MIT Joint Program on the Science and Policy of Global Change

Analyzing Methane-Emitting Activities: *Longitudinal Data, Emissions Coefficients, and Spatial Distributions*

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Abstract

We assemble a longitudinal data set for analyzing methane-emitting activities within the Massachusetts Institute of Technology (MIT) Integrated Global System Model (IGSM). It is an earth system model of intermediate complexity that, for forward simulations, is driven by anthropogenic emissions as projected by the Emissions Prediction and Policy Analysis (EPPA) model. We develop initial estimates of emissions coefficients for each of the main methane-emitting activities along with corresponding uncertainty estimates to be utilized as "priors" in inverse calculations. In addition, baseline maps for the spatial distribution of methane emissions by individual activities are coded to EPPA regions for later use with emissions coefficient estimates produced by these inverse calculations.

Contents

1. INTRODUCTION

This technical note documents a time-series and cross-sectional (*i.e.* longitudinal) data set for analyzing methane (CH_4) emitting activities within the Massachusetts Institute of Technology (MIT) Integrated Global System Model (IGSM), an earth system model of intermediate complexity (Sokolov *et al.*, 2005). One focus is on utilizing this data within the anthropogenic component of MIT IGSM, namely the Emissions Prediction and Policy Analysis (EPPA) model (Paltsev *et al.,* 2005). EPPA is a recursive-dynamic multi-regional general equilibrium model of the world economy, which is built on the Global Trade Analysis Project (GTAP) version 5 database (Hertel, 1997; Dimaranan and McDougall, 2002) and additional data for advanced energy and transportation technologies. As presented in **Table 1**, the EPPA version 4 (*i.e.* EPPA4) model includes 16 countries/regions, 6 non-energy sectors, and 15 energy sectors/technologies. The base year of data utilized by EPPA4 is 1997 and it produces anthropogenic emissions projections of greenhouse gases, aerosols, and other air pollutants and their precursors through the year 2100.

Chen (2003) used the inverse method to estimate CH_4 emissions for a fixed spatial pattern of emissions-generating activities, specifically: wetland areas, rice areas, areas where biomass burning occurred, and the location of coal, oil, and gas mines. He succeeded in estimating methane emissions from each of these activities at roughly continental scale geographic areas. Our objective is to improve on the Chen (2003) work in two (2) ways: 1) to translate the geographic resolution of the estimates to match the EPPA4 regions; and 2) to use the inverse method to estimate an emissions coefficient related to an activity level underlying the EPPA data rather than to estimate emissions per se. These improvements will allow us to estimate

Table 1. Regions and Sectors in the EPPA4 Model.

Country/Region	Sectors
Annex B	**Non-Energy**
United States (USA)	Agriculture (AGRI)
Canada (CAN)	Services (SERV)
Japan (JPN)	Energy Intensive products (EINT)
European Union+[a] (EUR)	Other Industries products (OTHR)
Australia/New Zealand (ANZ)	Industrial Transportation (TRAN)
Former Soviet Union (FSU)	Household Transportation (HTRN)
Eastern Europe[b] (EET)	**Energy**
Non-Annex B	Coal (COAL)
India (IND)	Crude Oil (OIL)
China (CHN)	Refined Oil (ROIL)
Indonesia (IDZ)	Natural Gas (GAS)
Higher Income East Asia[c] (ASI)	Electric: Fossil (ELEC)
Mexico (MEX)	Electric: Hydro (HYDR)
Central and South America (LAM)	Electric: Nuclear (NUCL)
Middle East (MES)	**Advanced Energy Technologies**
Africa (AFR)	Electric: Biomass (BELE)
Rest of World[d] (ROW)	Electric: Natural Gas Combined Cycle (NGCC)
	Electric: NGCC w/ Sequestration (NGCAP)
	Electric: Integrated Coal Gasification with Combined Cycle and Sequestration (IGCAP)
	Electric: Solar and Wind (SOLW)
	Liquid fuel from biomass (BOIL)
	Oil from Shale (SYNO)
	Synthetic Gas from Coal (SYNG)

[a] The European Union (EU-15) plus countries of the European Free Trade Area (Norway, Switzerland, Iceland).
[b] Hungary, Poland, Bulgaria, Czech Republic, Romania, Slovakia, Slovenia.
[c] South Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand
[d] All countries not included elsewhere: Turkey, and mostly Asian countries.

parameters directly useful for EPPA forward simulations. Since the emissions coefficients specified in EPPA vary across regions, it is obviously useful to mirror the geographical resolution of EPPA. In addition, over the estimation period, the activity level (*e.g.*, tons of rice produced, area of rice production, exajoules of fossil fuels produced) varies substantially, and we expect this will lead to changing levels of emissions. Projected changes in these activities are indeed the basis for projections of changing emissions we forecast.

We hypothesize that emissions per unit of activity could be approximated as constant, albeit highly uncertain. The 'known' variation in the level activity and the highly uncertain emissions per unit of activity give rise to varying emissions over time. Thus, using the inverse method to estimate the emissions coefficient should generate an estimate of emissions consistent with observed concentrations, as well as constrain uncertainty in the estimated coefficient (emissions per unit of activity).

The remainder of this technical note details the three main steps towards this goal: (1) construct a longitudinal data set of methane-emitting activities; (2) generate an initial (*i.e.* "prior") estimate of the emissions coefficient relevant to each activity to be used as input for inverse calculations; and (3) translate the geographic resolution of base Chen (2003) maps to match EPPA4 regions.

2. LONGITUDINAL DATA

We constructed a longitudinal data set with the following main variables: year, EPPA4 region, and output by CH_4-emitting activity. This is accomplished by synthesizing data from the International Energy Agency (IEA), the Food and Agriculture Organization Statistical Database (FAOSTAT) of United Nations, and the World Bank's World Development Indicators. We determined the common time series in which data was available from all three sources to be from years 1980 to 2001, extracted data at the individual country level, and then aggregated to the EPPA4 regional definitions.

Given the relative importance of rice production as a source of CH_4 emissions, we opted to compile both land area devoted to rice production measured in millions of hectares (MHA) and rice produced measured in million metric tons (MMT); these data are in **Table 2** (pages 7-13). Both of these variables can be utilized individually or combined into a single measure, namely rice yield. For fossil fuel activities, we were able to compile data on coal production, petroleum production, and natural gas consumption from the IEA (2004) data measured in exajoules (EJ); these data are reported in **Table 3** (pages 14-21).

For livestock, we collected data on total livestock measured in millions of heads (MH). Although it is desirable to disaggregate into individual species (e.g., cattle, buffalo, sheep, goat, pigs, and camels), data was only available for pigs. It may be possible to weigh total livestock by an estimate of varying CH_4 emissions for different species to generate an estimate of "cattle equivalent" head of livestock. However, more investigation is needed to arrive at such a "cattle equivalent" measure. For example, dairy cattle typically generate more CH_4 emissions per head than beef cattle and, hence, would have a weight greater than one; similarly, while we imagine that sheep and goats produce less CH_4 emissions than beef cattle, they would have a weight less than one.

For waste activities, unfortunately, data on tons of either waste or sewage was not available. Thus, population data is a proxy on the basis that both waste generation per capita and resulting methane generation per ton of waste are uncertain; data on livestock and population are presented in **Table 4** (page 22-29). Lastly, for biomass burning, we are not sure that we can improve on the approach of Chen (2003) given that time series data on area and/or quantity of material burned is not currently available.

3. INITIAL ESTIMATES OF EMISSIONS PER UNIT OF ACTIVITY

Here we use estimates of methane emissions reviewed by Chen (2003), divided by our activity data to compute an initial estimate of both the mean global emissions coefficient for each activity as well as the corresponding standard deviation as an estimate of uncertainty; see **Table 5** (page 30). These estimates represent the "priors" to be utilized in inverse calculations. Although the emissions coefficients reported in Table 5 are global means, the next Section discusses the coding of the Chen (2003) emissions maps by EPPA4 regions. This allows for the possibility of also generating region-specific emissions coefficients using these maps in conjunction with the longitudinal data.

