Tech. Bull. Fac. Agr. Kagawa Univ., Vol. 62, 25～32, 2010

Regional Productivity with Agro-climatic and Environmental variables, and Impact of Climate Change to the land use in agriculture

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Abstract

This paper has two parts, regional comparison of productivity and regional cropping pattern simulation. The first part aims to demonstrate the application of interregional technical inefficiency comparison. Historically the agro-climatic and other environment variables are omitted with the justification assuming these are beyond the control of the farmers, they are treated as random variables. The second part aims to demonstrate the simulation for the land use pattern change by crop yield change as the climate change impact, based on positive mathematical programming.

Key words：Inefficiency Frontier Model, productivity, Positive Mathematical Programming, land use

Part I Agro-climate impact to the productivity by Province

Introduction

The related research project had been implemented in Adana province in Turkey by the support of Faculty of Agriculture in Çukurova University. The project reports are provided through project web site, ICCAP（2007）. There are geographically and climatically 7 regions by in Turkey（Kameyama et al 2006）（Fig. 1）.

As positioning of Adana province, for the regional comparison of productivity, the Technical Inefficient Effects model is applied using panel data. To see the regional variability to this impact, agro-climatic and other environment variables are critical（Demir and Mahmud 2002）. In Mediterranean region, only Adana province increases the technical efficiencies score in three years.

The Model

Inefficiency Frontier Model for Panel Data is employed（Battese and Coelli 1995）by Coelli's FRONT4.1（Coelli T, 1996）. As the option, TE effects model and production function are used.

Output（VA）is set as Lhs variable, and as Rhs variables 19 X variables（16 Z variables）are set. The 19 X variables include Land, Labor, Capital, Land-quality and Rainfall in

Fig. 1　Turkey region map

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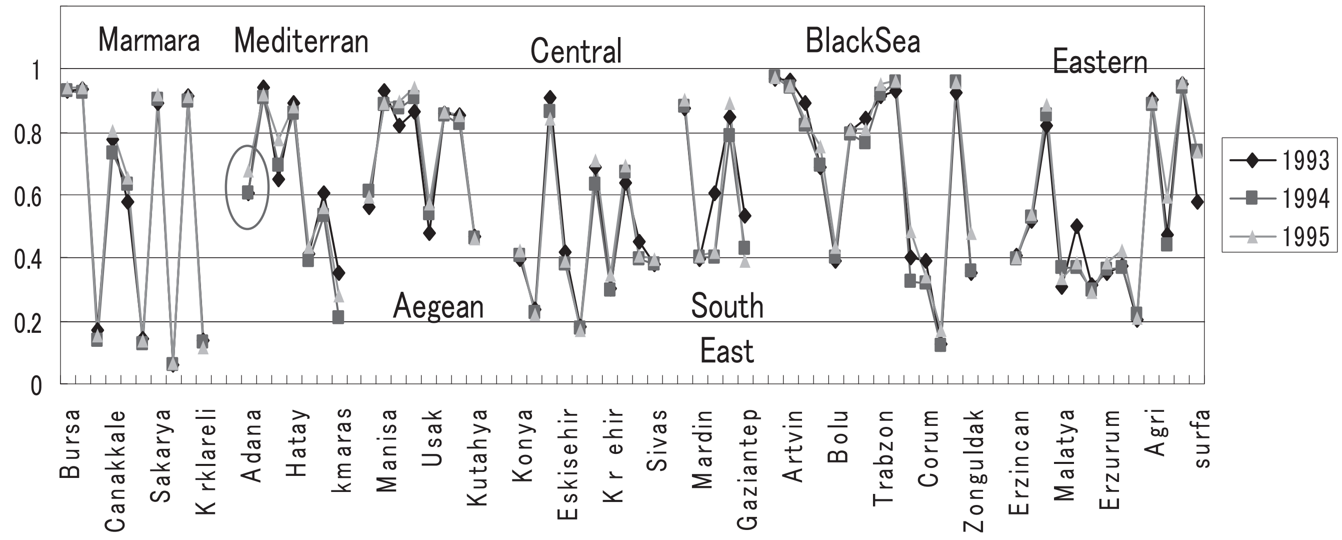

