Chapter 6
Development of the Rice Econometric Model with Endogenous Water in Lower Mekong Countries (REMEW-MEKONG)

6-1. Introduction

Land, labor, and capital are three main inputs for agricultural economic analyses, and though it is often disregarded in econometric analysis, water is one of important inputs for crop production. Climate change caused by global warming may lead to the activation of the water cycle and expanded fluctuations of the water supply to cultivated land. Accounting for problems caused by changes of water accounting, researchers of hydrology and climatology have analyzed relationships between changes in the global water cycle and crop production. The changes will affect not only the supply of crops but also the demand prices change in the market. Therefore, econometric analyses related to water cycle changes are important to aid the design of agricultural policy.

A supply and demand model for rice in the lower Mekong river countries i.e., Laos, Cambodia, Thailand, and Vietnam, which includes among other factors evapotranspiration as a water supply variable impacting regional yields and planted areas, is developed to aid in the design of agricultural policies and planning. Impacts are analyzed deterministically by drawing on regional data and maps for relationship between water cycle changes and production of rice considering local rice markets.

6-2. Model

Supply and demand models for rice in Laos, Cambodia, Thailand, and Vietnam which includes a water supply variable are developed. Planted area, yield, and production for each province or region can be analyzed with these models. Monthly evapotranspiration (ET) is used as an explanatory variable, which is a proxy for available water supplies in yield and planted area functions. Models of Laos and Cambodia are provincial models, the model of Vietnam is a regional model, and the model of Thailand can analyze production for each province in the North-East region, but the other provinces are aggregated into three regions. Areas of province are close to those of small river basins, thus, it is sufficient to analyze the impacts of water cycle changes for the Mekong River basin. Models of these four countries are developed independently and the world price of rice is exogenous for Laos, Cambodia, and Vietnam. These four models are jointed through the world price, i.e., retail price of rice in Thailand. Figure 6-1 shows the relationship among these supply and demand models of rice in the four countries.

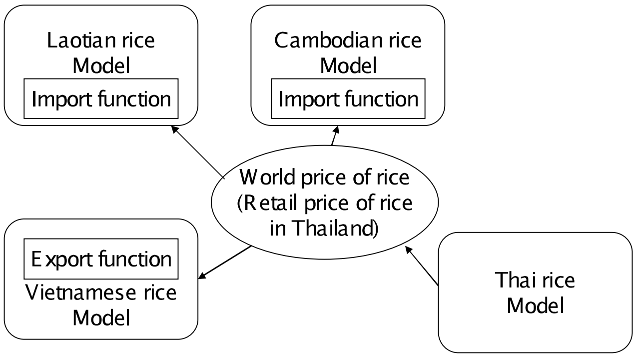

Fig. 6-1. Flowchart of REMEW-MEKONG

6-2-1. Supply and demand model of rice in Lao PDR

The supply and demand model for rice in Laos consists of yield functions, planted area functions, production identities, supply identities, an import function, a stock change function, a demand function, and a price linkage function. There are seventeen provinces and three cultivation types, i.e., wet season rice, dry season rice, and upland rice. Yield and planted area functions of wet season and upland rice are estimated for each province and those of dry season rice are estimated for the main provinces such as Vientiane and Savannakhet provinces and aggregate regions. The generalized forms of these functions are as follows:

Yield function of wet season:

$$LYW^i = f_{LYW}\,(T,\ LETMAY^i_{,t},\ \ldots\ ,\ LET^{\ i}_{NOV,t}), \qquad (6\text{-}1)$$

Planted Area function of wet season:

$$LYW^i_t = f_{LAW}\,(LAW^i_{,t\text{-}1},\ LFP_{t\text{-}1},\ LET^{\ i}_{MAY,t\text{-}1},\ldots,\ LET^{\ i}_{NOV,t\text{-}1}), \qquad (6\text{-}2)$$

Production of wet season:

$$LQW^i = LYW^iLAW^i\ ,\ \mathrm{LQW} =\ {}_iLQW^i, \qquad (6\text{-}3)$$

Yield function of dry season:

$$LYD^i = f_{LYD}\,(T,\ LET^{\ i}_{NOV,t\text{-}1},\ \ldots\ ,\ LET^{\ i}_{MAY,t}), \qquad (6\text{-}4)$$

