CLIMATE CHANGE AND FOOD SECURITY IN DEVELOPING COUNTRIES AND ROLE OF SOCIAL SCIENCES

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ABSTRACT

The Intergovernmental Panel on Climatic Change (IPCC) reports that the average air temperature at the end of 21st century will rise 4.0 degrees Celsius from current levels in the case of the fossil energy intensive scenario, i.e., A1FI (IPCC (2007)). Agricultural production will be affected by global warming through changes in yields and market prices.

The relationship between yield or productivity and climate changes has been investigated since the late 1950's. These studies are based on crop models and expand the relationship between biomass and environment to a regional or global scale. The global model focusing on productivity in dry matter production by Lieth (1975) is a forerunner of these studies. Recent models are more sophisticated; for example, Jones and Thornton (2003) evaluated the impacts of climate changes on maize production by using a rainfall model, a crop model, and outputs of the Global Circulation Model (GCM).

Development of these biological or ecosystem studies has led to more accurate projection of changes in global vegetation patterns. However, environmental changes in a region will affect agricultural productions in other regions through trade in agricultural products. Considering relationships between food producers and consumers through trade, it is likely that climate change, such as global warming, may cause drastic changes in agricultural markets even in the mid-term.

Will producers and consumers of farm products be negatively affected by global warming? To provide an answer to the question, some synthesized models are developed. Parry *et al*. (1999, 2004, 2005) combined a supply and demand model of agricultural products, i.e., Basic Linked System, and crop models such as CERES-Wheat. On the other hand, Wu *et al*. (2007) combined a crop choice model, a crop yield model, i.e., EPIC, and a world food model, i.e., IFPSIM (1996). The former model is based on the supply and demand model of agricultural products and it is extended to a model which can evaluate climate changes. The latter model is based on the GIS based crop yield model and it is extended to the global scale model.

The yield functions of these models are based on crop process models and the maps of outputs of these models are based on GIS technologies. Evaluating the economic impacts of climate changes on the food security, supply and demand models are necessary. These models are suitable for the "platform" of synthesized models which will be consisted of models of the crop, the soil, the water, and the market, because the supply and demand models treat consumers such as rural poor.

This research examines possible effects of climatic change focusing on global warming and its impacts on world agricultural product markets, by using a world food model (IFPSIM) developed by the Japan International Research Center for Agricultural Sciences (JIRCAS). The basic world food model was developed by Oga and Yanagishima (1996) and is extended to consider changes in temperature and rainfall and their impact on crop yields (Furuya & Koyama (2005)). Furthermore, the model is extended to a stochastic world food model (Furuya & Kobayashi (2009)). The term of the outlook is 25 years, which is considered a mid-term projection in this context.

IPCC constructed several socio-economic based scenarios i.e., A1B, B1, A2, and B2, which are called SRES (Special Reports on Emission Scenarios) (IPCC (2000)). GDP and population measures for these scenarios are localized for each country by the Data Distribution Center (DDC) of IPCC and climate data such as temperature and rainfall for each scenario are reported by the Hadley Center. These data are combined for the scenarios used in this research.

The A1B scenario assumes that trade liberalization progresses and the economic growth rate is high. Furthermore, technological progress for the energy industry is well balanced between fossil and clean energies. The annual per capita income is $21,000 in 2050, while population reaches 8.7 billion people. The A2 scenario assumes that each country holds its own culture and trade, labor movement, and that technology transfer is restricted. Given these constraints, per capita GDP grows slowly and the annual average per capita income is $7,200 in 2050, while the world population reaches 11 billion people.

The B1 scenario assumes that consumption of natural resource is at a low level and low CO2 emission energy technology is developed, while the low population growth rate and high economic growth rate are same as those in the A1 scenarios. The B2 scenario assumes that trade is restricted and the cultural practices of each country are maintained such as those in the A2 scenario; however, low CO2 emission energy technology is developed. The per capita income is $12,000 in 2050 while the world population reaches 9.4 billion people in this scenario.