4. SPATIAL DISTRIBUTION OF METHANE EMISSIONS

In order to later use the estimates of emissions coefficients produced by the inverse calculations related to an activity level underlying the EPPA data, it is necessary to translate/ code the Chen (2003) fixed methane-activity maps into the EPPA4 regional scheme. This involved the use of Geographical Information System (GIS) software to first translate the maps from their initial 1.8° x 1.8° grid projection to a 1.8° x 1.8° latitude-longitude raster format in order to be compatible with the IGSM. A spatial overlay between these raster maps and a global coverage of country boundaries allowed for coding said maps by country and then aggregating to the EPPA4 regions[1]. **Figures 1** through **4** are samples of the revised Chen (2003) CH_4 emissions maps with EPPA4 region codes[2]. It is important to note that, in their original form, the Chen (2003) maps consist of gridded data such that each individual grid location corresponds only to CH_4 emissions data. Thus, after grids are coded by EPPA4 regions, each grid location now has the following three attributes: CH_4 emissions data, a country code, and an EPPA4 region code. Given this format, no country or regional boundaries exist in this data. Therefore, in order to clearly distinguish between the land and bodies of water, we overlay these revised Chen (2003) maps with the global polygon coverage of all country boundaries from Olivier *et al.* (2001). This overlay is performed solely for aesthetic purposes and, given the fact we are mixing raster and vector formats, it is expected that some grids do not match exactly with these boundaries because of the relatively unusual 1.8 degree grid size of the original and revised Chen (2003) data. Lastly, **Figure 5** highlights the EPPA4 regions corresponding to each of the grids for the Chen (2003) emissions maps.

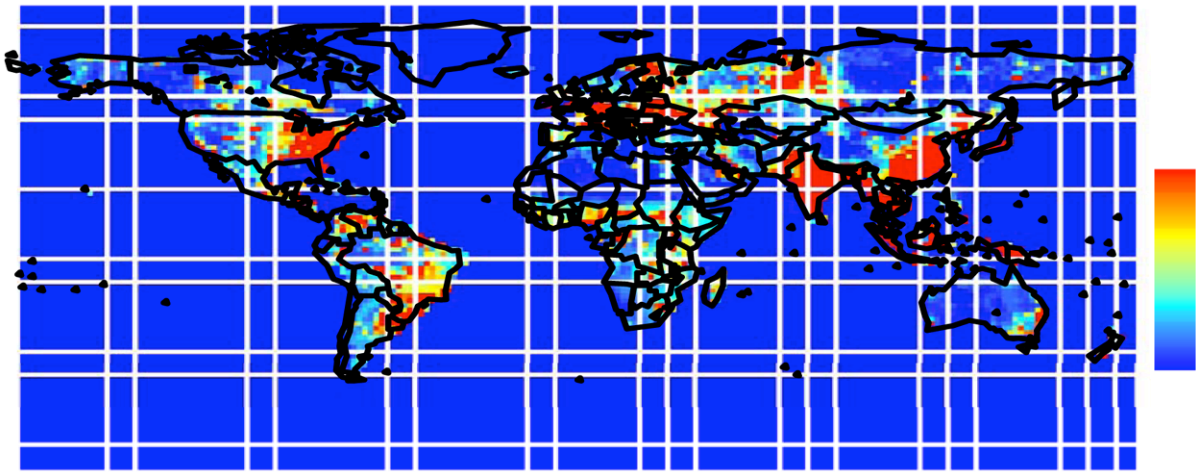

Figure 1. CH_4 Total Reference Emissions: Annual Total.
(Common graduated scale in kg/m^2/s.)

[1] The initial global country coverage is provided by Olivier *et al.* (2001), although required re-projection from 1° x 1° latitude-longitude to 1.8° x 1.8° latitude-longitude using GIS before overlay with methane-activity maps.

[2] Chen (2003) map data is reported monthly. These data were aggregated to produce annual emissions maps for illustration here.

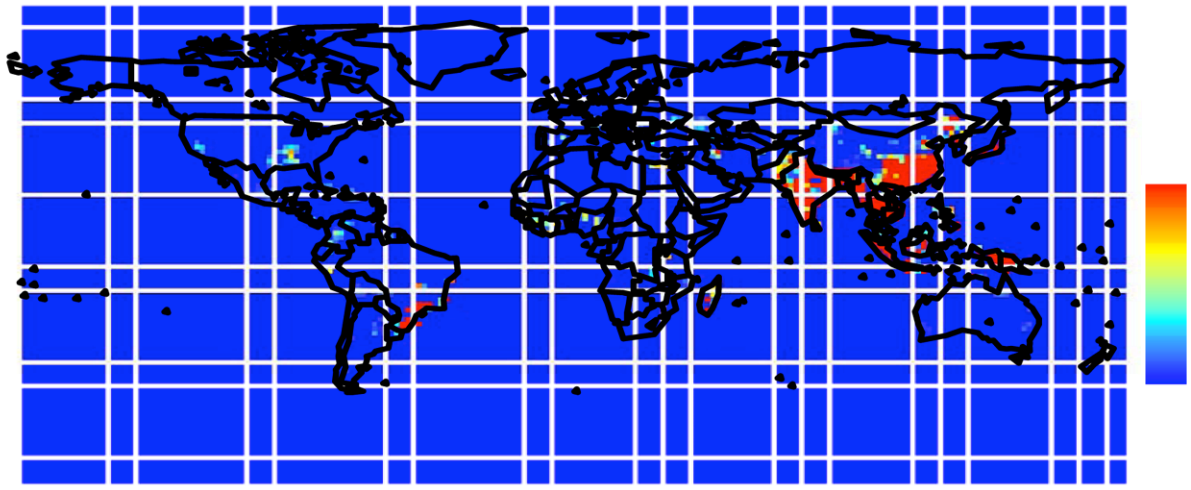

Figure 2. CH_4 Emissions from Rice & Wetland in Southeast Asia: Annual Total.

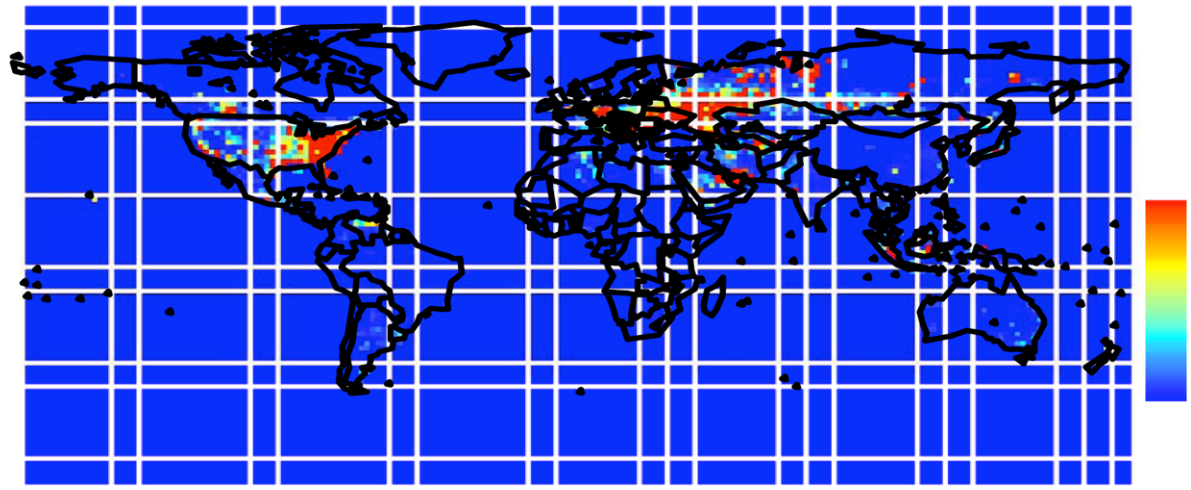

Figure 3. CH_4 Emissions from Natural Gas: Annual Total.

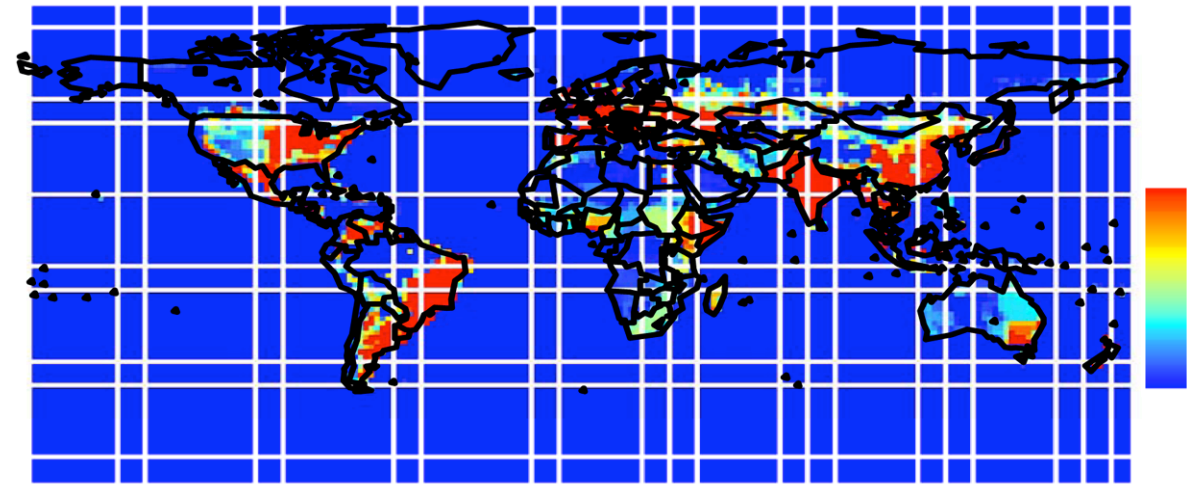

Figure 4. CH_4 Emissions from Animal & Waste: Annual Total.

