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FINAL TECHNICAL REPORT

SUPPLEMENTAL GRANT AID/CSD-2824

ECONOMIC DEVELOPMENT AND AGRICULTURAL SECTOR ANALYSIS

Center for Agricultural and Rural Development

Iowa State University

June, 1979

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FINAL TECHNICAL REPORT

SUPPLEMENTAL GRANT AID/CSD - 2824

TITLE: Economic Development and Agricultural Sector Analysis

GRANTEE: Center for Agricultural and Rural Development
Iowa State University

PROGRAM DIRECTOR: Earl O. Heady

AID Technical Office: ASIA/TR/ARD

AID PROJECT COORDINATOR: Gleason D. Rohlfs

STATISTICAL SUMMARY:

Period of Grant:	2/26/73 - 6/30/79	
Amount of Grant:		$ 400,000.00
Total Expenditures:	2/26/78 - 6/30/79	$ 400,000.00

BACKGROUND AND DESCRIPTION

The proposal for a supplemental grant was submitted to the Agency for International Development in response to an indication from AID that it was prepared to consider funding of a research and training project directed at advancing the state-of-the-art and applicability of current sector analysis techniques to the dynamics of LDC agricultural development and economic growth processes. Although the terms of the supplemental grant were not country-specific, it was decided to select one particular country as a test case for the research and training activities. This was done to provide analyses which would have immediate and usable benefits to real-world development and growth problems. The techniques developed and used for the test case country can be applied to other lesser developed countries by making appropriate modifications in the model complex.

The country selected for the test case study was Thailand. Research and training activities of the supplemental grant therefore complemented the efforts being carried out under the contract-funded agricultural sector analysis project in Thailand. Formal training activities were provided on campus for DAE staff members who returned to Thailand to collaborate with ISU team members as DAE counterpart professionals. On-campus staff members also carried out important backup research work for the Thailand project by developing and analyzing basic models which were used in Thailand. When needed, on-campus staff members traveled to Thailand to provide direct short-

term assistance to the contract project as well as to gain a closer and better insight of Thai agricultural development problems and the applicability of alternative modeling approaches to local conditions.

Purpose of Supplemental Grant

Purpose of the supplemental grant was to support activities aimed at further developing the University's competence on LDC agricultural sector analysis and the numbers of American economists knowledgeable of the relevant methodologies involved in such an analysis. The funds were used to initiate research and training in advancing the state-of-the-art and the applicability of current sector analysis techniques to the dynamics of LDC agricultural development and economic growth processes.

Objectives of Supplemental Grant

Specific objectives of the supplemental grant were to:

(1) Adapt and test existing quantitative analytical methodologies towards constructing a micro-macro level planning and policy analysis mechanism.

(2) Conduct research on conceptual and methodological issues designed to enhance the scope and reliability of quantitative agricultural sector planning mechanisms of this nature.

(3) Train personnel for continually upgrading, operationalizing, and applying quantitative planning mechanisms for administrative and political decision makers.

(4) Develop models to be used in sector analysis work of Thailand.

(5) Facilitate computer solutions of Thailand programming models.

(6) Write and publish reports representing sector analyses research completed in Thailand and elsewhere.

Originally it was intended that each of the above objectives would have equal emphasis. Because of the way in which the project evolved, however, greater emphasis was placed on the second, third, and fourth objectives during the beginning and intermediate phases of the project. More than twenty DAE staff members were on campus pursuing graduate degree programs during these two project phases and considerable professional resources had to be devoted to guiding their academic and research efforts. Also, the pipeline of usable economic data was slow to develop so that initial research efforts fell more closely within the scope of the second objective. As more usable data and working models became available, it was possible to place stronger emphasis on objectives one and six to provide a more even overall balance among the objectives.

Review of Critical Assumption

A close working relationship existed between the Department of Agricultural Economics in the Ministry of Agriculture and Cooperatives of Thailand and Iowa State University since inception of the supplemental grant and contract projects. It was assumed that, because of this relationship, primary data and working models developed in Thailand would be readily available to on-campus staff for research purposes. This assumption was not completely valid during initial project phases. During early project phases, on-campus research was handicapped because of insufficient primary data and working models. Significant changes occurred so that this critical assumption was finally realized. The delay in

obtaining primary data and working models impeded completion of research activities at the beginning of the project, however, and causes emphasis on applied research to be shifted forward in time to later and extended phases of the project.

Accuracy and completeness of data were considered to be another critical assumption of the project. Much of the initial data generated in Thailand was classified as preliminary data and subject to further revisions and adjustments. The preliminary nature of early data was a significant factor in the slow release of data for on-campus research. Suggestions were made for additional data collection needs and ways for improving quality control of the data. As the quality and completeness of the data were improved, the primary data became more readily available for on-campus use. The unanticipated delay in fulfilling the validity condition of this critical assumption was an additional factor in shifting emphasis on quantitative research activities to the later and extended phases of the project.

ACCOMPLISHMENTS

Major emphasis was placed on the design and completion of quantitative research activities and dissemination of results. Significant effort also was devoted to providing backup modeling support for the ISU-DAE team in Thailand. Training of DAE personnel also was a high priority on-campus activity and considerable staff time was used to direct the academic and research programs of Thai graduate students.

The above mentioned activities were part of an overall project development continuum. Research models were developed in response to priority policy questions raised in Thailand. After quantitative application of the models and evaluation of results, draft reports were completed for professional review and editing. Research results were then published and disseminated to user agencies and interested professionals. As additional policy questions were raised, the process was repeated. Staff training has been a part of this project development continuum. Graduate students participated in research projects as part of their training programs. Following completion of an initial graduate training program, DAE staff members returned to Thailand to conduct research tasks. After a suitable period of on-the-job research experience, selected staff members returned to campus for more advanced training which provided them with the skills needed for directing and carrying out research projects of a higher order requiring the use of more sophisticated analytical techniques. It therefore is difficult to relate individual accomplishments to a specific time period, and project accomplishments should be viewed within the context of overall progress throughout the lifespan of the project.

Research Activities Related to Agricultural Sector Analysis

Research on the various components of agricultural sector analysis has been an important part of work conducted at Iowa State University throughout the life of the project. The research has been directed at analysis, development, and application of models which can be used by the field team in Thailand. Considerable staff time has gone into the initial specification of the national agricultural programming model for five year planning, specification of regional planning models, development of market sector models, and design of demand and international trade models with specific reference to Thailand. During the latter phases of the project, emphasis was placed on developing a linkage between the agricultural sector model and the macroeconometric model, application of the national agricultural model to evaluation of agricultural supply response and related effects on farm income and employment, empirical estimation of consumer demand for food in Thailand, and design of a simulation model of the world rice economy with special reference to Thailand. Additional attention was given to the design of preliminary farm firm simulation models for analyzing the impact of alternative national policy actions. The more important accomplishments of recent research activities are discussed in the following sections of this report.

Models and Linkages

The initial emphasis of the work was on developing regional models. The model for each region could then "stand on its own" with respect to

analysis of development activities for the specific region. These models were then repeated for other regions and finally were linked together in a national, interregional programming model of the Thai agricultural sector. Although some attention was given to the specification of an econometrically estimated macro model for the entire economy in the initial year of the project, fullscale work on it did not commence until the second year. This macro model was completed in years two and three of the project.

The agricultural sector model and the macroeconometric model originally were developed as separate models which could stand alone for analytical purposes. The agricultural sector model was designed to measure and evaluate the impact of alternative policy actions on the various levels and sub-components within the agricultural sector. The independently developed macroeconometric model was designed to measure interactions between and among the several separate sectors of the total Thai economy. Linkage of the two models permits a much broader range of policy issues to be addressed for both national and sector planning purposes.

Linkage at the national level between the agricultural and the non-agricultural sectors was modeled through an interface between the macro-econometric model and the national linear programming model of the agricultural sector. The interface developed allows people in policy making decision positions to relate changes in the agricultural sector to the remaining sectors of the economy. It also permits measurement of the impact of changes in the nonagricultural sectors on the agricultural sector.

In the macroeconometric model the Gross Domestic Product of Thailand's economy was divided into seven major sectors which are consistent with the

National Income Accounts. Variables of the macro model then represent the subaccounts of each separate sector. The second version of the macro model was used for the linkage process. It contains 55 equations and 9 accounting identities. The linkage retains the essential structure of the macro model but substitutes a disaggregated programming model of agricultural crop and livestock production, raw material processing, marketing, and transportation activities for all or part of the relevant macro equations.

The combined macro-agriculture model is recursive in two senses. First, the combined system is recursive in the traditional sense that current year variables are dependent in part on their values from previous years. However, within each year the models are recursive in a second sense in that the agricultural model depends on macro equations to set or partially determine domestic demand for agricultural products, exports, labor supply, and other factors which affect agricultural inputs and outputs. The outputs from the agricultural model then become predetermined variables which are used to solve the remaining equations of the macro model. The current period results of the combined macro-linear programming model are then used to update the agricultural and macro models for the following year.

Some of the policy issues which can be considered by Thai decision makers from the interface between the linear programming model and the macroeconometric model are as follows:

(1) Influence of export expansion and import substitution on farm income levels and the balance of payments.

(2) Effect of agricultural price policies on the cost of living.

(3) Ability of the economy to provide employment for a growing population.

(4) The effect of agricultural development policies on the non-agricultural sectors and the total economy as related through:

(a) The level of farm income
(b) The level of agricultural employment
(c) Changes in investment in agriculture and related agricultural industries
(d) Changes in purchases of inputs by agriculture from non-agricultural sectors.

(5) Annual updating of the Five-Year Development Plan.

The essential elements involved in the linkage between the linear programming agricultural model and the macroeconometric model include the following:

(1) The interface between the linear programming model and the macro model is recursive. This is dictated in part by the recursive nature of the macro model and by the algebraic differences between the two models.

(2) A system of crop flexibility restrictions is used to constrain the linear programming model to reflect observed annual rates of change in planted areas. The flexibility restraints assume an adaptive expectations hypothesis and allow researchers to simulate disequilibrium conditions in what is normally an equilibrium model.

Supply Response Analysis

This study dealt with the future production potential of Thailand's agriculture. Because of the important role rice plays in the nation's economy, the study estimated rice-producing capacity for Thailand in 1981. More specifically, estimates were made of: (1) the national rice output at a range of prices, (2) employment, and (3) farm income.

The supply response study was made to estimate certain aspects of rice supply potential in Thailand. It was based on a national and inter-regional programming model developed for the purpose of planning and improving the Thai agricultural sector. The national linear programming model covered

71 changwats of Thailand, aggregated into 19 agroeconomic zones. Individual linear programming models were built for each of the 19 agroeconomic zones representing the crop sector. Capital, labor and land restraints were defined for each zone.

