Prospect Food Demand and Supply Using Economic and Spatial Models

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Abstract: According to United Nations, world population will reach to 9 billion in 2050. Especially, the countries in Asia will account for about 58% in the world population and economic development is remarkable in these countries. It takes feed consumption of livestock animals grow, and it needs more cereals. Furthermore, environmental issue, namely global warming, desertification and soil erosion, affect factor of decrease agricultural area. We use the model integrated IFPSIM and LUCM model. IFPSIM covers 31 regions mainly an Asian region, and 14 commodities, for instance, crops, livestock and processed foods. LUCM calculates the production of wheat, maize, rice, soybeans. LUCM is structure of spatial lattice point and the land productivity is calculated by given soil, temperature, precipitation, and amount of the fertilizer on each point. Which commodity is selected decided depending on yield, and own-cross producer price. IFPSIM calculates equilibrium price in t-2 time and t-1 time, LUCM calculates harvested area and yield in t time using change of two-period producer prices and given factors. We simulate from 1988 to 1994 only IFPSIM and since 1995 use integrated model. We use exogenous variables such as population and GDP growth are taken from United Nations World Population Prospects; medium variant, and IPCC SRES. The result of our simulation clearly shows that harvested area and yield from 1995 to 2004 are not so much difference comparing with actual data. But, after 2015, the range of world price change is dramatic, and cannot compute applying SRES A1b scenario until 2025. This indicates high economic growth becomes estrangement between demand and supply, and high economic growth causes failure of food security. The future direction of this study will be one that we modify agricultural policy in IFPSIM and simulation the global warming using change of harvested and forest area.

Keywords: International Trade Model, Land Use, Land Productivity, Forecast Food Situation, Climate Change

1. Introduction

The purpose of this study is to prospect food demand and supply in the future applying integrated economic and spatial models. According to United Nations [12], world population will reach to 9 billion in 2050. Especially, the countries in Asia will account for about 58% in the world population. In addition, economic development is remarkable in these countries, for this reason the demand for livestock and dairy food will increase. It takes feed consumption of livestock animals grow, and it needs more cereals. Furthermore, environmental issue, such as global warming, desertification and soil erosion lead to decrease agricultural area. In short, the food supply and demand situation might tighten in the future.

Some international institutes forecast food demand and supply in the future with economic models, such as ERS/PENN State Trade Model [9], World Food Model [3], International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model [7], but these don't take into account spatial extension and environmental affects. For example, Rosegrant et al [8] took water model in food model, IMPACT, however, it does not include change of temperature in the future. On the other hand, IIASA employed integrated economic and land use change model, Agro-Ecological Zones (AEZ) and Basic Linked System (BLS) [5]. The methodology they employed model is different from ours in that including non-agricultural sector treats endogenous variables.

In this paper, integration of economic model and spatial model is proposed, which is IFPSIM (International Food Policy Simulation Model) and LUCM (Land Use Choice Model). With this integration model, we simulate world food and supply in the future using exogenous variables as UN population prospect [12] and IPCC SRES GDP growth [1].

The most important part of this simulation is that harvested area and yield are taken from LUCM.

2. Methodology

1) Structure of IFPSIM

IFPSIM was developed by Oga Keiji [6]to simulate agricultural policy change and covers 31 regions (Table1.) and 14 commodities (Table2.). IFPSIM is a partial equilibrium model and an interactive in that it allows for the simultaneous determination of supply, demand, trade, stock levels and prices for all the commodities covered. Solving for world market clearing prices by equating the sum of gross imports and the sum of gross exports. Sources and destinations of trade flows are not identified by the model. On the grounds that non-agricultural sector variables, such as population and GDP are taken by out of the model. In the model, production of crops is determined by harvested area and yield, whose growth rates are fixed. Harvested Area is computed by own-price, cross-price and constant term.

$$AB = a0 \times AB_{-1}^{\;al} \times PS_{-1}^{\;a2} \times \prod PS_{-1}^{\;ak} \qquad (1)$$

where AB is area of crop, PS is producer price, a0 is constant term, a1, a2 and ak are elasticities, and “-1” means previous year’s value. Production of livestock similarly calculates Eq.(1).

