AGRICULTURAL MECHANIZATION POLICY AND STRATEGY

THE CASE OF THAILAND

A. G. RIJK

1989

STELLINGEN

1

Het is nodig dat ontwikkelingslanden een landbouwtechnologiebeleid en -strategie formuleren, waarvan de landbouwmechanisatie onderdeel is.
(dit proefschrift).

2

Indien in ontwikkelingslanden de kosten verbonden aan het gebruik van landbouwmachines de werkelijke economische waarde vertegenwoordigen, zullen de vaak aangehaalde nadelige sociale en economische gevolgen van de landbouwmechanisatie uitblijven, en kan mechanisatie bijdragen tot gunstige ontwikkeling van het platteland.
(dit proefschrift).

3

Voor marginale landbouwproduktiesystemen (gekenmerkt door lage opbrengst) waarvan de produktie tegen relatief lage (wereldmarkt)prijzen afgezet moet worden, zal bij toenemende arbeidskosten landbouwmechanisatie in vele gevallen slechts in beperkte mate een oplossing zijn om de produktie in stand te houden.
(dit proefschrift).

4

De brandstofprijs is geen geschikt beleidsinstrument om het landbouwmechanisatieproces te beïnvloeden.
(dit proefschrift).

5

Ervaringen met de zogenoemde aangepaste technologie gericht op de ontwikkelingslanden, duiden erop dat tijdens de opleiding van deskundigen teveel nadruk wordt gelegd op (ontwerp)technische zaken en te weinig op sociale en economische aspecten van de toepassing van technologie.

6

Er is dringend behoefte aan onderzoek naar het gebruik, de verwachte levensduur, de onderhouds- en de reparatiekosten van landbouwwerktuigen in ontwikkelingslanden, om zodoende specifieke informatie te verkrijgen over de kosten van de landbouwmechanisatie in deze landen.

7

Het pleidooi dat donorlanden een aanzienlijk hoger percentage van hun bruto nationaal product aan ontwikkelingshulp zouden moeten besteden, moet worden gezien als een eenzijdige macro-analyse van de problematiek aangaande de ontwikkelingslanden. Om deze hulp efficiënt en effectief in een ontwikkelingsland te kunnen besteden is het in de eerste plaats nodig dat in voldoende mate aan de noodzakelijke randvoorwaarden is voldaan, met name op het gebied van het overheidsbeleid, en de capaciteit en kwaliteit van het overheidsapparaat.
(J. Tinbergen."Het gaat om het inkomen" in *NRC-Handelsblad: supplement economie*, 16 maart 1989).

8

De integratie tot één Dienst Buitenlandse Zaken van de ambtenaren van de Buitenlandse Dienst en personeel van het Departement van Buitenlandse Zaken, waarvan het Directoraat-Generaal Internationale Samenwerking deel uitmaakt, en het feit dat sectorspecialisten op contractbasis te werk worden gesteld, suggereert dat de Nederlandse overheid niet primair is geïnteresseerd in de kwaliteit en continuïteit van de specifieke expertise die nodig is voor ontwikkelingssamenwerking.

9

De gewoonte in Nederland om universiteiten in de avonduren en weekeinden te sluiten staat in schril contrast met die in andere landen, met name in Noord Amerika, en moet worden gezien als een ondoelmatig gebruik van schaarse middelen en een slechte voorbereiding van de student op een belangrijke funktie in de private sector.

10

Het verschijnsel dat in sommige landen verkeersovertredingen ter plekke ondershands worden afgehandeld met de politieagent, kan als privatisering van een overheidsfunctie worden uitgelegd.

A.G. Rijk. *Agricultural mechanization policy and strategy: The case of Thailand*. Wageningen, 28 september 1989.

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AGRICULTURAL MECHANIZATION POLICY AND STRATEGY

THE CASE OF THAILAND

A. G. RIJK
1989

Proefschrift
ter verkrijging van de graad
van doctor in de landbouwwetenschappen,
op gezag van de rector magnificus,
dr. H. C. van der Plas
in het openbaar te verdedigen
op 28 September 1989
des namiddags te vier uur in de aula
van de Landbouwuniversiteit te Wageningen.

ABSTRACT

Rijk, A.G. (1989), Agricultural Mechanization Policy and Strategy: The Case of Thailand. Dissertation, Wageningen Agricultural University, the Netherlands. (This dissertation has also been published by the Asian Productivity Organization, Tokyo, ISBN: 92-833-1111-6 [casebound], 92-833-1112-4 [limpbound]). xxx + 285 pages, 20 figures, 48 tables, 1 map, 232 references, 7 appendixes, English and Dutch summaries.

The role of agricultural mechanization in a developing economy is examined in order to enhance the formulation of mechanization policy and strategy. As a result of the review and assessment of the mechanization process, seven distinct stages in the mechanization process are specified and the rationale for mechanization is identified. General guidelines for the formulation of an agricultural technology strategy are given. The need for mechanization policy and strategy is highlighted as a complementary input to agricultural development plans. Agricultural mechanization in Thailand is reviewed as a case study, and its salient features are discussed. To analyze the effect of technical and economic variables on the mechanization process and to support mechanization policy and strategy formulation, a mechanization model (MECHMOD) is developed and, as a test case, applied to the Central Region of Thailand. MECHMOD's basic structure consists of a linear programming tableau which imitates multiple cropping, and in which the demand for labor, draft animals and machinery is specified according to crops, farm operations, working methods and time period. The results of the experiments performed with MECHMOD are discussed in a two-fold fashion. First, the applicability of MECHMOD is discussed. Second, the outcome from the experiments are interpreted in terms of mechanization policy and strategy for Thailand.

Free descriptors: Agricultural mechanization, agricultural development, crop production, income, employment, social change, technology transfer, energy consumption, policy, strategy, model, linear programming, aggregation, wage rate, fuel price, machinery acquisition cost, interest rate, labor force, Thailand.

To my father

ACKNOWLEDGEMENTS

This dissertation is the indirect result of my involvement and interest in agriculture and agricultural mechanization in Asia since 1975. A direct motive for undertaking the research and writing this book was my consultancy assignment with the Economic and Social Commission for Asia and the Pacific's Regional Network for Agricultural Machinery in 1980. The objective of that assignment was to provide guidance to the participating countries on how agricultural mechanization can best be organized and allocated to support national development. The assignment made me aware of the need to quantify the effect of key variables on the process of mechanization, and to develop a methodology for the formulation of mechanization policy and strategy for specific countries and situations. This idea gradually developed into a research proposal, but major progress in its implementation was only possible after study leave was obtained from my present employer.

I am indebted to many people who directly or indirectly contributed to the shaping of my ideas and to my putting them on paper. Mentioning them all would be impossible, but because of their direct contributions several persons ought to be specifically mentioned.

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I am also grateful to the Management of the Asian Development Bank for granting me study leave to complete my research. I further appreciate the publishing of the manuscript by the Asian Productivity Organization. However, these organizations do not necessarily endorse the findings of this study, and the content and conclusions in this book are my sole responsibility.

Finally, the burden of writing this book was alleviated by the fond memories of working closely with farmers and counterparts in Asia, in particular in Thailand, Nepal and Indonesia. I thank all those persons and institutions who contributed to the completion of this study.

A.G. Rijk
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ABBREVIATIONS AND ACRONYMS

ADB	-	Asian Development Bank
ADBP	-	Agricultural Development Bank of Pakistan
AED	-	Agricultural Engineering Division
ASAE	-	American Society of Agricultural Engineers
BAAC	-	Bank for Agriculture and Agricultural Cooperatives
BY	-	Base year
CAAM	-	Chinese Academy for Agricultural Mechanization
CIF	-	Cost of insurance and freight
DA	-	Draft animal
DAE	-	Department of Agricultural Extension
DIP	-	Department of Industrial Promotion
DOA	-	Department of Agriculture
EC	-	European Community
ECE	-	(United Nations) Economic Commission for Europe
ESCAP	-	Economic and Social Commission for Asia and the Pacific
FAO	-	Food and Agriculture Organization of the United Nations
FMPC	-	Farm Mechanization Promotion Centre
HYV	-	High yielding variety
ICRISAT	-	International Crops Research Institute for the Semi-Arid Tropics
IDA	-	International Development Association
IDP	-	Integrated Development Project
IRRI	-	International Rice Research Institute
ISI	-	Industrial Services Institute
LP	-	Linear programming
MECHMOD	-	Mechanization model
MG	-	Matrix-Generator
MGG	-	Matrix-Generator-Generator
MOAC	-	Ministry of Agriculture and Cooperatives
MOI	-	Ministry of Industries
MPC	-	Mechanization possibility curve
MPS	-	Mathematical programming system
NCAM	-	National Committee on Agricultural Machinery
NESDB	-	National Economic and Social Development Board
NIC	-	Newly industrialized country

NSO	-	National Statistics Office
OAE	-	Office of Agricultural Economics
OECD	-	Organization for Economic Cooperation and Development
RIPC	-	Regional Industrial Promotion Center
RNAM	-	Regional Network for Agricultural Machinery
SOW	-	Stichting Onderzoek Wereldvoedselvoorziening (Centre for World Food Studies)
UNDP	-	United Nations Development Program
UNIDO	-	United Nations Industrial Development Organization
USAID	-	US Agency for International Development

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EXECUTIVE SUMMARY

This study is concerned with the role of agricultural mechanization in a developing economy. **Chapter 1** gives a general introduction and provides the rationale, objectives and scope of the study as well as definitions, terminology and concepts. In its broadest meaning, agricultural mechanization embraces the use of tools, implements and machines for agricultural land development, production, harvesting, and on-farm processing; and includes human, animal and mechanical power. A specific objective of this study is to develop a rational approach to mechanization policy and strategy formulation, including the development of a model to analyze the effect of policy and development scenarios on the progress of mechanization. For development and testing of the model, the Central Region of Thailand serves as a case study.

Chapter 2 is a review and assessment of the mechanization process in a historical and economic context. Seven distinct stages in the mechanization process are proposed. These stages are, in order of increasing sophistication, *Stationary Power Substitution, Motive Power Substitution, Human Control Substitution, Cropping System Adaptation, Farming System Adaptation, Plant Adaptation,* and *Automation*. In addition, three principal objectives of mechanization are identified, namely, increase in labor productivity, increase in land productivity, and decrease in production cost. Conflicting views on mechanization have resulted in a large number of studies and publications on the economic and social impact of mechanization. The chapter therefore discusses key developmental issues often considered in relation to mechanization. These issues are the effect of mechanization on crop production, farm family income, employment, social change, aspects related to technology transfer, and fossil energy consumption. Two crucial conclusions emerge from Chapter 2: (i) The agricultural mechanization process is the result of induced innovation and is governed by changing relative prices for agricultural produce, cost of capital investment and cost of labor. The driving force for this process is the farmer's effort to increase or maintain income. (ii) The net effects of mechanization on production and the society highly depend on the agricultural production system and socio-economic situation of the particular locality where mechanization is being applied. These effects must therefore be assessed on a case by case basis for a particular country, region, program or project.

