95-1.05% range of reported value and 95.5% of estimated value is in 0.80-1.20% range. 2.0% of estimated values are more than 50% far from reported value. As for production value, 67.4% of estimated value is in 0.95-1.05% range of reported value and 91.6% of estimated value is in 0.80-1.20% range. 2.5% of estimated value is more than 50% far from reported value.

On the other hand, for import and export data, 44.7% and 43.2% of estimated value is in 0.95-1.05% range of reported value and 69.3% and 70.7% of estimated value is in 0.80-1.20% range respectively. 13.5% and 14.0% of estimated value are more than 50% far from reported value. As for import value and export value, 34.3% and 33.0% of estimated value is in 0.95-1.05% range of reported value and 61.2% and 64.8% of estimated value is in 0.80-1.20% range respectively. 17.4% and 15.4% of estimated value are more than 50% far from reported value.

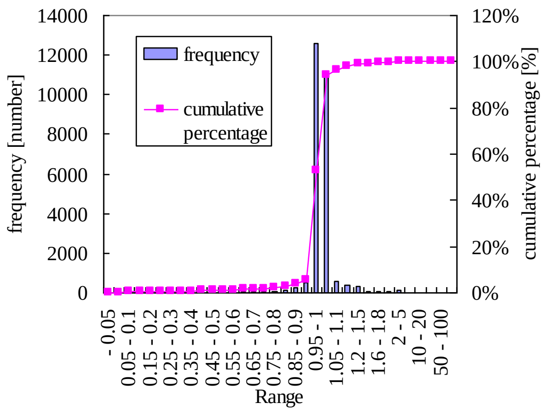

Figure 1 Histograms of absolute differences between estimated values and statistical values from 1971 to 2000 in production data

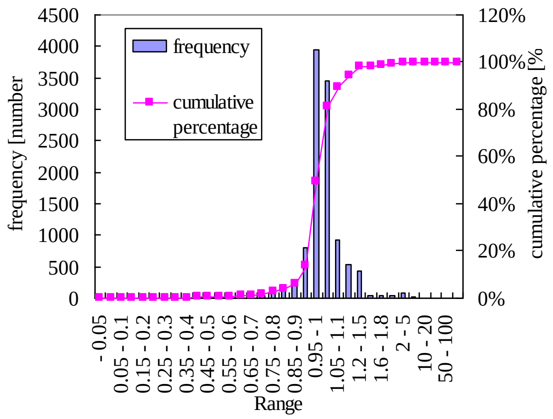

Figure 2 Histograms of absolute differences between estimated values and statistical values from 1971 to 2000 in production value data

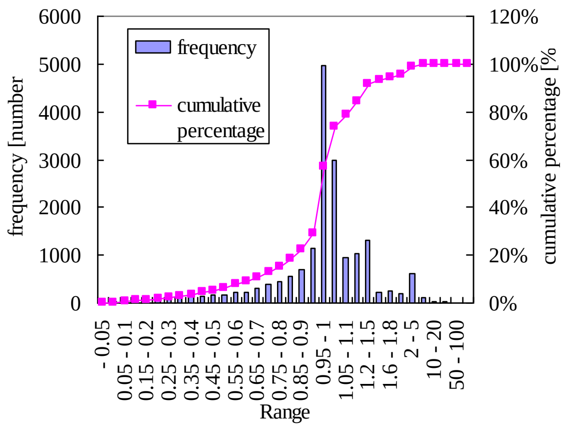

Figure 3 Histograms of absolute differences between estimated values and statistical values from 1971 to 2000 in export data

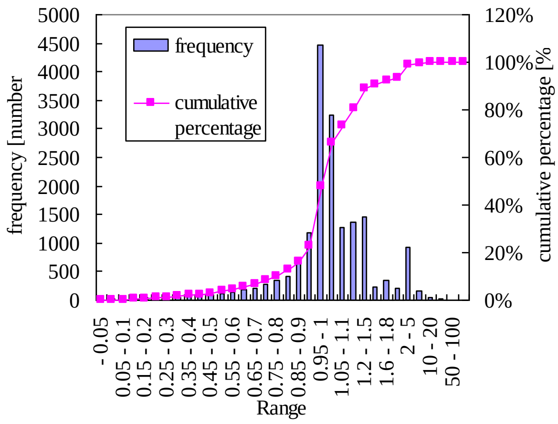

Figure 4 Histograms of absolute differences between estimated values and statistical values from 1971 to 2000 in import data