Fig. 2 Product Efficiency Coefficients by Province in Turkey x

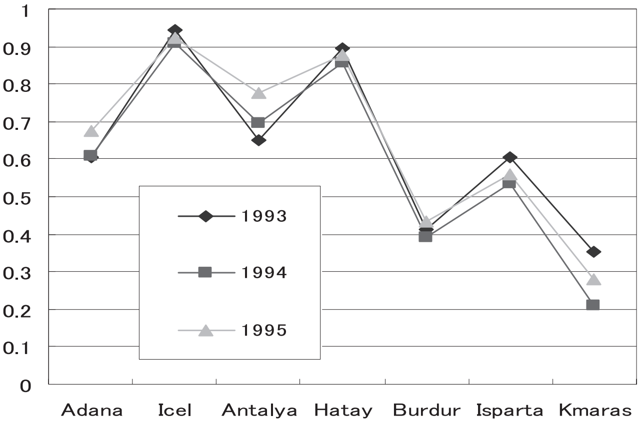

Fig. 3 Product Efficiency Coefficients by Province in Mediterranean region

linear form, and squared and cross terms since the production function is a Translog. Note that for the column Rainfall, the model does not have a square term because the variable is a dummy and the square of a dummy would because linear dependence which would cause problem of matrix inversion.

The 16 Z variables are the environmental variables and their interactions with factor inputs-X variables. The environmental variables are, Z1: Land-ownership distribution (measured by GINI coefficient G), Z2: Land quality (measured by a land quality index Q), Z3: general crop-pattern (a dummy variable taking 1 for intensive cultivation, 0 for cereals and traditional livestock C) and Z4: Precipitation (rain+snow) (a dummy variable taking 1 for precipitation above the national average R). The remaining 12 Z variables are interactions Z*X (interactions with land, labor and capital 4x3 =12).

Data and results

Employed the data from 67 province, aggregate at provincial level, covering the 1993, 1994 and 1995. The original panel data analysis is provided by Demir and Mahmud (2002). The variation is different by agricultural region. Central region and eastern region have low score. Even Mediterranean region, where water resource abundant region, some have low score. Adana locates as relatively 0.61 –0.67, not so high (Fig. 2, Fig. 3).

Part II Impact of Climate Change to the Land Use in agriculture

Introduction

This part aims to introduce the primary model framework for regional agricultural production model, focusing on land use by crops. The effects of climate change may be caused by change of temperature and rainfall pattern. Its effects of climate on yield levels and variances are investigated and used well following this procedure (Chen, McCarl and Schimmelpfennig 2000, Adams, McCarl and Mearns 2003). The former uses panel data in U.S. Agriculture with different climate change scenario. For site specific research, further field survey will be needed for the crop growth model.

The pilot site locates in the middle of Adana province. Ceyhan Plain Irrigation Project Area is the water abundant area and the irrigated crops are varied by water users association.

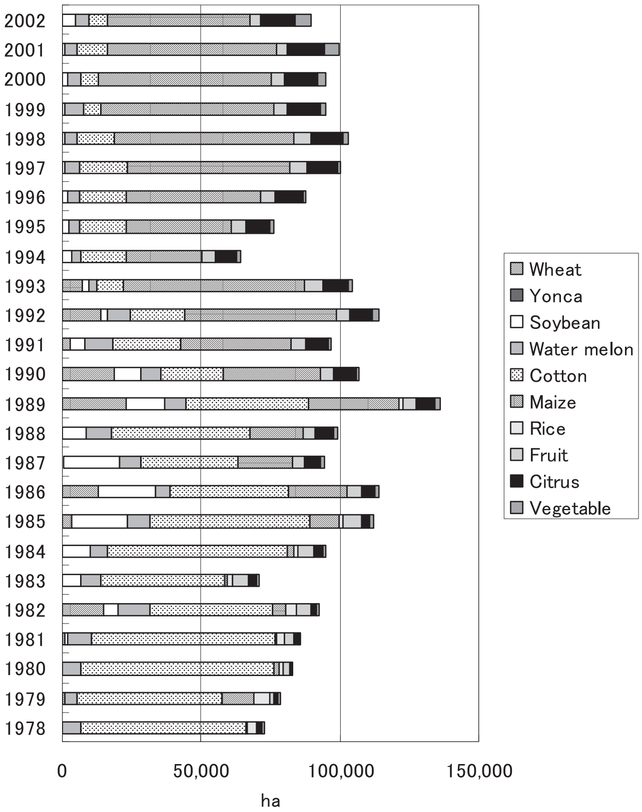

Fig. 4 Irrigation area by crop in Lower Ceyhan Plain Irrigation Project Area

The main reason is on the level of the infrastructure development and accessibility to water.

