Mapping the Global Supply and Demand Structure of Rice

Kan-ichiro Matsumura[1)], Rover J. Hijmans[2)], Yann.Chemin[2)],
Christopher D.Elvidge[3)], Kenji Sugimoto[4)], Wenbin Wu[4)], Yang-won Lee[4)],
Ryosuke Shibasaki[4)]

1. Dept of Informatics, School of Policy Studies, Kwansei Gakuin University
2. International Rice Research Institute
3. U.S. Department of Commerce, NOAA National Geophysical Data Center,
4. Center for Spatial Information Science, The University of Tokyo

K Matsumura
Dept of Informatics, School of Policy Studies, Kwansei Gakuin University
Sanda, Hyogo 669-1337, JAPAN
Tel: +81-79-565-9026 Fax: +81-79-565-7605
any85636@kwansei.ac.jp

R Hijmans・Y Chemin

Geography (GIS) lab, International Rice Research Institute, Los Banos, Laguna, Philippines
R.Hijmans@cgiar.org , Y.Chemin@cgiar.org
TEL:+63 (2) 580-5600 Fax: +63 (2) 580-5699 (Contact Information)

C.D. Elvidge
U.S. Department of Commerce, NOAA National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80205 USA
Fax: 303-497-6513
chris.elvidge@noaa.gov

K Sugimoto, W Wu, Y Lee, R Shibasaki
Center for Spatial Information Science, The University of Tokyo
4-6-1, Komaba, Meguro-ku, Tokyo 153-8505, Japan
TEL:+81-3-5452-6412 Fax:+81-3-5452-6414
koc@iis.u-tokyo.ac.jp, wwbyn@iis.u-tokyo.ac.jp
lee@iis.u-tokyo.ac.jp, shiba@csis.u-tokyo.ac.jp

Abstract

The constraints of maintaining sustainable rice production are closely linked to the relationship between the distribution patterns of human activity on the planet and economic growth occurring on the landscape. In this study, each country includes regions and we discussed for regional distribution. A region is delineated by its administrative boundaries. The number of region where rice is produced is about 13,839.

Rice plays a major role in the global supply and demand for sustainable food production. Global patterns of rice production can be mapped by using various criteria linked to domestic income, population patterns, and associated satellite brightness data of rice producing regions. Prosperous regions have more electric lighting. There are documented correlations between Gross Domestic Product (GDP) and nighttime lights. Nominal value of GDP is used. We thought that it would be advisable to look at the global rice production pattern on a geographical basis. We used gridded spatial population distribution data overlain by nocturnal light imagery derived from satellite imagery. The resultant relationship revealed a correlation to regional income in the world. The following criteria were used to obtain the supply and demand structure of rice.

·global rice consumption=“caloric rice consumption per day per capita” multiplied by “regional population values”.

·regional rice yields=“country based production” divided by “harvested area” (multiple harvests are taken into consideration)

·regional rice production = “regional harvested areas” multiplied by “rice yield values”

We compared regional rice consumption and production values using the methods given above. An analysis of these data sets generated a map of rice supply and demand. Inter-regional shipping costs were not accounted for. This map can contribute to an understanding of food security issues in rice producing regions and to estimating potential population values in the respective regions.

Key words: Rice consumption, Nocturnal lights, Gridded population, Harvested area

1. Introduction

Rice production has consistently outpaced population growth. Subsequently, rice plays a crucial role in the supporting continued global population growth. World rice production in 2007 was approximately 645 million tons, with Asian farmers producing 90% and China and India producing 50% of the global rice supply (Kawashima 2008). In 1962, Asian farmers produced 92% of world rice production. According to Food Balance Sheet (year 2002), feed use of rice is less than 1.8% of total production (IRRI 2008). In recent years, a rice production deficit due to high population growth has threatened the historic trend of sustainable global rice production. The amount of traded rice is very small. Rice shortages have been occurring in some regions of the world. Our research is focused on the global supply and demand for rice. Methodology is illustrated by the flowchart analysis in Figure1. Key points of our research are following.

Demographic income and population: Spatial distribution of income and associated population values, makes it possible for us to estimate consumption (caloric intake of rice per capita.) Earth Observation Group (EOG), NOAA has compiled a data archive (DMSP 2008), conducted research in the Products of Defense Meteorological Satellite Program (DMSP), and produced a global poverty map produced using a poverty index (Elvidge.C.D.et al. 2006). This is calculated by: “population values” divided by “the brightness of satellite observed lighting (DMSP nighttime lights)”. Night time data can be useful tools to estimate intensity of economic activities and spatial distribution of income.

Regional incomes: Derived from national income in each respective region are obtained using both nocturnal light satellite imagery, and from spatial population distribution datasets.

Rice consumption: A time series dataset of country based daily caloric rice intake per capita is provided by Commodities and Trade Division, FAO. To avoid the influence of currency exchange rates skewing the datasets, the respective country’s national currency based nominal GDP is used. The daily caloric rice intake per capita of each region in a country is obtained by applying the regional income to this formula. The rice area per region of each country is developed by the International Rice Research Institute (IRRI) in the Philippines.

Rice Yield: Country based Rice production and harvested area are obtained from the website provided by Food and Agricultural Organization (FAO-STAT) and a yield is obtained dividing “rice production” by “harvested area”.

Rice Production: The rice production is obtained multiplying a yield by a regional harvested area. This process generates a map of rice supply and demand. It thus becomes possible to pinpoint the areas where agricultural investment is most necessary. This map of rice supply and demand will allow investors to identify the areas where agricultural investment is most vital.