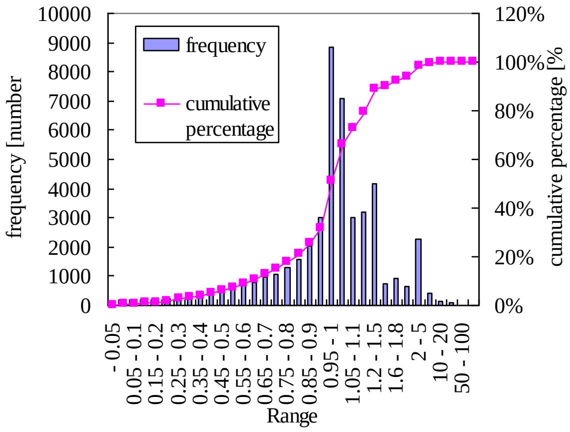

Figure 5 Histograms of absolute differences between estimated values and statistical values from 1971 to 2000 in export value data

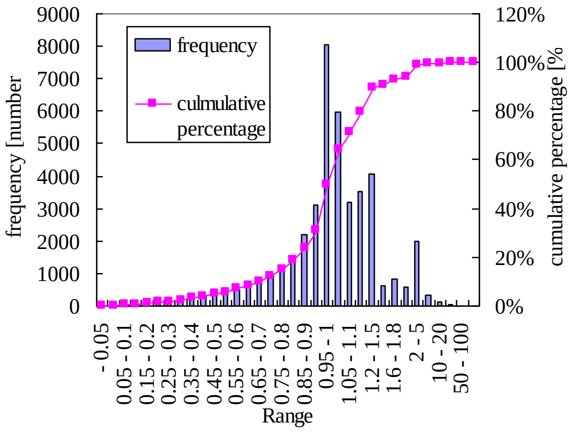

Figure 6 Histograms of absolute differences between estimated values and statistical values from 1971 to 2000 in import value data