Chapter 3 describes the history and status of agricultural mechanization in Thailand, including characteristics of the machinery industry, research and development, and relevant institutional aspects. For the latter, a rationalization of the role and function of the Agricultural Engineering Division of the Ministry of Agriculture and Cooperatives is proposed. A salient feature of the mechanization process in Thailand is that the government interfered very little with mechanization. Adverse policies favoring mechanical technology at the expense of employment were insignificant in Thailand. In fact, several government policies were disadvantageous for mechanization, and subsequently the evils frequently associated with mechanization did not occur in Thailand, but mechanization contributed significantly to development.

Chapter 4 reiterates that under certain conditions, agricultural mechanization is an important input in facilitating agricultural and economic growth, but in other circumstances mechanization does not make the desired impact and even contributes to undesirable developments. There is no single solution to the mechanization issue which may be applied universally. It is therefore necessary for a developing economy to formulate a mechanization policy and strategy as part of the agricultural development plan and to safeguard the efficient utilization of scarce resources. The content and scope of these policies and strategies depend on the stage of agricultural and economic development and priorities for development. General guidelines for the formulation of an agricultural technology strategy may be summarized as follows: (i) Where land is in surplus but labor is a limiting factor, mechanization is needed to increase production. (ii) Where land is scarce but labor is in surplus, high-yielding technology and crop intensification are required. (iii) Where both land and labor are underutilized due to pronounced seasonality, mechanization is required to help eliminate labor shortage bottlenecks. (iv) Where a shortage of both labor and land exists, a combination of labor-saving mechanization and biological and chemical technology should be applied. (v) Where the cost of traditional power sources has become high relative to mechanical power, mechanization is required to reduce cost of production. (vi) Human labor and draft animals remain a major power source in many developing countries, and due consideration must be given to the development and introduction of more efficient tools and implements to be used with these two power sources.

Chapter 5 describes the development and implementation of MECHMOD, a model for analyzing the mechanization process and for supporting mechanization policy and strategy formulation. Review of existing methodologies identified principal shortcomings as one or more of the following. (i) Most approaches are technically inspired and do not include the effect of economic changes. (ii) Factor substitution possibilities through alternative mechanization options are not explicitly included. (iii) The methods do not provide for a quick evaluation of a set of development or policy scenarios. (iv) The models are limited to micro-level farm management economics and do not evaluate the farm power situation of the sector as a whole.

Through identifying the appropriate design criteria, features and rationale, MECHMOD aims to overcome these shortcomings. MECHMOD is a partial and static model and aggregated at the regional level, with exogenously supplied technical and economic variables. MECHMOD's basic structure consists of a linear programming (LP) tableau which imitates the cultivation of crops; and in which the demand for labor, draft animals and machinery is specified according to crops, farm operations, working methods and time period. The limiting scarce resources are land, labor and draft animals. Four land resources are distinguished by their capability. Labor is subdivided into farm family labor and hired labor, and male labor of certain age is considered a sub-category. The objective function maximizes farm family income, including earnings from non-agricultural work. MECHMOD is written in high-level computer language and has been developed and implemented on a main-frame computer, applying data from the Central Region of Thailand.

The validation of MECHMOD includes a comparison of its outcome with the actual situation in 1986, and a judgment of its suitability for its stated purpose. The strength of MECHMOD lies in its flexibility, and its mechanism is easily understood. However, because of limitations on information on price and cross-elasticities of demand and other complexities, it was not feasible to include cropping patterns as endogenous equilibrium variables. MECHMOD's principal strength lies in providing information regarding relative changes in the progress of mechanization as a result of different development and policy scenarios.

Chapter 6 describes experiments performed with MECHMOD. These experiments are grouped into three series. In *Series I* experiments, the effect of one exogenous key variable on capital stock for mechanization is examined. These key variables are wage rate, price of fuel, acquisition cost of machinery, interest rate, size of agricultural labor force, and the portion of the farm family labor force which is freely exchangeable with non-agricultural work. In *Series II* experiments, the combined effect of a simultaneous change in crop area, labor force and wage rate on capital stock is studied. In *Series III* experiments, crop area is also treated as an endogenous variable. The purpose of this series is to study the effect of wage rate on agricultural production;

particularly area expansion or contraction, the role of mechanization, and the effect of certain policies.

The findings and conclusions of the study are presented in **Chapter 7.** The results of the experiments are discussed in a two-fold fashion. First, the applicability of MECHMOD is discussed. Second, the results of the experiments are interpreted in terms of formulating a mechanization policy and strategy for Thailand. MECHMOD facilitates a quick evaluation of the effect of key variables on the process of mechanization, and can easily be modified to include additional features. The performance of MECHMOD adheres to principles and theories of factor substitution, opportunity cost and economies of scale, *machine-centered* versus *manpower-centered* mechanization processes, technical innovation, *power-intensive* versus *control-intensive* mechanization, and staged development in mechanization. Experimenting with MECHMOD enhances the understanding of the impact of policy decisions and economic development on the process of mechanization. Further recommended work relates to the adaption of MECHMOD for use on personal computers.

Forecasting the course of further mechanization in Thailand will depend on the correct forecast of economic development, particularly in the agricultural sector. Because of structural changes in the world market for traditional Thai agricultural export commodities, the favorable prices of the 1970s are unlikely to return. Also, area expansion is becoming increasingly difficult, and depending on the pace of industrialization, marginal agricultural land may ultimately be taken out of production. Taking these factors into account, the likely future scenario suggests that land preparation in the Central Region will soon be fully mechanized, while the use of mechanical reapers for the paddy crop and sugarcane harvesters is imminent. The machinery capital stock in the Central Region will increase at 5 to 6 per cent per annum, lower than in the 1970s. However, this growth rate relates to a higher machinery stock, while replacement of equipment will increasingly constitute an important market for the domestic industry. Therefore, there is little reason to be pessimistic about the future demand for agricultural machinery, since Thailand's other regions are still in a much less advanced stage of mechanization and will subsequently achieve higher rates of investment in mechanization technology.

Additional conclusions and recommendations may be summarized as follows:

(i) Increase in crop area at a higher rate than the agricultural labor force leads to further mechanization of land preparation. Mechanization of control-intensive operations may only become significant if labor cost increases relative to mechanical operations.

(ii) With the exception of chemical weed control, mechanical paddy reaping, and cane harvesting, mechanization in Thailand will not significantly proceed into Stage III (Human Control Substitution) in the next 5 to 10 years, because a substantial wage rate increase will be required before control-intensive mechanization becomes competitive with human labor.

(iii) Once Stage I (Stationary Power Substitution) and Stage II (Motive Power Substitution) of the mechanization process have been completed, mechanization will only be a limited solution to offset the increasing cost or shortage of labor due to the high cost of sophisticated machinery. Unless the farmgate prices or yields increase, the marginal farming systems will be incapable of financially supporting the more advanced and costly control-intensive mechanization technology, and ultimately land may be left fallow.

(iv) Provision of institutional credit from BAAC without limitations to type of technology, its origin or its utilization, and abolishing the restrictions on importation of second-hand small tractors, can reduce agricultural production cost without need for government subsidy. The policy change on small tractor importation must be accompanied by promotional work on their use in flooded paddy fields.

(v) No justification exists for the present policy of making credit from the Bank for Agriculture and Agricultural Cooperatives exclusively available for small-scale indigenous machinery. In fact, these technologies are the least in need of this institutional credit, and the policy places the upland farmer at a disadvantage. The view that this institutional credit for more sophisticated, high capacity machines will only benefit the large farmer is (at least in the case of Thailand) erroneous.

(vi) Mechanical paddy reapers are likely next in line for rapid adoption, provided low-cost designs are promoted. Mechanization of the sugarcane harvest may succeed if real wages increase by 5 to 10 per cent.

(vii) The cost of fuel mainly affects mechanical land preparation for upland crops with big tractors. Therefore, also for practical reasons, manipulation of the fuel price is not recommended as a policy instrument for agricultural mechanization.

(viii) Unlike many developing countries, Thailand has not experienced a bias toward mechanization at the expense of labor. In fact, several government policies have placed mechanical technology at a disadvantage. Labor-saving (or labor-cost reducing) technology will become increasingly important for the Thai agricultural sector, and the government must eliminate policies which cause a bias against mechanization.

(ix) Because of its cost as compared with mechanical power, draft animal technology is rapidly disappearing in Thailand. Therefore, research and development on improved draft animal technology is no longer justified.

(x) Because increased labor cost will cause a shift toward broadcast paddy, research and development efforts are unjustified for mechanical transplanting technology.

(xi) For both economic and technical reasons, the machinery developed for conditions in East Asian countries may be unsuited for most conditions in Thailand.

(xii) The Thai agricultural machinery manufacturing industry has been highly successful in applying low-cost production technology, but it is still in an early stage of development. The industry does not yet have the knowledge and research and development capability needed to develop and produce the more sophisticated machinery needed in the near future. The investment required for the development and manufacture of this machinery is unlikely to be attractive to the individual Thai entrepreneur. Therefore, a sustainable and competitive agricultural machinery industry for both domestic and export markets will likely only come about with the collaboration of foreign manufacturers.

(xiii) With regard to the manufacture, supply and financing of agricultural machinery, market forces should prevail to let mechanization develop in the most efficient way. Reasonable protection of the domestic machinery manufacturing industry may be justified for specific machinery in the initial years to promote the domestic farm machinery industry, but the cost of these protectionist measures should not be transferred to farmers.

(xiv) The government's role should be limited to providing the required institutional and infrastructural support, including a promotional role in research and development. In connection with (xii) above, it is recommended that the function and role of the Agricultural Engineering Division (AED) be rationalized and strengthened. AED should focus on assessment of bottlenecks in the agricultural production system which may be eliminated by mechanization, and import the potentially suitable prototype machinery for extensive testing and modification. Once a suitable technology has been obtained, AED should play a leading role in promotional work, extension and advisory services in order to stimulate farmers' adoption of this technology.

SAMENVATTING

Het onderwerp van deze studie is de rol van de landbouwmechanisatie in ontwikkelingslanden. Hoofdstuk 1 bevat een algemene inleiding, definities en begrippen, en geeft de doeleinden en omvang van de studie aan. In de meest ruime betekenis heeft landbouwmechanisatie betrekking op het gebruik van gereedschappen, werktuigen en machines voor het in cultuur brengen en houden van landbouwgrond en voor de produktie en verwerking van landbouwprodukten op het boerenbedrijf, en omvat zij de menselijke, dierlijke, en mechanische krachtbronnen. Specifieke doelstellingen van deze studie zijn het ontwikkelen van een rationele benadering voor mechanisatiebeleid en strategieformulering, alsmede het ontwikkelen van een model om de gevolgen van beleidsbeslissingen en mogelijke ontwikkelingscenario's op de voortschrijding van de landbouwmechanisatie te analyseren. De centrale regio van Thailand dient als een case study voor de ontwikkeling en het testen van het model.