Planted Area function of dry season:

$$LAD^i_t = f_{LAD}\,(LAD^i_{,t\text{-}1},\ LFP_{t\text{-}1},\ LET^{\ i}_{NOV,t\text{-}2},\ \ldots\ ,\ LET^{\ i}_{MAY,t\text{-}1}), \qquad (6\text{-}5)$$

Production of dry season:

$$LQD^i = LYD^iLAD^i\ ,\ LQD =\ {}_iLQD^i, \qquad (6\text{-}6)$$

Yield function of upland:

$$LYU^i = fLYU\,(T,\ LET^{\ i}_{MAY},\ \ldots\ ,\ LET^{\ i}_{NOV}), \qquad (6\text{-}7)$$

Planted Area function of upland:

$LAU^{i}_{t} = f_{LAU}\ (LAU^{i}_{,t\text{-}1},\ LFP_{t\text{-}1},\ \ln LET_{MAY\ ,t\text{-}1}^{\ \ i},\ \ldots\ ,$
$\ln LET_{NOV\ ,t\text{-}1}^{\ \ i}),$ (6-8)

Production of upland:

$LQU^{i} = LYU^{i}LAU^{i}\ ,\ LQU = \ \ _{i}LQU^{i},$ (6-9)

Total production:

$LQ = 0.667(LQW + LQD + LQU),$ (6-10)

Import function:

$LIMP = f\ (WP{*}LEXR,\ \mathbf{LQ}),$ (6-11)

Stock change function:

$LSTC = f_{LSTC}\ (LFP_{t,t\text{-}1},\ LQ_{t,t\text{-}1}),$ (6-12)

Total supply:

$LQS = LQ + LIMP - LSTC,$ (6-13)

Demand function:

$LQS/LPOP = f_{LQS}\ (LRP,\ LGDP/LPOP),$ (6-14)

Price linkage function:

$LFP = f_{LFP}\ (LRP),$ (6-15)

where i is the province, t denotes that the data are measured at time t, T is time trend, LET_{MAY} through LET_{NOV} are evapotranspiration values for May through November, *LYW*, *LAW*, and *LQW* are yield, planted area, and production of wet season rice, *LYD*, *LAD*, and *LQD* are yield, planted area, and production of dry season rice, *LYU*, *LAU*, and *LQU* are yield, planted area, and production of upland rice, *LQ* is total production in milled equivalent, *LIMP* is imports, *LSTC* is the annual change in stocks, *LPOP* is population, *LGDP* is gross domestic products, *WP* is the world price of rice (Thailand, 5% broken, FOB), *EXR* is exchange rate, *LFP* is the producer price of rice, and *LRP* is the retail price of rice. All functions are specified as linear functions.

6-2-2. Supply and demand model of rice in Cambodia

The structure of the supply and demand model for rice in Cambodia is same as that of the Lao model. There are twenty two provinces and two cultivation types, i.e., wet and dry season rice. Yield and planted area functions for the wet season are estimated for each province and those for the dry season are estimated for twelve provinces where irrigated fields exist. The generalized forms of these functions are as follows:

Yield function of wet season:

$CYW^{i} = f_{CYW}\ (T,\ CET_{MAY\ t}^{\ \ i},\ \ldots\ ,\ CET_{JLY\ t}^{\ \ i}),$ (6-16)

Planted Area function of wet season:

$CAPW^{i}_{t} = f_{CAPW}\ (CAPW^{i}_{t\text{-}1},\ CFP_{t\text{-}1},\ CET_{MAY\ t,t\text{-}1}^{\ \ i},$
$CET_{JUN\ t,t\text{-}1}^{\ \ i})$ (6-17)

Harvested area of wet season:

$CAHW^{i}_{t} = CAPW^{i}_{t} - CABW^{i}_{t}$
$= CAPW^{i}_{t}(1\text{-}CRABW^{i}_{t})$ (6-18)

Production of wet season:

$CQW^{i} = CYW^{i}CAHW^{i}\ ,$
$CQW = \ \ _{i}CQW^{i},$ (6-19)

Yield function of dry season:

$CYD^{i} = f_{CYD}\ (T,\ CETJAN^{i}_{t},\ \ldots\ ,\ CET_{MAY\ t}^{\ \ i}),$ (6-20)