Demand side is divined into three factors; food demand, feed demand and other demand. Food demand is a function of own-price, cross-price, GDP per capita and population.

$$QF = a0 \times VV^{a1} \times YY^{a2} \times PD^{a3} \times \prod PD^{ak} \qquad (2)$$

where QF is quantity of food demanded, VV is GDP, YY is population, PD is consumer price, a0 is constant term, a1, a2, a3 and ak are elasticities. Feed demand is almost same, but includes production of livestock. Other demand determines using GDP in present year and past year. World prices every commodities excluding Milk, that is matched domestically for demand and supply, are determined by sum of world net export is equals zero (Market Cleaning System). That is,

$$\sum QN = 0 \qquad (3)$$

Net export are calculated following equation in all regions,

$$QN = QS + ST_{-1} - (QD + ST) \qquad (4)$$

where QN is net export, QS is quantity of supplied, ST is change of stock, QD is quantity of demanded. We would like to focus attention on ignoring the differences of quality by place of production. For instance, rice made in Japan and one made in Thailand, they cannot be distinguished. The equilibrium price determined by this way is cited to decide world price in the next year.

Table 1. Classification of Commodities.

Commodity (14)	
livestock	Beef, Pork, Sheep, Poultry, Egg, Milk
crop	Wheat, Maize, Other Coarse Grain, Rice, Soybeans
processed	Manufactured Milk, Oil Meal, Oil and Fat

Table 2. Classification of Regions.

Region (31)	
Single Country	USA, Japan, Canada, Australia, New Zealand, Mexico, Brazil, Argentina, Nigeria, Other Africa, Egypt, India, Pakistan, Bangladesh, Indonesia, Thailand, Malaysia, Philippine, China, Singapore, Korea
Aggregated Countries as a Region	EC12, Other West Euro, East Euro, Other Developed Countries, USSR, Other Latin and Caribbean, Other Africa, Other Near East, Other Far East, Other Developing Countries, Rest of the World

2) Structure of LUCM

LUCM can be separated with EPIC (Erosion-Productivity Impact Calculator) and Logit model. EPIC can calculate crop productivity and Logit select which crop plant. EPIC was developed by USDA to estimate the relationship between soil erosion and crop productivity [13]. EPIC operates on a dairy step and includes components for whether simulation, hydrology, nutrient cycling, plant growth, tillage and crop management [2]. Tan and Shibasaki [11] proposed a methodology GIS-based EPIC, integrating EPIC, GIS (Geographical Information System) and IE (Inference Engine), and can estimate crop productivity at global level. GIS-based EPIC is structure of spatial lattice points, 3600(from east to west; 180 00 E to 180 00 W) times 1405(from north to south; 84 00 N to 56 50 S). The weather data, temperature and precipitation, are derived by IPCC from the first version of Canadian Global Coupled Model (CGCM1).

Logit model computes which crop farmers select by their utility, it includes producer price in past two years, and crop productivity from EPIC,

$$U_i = F_i(Y) + S_i(X) \quad @\ i\ @1,\ 2, @.@ n \tag{5}$$

and

$$P_i = \exp(U_i) \Big/ \sum_{j=1}^{n} \exp(U_i) \quad @\ \forall @ \tag{6}$$

where U is stochastic utility function; F and S are the linear function of basic environment concluding population density, income and traffic accessibility and main socioeconomic variables about climate, rain-fed and temperatures; P is the probability; i and n are numbers of land use choices.

We select four commodities applying Logit model, wheat, maize, rice, soybeans. The reason why soybeans is selected that it consumes for feed rather than food use. Particular, feed demand will increase to come from rearing livestock hereafter.

3) Integration of IFPSIM and LUCM

The methodology of integration of IFPSIM and LUCM is explained Fig.1. IFPSIM calculates an equilibrium price where world net export becomes zero in t-2 time and t-1 time, then, LUCM calculates harvested area and yield of wheat, maize, rice and soybeans in t time using change of two-periods producer prices, yield from EPIC model and given factors. Using these supply side variables, price in t time is decided and this is taken by computing area and yield in t+1 time.