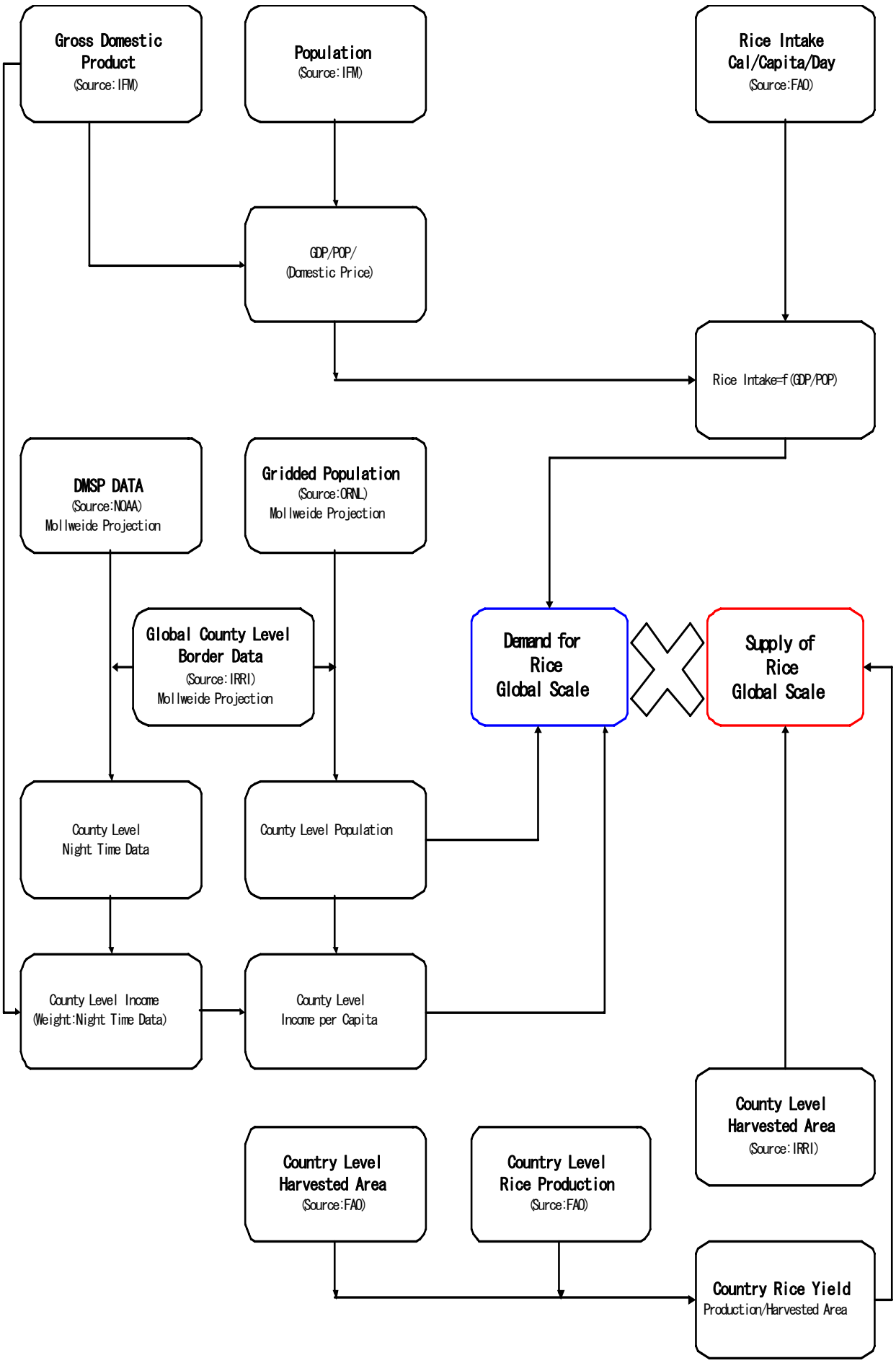
Gross Domestic Product
(Source:IFM)
Population
(Source:IFM)
Rice Intake Cal/Capita/Day
(Source:FAO)
GDP/POP/
(Domestic Price)
Rice Intake=f(GDP/POP)
DMSP DATA
(Source:NOAA)
Mollweide Projection
Gridded Population
(Source:ORNL)
Mollweide Projection
Global County Level Border Data
(Source:IRRI)
Mollweide Projection
Demand for Rice Global Scale
Supply of Rice Global Scale
County Level Night Time Data
County Level Population
County Level Income
(Weight:Night Time Data)
County Level Income per Capita
County Level Harvested Area
(Source:IRRI)
Country Level Harvested Area
(Source:FAO)
Country Level Rice Production
(Surce:FAO)
Country Rice Yield
Production/Harvested Area

Fig.1. Flowchart of data analysis

2. Materials

2.1 Satellite image data of nocturnal light on the earth

The existence of Defense Meteorological Satellite Image Data (DMSP) is well known. Nocturnal light data has been used as an indicator of economic activities. The data is being used to estimate population size and economic activity in various places on the earth, such as the expansion of urban areas (Nakaya 2002), energy consumption and GDP (Imhoff et al. 1997). In recent years, earth's nocturnal light data, collected by multiple satellites from 1992-2003, has been available on the Internet[3)]. In order to achieve consistency with our population data, we used data on amount of nocturnal light collected by the F15 satellite in 2002. The amount of light is given as a numerical value ranging from 0 to 64. We define light volume as multiplying light intensity in each grid by grid numbers surrounded by country border.