Planted Area function of dry season:

$CAPD^{i}_{t} = f_{CAPD}\ (CAPDi_{t\text{-}1},\ CFP_{t\text{-}1},\ \ln CET_{DEC\ t\text{-}1,t\text{-}2}^{\ \ i},$
$\ln CET_{JAN\ t,t\text{-}1}^{\ \ i})$ (6-21)

Harvested area of dry season:

$CAHD^{i}_{t} = CAPD^{i}_{t} - CABD^{i}_{t}$
$= CAPD^{i}_{t}(1\text{-}CRABD^{i}_{t})$ (6-22)

Production of dry season:

$CQD^{i} = CYD^{i}CAHD^{i}\ ,\ CQD = \ \ _{i}CQD^{i}_{t},$ (6-23)

Total production:

$CQ = 0.667(CQW + CQD),$ (6-24)

Import function:

$CIMP = f_{CIMP}\ (WP{*}CEXR,\ CQ),$ (6-25)

Stock change function:

$CSTC = f_{CSTC}\ (CFP_{t,t\text{-}1},\ CQ_{t,t\text{-}1}),$ (6-26)

Total supply:

$CQS = CQ + CIMP - CSTC,$ (6-27)

Demand function:

$CQS/CPOP = fCQS\ (CFP,\ CGDP/CPOP),$ (6-28)

where i is the province, t denotes that the data are measured at time t, T is a time trend, $CET_{JAN}^{\ \ i}$ through $CET_{DEC}^{\ \ i}$ are evapotranspiration values for January through December, *CYW*, *CAPW*, *CAHW*, *CABW*, and *CQW* are yield, planted area, harvested area, abandoned area, and production of wet season rice, *CYD*, *CAPD*, *CAHD*, *CABD*, and *CQD* are yield, planted area, harvested area, abandoned area, and production of dry season rice, *CQ* is total production, *CIMP* is imports, *CEXP* is exports, *CSTC* is the annual change of stocks, i.e., ending stock minus beginning stock, *CQS* is total supply, *CPOP* is population, *CGDP* is gross domestic products, *CEXR* is the exchange rate, *WP* is the world price of rice (Thailand, 5% broken, FOB), *FP* is the producer price. All functions are specified as linear functions.

The planted area functions are specified based on an adaptive expectation model and ET is exogenous for the Cambodian model. In this case, ET takes both current and lagged values. On the other hand, it is assumed that ET is the expected value in the planted area function of the Lao model, and ET takes only the lagged value similar to the use of the lagged farm price. Laos is located further up in the drainage of the Mekong River basin than is Cambodia, and more accurate forecasting of water supply changes in the upper region may be required by farmers than in the lower region. Therefore, ET is expected variable in Laotian model and exogenous variable in Cambodian model.

Planted area differs from harvested area by abandoned or damaged area. Data of the retail price of rice is not available; therefore, the farm price is used in the demand function.

6-2-3. Supply and demand model of rice in Thailand

The supply and demand model of rice in Thailand focuses on the North-East region because the region is part of the Mekong River basin which this modeling effort focuses on. Yield and planted area functions are estimated for each province in the North-East region and those in the North, Central, and South regions are estimated as regional aggregates. There are nineteen provinces in the North East region. There are two cultivation types, i.e., main season or rainy season and second season or dry season cultivations. The generalized forms of the model are as follows:

Yield function of main season:

$$TYW^{i} = f\,(T, TET_{MAR\,t}^{\;i}, \ldots , TET_{DEC\,t}^{\;i}), \qquad (6\text{-}29)$$

Planted Area function of main season:

$$TAPW^{i}_{t} = f\,(TAPW^{i}_{t\text{-}1}, TFP_{t\text{-}1}, TET_{MAR\,t\text{-}1}^{\;i}, \ldots , TET_{DEC\,t\text{-}1}^{\;i}) \qquad (6\text{-}30)$$

Harvested area of main season:

$$TAHW^{i}_{t} = TAPW^{i}_{t} - TABW^{i}_{t} = TAPW^{i}_{t}(1\text{-}TRABW^{i}_{t}) \qquad (6\text{-}31)$$