The overall programming model was solved for six different supply prices for nonglutinous rice at Bangkok. Because the model was solved for each price level, there are six solutions referred to respectively as the base, and steps I through V. The rice price used in the base was set at a level indicated by previous model solutions as the minimum supply price necessary to bring forth sufficient rice to fill subsistence and domestic demand. The base price was 600 baht per ton. After the base price solution, the price was increased to 1,200 baht per ton of nonglutinous rice for the Step I solution. The 600 baht stepwise increases continued until one of the restraints in the model become binding for rice production. This point in the supply function was estimated to occur at a price of 3,600 baht per ton. The upper bound on the rice price was selected as the price level which would not appreciably alter the quantity of rice produced in Thailand, as indicated by the programming model.

Although the linear programming model included 40 crops and commodities, we discuss only output, harvested area, and yields for a selected subset of crops that are considered to be most important for domestic and export purposed. The crops selected include: nonglutinour rice, glutinous rice, maize, cassava, kenaf, rubber, and sugar.

Base Solution, 600 Baht per ton for nonglutinous rice. By specification of the model, agriculture was forced to produce enough rice to meet

subsistence demand. At the base price level 13.8 million tons of rice were produced, 8.1 million tons of which was nonglutinous rice in the Base Solution. During the crop year 1970/71 rice production was 13.7 million tons, which then brought a price of 628.63 baht per ton. Data are shown in Table 1 for the 1972/73-74/75 average, the Base Solution, (600 baht), Step I Solution (1200 baht), Step II Solution (1800 baht), Step III Solution (2400 baht), Step IV Solution (3000 baht), and Step V Solution (3600 baht). National production of maize, cassava, rubber, and sugar is well above the 1972-73 to 1974-75 national average. Kenaf production remains slightly behind for all solutions.

Step I, 1200 Baht per ton nonglutinous rice. A doubling of the price of rice increased total rice production by 19 percent and nonglutinous rice production by 29 percent. National rice production increased by 2.7 million to 16.5 million tons under the Step I solution as compared to the base solution. Using the arc elasticity formula the price elasticity was estimated to be 0.38 between the base and Step I solutions. Hence, production is estimated to increase 3.8 percent when the price of rice increases by 10 percent.

Step II, 1800 Baht per ton nonglutinous rice. The elasticity of supply between Setp I and Step II declined to .23. The supply elasticity was partly a reflection of the constraints included in the model. Except for a relatively small area of Land II that can be planted to upland crops in the dry season, and a somewhat larger area of Land IV that can be planted to rice, the rice land base was fixed. Given the bounds on rates of increase on use

Table 1. Output, harvested area, and yields of principal crops at different price levels for non-glutinous rice in the Kingdom.

Crop	72/73-74/75 Average[a]	Solution					
		Base	I	II	III	IV	V
		Production (000 metric tons)					
Rice nonglutinous	13,656.7	8,098.2	10,417.9	11,409.5	12,102.6	12,415.7	12,535.8
Rice glutinous		5,744.9	5,744.9	5,744.9	5,745.1	5,745.0	5,744.9
Maize	2,077	4,051.3	4,051.4	4,051.3	3,694.3	4,051.3	4,051.3
Cassava	5,869	10,799.2	10,799.2	10,799.2	10,799.2	10,799.2	10,799.2
Kenaf	426.9	409.0	409.0	409.0	409.0	409.0	409.0
Rubber	362.2	417.1	417.1	417.1	417.1	417.1	417.1
Sugar	12,481	13,723.9	13,723.9	13,723.9	13,723.9	13,723.9	13,723.9
		Harvested Area (000 rai)					
Rice nonglutinous	45,534	25,505.6	31,151.5	32,396.6	33,707.6	33,408.0	33,693.2
Rice glutinous		21,993.6	21,584.5	20,585.1	20,033.2	19,623.5	19,336.8
Maize	7,050	14,624.3	14,855.2	14,981.6	14,000.7	15,111.6	15,171.3
Cassava	2,589	4,853.5	5,663.1	4,794.3	4,794.3	4,791.3	4,791.3
Kenaf	2,729.6	2,696.0	2,686.9	2,686.9	2,686.7	2,686.9	2,656.8
Rubber	5,547.3	7,080.2	7,062.8	7,062.8	7,062.8	7,062.8	7,062.8
Sugar	1,561	1,573.1	1,626.0	1,628.7	1,628.7	1,627.5	1,627.5
		Yield (kilogram/rai)					
Rice nonglutinous	274.3	317.5	312.0	352.1	359.0	371.6	372.0
Rice glutinous		261.2	260.6	279.0	286.8	292.7	297.0
Maize	287.0	277.0	272.0	270.4	263.9	268.0	267.0
Cassava	2,267.0	2,225.0	2,216.3	2,252.4	2,252.5	2,253.8	2,253.8
Kenaf	156.4	151.6	152.2	152.2	152.2	152.2	153.9
Rubber	65.3	58.9	59.0	59.0	59.0	59.0	59.0
Sugar	7,995.5	8,723.8	8,440.0	8,426.3	8,426.3	8,432.5	8,432.5

[a]SOURCE: Division of Agricultural Economics. Agricultural Statistics of Thailand, Crop Year 1974-1975. Agricultural Statistics No. 41. Office of the Under Secretary of State, Ministry of Agriculture and Cooperatives, Bangkok. 1976.

of new seed varieties, irrigation, and area fertilized, land was the major resource restraint to further increases in production. As the area fertilized increased, the demand for fertilizer increased rapidly. With the price of nonglutinous rice at 1800 baht per ton, production was estimated to be 11.4 million tons, more than 2.5 million tons of rice more than the historic high of the 1973/74 crop year. As rice production increased, yields also increased as a result of the greater use of fertilizer, high yield RD varieties, and irrigation facilities.

Step III, 2400 Baht per ton nonglutinous rice. A slightly larger land base and modest increases in yields caused total rice to reach 17.8 million tons in the Step III solution. The Northeast and the Central Plains regions accounted for almost all of the increase with 138,000 and 448,000 tons or rice, respectively, over the Step II solution. Rice yields also were higher as more technological inputs were used for the higher priced output. The Central Plain had the highest rice yield, 473 kg under the Step III solution.

Step IV, 3000 Baht per ton of nonglutinous rice. Rice production at the Kingdom level was 18.2 million tons at farm prices of 3000 Baht per ton. The supply elasticity between Step III and Step IV solutions was .12. National output increased by only 313,000 tons over the Step III solution. Most of the increase was produced in the Central Plain.

Step V Alternative, 3600 Baht per ton nonglutinous rice. At supply prices of 3600 Baht per ton of nonglutinous rice, the country's rice production reached a near maximum, given the constraints inherent in the programming model. The supply elasticity declined to .05 between solutions for Step IV and Step V. Total output increased by only 120,000 tons. The

Northeast and the North regions produced the additional output. The Northeast switched some land from glutinous rice production to nonglutinous rice, while the converse occurred in the North. At this price level, yields ranged from 374 kg in the Central Plain to 208 kg in the Northeast. Once the land base was exhausted, use of technological inputs increased. For example, the North region did not use any fertilizer until the rice price increased to 1200 Baht per ton (Table 12). At Step II, 883 tons of fertilizer were used. As the rice price increased to 2400 Baht, fertilizer use increased to 7000 tons at 2400 Baht and to 13,500 tons at 3000 Baht. Although somewhat less pronounced, the same directional movement was true for the other regions Fertilizer use increased almost 600 percent between the Base and the Step V Solution. Although it was assumed that Thai agriculture can acquire this amount of fertilizer at the initial price, this assumption may not be realistic relative to government fertilizer import policies, the shortages experienced in the past, and the short-run production capacity of the Thai fertilizer industry.

Farm income. The price increments used to analyze supply potentials were relatively large. Obviously, net farm income should increase accordingly. Rice price had a major effect on Thai farm income because it constitutes the major crop. As the rice price increases, those regions with the large and more productive land base suitable for rice experienced the greatest increases in income. The Base solution provided low farm incomes in the Northeast and South regions (Table 2). As price was increased through the Step V Solution, net farm income per farm increased by more than 1,000 percent for Thailand as a whole. It increased by an even

Table 2. Estimated BE 2524 net farm income per farm for each step by region[a]

Solution	Net Farm Income (Baht)				
	Northeast	North	Central Plain	South	Kingdom
1970 Actual	952	2,187	1,343	1,784	1,486
Base	170	2,148	2,221	646	1,117
Step I	1,404	5,844	5,356	1,123	2,742
Step II	2,865	9,144	9,603	1,716	5,563
Step III	4,324	12,613	13,859	2,367	7,981
Step IV	5,690	16,146	17,883	3,000	10,313
Step V	7,184	19,717	21,731	3,646	12,665

[a]Farm numbers are projected for 1981 by region: Northeast 2,026,381, North 927,919; Central Plain 1,144,132; South 644,205.

larger relative amount in the Northeast but by a relatively smaller amount in the South. While the rate of increase in the North and Central Plain regions was smaller than for the Northeast, the former two regions had a much larger net farm income per farm at the higher price levels. These regions were able to increase the absolute amount of net farm income by a greater amount because they possessed more rice land on which new technologies have a greater yield response.

The effect of the alternative prices of rice on the equality or inequality of income distribution for each measure of income is shown in Table 3. The Gini[1/] ratios in Table 3 were calculated by assuming that

[1/]Gini coefficients reflect the degree of inequality of income between groups or individuals. If each person has the same income, the Gini coefficient is zero. Conversely, if one person has all the income the Gini coefficient would be one.

Table 3. Gini ratios measuring the inequality of crop and total farm income among regions of Thailand for alternative farm prices of rice

Farm Price of Rice	Crop Income		Total Farm
	Upland Crops Price at Opportunity Cost	Upland Crops Measured at Market Prices (Gini ratios)	Rice Plus Upland Crops--Vegetables, Livestock--Measured at Market
600	.477	.414	.377
1,200	.339	.280	.312
1,800	.317	.262	.256
2,400	.314	.251	.247
3,000	.310	.247	.246
3,600	.306	.243	.243

all households in each region received the same level of income. The Gini ratios shown here are not the same ratios one would obtain if all households in Thailand were ranked in order of increasing income. The results in Table 3 indicate that the distribution of income would move in the direction of greater income equality as the price of rice increases from 600 to 3600 Baht per ton of paddy. However, changes in the Gini ratios are small after the price of rice has reached 1800 Baht. The movement in the direction of greater income equality occurs because of the large proportionate increase in income in the Northeast farm household. Gini ratios reflect proportional increases in income and so there is movement toward greater equality of income even though the absolute difference between, say, the Northeast and the Central Plain household is increasing.