Hoofdstuk 2 beschrijft en analyseert de voortschrijding van de landbouwmechanisatie in zowel ontwikkelings- als geïndustrialiseerde landen binnen een historisch en economisch verband. De studie onderscheidt zeven verschillende stadia tijdens de voortschrijding van de landbouwmechanisatie. Deze stadia zijn, in toenemende mate van ontwikkeling en gecompliceerdheid: (i) de mechanisatie van stationaire bewerkingen; (ii) de vervanging van louter spierkracht door mechanische kracht voor veldwerkzaamheden; (iii) mechanisatie van die bewerkingen waarbij menselijke handelingen en beslissingen centraal staan; (iv) de aanpassing van de teelttechniek aan de eisen van de mechanisatie; (v) de aanpassing van het bedrijfssysteem aan de eisen van de mechanisatie; (vi) de aanpassing van de plant aan de eisen van de mechanisatie; en (vii) de automatisering. Verder kunnen er drie belangrijke redenen voor mechanisatie onderscheiden worden, te weten toename van de arbeidsproduktiviteit, toename van de grondproduktiviteit, en vermindering van de produktiekosten.

Er bestaan tegenstrijdige meningen aangaande de invloed van mechanisatie in ontwikkelingslanden op de economie en de samenleving. Daarom worden in dit hoofdstuk de belangrijkste ontwikkelingsfaktoren besproken die vaak in verband gebracht worden met mechanisatie. Deze factoren zijn de invloed van de mechanisatie op de landbouwproduktie, het gezinsinkomen van de boer, de werkgelegenheid, sociale veranderingen, de overdracht van technologie, en het gebruik van fossiele energie. Twee belangrijke conclusies komen naar voren in hoofdstuk 2: (i) het landbouwmechanisatieproces wordt gestuurd door veranderende prijsverhoudingen voor agrarische produkten, de kosten van kapitaalsinvesteringen, en de loonkosten. De stuwende kracht voor dit proces is de poging van de boer om zijn inkomen te vermeerderen of te behouden; en (ii) het effect van de mechanisatie op produktie en samenleving hangt nauw samen met het landbouwproduktiesysteem en de sociaal-economische situatie ter plaatse. Daarom behoren de effecten van mechanisatie bestudeerd te worden van geval tot geval.

Hoofdstuk 3 beschrijft voor Thailand de geschiedenis en de huidige stand van de landbouwmechanisatie, de landbouwwerktuigenindustrie, onderzoeks- en ontwikkelingsinstellingen voor de mechanisatie, en andere relevante institutionele kenmerken. Een rationalisatie van de rol en de functie van de Landbouwmechanisatiedivisie van het Thaise Ministerie van Landbouw wordt voorgesteld. Een kenmerkende eigenschap van het mechanisatieproces in Thailand is het feit, dat de overheid weinig interveniëerde in het mechanisatieproces vergeleken met sommige andere ontwikkelingslanden, terwijl beleidsmaatregelen die mechanisatie bevoorrecht zouden hebben ten koste van de werkgelegenheid, verwaarloosbaar zijn. In feite hebben verschillende overheidsmaatregelen ten nadele van de mechanisatie gewerkt. Zodoende zijn in Thailand de negatieve invloeden die vaak in verband worden gebracht met landbouwmechanisatie achterwege gebleven en heeft mechanisatie een duidelijke bijdrage aan de ontwikkeling van Thailand geleverd.

Hoofdstuk 4 benadrukt dat onder bepaalde omstandigheden landbouwmechanisatie een belangrijke bijdrage kan leveren om agrarische en economische groei te bevorderen. Er zijn echter ook gevallen bekend waarbij mechanisatie niet het gewenste effect heeft gehad, of zelfs heeft geleid tot nadelige ontwikkelingen. Er is geen eenduidige, overal toepasbare oplossing voor het mechanisatievraagstuk. Daarom wordt de nadruk in dit hoofdstuk gelegd op het feit dat het voor een zich ontwikkelende economie noodzakelijk is om een mechanisatiebeleid en -strategie te formuleren als een bijdrage aan (landbouw)ontwikkelingsplannen, om zodoende een efficiënt gebruik van de schaarse middelen te bewerkstelligen. De inhoud en omvang van de beleidsbeslissingen en strategieën zullen in hoge mate afhankelijk zijn van het stadium van de agrarische en economische ontwikkeling van het land, en de prioriteiten die het land zich voor zijn verdere ontwikkeling heeft gesteld. Algemene richtlijnen voor de formulering van een strategie op het gebied van de landbouwtechnologie kunnen als volgt worden samengevat: (i) wanneer geschikt land in ruime mate aanwezig is maar arbeid een beperkende factor vormt voor de volledige benutting, is mechanisatie nodig om de produktie te verhogen; (ii) wanneer land een beperkende factor is maar arbeid in ruime mate aanwezig is, is opbrengstverhogende technologie en intensivering van de gewasteelt nodig; (iii) wanneer zowel land als arbeid niet optimaal gebruikt kunnen worden vanwege duidelijke seizoensinvloeden, is mechanisatie nodig om het arbeidstekort in de piekperioden op te heffen; (iv) wanneer er zowel een tekort aan land als arbeid bestaat moet een combinatie van arbeidsbesparende mechanisatie en biologische en chemische technologie worden toegepast; (v) wanneer de kosten van de traditionele krachtbronnen hoog zijn vergeleken met het gebruik van mechanische krachtbronnen is mechanisatie noodzakelijk om de produktiekosten te verlagen; (vi) voor vele ontwikkelingslanden zullen menselijke arbeid en dierlijke trekkracht voorlopig de belangrijkste krachtbronnen blijven, en zal de nodige aandacht moeten worden besteed aan de ontwikkeling en de introduktie van meer efficiënte gereedschappen en werktuigen die in combinatie met deze twee krachtbronnen worden gebruikt.

Hoofdstuk 5 beschrijft de ontwikkeling en de toepassing van MECHMOD, een computermodel dat het mechanisatieproces analyseert en dat behulpzaam kan zijn bij de formulering van mechanisatiebeleid en -strategie. Voornaamste tekortkomingen van bestaande relevante methodieken zijn het gevolg van één of meer van de volgende eigenschappen: (i) de meeste methodieken zijn technisch geïnspireerd en laten de invloed van economische veranderingen buiten beschouwing; (ii) mogelijkheden voor factorsubstitutie met behulp van alternatieve mechanisatievormen zijn niet expliciet in de methodiek opgenomen; (iii) de methodieken voorzien niet in een (snelle) evaluatie van een aantal mogelijke ontwikkelings- of beleidsscenario's; (iv) de modellen beperken zich tot de analyse van de mechanisatie op het niveau van een afzonderlijk landbouwbedrijf in plaats van de landbouwsector in zijn geheel. Door het kiezen van de juiste ontwerpcriteria en het juiste werkingsmechanisme beoogt MECHMOD deze tekortkomingen te elimineren.

MECHMOD is een partieel en statisch model dat geaggregeerd is naar het regionaal niveau, met exogene technische en economische variabelen. De basisstructuur van MECHMOD bestaat uit een lineair programmeringsmodel dat meervoudige gewasteelt nabootst, en waarin de vraag naar menselijke arbeid, dierlijke trekkracht en machines gekwantificeerd is per gewas, bewerking, bewerkingsmethode, en tijdsperiode. De beperkende schaarse middelen zijn grond, menselijke arbeid, en dierlijke trekkracht, maar menselijke arbeid en dierlijke trekkacht kunnen vervangen worden door mechanisatie tegen bepaalde kosten. Vier grondgebruikstypen worden onderscheiden naar teeltmogelijkheid, namelijk drie grondsgebruikstypen voor natte rijstverbouw en één type voor andere gewassen. Arbeid wordt onderverdeeld in gezinsarbeid en ingehuurde arbeid, waarbij mannelijke arbeid van een bepaalde leeftijd beschouwd wordt als een sub-categorie die voor bepaalde werkzaamheden noodzakelijk is. De doelfunktie van MECHMOD maximaliseert het boerengezinsinkomen inclusief de inkomsten uit niet-agrarische werkzaamheden. MECHMOD is geschreven in een hoogwaardige computertaal en is ontwikkeld en toegepast met gebruikmaking van een centrale (main-frame) computer.

Het toetsen van de geldigheid van MECHMOD bestaat uit het vergelijken van de uitkomst van het model met de eigenlijke situatie en een beschouwing over de toepasbaarheid van MECHMOD en zijn tekortkomingen. MECHMOD heeft als sterke eigenschap dat het flexibel is en dat bovendien de werking ervan gemakkelijk te begrijpen is. Onder andere vanwege de beperkingen met betrekking tot informatie over kruiselingse elasticiteiten en prijsverwachtingen van de gewassen bleek het echter niet mogelijk om het gewassenpatroon als een endogene evenwichtsvariabele op te nemen. De belangrijkste eigenschap van MECHMOD is dat het informatie kan verschaffen over veranderingen in het mechanisatieproces als gevolg van mogelijke economische ontwikkelings- en beleidsscenario's.

Hoofdstuk 6 beschrijft de experimenten die met MECHMOD zijn uitgevoerd. Deze experimenten zijn in drie series samengevat. In serie I is de invloed van verschillende waarden van één karakteristieke exogene variabele op de mechanisatieuitrusting bestudeerd. Deze karakteristieke variabelen zijn: arbeidsloon, prijs van dieselolie, aanschaffingskosten van machines, rentevoet, aantal personen werkzaam in de landbouw, en aantal gezinsarbeidskrachten dat met niet-agrarisch werk uitwisselbaar is. In serie II experimenten is het gecombineerde effect van een gelijktijdige verandering in gewasareaal, aantal personen werkzaam in de landbouw, en arbeidsloon op de mechanisatieuitrusting bestudeerd. In serie III experimenten is het gewasareaal tot op zekere hoogte ook beschouwd als een endogene variabele. Het doel van deze serie experimenten is om het effect van de loonkosten op de landbouwproduktie, in het bijzonder op uitbreiding of inkrimping van het areaal, en de invloed hierbij van de mechanisatie en bepaalde beleidsbeslissingen te analyseren.