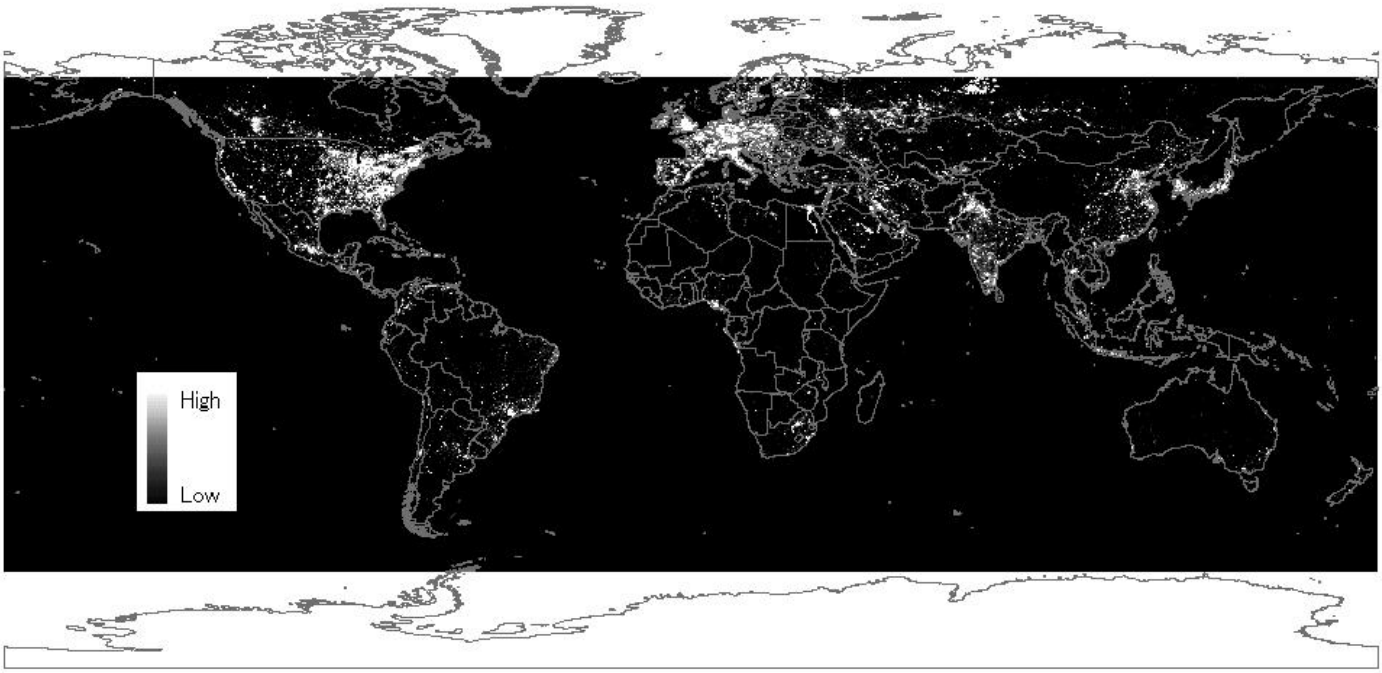

Fig.2. Defense Meteorological Satellite Image Data showing intensity of light

The relationships between logarithmic GDP and logarithmic Light Volume were calculated and shown in Table 1.

Table.1. Correlation coefficient and regression coefficient of Volume of Light and GDP

Regression Coefficient	Constant	Correlation Coefficient	Significance
0.87	12.01	0.823	1%

The light volume (F15 Satellite, 2002) and GDP in US dollars at the same period are shown in Figure 3.

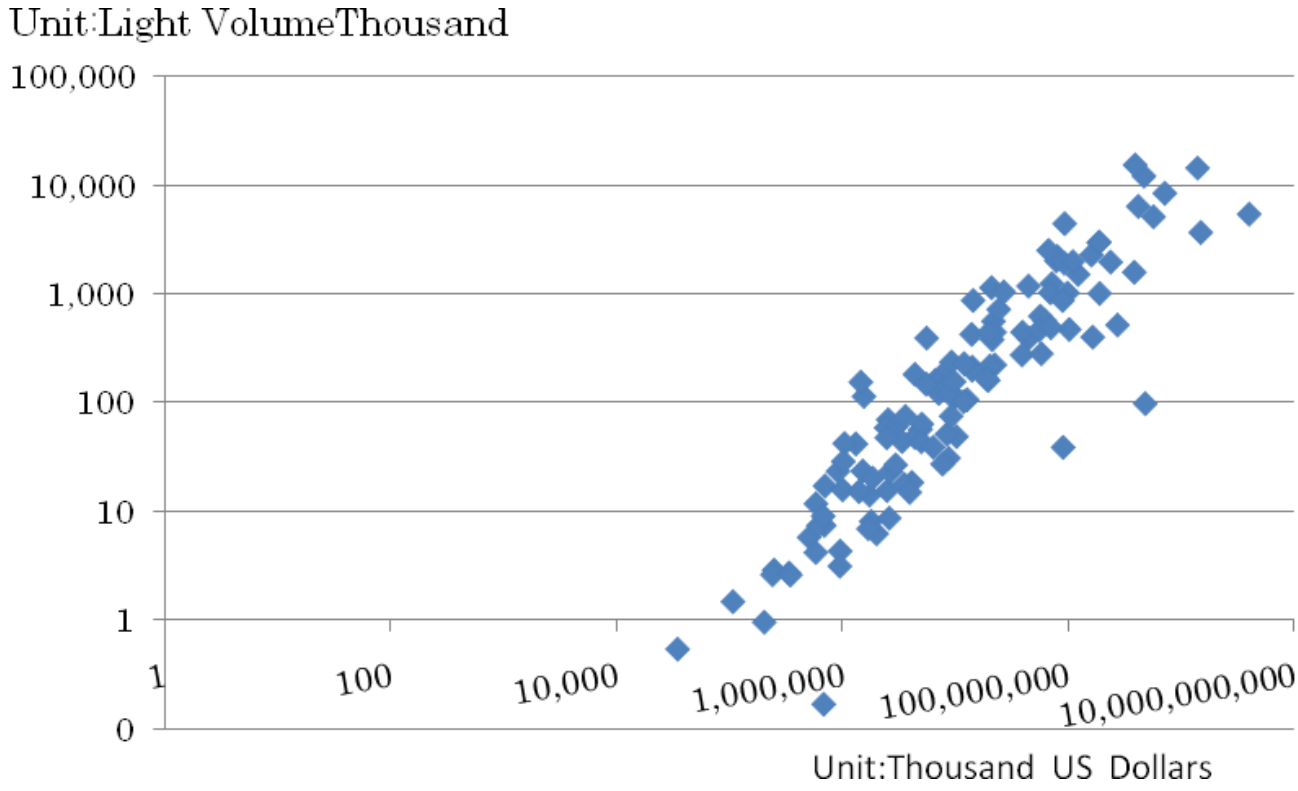

Fig.3. GDP and Light Volume in 2002

2.2 Gridded Population Data

We used a data set of population distribution (Land Scan 2003) for 2002 from the Global Population Project for estimating ambient populations at risk collected by the Oak Ridge National Laboratory (ORNL). The grid size is 30 seconds by 30 seconds (often referred to as 1-km spatial resolution).