Production of main season:

$$TQW^{i} = TYW^{i}TAHW^{i}\ , TQW = \ {}_{i}TQW^{i}, \qquad (6\text{-}32)$$

Yield function of second season:

$$TYD^{i} = f\,(T, TET_{NOV\,t\text{-}1}^{\;i}, \ldots , TET_{JUN\,t}^{\;i}), \qquad (6\text{-}33)$$

Planted Area function of second season:

$$TAPD^{i}_{t} = f\,(TAPD^{i}_{t\text{-}1}, TFP_{t\text{-}1}, TET_{NOV\,t\text{-}2}^{\;i}, \ldots , TET_{JUN\,t\text{-}1}^{\;i}) \qquad (6\text{-}34)$$

Harvested area of second season:

$$TAHD^{i}_{t} = TAPD^{i}_{t} - TABD^{i}_{t} = TAPD^{i}_{t}\ (1\text{-}TRABD^{i}_{t}) \qquad (6\text{-}35)$$

Production of second season:

$$TQD^{i} = TYD^{i}TAHD^{i}\ , TQD = \ {}_{i}TQD^{i}_{t}, \qquad (6\text{-}36)$$

Total production:

$$TQ = 0.667(TQW + TQD), \qquad (6\text{-}37)$$

Export function:

$$TEXP = f\,(T, TQ), \qquad (6\text{-}38)$$

Stock change function:

$$TSTC = f\,(T, TFP_{t,t\text{-}1}, TQ_{t,t\text{-}1}), \qquad (6\text{-}39)$$

Total supply:

$$TQS = TQ + TIMP - TEXP - TSTC, \qquad (6\text{-}40)$$

Demand function:

$$TQS/TPOP = f\,(TRP, TGDP/TPOP), \qquad (6\text{-}41)$$

Price linkage function:

$$TFP = f\,(TRP), \qquad (6\text{-}42)$$

where i is the province in the North-East region and that of region in other regions, t denotes that the data are measured at time t, T is a time trend, $TET_{JAN}^{\;i}$ through $TET_{DEC}^{\;i}$ are evapotranspiration values for January through December, *TYW*, *TAPW*, *TAHW*, *TABW*, and *TQW* are yield, planted area, harvested area, abandoned area, and production of main season rice, *TYD*, *TAPD*, *TAHD*, *TABD*, and *TQD* are yield, planted area, harvested area, abandoned area, and production of second season rice, *TQ* is total production, *TIMP* is imports, *TEXP* is exports, *TSTC* is the annual change of stocks, i.e., ending stock minus beginning stock, *TQS* is total supply, *TPOP* is population, *TGDP* is gross domestic products, *TEXR* is exchange rate, *TFP* is the producer price, *TRP* is the retail price. The retail price is fed to the other three countries' models through price linkage functions. “Bangkok 5% broken” is fed to in the Laotian and Cambodian models and “Bangkok 35% broken” is fed to the Vietnamese model. All functions are specified as linear functions.

6-2-4. Supply and demand model of rice in Vietnam

The model in Vietnam is divided into eight regions for supply and the basic structure of the model is same as those of other countries. There are three types of cultivation, i.e., spring, summer, and winter season rice. Spring season rice transplanting occurs in December and the harvest occurs during April and May. For summer season rice transplanting occurs from May to June and harvesting from September to October. Finally, transplanting of winter season rice occurs in September to October and harvesting occurs in December in the Mekong Delta region. Spring and Summer rice are cultivated in irrigated fields as a two season crop and winter rice is cultivated in rain-fed fields as a single season crop. The generalized forms of the supply and demand model of rice are as follows:

Yield function of spring season:

$$VYS^{i} = f\,(T, VET_{DEC\,,t\text{-}1}^{\;i}, \ldots , VET_{JLY\,,t}^{\;i}), \qquad (6\text{-}43)$$

Planted Area function of spring season:

$$VAS^{i}_{t} = f\,(VFP_{t\text{-}1}, VEYS^{i}_{t}, VET_{JAN\,t}^{\;i}), \qquad (6\text{-}44)$$

Planted Area function of spring season in the Mekong River Delta region:

$$VAS^{MRD}_{t} = f\,(T, VASMRD_{t\text{-}1}, VFP_{t\text{-}1}, VEYSMRD_{t}, VET_{JAN\,t}^{\;i}, VET_{FEB\,t}^{\;i}), \qquad (6\text{-}45)$$