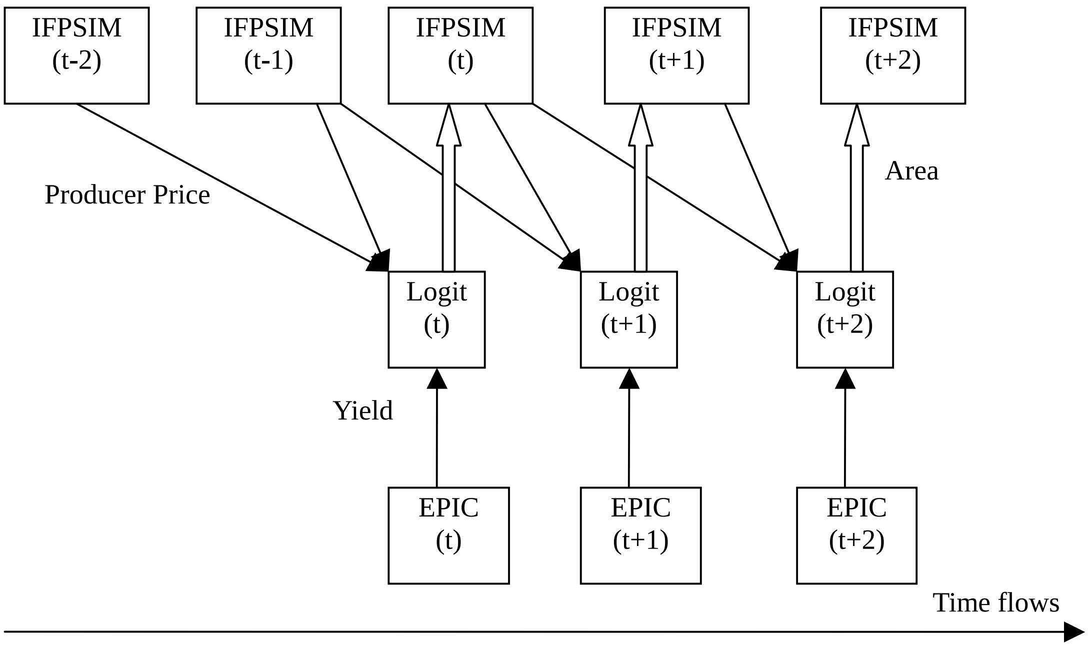
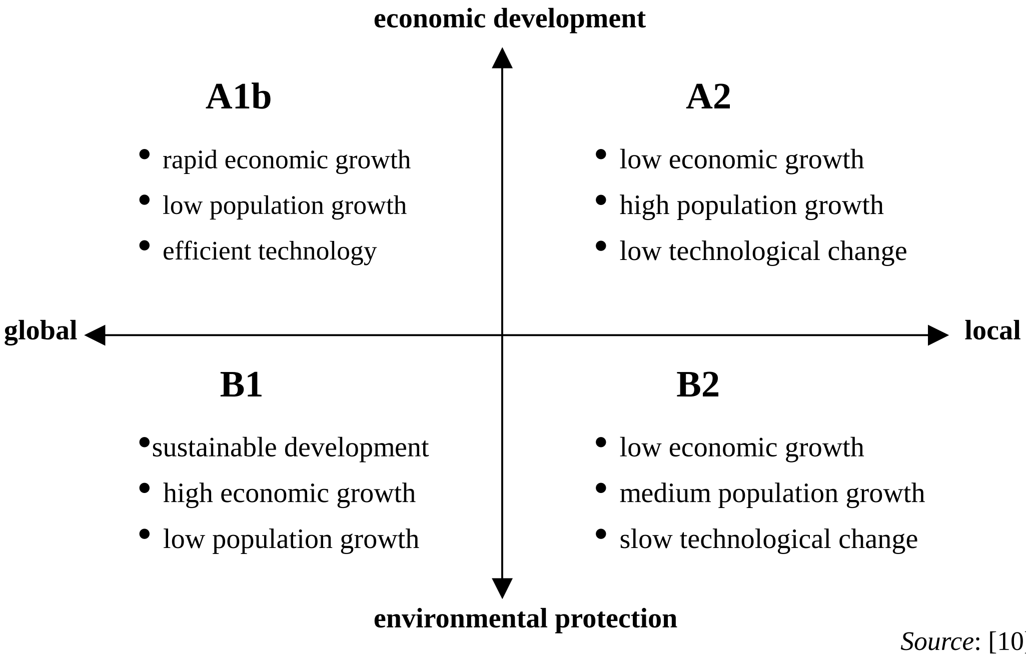


Fig.1. Time Flow of calculations

3 Assumption and Results

1) GDP and Population Assumptions

We use variables such as population and GDP growth from other models. Population is taken from United Nations Population Prospect; medium variant. This data explains country level, so we aggregate according to IFPSIM classification. And GDP growth is quoted form IPCC SRES (Special Report on Emissions Scenarios); A1b (policy maker model is AIM), A2 (ASF), B1 (IMAGE), B2 (MESSAGE) [1]. See Fig 2. about their features of each scenario.



Source: [10] and [11]

Fig.2. Characteristics of IPCC SRES.

2) Policy Assumptions

IFPSIM is agricultural simulation model, we can change policy variables. Hence, we modify these variables, producer subsidy equivalent, consumer subsidy equivalent and set-aside. Due to LUCM calculate depending on two-periods price, we set policy variables unchangeable to avoid incomputable.