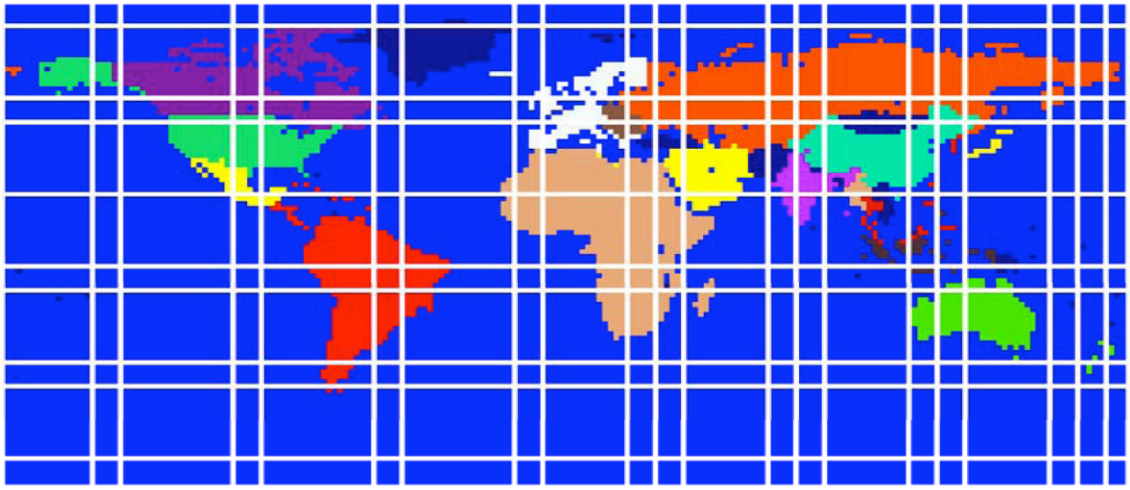

Figure 5. EPPA4 Regions for Chen (2003).

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Table 2. Rice Activities

Year	EPPA4 Region	Rice Area (MHA)	Rice Production (MMT)
1980	USA	1.340	6.629
1981	USA	1.535	8.289
1982	USA	1.320	6.969
1983	USA	0.878	4.523
1984	USA	1.134	6.296
1985	USA	1.009	6.122
1986	USA	0.955	6.049
1987	USA	0.944	5.879
1988	USA	1.174	7.253
1989	USA	1.087	7.007
1990	USA	1.142	7.080
1991	USA	1.125	7.230
1992	USA	1.268	8.149
1993	USA	1.147	7.081
1994	USA	1.342	8.971
1995	USA	1.252	7.887
1996	USA	1.135	7.784
1997	USA	1.256	8.301
1998	USA	1.318	8.364
1999	USA	1.421	9.344
2000	USA	1.230	8.658
2001	USA	1.342	9.764
1980	CAN	0.000	0.000
1981	CAN	0.000	0.000
1982	CAN	0.000	0.000
1983	CAN	0.000	0.000
1984	CAN	0.000	0.000
1985	CAN	0.000	0.000
1986	CAN	0.000	0.000
1987	CAN	0.000	0.000
1988	CAN	0.000	0.000
1989	CAN	0.000	0.000
1990	CAN	0.000	0.000
1991	CAN	0.000	0.000
1992	CAN	0.000	0.000
1993	CAN	0.000	0.000
1994	CAN	0.000	0.000
1995	CAN	0.000	0.000
1996	CAN	0.000	0.000
1997	CAN	0.000	0.000
1998	CAN	0.000	0.000
1999	CAN	0.000	0.000
2000	CAN	0.000	0.000
2001	CAN	0.000	0.000
1980	MEX	0.127	0.445
1981	MEX	0.175	0.710
1982	MEX	0.157	0.516
1983	MEX	0.133	0.421
1984	MEX	0.126	0.487
1985	MEX	0.216	0.808

Year	EPPA4 Region	Rice Area (MHA)	Rice Production (MMT)
1986	MEX	0.157	0.545
1987	MEX	0.155	0.591
1988	MEX	0.127	0.457
1989	MEX	0.151	0.527
1990	MEX	0.105	0.394
1991	MEX	0.085	0.347
1992	MEX	0.090	0.394
1993	MEX	0.059	0.287
1994	MEX	0.088	0.374
1995	MEX	0.078	0.367
1996	MEX	0.087	0.394
1997	MEX	0.113	0.469
1998	MEX	0.102	0.458
1999	MEX	0.083	0.394
2000	MEX	0.084	0.351
2001	MEX	0.053	0.227
1980	JPN	2.377	12.189
1981	JPN	2.278	12.824
1982	JPN	2.257	12.838
1983	JPN	2.273	12.958
1984	JPN	2.315	14.848
1985	JPN	2.342	14.578
1986	JPN	2.303	14.559
1987	JPN	2.146	13.284
1988	JPN	2.110	12.419
1989	JPN	2.097	12.934
1990	JPN	2.074	13.124
1991	JPN	2.049	12.005
1992	JPN	2.106	13.216
1993	JPN	2.139	9.793
1994	JPN	2.212	14.976
1995	JPN	2.118	13.435
1996	JPN	1.977	12.930
1997	JPN	1.953	12.531
1998	JPN	1.801	11.200
1999	JPN	1.788	11.469
2000	JPN	1.770	11.863
2001	JPN	1.706	11.320
1980	ANZ	0.116	0.613
1981	ANZ	0.106	0.760
1982	ANZ	0.127	0.857
1983	ANZ	0.077	0.520
1984	ANZ	0.119	0.634
1985	ANZ	0.122	0.864
1986	ANZ	0.106	0.687
1987	ANZ	0.096	0.549
1988	ANZ	0.105	0.761
1989	ANZ	0.097	0.805
1990	ANZ	0.105	0.924
1991	ANZ	0.089	0.787
1992	ANZ	0.127	1.122

Year	EPPA4 Region	Rice Area (MHA)	Rice Production (MMT)
1993	ANZ	0.125	0.955
1994	ANZ	0.133	1.082
1995	ANZ	0.129	1.137
1996	ANZ	0.150	0.951
1997	ANZ	0.167	1.388
1998	ANZ	0.141	1.331
1999	ANZ	0.152	1.390
2000	ANZ	0.133	1.101
2001	ANZ	0.177	1.643
1980	EUR	0.304	1.661
1981	EUR	0.284	1.555
1982	EUR	0.299	1.663
1983	EUR	0.272	1.479
1984	EUR	0.307	1.714
1985	EUR	0.318	1.897
1986	EUR	0.333	1.961
1987	EUR	0.331	1.886
1988	EUR	0.348	1.943
1989	EUR	0.332	1.944
1990	EUR	0.375	2.238
1991	EUR	0.370	2.191
1992	EUR	0.361	2.165
1993	EUR	0.339	1.974
1994	EUR	0.377	2.215
1995	EUR	0.367	2.109
1996	EUR	0.429	2.662
1997	EUR	0.425	2.717
1998	EUR	0.407	2.668
1999	EUR	0.399	2.696
2000	EUR	0.401	2.463
2001	EUR	0.398	2.548
1980	EET	0.052	0.130
1981	EET	0.050	0.160
1982	EET	0.050	0.169
1983	EET	0.056	0.204
1984	EET	0.062	0.204
1985	EET	0.062	0.230
1986	EET	0.068	0.262
1987	EET	0.072	0.208
1988	EET	0.076	0.225
1989	EET	0.075	0.141
1990	EET	0.062	0.131
1991	EET	0.038	0.073
1992	EET	0.026	0.068
1993	EET	0.020	0.060
1994	EET	0.010	0.033
1995	EET	0.012	0.042
1996	EET	0.014	0.039
1997	EET	0.010	0.029
1998	EET	0.008	0.023
1999	EET	0.005	0.018