Production of spring season:

$$VQS^{i} = VYS^{i}VAS^{i}\ , VQS = \ {}_{i}VQS^{i}, \qquad (6\text{-}46)$$

Yield function of summer season:

$$VYMi = f\,(T, VET_{MAR\,,t}^{\;i}, \ldots , VET_{OCT\,,t}^{\;i}), \qquad (6\text{-}47)$$

Planted Area function of summer season:

$$VAM^{i}_{t} = f\,(VFP_{t\text{-}1}, VEYM^{i}_{t}, VET_{JAN\,t}^{\;i}, \ldots , VET_{AUG\,t}^{\;i}) \qquad (6\text{-}48)$$

Planted Area function of summer season in the Mekong Delta region:

$$VAM^{MRD}_{t} = f\,(T, VFP_{t\text{-}1}, VEYM^{MRD}_{t}, VET_{MAY\,t}^{\;i}), \qquad (6\text{-}49)$$

Production of summer season:

$$VQM^{i} = VYM^{i}VAM^{i}\ , VQM = \ {}_{i}VQM^{i}, \qquad (6\text{-}50)$$

Yield function of winter season:

$$VYW^{i} = f\,(T, VET_{JUN\,,t\text{-}1}^{\;i}, \ldots , VET_{NOV\,,t}^{\;i}), \qquad (6\text{-}51)$$

Planted Area function of winter season:

$VAW^i_t = f\,(T, VFP^i_{,t\text{-}1}, VEYW^i_t, VET_{JUN\,t}^{\;i}, \dots ,$
$VET_{OCT\,t}^{\;i})$ (6-52)

Planted Area function of winter season in the Mekong River Delta region:

$VAWMRD^i = f\,(T, VFP_{t\text{-}1}, VEYW_{MRD}^{\;i}, VET_{JUN\,t}^{\;i},$
$VET_{JLY\,t}^{\;i}),$ (6-53)

Production of winter season:

$VQW^i = VYW^iVAW^i\,,\; VQW = \;{}_{i}VQW^i,$ (6-54)

Total production:

$VQ = 0.667(VQS + VQM + VQW),$ (6-55)

Export function:

$VEXP = f\,(WP{*}VEXR, VQ),$ (6-56)

Stock change function:

$VSTC = f\,(VFP_{t,t\text{-}1}, VQ_{t,t\text{-}1}),$ (6-57)

Total supply:

$VQS = VQ + VIMP - VEXP - VSTC,$ (6-58)

Demand function:

$VQS/VPOP = f\,(VRP, VGDP/VPOP),$ (6-59)

Price linkage function:

$VFP = f\,(VRP),$ (6-60)

where i is the region, t denotes that the data are measured at time t, T is a time trend, $VET_{JAN}^{\;i}$ through $VET_{DEC}^{\;i}$ are evapotranspiration values for January through December, *VYS*, *VAS*, *VEYS*, and *VQS* are yield, planted area, expected yield, and production of spring season rice, *VYM*, *VAM*, *VEYM*, and *VQM* are yield, planted area, expected yield, and production of summer season rice, *VYW*, *VAW*, *VEYW*, and *VQW* are yield, planted area, expected yield, and production of winter season rice, *VQ* is total production, *VIMP* is imports, *VEXP* is exports, *VSTC* is the annual change of stocks, i.e., ending stock minus beginning stock, *VQS* is total supply, *VPOP* is population, *VGDP* is gross domestic products, *VEXR* is exchange rate, *VWP* is the world price of rice (Thailand, 35% broken, FOB), *VFP* is the producer price, *VRP* is the retail price. All functions are specified as linear functions.

The planted area function is based on the naïve expectation model because Mekong Delta region, where is the main production region, locates in lower Mekong River. Water harvesting and forecasting of water supply changes in lower regions are easier than those in upper regions, therefore the planted area functions of the Vietnamese model take a simpler form than those of the Laotian and Cambodian models.

The number of functions of the Laotian, Cambodian, Vietnamese, and Thai rice models are 78, 65, 46, and 80 respectively, i.e., total 269 functions. The number of identities of these models are 43, 36, 36, and 45 respectively, i.e., total 160 identities.