3) Simulation Results

We simulate from 1992 to 1994 with only IFPSIM, after 1995 using integrated model. The result of GIS-based EPIC (See Fig.3-6) clearly shows that harvested area and yield from 1995 to 2004 are not so much difference comparing actual data from FAOSTAT [4]. It follows from this that there is integrity between GIS-based EPIC and actual data. Though there are underestimating or overestimating regions, we might go on to adjustment model structure and classification of regions.

Fig. 7-10 shows the world price from 1992 to 2020 of wheat, maize, rice and soybeans. After 2005, the range of world price change is dramatic, and cannot compute applying SRES A1B scenario until 2025. This phenomenon did not occur suddenly, it did since a few years before 2025. Consequently, we show the figure until 2020. The view of market cleaning system, it is normality that the equilibrium price grows or declines adjusting demand and supply. We can deduce from this that high economic growth becomes estrangement between demand and supply, and high economic growth causes failure of food security. In fact, consumer and producer act adapting own their surroundings. Therefore, these results are due to consumer and producer act to follow same liking in the future, even though it is not realistic in general.

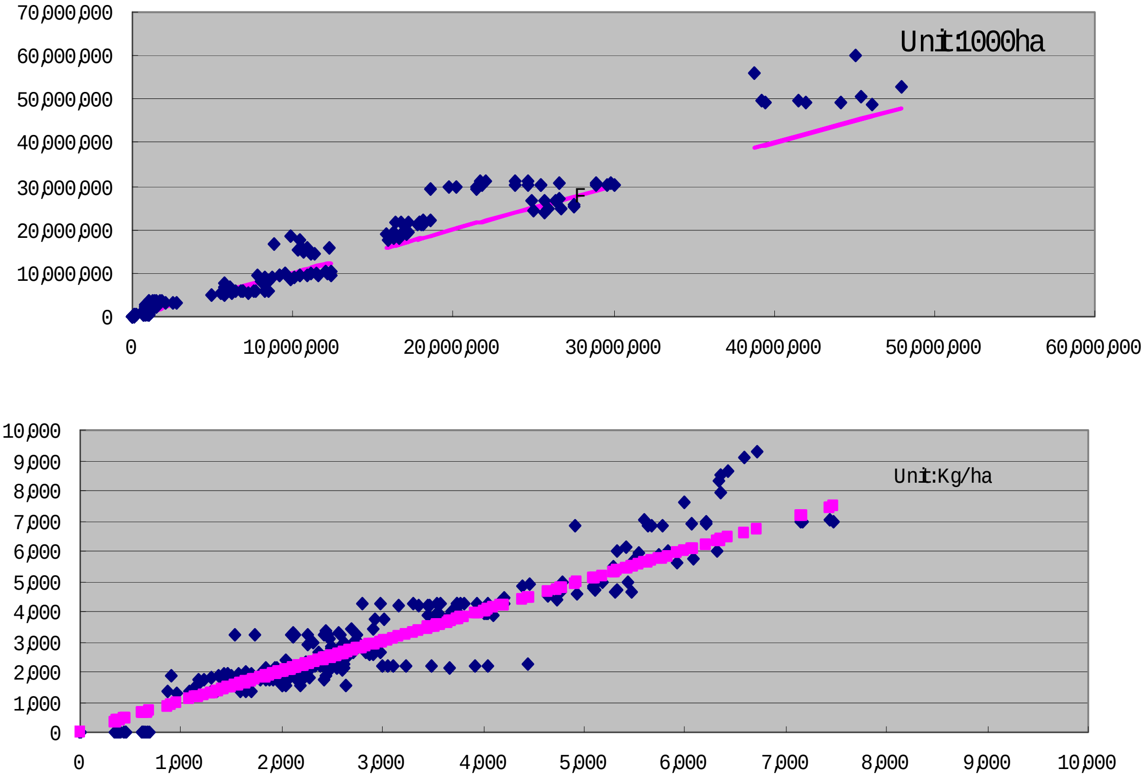


Fig.3. Harvested Area (Upper) and Yield (Lower) of Wheat.

