Chapter 1
Introduction

Water is an indispensable input for agricultural production and the supply is highly influenced by hydrological cycle changes. The hydrological cycle is the water movement among atmosphere, land surface, subsurface, and the ocean, and it is summarized as follows: first, precipitation is formed in the condensation process of water vapor and it falls reaching the ocean and land surfaces. Second, precipitation brings about moistness, infiltration, storage, and flowage on the land surface depending on soil conditions. The surface water evaporates, and the water,which is absorbed by roots of plants, is traspirated through stomas. The residual water pools or flows out and reaches the ocean through rivers and estuaries. Evaporated water from the ocean surface becomes water vapor in the atmosphere. This is a repeating hydrological cycle and the scale for analysis is selected from the city, river basin, province, nation, and the globe depending on the purpose of the research.

Climatic changes caused by global warming leads to the activation of the water cycle and are anticipated to expand water supply fluctuations. Clearing problems caused by changes of water accounting, researchers of hydrology and climatology have analyzed changes in the global water cycle. The changes will affect the supply and demand of crops, therefore, econometric analyses related to the cycle changes are important to aid the design of agricultural policies and plans.

There are two approaches for production or economic analyses of water supply changes; i.e., production and yield function approaches. The production function approach uses a production function per area and it includes a water variable. Hexem and Heady (1978) obtained optimum water and fertilizer input quantity by estimating production functions, which are specified as quadratic forms, for maize, wheat, and other crops. On the other hand, the yield function approach uses a crop physiological model and optimum water allocations are obtained. The water stress model such as the models of Dinar and Letey (1996) and the dry matter production model such as the model of Horie *et al.* (1997) take the yield function approach. These yield functions can then be used in supply and demand models to determine production.

The "production function approach" directly estimates a production function which represents technological relationships among inputs and outputs. On the other hand, the "yield function approach" indirectly estimates a supply function of which water is a fixed factor. The relationship between the two approaches corresponds to the relationship between a production function and a profit function which are linked through dual approach in micro economic theory.

It is assumed that there are supply response functions for crops in supply and demand models, and these functions are divided into planted area functions which respond to the farm price and yield functions which respond to a technological progress. This study introduces water variables in yield and area functions, then, supply responses of rice to water supply changes are analyzed. Hexem and Heady (1978) and Hazlewood and Livingstone (1982) analyzed supply and demand of water using actual irrigation water, however, obtaining data for irrigation water flow or stock is difficult in a large area. Thus, evapotranspiration (ET), which is approximated from climatic data and the summation of transpiration from crops and evaporation from the surface, is used as a water variable in yield and planted area functions in the supply and demand models which are developed in this study.

Many water stress models are based on the following function in relation to a relative decrease of yield and shortage of ET; $(1 - Ya/Ym) = ky(1 - ETa/ETm)$ where Ya is the actual yield, Ym is the yield under optimal growth environment, ETa is the actual ET, ETm is the ET which coincides with the water demand of a crop, and ky is the yield response factor. IMPACT-WATER, which is a world food model including a water accounting sector and developed by Rosegrant, Cai, and Cline (2002), introduces the ET ratio into intercepts of yield and area functions, and if there is water stress, yield and area will be negatively affected. This type of model is effective for upland crops; however, in the case of rice which is cultivated in wet land, the differences between ETa and ETm are quite small. In addition to the condition of the paddy field, a yield response factor including regional differences, in the form of regional monthly actual ET (ETa), is used as a key water variable in our model.

Farmers, who are in developing countries where the share of irrigated fields is low, are at risk of severe damage by global hydrological changes. Simulation results of the supply and demand model considering water cycle changes for each region will provide important information for the formation of policies to offset or mitigate the negative consequences of climate changes. Given these conditions, the developing countries of Southeast Asia are the target subjects for this study.

Climate conditions of the four countries of Southeast Asia are investigated in the following section. Figure 1-1 through Figure 1-4 show national averages from 1961 to 1990 of temperature, rainfall, and solar radiation for Laos, Cambodia, Thailand, and Vietnam. Laos, Thailand, and southern Vietnam belong to the Savanna climate and Cambodia and northern Vietnam belong to the Tropical monsoon climate.

There are two seasons in the four countries, the wet season from May to Ocober and the dry season from November to April. The annual rainfalls of the countries range from 1700mm to 2000mm, and the rainiest month is August and the driest month is January. Alternatively, the profiles of temperature are quite different in the four countries. The difference of maximum and minimum temperature in Cambodia is 4.1 degrees Celsius; however, those in Laos and Vietnam are 7.2 degrees Celsius. The low temperatures in the later two countries sometimes lead to crop damage from cold weather.

Next, trends and variations of ET, which represent the water supply for crops, for each region of the countries are investigated. Data on ET are the numbers of Ishigooka et al. (2005) and are monthly data. The regressed function is as follows:

$$ET^i = a_0 + b_1T + b_2D_{FEB} + \ldots + b_{12}D_{DEC} \qquad (1\text{-}1)$$

where ET^i is the ET of i^{th} region, T is the time trend, D_{FEB} through D_{DEC} are monthly dummies. The function (1-1) is estimated for two terms; January 1981 through December 1990 and January 1991 through December 2000. Table 1-1 shows parameters of the time trend and coefficients of variation of the estimates. Positive parameters of the time trend are significant and those of later period are greater than those of former period for all regions. On the other hand, the variances are increasing for almost all regions.