Year	EPPA4 Region	Rice Area (MHA)	Rice Production (MMT)
2000	EET	0.008	0.032
2001	EET	0.007	0.028
1980	FSU		2.594
1981	FSU		2.314
1982	FSU		2.306
1983	FSU		2.430
1984	FSU		2.539
1985	FSU		2.400
1986	FSU		2.405
1987	FSU		2.428
1988	FSU		2.597
1989	FSU		2.253
1990	FSU		2.166
1991	FSU		1.986
1992	FSU	0.448	
1993	FSU	0.447	
1994	FSU	0.373	
1995	FSU	0.298	
1996	FSU	0.318	
1997	FSU	0.301	
1998	FSU	0.273	
1999	FSU	0.312	
2000	FSU	0.365	
2001	FSU	0.289	
1980	ASI	14.609	32.371
1981	ASI	14.483	34.854
1982	ASI	14.050	34.604
1983	ASI	14.641	36.186
1984	ASI	14.706	37.276
1985	ASI	15.127	38.670
1986	ASI	14.484	37.705
1987	ASI	14.324	36.191
1988	ASI	15.230	40.190
1989	ASI	15.297	39.903
1990	ASI	14.036	36.685
1991	ASI	14.370	39.292
1992	ASI	14.226	38.746
1993	ASI	13.593	36.493
1994	ASI	14.428	40.672
1995	ASI	14.600	41.071
1996	ASI	14.953	42.965
1997	ASI	15.498	44.280
1998	ASI	14.412	40.728
1999	ASI	15.728	45.028
2000	ASI	15.701	47.571
2001	ASI	15.941	48.979
1980	CHN	34.482	142.877
1981	CHN	33.928	146.960
1982	CHN	33.697	164.741
1983	CHN	33.782	172.009
1984	CHN	33.765	181.096

Year	EPPA4 Region	Rice Area (MHA)	Rice Production (MMT)
1985	CHN	32.634	171.319
1986	CHN	32.798	174.721
1987	CHN	32.694	176.662
1988	CHN	32.459	171.442
1989	CHN	33.176	182.485
1990	CHN	33.519	191.615
1991	CHN	33.019	185.693
1992	CHN	32.487	188.292
1993	CHN	30.746	179.747
1994	CHN	30.537	177.994
1995	CHN	31.107	187.298
1996	CHN	31.754	197.033
1997	CHN	32.129	202.772
1998	CHN	31.572	200.572
1999	CHN	31.637	200.403
2000	CHN	30.301	189.814
2001	CHN	29.144	179.305
1980	IND	40.152	80.312
1981	IND	40.708	79.883
1982	IND	38.262	70.772
1983	IND	41.244	90.048
1984	IND	41.159	87.553
1985	IND	41.137	95.818
1986	IND	41.167	90.779
1987	IND	38.806	85.339
1988	IND	41.736	106.369
1989	IND	42.167	110.311
1990	IND	42.687	111.517
1991	IND	42.649	112.042
1992	IND	41.775	109.001
1993	IND	42.539	120.400
1994	IND	42.814	122.640
1995	IND	42.800	115.440
1996	IND	43.400	122.500
1997	IND	43.470	123.700
1998	IND	44.802	129.055
1999	IND	45.160	134.496
2000	IND	44.712	127.400
2001	IND	44.622	139.900
1980	IDZ	9.005	29.652
1981	IDZ	9.382	32.774
1982	IDZ	8.988	33.584
1983	IDZ	9.162	35.303
1984	IDZ	9.764	38.136
1985	IDZ	9.902	39.033
1986	IDZ	9.988	39.727
1987	IDZ	9.923	40.078
1988	IDZ	10.138	41.676
1989	IDZ	10.531	44.726
1990	IDZ	10.502	45.179
1991	IDZ	10.282	44.688

Year	EPPA4 Region	Rice Area (MHA)	Rice Production (MMT)
1992	IDZ	11.103	48.240
1993	IDZ	11.013	48.181
1994	IDZ	10.734	46.642
1995	IDZ	11.439	49.744
1996	IDZ	11.570	51.102
1997	IDZ	11.141	49.377
1998	IDZ	11.730	49.237
1999	IDZ	11.963	50.866
2000	IDZ	11.793	51.898
2001	IDZ	11.500	50.461
1980	AFR	4.957	8.580
1981	AFR	5.048	8.528
1982	AFR	5.176	8.888
1983	AFR	5.076	8.928
1984	AFR	5.095	8.932
1985	AFR	5.119	9.390
1986	AFR	5.245	9.805
1987	AFR	5.214	10.126
1988	AFR	5.520	10.303
1989	AFR	6.416	12.680
1990	AFR	6.037	12.316
1991	AFR	6.507	13.421
1992	AFR	6.598	13.677
1993	AFR	6.527	14.204
1994	AFR	6.784	13.849
1995	AFR	6.904	14.693
1996	AFR	6.968	16.075
1997	AFR	7.374	16.860
1998	AFR	7.540	16.110
1999	AFR	7.668	17.709
2000	AFR	7.616	17.631
2001	AFR	7.584	16.595
1980	MES	0.514	1.549
1981	MES	0.532	1.954
1982	MES	0.561	1.955
1983	MES	0.499	1.531
1984	MES	0.506	1.764
1985	MES	0.538	2.046
1986	MES	0.526	2.059
1987	MES	0.580	2.078
1988	MES	0.518	1.681
1989	MES	0.585	2.184
1990	MES	0.571	2.211
1991	MES	0.623	2.557
1992	MES	0.639	2.575
1993	MES	0.633	2.506
1994	MES	0.604	2.459
1995	MES	0.616	2.501
1996	MES	0.655	2.965
1997	MES	0.618	2.625
1998	MES	0.675	3.086

Year	EPPA4 Region	Rice Area (MHA)	Rice Production (MMT)
1999	MES	0.652	2.688
2000	MES	0.592	2.321
2001	MES	0.574	2.350
1980	LAM	8.080	15.998
1981	LAM	8.081	15.102
1982	LAM	8.082	17.018
1983	LAM	6.974	14.418
1984	LAM	7.414	16.462
1985	LAM	6.774	16.198
1986	LAM	7.494	17.077
1987	LAM	8.037	17.995
1988	LAM	8.011	19.405
1989	LAM	7.434	19.323
1990	LAM	6.071	15.181
1991	LAM	6.212	17.072
1992	LAM	6.956	18.374
1993	LAM	6.629	18.415
1994	LAM	6.824	19.806
1995	LAM	6.852	20.943
1996	LAM	5.847	18.912
1997	LAM	5.598	19.126
1998	LAM	5.597	17.820
1999	LAM	6.613	24.116
2000	LAM	6.303	22.637
2001	LAM	5.748	22.045
1980	ROW	27.627	60.620
1981	ROW	27.831	62.768
1982	ROW	27.905	64.432
1983	ROW	27.135	66.384
1984	ROW	27.109	66.725
1985	ROW	27.725	68.063
1986	ROW	28.093	69.507
1987	ROW	27.104	67.217
1988	ROW	27.856	69.800
1989	ROW	28.497	76.215
1990	ROW	28.813	76.838
1991	ROW	28.351	78.431
1992	ROW	28.620	81.789
1993	ROW	29.421	87.135
1994	ROW	29.393	84.703
1995	ROW	30.421	88.663
1996	ROW	30.455	90.875
1997	ROW	30.482	91.440
1998	ROW	30.863	96.945
1999	ROW	32.947	108.985
2000	ROW	32.747	113.812
2001	ROW	32.308	111.591

Table 3. Fossil Fuel Activities

Year	EPPA4 Region	Coal Production (EJ)	Petroleum Production (EJ)	Natural Gas Consumption (EJ)
1980	USA	18.753	18.311	15.701
1981	USA	18.528	18.207	15.422
1982	USA	18.825	18.371	14.186
1983	USA	17.441	18.454	13.446
1984	USA	19.961	18.958	14.425
1985	USA	19.471	19.103	13.804
1986	USA	19.598	18.526	13.154
1987	USA	20.479	17.814	13.638
1988	USA	20.838	17.417	14.863
1989	USA	21.516	16.245	14.601
1990	USA	22.573	15.695	14.099
1991	USA	21.705	15.826	13.978
1992	USA	21.693	15.344	14.137
1993	USA	20.429	14.610	14.808
1994	USA	22.426	14.215	14.877
1995	USA	22.255	13.997	15.186
1996	USA	22.908	13.832	15.856
1997	USA	23.527	13.767	16.240
1998	USA	24.037	13.341	15.384
1999	USA	23.493	12.550	15.345
2000	USA	22.731	12.457	16.747
2001	USA	24.057	12.379	15.591
1980	CAN	0.859	2.744	1.686
1981	CAN	0.934	2.451	1.660
1982	CAN	0.990	2.401	1.697
1983	CAN	1.013	2.493	1.680
1984	CAN	1.327	2.797	1.811
1985	CAN	1.413	2.781	1.927
1986	CAN	1.313	2.786	1.848
1987	CAN	1.324	2.943	1.846
1988	CAN	1.534	3.078	1.980
1989	CAN	1.631	2.934	2.052
1990	CAN	1.588	2.931	2.015
1991	CAN	1.663	2.877	2.053
1992	CAN	1.480	2.996	2.132
1993	CAN	1.571	3.135	2.225
1994	CAN	1.650	3.237	2.303
1995	CAN	1.710	3.347	2.361
1996	CAN	1.741	3.424	2.511
1997	CAN	1.801	3.619	2.486
1998	CAN	1.703	3.815	2.316
1999	CAN	1.640	3.535	2.389
2000	CAN	1.553	3.763	2.485
2001	CAN	1.575	3.777	2.269