De bevindingen en conclusies van de studie zijn gepresenteerd in hoofdstuk 7. De resultaten van de experimenten worden op twee manieren besproken. Allereerst wordt de toepasbaarheid van MECHMOD besproken, terwijl daarna de uitkomsten van de experimenten worden geïnterpreteerd voor de formulering van een mechanisatiebeleid en -strategie voor Thailand. MECHMOD bewerkstelligt een snelle evaluatie van de invloed van belangrijke variabelen op de voortgang van de mechanisatie, terwijl het gemakkelijk aangepast kan worden om er andere factoren bij te betrekken. De werking van MECHMOD sluit aan op economische principes en theorieën zoals factorsubstitutie, alternatieve aanwending van produktiefactoren, schaalvergroting, mechanisatie waarbij de machine optimaal benut wordt als tegengesteld aan mechanisatie waarbij de menselijke arbeid optimaal wordt benut, technische vooruitgang, vermogensintensieve mechanisatie als tegengestelde van mechanisatie waarbij de nadruk wordt gelegd op vervanging van de menselijke handelingen en beslissingen, en het onderscheid van karakteristieke stadia tijdens de voortschrijding van de mechanisatie. Door te experimenteren met MECHMOD wordt de invloed van beleidsbeslissingen en economische ontwikkeling op de voortschrijding van de mechanisatie beter begrijpelijk. De studie beveelt aan dat verder onderzoek zich zou moeten richten op de aanpassing van MECHMOD voor gebruik op personal computers.

Een juiste voorspelling over het verloop van de verdere mechanisatie in Thailand hangt nauw samen met een correcte inschatting van de economische ontwikkeling, in het bijzonder die van de landbouwsector. Door structurele veranderingen op de wereldmarkt voor traditionele Thaise agrarische exportprodukten, lijkt het onwaarschijnlijk dat de aantrekkelijke prijzen van de zeventiger jaren zullen terugkeren. Verdere uitbreiding van het areaal is beperkt en afhankelijk van de snelheid van industrialisatie zal marginale landbouwgrond uit produktie worden genomen. Grondbewerking in de centrale regio zal spoedig volledig zijn gemechaniseerd, terwijl zwadmaaiers voor het rijstgewas en oogstmachines voor de suikerrietteelt spoedig hun intrede zullen doen. De verwachting is dat het machinepark in de centrale regio met 5 tot 6 percent per jaar zal toenemen hetgeen lager is dan wat in de zeventiger jaren is gerealiseerd. Dit groeipercentage heeft betrekking op een groter bestaand machinepark terwijl de vervangingsmarkt voor landbouwwerktuigen ook belangrijker wordt voor de producenten van landbouwwerktuigen. Er lijkt daarom weinig aanleiding te zijn voor pessimisme aangaande de toekomstige vraag naar landbouwmachines, ook al omdat de andere regio's in Thailand nog steeds in een minder vergevorderd stadium van mechanisatie verkeren, en daarom een hogere groei in de mechanisatie zullen doormaken.

De overige conclusies en aanbevelingen zijn als volgt samengevat:

(i) Areaaluitbreiding tegen een hoger groeipercentage dan de toename in landbouwberoepsbevolking leidt voornamelijk tot verdere mechanisatie van de grondbewerking. Mechanisatie van de bewerkingen waarbij menselijke handelingen en beslissingen centraal staan zal voornamelijk verder toenemen indien de loonkosten stijgen vergeleken met de kosten van mechanisatie.

(ii) Met uitzondering van de chemische onkruidbestrijding en de mechanisatie van het maaien van het rijstgewas en van de suikerrietoogst, zullen de mechanisatietechnologieën die karakteristiek zijn voor het derde stadium (mechanisatie van de bewerkingen waarbij menselijke handelingen en beslissingen centraal staan) in de komende 5 tot 10 jaar geen beduidende rol spelen in Thailand omdat deze technologieën niet kunnen concurreren met menselijke arbeid zolang de loonkosten niet aanzienlijk zijn gestegen.

(iii) Wanneer het eerste stadium (mechanisatie van de stationaire bewerkingen) en het tweede stadium (de vervanging van louter spierkracht door mechanische kracht voor veldwerkzaamheden) van de mechanisatie zich hebben voltrokken, zal mechanisatie slechts in beperkte mate een oplossing zijn om de toenemende loonkosten of arbeidstekorten op te heffen vanwege de hoge kosten van de meer geavanceerde mechanisatie. Tenzij de prijzen van de landbouwprodukten of de gewasopbrengsten toenemen, zullen de marginale landbouwsystemen niet in staat zijn om de meer geavanceerde en kostbare machines financieel op te brengen, en als gevolg van de stijgende lonen zal land uiteindelijk braak komen te liggen.

(iv) Krediet van de Bank of Agriculture and Agricultural Cooperatives (BAAC krediet) dat geen beperkingen oplegt ten aanzien van het type machine, de oorsprong of het gebruik, en afschaffing van de beperkingen op de invoer van tweedehands lichte tekkers, kan de produktiekosten verlagen zonder dat daarbij overheidssubsidie nodig is. Een beleidsverandering ten aanzien van de invoer van de lichte trekkers moet gepaard gaan met voorlichting over hun gebruik in bevloeide rijstvelden.

(v) Het huidige beleid om BAAC krediet alleen beschikbaar te stellen voor de lokaal gefabriceerde machinerieën is onjuist. Deze technologie heeft in feite dit krediet het minst nodig, en het huidige beleid is nadelig voor de boer op de droge landbouwgrond. De mening dat dergelijk krediet voor de meer geavanceerde machines met hoge capaciteit alleen de grote bedrijven bevoordeelt, is (tenminste in het geval van Thailand) foutief.

(vi) Zwadmaaiers voor het rijstgewas zullen snel worden aanvaard en ingevoerd indien goedkope ontwerpen worden gestimuleerd. Mechanisatie van de suikerrietoogst zal vooruitgang boeken indien de lonen met 5 tot 10 percent toenemen.

(vii) De brandstofprijs is voornamelijk van invloed op mechanische grondbewerking met grote trekkers voor de droge landbouw. Ook om praktische redenen is manipulatie van de brandstofprijs daarom niet aanbevolen als een beleidsinstrument voor de landbouwmechanisatie.

(viii) In tegenstelling tot vele andere ontwikkelingslanden is er in Thailand geen voorkeursbehandeling geweest voor mechanisatie ten koste van werkgelegenheid. In feite hebben verschillende overheidsmaatregelen de voortgang van de mechanisatie benadeeld. Arbeidsbesparende (of te wel arbeidskosten verlagende) technologie zal in toenemende mate belangrijk worden voor de Thaise landbouwsector en de overheid moet de beleidsmaatregelen die de voortgang van de mechanisatie vertragen afschaffen.

(ix) Vanwege de kosten verbonden aan het gebruik van dierlijke trekkracht in vergelijking met mechanische trekkracht in Thailand, zullen trekdieren in toenemende mate worden vervangen door trekkers. Aandacht aan onderzoek en ontwikkeling voor verbeterde dierlijke trekkracht is in het geval van Thailand daarom niet meer gerechtvaardigd.

(x) Toename van de arbeidskosten zal een verschuiving teweegbrengen naar breedwerpig rechtstreeks inzaaien van rijst, en onderzoek en ontwikkeling naar mechanische rijstverplanters is daarom niet gerechtvaardigd.

(xi) Om zowel economische als technische redenen zijn machines, die ontwikkeld zijn voor de omstandigheden in Oostaziatische landen, in het algemeen niet erg geschikt voor de meeste omstandigheden in Thailand.

(xii) De Thaise landbouwwerktuigenindustrie heeft in belangrijke mate succes geboekt met het toepassen van goedkope produktietechnologie maar is nog in een vroeg stadium van haar ontwikkeling. De industrie heeft nog niet de kennis en onderzoekscapaciteit die noodzakelijk zijn om de meer geavanceerde machines (nodig in de nabije toekomst) te ontwikkelen en te fabriceren. De investeringen die gepaard gaan met de ontwikkeling en fabrikage van deze machines zijn waarschijnlijk niet aantrekkelijk voor de individuele Thaise ondernemer. Een permanente en concurrerende landbouwwerktuigenindustrie voor zowel de nationale als de internationale markt zal daarom alleen kunnen ontstaan door samenwerking met buitenlandse bedrijven.

(xiii) Met betrekking tot de fabricage, voorziening en financiering van landbouwwerktuigen, moeten de vrije marktkrachten de overhand hebben om mechanisatie op de meest efficiënte manier tot stand te doen komen. Redelijke bescherming van de nationale werktuigindustrie kan gerechtvaardigd zijn voor bepaalde machinerieën in de aanloopfase om de nationale fabricage op gang te helpen, maar de kosten van deze beschermende maatregelen behoren niet op de boeren te worden verhaald.

(xiv) De rol van de overheid behoort zich te richten op voorziening van de noodzakelijke institutionele en infrastructurele steun, alsmede op een stimulerende invloed op het gebied van onderzoek en ontwikkeling. In verband met het voorafgaande verdient het aanbeveling dat de functie en rol van de Landbouwmechanisatiedivisie van het Ministerie van Landbouw wordt gerationaliseerd en versterkt. De divisie behoort zich te richten op die knelpunten in het landbouwbedrijf die door landbouwmechanisatie kunnen worden opgelost. De divisie moet potentieel geschikte machines het land binnenbrengen voor uitvoerig uitproberen, en eventueel aanpassen aan de Thaise omstandigheden. Wanneer eenmaal een geschikte technologie is gevonden of ontwikkeld, zal de divisie een voortrekkersrol moeten vervullen bij de promotie, voorlichting en adviesverlening, om op die manier de boer te stimuleren om deze technologie toe te passen op zijn bedrijf.

1

INTRODUCTION

1.1 RATIONALE, OBJECTIVES AND SCOPE OF THE STUDY

The role of agricultural mechanization in the development process has been extensively researched and discussed. Of all modern agricultural technologies, mechanization has probably stimulated the most critical debate, since it is often associated with rural unemployment and other adverse developments. 1/ Conflicting views on mechanization have resulted in numerous studies and publications concerning the impact of mechanization on production, employment and social change. 2/ The findings of these studies are not conclusive for general application. In certain economic and agro-ecological conditions, agricultural mechanization has proved to be an important input and contributed significantly to agricultural and economic development. On the other hand, there is also evidence that in a number of cases, agricultural mechanization did not yield the desired impact. Several studies have reported that erroneous government policy on mechanization has had adverse socio-economic impact. 3/ Prior to implementation of mechanization programs and projects, therefore, a sound mechanization strategy must be formulated to ensure that the objectives are achieved with minimal social and economic costs. Equally important is the set of specific policy measures needed to provide incentives for following the proposed strategy.