Impacts of global warming on the food consumption of the two large population countries are investigated. Table 1 shows the increasing rate of per capita consumption of several primary agricultural commodities in China. The rate of growth shown is the difference in consumption between 2010 and 2030 divided by consumption in 2010. The growth rate of the A1B scenario is higher than other three. Particularly, consumption of coarse grains and soybeans increase steadily under the A1B scenario, because higher income leads to greater consumption of livestock products and feed input demand will increase. The consumption of rice decreases for all scenarios due to the negative income elasticity of demand.

Table 2 shows the growth rate of per capita consumption in India. The growth rate of consumption of rice is quite high, while that of maize is almost zero. The growth rate for soybeans is high for A1B, B1, and B2 scenarios; however, in scenario A2 it is quite a bit lower. This distinction comes from the restricted trade under the A2 scenario.

Table 1 Growth rate of per capita consumption in China

	A1B	B1	A2	B2
Wheat	43.43	32.83	28.86	39.99
Maize	50.08	37.56	20.43	33.14
Coarse grains	72.21	38.06	19.86	45.67
Rice	-9.25	-5.04	-2.81	-5.95
Soybeans	35.48	22.92	15.06	24.94

Table 2 Growth rate of per capita consumption in India

	A1B	B1	A2	B2
Wheat	54.98	62.24	22.52	51.55
Maize	6.97	12.53	-1.15	8.33
Coarse grains	28.36	36.21	16.85	33.82
Rice	100.42	102.61	72.08	91.52
Soybeans	84.95	92.72	16.69	68.73

Changes in the consumption of food in developing countries depends on the growth of income and the eating habits. Not only researches of food production but analyses of consumer behavior in developing countries will be important for researches related to climate changes.

KEYWORDS

Climate change, Socio economic scenario, Food demand

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JIRCAS Symposium
Role of social sciences in the international agricultural research and development
Date: November 4-5, 2009
Venue: University of Tokyo, Yayoi Auditorium

Climate change and food security in developing countries and role of social sciences

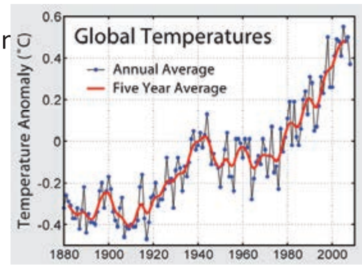
JIRCAS
Jun Furuya

Topics

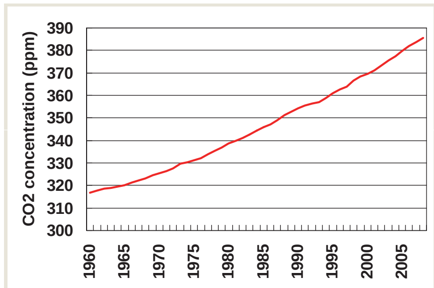
- Higher temperature and agriculture
- Role of the social science
- Estimation of yield function
- World food model
- IPCC SRES scenarios
- Analysis of impacts of global warming
- Stochastic analyses and food security

Rising temperature

- 0.5 to 1.0 degrees Celsius increased in 20th century
- 0.12 to 0.22 degrees Celsius Increased in this 10years



Increasing CO2 concentration



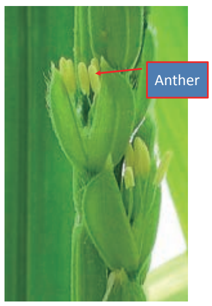
At Mauna loa observatory, University of California

Relationship between crop production and concentration of CO2

- Increasing concentration of CO2 activates plant photosynthesis.
- If CO2 concentration increases an additional 200 ppm, the yield of rice increase 15%.
- The yield increases at a higher CO2 concentration are known as the “fertilizer effect.”