As the land use of agriculture, this area has extended with cotton, the soil is suitable to maize as well. As the administrative long term plan, the major crop would be corn or maize. In the national plan cotton is assigned in GAP (South east) region for the regional development plan with relatively low wage rate. Cotton seasonal labor has come from GAP region, then the cultivation technology has already transferred and the potential has been going up by the irrigation systems development. Without these long term regional development plan, here, we would demonstrate the impact assessment of climate change by yield change.

The irrigated crops have been changed from cotton to maize as the water users association's record (Fig. 4). But even now some areas have much crop variety, such as with citrus and vegetables (DSI, 2002) (Fig. 5).

Brief behavioral calibration theory

Howitt (1995a,b) has opened these series of theory and practices. The process of calibrating models to observed outcomes is integral part of constructing physical and engineering models, but is rarely formally analyzed for optimization models in agricultural economics. The observed behavioral reactions yield a basis for calibrating models in a formal manner. Analogously to econometrics, the calibration approach draws a distinction between the two modeling phases of calibration (estimation) and policy prediction.

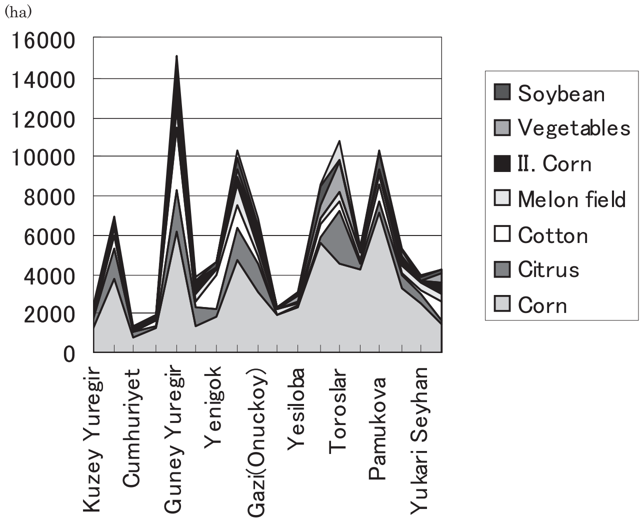

Fig. 5 Major Irrigated Crops by Water Users Association

As a regional level, the information on the product output levels and on farm land allocations is usually more accurate than the estimates of marginal crop production costs. This is particularly true when micro data on land class variability, technology, and risk feature in the farmers' decisions, are absent in the aggregate cost data available to the model builder. Accordingly, the PMP (Positive Mathematical Programming) approach uses the observed acreage allocations and outputs to infer marginal cost conditions for each regional crop allocation observed. This inference is based on parameters that are known to be accurately observed and the usual profit maximizing and concavity assumptions.

Model Calibration Method

PMP, non-linear calibration approach, is applied to any non-degenerate linear problem. The deviation of the general results proceeds in three steps. The first step shows that the dual value on the calibration constraint for the calibrated activity set is equal to the reduced cost of the activity x_i in the un-calibrated base problem. The second step shows that if the correct non-linear penalty function is added to the objective function, the resulting nonlinear problem satisfies the necessary conditions for optimality at the required value of each activity level. The implementation of calibration methodology can also provide information about the general structure of the model (Cakmak H. E, and H Kasnakoğlu 2001).

The first step of the model can be written in simple matrix notation as follows:

$$\text{Max} \quad Z = f(D) \qquad (1)$$

$$Ax : \leq b \qquad (2)$$

$$Ix = \tilde{\chi} + \varepsilon \qquad (3)$$

$$x \geq 0 \qquad (4)$$

where Z is the objective function. The costs of the products and the variable costs of all production activities are included in the objective function. The vector x and the matrix A denote the activities and input-output coefficients. Vector b shows the RHS of the equations.

Equation (3) is called calibration constraint. $\tilde{\chi}$ is formed by the base period levels of the activities, and ε is the perturbation factor (equals 0.001) to prevent degenerate solution. The dual values of the calibration constraints provide the missing information about the marginal costs of the activities. The intercept and slope terms of the activity specific marginal cost functions are estimated by using the prevailing product pattern in the base period. The slope terms are dependent on the gross revenue and the level of activities:

$$\gamma_{r,a,t} = -1/SE_{\alpha} \cdot \sum_{0} (P_0 \cdot Y_{r,a,t,0})/BPA_{r,a,t} \qquad (5)$$

where γ is the slope term, SE and P represent supply elasticity and price, respectively; Y is the yield, and BPA denotes base period activity level. The indices are defined as follows. r: region, a: production activity, t: technology, and o: output.