Year	EPPA4 Region	Coal Production (EJ)	Petroleum Production (EJ)	Natural Gas Consumption (EJ)
1980	MEX	0.076	4.532	0.597
1981	MEX	0.075	5.405	0.692
1982	MEX	0.087	6.390	0.719
1983	MEX	0.108	6.186	0.766
1984	MEX	0.117	6.256	0.681
1985	MEX	0.118	6.104	0.696
1986	MEX	0.123	5.660	0.596
1987	MEX	0.135	5.954	0.645
1988	MEX	0.117	5.892	0.628
1989	MEX	0.127	5.895	0.605
1990	MEX	0.129	5.872	0.659
1991	MEX	0.115	6.168	0.698
1992	MEX	0.120	6.157	0.676
1993	MEX	0.129	6.175	0.674
1994	MEX	0.173	6.149	0.715
1995	MEX	0.181	5.985	0.776
1996	MEX	0.203	6.287	0.722
1997	MEX	0.209	6.685	0.657
1998	MEX	0.222	6.787	0.570
1999	MEX	0.204	6.529	0.517
2000	MEX	0.227	6.620	0.498
2001	MEX	0.223	6.793	0.411
1980	JPN	0.457	0.018	0.272
1981	JPN	0.463	0.017	0.281
1982	JPN	0.455	0.009	0.287
1983	JPN	0.427	0.009	0.318
1984	JPN	0.415	0.009	0.398
1985	JPN	0.403	0.015	0.400
1986	JPN	0.392	0.019	0.433
1987	JPN	0.313	0.019	0.448
1988	JPN	0.267	0.018	0.466
1989	JPN	0.242	0.015	0.522
1990	JPN	0.189	0.018	0.538
1991	JPN	0.188	0.028	0.583
1992	JPN	0.180	0.031	0.614
1993	JPN	0.171	0.028	0.663
1994	JPN	0.160	0.027	0.685
1995	JPN	0.150	0.027	0.738
1996	JPN	0.146	0.026	0.777
1997	JPN	0.094	0.024	0.822
1998	JPN	0.088	0.021	0.830
1999	JPN	0.087	0.018	0.875
2000	JPN	0.065	0.016	0.931
2001	JPN	0.070	0.014	0.942
1980	ANZ	2.202	0.830	0.250

Year	EPPA4 Region	Coal Production (EJ)	Petroleum Production (EJ)	Natural Gas Consumption (EJ)
1981	ANZ	2.536	0.815	0.273
1982	ANZ	2.681	0.813	0.289
1983	ANZ	2.880	0.792	0.309
1984	ANZ	3.047	0.965	0.338
1985	ANZ	3.401	1.121	0.380
1986	ANZ	3.739	1.173	0.402
1987	ANZ	4.151	1.160	0.423
1988	ANZ	3.834	1.168	0.429
1989	ANZ	4.215	1.065	0.441
1990	ANZ	4.450	1.196	0.462
1991	ANZ	4.648	1.198	0.476
1992	ANZ	4.919	1.056	0.481
1993	ANZ	4.982	1.040	0.496
1994	ANZ	4.969	0.972	0.524
1995	ANZ	5.352	1.020	0.558
1996	ANZ	5.442	0.951	0.582
1997	ANZ	5.840	0.979	0.595
1998	ANZ	6.251	1.017	0.608
1999	ANZ	6.418	0.771	0.632
2000	ANZ	6.835	1.120	0.667
2001	ANZ	7.466	1.179	0.690
1980	EUR	10.514	4.894	6.814
1981	EUR	10.728	5.250	6.837
1982	EUR	10.755	5.919	6.577
1983	EUR	10.378	6.788	6.749
1984	EUR	8.729	7.458	7.102
1985	EUR	9.888	7.772	7.471
1986	EUR	10.051	7.851	7.542
1987	EUR	9.647	8.165	7.999
1988	EUR	9.481	8.161	7.879
1989	EUR	9.363	7.854	8.093
1990	EUR	8.730	8.235	8.272
1991	EUR	8.011	8.778	9.027
1992	EUR	7.403	9.452	8.973
1993	EUR	6.520	9.997	9.236
1994	EUR	5.783	11.980	9.209
1995	EUR	5.851	12.318	9.753
1996	EUR	5.488	12.997	10.687
1997	EUR	5.305	12.960	10.329
1998	EUR	4.721	12.803	10.608
1999	EUR	4.591	13.056	10.746
2000	EUR	4.187	13.335	11.069
2001	EUR	4.156	12.595	11.378
1980	EET	7.440	0.582	2.149
1981	EET	6.705	0.587	2.190

Year	EPPA4 Region	Coal Production (EJ)	Petroleum Production (EJ)	Natural Gas Consumption (EJ)
1982	EET	7.366	0.588	2.219
1983	EET	7.547	0.574	2.247
1984	EET	7.655	0.567	2.334
1985	EET	7.636	0.539	2.072
1986	EET	7.717	0.510	2.161
1987	EET	7.814	0.480	2.207
1988	EET	7.795	0.476	2.141
1989	EET	7.301	0.467	2.164
1990	EET	6.227	0.415	2.063
1991	EET	5.908	0.366	1.715
1992	EET	5.885	0.358	1.359
1993	EET	5.808	0.360	1.388
1994	EET	5.669	0.360	1.510
1995	EET	5.746	0.365	1.656
1996	EET	5.925	0.354	1.742
1997	EET	5.755	0.344	1.691
1998	EET	5.070	0.335	1.598
1999	EET	4.739	0.331	1.544
2000	EET	4.659	0.332	1.583
2001	EET	4.701	0.332	1.687
1980	FSU	14.182	24.876	8.454
1981	FSU	13.793	25.091	8.882
1982	FSU	13.718	25.230	9.198
1983	FSU	13.307	25.364	9.612
1984	FSU	12.998	25.192	10.077
1985	FSU	13.083	24.530	10.603
1986	FSU	13.560	25.214	11.064
1987	FSU	13.617	25.531	11.590
1988	FSU	13.893	25.494	12.097
1989	FSU	13.327	24.788	12.375
1990	FSU	12.582	23.248	12.891
1991	FSU	11.583	20.784	12.238
1992	FSU	11.564	18.658	10.643
1993	FSU	10.446	16.612	10.432
1994	FSU	9.353	15.059	9.322
1995	FSU	8.499	14.561	9.013
1996	FSU	7.569	14.459	9.137
1997	FSU	7.272	14.801	8.546
1998	FSU	7.032	14.855	8.692
1999	FSU	7.468	15.161	9.149
2000	FSU	7.778	16.096	9.240
2001	FSU	8.168	17.412	9.327
1980	ASI	0.367	0.628	0.001
1981	ASI	0.392	0.580	0.002
1982	ASI	0.408	0.697	0.002