The need for the formulation of mechanization policies and strategies was already identified in the early 1970s. 4/ Stout and Downing explicitly addressed this matter in 1975 in a paper for a Food and Agriculture Organization (FAO) Expert Meeting. 5/ Their paper discussed specific aspects of agricultural mechanization for which policies were to be established. Subsequently, FAO recognized the importance of mechanization policy and strategy formulation and, in the late 1970s, emphasized the need for institutional development warranting country-specific mechanization policy and strategy formulation. Several studies were undertaken with FAO support, and seminars and workshops were organized to promote mechanization policy and strategy formulation. These FAO promotional efforts were received favorably. However, little work was undertaken to develop a systematic approach to country-specific mechanization strategy formulation and analysis of the effect of the various policy options available. Moreover, FAO recognized that mechanization policy and strategy formulation required expertise difficult to find. [6/]

It is in this context that this research was undertaken. The overall objective of this study is to contribute to the understanding of the role of mechanization technology in a developing economy, with the ultimate objective of improving the lot of the rural community. The specific objective of this study is to develop a rational approach to mechanization policy and strategy formulation, including the development of a model for analyzing the effect of policy and development scenarios on the progress of mechanization. The basic thrust of the study is the common hypothesis that mechanization proceeds as a result of the effort of a farm household to maintain or increase family income. For the development and testing of the model, the Central Region of Thailand serves as a case study. [7/]

1.2 JUSTIFICATION FOR THE STUDY AND AUDIENCE

Studies on farm mechanization have often only evaluated the socio-economic implication of mechanical power technology, but specific recommendations for future mechanization requirements in a specific country, region or agricultural subsector are usually not substantiated. Absence of a comprehensive approach to mechanization strategy formulation has prevented various government programs from achieving the desired objectives, and has often resulted in substantial financial, economic or social costs.

Increased levels of mechanization may be required in developing countries to support agricultural development or even to sustain present levels of production. This is true not only in Thailand, but in newly industrialized countries (NICs) like the Republic of Korea, Malaysia, and the Republic of China. Because of the usually high capital-intensive nature of mechanization and its medium- to long-term impact, it is necessary to design mechanization programs or projects well.[8/] Consequently, reliable projections, efficient strategy formulation, and sound policy decisions will become increasingly important to governments (which may have to provide the institutional support), and to private entrepreneurs involved in the manufacture, import, distribution, and hire services of machinery.

This study is of direct interest to three main groups: (i) planners and decision makers in governments, multilateral and bilateral aid organizations, and development and financing institutions involved in the formulation of mechanization policies, programs and projects; (ii) engineers, economists, social scientists and others concerned with specific aspects of mechanization and development; and (iii) the private sector involved in the importation, manufacture, distribution, operation and maintenance of machinery.

1.3 ORGANIZATION OF THE RESEARCH AND PLAN OF THE BOOK

The research for this study took place in three phases. The first phase of the research focused primarily on literature review, analysis and interpretation of available data concerning agricultural mechanization in Asia. This phase was not country-specific, but provided the broad guidelines and reference framework for the formulation of general mechanization policy and strategy.

The second phase of the research was country-specific and analyzed relevant features of Thai agriculture. It provided details on agricultural mechanization in Thailand, using information from both primary and secondary sources. This phase was an important part of the country-specific mechanization strategy formulation since it provided the basis for future extrapolation.

During the third phase of the research, efforts undertaken concerning mechanization policy and strategy formulation were reviewed. A farm mechanization model was formulated and developed, and experiments were carried out using the Central Region of Thailand as a case study.

The three phases of the research are reflected in the plan of the book. Following the introduction, Chapter 2 contains a review and assessment of the mechanization process in a historical and economic context. The chapter ends with a discussion of the salient developmental issues and features of mechanization. In Chapter 3, the history and status of agricultural mechanization in Thailand are briefly discussed and assessed, including an interpretation of the process of mechanization in Thailand. Much of the factual data and information are presented in Appendix 1. Chapter 4 provides the rationale for mechanization policy and strategy formulation and establishes some general guidelines. Chapter 5 describes the development of MECHMOD, a normative computer model designed to analyze the mechanization process and to support the formulation of mechanization policies and strategies. The chapter establishes the model design criteria and describes its features, rationale, software, construction and application to the Central Region of Thailand. In Chapter 6, experiments conducted to analyze the effect of various development and policy scenarios on the progress of mechanization are discussed. Finally, in Chapter 7, the findings of the research are reviewed and discussed in a two-fold fashion: first, the suitability and application of MECHMOD as a model to support mechanization policy and strategy formulation; and second, the implications of the findings of the experiments and conclusions for the formulation of a mechanization strategy and relevant policies for Thailand.

1.4 DEFINITIONS, TERMINOLOGY AND CONCEPTS

The definitions and terminology to describe agricultural mechanization[9/] or machinery are not standardized on a world-wide basis. A term commonly used in one country may not have the same meaning in another. Whenever applicable and feasible, the terminology adopted by the European Community (EC) countries has been used.[10/] In the case of tractors, the different types used in Thailand have distinct technical features and play a key role in the mechanization process in the country. Their features and usage are described in Section 3.1.

The definition of mechanization is sometimes limited to a description of mechanical power technology only, but in this study the following definitions and concepts have been applied.[11/]

Agricultural mechanization embraces the use of tools, implements and machines for agricultural land development, production, harvesting, and on-farm processing. It includes three main power sources: human, animal, and mechanical. Natural power (wind and water) has been included under mechanical power, since a mechanical device is required to transfer this power into useful work. As a discipline, agricultural mechanization covers the manufacture, distribution, and utilization of tools, implements, and machines. Farm mechanization is a sub-category within the agricultural mechanization discipline addressing the power sources, tools, implements and machinery used on farms for crop production and processing.

Handtool technology is the simplest and most basic level of agricultural mechanization: the use of tools and simple implements powered by human muscle. FAO estimated in 1980 that 25 per cent of the cultivated area in developing countries is farmed using handtool technology only.[12/] In many developing countries, manual labor remains the most important agricultural power source. Even where sophisticated levels of mechanization are commonly used, handtool technology retains importance in agricultural operations.

Draft animal technology refers to implements and machines utilizing animal muscle as the power source. FAO estimated that in 1980 this type of mechanization technology was used on about half of the cultivated area in developing countries. In Thailand, bullocks and water buffalo are still important sources of farm power, but their number is rapidly declining.[13/]

Mechanical power technology is the most sophisticated level of agricultural mechanization. According to FAO estimates, about a quarter of the cultivated land in developing countries is farmed using this technology. Mechanical power technology embraces all agricultural machinery powered by mechanical sources.

Within each level of mechanization technology, degrees of sophistication can be distinguished.[14/] In order to distinguish between mechanization technologies required for developed and developing countries, their capital and know-how requirements, new terminology is introduced such as *intermediate technology* and *selective mechanization*. Gifford and Rijk concluded that such definitions are either inappropriate or have no practical use and recommended the term *appropriate mechanization*.[15/] Appropriateness refers to the level of mechanization and how it is used for a specific situation. It can only be determined after carefully considering the technical, economic and social characteristics of each situation. Generalizations should be avoided concerning the appropriateness of a particular type of mechanization or particular agricultural machine for rural development.[16/]

Agricultural work can further be classified according to various farm activities: land clearing, land development, land preparation, planting, crop husbandry, harvesting, on-farm processing, crop storage, handling and rural transport. Table 1.1 lists farm activities using different levels of mechanization technology. Within each level, examples of different degrees of sophistication for Thailand are presented.[17/]

Table 1.1. Levels of mechanization technology with examples of degrees of sophistication for Thailand.

	Level of Mechanization Technology [a/]		
Farm Activity	Handtool	Draft Animal Power	Mechanical Power
Land Clearing	axe hand saw	elephant for for skidding and loading	tract-type tractor 4-wheel tractor
Land Development	hoe	plow	4-wheel tractor tract-type dozer
Land Preparation	hoe	wooden plow comb harrow steel plow rotary puddler	single-axle tractor power tiller two-axle tractor with various implements
Planting	no tool (broadcasting) planting stick row marker hand-pushed seeder hand-operated transplanter	furrow opener (plow) seed drill	paddy transplanter seed drill
Harvesting	finger-held knife sickle threshing basket pedal thresher	peanut lifter treading (threshing)	power reaper binder treading by tractor power thresher combine harvester
Crop Husbandry	(weeding) hoe hand sprayer water can irrigation scoop	ridger interrow weeder	interrow weeder motor knapsack sprayer tractor boom sprayer spraying with aircraft diesel or electric irrigation pumps
Crop Drying	sun drying		mechanical dryer (fuel)
Crop Storage	bag storage		bulk storage
Processing	pestle and mortar flour grinding stone	sugarcane crusher	single pass rice mill multi-pass rice mill cassava chipper
Handling	carrying sack truck		elevator fork-truck
Rural Transport	porter push cart rickshaw	pack animal bullock cart	motorized rickshaw power tiller with trailer two-axle tractor with trailer farm truck 4 to 10-wheel truck

a/ Within each operation and level of mechanization technology, the degree of sophistication is presented vertically.

The review and analyses made in this study are country-specific (for Thailand). In the main text, therefore, areas are expressed in both hectares and rai (1 hectare equals 6.25 rai). Similarly, power potential is expressed in kilowatt with the horsepower equivalent in brackets, and monetary units are expressed in US dollar and baht (depending on exchange rate fluctuations, 1 dollar equals about 26 baht). Because the Thai audience is unfamiliar with hectares, only rai and baht are used in the appendices because of editorial considerations. The metric ton applies whenever "ton" is used.

NOTES AND REFERENCES TO CHAPTER 1

1/ The statements made in this introduction are further substantiated in subsequent chapters.

2/ Much of the controversy over mechanization at the policy-making and academic levels has emerged from the fact the mechanization is often considered only as the application of mechanical power technology, particularly tractors. There are, however, three main levels of mechanization technology to be considered; handtool technology, draft animal technology, and mechanical power technology; and within each level of technology there are various degrees of sophistication. Each of the technologies has different technical, financial, economic and social consequences which should be considered prior to selection of the technology.

3/ See for example Binswanger 1978. Several other studies have been reviewed and summarized in Rijk 1983.

4/ Shaw 1970; Abercrombie 1972 as quoted in Stout and Downing 1975, pp. 10-11.

5/ Stout and Downing 1975.

6/ Personnel communication with R.C. Gifford, FAO Agricultural Engineering Services, June 1985.

7/ The reasons for choosing Thailand were because the researcher had had exposure to the country's mechanization process since 1975, because mechanization in Thailand has been expanding rapidly, and because Thailand is considered a successful example of technology transfer and development (see further Chapter 3).

8/ Gifford and Rijk 1980, pp. 7-8.

9/ In this study, the term is simply written as *mechanization* since it is used only in relation to agriculture.

10/ Steinmetz 1964. This illustrated dictionary in six languages was prepared for farm machinery and tools used in EC when difficulties were encountered in choosing the appropriate terms for agricultural machinery or tools. As the dictionary covers many of the tools and machinery used in countries outside the EC, including Thailand, its terminology is used in this study whenever practical.