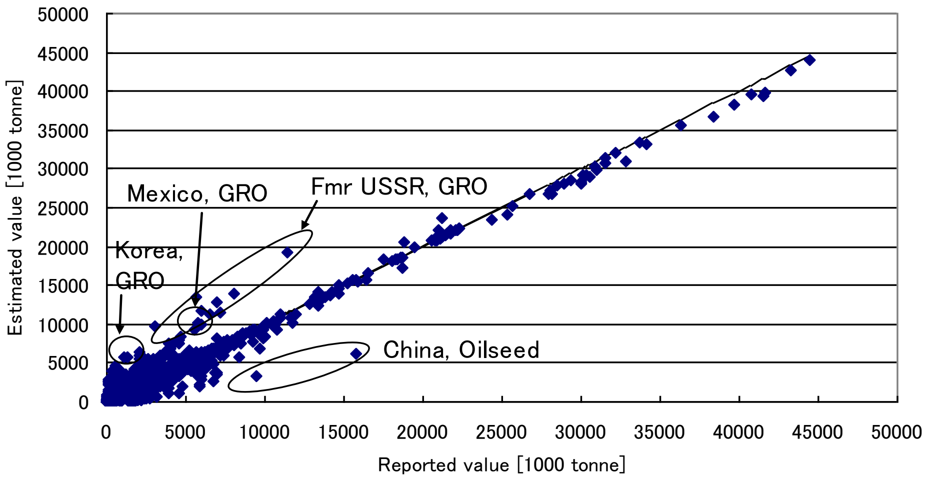

Figure 7 Reported value and estimated value of import data

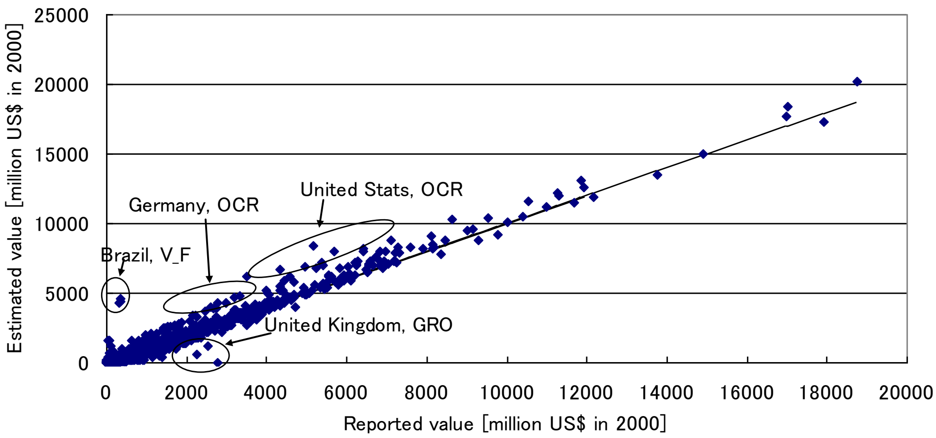

Figure 8 Reported value and estimated value of import value data

We discuss estimated trade value which has large range from reported data.

Material and monetary import

Estimated value is shown comparing with reported value for material and monetary import from FAOSTAT (2007) and import value in Figure 7 and Figure 8. In more than 10 million tones area, estimated value is close to reported value. In lesse than 10 million tones area, there are larger differences between estimated value and reported value. We show some examples. For other grains (GRO) in Korea, Mexico and Former USSR, estimated value is far from reported values. One of the reasons is due to large ranges between referred statistical data: PSD, FAOSTAT (FAO, 2005, 2007) For example, in the case of Korea, import of FAOSTAT (2007) is much smaller than that of PSD and FAOSTAT (2005) (Figure 9). However, all the data is used for estimation. Therefore, the value is estimated to be middle of these data. A part of outliers in the data was modified. As an example, Figure 10 represents import of wheat in Egypt and Russia. They have an outlier in one statistical data in 1993 and 1992 respectively. It was modified by based on the other data.

As for import monetary data, most of estimated values are close to the reported values. However, in some cases, such as other coarse grains (OCR) of Germany and United States, the estimated values are far from those reported because of the balance conditions.

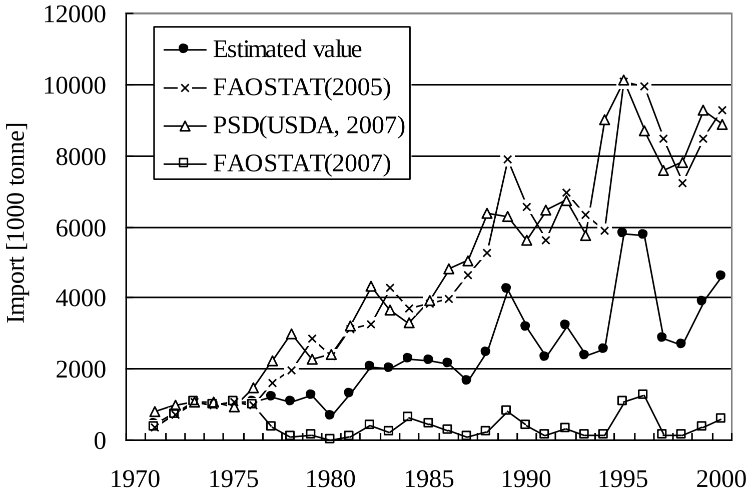

Figure 9 Import of other grains (GRO) in Korea

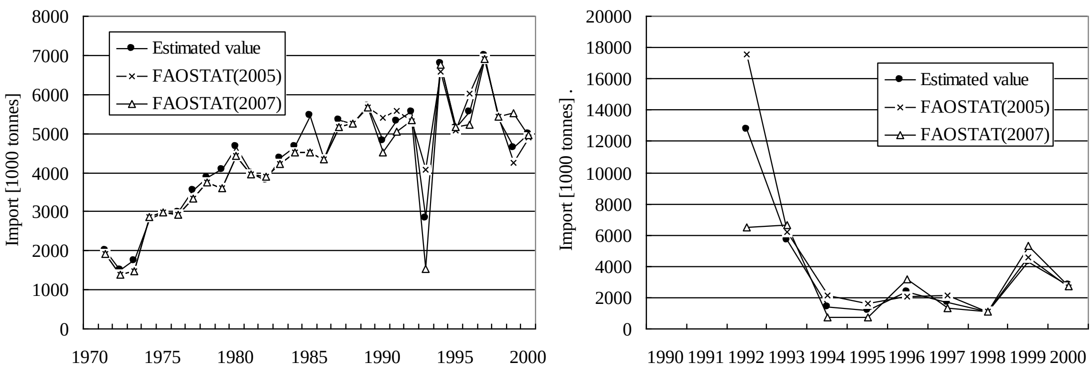

Figure 10 Import of wheat (WHT) in Egypt (left) and Russia (right)