6-3. Data

6-3-1. Evapotranspiration

Evapotranspiration is used as a water supply variable for crops. The ET for a basin is obtained from the following identity:

$$\begin{aligned} ET = {} & \text{Irrigation} + \text{Rainfall} + \text{Capillary rise} \\ & + \text{Subsurface flow in} - \text{Runoff} \\ & - \text{Deep percolation} - \text{Subsurface flow out} \end{aligned} \quad (6\text{-}61)$$

The equation suggests that ET is equivalent to the available water for crops, then, it is used as a water variable in the model of this study. However, if the target region is large such as a entire country, the cost of the survey will be very high. Therefore, the ET is approximately calculated from climatologic data have been presented over fifty years. The actual ET (*ETa*) is equal to the reference ET (*ETo*) times the crop coefficient (*Kc*) and the stress coefficient (*Ks*). The estimation method of ETo of IMPACT-WATER, as applied in the IFPRI world food model which was the first world food model to consider water accounting, is the Penman method (Doorenbos and Kassam [2]), however, Penman-Monteith method (Allen et al. [1]) which considers aerodynamics of leaves is used for calculating ET in our study. Ishigooka *et al*. [5] provides the ET data for every province and month. The climatic data for the calculation are 0.5 degree grid data and these are averaged for each province.

6-3-2. Data of Laotian rice model

The time series data for production and planted area for each province is provided by the Department of Planning in the Ministry of Agriculture and Forestry of Laos. The farm price for rice is obtained from FAO-STAT and the retail price of rice is obtained from the National Statistics Center of the Committee for Planning and Cooperation of Laos. These prices are a national average prices for Laos. Consumer Price Index (CPI), GDP, and population are from the Asian Development Bank (ADB) and the exchange rate and the world price of rice are data from the IMF. The estimation period for yield, planted area, import, stock change, and demand functions is from 1980 to 2000 which starts in the earliest available year for CPI and ends in the last year of available ET values.

6-3-3. Data of Cambodian rice model

Availability of statistics on rice production in Cambodia is limited, as the nation was a planned economy until 1993 following the Pol Pot regime from 1976 to 1979. Data on rice production which is divided into wet and dry season are available from 1995. The short data period, along with data quality, is one of restrictions in estimating and validating the supply and demand model of rice. The time series data for production, planted area, and harvested area for the two seasons of rice production for each province are provided by the Department of Planning, Statistics and International Cooperation in the Ministry of Agriculture, Forestry and Fisheries of Cambodia. The farm price for rice is obtained from FAO-STAT and the price is a national average for Cambodia. CPI, GDP, and population are from the ADB and exchange rate and the world price of rice (Bangkok broken 5%, FOB) are numbers from IMF. The production data are available from 1995, and the yield and planted area functions are estimated using pooled data from 1995 to 2000 for each province. Import, stock, and demand functions are estimated using time series data which are available from 1983 to 2001. The yield and planted area functions of both seasons are not estimated for each province due to the lack of time series data, parameters are obtained by estimating one function which includes provincial dummies using pooled data for nineteen provinces over six years. The estimation periods of these yield and planted area functions are from 1995 to 2000 which starts in the earliest available year for statistics of production of the two seasons and ends in the last year of available ET values.

6-3-4. Data of Thai rice model

The time series data for production and planted area of the two types of rice cultivations for each province is provided by the Center for Agricultural Information at the Office of Agricultural Economics of the Ministry of Agriculture and Co-operatives of Thailand. The farm price for rice is obtained from FAO-STAT and the retail price of rice is obtained from the IRRI, which is available from 1961 to 1997 and then carries the same values forward after 1997. These prices are a national average for Thailand. CPI, GDP, and population are from the ADB and the exchange rate and the world price of rice are numbers from the IMF. The estimation period for yield and planted area functions for each province in the North East region and aggregated other regions, imports, stock change, and demand functions for the whole country are from 1982 to 2000 which starts in the earliest available year for statistics of production and ends in the last year of available ET values.