Employment. Although the employment situation was of secondary concern in this analysis, it continues to be a major problem for Thailand. Thailand has a rapidly growing population and is experiencing an increasing proportion of underemployment and unemployed labor.

Because of the labor intensive nature of Thai agriculture, labor requirements vary widely among seasons (Table 4). Even if Thailand were to have 80 percent of its labor unemployed in the dry season, it needs a majority of these people in the peak labor months of planting and harvesting. If Thailand's agriculture remains labor intensive and adopts new labor intensive technology, labor utilization could increase, but perhaps not enough. Labor use was relatively higher in the Step V Solution than other solutions. At the Kingdom level, however, only 16 percent more labor was needed to produce the additional 4.5 million tons of rice in the Step V Solution as compared to the Base Solution.

It does not seem that increased rice production is the solution to Thailand's rural unemployment problems. To solve the employment problem, part of the labor force must be employed outside the sector. Also, agriculture must be directed toward producing more labor-intensive crops.

Table 4. Employment situation by step and by region for the dry season and monthly for the wet season (in million hours)

Base Month	Northeast			North			Central Plain			South			Kingdom		
	Available Labor	Labor Used	% Used	Available Labor	Labor Used	% Used	Available Labor	Labor Used	% Used	Available Labor	Labor Used	% Used	Available Labor	Labor Used	% Used
Dry Season	6,325	548	9	2,723	502	18	1,877	650	35	1,479	616	42	12,404	2,316	19
July	1,254	879	70	540	246	46	372	202	54	291	0	0	2,458	1,327	54
August	1,362	526	39	588	387	66	403	206	51	317	0	0	2,670	1,119	42
September	1,308	88	7	564	181	32	388	212	55	304	145	48	2,564	626	24
October	1,254	213	17	540	228	42	372	123	33	291	197	68	2,457	762	31
November	1,254	226	18	540	205	38	372	142	38	291	100	34	2,457	673	27
December	1,308	636	49	564	349	62	388	202	52	304	178	58	2,564	1,365	53
Step I Solution															
Dry Season	6,325	636	10	2,723	555	20	1,877	716	38	1,479	616	42	13,433	2,669	19
July	1,254	930	74	540	276	61	372	215	58	291	0	0	2,459	1,610	60
August	1,362	525	39	588	422	72	403	208	52	317	0	0	2,670	1,404	49
September	1,308	69	5	564	178	31	388	257	66	304	146	48	2,564	680	24
October	1,254	348	28	540	234	44	372	146	39	291	200	69	2,457	954	36
November	1,254	244	19	540	199	27	372	235	63	291	109	37	2,457	811	30
December	1,308	660	50	564	379	67	388	162	42	304	178	59	2,564	1,580	57
Step II Solution															
Dry Season	6,325	623	10	2,723	584	21	1,877	730	39	1,479	616	42	12,404	2,553	20
July	1,254	927	74	540	288	53	372	211	57	291	0	0	2,457	1,425	58
August	1,363	522	38	588	429	73	403	204	51	317	0	0	2,670	1,155	43
September	1,308	69	5	564	178	32	388	254	66	304	146	48	2,564	647	25
October	1,254	353	28	540	242	45	372	158	42	291	200	69	2,457	953	39
November	1,254	259	21	540	206	38	372	250	67	291	109	37	2,457	823	34
December	1,308	666	51	564	377	67	388	161	41	304	178	59	2,564	138	54

Table 4. Continued.

Base Month	Northeast			North			Central Plain			South			Kingdom		
	Available Labor	Labor Used	% Used	Available Labor	Labor Used	% Used	Available Labor	Labor Used	% Used	Available Labor	Labor Used	% Used	Available Labor	Labor Used	% Used
Step III															
Dry Season	6,325	622	10	2,723	583	21	1,877	730	39	1,479	616	42	12,404	2,553	21
July	1,254	921	73	540	576	53	372	421	57	291	0	0	2,457	2,845	58
August	1,363	523	38	588	858	73	403	408	51	317	0	0	2,670	2,310	43
September	1,308	69	5	564	356	32	388	507	65	304	292	48	2,564	1,293	25
October	1,254	359	29	540	485	45	372	316	42	291	399	69	2,457	1,911	39
November	1,254	264	21	540	412	38	372	498	67	291	218	37	2,457	1,650	34
December	1,308	666	51	564	753	67	388	321	41	304	357	59	2,564	2,762	54
Step IV															
Dry Season	6,325	623	10	2,723	585	21	1,877	723	39	1,479	616	42	12,404	2,547	21
July	1,254	922	63	540	288	53	372	203	54	291	0	0	2,457	1,913	57
August	1,363	523	38	588	431	73	403	203	50	317	0	0	2,670	1,156	43
September	1,308	70	5	564	183	32	389	258	66	304	146	48	2,564	656	26
October	1,254	358	29	540	232	43	372	180	48	291	200	69	2,457	969	39
November	1,254	263	21	540	215	40	372	260	70	291	109	37	2,457	846	34
December	1,308	666	51	564	377	67	388	165	42	304	178	59	2,564	1,385	[illegible]
Step V															
Dry Season	6,325	623	10	2,723	585	21	1,877	723	39	1,479	616	41	12,404	2,547	21
July	1,254	930	74	540	292	54	372	203	54	291	0	0	2,457	1,924	58
August	1,363	523	38	588	432	73	403	203	50	317	0	0	2,670	1,157	43
September	1,308	64	5	564	197	35	388	258	66	304	146	48	2,564	664	26
October	1,254	386	31	540	232	43	372	180	48	291	200	69	2,457	998	41
November	1,254	266	21	540	211	39	372	260	70	291	109	37	2,957	846	34
December	1,308	652	50	564	377	67	388	164	42	304	173	59	2,564	1,371	53

Consumer demand analysis

An analysis of consumer demand was conducted to achieve a better understanding of the behavior of demand for food in Thailand. It also was conducted to furnish policymakers with some insights on demand structure which might be useful in the development of the agricultural sector. The questions that might reasonably be asked in this connection take many forms. For instance, if the legal age of buffaloes to be slaughtered were reduced, what would be the probable changes in the prices of other meats and close substitutes for meat? How much would the rice demand quantity be reduced if the price of rice jumped by 10 percent as a result of removal of the rice export tax? To answer such questions, a systematic description of the economic relationships between the quantities of farm products available and the prices at which farm products can be sold is required.

Some policy questions can be clarified by estimating the demand function for a single food, or by estimating a set of demand functions for two or more foods which are fairly close substitutes. However, there are conceptual advantages in specifying the relationships for all foods and farm products simultaneously by means of a comprehensive demand model. Such a model was pioneered in the early 1960s by Brandow, and this approach was used in this study. A discussion and interpretation of results obtained for the various food types is presented in the following sections.

Rice. Rice is the most important food item in the Thai people's diet. According to this study, rice accounted for 53 percent of food expenditures and 26 percent of total expenditures in 1971. The own price elasticity of rice is not significantly different from zero. Thus, rice can be considered as an inferior economic good in Thailand. If the price of rice goes up, low income families will consume less of other more expensive foods and more rice, but when the price falls the increase in consumption will be very small.[2] This is one of the reasons for the estimate of a zero price elasticity for rice. Another reason for this result is the government's activity in the rice market. There is no very close substitute commodity for rice in Thailand. Own price, cross price, and income elasticities of demand for food commodities at the retail level are shown in Table 5.

Total food. The direct price elasticity of demand for all food is equal to .505. The income elasticity for all food is .352, indicating that if disposable personal income changes by 1 percent the percentage change in total food consumption will be .352. The cross price elasticity of total food consumption on nonfood prices is .153. The sum of the own price, cross price and income elasticities of total food is equal to zero.

Nonfood. The "total nonfood" commodity is elastic with respect to its price. The estimated own price elasticity for total nonfood is 1.14 and its income elasticity is 1.65, which shows the high responsiveness of quantity demanded for all nonfood items with respect to change in income. The cross price elasticity of total nonfood consumption on all food prices is .51.

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[2]This conclusion also has been proposed by other studies of rice in Thailand.

Table 5. Own price, cross price, and income elasticities of demand at the retail level

	Rice	Beef	Pork	Poultry	Fish	Potatoes	Chili	Garlic	Onions	Water-melon
1-Rice	0	.01814	.02416	.0105	.02984	.03807	.00722	.00411	.00213	.00677
2-Beef	.01221	-.95787	.00700	.16963	.18647	.01544	.0092	.00881	.00367	.00990
3-Pork	.01223	.0000	-.32096	.0000	.0000	.00296	.00559	.00321	.00165	.00526
4-Poultry	.0054	.0000	.15241	-.27390	.0000	.00444	.00665	.00492	.00049	.00453
5-Fish	.0181	.33164	.28286	.24212	-.22262	.00439	.00658	.00469	.00194	.00218
6-Potatoes	.000212	.00249	.00033	.00119	.00010	-.52973	.0000	.06667	-.14507	.00491
7-Chili	.00261	.00194	.0000	.00367	.00550	.0000	-.34885	.0000	.05093	.00466
8-Garlic	.00186	.00130	.00078	.00159	.00053	.0000	.0000	-.48474	.0000	.00581
9-Onion	.00057	.00420	.0000	.00082	.00014	.0000	.37410	.07892	-.35365	.00402
10-Watermelon	.000367	.00310	.00239	.000217	.0000	.01100	.005418	.009746	.0131	-.67803
11-Coconuts	.0153	.0398	.02052	.0442	.0494	.00974	.05177	.10830	.04537	.0000
12-Pineapple	.00352	.00218	.00901	.00791	.0001	.00925	.00553	.00913	.0132	.0000
13-Bananas	.02097	.01629	.03333	.0037	.032182	.00571	.0247	.00231	.00081	.0000
14-Sesame	.00028	.0000	.0000	.0000	.00001	.0002	.0000	.0001	.00748	.00012
15-Cotton	.00029	.0000	.0000	.00451	.00002	.0000	.0000	.0000	.00001	.00061
16-Coconut Oil	.00164	-.00004	.00012	.00018	.28178	.00082	.0005	.00068	.00045	.0080
17-Groundnut Oil	.00178	.0000	.00014	.00017	.0000	.00092	.008157	-.4231	.00086	.00051
18-All Food	-.1509	-.03607	-.04909	-.02603	-.05339	-.01799	-.0100	-.01695	-.0030	-.01224
Nonfood	-.3643	-.00937	-.01925	-.0028	-.02786	-.00244	-.01107	-.00454	-.00338	-.00563
Expenditure Proportions	.2587	.0226	.0340	.0143	.0405	.0055	.0105	.0057	.0032	.0089