Year	EPPA4 Region	Coal Production (EJ)	Petroleum Production (EJ)	Natural Gas Consumption (EJ)
1983	ASI	0.411	0.896	0.003
1984	ASI	0.446	1.050	0.014
1985	ASI	0.504	1.067	0.029
1986	ASI	0.538	1.192	0.048
1987	ASI	0.554	1.170	0.053
1988	ASI	0.563	1.277	0.057
1989	ASI	0.519	1.369	0.069
1990	ASI	0.494	1.450	0.088
1991	ASI	0.481	1.505	0.110
1992	ASI	0.418	1.547	0.144
1993	ASI	0.384	1.571	0.193
1994	ASI	0.367	1.594	0.236
1995	ASI	0.354	1.683	0.300
1996	ASI	0.376	1.728	0.392
1997	ASI	0.391	1.738	0.458
1998	ASI	0.349	1.755	0.491
1999	ASI	0.322	1.636	0.603
2000	ASI	0.321	1.602	0.729
2001	ASI	0.338	1.700	0.796
1980	CHN	13.009	4.516	0.296
1981	CHN	13.020	4.314	0.278
1982	CHN	13.958	4.353	0.268
1983	CHN	14.976	4.521	0.271
1984	CHN	16.551	4.885	0.290
1985	CHN	17.532	5.323	0.414
1986	CHN	17.983	5.570	0.439
1987	CHN	18.675	5.717	0.439
1988	CHN	19.780	5.841	0.467
1989	CHN	21.322	5.867	0.499
1990	CHN	22.494	5.791	0.517
1991	CHN	22.634	5.903	0.514
1992	CHN	23.314	5.949	0.487
1993	CHN	24.159	6.078	0.497
1994	CHN	26.048	6.116	0.515
1995	CHN	28.920	6.282	0.522
1996	CHN	30.068	6.587	0.546
1997	CHN	29.876	6.730	0.514
1998	CHN	29.038	6.741	0.592
1999	CHN	28.066	6.699	0.623
2000	CHN	28.404	6.824	0.701
2001	CHN	29.256	6.865	0.796
1980	IND	2.337	0.450	0.032
1981	IND	2.550	0.693	0.047
1982	IND	2.705	0.901	0.054
1983	IND	2.837	1.113	0.061

Year	EPPA4 Region	Coal Production (EJ)	Petroleum Production (EJ)	Natural Gas Consumption (EJ)
1984	IND	3.084	1.240	0.072
1985	IND	3.193	1.291	0.105
1986	IND	3.504	1.304	0.140
1987	IND	3.776	1.299	0.146
1988	IND	4.110	1.371	0.225
1989	IND	4.223	1.459	0.274
1990	IND	4.522	1.413	0.262
1991	IND	4.896	1.298	0.267
1992	IND	5.088	1.153	0.324
1993	IND	5.210	1.156	0.321
1994	IND	5.346	1.379	0.342
1995	IND	5.660	1.505	0.359
1996	IND	5.966	1.408	0.369
1997	IND	6.174	1.449	0.428
1998	IND	6.009	1.400	0.394
1999	IND	6.124	1.391	0.430
2000	IND	6.319	1.387	0.452
2001	IND	6.541	1.371	0.418
1980	IDZ	0.008	3.329	0.110
1981	IDZ	0.009	3.378	0.123
1982	IDZ	0.012	2.774	0.123
1983	IDZ	0.013	2.787	0.147
1984	IDZ	0.028	3.128	0.174
1985	IDZ	0.051	2.783	0.225
1986	IDZ	0.066	3.005	0.250
1987	IDZ	0.078	2.639	0.258
1988	IDZ	0.119	2.499	0.264
1989	IDZ	0.227	2.605	0.239
1990	IDZ	0.270	2.710	0.244
1991	IDZ	0.353	2.985	0.265
1992	IDZ	0.576	2.813	0.301
1993	IDZ	0.755	2.855	0.325
1994	IDZ	0.831	3.036	0.321
1995	IDZ	1.059	3.034	0.363
1996	IDZ	1.292	3.008	0.380
1997	IDZ	1.413	3.000	0.390
1998	IDZ	1.597	2.965	0.403
1999	IDZ	1.900	2.859	0.504
2000	IDZ	1.972	2.698	0.556
2001	IDZ	2.383	2.557	0.520
1980	AFR	2.929	12.723	0.135
1981	AFR	3.215	9.807	0.166
1982	AFR	3.471	9.273	0.189
1983	AFR	3.626	9.236	0.195
1984	AFR	4.054	10.075	0.229

Year	EPPA4 Region	Coal Production (EJ)	Petroleum Production (EJ)	Natural Gas Consumption (EJ)
1985	AFR	4.319	10.530	0.257
1986	AFR	4.416	10.366	0.336
1987	AFR	4.437	10.273	0.349
1988	AFR	4.548	10.746	0.335
1989	AFR	4.416	11.554	0.332
1990	AFR	4.395	12.409	0.417
1991	AFR	4.493	12.973	0.451
1992	AFR	4.410	13.107	0.491
1993	AFR	4.679	12.966	0.522
1994	AFR	4.845	13.055	0.506
1995	AFR	5.078	13.450	0.526
1996	AFR	5.065	14.139	0.533
1997	AFR	5.375	14.563	0.563
1998	AFR	5.439	14.692	0.590
1999	AFR	5.452	14.332	0.678
2000	AFR	5.466	14.830	0.790
2001	AFR	5.445	14.868	0.861
1980	MES	0.281	39.700	0.613
1981	MES	0.312	33.877	0.552
1982	MES	0.336	27.607	0.590
1983	MES	0.356	24.911	0.681
1984	MES	0.397	24.275	0.827
1985	MES	0.475	21.856	0.936
1986	MES	0.509	25.631	1.304
1987	MES	0.543	26.403	1.546
1988	MES	0.504	30.350	1.641
1989	MES	0.558	33.553	1.931
1990	MES	0.542	34.103	1.740
1991	MES	0.519	34.187	1.870
1992	MES	0.526	37.389	2.099
1993	MES	0.518	39.380	2.284
1994	MES	0.535	39.668	2.589
1995	MES	0.535	40.107	2.875
1996	MES	0.539	40.291	3.031
1997	MES	0.574	42.113	3.245
1998	MES	0.614	44.547	3.356
1999	MES	0.585	43.067	3.481
2000	MES	0.586	45.463	3.772
2001	MES	0.570	44.253	3.674
1980	LAM	0.263	8.304	0.709
1981	LAM	0.277	8.229	0.665
1982	LAM	0.295	7.824	0.735
1983	LAM	0.314	7.770	0.799
1984	LAM	0.379	8.178	0.895
1985	LAM	0.439	8.052	0.922

Year	EPPA4 Region	Coal Production (EJ)	Petroleum Production (EJ)	Natural Gas Consumption (EJ)
1986	LAM	0.490	8.566	0.940
1987	LAM	0.548	8.477	1.015
1988	LAM	0.649	8.834	1.020
1989	LAM	0.754	8.925	1.052
1990	LAM	0.800	9.682	1.113
1991	LAM	0.768	10.251	1.179
1992	LAM	0.801	10.508	1.195
1993	LAM	0.814	10.964	1.305
1994	LAM	0.875	11.476	1.364
1995	LAM	0.947	12.474	1.461
1996	LAM	1.044	13.810	1.613
1997	LAM	1.170	14.545	1.587
1998	LAM	1.266	14.827	1.689
1999	LAM	1.215	14.374	1.751
2000	LAM	1.401	14.661	1.826
2001	LAM	1.525	14.583	1.926
1980	ROW	1.227	0.644	0.186
1981	ROW	1.285	0.471	0.219
1982	ROW	1.354	0.475	0.257
1983	ROW	1.364	0.485	0.267
1984	ROW	1.373	0.487	0.269
1985	ROW	1.447	0.522	0.279
1986	ROW	1.446	0.544	0.292
1987	ROW	1.426	0.506	0.333
1988	ROW	1.407	0.518	0.353
1989	ROW	1.371	0.540	0.377
1990	ROW	1.288	0.604	0.372
1991	ROW	1.260	0.696	0.372
1992	ROW	1.174	0.917	0.514
1993	ROW	1.123	0.924	0.503
1994	ROW	1.055	0.936	0.524
1995	ROW	1.076	0.936	0.576
1996	ROW	1.023	0.965	0.608
1997	ROW	1.035	1.003	0.632
1998	ROW	0.987	1.090	0.660
1999	ROW	1.005	1.234	0.679
2000	ROW	1.097	1.308	0.698
2001	ROW	1.150	1.359	0.751