6-3-5. Data of Vietnamese rice model

The time series data for each region for production and planted area of the three types of rice cultivation is provided by the General Statistics Office of the Statistical Publishing House of Vietnam. The farm price for rice is obtained from FAO-STAT and the retail price of rice is obtained from the USDA. These prices are a national average for Vietnam. GDP, GDP deflator and population are from the ADB and the exchange rate and the world price of rice are data from the IMF. The estimation period for the yield and planted area functions in the Mekong Delta region, imports, stock change, and demand functions for whole country are from 1985 to 2000 which starts in the earliest available year for GDP deflator and ends in the last year of available ET values. Functions for yield and planted area in seven regions outside the Mekong Delta region are estimated using pooled data from 1985 to 2000.

6-4. Results and simulation

The simulation term is from 2001 to 2015. The assumptions of the simulation are as follows; (1) the growth value of population is the average annual growth between 1996 and 2003, (2) the growth value of real GDP is the average annual growth between 1996 and 2003, (3) the growth value of exchange rate is the average annual growth between 1999 and 2004, (4) the assumed growth value of deflators such as CPI is the average annual growth between 1998 and 2000, (5) monthly ET values are the average values for each month between 1998 and 2000, (6) the linear trend of the yield functions are continued, (7) the linear trend of area functions takes same numbers of the 2000 during the simulation period. The results of simulations in Laos and Cambodia are reported in Furuya and Meyer [3] and Furuya and Meyer [4].

Evaluating affects of water supply changes on the rice market, a scenario to decrease the ET value by 20% in 2014 and 2015 are contrasted with the baseline case showing a decreasing rate of yield and planted area in the wet season and dry season. Results of wet season cultivation in Laos and Cambodia, winter season cultivation in Vietnam, and the main rice cultivation in Thailand are classified as wet season cultivation in the results, and results of dry season cultivation in Laos and Cambodia, spring season cultivation in Vietnam, and second rice cultivation in Thailand are classified as dry season cultivation in this simulation.

Figure 6-2 and Figure 6-3 show the impacts of decrease by 20% of ET values in May and June on yield of wet season cultivation in 2015. The yield will decrease in the region in correlation to the degree of shading and yield will increase in the region where the color is white. These figures suggest that if the water supply in May decreases, the yield of wet season rice will decrease dramatically in the south and west part of the Indochina peninsula, and if the water supply in June decreases, yield of wet season rice will increase in the southern part of the peninsula. The water supply in May greatly affects the yield of wet season rice in the southern part of the region which is centered on Cambodia.

Figure 6-4 and Figure 6-5 show the impacts of 20% decrease in the ET value in May and June on the planted area. Note that the planted area of the following year will increase when the current price of rice increases. These figures suggest that if the water supply in May decreases, planted area will increase in the western side of the Annamite Mountains and will decrease around the Kholat Plateau. On the other hand, if the water supply in June decreases, planted area will decrease in the Mekong Delta region. These results indicate that abundant water supplies in May leads to an expansion of planted area in regions of the middle section of the Mekong River basin and a water shortage in June leads to a decrease in planted area in the lower section of the river.

Figure 6-6 and Figure 6-7 show the impacts of 20% decrease in the ET in November and December on rice yields in the dry season. These figures suggest that if the water supply decreases in November, yield will dramatically decrease in the eastern part of the Indochina peninsula and increase in the north central part of the region. Alternatively, if the water supply decreases in December, yield will decrease in the north central portion. Impacts of water supply changes on yield are intricate in the North East region in Thailand and the North region in Lao and rice cultivation in these regions are probably vulnerable to water cycle changes.

Figure 6-8 and Figure 6-9 show the impacts of a 20% decrease in the ET value in November and December on the planted area of rice in the dry season. These figures suggest that if the water supply decreases in November, farmers in west part of the region will increase their planted area because an increase in the price farmers receive for their rice will encourage them to try to expand their production. If the water supply decreases in December, the planted area will decrease around the Kholat Plateau.

There are some regions where the planted area increases when the water supply decrease in the planting season. This is probably because the water supply may be in excess in these regions and a decrease in the supply of water will move the accumulated supply of water closer to optimum amounts. Note that the planted area responds to the price of rice and if productions in other regions decrease, farmers in the region will increase their planted area in the following year. Results of the model provide not only impacts of water supply changes on the production per area, but also clearly show impacts of it through the rice market on the total production.