Relationship between crop production and higher temperature

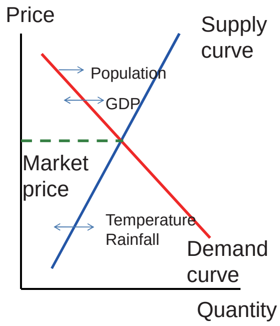
- The rise in temperature shortens the growth period due to early flowering and fruit bearing.
- HT decreases the nourishment sent to the seed due to increased respiration.
- HT during flowering period cause spikelet sterility.
- HT becomes difficult for the anther to tear when air temperature is over 34^{0}C.



Purpose

- Climatic changes probably make large impacts on agricultural production and food market.
- Climatologist and crop scientists estimates yield functions including climatic variables.
- We estimated (macro) yield functions and replace them with yield functions of the world model.
- We examine possible impacts of climatic change focusing on global warming and its impacts on world agricultural market by using a world food model.

Role of social science



- We consider not only production but consumption of food.
- The demand will shift by changes in population and GDP.
- The equilibrium price will determine planted area of next year.

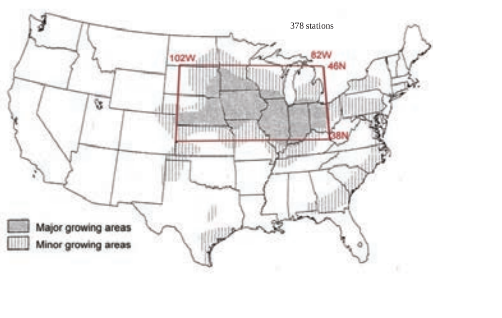
Estimation of Yield Functions

- Specification
  - $\ln YH_t = a + b_1 T + b_2 \ln TMP_t + b_3 \ln PRC_t$ (1)
    - YH: Yield, T: trend,
    - TMP: temperature, PRC: precipitation
      - (Heading Season: 1-2 months before harvest s.)
  - $d\ln YH_t = a + b_2 d\ln TMP_t + b_3 \ln PRC_t$ (2)
    - $d\ln YH_t = \ln YH_t - \ln YH_{t-1}$
- Estimation
  - OLS, AR ← serial correlation
- Unit Root Test
  - Augmented Dickey-Fuller Test (10%)

Data of yield functions

- Yield
  - FAO-STAT
- Temperature, rainfall
  - GHCN (Global Historical Climatology Network)
- Flowering season (months) are selected using cropping calendar
  - USDA
- Cropping regions are selected in large countries such as the USA
  - USDA

Maize planting region in the USA



This map was originally drawn by the USDA and modified.

Elasticity of yield for temperature and rainfall

Wheat		
	Elasticity of yield	
Country	Temp.	Rainfall
USA	-0.327	0.002
EU	-1.076	-0.117
Ex-USSR	-0.454	0.636
India	-0.333	0.050
China	-0.585	-0.071

Maize		
	Elasticity of yield	
Country	Temp.	Rainfall
USA	-1.226	0.186
EU	-0.211	0.136
E. Europe	-2.222	0.417
Brazil	-0.012	0.054
China	-0.967	0.197

If temperature increases 1 %,
the yield of maize in the USA will decrease 1.226%.

Elasticity of yield for temperature and rainfall (cont'd)

Other Coarse Grains		
	Elasticity of yield	
Country	Temp.	Rainfall
USA	-1.061	0.083
EU	-0.772	-0.017
Australia	-0.110	0.423
E. Europe	-0.529	-0.013
Ex-USSR	-2.070	0.360

Rice		
	Elasticity of yield	
Country	Temp.	Rainfall
USA	-1.125	-0.004
India	-2.023	0.008
Indonesia	-0.082	-0.038
Thailand	0.078	0.152
China	-0.270	-0.028