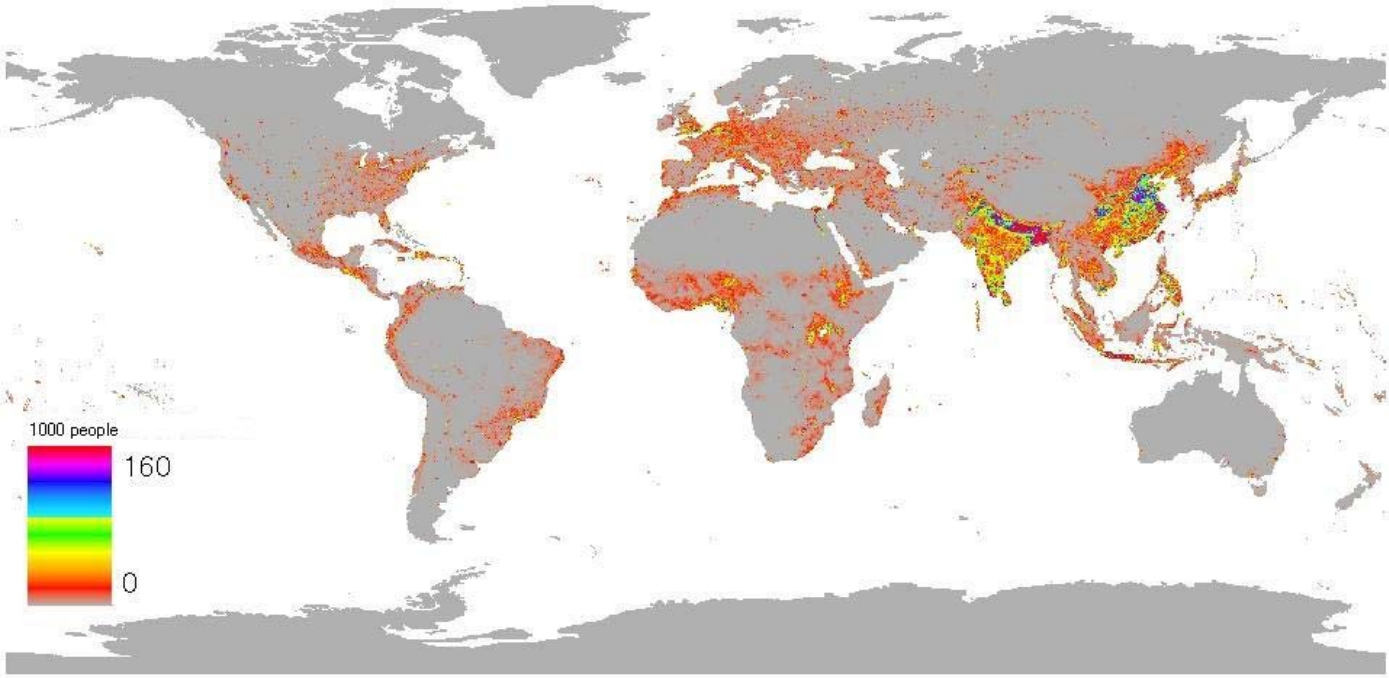

Fig.4. Gridded Population Data in 2002

2.3 Rice cultivation area data

We used a dataset produced by the GIS Team of the International Rice Research Institute (IRRI). The dataset is in a shape file format and provides information about rice cultivation areas by region for each country. Figure 5 shows the example of rice cultivation area in Nepal. In each region, country name, area name, rice area and irrigated area are provided.

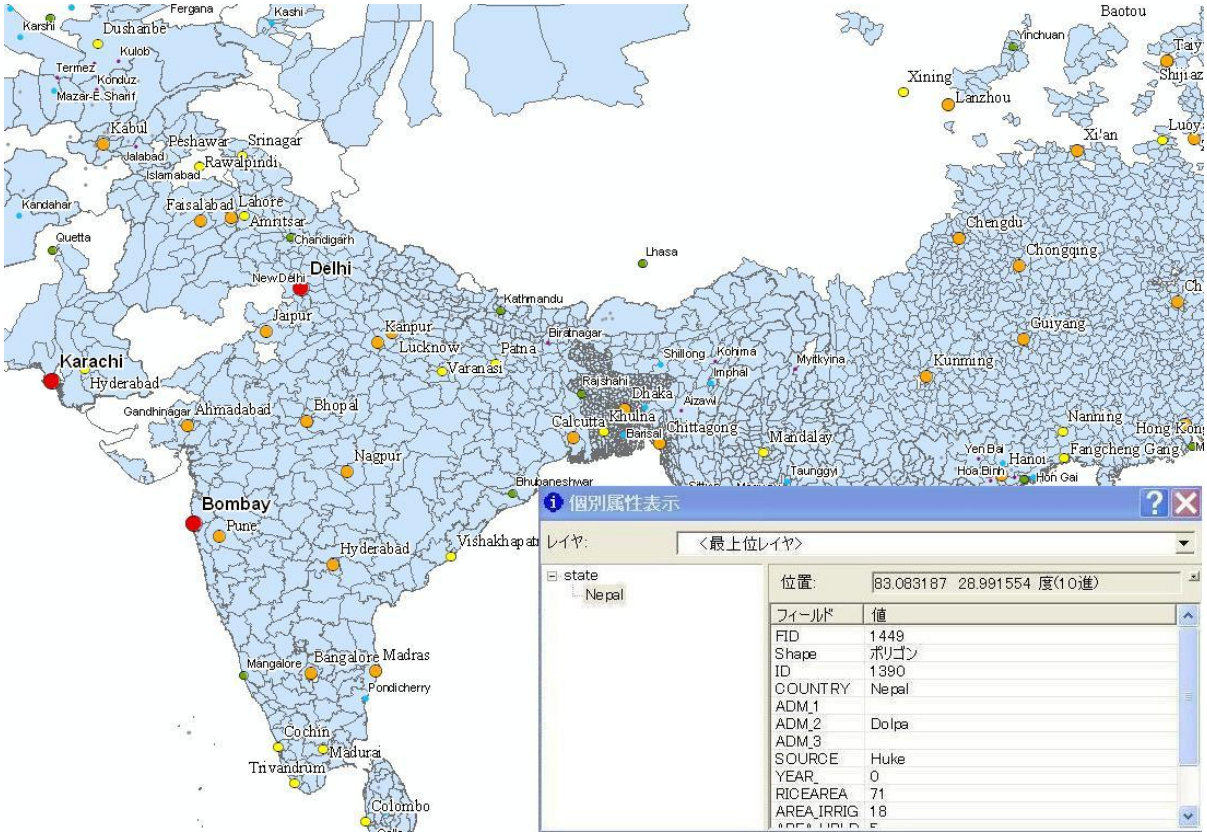

Fig.5. Rice Cultivation Area Dataset

2.4 Yield per region

The country based rice production per unit area in each country is calculated by dividing the rice production figures provided by the Food and Agriculture Organization (FAO) by the rice cultivation area(FAOSTAT 2008). We then applied the yield per region for each country uniformly to each of the regions in that country.

2.5 Population and income data

We used the information on the Gross Domestic Product and population provided in the IFS data set from the IMF(IFS CD-ROM 2009). We used nominal value of Gross Domestic Product per capita of each country in that country's own currency in order to avoid the influence of exchange rates.

2.6 Rice intake per capita per day

We used a dataset for caloric rice intake per capita per day. This dataset is developed by Dr.Koji Yanagishima, FAO and based on data collected during the period from 1960-2000. Least squares method was used to obtain the relationship between real income per capita in the local currency and caloric rice consumption per capita per day.