Table 5. (continued)

	Coco-nuts	Pine-apple	Bananas	Sesame	Cotton	Coconut Oil	Ground-nut Oil	All Food	Non-food	Income Elastic-ities
1-Rice	.02333	.00680	.03403	.002	.0010	.0011	.0019	-.210	.06063	.141
2-Beef	.03110	.0079	.0095	.0022	.0004	.0033	-.03010	-.9108	.26273	.611
3-Pork	.01805	.00181	.02394	.00098	.00026	.00153	-.20164	-.58344	.17544	.408
4-Poultry	.02115	.00619	.02805	.00091	.00031	.00190	-.44500	-.6835	.2055	.478
5-Fish	.0000	.000128	.02996	.0009	.0003	-.48161	-.3945	-.6764	.2034	.473
6-Potatoes	.01686	.00493	.02266	.00073	.00044	.00152	.00153	-.54483	.16383	.381
7-Chili	.01602	.00469	.00469	.00069	.00023	.00144	-.2855	-.5177	.1557	.362
8-Garlic	.01996	.00584	.02646	.00086	.000293	.00179	-.2277	-.6449	.1939	.451
9-Onion	.01380	.00404	.01831	.00059	.00020	-.47144	-.10125	-.44616	.13416	.312
10-Watermelon	.0000	-.212123	.0000	.00061	.00188	.00061	.01172	-.7537	.2267	.527
11-Coconuts	-.54271	.0000	.0000	.00107	.00067	-.2894	.00226	-.8022	.24123	.561
12-Pineapple	.0000	-.76816	.0000	.0163	.00512	.03184	.03216	-.7164	.2154	.501
13-Bananas	-.2357	.0000	-.5909	.00100	.00034	.06209	.00217	-.75218	.22618	.526
14-Sesame	.0036	.0000	.0000	-1.03181	.0000	.0000	.48131	-.5076	.1526	.355
15-Cotton	.0001	.0034	.0086	.22914	-.67953	.0000	.0000	-.5076	.1526	.355
16-Coconut Oil	.0020	.0100	.0090	.0000	.0000	-.30682	.0000	-.5849	.1759	.409
17-Groundnut Oil	.00062	.0012	.00013	.55346	.0000	.0000	-.63922	-.5849	.1759	.409
18-All Food	-.02144	-.0159	-.05796	-.00541	.0095	.00158	-.00963	-.505	.153	.352
Nonfood	-.01694	-.00634	-.02590	-.00146	-.00049	-.00243	-.00278	-.51	-1.14	1.65
Expenditure Proportions	.0300	.0091	.0406	.00148	.0005	.0028	.003	.495	.505	1.000

Meat group. Total meat accounted for 21 percent of food expenditure, 10.7 percent of total expenditure, and was second only to rice in its proportion of total expenditure. The estimated percentage increase in own consumption when the retail price of an individual meat falls by 1 percent, but other retail prices do not change, is .958 for beef and buffaloes, .32 for pork, .27 for poultry, and .22 for fish. The cross price elasticities estimated for the meat group indicate that the changes in quantity of pork consumed with respect to changes in other meat prices are not significantly different from zero. But if the price of poultry or fish changes by 1 percent the quantity of beef consumed will change by .17 and .19 percent, respectively. Beef, pork, and poultry meat are comparably high substitutes for fish and their cross price elasticities are .33, .28, and .24, respectively.

Vegetable group. Vegetables are very important in the Thai diet although the expenditure weight of this group is not as high as for rice and meat. Potatoes have the highest price elasticity in this group (.52). There does not appear to be a close substitute for potatoes, although onions and potatoes seem to be complementary goods. Own price elasticities for chili, garlic, and onions are .35, .48, and .35, respectively. In general, commodities in the vegetable group are not very competitive, so changes in the price of one does not seem to change the consumption of other food in this group. The only competitive commodities in this group appear to be chili and onions. The value of the cross price elasticity of chili for onions is .37. Changes of 1 percent in disposable personal income evidently change the quantity demanded of potatoes by .38, chili by .36, garlic by .45, and onions by .31.

Fruit group. This group accounted for 18 percent of consumers' expenditures on food and 8.8 percent of consumers' total expenditure. A 1 percent change in the price of watermelon changes the quantity demanded by .68 percent, assuming other things constant. The changes in quantity demanded of coconuts, pineapples, and bananas associated with 1 percent changes in their own prices are .54, .77 and .59, respectively. Income elasticities for the commodities in this group are very similar (.53 for watermelons, .56 for coconuts, .50 for pineapples, and .53 for bananas); a change in disposable personal income has fairly equal percentage effects on the consumption of each fruit in this group. There seems to be little substitution of one fruit for another in this group. One reason for this situation is that these fruits are not supplied to the market in the same seasons, and no storage facilities for such perishable products are available to supply them to the market gradually over a period of months.

Vegetable oil group. Commodities included in this group include sesame, cotton seed, coconut oil, and groundnut oil. The oil group accounted for about 1.5 percent of consumers' expenditures on food. The income elasticities for sesame and cotton seed are about the same (.355), and those for coconut oil and groundnut oil are equal at .409.

Sesame, with 1.03, has the highest own price elasticity among the commodities in this group. The commodity which substitutes most closely for sesame is groundnut oil. The cross price elasticity of groundnut oil for sesame is .48. The own price elasticity for cotton seed is .68; the corresponding values for coconut oil and groundnut oil are .31 and

.64, respectively. The cross price elasticities of other commodities in this group for coconut oil are zero. However, sesame is a good substitute for cotton seed and groundnut oil; the value of the cross price elasticity for the former is .22 and for the latter is .56.

Farm level demand for food. Approximately fixed relations exist between the flows of commodities from farms and the quantities going into consumption. Changes in inventories may be important for some products. The marketing margin is the difference between a farm price and a retail price. The farm level demand is usually less elastic than the demand at retail, and may be very much less elastic if the marketing margin absorbs a large percentage of the retail price and contains charges which are fixed in absolute amount. Under these circumstances, large percentage changes in prices of food products at the farm level may result from small changes in the level of food production.

In this study, eight commodities show lower own price elasticities at the farm level than at retail. Beef, onions, and garlic show approximately equal elasticities at farm and retail levels. Because of lack of data and information, it was not possible to calculate the elasticities at the farm-level for all 18 of the commodities included in this study. Therefore, seven commodities were dropped from the demand matrix for the farm-level analysis. Own price, cross price and income elasticities of demand at the farm level are shown in Table 6.

Table 6. Own price, cross price, and income elasticities of demand at the farm level

	Beef	Hogs	Poultry	Chili	Garlic	Onions	Water-melon	Coco-nuts	Pine-apple	Bana-nas	Cotton-seed
Beef	-.95787	.00700	.16963	.0092	.00881	.00367	.00990	.0311	.0079	.0095	.0004
Hogs	.0000	-.2665	.0000	.00461	.00260	.00136	.00435	.0149	.00149	.0197	.00021
Poultry	.0000	.1280	-.23007	.00558	.00413	.00041	.00380	.0178	.00520	.02356	.00026
Chili	.00163	.0000	.00308	-.29303	.0000	.04277	.00391	.01346	.003939	.003855	.00121
Garlic	.00130	.00078	.00159	.0000	-.48474	.0000	.00581	.01996	.00584	.02646	.0029
Onions	.00420	.0000	.00082	.3741	.07892	-.35365	.00402	.01380	.00404	.01831	.0002
Watermelon	.00208	.00160	.00014	.00363	.006529	.00878	-.4543	.0000	-.14212	.0000	.0004
Coconuts	.03423	.01765	.0380	.04452	.09314	.03901	.0000	-.46673	.0000	.0000	.00161
Pineapple	.00109	.00450	.00395	.00275	.00457	.0066	.0000	.0000	-.38485	.0000	.00256
Bananas	.01548	.03166	.0035	.02346	.002194	.0077	.0000	-.2257	.0000	-.56136	.00032
Cottonseed	.0000	.0000	.00029	.0000	.0000	.0000	.0000	.00037	.00006	.00218	-.4349

Utilization of the study. Agricultural policies implemented by governments frequently consist of policies which are directed at benefiting producers and/or consumers. These policies may be categorized as either developmental or compensational policies. Developmental policies frequently focus on increasing commodity supplies for the purpose of reducing food prices at the consumer level. Compensational policies promote the expansion of food supplies, but they also provide compensation to farmers for income which might be lost as a result of lower farm level prices. Knowledge of demand relationships is important for evaluating the possible effects of alternative developmental and compensational policies. To demonstrate the importance of demand analysis for agricultural policy development, several possible situations are considered in subsequent paragraphs.

If a government should desire to increase farm-level income by promoting the expansion of a certain commodity such as beef, the income effects from an expanded beef supply would be directly related to the price elasticity of demand for beef and the way in which the farmers costs vary with the quantity of product. If demand for beef were price elastic and unit costs remained constant, an increase in the supply of beef would result in an increase in farm-level income. However, if the demand for beef were price-inelastic and unit-costs remained constant, an increase in the supply of beef would result in a decline in farm-level income. With the exception of sesame oil, all commodities included in this study were found to be price-inelastic.

Results of demand analysis could also be used in the evaluation of alternative policies directed at changing the protein or caloric intake of consumers. Should a government desire to increase the average per capita intake of protein by increasing the consumption of specific commodities such as beef and rice, demand analysis such as is provided by this study would be helpful by indicating the effects of such a program on the price of individual commodities, on the price of close substitute goods, and on total food prices.

Supply control is another area in which the results of this or similar studies could be useful for policymakers. If the local market supply of a commodity such as rice were to be curtailed for the purpose of increasing the price received by farmers, information concerning the demand elasticities of rice and other close substitutes would be highly desirable. The extent to which a change in the supply of a commodity will effect a change in price will depend on the demand elasticities of the specific good and its close substitutes. When the demand for a product is highly price-inelastic, a small decrease in the supply of the product will cause a large increase in the price.

Quadratic programming is an additional area where the results of this study could be used. The elasticities determined by this study, in combination with mean prices and quantities, could be used to determine linear demand equations. A quadratic programming routine could then be used to solve a spatial equilibrium problem in which both product prices and consumption levels would be determined.