Material and monetary export

Estimated value is shown comparing with reported value for material and monetary export from FAOSTAT (2007) and import value in Figure 11 and Figure 12. We can see most of estimated value is close to the reported value. In part of them, reported values are larger than estimated ones. For example, in case of forest products (FRS) of United States, 3200 million US$ of export value is reported by CONTRADE and FAOSTAT (2005). On the other hand, FAOSTAT (2007) reports 900 million US$ of it. That is because the data of "Case Materials", "Uncoated Mechanical" and "Uncoated Wood free" after 1990 is missing in FAOSTAT (2007)

All the data is used for estimation, and the value is estimated to be 2200 million US$ which is middle of the data. In New Zealand and Switzerland, the same situation was found. We modified aggregated data and we did not modify the disaggregated data with missing value.

As for material export, most of estimated value is close to reported value. In part of them such as forest products (FRS) of Russia and United States, estimated values are far from reported value because of balance conditions.

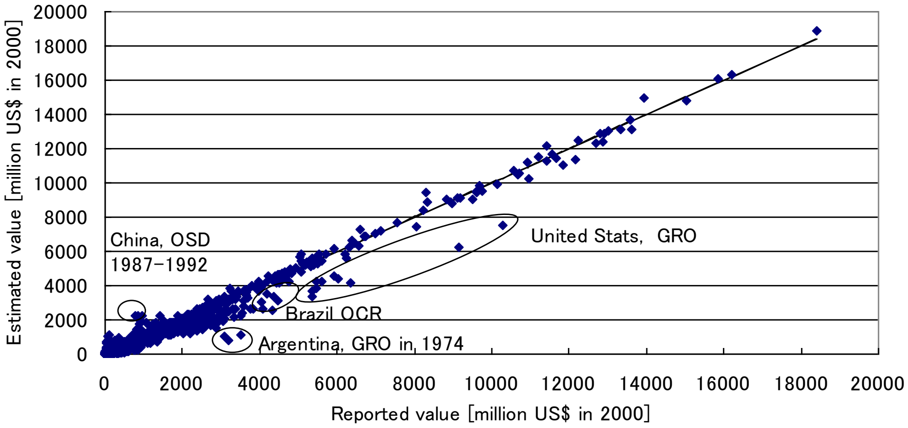

Figure 11 Reported value and estimated value of export value data

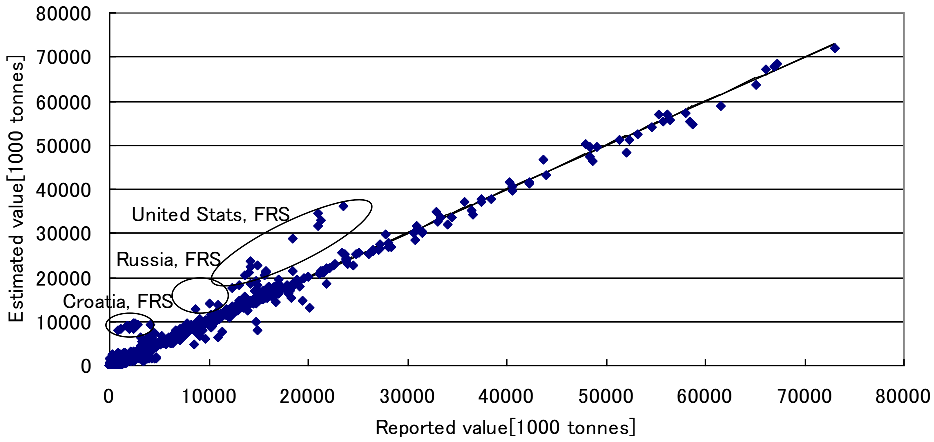

Figure 12 Reported value and estimated value of export data

Production and Harvested area

Estimated values of production and harvested area are similar with FAOSTAT (FAO, 2007) because only the data was used as reference data. A part of outliers in the data was modified. As an example, Figure 13 represents production value of vegetable, fruit and nuts (V_F) in Argentina. It has an outlier in 1975 in FAOSTAT (2007). It was modified by based on FAOSTAT (2005).