3. Data Analysis

3.1 Projections

In this study some of datasets are converted to Mollwide projection method. Projection methods are an important issue in cartography. The system generally used is based on a one-to-one ratio for longitude and latitude, causing distances to be distorted more and more as you near the poles. We made the decision to do our analysis using a Mollweide projection because the effects of area cannot be ignored in regions near the poles when calculating the total amount of nocturnal light in each region of the world. The projection method was not changed for population because that data is provided for areas with identifiable borders. There are many different map projections that can be used to express things in the form of a map, but to maintain the accuracy of the amount-of-light data extracted from the DMSP one has to use an equal-area projection. In an equal-area projection, distortion increases towards the edge of the map, but the distortion is not as extreme as on a sinusoidal projection. A Lambert azimuth equal-area projection gives equal areas, but is disk shaped which can be confusing, leading us to choose the Mollweide projection because it is the easiest to view and conceptualize.

3.2 Estimating the population in each region

We extracted the population of each region of the world from data on population distribution provided by the Oak Ridge National Laboratory (ORNL), using data on the borders by region of the world provided by the International Rice Research Institute.

3.3 Estimating income by region of the world

We obtained the total amount of light (light intensity *times* area) for each region of each country, derived from the satellite image data of nocturnal light on the earth. We calculated the income for each region of each country by multiplying (the real income of the whole country in the national currency) times (the region's amount of light divided by the amount of light for that whole country).

3.4 Relationships between income and caloric consumption of rice

We examined the relationship between the calorie consumption of rice per capita per day and the income (in the local national currency) country basis. Elasticity, intercept and co-relation are listed in Table.3. Gross Domestic Product (GDP) is used as income data. GDP is obtained from International Financial Statistics (IFS). Some countries provide very precise information such as deflator but some countries are not. The consumption of rice is function of own price, alternative price and income. However in this study, we defined rice consumption as function of domestic GDP per capita. We tried to estimate world wide rice consumption even in the undocumented areas.

Table.3. Caloric consumption of Rice and GDP per capita

	Periods of Estimation	Elasticity	Intercept	Corelation
Afghanistan, I.R. of				
Albania	1986	1.515	35.505	0.214
Algeria	1986	2.914	2.059	0.659
Angola	1992	-4.047	67.401	-0.606
Anguilla	Rice No Data			
Antigua and Barbuda		30.733	-209.358	0.872
Argentina		-1.089	54.337	-0.293
Armenia	1994	-7.086	121.198	-0.308
Aruba	Rice No Data			
Australia		56.717	-126.694	0.956
Austria		-0.318	45.465	-0.009
Azerbaijan, Rep. of	1995	-3.503	66.604	-0.063
Bahamas, The	1995	-106.803	1217.050	-0.640
Bahrain, Kingdom of	Rice No Data			
Bangladesh		76.902	1342.769	0.505
Barbados		-166.934	1804.931	-0.556
Belarus	1992	-0.890	18.451	-0.465
Belgium	Rice No Data			
Belize		131.759	-879.442	0.827
Benin		35.861	-5.009	0.240
Bhutan	Rice No Data			
Bolivia		36.375	-82.117	0.544
Bosnia & Herzegovina	96-	18.889	-133.035	0.712
Botswana		14.934	-66.265	0.765
Brazil		#NUM!	#NUM!	#NUM!
Brunei Darussalam		-317.048	3923.418	-0.275
Bulgaria		-2.342	48.605	-0.592
Burkina Faso		36.143	-302.173	0.449
Burundi		#DIV/0!	#DIV/0!	#DIV/0!
Cambodia	87-	-0.660	1473.054	-0.021
Cameroon		68.703	-299.336	0.495
Canada		69.424	-164.121	0.925
Cape Verde		208.869	-1885.943	0.759
Central African Rep.		18.463	-56.116	0.419
Chad		-16.875	164.964	-0.235
Chile		-6.176	115.666	-0.764
China,P.R.: Mainland		-14.391	957.337	-0.837
China,P.R.:Hong Kong		-128.181	1213.337	-0.681
China,P.R.:Macao		-144.793	2173.268	-0.935
Colombia		-17.657	429.058	-0.725
Comoros	until 95	-177.538	1555.150	-0.508
Congo, Dem. Rep. of	94-	-2.990	68.004	-0.944
Congo, Republic of		99.237	-494.764	0.574
Costa Rica		67.214	75.142	0.649
Côte d'Ivoire		136.115	-233.206	0.706
Croatia		9.572	-81.821	0.791
Cyprus		12.734	-67.363	0.711
Czech Republic	93-	19.062	-57.164	0.822
Denmark		1.655	9.770	0.034
Djibouti	GDP No Data			
Dominica		-43.366	498.904	-0.455
Dominican Republic		-27.517	692.209	-0.545
ECCU	Rice No Data			
Ecuador	GDP No Data			
Egypt		100.418	-415.988	0.978
El Salvador	GDP No Data			
Equatorial Guinea	Rice No Data			
Eritrea	GDP, Rice No Data			
Estonia	93-	10.150	-87.548	0.757
Ethiopia		0.561	-3.008	0.264
Fiji		46.678	117.599	0.311
Finland		6.643	10.106	0.147
France		18.877	-49.150	0.461
Gabon		155.850	-933.017	0.573
Gambia, The	Until 94	-135.041	1775.822	-0.475
Georgia	96-	-20.723	150.044	-0.823
Germany		21.974	-49.528	0.793
Ghana	Until 97	12.838	72.464	0.326
Greece		9.943	-23.529	0.815
Grenada		-50.406	657.284	-0.223
Guatemala		-2.464	57.062	-0.132
Guinea	GDP No Data			
Guinea-Bissau		-82.671	2010.586	-0.320
Guyana		-23.672	1084.849	-0.504
Haiti		136.386	-826.026	0.896
Honduras		16.838	-75.550	0.650
Hungary		3.227	28.635	0.526
Iceland		13.404	-167.532	0.846
India		8.743	735.172	0.153
Indonesia		60.773	982.857	0.830
Iran, I.R. of		7.269	266.841	0.142
Iraq	Until 93	-66.340	852.588	-0.657
Ireland		18.774	-149.663	0.919
Israel		21.093	-134.495	0.853
Italy		21.713	-19.054	0.952
Jamaica		36.057	-112.871	0.692
Japan		-183.488	2181.611	-0.841
Jordan		44.717	-111.453	0.218
Kazakhstan	93-	-17.657	142.319	-0.880
Kenya		9.743	-69.681	0.502
Korea		-173.483	2603.119	-0.962
Kuwait		247.348	-1598.668	0.690
Kyrgyz Republic	91-	3.425	-7.705	0.845
Lao People's Democratic Republ				
Lao People's Dem.Rep		-2.920	1542.095	-0.078