The intercept terms are found by using the dual values of the calibration constraints and the slope terms:

$$\alpha_{r,a,t} = -DVC_{r,a,t} - \gamma_{r,a,t} \cdot BPA_{r,a,t} \qquad (6)$$

where α is the intercept term of the cost function, and DVC denotes the dual value of the calibration constraint in (3). Hence, the cost functions are obtained from the production decisions of the farmers in the base period.

In the second step the cost functions are incorporated in the model shown in equations from (1) to (4), and calibration constraints (3) are removed. The model used for policy experiments is shown below:

$$\text{Max} \quad Z = f(D) + \sum_{r,a,t} \chi_{r,a,t} (\alpha_{r,a,t} + 0.5\gamma_{r,a,t} \cdot \chi_{r,a,t}) \qquad (7)$$

$$Ax \leq b \qquad (8)$$

$$x \geq 0 \qquad (9)$$

The model is consistent with the microeconomic theory (Howitt1995a, b), and it replicates the base year production and prices without the calibration constraints.

Data

For mathematical programming modeling, dataset consists of three main clusters : (a) gross margin, (b) resource requirements for unit acres, (c) resource availability. For (a) and (b) AERI (2001), Koral and ALTUN (2000). Labor, capital, water availability are obtained from DSI (2002).

Input-Output coefficients: The input resource requirements of land, labor, machine, water per hectare (Henrichsmeyer and Kasnakoğlu 1992)

Value of crop production: The area sown, yield, production, price, and value (Agricultural Structure, State Institute of Statistics (SIS) 2000). Table 1 shows the value of crop production in Adana as a whole. Table 2 shows value of major crops in Adana. For vegetables and fruits, area data is not available. As in table 1 the share of vegetables and fruits in values of marketable are very high and, based on the trend analysis, are continuingly expected to increase, so area as well.

Cost and value: Cost data is available for following crops (Budak , Budak and Dagistan 2001).

(1) Cotton, wheat, corn (second crop), watermelon (greenhouse growing), melon (greenhouse growing) in Adana Province.

(2) Grapes, orange, mandarin, lemon in Cukurova and cotton in Kahramanmaras.

(3) variable cost: the production costs and gross margin in Adana (Table 3). For groundnut, soybean and water melon, the ratio of variable cost sets at around 75%.

(4) Price elasticity of supply: All set at 1.0.

Table 1 Value of crop production in Adana

	Production (ton)	Value (MillionTL)	Value of market-able (MillionTL)	(%)
Field crops	2,144,640	249,647,956	174,818,149	48
Vegetables	868,085	97,005,729	81,005,587	22
Fruit	715,220	119,872,682	108,348,235	30
Total	3,727,945	466,526,367	364,171,971	100

Source: Agricultural Structure (Production, Price, Value), State Institute of Statistics, 2000.

Table 2　Value of crop production（major field crops and ）in Adana

Crop	Harvested（ha）①	Yield（kg/ha）②	Production（Tons）③＝①*②/1000	Price（TL/kg）④	Value（Million TL）⑤＝③*④/1000	(%)
Wheat	324,116	3,593	1,164,549	102,295	119,127,518	(42)
Maize	84,617	6,550	554,241	85,111	47,172,036	(17)
Chickpeas	12,705	782	9,935	377,510	3,750,679	(1)
Sugar beat	614	29,155	17,901	36,612	655,398	(0)
Cotton	44,926	3,177	142,730	255,424	36,456,642	(13)
Groundnuts	7,900	3,377	26,678	522,917	13,950,537	(5)
Soybean	7,277	3,035	22,086	144,722	3,196,286	(1)
Watermelon	15,830	41*	641,246	93,667	60,063,589	(21)

Source: Agricultural Structure（Production, Price, Value）, State Institute of Statistics, 2000.
Calculated by authors

Table 3　Production costs and gross margin in Adana

Crop	Price	Yield	Gross Production Value	Variable cost（per ha）		Actual Area	Gross Margin	
Unit	（1000TL/kg）①	（ton/ha）②	（Million TL）③＝①*②	（Million TL）④	(%)	（ha）⑤	（Million TL）（(③−④) ＊⑤）	(%)
Wheat	102,295	3.598	368,057	288,325	78.3	324,116	25,842,549,800	40
Maize	85,111	6.55	557,477	435,000	78.0	84,617	10,363,640,540	16
Cotton	255,424	3.177	811,482	620,000	76.4	44,926	8,602,522,488	14
Groundnut	522,917	3.377	1,765,891	1,324,400	75.0	7,900	3,487,776,601	5
Soybean	144,722	3.035	439,231	330,000	75.1	7,277	794,875,952	1
water melon	93,667	40.5	3,793,514	2,884,000	76.0	15,830	14,397,598,705	22
Total							63,488,964,086	100

Source: Agricultural Structure（Production, Price, Value）, State Institute of Statistics, 2000.
Calculate by authors.