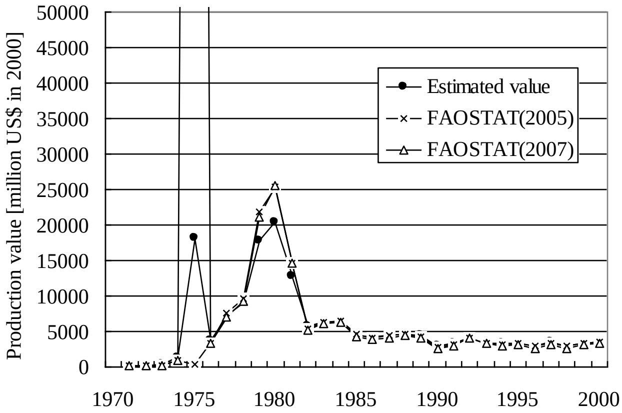

Figure 13 Production value of vegetable, fruit and nuts (V_F) in Argentina

World trade balance

Figure 14 to Figure 16 show net trade of wheat, livestock animal and rice. World balance of wheat was improved. The estimated value is similar with FAOSTAT (2007). For livestock animal, world balance was improved before 1990 but, world trade balance goes worse after 1990 except 1971 due to domestic balance condition. There is a large imbalance in FAOSTAT (2007) in 1997, which is occurred by an outlier in the data of the rest of South America (XSM). It was improved.

For rice, world trade balance goes worse before 1993. Total import is much larger than total export. One of the reasons is an overestimation of import. Overestimations occurred in some countries in which there is a large amount of import only in a few years (i.e. food aid). In this case, the data in the other years, whose original data is zero, is overestimated by referring to these couple of large import data. For example, according to FAOSTAT (2007), a large amount of rice is imported only in one year in Pakistan (Figure 17). 13,000 tonnes of rice is imported in 1993 from FAOSTAT (2007) and the same amount in 1994 from FAOSTAT (2005). There is no import in the other year. However, some amount of rice is estimated to be imported in these years.