	Periods of Estimation	Elasticity	Intercept	Corelation
Latvia	93-	22.709	-144.489	0.984
Lebanon		3.811	72.637	0.851
Lesotho		2.564	-5.289	0.777
Liberia	GDP No Data			
Libya		59.021	-298.917	0.909
Lithuania	93-	17.715	-143.168	0.957
Luxembourg	RICE No Data			
Macedonia, FYR	GDP No Data			
Madagascar		-76.211	1345.237	-0.790
Malawi		6.100	-10.709	0.686
Malaysia		82.190	91.865	0.771
Maldives		95.302	-454.292	0.710
Mali		197.262	-604.649	0.840
Malta		17.761	-98.945	0.799
Mauritania		10.072	378.733	0.052
Mauritius		-89.779	1589.928	-0.807
Mexico		4.826	38.007	0.638
Micronesia, Fed.Sts.	GDP, Rice No Data			
Moldova	91-	3.475	-10.778	0.564
Mongolia		-9.029	148.328	-0.658
Montenegro, Rep. of	GDP, Rice No Data			
Montserrat	RICE No Data			
Morocco		0.857	7.870	0.035
Mozambique		-0.569	87.391	-0.089
Myanmar		21.073	1843.698	0.473
Namibia		442.226	-3501.103	0.858
Nepal		-18.354	1069.860	-0.119
Netherlands		28.125	-62.809	0.535
Netherlands Antilles	GDP No Data			
New Zealand		84.416	-799.978	0.961
Nicaragua	91-	26.520	124.307	0.355
Niger		41.918	-87.895	0.386
Nigeria		13.541	193.746	0.539
Norway		20.230	-77.767	0.910
Oman	RICE No Data			
Pakistan		-17.931	199.013	-0.314
Panama		-236.285	2330.744	-0.513
Papua New Guinea		-28.949	563.025	-0.285
Paraguay		3.332	109.781	0.099
Peru		9.831	349.085	0.641
Philippines		28.367	831.137	0.193
Poland		-0.061	18.761	-0.033
Portugal		-8.716	227.089	-0.247
Qatar	RICE No Data			
Romania		-1.149	39.556	-0.329
Russia	92-	-1.080	-1.851	0.904
Rwanda		10.105	-17.420	0.561
Samoa	RICE No Data			
San Marino	RICE No Data			
São TomE& Prú«cipe	GDP No Data			
Saudi Arabia		225.385	-413.902	0.645
Senegal		153.364	-203.645	0.529
Serbia, Republic of	GDP, Rice No Data			
Seychelles		-862.198	9381.427	-0.928
Sierra Leone		0.292	896.694	0.009
Singapore	RICE No Data			
Slovak Republic	93-	10.594	-74.437	0.396
Slovenia	92-	55.028	-1329.420	0.736
Solomon Islands		154.150	-702.124	0.813
South Africa		42.573	-294.851	0.967
Spain	GDP No Data			
Sri Lanka		-46.763	1390.087	-0.541
St. Kitts and Nevis		-56.451	778.352	-0.436
St. Lucia		130.906	-1084.618	0.571
St. Vincent & Grens.		-19.880	334.964	-0.072
Sudan		-1.245	16.875	-0.746
Suriname		-18.420	848.560	-0.434
Swaziland		39.911	-244.183	0.784
Sweden		3.369	26.358	0.106
Switzerland		35.391	-89.407	0.890
Syrian Arab Republic		-5.534	150.682	-0.926
Tajikistan	92-	-3.553	69.574	-0.934
Tanzania	GDP No Data			
Thailand		-164.379	1765.123	-0.855
Timor-Leste	GDP, Rice No Data			
Togo		170.681	-679.826	0.666
Tonga	RICE No Data			
Trinidad and Tobago		-62.939	930.140	-0.412
Tunisia		7.263	-41.404	0.707
Turkey	87-	2.159	52.881	0.505
Uganda		7.252	-9.250	0.767
Ukraine	92-	1.056	15.658	0.733
United Arab Emirates		236.092	-422.228	0.537
United Kingdom		-7.597	42.689	-0.724
United States		63.171	-126.270	0.969
Uruguay		7.826	29.995	0.777
Vanuatu	GDP No Data			
Venezuela, Rep. Bol.		10.235	143.913	0.551
Vietnam	90-	58.831	1180.740	0.806
West Bank and Gaza	RICE No Data			
Yemen, Republic of	90-	-7.611	191.310	-0.271
Zambia		0.198	11.547	0.118
Zimbabwe		3.182	10.790	0.456

3.5 Estimating the rice production

We estimated each country's rice productivity per unit area from its rice yield and rice cultivation area, dividing production by harvested area. Calculated values take into account multiple cropping. Rice production in each region is calculated multiplying yield by regional harvested area provided by the International Rice Research Institute (IRRI).

3.6 Estimating the caloric consumption of rice by region and country

We estimated the caloric consumption of rice per capita per day on the basis of the regional income of each country. We also estimated the annual rice intake on a caloric basis in each region of that country by multiplying the above estimation by the population of each region. In 2006, world rice production was reported by FAOSTAT to be 634,605,733 tons. On the other hand, the USDA PS&D(USDA 2008) reported that the world's rice production was 420,561 (thousand metric tons) in each of 2006 and 2007. It can be hypothesized that the rice yield may be reduced by about 1/3 by threshing. Rice has about 351 Kcal per 100 grams. With these statistics and the total caloric base of a region we can calculate the pre-threshing base quantity of rice that will be needed by each region.

3.7 Results

We calculated the rice supply and demand using income data obtained as of 2002. The IRRI data on rice cultivation areas were also collected around 2002. We obtained the size of the rice supply by multiplying the rice cultivation area by the rice yield per unit area in 2002. Figure 6 and 7 shows the difference in supply and demand by region. For example, if the difference is 0%, this means that the supply for rice does not match the demand in that region; if it is 100%, that means that the demand and the supply are equal in that region; and if it is 200%, that means that the supply exceeds the demand by 100% in that region.