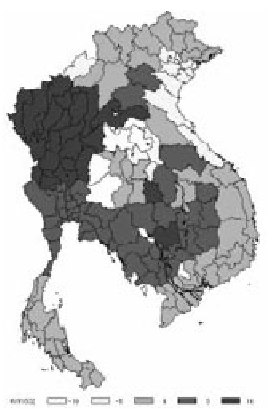

Fig. 6-2. Impact of ET changes in May on yield in the wet season

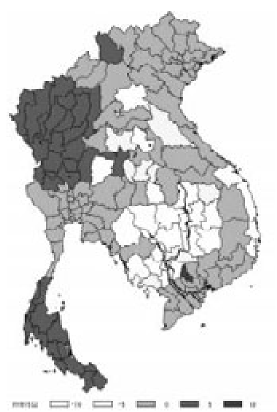

Fig. 6-3. Impact of ET changes in June on yield in the wet season

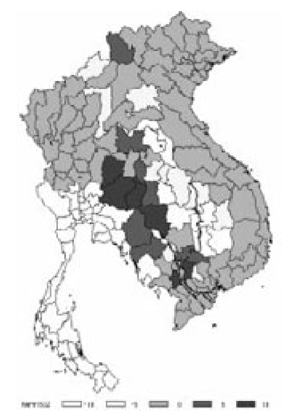

Fig. 6-4. Impact of ET changes in May on planted area in the wet season

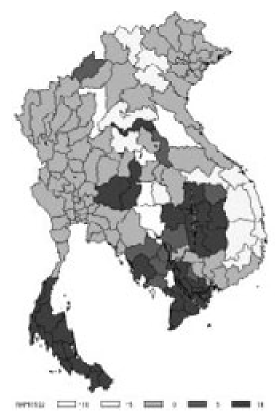

Fig. 6-5. Impact of ET changes in June on planted area in the wet season

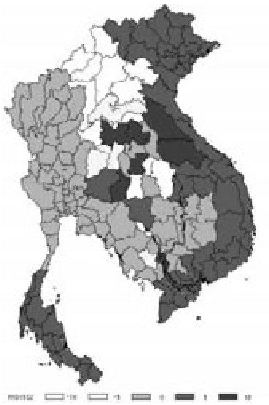

Fig. 6-6. Impact of ET changes in November on yield in the dry season

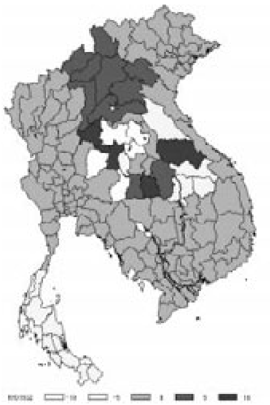

Fig. 6-7. Impact of ET changes in December on yield in the dry season

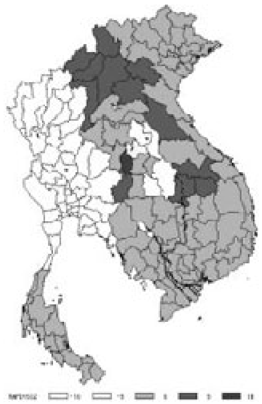

Fig. 6-8. Impact of ET changes in November on planted area in the dry season

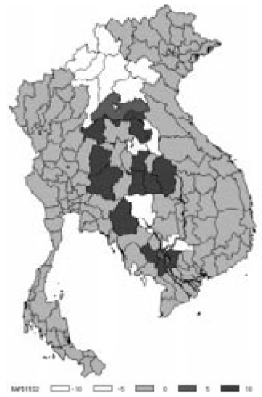

Fig. 6-9. Impact of ET changes in December on planted area in the dry season

6-5. Conclusions

A Supply and demand model of rice in four countries in the lower Mekong River basin is developed and the impacts of the water cycle changes are evaluated by using an economic model. The model can analyze changes in production for each province which areas are close to small river basin in the Mekong River basin. The developed supply and demand model of rice in Laos and Cambodia is the first attempt in the world and the rice economic model is also unparalleled in considering water supply changes. This model highlights the regions where changes of the water supply have serious impacts on the production of rice. The results consider the supply response of farmers to price changes. In particular, famers in the western part of the Indochina peninsula will decrease their planted area of rice when the water supply decreased in May, i.e., the transplanting season. The policies mitigating impacts of water cycle changes on agricultural production, such as introduction of a new water management method, will be evaluated by joining models of water accounting model, crop model, and this economic model.