Rice trade model

The general objective of this study was to build a rice trade model for Thailand. The trade model has three major subsectors: (a) domestic production and use, (b) foreign demand, and (c) export price. Domestic production and use can be controlled by local government but the other two factors cannot. International commodity trade is a complex phenomenon and depends on economic and noneconomic factors which differs with time and country. Hence, the trade model is built with provisions for solving it under different assumptions. In developing the model, we followed this order: (a) establishing assumptions involved in aggregating the countries, (b) specifying the model and estimation of the structural equations, (c) setting up the simulation experiment and results, (d) developing a stochastic simulation experiment for future prediction, and (e) forecasting under different alternative assumptions.

The major rice producing and consuming countries are situated in Asia. Other countries produce and consume rice but to lesser extents. In the latter group the United States potentially is most influential in the world rice economy. We have divided the countries into two broad groups; (a) net exports and (b) net importers of rice. Based on past data we computed net trade of every country for the period of 1957 to 1975. Most of the countries fall clearly in either group. However, a few small countries are cross-overs between groups in some years. The trade model presented here is based on the two major groups, exporters and importers.

It was pointed out earlier that this study focuses on Thailand. Although different policy runs can be performed for the world as a whole, we report here only some of the policy runs specific to Thailand. One of the two objectives of this study was to develop a readily workable package program of rice trading which can be used by government officials to get a quantitative idea concerning outcomes of alternative policies. The policy runs which are presented in this section should be treated as illustrative examples rather than an attempt to suggest specific policies.

A previous study of world rice markets by the Department of Economic Research, Bank of Thailand, concluded: "Relative insensitivity of world prices to changes in Thailand's export tax rates on rice indicates an almost perfect case of the small country position of Thailand in the international rice market. Thailand is practically a 'price-taker' in the world market. Even though Thailand accounts for 15-25 percent of total rice exports, its output is less than 5 percent of world output." The same study also notes, "simulation results ... indicate clearly that the world demand for rice must be relatively inelastic. It can be seen that a 10 percent increase in the world price will result in about a 1 percent reduction in total world demand for rice." Alternatively, a slight change in world demand can cause considerable fluctuation in world equilibrium export price.

The above two findings, that Thailand is a price-taker in the world market and the fact that world demand is relatively inelastic, played a major role in designing the present illustrative policy runs. In the

short-term we do not expect much fluctuation in the world import demand. Accordingly, the world export price should be near its trend level. Price might fluctuate due to a production shortfall or production excess as a result of bad or good weather. If drastic weather change does take place, the price still should be within a reasonable range. In the assumptions of the model, the policy option left to Thailand is to increase her own exports. This can be done in three ways: (1) by increasing domestic production, (2) by decreasing domestic consumption, and (3) both. In all cases the export revenue can be computed within the model. Total simulated world production of rice and Thailand's production of rice have a slightly increasing trend over time, whereas simulated Thai exports have a decreasing trend.

Table 7 summarizes the results of three alternative policies; (A) a 10 percent decrease of consumption in Thai exports, (B) a 10 percent increase in rice production, and (C) a 10 percent increase in production together with a 10 percent decrease in consumption. Henceforth, the three policies will be referred to as policy A, policy B, and policy C. Export prices are computed under the two different coefficient sets which are given in Table 7. Table 8 shows the mean export earnings as a result of Thai export increases under the three alternatives policies (A, B, C) with two different mean price sets.

Referring to Tables 7 and 8, the largest amount of exports and thus, the largest amount of export revenue, is achieved by policy C which simultaneously reduces consumption and increases production.

Table 7 Simulation of effect of (a) 10 percent cut in consumption coefficient (b) 10 percent increase in share of production (c) 10 percent decrease in consumption coefficient together with 10 percent increase in share of production on Thai export $(THTR)_T$.

	Base Run (no policy) export (000 M. Ton)			10% cut in consumption coefficients export (000 M. Ton)			10% increase in share of production export (000 M. Ton)			10% cut in consumption coeff. and 10% increase in prodn. coeff. export (000 M. Ton)			Mean export price (first set) (S/M. Ton) 1963 = 00	Mean export price (second set) (S/M. Ton) 1963 = 00
Year	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum		
1979	22	-3205	3328	908	-2893	5520	1461	-1867	4855	2344	-1556	7088	60.18	67.36
1980	-108	-4293	4694	545	-3994	4882	1351	-2920	6287	2002	-2667	6463	55.13	63.18
1981	-133	-3609	4511	702	-3023	5422	1349	-2255	6118	2183	-1644	7050	51.76	60.68
1982	-164	-3666	3652	575	-4128	4823	1341	-2259	5261	2084	-2749	6445	45.97	55.77
1983	-603	-4413	3320	608	-3390	5013	926	-2980	4945	2142	-1975	6558	41.11	51.78
1984	-655	-4573	3413	368	-4257	4209	548	-3474	4766	1722	-2839	5876	35.23	46.77
1985	-670	-4583	3294	690	-4255	5823	1180	-2866	5260	2292	-2807	7551	27.93	41.22

Table 8. Simulated mean export earnings from three alternative policies (millions of dollars at 1963 prices)

Year	Export Revenue with Policy A		Export Revenue with Policy B		Export Earning with Policy C	
	First Set of Mean Export Price	Second Set of Mean Export Price	First Set of Mean Export Price	Second Set of Mean Export Price	First Set of Mean Export Price	Second Set of Mean Export Price
1979	54.5	60.8	87.9	98.4	141.0	157.8
1980	30.0	34.4	74.5	85.3	110.4	126.5
1981	36.3	42.6	69.8	81.9	113.0	132.3
1982	26.4	32.1	61.6	74.8	95.8	116.2
1983	24.9	31.5	38.1	48.0	88.1	110.9
1984	13.0	26.2	19.3	25.6	62.4	80.5
1985	19.3	28.5	32.9	48.6	64.0	94.5

In policy A (decreasing consumption), the production figures remain unchanged. But in the other policies, the production has to increase and added land is brought under rice cultivation. The amount of land necessary to sustain the required level of production can be computed easily by dividing the production figure by average yield figure. Table 9 summarizes the results of simulated mean production and required mean land area under rice cultivation under policy alternative B. Production under policy C will be the same as that under B.

The increased land requirement for rice cultivation under policy B is obvious. Corresponding to each year under policy B, 9 percent more land under rice cultivation is required to sustain the increased production target. The land requirement for rice cultivation under policy C is the same as policy B.

Table 9. Simulated mean production and required land area under rice cultivation in Thailand

Year	No Policy		Policy B or C	
	Mean Production (thousand metric tons)	Mean Land Area (thousand hectares)	Mean Production (thousand metric tons)	Mean Land Area (thousand hectares)
1979	15,046	7,998	16,486	8,746
1980	15,255	8,110	16,715	8,886
1981	15,500	8,240	16,983	9,028
1982	15,734	8,365	17,239	9,164
1983	15,986	8,499	17,516	9,312
1984	16,230	8,628	17,784	9,454
1985	16,518	8,781	18,370	9,766

International trade is a complex and sometimes quite unpredictable phenomenon. It can be argued that economic models of foreign trade may be rendered useless by political factors. But, an economic model is valid if it fairly accurately reflects the pattern of trade and prices that would result from given initial conditions in the absence of further policy changes. Such a model at least reflects the economic pressures that are imposed upon exporters and importers in different countries. The governments of these countries may then undertake actions to offset such pressures.

Farm models

Typical farm programming models are being developed for the major agro-climatic, farm size, commodity, and location groupings of farms in Thailand. These models allow the results from national and regional models to be projected through typical farm situations to show the effect of developmental and other policies on farm production, income and employment. They also show the physical inputs and capital requirements necessary for implementation of policies at the farm level.

Development of the logical structure for these models and the quantitative work completed on campus was based on the information and data available at Ames. A major effort is presently underway in Thailand to reestimate linear programming coefficients for purposes of updating the farm level, regional and national models.

Both static and dynamic farm planning models were developed on-campus with the collaboration of DAE staff members. The model reported here is a time-phased model integrating both the production and consumption aspects of a typical farm in northern Thailand.[3/]

[3/] Based on a research study entitled, "Integrated Production-Consumption Time-Phased Simulation of a Typical Farm in Northern Thailand: An Application of Dynamic Linear Programming," by R. A. Hoffman and Boontam Prommani. A working paper, Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa. 1977.

This time-phased model is based on a larger scale static programming model which was used to obtain an in-depth analysis of the same farm prior to development of the time-phased model.

The representative farm selected for dynamic programming analysis is typical of the larger farms of agroeconomic zone 6 in northern Thailand. Selection of a larger farm for this study permitted the incorporation of a broader range of activities than would have been available for a smaller size farm. The typical farm is owner-operated. Available land includes 10 rai of class I land, 8 rai of class II land, 36 rai of class III land, and 30 rai of class IV land. Initial capital available to the owner-operator is 3,600 Baht. Additional capital can be borrowed during any one of the four three-month annual time periods up to a maximum of 10,000 Baht per time period. Capital not used in any of the three-month period is invested in off-farm alternatives. The model also incorporates consumption requirements for rice and other family expenditures. These consumption requirements must be satisfied before capital accumulated in one production year can be transferred to a following year. Family labor available is 6,400 hours or 800 work days per year. Although constant prices are used for buying and selling activities, multiple "C" row analysis would allow consideration of alternative price levels as was done in the previously developed static model of the typical farm. The overall time frame considered by the dynamic model is four years.

Analysis of the four-year time-phased model was carried out for five different situations. Situation I considers the existing farm with available land, labor and capital. Additional capital borrowing is permitted

up to 10,000 Baht per quarter. The other four situations analyzed build on the base case by adding or excluding activities as follows: (1) Situation II adds a hired labor activity; (2) Situation III includes corn buying for hog feeding; (3) Situation IV adds a fertilizer buying activity for rice production but excludes corn buying; and (4) Situation V incorporates all of the activities previously described.

Situation I. This base situation considers available farm resources and borrowing of additional capital up to 10,000 Baht per quarter. The optimum farm plan includes production of nonglutinous rice, glutinous rice, corn, and market hogs fed out from purchased feeder pigs. On-hand capital increases from 3,600 Baht to 32,202 Baht over the four-year period. Net income earned expands from 18,642 Baht in the first year to 29,743 Baht in the fourth year as shown in Table 10.