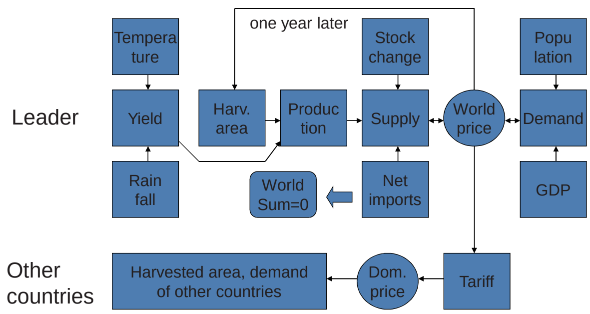
Elasticity of yield for temperature and rainfall (cont'd)

Soybeans		
	Elasticity of yield	
Country	Temp.	Rainfall
USA	-0.791	0.220
Brazil	0.141	0.067
Argentina	-1.248	0.067
India	0.115	0.131
China	0.276	0.131

Structure of the world food model

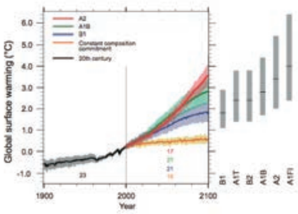
- Yield function: double log form
  - *YH=f*(time trend, temperature, rainfall)
- World food model (IFPSIM)
  - 14 commodities
  - 32 countries or regions
  - Structures of IMPACT (IFPRI) and WFM (FAO) are same as that of IFPSIM
  - Program: FORTRAN

Flowchart of world food model (Crop sector)



Scenarios of IPCC

(Intergovernmental Panel on Climate Change)



- IPCC Socioeconomic Scenarios
  - A: Priority to economy
  - B: Priority to ecology
  - 1: Global economy
  - 2: Local economy
- Type of Scenarios
  - A1: High growth society
  - A2: Diversified society
  - B1: Cyclical society
  - B2: Coexistent society

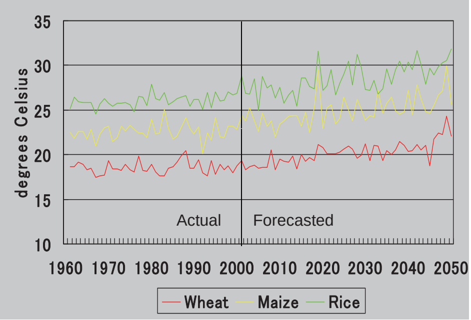
Income and population of scenarios

- A1B (high growth society) scenario assumes that the annual per capita income is $21,000 in 2050, while population reaches 8.7 billion people.
- A2 (diversified society) scenario assumes that the annual average per capita income is $7,200 in 2050, while the world population reaches 11 billion people.

Income and population of scenarios (cont'd)

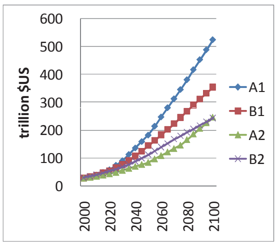
- B1 (cyclical society) scenario assumes that population growth rate and economic growth rate are same as those in the A1 scenarios.
- B2 (coexistent society) scenario assumes that the per capita income is $12,000 in 2050 while the world population reaches 9.4 billion people in this scenario.

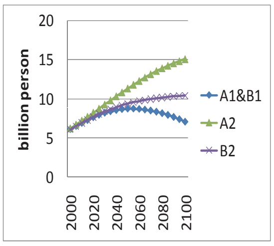
Temperature of flowering season in the USA (A2 scenario)



1961-2000: UEA/CRU,DDC, 2001-2050: HadCM3, A2

GDP and Population of the SRES scenario





Assumptions of the simulation

- (1) The cropping calendar is fixed.
- (2) The cropping region is fixed.
- (3) The climatic variables directly affect yields.
- (4) The temperature and rainfall for all countries and regions follows the data of HadCM3 for each scenario.
- (5) All parameters are fixed.
- (6) Current trade policy is not changed.
  - → mid-term forecast (2010-2030)

Partial impacts of changes in climate variables on production

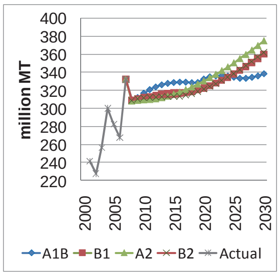
- Results of each scenarios and baseline which climate variables are fixed are compared.
- Production of wheat and maize will decrease more than rice.
- Decrease rates in scenario A2 and B2 of wheat, maize, and other c. grains are higher than those of A1B and B1.