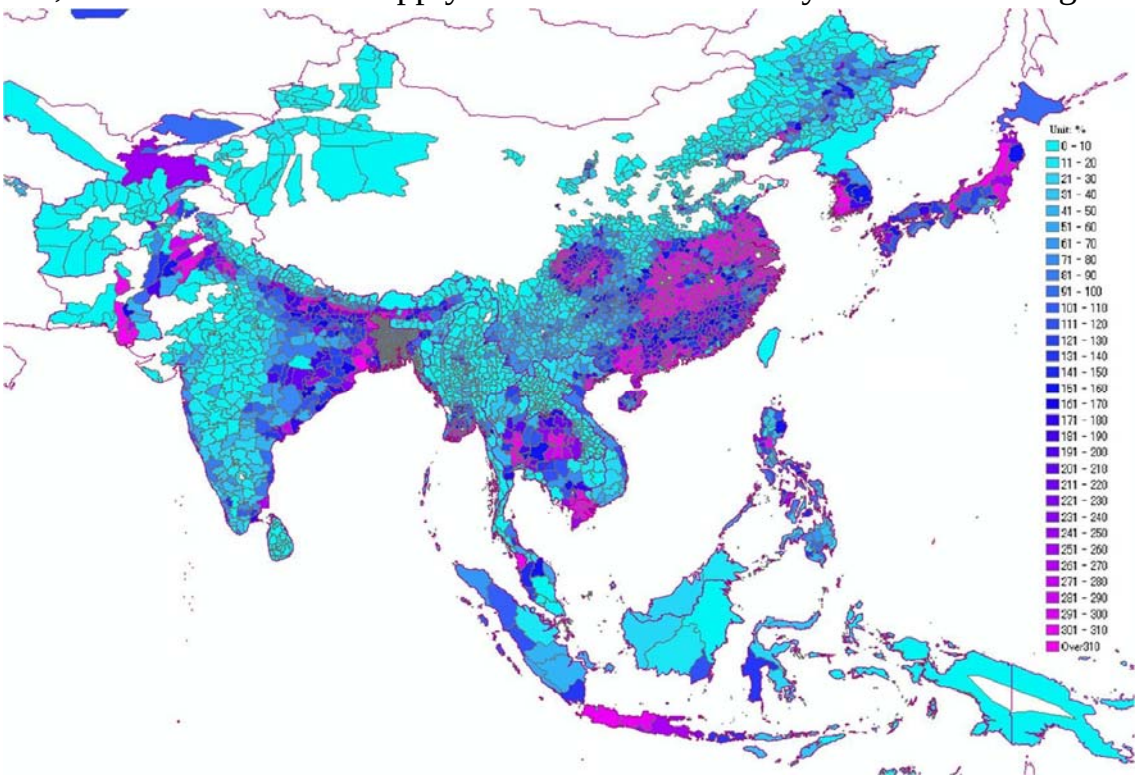

Fig.6. Rice Sufficiency: Asia

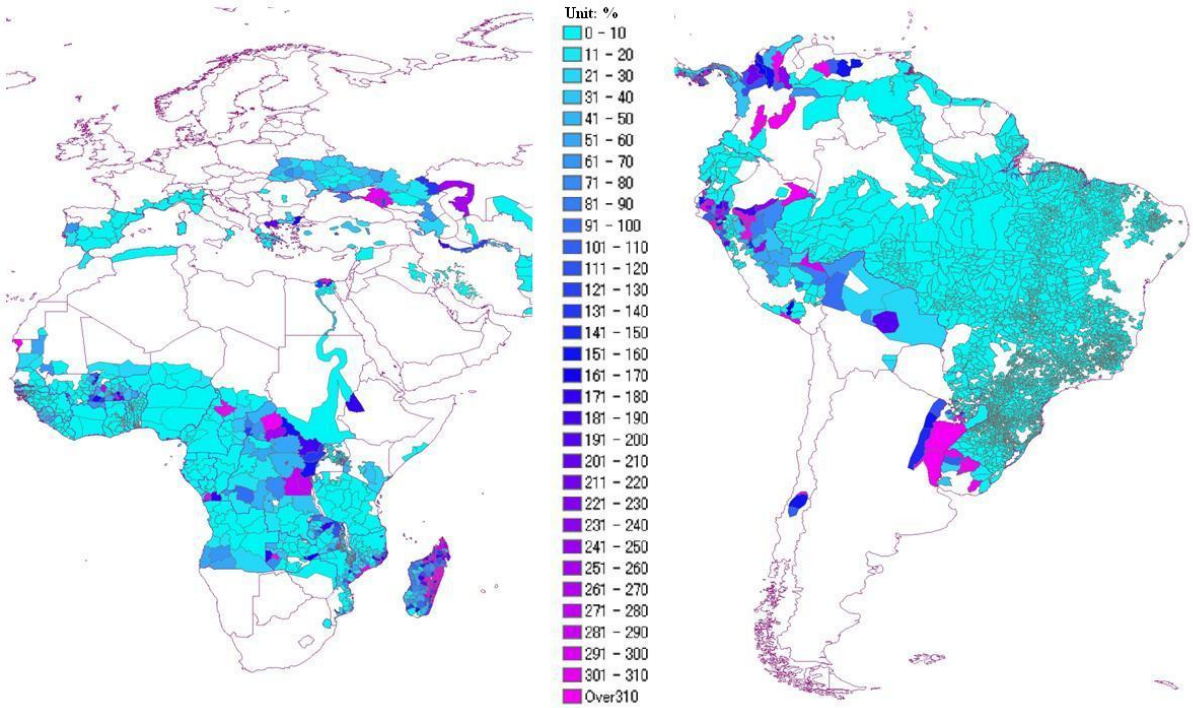

Fig.7. Rice Sufficiency: Africa and South America

4. Discussion and future research

The country based relationships between income and rice consumption are calculated. We used the satellite image data of nocturnal light on the earth to estimate the income of each region and then used that data to estimate the demand for rice in each region. We calculated the supply of rice by multiplying a dataset of the rice cultivation area of each region times the rice production per unit area in each country, thus creating a global scale map of rice supply and demand. There is an impending crisis due to the increased demands for foodstuffs caused by increases in the world's population and by economic development. Using the maps we have created on the basis of this research, we believe it is possible to identify the areas most in need of increased rice yield. Even though it may be impossible to increase the rice yield for all regions, we believe it is valuable to identify priority regions for improvement.

For future research, the accuracy of datasets should be discussed using other datasets such as PS&D of FAS-USDA datasets and time series of precipitation datasets will make it possible to estimate the change of yield and the impact of climate change. Elevation datasets are expected to calculate improvement costs of paddy field.

Precipitation plays very important role for rice production. We are working on monthly precipitation datasets provided by Global Precipitation Climatology Centre in Germany (GPCC 2008) and overlaying rice production area with this data. Hypothesizing rice production deficits in high stress areas may be determined by analyzing the relationship between "rice yield" and "precipitation values".

We also developing a web-site where students can add comments related to various topics such as light intensity, food shortage, population change. Regions affected by rice shortages can be highlighted and students can study the relationships between affected areas and the various datasets available to them such as GIS and economic datasets (ISS 2008).