11/ See also Gifford and Rijk 1980, pp. 6-7. *Agricultural implement* and *agricultural equipment* are often used interchangeably to describe what is attached to, pulled behind, pushed, or used by a human, animal, or mechanical power source in order to carry out an agricultural operation. In this context, *agricultural handtools* refer to implements which use human muscle power. *Agricultural machine* normally refers to a mechanical device with a number of moving parts. *Agricultural machinery* is a general term used to describe tractors, implements, equipment, machines and any other device more sophisticated than a handtool as a group.

12/ The FAO estimates for handtool technology, animal draft technology, and mechanical power technology in 1980 are quoted from Gifford and Rijk 1980, p.6.

13/ See Table A1.1.

14/ For example, the small finger-held knife, the sickle made from scrap iron, an improved sickle with hardened blade, and the reaping scythe are all handtools used for the harvest of paddy, but differ substantially in capital cost and performance. Similarly, in Thailand mechanical power technology includes locally made single-axle tractors and power tillers of about 6-9 kW (8-12 hp) and two-axle tractors of different design, capacity (13-59 kW; 18-80 hp), capability and sophication. Rijk 1983, p. 4.

15/ Gifford and Rijk 1980, p. 6.

16/ World Bank 1978, p. 46.

17/ Table 1.1 has been adapted for Thailand from Rijk 1986.

2

REVIEW OF THE AGRICULTURAL MECHANIZATION PROCESS

2.1 MECHANIZATION IN A HISTORICAL CONTEXT

Review of mechanization development conditions and patterns in both developed and developing countries suggests that country-specific situations are seldom unique. Similar economic constraints and opportunities lead to similar patterns of agricultural mechanization in different countries despite variations in agro-climatic, economic and cultural conditions. [1] Many of the mechanization issues discussed by planners, economists and engineers in developing countries were also important issues in the early stages of mechanization in Western Europe and East Asia. [2] Therefore, the following review and analysis of mechanization patterns in the USA, Western Europe and Asia aim to contribute to the better understanding of the topic and to establish common hypotheses for the design of mechanization strategies.

Throughout history, attempts have been made to increase labor efficiency in food production, and the history of agricultural tools and machines is long. [3] Although the history of mechanization is often described in terms of technological development, Slicher van Bath describes the influence of economic conditions on the development of agricultural tools and machines.[4] Research in agricultural development and growth has shown that throughout history, agricultural technology innovation and production have been influenced by land and labor endowment, fluctuations in the level of prices for agricultural products, and changing relative prices (for example, the ratio of grain prices to those of commercial crops, the prices of arable land products to those of dairy produce, and the ratio of prices for produce and capital relative to wages). [5] In general, the process of mechanization conforms to the concept of induced innovation; specifically, the direction of innovations is influenced by changes in relative prices. [6] The development of agricultural tools and machinery has also been influenced by long-run price fluctuations: more tools and machines are invented and sold in periods of high prices for farm produce than in periods of low prices. [7]

Large-scale mechanization, which started in the 19th century in the USA, had limited application in Western European agriculture because the small-sized farms and diversified agriculture impeded the application of the large English and American machines. Initial mechanization in the United States was spurred by the availability of land and an export market in Europe.[8] Although labor input per hectare of cultivated land decreased due to mechanization, the labor released was to a large extent redeployed within the US agriculture sector. In the 1960s and 1970s, a similar agricultural development pattern can be observed for Thailand when attractive world market prices resulted in rapid increase of the cultivated area. Favorable agricultural commodity prices in the 1970s caused agricultural land area to increase by about 4 per cent annually on average. [9] Given the limitations on growth in draft animals and agricultural labor, agricultural machinery sales were high during this period as compared with the first half of the 1980s, when crop prices or yields were generally depressed.

From the early 1940s to the late 1960s, the overriding reason for mechanization in the USA was the rapidly rising industrial wages which drew workers and farmers away from agriculture. [10] During that period the agricultural labor force in the USA declined dramatically as labor was redeployed in non-agricultural sectors of the economy rather than in agriculture itself. The number of workers per farm remained more or less constant, but farm sizes grew rapidly from an average of 167 ha in 1950 to 401 ha in 1978. About ten years later, Europe experienced an equally dramatic post-war change, but farm size did not increase as much as in the USA. [11] A similar phenomenon occurred in the 1980s in the so-called newly industrialized countries (NICs) (the Republic of Korea and the Republic of China), where reduction of agricultural labor input was emphasized over increased agricultural production.

The history of agricultural growth in all countries has indicated that land limitations are not a critical constraint on the growth of agricultural output. However, depending on land and labor endowment, countries rely on different technological strategies in achieving agricultural output growth. For example, Japan emphasized yield raising technology, even though mechanization played only a minor role up to the 1950s (although as early as 1870 machinery was imported for testing and evaluation). Reaper-binders had a significant impact in Japan only after

1967, almost 100 years later than in the USA. Up to 1950, Japanese agriculture could still be categorized as being non-mechanized. Rather than yield increasing technology, the United States emphasized mechanical technology even before 1880. [12] After 1950, the Japanese trend toward mechanization should be seen as a drive to reduce production cost, pushed by rising labor costs, rather than as a continuation of the earlier drive to increase yields. [13] Unlike other Asian countries, Thailand has rapidly expanded its agricultural area rather than applying yield raising inputs. [14] In the period 1960-83, 78 per cent of the growth of agricultural production in Thailand may be explained by planted area expansion and 22 per cent by increase in land productivity. [15]

The agricultural growth pattern of the USA and Thailand conform to the *resource exploitation model*.[16] This model represents situations whereby agricultural production increases as a result of area expansion, rather than increase in land productivity. Under the resource exploitation model type of agricultural development, Hayami and Ruttan include the *staple model*[17] and *vent-for-surplus model*. The staple model explains the rapid growth of commodity production and exports in the newly settled areas of North America. Land was in surplus, while immigration and mechanization provided the farm power. The vent-for-surplus model emerged from Hla Myint's efforts to explain the rapid growth of production and trade in a number of countries during the nineteenth century, particularly the rapid growth of production by peasant producers. His explanation is that surplus land and labor capacity enabled peasant producers (despite confronting relative fixed technical coefficients) to rapidly expand production under the stimulus of new markets created by the reduction of transport costs. His example was the dramatic increase in rice production for export from continental Southeast Asia that occurred in the late nineteenth century in response to the lower transport cost between Southeast Asia and Europe associated with the opening of the Suez Canal and the development of the steamship. [18] A more recent example of the resource exploitation model is the rapid upland expansion into forest areas in the North and Northeast of Thailand facilitated by the development of an extensive road network since the 1960s, initially aimed at supplying the US bases and counteracting insurgency. When labor supply became a constraint, further area expansion was facilitated by mechanization of land preparation, in particular through development of an efficient contractor system. [19]

Following the Japanese pattern, the Republic of Korea and the Republic of China initially emphasized yield increasing technology and later pursued mechanization. More efficient and expanded water control was one of the few ways to improve the productivity of agricultural land in the high man/land ratio economies of East Asia. [20/] Other investments in land development were important prerequisites for successful development of mechanized systems on the small farms of Western Europe and in East Asia. Enlargements of plots, consolidation of fragmented plots, and construction of farm roads to individual plots were all important in facilitating mechanized production systems. [21/] Although the purpose of land consolidation in the Republic of China was initially the improvement of irrigation, drainage and field access, it facilitated at the same time the use of machinery, and mechanization spread rapidly after completion of the schemes. [22/] A similar phenomenon was observed after land consolidation, irrigation and drainage schemes in the Central Plain of Thailand were completed. Completion of the schemes made the use of machines technically more feasible and financially attractive (higher utilization because of multiple cropping), while high crop intensity required more labor (or machines to substitute for labor).

Next to capital investment in land development including irrigation, small threshing machines were among the first mechanical devices to be widely adopted in East Asia, generally much before tractors. Threshing machines were desirable because the *Japonica* varieties grown in East Asia require relatively large threshing power input and, being a stationary machine, their operation requires little skill. Similarly, South and Southeast Asian investment in private pumps has generally had priority over mechanization of other farming operations. [23/] Unlike East Asia, however, land preparation is usually mechanized in Southeast Asia prior to threshing; probably because the high-yielding *Indica* paddy varieties grown in Southeast Asia require little power for threshing compared with land preparation, while low-cost land preparation technology was developed prior to low-cost mechanical threshers. Wheat threshing in India and Pakistan (also a power intensive operation) is usually also mechanized prior to mechanical land preparation and paddy threshing. In Nepal, the pedal thresher and power thresher appear to be more popular with farmers than mechanized land preparation. [24/]

Following the two distinct agricultural growth patterns described above, agricultural technology can be grouped into: (i) *land-saving* technology (all land-productivity increasing technologies: for example improved seed, fertilizer, irrigation and drainage); and (ii) *labor-saving* technology (all labor-productivity increasing technologies: mechanization, herbicides, varieties and cropping techniques which require less labor input). [25/] The concepts of land productivity and labor productivity are closely related, and changes in land productivity as well as labor productivity are often caused by changes in both biological technologies and mechanical technologies.

Analogous to Hick's original definition, technical change is labor-saving if the labor/land ratio decreases, while technical change is land-saving if the labor/land ratio increases.[26] This is further reflected in Figure 2.1. Technical change or innovation is represented by a shift of the isoquant towards the origin. PP represents the labor/land price ratios. I_0 is the original situation, I_1 represents the result of a labor-saving technical change, while I_2 is a result of land-saving technical change. I_n represents a neutral technical change. Mechanical innovations are not always motivated by incentives to save labor (for example, pump irrigation), nor are all biological innovations necessarily motivated to save land (for example, herbicides).

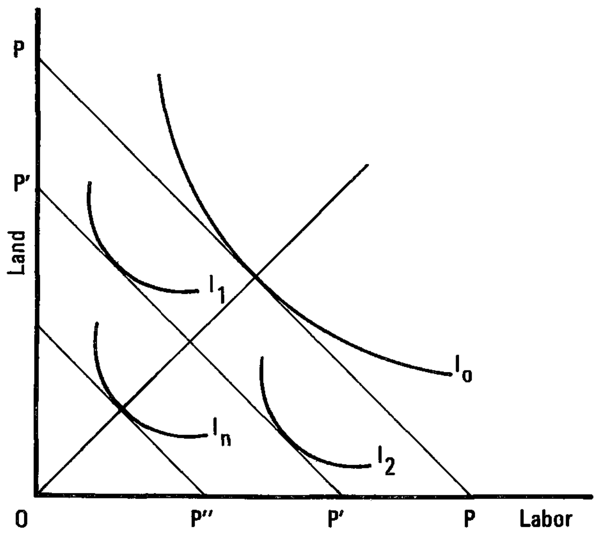


Figure 2.1. Land-saving versus labor-saving technical change. [27]

2.1.1 Distinct Stages in the Mechanization Process

Binswanger considers two distinct stages in the farm mechanization process: mechanization of *power-intensive* operations (for example, land preparation, threshing) precedes the mechanization of *control-intensive* operations (for example, weeding, harvesting). [28]

However, when reviewing the process of labor-saving innovations in agriculture, the following seven distinct stages can be identified in adoptation of labor-saving mechanization technology:

Stage I: Stationary Power Substitution. At this stage, mechanical power is substituted for human power used in stationary operations. Stationary operations are mechanized first because motive power sources required to move across the field are technically more complex and therefore require higher investment. [29/] Typically, operations mechanized at this stage are paddy dehusking, grain (flower) mills, pumping water and threshing grain.