	A1B	B1	A2	B2
Wheat	7.1	7.0	7.6	7.7
Maize	7.0	7.1	7.2	7.4
C.grains	5.2	5.3	5.7	6.1
Rice	5.0	5.1	5.1	4.8
Soybeans	6.2	6.2	6.1	6.1

(%)

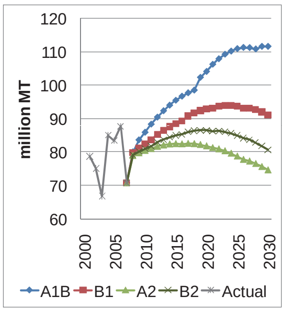
The table shows of the percent decline in production of crops in the world under the climate change for average through from 2028 to 2030.

Production of maize in the U.S.



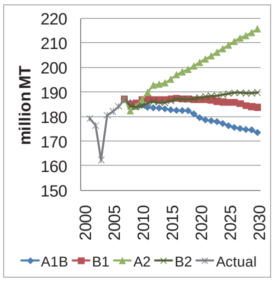
- Production in A2 scenario increases from 310 mMT in 2010 to 375 mMT in 2030, and B1 and B2 scenarios also follow this trend.
- Production growth rate in A1B scenario is the lowest among the scenarios, because productions in Argentina and Brazil will increase under the conditions of climate, GDP, and population.

Production of soybeans in the U.S.



- Production paths are clearly different in each scenario, and production will hit ceiling before 2030 for all scenarios.
- Production in the A2 scenario decreases from 80 million MT in 2010 to 74 million MT in 2030. Economic growth in the A2 scenario is the slowest and income elasticity of demand of meal and feed are relatively high. The slower economic growth decreases the demand for soybeans.

Production of rice in China



- Production outlooks are distinct for the different SRES scenarios: Production of rice will increase under scenarios A2 and B2 while it will decrease under scenarios B1 and A1B.
- The differences in GDP for each scenarios leads to differences in trends in rice production. Higher GDP leads to smaller demand for rice due to the negative income elasticity of demand of rice.

Growth rate of per capita consumption in China

- Growth rate of the A1B scenario is higher than other three.
- Consumption of coarse grains and soybeans increase steadily under the A1B scenario.
- Higher income leads to greater consumption of livestock products and feed input demand will increase.

	A1B	B1	A2	B2
Wheat	43	33	29	40
Maize	50	38	20	33
C.grains	72	38	20	46
Rice	-9	-5	-3	-6
Soybeans	35	23	15	25

(%)

The rate of growth shown is the difference in consumption between 2010 and 2030 divided by consumption in 2010.

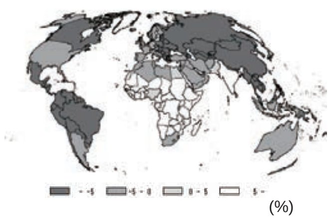
Growth rate of per capita consumption in India

- Growth rate of consumption of rice is quite high, while that of maize is almost zero.
- Growth rate for soybeans is high for A1B, B1, and B2 scenarios; however, in scenario A2 it is quite a bit lower. This distinction comes from low income under the A2 scenario.

	A1B	B1	A2	B2
Wheat	55	62	23	52
Maize	7	13	-1	8
C.grains	28	36	17	34
Rice	100	103	72	91
Soybeans	85	93	17	69

The rate of growth shown is the difference in consumption between 2010 and 2030 divided by consumption in 2010.