Table 4. Livestock and Waste Activities

Year	EPPA4 Region	Livestock (MH)	Pigs (MH)	Population (MH)
1980	USA	125.390	67.341	227.332
1981	USA	128.729	64.487	229.576
1982	USA	129.901	58.723	231.776
1983	USA	128.614	54.560	233.907
1984	USA	126.393	56.720	235.943
1985	USA	121.902	54.099	238.045
1986	USA	117.347	52.341	240.257
1987	USA	114.341	50.947	242.416
1988	USA	112.424	54.411	244.628
1989	USA	109.528	55.484	246.951
1990	USA	109.156	53.803	249.757
1991	USA	109.478	54.431	253.119
1992	USA	110.433	57.664	256.656
1993	USA	111.418	58.217	260.063
1994	USA	112.853	57.955	263.269
1995	USA	113.705	59.753	266.422
1996	USA	113.994	58.216	269.539
1997	USA	111.411	56.139	272.803
1998	USA	109.050	61.173	276.003
1999	USA	107.761	62.221	279.192
2000	USA	106.611	59.357	282.379
2001	USA	105.723	59.154	285.475
1980	CAN	12.637	10.091	24.593
1981	CAN	12.722	10.190	24.900
1982	CAN	12.761	9.970	25.202
1983	CAN	12.455	9.890	25.456
1984	CAN	12.209	10.346	25.702
1985	CAN	11.872	10.573	25.942
1986	CAN	11.475	9.967	26.204
1987	CAN	11.182	9.998	26.550
1988	CAN	11.307	10.801	26.895
1989	CAN	11.575	10.951	27.379
1990	CAN	11.847	10.392	27.791
1991	CAN	11.949	10.172	28.172
1992	CAN	12.548	10.596	28.520
1993	CAN	12.524	10.744	28.833
1994	CAN	12.683	10.534	29.112
1995	CAN	13.358	11.291	29.354
1996	CAN	14.077	11.588	29.672
1997	CAN	14.072	11.480	29.987
1998	CAN	14.055	11.985	30.248
1999	CAN	13.962	12.429	30.499
2000	CAN	14.028	12.904	30.770
2001	CAN	14.590	13.576	31.082

Year	EPPA4 Region	Livestock (MH)	Pigs (MH)	Population (MH)
1980	MEX	50.212	16.890	67.570
1981	MEX	51.766	17.562	69.193
1982	MEX	52.889	18.096	70.785
1983	MEX	52.467	19.364	72.354
1984	MEX	52.465	19.393	73.911
1985	MEX	55.156	17.233	75.465
1986	MEX	54.401	18.397	77.016
1987	MEX	53.858	18.722	78.566
1988	MEX	53.432	15.884	80.116
1989	MEX	55.528	16.157	81.668
1990	MEX	54.706	15.203	83.226
1991	MEX	54.248	15.786	84.793
1992	MEX	53.738	16.502	86.369
1993	MEX	54.225	16.832	87.954
1994	MEX	53.477	16.200	89.546
1995	MEX	52.999	15.923	91.145
1996	MEX	51.571	15.405	92.571
1997	MEX	52.487	15.735	93.926
1998	MEX	52.424	14.972	95.251
1999	MEX	51.740	15.748	96.584
2000	MEX	51.804	16.088	97.966
2001	MEX	52.028	17.584	99.377
1980	JPN	4.327	9.998	116.782
1981	JPN	4.463	10.065	117.648
1982	JPN	4.564	10.040	118.449
1983	JPN	4.668	10.273	119.259
1984	JPN	4.759	10.423	120.018
1985	JPN	4.772	10.718	120.754
1986	JPN	4.816	11.061	121.492
1987	JPN	4.769	11.354	122.091
1988	JPN	4.737	11.725	122.613
1989	JPN	4.748	11.866	123.116
1990	JPN	4.825	11.817	123.537
1991	JPN	4.940	11.335	123.921
1992	JPN	5.044	10.966	124.229
1993	JPN	5.085	10.783	124.536
1994	JPN	5.045	10.621	124.961
1995	JPN	4.966	10.250	125.439
1996	JPN	4.875	9.900	125.761
1997	JPN	4.795	9.823	126.091
1998	JPN	4.750	9.904	126.410
1999	JPN	4.703	9.879	126.650
2000	JPN	4.633	9.806	126.870
2001	JPN	4.576	9.788	127.140
1980	ANZ	239.329	2.952	17.805

Year	EPPA4 Region	Livestock (MH)	Pigs (MH)	Population (MH)
1981	ANZ	237.783	2.850	18.072
1982	ANZ	241.084	2.778	18.359
1983	ANZ	233.995	2.899	18.591
1984	ANZ	239.438	2.963	18.797
1985	ANZ	249.146	2.966	19.030
1986	ANZ	247.197	2.989	19.295
1987	ANZ	244.919	3.036	19.569
1988	ANZ	248.934	3.120	19.882
1989	ANZ	254.343	3.082	20.212
1990	ANZ	260.971	3.042	20.513
1991	ANZ	251.406	2.939	20.779
1992	ANZ	233.679	3.204	21.024
1993	ANZ	221.367	3.041	21.234
1994	ANZ	217.197	3.198	21.467
1995	ANZ	205.170	3.084	21.736
1996	ANZ	204.365	2.950	22.044
1997	ANZ	202.677	2.962	22.315
1998	ANZ	198.066	3.119	22.566
1999	ANZ	196.900	2.995	22.802
2000	ANZ	197.860	2.880	23.040
2001	ANZ	188.372	3.102	23.295
1980	EUR	188.571	115.104	365.909
1981	EUR	189.514	116.096	367.175
1982	EUR	193.885	117.037	367.920
1983	EUR	195.689	116.419	368.448
1984	EUR	198.900	117.620	368.910
1985	EUR	199.268	118.722	369.542
1986	EUR	212.094	125.476	370.298
1987	EUR	210.674	124.588	371.149
1988	EUR	217.822	127.112	372.217
1989	EUR	221.727	123.825	374.033
1990	EUR	223.790	124.445	375.767
1991	EUR	222.750	119.310	377.443
1992	EUR	219.469	117.885	379.275
1993	EUR	217.117	121.530	380.955
1994	EUR	215.982	122.156	382.226
1995	EUR	214.036	121.495	383.203
1996	EUR	211.442	119.462	384.412
1997	EUR	214.915	122.408	385.766
1998	EUR	215.471	122.820	386.584
1999	EUR	214.192	125.476	387.781
2000	EUR	212.861	124.437	389.088
2001	EUR	204.230	124.280	390.405
1980	EET	57.645	44.410	72.265
1981	EET	57.164	42.159	72.721

Year	EPPA4 Region	Livestock (MH)	Pigs (MH)	Population (MH)
1982	EET	58.436	44.075	73.117
1983	EET	57.671	41.076	73.513
1984	EET	60.234	44.616	73.893
1985	EET	60.245	45.361	74.224
1986	EET	57.347	44.791	74.496
1987	EET	56.282	45.378	74.704
1988	EET	54.488	46.183	74.918
1989	EET	53.840	45.632	74.896
1990	EET	51.184	43.147	74.846
1991	EET	46.290	46.057	74.816
1992	EET	42.031	42.703	74.850
1993	EET	40.341	44.226	74.847
1994	EET	36.997	42.643	74.912
1995	EET	34.328	40.993	74.901
1996	EET	33.552	39.780	74.847
1997	EET	32.161	39.776	74.790
1998	EET	30.370	39.076	74.705
1999	EET	29.179	39.118	74.598
2000	EET	27.998	35.626	74.385
2001	EET	26.696	33.566	73.943
1980	FSU		73.893	265.752
1981	FSU		73.382	268.007
1982	FSU		73.302	270.235
1983	FSU		76.671	272.569
1984	FSU		78.722	274.983
1985	FSU		77.914	277.473
1986	FSU		77.772	279.960
1987	FSU		79.501	282.496
1988	FSU		77.403	285.057
1989	FSU		78.100	287.466
1990	FSU		78.963	289.089
1991	FSU		75.428	290.498
1992	FSU	247.417		291.550
1993	FSU	237.039		291.989
1994	FSU	221.816		291.921
1995	FSU	189.550		291.636
1996	FSU	166.406		291.257
1997	FSU	142.632		290.803
1998	FSU	127.841		290.304
1999	FSU	119.099		289.528
2000	FSU	116.720		288.469
2001	FSU	115.886		287.491
1980	ASI	10.827	15.575	149.054
1981	ASI	10.748	16.192	152.267
1982	ASI	11.243	16.804	155.503