Situation II. Labor hiring is added for the second situation. Crop production activities remain the same but a large increase occurs in the amount of land used for glutinous rice production on calls III land. Livestock production includes 42 feeder pigs fed out in the fourth year. Labor hired varies from 1,149 to 1,269 hours in the second and third quarters of the last year. The addition of hired labor increases capital accumulation and net income to 46,383 Baht and 38,320 Baht, respectively, at the end of the fourth year.

Situation III. This situation adds corn buying to previously described activities. The major effect of the corn buying activity is an increase from 42 to 62 in the number of pigs fed out during the fourth year. Both capital accumulation and net income increase by approximately 12 percent.

Table 10. Optimum 4-year plan for the case farm under situation I

1 Year	2 Available Capital (baht) on hand	borrowed capital	3 Resource Used	4 Optimum Combination of Activities	5 Net Return (baht)	6 Living Exp. (baht)	7 Fixed Exp. (baht)	8=5-(6+7) Net Income (baht)	9 Limiting Resource
1	3600	period II 3078 period III 6319 period IV 10000	Land I 10 rai for Land II 8 rai for Land III 4 rai for Land III 24 rai for Land IV 18 rai for Labor I = 31 hours Labor II = 1600 hours Labor III = 1600 hours Labor IV = 1600 hours	Nonglutinous rice, NV Nonglutinous rice, NV Nonglutinous rice, NV, TR Glutinous rice, NW, TR Corn Hog 6x2=13 head Rice consumption 1000 kg. Off-farm inv. I=57 baht	23,543	3,500	1,400	18,642	Capital borrowing Rice NG. Land III Capital borrowing
2	22,463	period III 3482 period IV 10000	Land I 10 rai for Land II 7 rai for Land III 22 rai for Land IV 23 rai for Labor I = 79 hours Labor II = 1600 hours Labor III = 1600 hours Labor IV = 1353 hours	Nonglutinous rice, NV Nonglutinous rice, NV Glutinous rice, NW Corn Hog 16x2=32 head Rice consumption 1000 kg. Off-farm inv. I=8924 baht Off-farm inv. II=2991 baht	31,317	3,500	1,400	26,417	Capital borrowing Capital borrowing Land II
3	30,111	period III 1578 period IV 9615	Land I 10 rai for Land II 2 rai for Land III 19 rai for Land IV 30 rai for Labor I = 106 hours Labor II = 1600 hours Labor III = 1600 hours Labor IV = 1043 hours	Nonglutinous rice, NV. Nonglutinous rice, NV. Glutinous rice, NW. Corn Hog 21x2 = 42 head Rice consumption 1000 kg. Off-farm inv. I=14149 baht Off-farm inv. II=6639 baht	34,234	3,500	1,400	29,334	Rice NG. NV. TR. Rice NG. NV. TR. Capital borrowing Capital borrowing Land II Off-farm investment Labor
4	33,202	period IV 5,943	Land I 10 rai for Land II 2 rai for Land III 19 rai for Land IV 30 rai for Labor I = 106 hours Labor II = 1600 hours Labor III = 1600 hours Labor IV = 1040 hours	Nonglutinous rice, NV. Nonglutinous rice, NV. Glutinous rice, NW. Corn Hog 21x2 = 42 head Rice consumption 1000 kg. Off-farm inv.I = 17594 baht Off-farm inv. II = 10154 baht Off-farm inv. III = 2007 baht	34,643	3,500	1,400	29,743	Rice NG. NV. BR. Rice NG. NV. TR. Capital borrowing Off-farm in[illegible] Land II Rice selling [illegible]. Labor

Situation IV. Fertilizer buying for rice production is added but corn buying is excluded from this situation. The crop acreage mix remains the same as the previous situation, but an improved rice variety with fertilization is substituted for a native variety with no fertilization in the production of all glutinous rice. Both capital accumulation and net income increase by about 6 percent.

Situation V. Base case and previous considered activities are incorporated into this final situation. The principal change is an increase in hog production to 72 feeder pigs fed out at the end of the fourth year. All glutinous rice is produced with improved varieties and fertilization. Labor is hired in the second, third and fourth quarters. Capital accumulation reaches 66,900 Baht and net income increases to 56,474 Baht at the end of the fourth year. Results of the optimum four-year plan under situation V are shown in Table 11. These results can be compared with those of Table 10 to obtain a view of changes in resource mix, land use, capital accumulation and net income resulting from the addition of new activities to the base case.

This study develops a sequential annual planning process for optimizing the four-year planning horizon of a typical farm in Thailand under five alternative situations. In all of the four year plans, family living and home use rice consumption are considered as exogenous activities, since exact family expenditure allowances and rice consumption are fixed for each year. Family living and home rice consumption, therefore, compete for the use of available operating capital. In each optimal plan,

Table 11. Optimum 4-year plan under Situation V

1 Year	2 Available Capital (baht) on hand	 borrowed	3 Resource Used	4 Optimum Combination	5 Net Return (baht)	6 Living Exp. (baht)	7 Fixed Exp. (baht)	8=5-(6+7) Net Income (baht)	9 Limiting Resource
1	3,600	period II 3,324 period III 6,952 period IV 10,000	Land I 10 rai Land II 8 rai Land III 36 rai Land IV 30 rai Labor I = 7 hrs. Lab. II1600+HL. 466 hrs. Rice consumption 1000 kg. Lab. III1600+HL.947 Buy fertilizer 936 kg. Lab. IV 1600+HL.226 Off-farm Inv. I = 1711 baht	NG. Rice, NV. BR. L I NG. Rice, NV. TR. L II GT. Rice, NW. TR. L.III FERT Corn L IV Hog = 2 head	32,697	3,500	1,400	27,797	Buy corn Hog raising Hired Labor Hired Labor Hired Labor
2	37,748	period III 883 period IV 10,000	Land I 10 rai Land II 8 rai Land III 36 rai Land IV 30 rai Labor I = 109 hrs. Lab.II 1600+HL. 527 hrs. Rice consumption 1000 kg. Lab. III1600+HL.1049hrs. buy fertilizer 936 kg. Lab.IV 1600+HL.288hrs. Buy corn 320 kg. Off-farm inv. I = 21124 baht Off-farm inv. II = 10225 baht	NG. Rice, NV. BR. L I NG. Rice, NV. TR. L II GT. Rice, NW. TR. L III Fert. Corn L IV Hog = 22x2=44 head	49,015	3,500	1,400	44,116	NG. Rice NV. BR. Buy corn Hired Labor -- Hired Labor Hired labor Capital borrowed Hired labor
3	54,666	period IV 10,000	Land I 10 rai Land II 8 rai Land III 36 rai Land IV 30 rai Labor I = 155 hrs Labor II 1600+HL. 555 hrs. Rice consumption 1000 kg. Lab III1600+HL.1095 hrs. Buy Fert. 936 kg. Lab IV 1600+HL.315 " Buy corn 4,244 kg. Off-farm inv. I = 34816 Off-farm inv. II = 21372 Off-farm inv. III = 1872	NG. Rice, NV. BR. L I NG. Rice, NV. TR. L II GT. Rice, NW. TR. L III FERT Corn L IV Hog = 31x2 = 62 head	55,778	3,500 3,500	1,400 1,400	50,878 50,878	Hired Labor Buy corn -- Hired Labor Hired labor Hired Labor
4	66,900	period IV 10,000	Land I 10 rai Land II 8 rai Land III 36 rai Land IV 30 rai Labor I = 188 hrs. Lab. II 1600+HL. 575hrs.Rice consumption 1000 kg. Lab. III1600+HL.1128 hrs. Buy FERT 936 kg. Lab. IV1600+HL.335 hrs. Buy corn = 7021 kg. Off-farm inv. I = 44511 baht Off-farm inv. II = 29266 baht Off-farm inv. III = 3828 baht	NG. Rice, NV. BR. L I NG. Rice, NV. TR L II GT. Rice, NW. TR. L III FERT Corn L IV Hog = 38x2 = 76 head	61,374	3,500	1,400	56,474	Hired labor Buy corn Hired labor Hired labor

capital surplus generated from crop and livestock production in any one year is transferred to the following year for use in farm production and household consumption. Capital borrowing is allowed up to a maximum of 10,000 Baht per quarter. The effect of the sequential planning process on the input-output mix is examined in relation to changes in on-hand capital and net income.

Research Conferences and Seminars

The methods and results of the agricultural sector analysis project in Thailand have been presented at several conferences and seminars including the First Regional Agricultural Sector Analysis Seminar held in Singapore, a Food and Agriculture Organization Sector Analysis Conference in Bangkok, and the Second Regional Agricultural Sector Analysis Seminar held in the Philippines. On-campus staff assisted in the writing of papers for the above-mentioned conferences. Grant staff members also presented papers at the conferences and seminars as well as serving as chairmen of individual sessions. The research conferences and seminars have greatly enhanced the dissemination of the analytical tools, research techniques and applications of these to agricultural sector development in Thailand.

Training Personnel in the Application of Quantitative Techniques

Training personnel in the use and application of sector analysis techniques was a priority activity throughout the life of the project. Primary emphasis was placed on the development of analytical skills of Thai staff members from the Division of Agricultural Economics, Ministry of Agriculture and Cooperatives. Some 27 graduate degree programs have been completed, or are in the process of being completed, by DAE staff members at Iowa State University. Another five advanced degree programs have been completed by staff members from other Thai ministries and institutions of higher education. Additional personnel trained in agricultural sector analysis at Iowa State University include not only graduate students carrying out grant-funded research, but also numerous other students from less-developed countries who have benefited significantly from interaction with the various elements of the ongoing sector analysis research.

Direction and supervision of graduate training programs in economic development and agricultural sector analysis required a considerable amount of staff involvement and professional time. Individual study programs necessarily had to be designed for each Thai graduate student, taking into consideration such background factors as: (1) amount of preparation in economics, agricultural economics and statistics prior to arrival at ISU; (2) facility in speaking, reading and writing English; (3) capability in analyzing and interpreting data forthcoming from a model

or quantitative solution; and (4) ability to organize thoughts and write up an orderly presentation of research results. To the extent that weaknesses were found in one or more of the above areas, it was necessary to work out special remedial programs to overcome the deficiencies encountered. The grant staff was actively involved in the training process by service formally on graduate student committees and as informal research advisors. In carrying out the research advisory role the grant staff had the opportunity to assist graduate students in defining research problems, formulating research strategies to investigate problems, and guiding them in the selection and application of appropriate quantitative techniques.