Stage II: Motive Power Substitution. At this stage of mechanization, substitution of mechanical power for muscle power takes place for field operations. It focuses on power-intensive field operations (for example, plowing), and machinery is of relatively simple design, inexpensive, and easy to operate. Mechanization is still straightforward, and crop production practices are usually unchanged. At Stages I and II, mechanization takes advantage of lower costs of new power sources as compared with traditional ones.

Stage III: Human Control Substitution. At this stage, the emphasis is on substitution for the human control functions. Depending on the complexity of the control function and the degree of its mechanization, machinery becomes increasingly complicated and costly. An improved weeding tool is simple, and much of the human control function is still necessary to operate it, but a cotton harvester replaces manual picking completely, and as such is a complex and expensive machine.

Stage IV: Cropping System Adaptation. This stage features the adaptation of the cropping system to the machine. Even with today's electronic technology, it is difficult or costly to mechanize certain human control functions. For example, removing weeds in broadcast crops cannot be done with machines. Subsequently, row seeding and seed drills were introduced to facilitate mechanization of weeding. Many mixed cropping systems disappeared for this reason, even though they are often agronomically more suitable than monocultures. [30/] Monocropping, however, became financially more attractive, since it could be mechanized and therefore gave higher return to labor. Other examples in this stage of the mechanization process include the increase in row distance and its normalization to accommodate heavier and larger machinery without the need to adjust wheel tread when changing to another crop.

Stage V: Farming System Adaptation. The adaptation of the farming system and production environment is effected to facilitate further mechanization. At this stage, the farming system is adapted to increase labor productivity and to benefit from economies of scale. An example of this is the rapid decline of mixed farming systems in Europe since the late 1960s when farmers specialized in dairy, poultry, hog, or crop production. One reason for this was that investment in highly specialized machinery became an important cost of production, and increasingly subject to the benefits of economies of scale. At this stage, crops (or varieties) which are difficult to mechanize may rapidly decrease in area or even totally disappear (for example, flax) if acceptable substitutes become available. New production systems such as minimum- and zero-soil tillage systems may be developed which become technically possible with the introduction of herbicides. At this stage, mechanization also becomes an important justification for investment in land development and land consolidation.[31/]

Stage VI: Plant Adaptation. This stage features the adaptation of the plant and animal to the mechanization system. Mechanization has advanced to a point that further efforts to increase labor productivity include adaptation of the plant or product to a machine rather than the other way around. Breeders increasingly take into account the suitability of new planting material for mechanized production (for example, resistance to lodging and threshability of grain crops, resistance to bruise damage of potatoes and tomatoes for mechanized harvesting, and the suitability of cows for efficient mechanical milking).

Stage VII: Automation of Agricultural Production. This stage is progressing in countries with high labor costs and sophisticated demands on production and quality. Examples are automated feeding of poultry, automated sprinkler irrigation systems activated by soil moisture, and automated and computerized rationing of concentrate feeding for individual dairy cows based on their milk production. [32/]

The above sequence in mechanization is generally identifiable at the farm level, although considering the agricultural sector as a whole the stages may seem less clearly pronounced. For example, in some countries Stage I and Stage II are adopted simultaneously, or Stage III may already be implemented on few large farms or estates while the majority of farmers have not yet adopted Stage II. In Thailand, for example, few large farmers use planting machinery. Economic policies which change relative factor prices may influence the speed or sequence of adoption. Although the mechanization stages have distinct technical features, they come about as a result of changes in relative prices (as explained in Section 2.1). Therefore, analogous to the Hicks-Ahmad

Model of price-induced technical changes,[33] the mechanization stages may be presented as the result of change in factor prices (Figure 2.2).

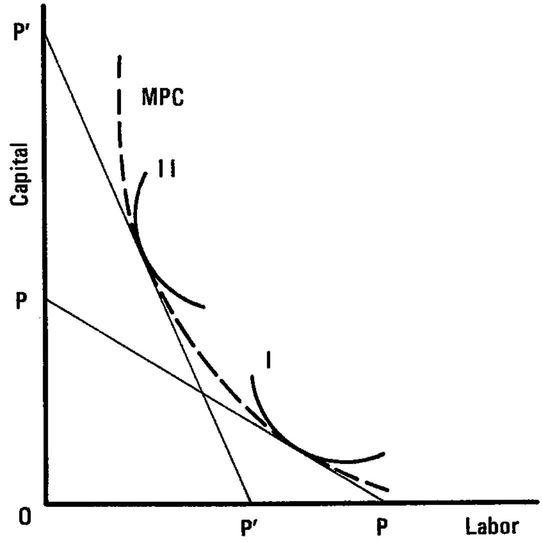


Figure 2.2. Mechanization Possibility Curve (MPC) with examples of staged mechanization development.

In Figure 2.2, the MPC is defined as the set of potential production processes whereby each process in the set is characterized by an isoquant with a relatively low elasticity of substitution. The MPC represents the envelope of all possible mechanization technologies which the farmer may select. Given the relative factor price for capital/labor PP, I is the cost minimizing process which represents Stage I in the mechanization process. If the relative factor price changes to P'P', II is the cost minimizing process and therefore Stage II in mechanization will come about. Thus, in a developing economy, the factor price ratio of capital and labor determines the stage of mechanization technology adoption.

In the discussions on the theory of induced technical and institutional innovation, a difference may be made between technical change and technological change,[34] and between invention and innovation, but the distinction is not always clear or universally accepted.[35] Whether a machine is a new invention, an innovation, an adaptation or an adoption of a technology already adopted in other countries is irrelevant at this juncture because the key issue in their adoption by farmers is the result of a change in relative factor prices.

As a general rule, the more sophisticated mechanization becomes, the higher investments must be made, not only in machinery but in research, land consolidation and development, and plant breeding. In most developing countries in Asia, mechanization has still not advanced beyond Stage II. (Exceptions are the Republic of Korea and the Republic of China, where Stages III and IV have been reached.) Although investments in land development and consolidation projects in some of the more advanced developing countries suggest that Stage V has been initiated, these investments were usually made to increase land productivity to offset land scarcity rather than to enhance mechanization.

2.1.2 Objectives of Mechanization

Several authors list a variety of objectives for mechanization.[36] In a developing economy, the principal objectives of mechanization may be summarized as follows.[37]

(i) *Increase in labor productivity.* The introduction of machinery to substitute for labor is a common phenomenon associated with the release of labor for employment in other sectors of the economy [38] or to facilitate cultivation of a larger area with the same labor force.[39]

(ii) *Increase in land productivity.* The purpose of mechanization here is to produce more from the existing land. Machinery is a complementary input, required to achieve higher land productivity. [40] Labor displacement or replacement is not intended and should be mitigated in labor surplus economies.

(iii) *Decrease in costs of production.* A newly invented or introduced machine may lower production costs or offset increased costs of draft animals or labor. A clear distinction must be made between private costs to the user and economic costs to the society at large. Because of price distortions of the production factors of capital and labor, a gap between these two costs may exist in developing countries.

All three of the above objectives of mechanization have been pursued in Asia. [41] Increase in labor productivity is particularly important in Thailand, where area expansion outpaces agricultural labor force growth. Additional benefits to the user may be associated with a reduction in the drudgery of farm work, greater leisure, or reduction of risk [42/]. These benefits can be quantified but may be difficult to translate into cash. The alleviation of drudgery is relative and subjective, and only has merit if the displaced labor finds more rewarding employment. A white collar worker considers most farm work drudgery but "... in an environment of stagnant or declining wages, loss of employment may relieve landless laborers of drudgery but it clearly increases rather than reduces their suffering". [43/] Mechanization can increase an individual's workload. It can also be hazardous to health or reduces the social pleasures associated with farm work.[44/]

The main reasons for mechanization are therefore economic. Mechanization in Asia, (as in USA and Europe) comes about when the farmer attempts to increase or maintain net income. This is usually the case when the industrial and service sector causes wage rates to rise relative to cost of machines and farmgate prices. [45/] The demand for machines in the USA and Thailand to facilitate cultivation of a larger area when crop prices are high also fits into this pattern.

Crop prices relative to the cost of inputs have an impact on the pace of mechanization. High crop prices increase use of high-yielding technology, which in turn requires more labor input (for fertilizer and pesticide application, better water control and more weeding, harvesting and threshing), or if not available, stimulates mechanization. This is illustrated in Figure 2.3. F(t) is a hypothetical production function under traditional technology whereby OX_1 labor (or farm power) input gives OY_1 output per unit area (yield). F(h) represents a high-yielding technology. High-yielding technology usually requires a certain level of inputs to achieve its potential. Therefore, F(h) initially lies under F(t), meaning that if only OX_1 labor is spent, F(h) will give a lower yield than F(t). [46/] If OX_2 labor is spent, F(h) will yield OY_2 , which is substantially higher than F(t). Although rice prices increased by 50 per cent between 1961 and 1976 in South and Southeast Asia, the increase was far less than in Japan, the Republic of Korea and the Republic of China, which have the highest rice prices in the world (in Japan, the rice price is about eight times the world market price), explaining the higher yields and farm power input.[47/]

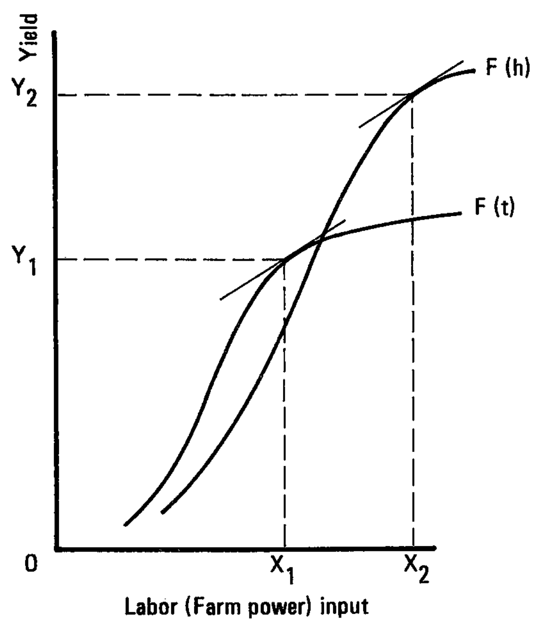


Figure 2.3. Hypothetical production functions indicating a possible effect of high-yielding technology F(h) on labor (farm power) input and output as compared with traditional technology F(t). [48]

2.2 DEVELOPMENTAL ISSUES

At the planning and policy making level for mechanization, various technical and developmental issues emerge. These issues include production and productivity, income, employment, and social change. Other key issues are the choice of mechanization technology in relation to capital cost, dependence on fossil energy, ownership of machinery, manufacturing and supporting institutional and infrastructure arrangements. Conflicting views on mechanization in developing countries have resulted in a large number of studies on the impact of mechanization on agricultural development. [49] These studies are important since they provide for better insight and understanding of the role of agricultural mechanization in development under various social, economic and agro-ecological conditions. The salient issues addressed in these studies relate to the effect of mechanization on crop production, income, employment, social change, technology transfer, and demand for fossil energy. Because these issues usually dominate the discussion, they are discussed in the following sub-sections.