Differences in increasing rate of per capita consumption of wheat for B1 and A1B



- Difference in scenario is regarded as difference of technological progress for clean energies.
- Map shows that per capita consumption of wheat in African and South Asian countries will increase under the scenario of technological progress resulting in low CO2 emissions.

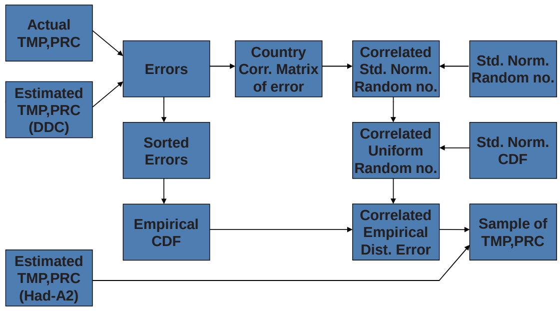
Food security: Stochastic analysis

- The temperature and rainfall variables entering into the yield functions are exogenous to the world food model.
- To evaluate the effect of changes in temperature and rainfall during flowering or silking seasons on the world food model, these climatic variables must be endogenized in a model.

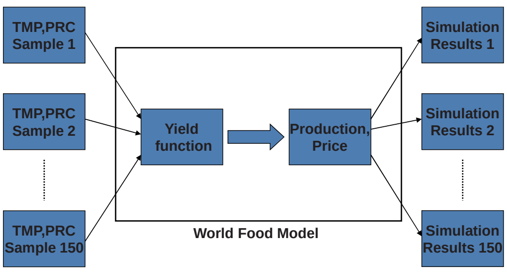
Climatic data estimation

- Linear function
  - $TMP_{ijt} = a^T_{ij} + b^T_{ij}T$
  - $PRC_{ijt} = a^R_{ij} + b^R_{ij}T$
  - i: country, j: crop, T: time trend
- % error correlation coefficient
  - 1961-2000
- Estimation of trend for forecasting
  - 2001-2050

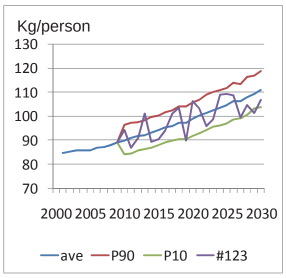
Flowchart of creating random climatic data



Flowchart of simulation of stochastic model

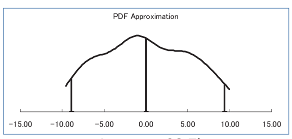


Per capita consumption of rice in India



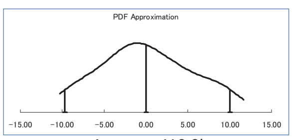
- The result of scenario A2 is shown.
- Per capita consumption of rice will steadily increase in India.
- The width of the fluctuation does not change.

Probability distribution of per capita consumption of rice in India



Average: 98.7kg

PDF of rice consumption in India in 2020



Average: 110.9kg

PDF of rice consumption in India in 2030

- Probability which is 5kg less than average
  - 2020: 19.75%
  - 2030: 18.88%
- Probability which is 8kg less than average
  - 2020: 4.99%
  - 2030: 8.29%
- Probability of extreme food shortage will increase. The tendencies of other developing countries are same as in India.

Conclusions

- Simulation results show that crop production in some countries or regions will have different paths depending on several conditioning factors.
- These conditioning factors include stronger GDP growth, population, temperature, and rainfall.
- Changes in the climatic variables are affected by differences in assumptions about technological progress in the development of low CO2 emission energy production and economic growth.

Conclusions (cont’d)

- Results suggest that the development of environment friendly technologies leads to greater consumption of food in many developing countries.
- Probability of extreme food shortage will increase.
- Relationships among environmental policies, clean energy development, and poverty elimination are worthy of future study.

Thank you very much!