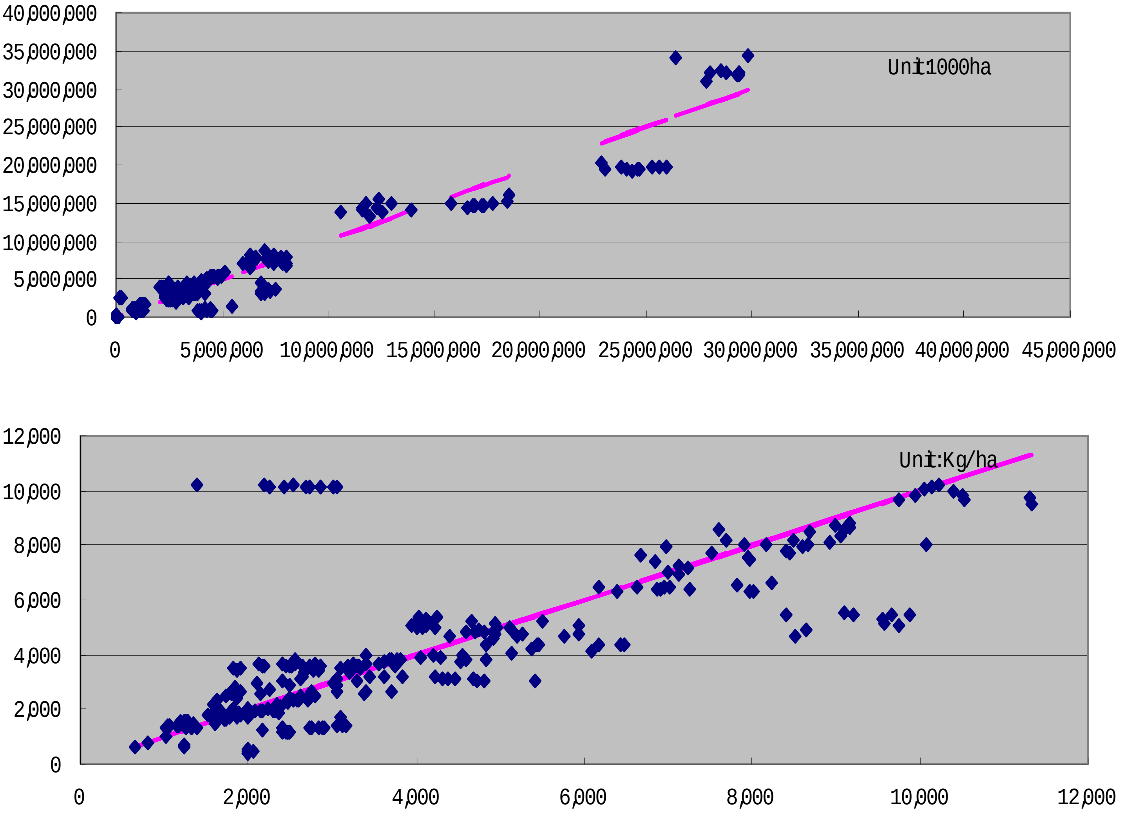


Fig.4. Harvested Area (Upper) and Yield (Lower) of Maize.