Much of the research training provided in economic development and agricultural sector analysis involved the application of mathematical programming models in the solution of national, regional and farm level problems. Research topics and degree completion times of DAE staff members are shown in Table 12. In addition to studies using mathematical programming techniques, other research topics included demand analysis for food and rice, production functions and fertilizer response for rice, analysis of marketing margins for livestock, statistical analysis of agricultural survey data, and evaluation of representative family farms in Thailand. Although each graduate student was assigned a specific research topic, there also was considerable interaction among DAE staff members in the analysis of alternative research techniques and in the collection and exchange of data. This interaction provided cross-training in the different

Table 12. Research topics and degree completion times of Division of Agricultural Economics staff members trained at Iowa State University

DAE Staff Member	Research Topic	Degree
1. Koset Manowalailo	Crop and Bovine Model, A Spatial Analysis Including Producing Areas and Consuming Regions.	Ph.D., F. 1978
2. Somporn Hanpongpandh	The ASEAN Rice Security Reserve: A Simulation Approach.	Ph.D., F. 1978
3. Apichart Pongsrihadulchia[a/]	Analysis, Design and Variance Estimation of Agricultural Survey Data.	M.S., S.S. 1978
4. Porntep Sangsuwan	Analysis of Agricultural Income Under Alternative Policies for the Northern Region of Thailand.	M.S., F. 1978
5. Winai Hirunsri	A Linear Programming Model of the Northern Region of Thailand.	M.S., S.S. 1977
6. Boontam Prommani	Integrated Production/Consumption Time-Phased Simulation of A Typical Farm in Northern Thailand, (An Application of Dynamic Linear Programming).	M.S., W. 1977
7. Boonchai Viroonsra	Statistics.[b]	M.S., W. 1977
8. Wannapha, Surisukdi	Statistics.[b]	M.S., W. 1977

Table 12. (continued)

DAE Staff Member	Research Topic	Degree
9. Thawach, Leelasuwanich	Statistics.[b]	M.S., F. 1976
10. Anchalee Ooraikul	Price Elasticity of Marketable Surplus of Rice in Thailand.	M.S., F. 1976
11. Somkid Klawkasikij	Analysis of Farm Planning Strategies Under Alternative Support Prices for Rice in Thailand.	M.S., F. 1976
12. Boonmee Juntaravong	Optimum Fertilizer Use for Rice Production in Thailand.	M.S., S.S. 1976
13. Sakol Ooraikul	Food Demand Analysis	M.S., S.S. 1976
14. Kitipong Surainrungsikul	Economic Analysis of Marketing Margins for Swine in Thailand.	M.S., S. 1976
15. Boonkerd Budhaka	Agricultural Economics.[b]	M.S., S. 1975
16. Orawan Ongkananamantlert	Problem Design, Computerized Analysis and Evaluation of Representative Family Farms in Thailand.	M.S., W. 1975
17. Prasit Supradit	Agricultural Economics.[b]	M.S., W. 1975
18. Banterng Masang [a/]	Agricultural Economics.[b]	M.S., W. 1975
19. Wisut Wangworawut [a/]	Agricultural Economics.[b]	M.S., W. 1974

Table 12. (continued)

DAE Staff Member	Research Topic	Degree
20. Winai Tayyaitieng	Agricultural Economics.[b]	M.S., W. 1974
21. Prasit Itharattana[a]	Agricultural Economics.[b]	M.S., W. 1974
22. Kajonwan Itharattana[a]	Agricultural Economics.[b]	M.S., W. 1974

NOTE: Additional graduate level training programs were carried out at the following cooperating Universities:
1. University of Kentucky, one Ph.D. and three M.S. programs;
2. Washington State University, three Ph.D. programs;
3. Western Illinois University, two M.S. programs;
4. North Carolina State University, one M.S. program;
5. Oklahoma State University, one M.S. program; and
6. University of Wisconsin, one M.S. program.

[a] Presently pursuing a second graduate training program at the Ph.D. level.

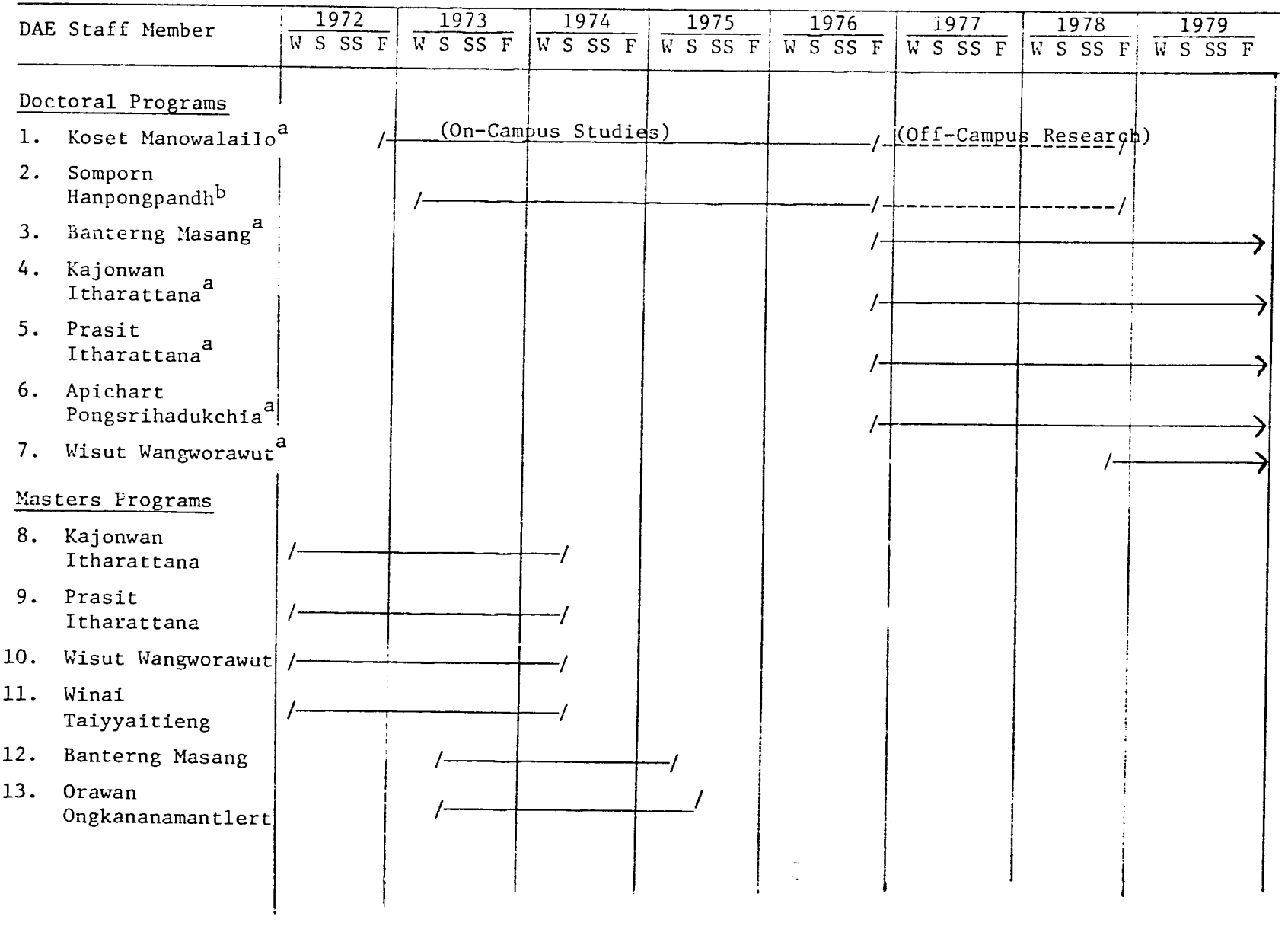
[b] Specific research topic not available.

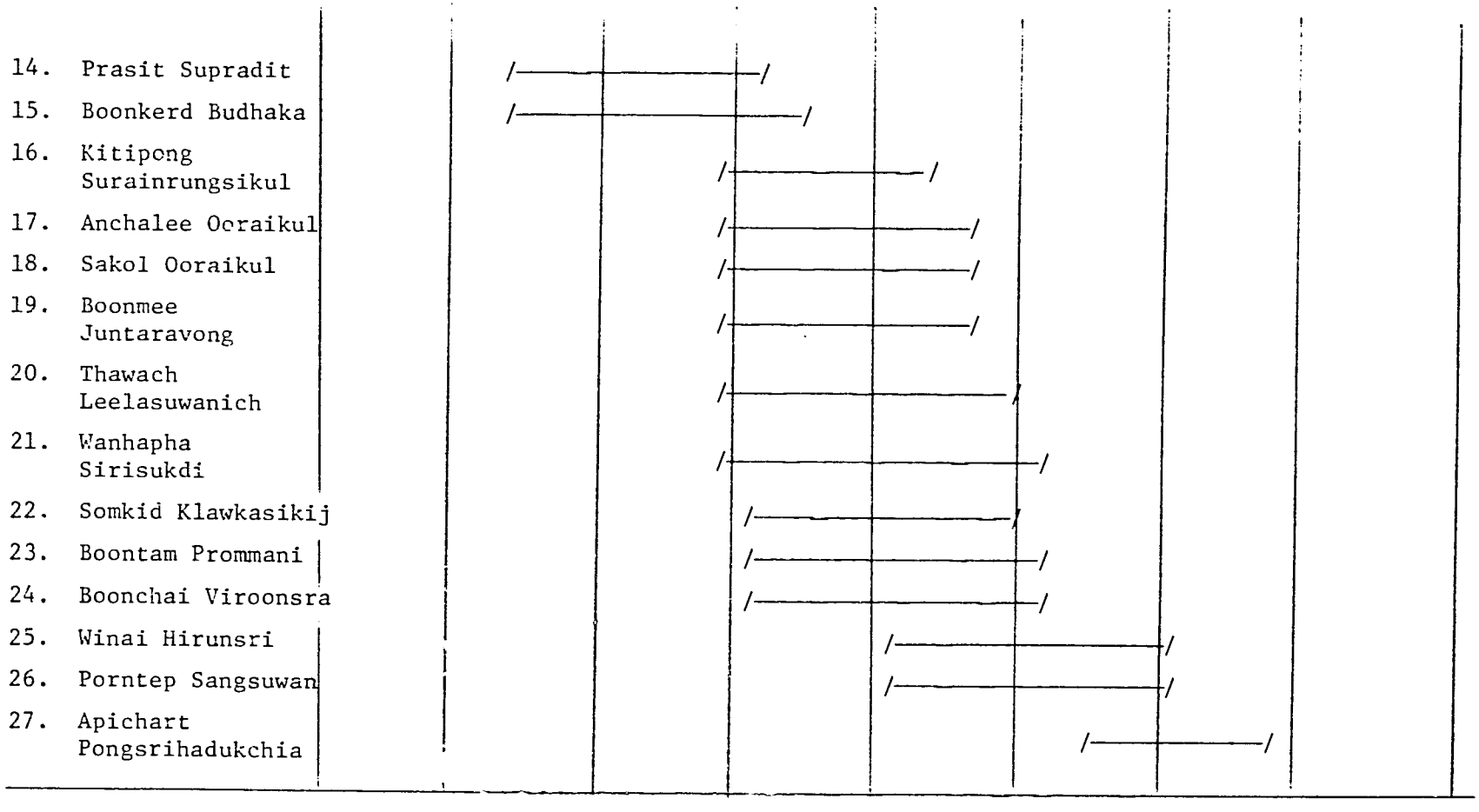
elements of agricultural sector analysis and has broadened the research experience base of the Thai graduate students.