Year	EPPA4 Region	Livestock (MH)	Pigs (MH)	Population (MH)
1983	ASI	12.053	18.733	158.646
1984	ASI	12.490	17.664	161.707
1985	ASI	13.196	17.181	164.596
1986	ASI	13.095	17.515	167.558
1987	ASI	13.027	18.249	170.669
1988	ASI	12.900	19.551	173.904
1989	ASI	13.252	20.083	177.236
1990	ASI	12.967	20.258	180.753
1991	ASI	13.534	20.869	183.950
1992	ASI	14.123	21.183	187.074
1993	ASI	15.107	21.734	190.098
1994	ASI	15.520	23.000	193.063
1995	ASI	16.159	24.111	196.180
1996	ASI	16.596	24.965	199.210
1997	ASI	16.703	27.092	202.307
1998	ASI	16.179	27.950	205.360
1999	ASI	15.793	26.835	208.403
2000	ASI	15.616	27.543	211.651
2001	ASI	15.453	28.694	214.777
1980	CHN	266.366	325.678	986.274
1981	CHN	271.198	310.723	999.005
1982	CHN	274.011	298.976	1013.832
1983	CHN	272.244	306.472	1028.595
1984	CHN	259.976	304.931	1042.195
1985	CHN	256.162	313.861	1056.496
1986	CHN	258.999	338.442	1072.314
1987	CHN	274.598	344.601	1089.616
1988	CHN	291.942	335.220	1107.257
1989	CHN	316.742	349.522	1124.336
1990	CHN	329.743	360.898	1140.890
1991	CHN	330.389	371.210	1156.535
1992	CHN	328.338	379.911	1170.772
1993	CHN	332.527	394.070	1184.341
1994	CHN	347.905	402.943	1197.833
1995	CHN	381.155	424.787	1211.011
1996	CHN	417.082	398.617	1223.986
1997	CHN	364.735	373.644	1236.564
1998	CHN	392.682	408.425	1248.479
1999	CHN	408.462	429.202	1260.342
2000	CHN	420.997	437.541	1269.310
2001	CHN	433.431	454.410	1278.575
1980	IND	386.601	9.000	687.332
1981	IND	395.789	9.600	702.821
1982	IND	408.487	10.072	718.426
1983	IND	414.070	10.200	734.072

Year	EPPA4 Region	Livestock (MH)	Pigs (MH)	Population (MH)
1984	IND	417.671	10.300	749.677
1985	IND	420.373	10.400	765.147
1986	IND	426.426	10.500	781.893
1987	IND	433.699	10.606	798.680
1988	IND	438.143	11.000	815.590
1989	IND	442.633	11.500	832.535
1990	IND	447.135	12.000	849.515
1991	IND	451.781	12.500	866.530
1992	IND	457.043	12.788	882.821
1993	IND	458.800	13.500	899.329
1994	IND	461.842	13.783	915.697
1995	IND	464.689	14.306	932.180
1996	IND	467.700	14.848	948.759
1997	IND	470.991	13.291	965.428
1998	IND	470.416	13.400	982.183
1999	IND	469.770	13.600	999.016
2000	IND	469.224	13.700	1015.923
2001	IND	468.678	13.900	1032.473
1980	IDZ	20.712	3.155	148.303
1981	IDZ	20.971	3.364	151.305
1982	IDZ	21.229	3.587	154.245
1983	IDZ	27.051	4.248	157.157
1984	IDZ	25.702	5.112	160.076
1985	IDZ	27.077	5.560	163.036
1986	IDZ	28.995	6.216	166.015
1987	IDZ	28.553	6.339	168.990
1988	IDZ	29.401	6.484	171.994
1989	IDZ	30.225	6.936	175.063
1990	IDZ	31.049	7.136	178.232
1991	IDZ	31.570	7.612	181.320
1992	IDZ	32.848	8.135	184.322
1993	IDZ	31.628	8.704	187.232
1994	IDZ	33.983	8.858	190.043
1995	IDZ	35.006	7.720	192.750
1996	IDZ	36.551	7.597	195.457
1997	IDZ	36.864	8.233	198.163
1998	IDZ	35.168	7.798	200.867
1999	IDZ	33.707	7.042	203.568
2000	IDZ	33.405	5.357	206.265
2001	IDZ	33.336	5.867	209.014
1980	AFR	402.032	10.173	464.062
1981	AFR	406.268	10.739	477.651
1982	AFR	414.352	10.449	491.637
1983	AFR	419.566	10.565	506.001
1984	AFR	410.232	11.103	520.702

Year	EPPA4 Region	Livestock (MH)	Pigs (MH)	Population (MH)
1985	AFR	417.622	12.038	535.725
1986	AFR	423.292	13.274	550.843
1987	AFR	431.301	13.948	566.281
1988	AFR	441.951	14.326	582.044
1989	AFR	459.335	15.540	598.246
1990	AFR	472.123	16.414	615.035
1991	AFR	478.824	16.669	632.023
1992	AFR	494.442	16.997	649.337
1993	AFR	561.985	17.126	663.536
1994	AFR	577.943	17.453	678.507
1995	AFR	586.890	17.871	696.419
1996	AFR	598.521	17.932	714.377
1997	AFR	621.610	18.404	733.358
1998	AFR	638.648	18.799	750.862
1999	AFR	658.573	18.627	768.117
2000	AFR	661.547	19.538	785.142
2001	AFR	676.658	20.819	802.989
1980	MES	174.040	0.149	136.038
1981	MES	179.682	0.152	140.487
1982	MES	183.840	0.156	145.231
1983	MES	187.938	0.154	150.148
1984	MES	188.123	0.148	155.238
1985	MES	176.181	0.166	160.555
1986	MES	184.023	0.160	165.605
1987	MES	184.214	0.177	170.683
1988	MES	184.127	0.181	175.771
1989	MES	194.065	0.174	180.817
1990	MES	194.705	0.177	187.872
1991	MES	189.958	0.182	193.157
1992	MES	192.863	0.182	196.502
1993	MES	193.458	0.178	201.111
1994	MES	193.203	0.182	205.678
1995	MES	193.029	0.197	212.090
1996	MES	193.759	0.191	217.791
1997	MES	195.534	0.205	221.496
1998	MES	193.726	0.203	226.181
1999	MES	190.068	0.156	230.863
2000	MES	191.628	0.170	235.629
2001	MES	186.736	0.181	240.446
1980	LAM	402.362	58.402	292.135
1981	LAM	407.926	56.096	298.404
1982	LAM	407.356	56.981	304.754
1983	LAM	406.008	56.225	311.123
1984	LAM	406.579	57.467	317.485
1985	LAM	410.721	56.509	323.845

Year	EPPA4 Region	Livestock (MH)	Pigs (MH)	Population (MH)
1986	LAM	416.516	57.156	330.162
1987	LAM	422.588	57.243	336.441
1988	LAM	431.721	57.802	342.619
1989	LAM	440.941	56.939	348.816
1990	LAM	443.762	57.498	354.973
1991	LAM	447.740	59.309	361.180
1992	LAM	451.104	60.390	367.394
1993	LAM	440.292	60.663	373.583
1994	LAM	444.565	62.567	379.782
1995	LAM	443.606	62.533	385.984
1996	LAM	429.952	55.376	392.153
1997	LAM	431.550	55.672	398.250
1998	LAM	429.108	56.387	404.300
1999	LAM	432.319	59.343	410.245
2000	LAM	439.306	61.216	416.073
2001	LAM	445.417	62.435	422.198
1980	ROW	173.338	19.932	360.536
1981	ROW	177.548	21.280	368.498
1982	ROW	181.903	22.717	376.336
1983	ROW	186.438	23.324	384.249
1984	ROW	192.139	24.352	392.346
1985	ROW	196.061	24.894	400.707
1986	ROW	200.432	25.231	409.828
1987	ROW	205.522	26.120	419.166
1988	ROW	210.856	26.274	428.630
1989	ROW	214.654	27.429	438.125
1990	ROW	220.756	26.681	447.471
1991	ROW	225.803	27.180	456.005
1992	ROW	241.486	34.050	460.694
1993	ROW	247.954	34.674	470.347
1994	ROW	254.640	34.777	480.155
1995	ROW	262.697	35.319	471.638
1996	ROW	260.192	36.770	480.457
1997	ROW	264.811	36.982	489.365
1998	ROW	267.704	37.761	498.079
1999	ROW	273.608	39.487	506.991
2000	ROW	278.093	40.737	515.668
2001	ROW	278.504	39.282	524.640

Table 5. Initial Methane Emissions Coefficients with Uncertainty Measures

$\partial E / \partial p_i$		σ_{pi}	
$\partial E / \partial p_1$	3.598	σ_{p1}	4.880
$\partial E / \partial p_2$	23.433	σ_{p2}	68.952
$\partial E / \partial p_3$	19.117	σ_{p3}	45.133
$\partial E / \partial p_4$	178.403	σ_{p4}	927.336
$\partial E / \partial p_5$	0.143	σ_{p5}	0.144
$\partial E / \partial p_6$	0.069	σ_{p6}	0.048

Where:
E = Methane Emissions (MMT)
p_i = Methane-generating activity where i=1,2,…5
$\partial E / \partial p_i$ = Methane emissions coefficient
σ_{pi} = Standard deviation (*i.e.* uncertainty measure)
p_1 = Rice yield (MHA/MMT)
p_2 = Coal production (EJ)
p_3 = Petroleum production (EJ)
p_4 = Natural gas consumption (EJ)
p_5 = Total livestock (MH)
p_6 = Population (MH)