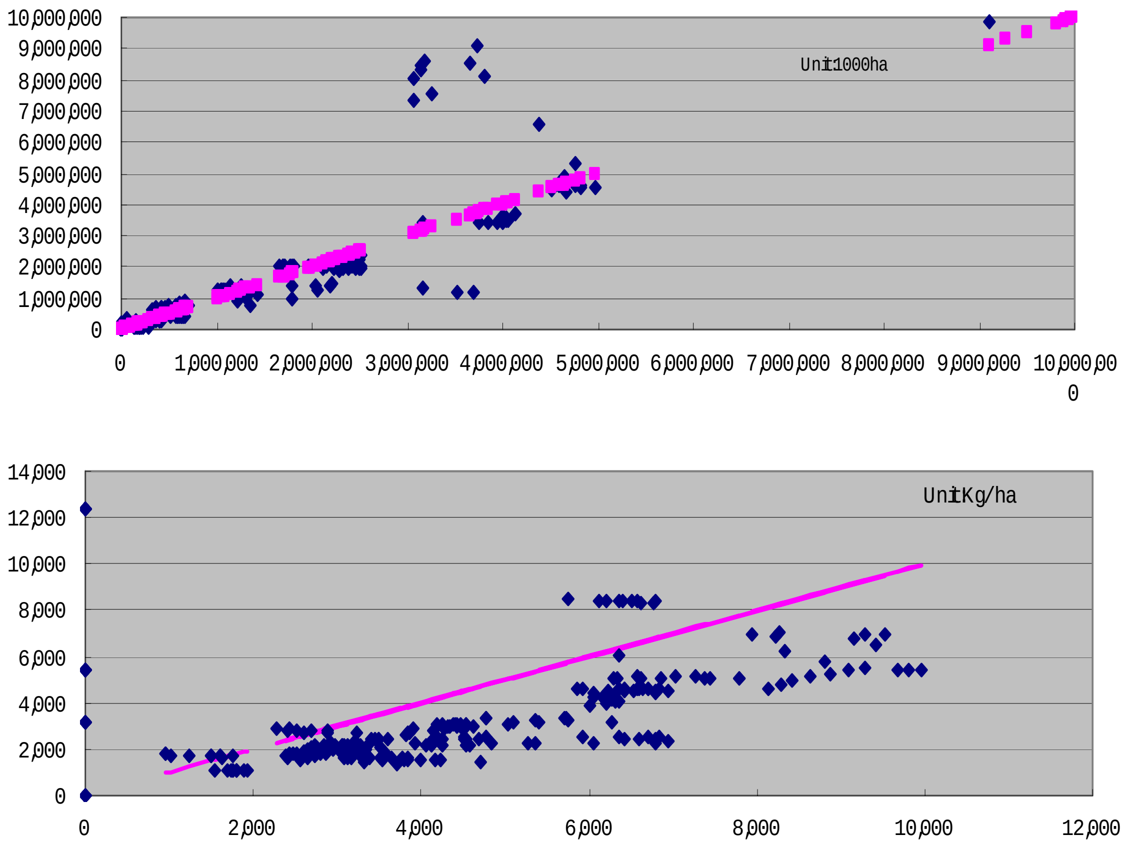


Fig.5. Harvested Area (Upper) and Yield (Lower) of Rice.

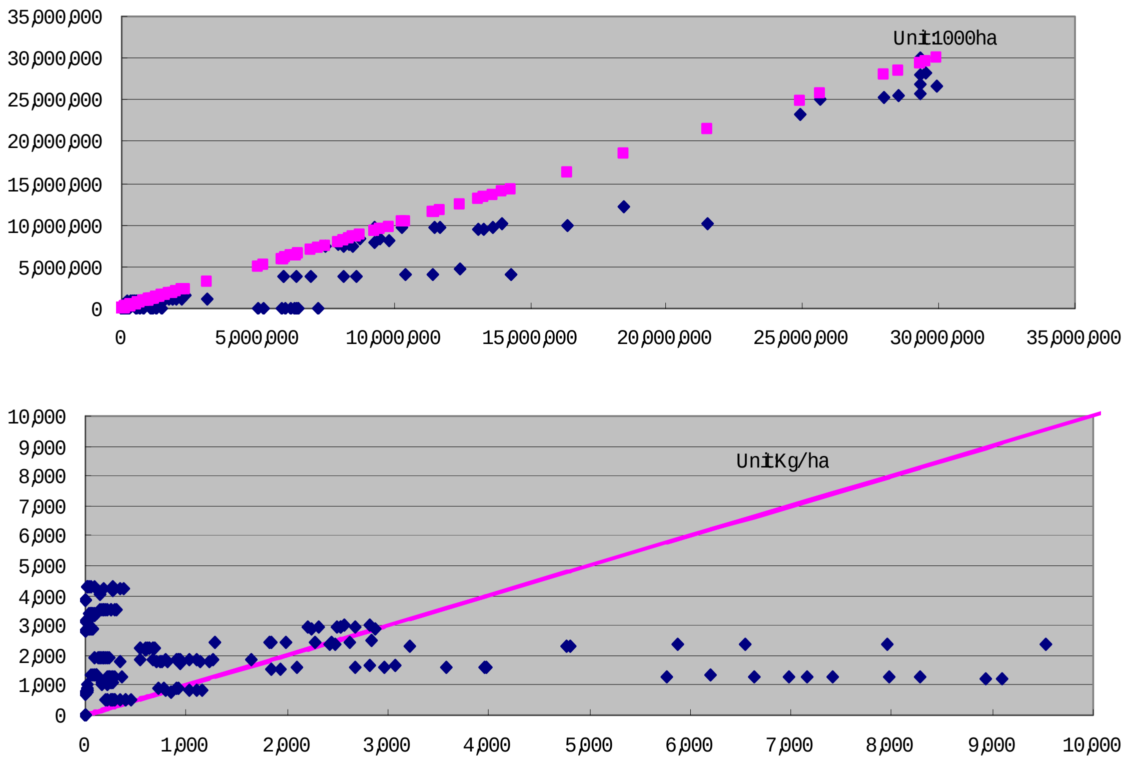


Fig.6. Harvested Area (Upper) and Yield (Lower) of Soybeans.