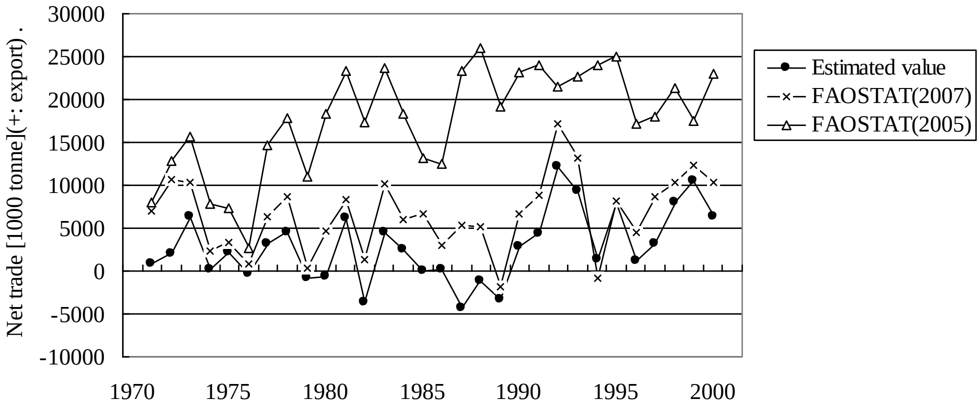

Figure 14 World material net trade of wheat

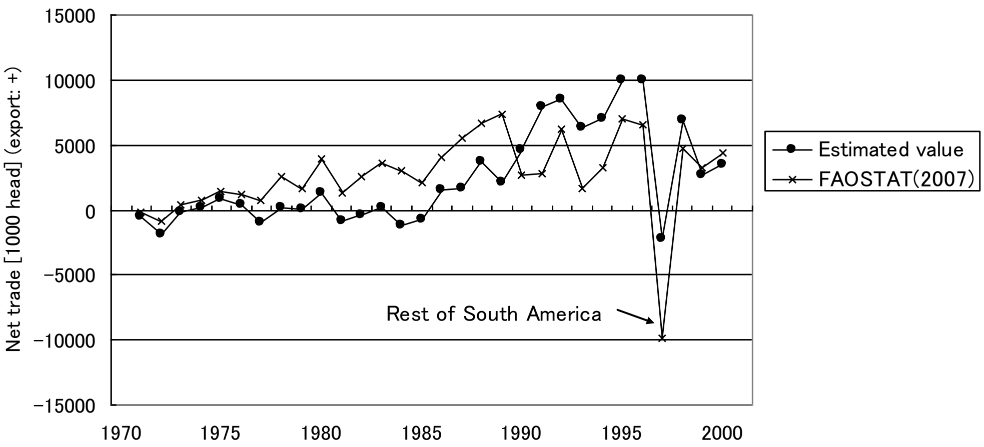

Figure 15 World material net trade of livestock animals

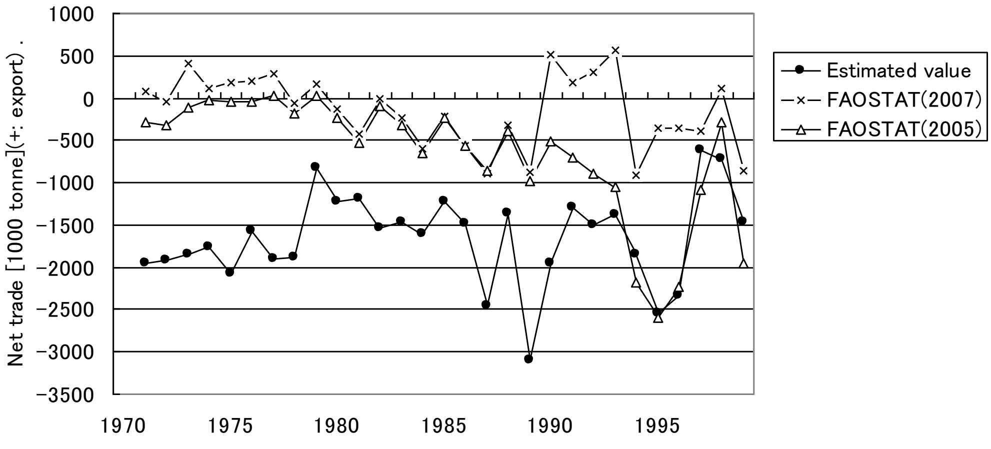

Figure 16 World net material trade of rice

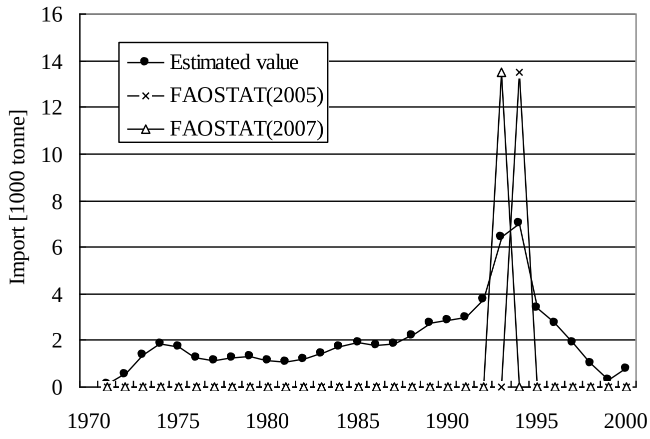

Figure 17 Import of rice (PDR) in Pakistan

Historical GHG emission compared with other researches

Figure 18 and Figure 19 represent total CH_4 and N_2O emissions from 1971 to 2000 comparing with other references: Bouwman (1997) [31], EDGAR (Olivier et al., 2005a) [32], FAO (2002) [33], GECS (Criqui, 2002) [34], baseline A, B and C of IMAGE 2.1 (Alcamo et al., 1999) [35], IPCC forth assessment report (2007) [36], Olivier et al. (2005b) [37], Stern et al. (1995) [38], USEPA (2006a) [39] and USEPA (2006b) [40]. Total CH_4 emission from agriculture is estimated to be 2450 $MtCO_2eq$ in 1971. The emission is estimated to have increased 1.3 times to 3140 $MtCO_2eq$ in 2000 in this study. Total N_2O emission from agriculture is estimated to be 1310 $MtCO_2eq$ in 1971. The emission is estimated to have increased 1.7 times to 2220 $MtCO_2eq$ in 2000 in this study. These two figures show our results are middle of other researches.