Table 4　Climate change impacts on crop productivity（% change）

	Region								
Commodity	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	Average
Rice	0	−18	−43	0	−24	−35	−13	−26	−26
Wheat	−12	−21	−53	−12	−5	0	−18	−22	−16
Other grains	−5	−20	−43	−8	−21	−40	−16	−16	−18
Other crops	1	−15	−43	−10	−15	−35	−16	−23	−19
Regional average	−3	−17	−43	−9	−17	−34	−16	−22	

Source: Tsigas, Frisvold and Kuhn, 1997
Note: Impacts do not Account for Direct Effects of CO_2 on Crop Growth

Impacts of Climate Change

The regional level production model is developed by calibration procedure. Although the impact of climate change is not obvious, the reason for this may be that little empirical evidence is available on sources of agricultural output variability. In Chen, McCarl and Schimmelpfennig（2000）precipitation and temperature individually have opposite effects on corn yield level and variability.

With this regional production model procedure, the policy issues are also can be discussed, due to the recent policy instrumental change from price support to direct-income payment, it will give the farmers more decision making choice so that cropping pattern may be cased by this policy change rather than climate change.

Regarding the Climate Change Impacts on crop productivity, several references are available in international modeling frame. Table 4 shows the impact（Tsigas, Frisvold and Kuhn

1977）. The figures in a parenthesis are % change at the world average.

In case of impact which do not account for direct effect of CO_2 on crop growth, rice （−26%）, wheat （−16%）, other grains （−18%）, other grains （−19%）. In case of impact which accounts for direct effects of CO_2 on crop growth, rice （−7%）, wheat （−6%）, other grains （−9%）, other crops （6%）. Accordingly, here the yield reduction in wheat is set for −15% as impact.

For more region specific coefficient, mathematical models EPIC （crop growth models） or CropSyst （Croping Systems Simulation Model） are required （Glardini, Berti, and Morari 1998）.

Result

Table 5 shows that the wheat yield reduction （−15%） leads the change to land allocation by crops, wheat reduces 0.27%, maize reduces 1.57%, cotton reduces 3.3%, whereas groundnut increases 0.90%, soybean no change, water melon increases 6.11%. As the total, 0.55% is reduced. water melon increases the cultivation area because of higher gross margin in our simulation.

The impact of climate change is considered in general as the seasonal change of temperature and rainfall. In this model frame work among these two impacts only the reduction of wheat is used. In reality the water resource availability in August is significant constraint. This PMP procedure sets it as prerequisite condition for farmers decision making process. So these water resource availability constraints are taken into considered as representative giant farmers behavior. In this model these constraint is not required as arbitrary constraint, however, it will be used as the decrease of water availability, like in August, as the seasonal change.

Table 5　Impact of wheat yield reduction

crop	observed	simulated	Change
	land allocation		
	ha	ha	（%）
wheat	324,116	323,243	−0.27
maize	84,617	83,292	−1.57
cotton	44,926	43,430	−3.33
groundnut	7,900	7,973	0.92
soybean	7,277	7,277	0.00
water melon	15,830	16,797	6.11
total	484,666	482,012	−0.55

Note: Simulation result

As further research to assess the impact of the climate change site specifically;

1） the water resource constraints, such as effective rain and irrigation water, would be incorporated by the data （DSI 1988, Özgenç and Erdogan 1988）, then net irrigation water requirements will be able to calculated.

2） Daily time series of data for crop growth conditions is required to use crop growth model to show the yield level change for specific crops.

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(Received October 31, 2009)

農業気候と環境変数による地域の生産性比較及び気候変動の農業的土地利用への影響

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要　約

本稿は、生産性の地域間比較と地域の作物の土地利用の２部構成からなる。第１部では、技術的非効率性の地域間比較の事例。農業気候と他の環境変数を説明変数として取り入れる。従来は、農民の制御を超えており確率的変数として除かれていた。第２部では気候変動は収量の減少をもたらすとし、地域の農業的土地利用にもたらす影響をシミュレーションする方法、記述的数理計画法を検討する。

Key words：Inefficiency Frontier Model, productivity, Positive Mathematical Programming, land use