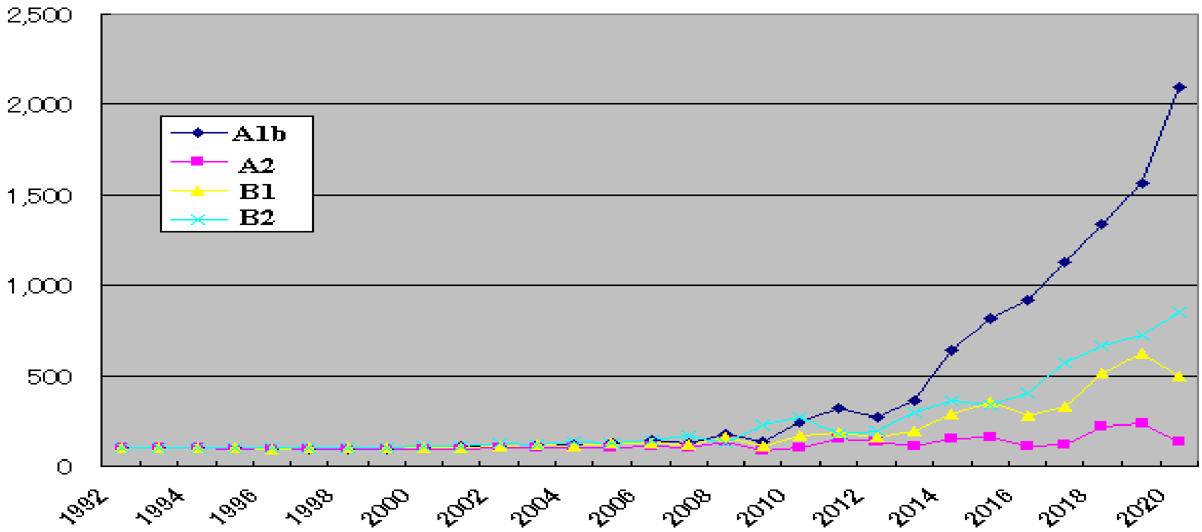


Fig.7. World Price of Wheat (1992=100)

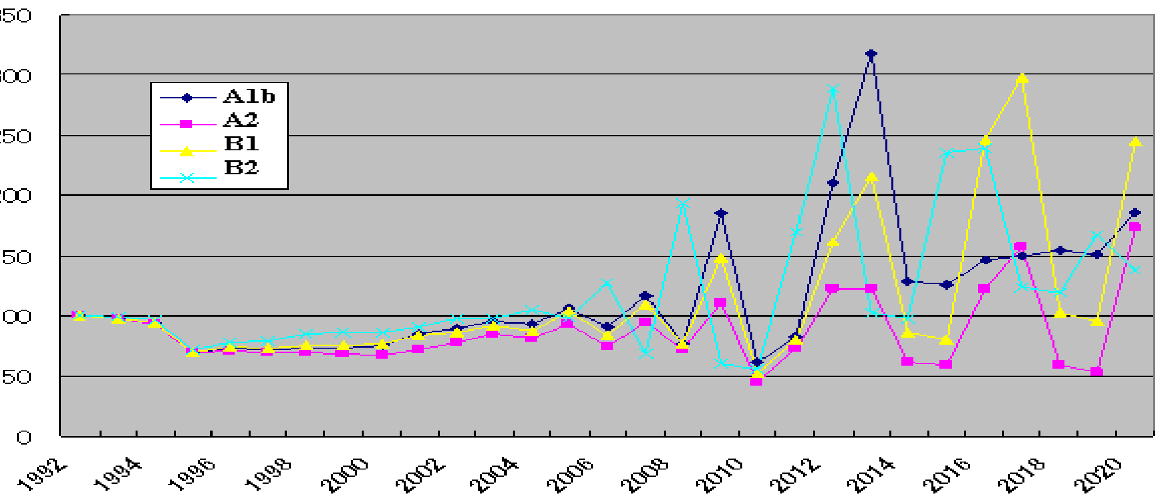


Fig.8. World Price of Maize (1992=100)