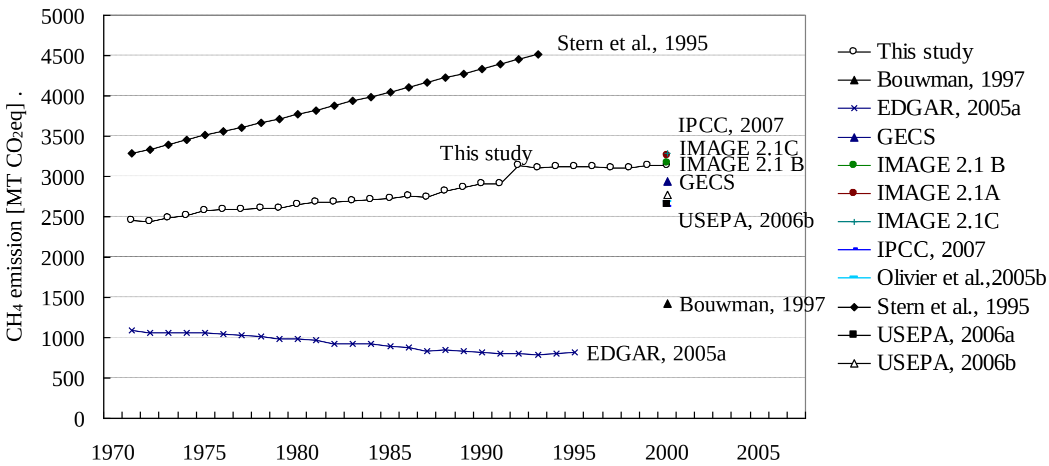

Figure 18 World CH_4 emission from 1971 to 2000

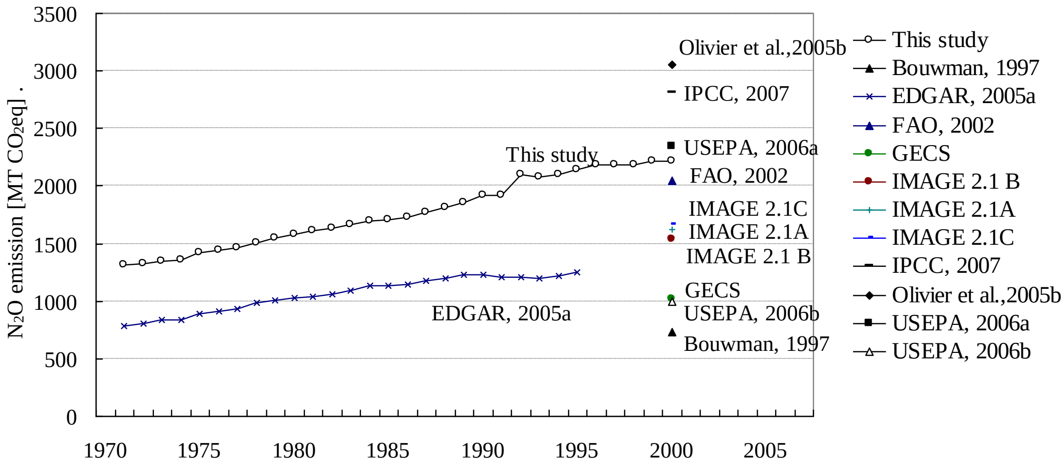

Figure 19 World N_2O emission from 1971 to 2000

Conclusion

This paper presents a new method to estimate emission accounting table of global agricultural activities which includes material and monetary flows of agricultural commodities. The table is estimated by using the method basing on several statistical data.

47.4% and 72.2% of all estimated value is in 0.95-1.05% and 0.80-1.20% range of reported value respectively. 12.4% of estimated values are more than 50% far from reported value. From this, it can be said that most estimated values are close to the reported values. World trade balance was improved in wheat and livestock animal and goes worse in rice due to overestimation of import. A part of outliers in the existing data was modified.

GHG emissions from agriculture activities are estimated as satellite data of material accounting table by using activity data. Total CH_4 and N_2O emission is estimated to have been 2450 $MtCO_2eq$ and 1310 $MtCO_2eq$ in 1971. They are estimated to have increased to 3140 $MtCO_2eq$ and 2220 $MtCO_2eq$ in 2000. Our results are satisfactory in comparison to those obtained by other researchers.

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