The magnitude of the training activity is shown in Figure 1. This figure provides a time-phased representation of the 27 degree programs which have been, or are being completed, by DAE staff at Iowa State University. On-campus training time for the 20 M.S. programs completed averaged about 24 months, while the Ph.D. programs require approximately twice this amount of on-campus time. Because of overlaps in timing, some 12 to 14 Thai graduate students were on campus at one time during the middle phase of the project.

Because of the large scale of the training activity, the demand on grant staff time was considerable. It is estimated that the training component required more than one and one-half man-years of grant staff time per annum. The value of this heavy investment of professional staff time in the training activity is found in the overall success of the activity. To date, all DAE staff members sent to Iowa State University for advanced training have successfully completed, or are completing, their respective degree programs. This success rate has been due in large part to the special assistance and personal guidance provided Thai graduate students in the planning, implementation and completion of their individual degree programs.

Figure 1. Time-phased representation of graduate training programs completed, or being completed, by DAE staff members at Iowa State University, 1972 to 1979





[a]Previously completed M.S. degree at Iowa State University.

[b]Previously completed M.S. degree at North Carolina State University.

NOTE: Time lines are approximate since final work may have been completed late in a quarter with actial degree awarded in absentia during the following quarter.

Preparation and Distribution of Publications

The preparation and distribution of publications was a key element in the documentation of project progress and the dissemination of research results to using agencies and interested professionals of the international development community. As individual phases of the agricultural sector analysis project were completed, results of each completed phase were written, published, and distributed. Completed publications were sent to development agencies and interested international development professionals throughout the United States and to some 16 foreign countries. This allowed professionals involved in agricultural sector analysis and international development to gain an insight into the research techniques and methodologies used and to benefit from the experience obtained through the application of analytical tools to the solution of real world agricultural sector development problems.

The professional and editorial staff edited and helped write eleven major research reports and four technical progress reports which have been published and distributed. A summary of the titles of the reports is found in Table 13.

The publication process placed a heavy demand on professional, editorial, and secretarial resources. Typically, a report passed through all of the following stages at least once and sometimes twice:

Table 13. Summary of DAE-CARD agricultural sector analysis reports

No. 1.	Agricultural Employment and Migration in Northeast Thailand: Application of a Regional Planning Model. DAE-CARD Sector Analysis Series. No. 1. Iowa State University, Ames, Iowa 1976.
No. 2	Second Annual Report: Agricultural Sector Analysis in Thailand. (Summary of Research and Project Progress.) DAE-CARD Sector Analysis Series. No. 2. Iowa State University, Ames, Iowa. 1977.
No. 3	Macroeconometric Analysis of Economic Activity in Thailand, 1962-1974. DAE-CARD Sector Analysis Series. No. 3. Iowa State University, Ames, Iowa. 1977.
No. 4	Agricultural Development Planning in Thailand: Some Supporting Analysis. DAE-CARD Sector Analysis Series. No. 4. Iowa State University, Ames, Iowa. 1977.
No. 5	Kenaf Demand in Thailand. DAE-CARD Sector Analysis Series. No. 5. Iowa State University, Ames, Iowa. 1977.
No. 6	Third Annual Report: Agricultural Sector Analysis in Thailand. (Summary of Research and Project Progress.) DAE-CARD Sector Analysis Series. No. 6. Iowa State University, Ames, Iowa.
No. 7	Singapore Symposium: Agricultural Sector Analysis in Thailand. DAE-CARD Sector Analysis Series. No. 7. Iowa State University, Ames, Iowa. 1977.
No. 8	Agricultural Supply Response in Thailand: Production, Resources, Income and Policy Implications. DAE-CARD Sector Analysis Series. No. 8. Iowa State University, Ames, Iowa. 1977.
No. 9	Potential Effects of Changes in Truck Transportation on the Value of Production and Incomes in Thailand's Rice Agriculture. DAE-CARD Sector Analysis Series. No. 9. Iowa State University, Ames, Iowa. 1978.
No. 10	Consumer Demand for Food Commodities in Thailand. DAE-CARD Sector Analysis Services. No. 10. Iowa State University, Ames, Iowa. 1978.

Table 13 (con't.)

No. 11	Structure of a Recursive Model for Policy Analysis in Thailand. DAE-CARD Sector Analysis Series. No. 11. Iowa State University, Ames, Iowa. 1978.
No. 12	Fourth Annual Report: Agricultural Sector Analysis in Thailand. (Summary of Research and Project Progress.) DAE-CARD Sector Analysis Series. No. 12. Iowa State University, Ames, Iowa. 1978.
No. 13	Normative Study of the Supply Response of Rice in Thailand. DAE-CARD Sector Analysis Series. No. 13. Iowa State University, Ames, Iowa. 1978.
No. 14	A Simulation Model of the World Rice Economy with Special Reference to Thailand. DAE-CARD Sector Analysis Series. No. 14. Iowa State University, Ames, Iowa. 1978.
No. 15	A National Crop Model of Agriculture in Thailand: A Mathematical Programming Approach. DAE-CARD Sector Analysis Series. No. 15. Iowa State University, Ames, Iowa. 1979.

(1) initial write up by the professionals involved; (2) typing of first draft; (3) proofing by secretarial staff; (4) professional review with suggestions for modification and changes; (5) typing of final copy; (6) editorial review for changes and corrections; (7) final typing corrections; and (8) publication. Because of the number of stages and time required for each, final publication and distribution can occur several months after completion of the research and project events described. It, therefore, was of considerable importance that sufficient project follow-through time was provided to permit the appropriate documentation of research and project accomplishments.

Considerable effort also was expended to prepare and store a computerized listing of report recipients. The automated system provided direct printout for various types of mailing labels, sorting of addresses by zip code for mailing, and rapid access for address corrections, additions and deletions. More than 250 addresses of report recipients were stored in the system including those of international development agencies, technical libraries, and interested international development professionals. Since some user agencies and libraries received more than one copy of the report, each mailing included a distribution of more than 300 reports.

EXPENDITURE SUMMARY

Amendment No. 7 to Supplementary Grant No. AID/csd-2824 authorized continuation of project work through June 30, 1979, without any increase in funds. Total amount of funds provided under the supplementary grant was $400,000. A summary of expenditures of supplementary grant funds, by line item, is shown in Table 14. Line item totals may differ slightly from amounts shown in the final financial report due to further verification and adjustment of some individual expense items. No tuition costs or fees were charged under the supplemental grant. Workshop and seminar expenditures for travel and related subsistence costs are included in the total of the travel line item.

Table 14. Expenditure Summary, Supplemental Grant No. AID/csd 2824 entitled "Economic Development and Agricultural Sector Analysis"

Line Item	Cumulative Total 2/26/73-6/30/78	Final Period 7/1/78-6/30/79	Total[a] Expenditures
Salaries:			
Professional	203,593	15,930	219,523
Graduate Student	52,345	10,601	62,946
Clerical	9,791	2,000	11,791
Benefits	28,703	3,124	31,827
International Travel	16,898	---	16,898
Domestic Travel	3,375	840	4,215
Computer, Data, and Related	34,019	12,237	46,256
Publications	---	4,359	4,359
Other[b]	---	2,185	2,185
TOTAL	348,724	51,276	$400,000

[a] Line item totals may differ slightly from amounts shown in final financial report due to further verification and adjustment of individual expense items.

[b] Final billing of unclassified expenditures pending.

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DAE-CARD SECTOR ANALYSIS SERIES

No. 1 Rogers, Keith D. and Prasit Itharattana. "Agricultural Employment and Migration in Northeast Thailand: Application of a Regional Planning Model." December 1976.

No. 2 Center for Agricultural and Rural Development. "Annual Report: Agricultural Sector Analysis in Thailand." February 1977.

No. 3 Stephenson, James A. and Kajonwan Itharattana. "Macroeconometric Analysis of Economic Activity in Thailand, 1962-1974." March 1977.

No. 4 Framingham, Charles F., et al. "Agricultural Development Planning in Thailand: Some Supporting Analysis," March 1977.

No. 5 Blakeslee, LeRoy and Thongchai Petcharatana. "Kenaf Demand in Thailand." June 1977.

No. 6 Center for Agricultural and Rural Development. "Third Annual Report: Agricultural Sector Analysis in Thailand." June 1977.

No. 7 Center for Agricultural and Rural Development. "Singapore Symposium: Agricultural Sector Analysis in Thailand." July 1977.

No. 8 Rogers, Keith and Prasit Itharattana. "Agricultural Supply Response in Northeast Thailand: Production, Resources, Income, and Policy Implications." October 1977.

No. 9 Conley, Dennis M., Chamnong Vathana and Earl O. Heady. "Potential Effects of Changes in Truck Transportation on the Value of Production and Incomes in Thailand's Rice Agriculture." March 1978.

No. 10 Dagostar, Bahram, et al. "Consumer Demand for Food Commodities in Thailand." March 1978.

No. 11 Stoecker, A. L., Kenneth Nicol, and Somnuk Sriplung. "Structure of a Recursive Model for Policy Analysis in Thailand." August 1978.

No. 12 Stoecker, A. L., Earl O. Heady, and Randall A. Hoffmann. "Fourth Annual Report: Agricultural Sector Analysis in Thailand." August 1978.

No. 13 Faber, Doeke C., Earl O. Heady, Wayne D. Ellingson, A. L. Stoecker, and Kenneth J. Nicol. "A Normative Study of the Supply Response of Rice in Thailand." August 1978.

No. 14 Sarkar, Hiren. "A Simulation Model of the World Rice Economy with Special Reference to Thailand." August 1978.

No. 15 Stoeker, A. L. "A National Crop Model of Agriculture in Thailand: A Mathematical Programming Approach." February 1979.