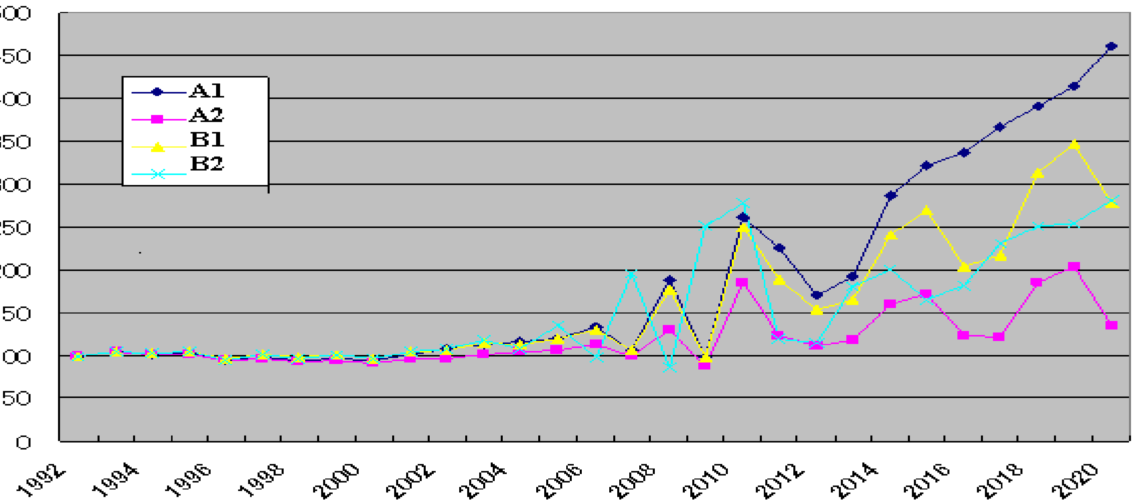


Fig.9. World Price of Rice (1992=100)

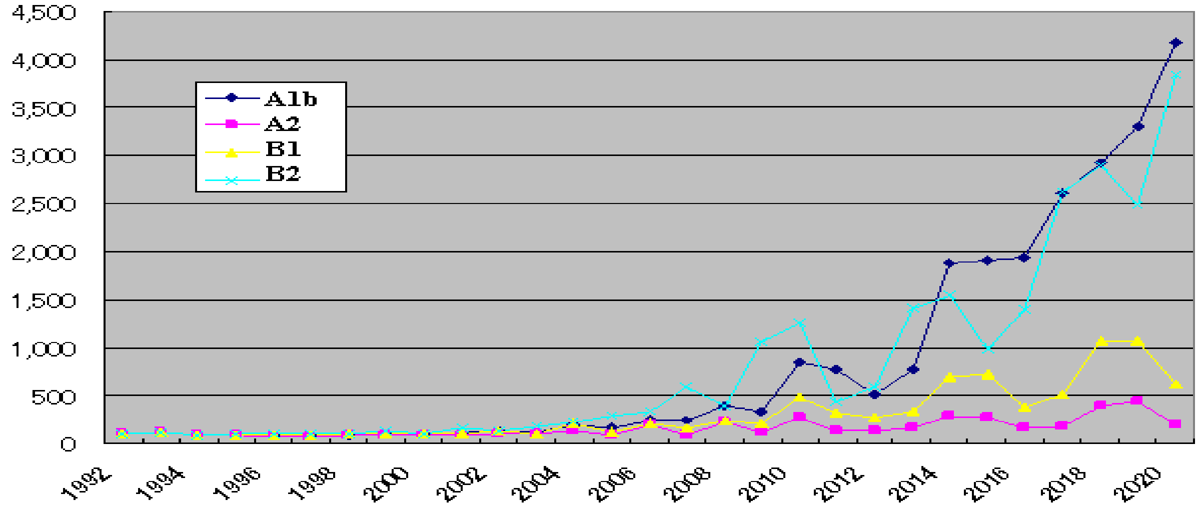


Fig.10. World Price of Soybeans (1992=100)

4. Conclusions

In this paper, it was found though simulation that we forecast food demand and supply in the future using integration of economic and spatial models to be accordance with actual data. However, as simulation time flows, change of price is dramatic. This means that something to modify and adjust parameters needs. Because LUCM uses cross-country data sets when parameters have gained, there is a possibility not suitable either in the calculation of long-term.

The future direction of this study will be one that IFPSIM modified agricultural policy. Now it discussing in WTO that the opinion of reduction support promoting farmers more product and abolish consumer protection that uses price differences between foreign and domestic prices. And LUCM doesn't adopt emission gases every SRES scenarios, it may be able to draw out futures that using brand-new climate data. And global warming relies on forest area, which is important place of absorb CO2. LUCM can calculate not only agricultural area but also forest area, thus we will be able to simulate global climate change and its affects.

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*IPCC SRES policy maker scenarios are quoted from following models;
A1b scenario: Tsuneyuki Morita and Kejun Jiang, National Institute for Environmental Studies (NIES) Tsukuba, Japan, AIM model
A2 scenario: Alexei Sankovski and William Pepper, ICF Consulting Washington, DC, USA, ASF model,
B1 scenario: Bert de Vries and Detlef van Vuuren, National Institute for Public Health and Environmental Hygiene (RIVM) Bilthoven, The Netherlands, IMAGE model,
B2 scenario: Nebosja Nakicenovic, Arnulf Grübler, R. Alexander Roehrl and Keywan Riahi, at the International Institute for Applied Systems Analysis (IIASA), MESSAGE model.