It is anticipated that floods and droughts will occur with greater frequency in the lower Mekong basin as a result of global warming. Arora and Boer (2001) report that the rainfall from 2070 to 2100 will decrease 16.4% from current levels due to global warming, and the rate of decline is anticipated to be the highest in large river basins. Furthermore, they also show that the probability of flooding will increase during the simulation period.

Impacts of hydrological cycle changes on rice productions in various ecosystems, such as lowland,

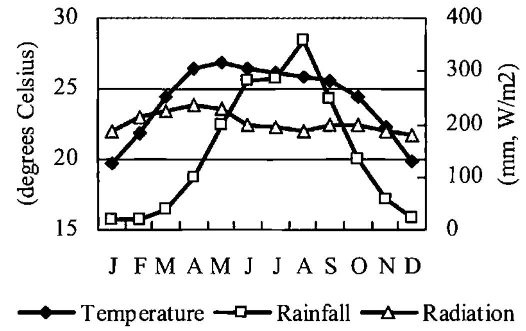

Fig. 1-1. Temperature, rainfall, radiation in Laos

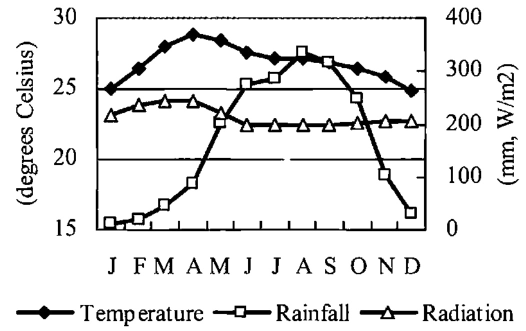

Fig. 1-2. Temperature, rainfall, radiation in Cambodia

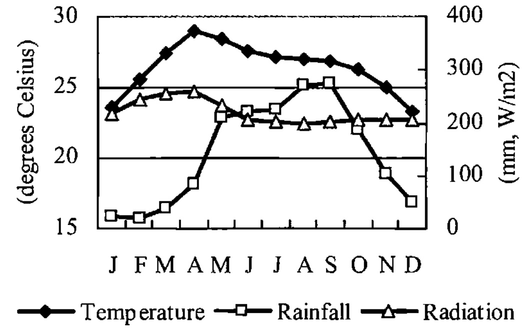

Fig. 1-3. Temperature, rainfall, radiation in Thailand

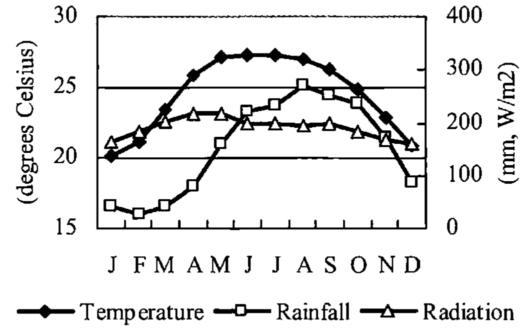

Fig. 1-4. Temperature, rainfall, radiation in Vietnam

Table 1-1 Parameter of time trend and coefficient of variation

Country	Region	Trend		CV	
		81-90	91-00	81-90	91-00
Laos	North	-0.003	0.054	12.54	14.80
Laos	Central	0.011	0.099	12.65	16.11
Laos	South	0.017	0.087	13.53	12.25
Cambodia	Plain	0.024	0.066	8.01	10.71
Cambodia	Tonle Sup Lake	0.056	0.063	11.58	11.74
Cambodia	Coastal	0.041	0.077	15.79	17.20
Cambodia	Plateau&Mountain	0.023	0.068	9.27	9.56
Thailand	Central	0.024	0.094	14.27	14.65
Thailand	North	0.035	0.071	12.41	16.18
Thailand	North East	0.025	0.085	11.51	13.76
Thailand	South	-0.004	0.046	14.68	17.20
Vietnam	Red River Delta	0.025	0.045	10.15	13.35
Vietnam	North East	0.002	0.031	11.69	14.04
Vietnam	North West	-0.006	0.048	12.44	14.93
Vietnam	North Central Coast	0.019	0.109	12.72	14.52
Vietnam	South Central Coast	0.018	0.062	9.86	10.02
Vietnam	Central Highlands	0.010	0.044	10.07	9.66
Vietnam	South East	-0.011	0.068	6.98	8.32
Vietnam	Mekong River Delta	0.013	0.048	8.74	11.28

CV: Coefficient of variation for estimates

irrigated field, upland, recessional fields, and deep water region, are quite different in lower Mekong countries. The share of planted area of lowland or wet season rice is about 66% of the total planted area of rice in these countries and the rain-fed cultivation is sometimes damaged by drought and inundation. Furthermore, there are some cases when rice cultivation in the dry season is impossible due to delayed wet season cultivation. Therefore, an analysis of how hydrological cycle changes will affect agricultural productions in each region is important to aid in the formation of counteracting policy measures in these countries.

This study tries to clarify impacts of water supply changes on producers and consumers of rice using a supply and demand model of rice considering hydrological cycle changes to aid in making agricultural policies and plans. The developed model is extended to a stochastic model and fluctuations of water supplies are analyzed.