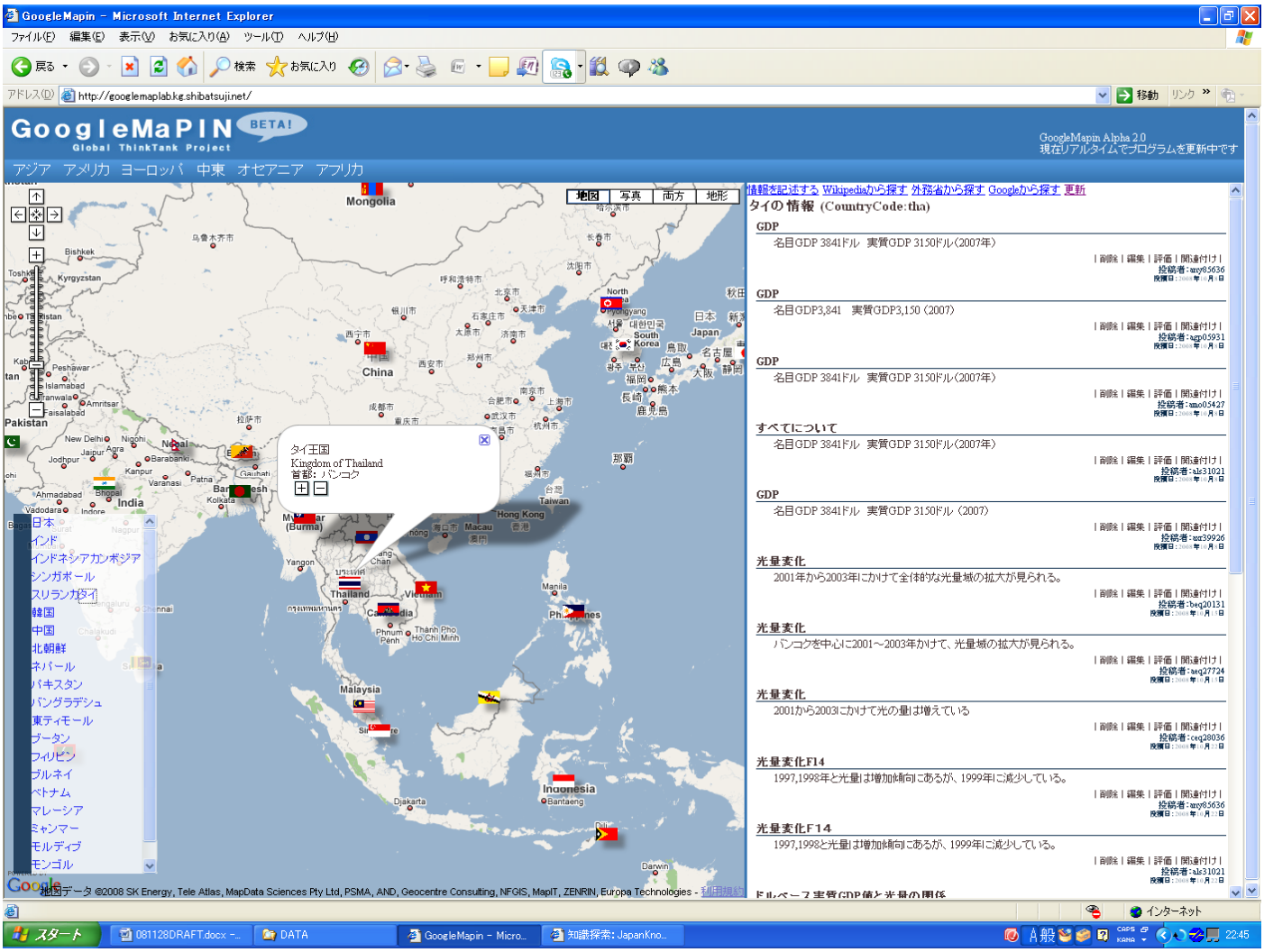

Fig.8. Sharing Information Web-site

Acknowledgments

Night time Image and data processing by NOAA's National Geophysical Data Center. DMSP data collected by US Air Force Weather Agency. Border data sets and River datasets are provided by ESRI company. Attached to ArcGIS Software.

References

Defense Meteorological Satellite Program (DMSP) Data Archive, Research, and Products (2008) Available at: http://www.ngdc.noaa.gov/dmsp/global_composites_v2.html

Elvidge, C.D., Paul S. Sutton, Kimberly E. Baugh, Benjamin T. Tuttle, Ara T. Howard, Edward H. Erwin, Budhendra Bhaduri (2006) A Global Poverty Map Derived From Satellite Data. Available at:http://www.ngdc.noaa.gov/dmsp/download_poverty.html

FAO STAT (2008) Available at: http://faostat.fao.org/site/567/default.aspx

GPCC (2008) Global Precipitation Climatology Centre
ftp://ftp-anon.dwd.de/pub/data/gpcc/html/fulldata_download.html

IFS CD-ROM (2009) Publications Services, International Monetary Fund, Washington, DC20431 USA

Imhoff, M. L., Lawrence, W. T., Stutzer, D. C. and Elvidge C. D. (1997) A Technique for Using Composite DMSP/OLS “City lights” Satellite Data to Map Urban Area, Remote Sensing Environment 61, pp. 361-370

IRRI Statistics Portal (2008), Available at:http://www.irri.org/science/ricestat/

ISS (2008) Information Sharing System
http://googlemaplab.kg.shibatsuji.net/
This system is developed by Mr.Yuta Shibatsuji, Kwansei Gakuin University. For base scripts refer to http://japonyol.net/
More information, please correspond with author.(any85636@kwansei.ac.jp)

Kawashima H (2008) World Food Production and Biomass Energy - The Outlook for 2050, University of Tokyo Press

Land Scan (2003) Available at: http://www.ornl.gov/sci/landscan/
“All users must register to access the data sets. Please see the Registration page for more information. For educational (K-12, universities, and colleges), U.S. Federal Government, und United Nations humanitarian users, Click here for the LandScan Registration and Data Access Process Document. This document will help you complete the registration form, obtain your username and password, and gain access to the LandScan Data”

USDA (2008) United States Department of Agriculture, Foreign Agricultural Service
Available at: http://www.fas.usda.gov/psdonline/

Nakaya T(2002) A Grid-surface Projection of Urban and Rural Population in China, 1990-2050, in Otsubo K.(ed) Study on the Processes and Impact of Land-use Change in China-Final Report of the LU/GEC Second Phase (1998-2000), Centre for Global Environmental Research,pp.89-98.