2.2.1 Mechanization and Crop Production

Planners as well as farmers are interested in factual and quantified data on increased output value, lower production cost, and lower risks for mechanized farm operations. Higher valued output may be obtained through higher yields, higher cropping intensities, increases in the cultivated area, reduction of crop losses, and/or changes in the cropping systems to higher valued crops. Binswanger introduced the concept of *net contribution effect* (increased crop production) and *substitution effect* (machinery substituting for labor) in his study on the impact of tractors in South Asia. [50/] It is difficult to isolate the specific economic benefits of mechanization technology because mechanization can be applied with superior production technology such as irrigation, improved seeds, higher application rates of fertilizer, pesticides, labor, and higher levels of management. [51/] A statistical correlation between the level of mechanization and yield does not necessarily indicate a causal relationship and may lead to the incorrect conclusion that mechanization increases production, while in fact the increased production and resulting higher net income may stimulate mechanization investment.[52/]

The net contribution of mechanization to increases in production is obvious if mechanization increases the cultivated land area, especially in areas with farm power shortage but ample land available (as was the case in the 19th century in the USA and during 1960-80 in Thailand). Even in densely populated Asia regions exist where labor shortage limits the area under cultivation. [53/]

Invention of agricultural machinery in Europe from the 16th to the 19th century was directed towards improvement of the plow and seed drills, rather than harvesting machines. Because of the low proportion of yield to seed, the first priority for farmers was to increase yield and improve the seed to yield ratio. This was achieved by deeper plowing and reduced sowing rate with drilling machines. [54/] It is often assumed that deeper soil tillage by tractors increases crop yields. Many sugarcane farmers in Northeast Thailand plow and plant very deeply to attain higher yields and decrease the risk of yield reduction associated with drought. [55/] Deeper soil tillage, however, does not always increase yield and may sometimes even decrease yield. [56/] A Bank for Agriculture and Agricultural Cooperatives (BAAC) survey in Thailand reported that single-axle tractors for paddy land preparation did not show a positive correlation between tractors and yield, and less than 4 per cent of the farmers interviewed attributed yield changes to single-axle tractor use. [57/] A similar finding was reported for an area near Chiang Mai. [58/] However, during another survey in Lampang Province, 66 per cent of tractor owners reported increase in land productivity due to factors attributed to timely and deep plowing. [59/]

It is usually assumed that mechanization contributes to increased cropping intensity because machinery completes operations faster, and the shorter turn-around-time therefore facilitates higher cropping intensity. Historical trends in Japan, the Republic of China, and the Republic of Korea, however, indicate that increased mechanization did not result in an increase of cropping intensity. Rather, intensified land use in East Asia was achieved independent of and prior to the introduction of machinery. Despite high levels of mechanization, the multiple cropping indeces in Japan, the Republic of Korea, and the Republic of China have steadily decreased since the 1960s. [60/] Double cropping in Thailand depends on irrigation investments rather than mechanization. [61/] Various research concludes that, except for water lifting, mere mechanization does not usually result in higher land productivity. [62/] Cross section studies in Bangladesh, Indonesia, the Philippines, and India found no difference in turn-around time between farms using different technologies. [63/] In fact, both Gill (Bangladesh) and Sinaga (Indonesia) found that farmers renting tractors usually planted later than farmers using bullock. [64/] These studies indicate that farmers who hire tractors waste time awaiting service since the density of tractors is low. High densities of tractors can only be achieved when the cost of draft animal and labor rises sufficiently compared with that of power technology. A high tractor density (to achieve short turn-around) is uneconomical in situations where animal and labor costs are low in relation to cost of machines, because the tractors must cover a large area to achieve a low fixed cost on a per unit area basis in order to be competitive with lower animal and labor costs. [65/] High wage rate, high farm machinery density, and low annual utilization rates in Japan support this explanation. An important constraint to faster turn-around may also be water availability and the need to synchronize planting with other farmers to reduce pest and rodent damage. [66/]

The above findings are plausible because mechanical power per se is not an entity of production, especially considering the low degrees of sophistication in developing countries. The fact that a tractor is faster and stronger than a buffalo does not necessarily imply better land preparation or timeliness. [67/] More important than the power source is its management, the design of the implement, and the manner in which the implement is used. In most developing countries, introduction of tractors has not been accompanied by complementary programs to improve soil and crop management techniques resulting in higher yields. Research at the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) suggests that this may also be achieved with bullock power. Research in Pakistan confirmed that using plows instead of tine cultivators can increase yield significantly. [68] Because of the absence of extension and training, the tine cultivator is used more commonly than the more expensive plow, which requires a more highly skilled operator. In some cases, other technologies or systems may compare favorably with mechanization. [69]

Substituting tractors for draft animals can make available crop land previously used to grow fodder. [70] This fact is of little importance in Thailand and most Southeast Asian countries, where draft animals are usually grazed on roadsides, fallow land, forests and wasteland. Binswanger found little support for the hypothesis that use of tractors results in farmers specializing more in livestock production, [71] nor is there evidence of this process in Thailand. It is even claimed that for some countries the introduction of tractors has contributed to decreases in the number of cattle and buffalo, and consequent shortages of livestock products. [72]

Crop losses occur at all stages of food production. [73] Research indicates that, especially at subsistence levels, losses are usually not alarming and may not justify high investment in technology for their prevention. [74] A pilot study on paddy losses conducted in Thailand jointly by FAO and Kasetsart University estimated losses (including harvest losses) at 18 per cent. [75] During 1979-81 FAO assisted the Department of Agricultural Extension (DAE) in assessing harvest losses and evaluating the scope for reduction through harvest machines. Depending on variety and harvesting practice, total harvest loss ranged from 11 to 15 per cent for existing manual harvest methods. Mechanical harvesting systems were evaluated, revealing that the average 9 per cent loss with traditional manual harvesting system could be reduced to 4 per cent using a reaper-binder or 5 percent using the combine harvester. But the practical utilization of the machines in farmers' fields proved difficult for technical reasons. The main problems were related to overly soft fields (farmers wanted to keep water in the field for dry season cropping), broadcasting rather than transplanting seed, clogging machines during wet season harvest, and lodging or short plants causing cutting problems. [76] Despite these demonstration activities, mechanized harvesting of paddy remains insignificant in Thailand.

Mechanical equipment can help reduce crop losses directly, but empirical evidence at the farm level remains scanty. The primary threshing operation may be followed by a secondary gleaning in which most of the losses are recovered. Initial harvest losses may be recovered directly through collection or herding ducks through the harvested fields. Machinery occasionally increases rather than reduces loss. [77/] Due to the more timely operation, however, risk of crop loss due to adverse weather can be reduced through mechanization and can offset the quantitative loss caused by the machine. [78/]

Mechanical dryers are frequently necessary inputs in multi-cropping systems with one harvest in the rainy season when sun drying is impossible or difficult. Numerous efforts have been made to introduce artificial drying to improve crop quality. In the Philippines and Indonesia (the latter with a highly subsidized price for kerosene), programs promoting use of mechanical dryers at the farm level failed because investment and operation cost were prohibitive when compared with the labor cost saved. In addition, the market system may not provide a premium for the farmer when selling superior dried produce. [79/] Similarly, in Thailand, mechanical paddy dryers introduced and demonstrated under the earlier mentioned FAO project attracted little interest. On the other hand, in the Republic of China, where farmers receive about three times the world price for rice and the cost of labor is high relative to Thailand, about 60 per cent of the crop is artificially dried (in particular the second crop harvested in the rainy season). [80/] In the Republic of Korea and Japan, artificial drying is also common because high crop prices and wage rates make it financially attractive.

2.2.2 Mechanization and Farm Family Income

Taking the objectives of mechanization into account (as listed in Sub-section 2.1.2), increased labor and land productivity (or decreased production costs) may increase the farm family income, assuming that the freed labor can be gainfully employed elsewhere and the higher land productivity is not offset by lower farmgate prices or higher input costs. Higher crop yields may increase income, but as discussed in Sub-section 2.2.1, findings remain inconclusive on the potential contribution of mechanization to yield.

An International Rice Research Institute (IRRI) study found that mechanization has the potential to increase farm family income by facilitating additional on-farm earning activities or off-farm employment. [81/] Similar findings have been reported for Thailand. [82/] An important aspect of ownership of a machine is the potential to earn additional income with contract work using excess machine capacity. This phenomenon was important in Western Europe, where small farmers provided machinery hire services to earn additional income. In India, small farmers have been encouraged to own machinery primarily for custom-hire services to supplement their income. [83/] In Pakistan, farmers owning tubewells sell excess water to other farmers. In Thailand tractors and other machinery are also owned by farmers to earn additional income. [84/]

2.2.3 Mechanization and Employment

With the exceptions of the Republic of China, Malaysia, and the Republic of Korea, the agricultural population and labor force continues to increase in Asia. [85/] It is unlikely that new agricultural labor force entrants will be required to achieve increased agricultural production. [86/] Governmental concern for unemployment and underemployment is consequently reflected in development policy, particularly the reluctance to introduce or increase agricultural mechanization. Mechanization decreases labor requirements either by direct displacement or obviating employment opportunities. It is unrealistic, however, to suggest that agricultural production could be increased substantially using only human labor, either because insufficient labor is available in peak agricultural seasons, or production cost is too high due to low returns to labor as compared with its opportunity cost. Studies undertaken on the consequences of agricultural mechanization on employment indicate that it is usually difficult to isolate the relationship between mechanization and employment because higher levels of mechanization are often accompanied by higher levels of other farm inputs and management and/or changes in cropping patterns or production systems, while structural changes may take place simultaneously. [87/] Clear distinctions should be made between: (i) labor input per farm; (ii) labor input per unit of cropped area; (iii) labor input per unit of cultivated area; and (iv) labor input per unit of output. Total man-days of hired labor employed per farm may remain the same or even increase after the introduction of mechanization.

Figure 2.4 shows that the issue is complex and needs to be considered on a case to case basis. The figure represents a holding with cropped area OA_1 and labor input OT_1. The line OT represents a constant labor input/unit area ratio under traditional technology. Similarly, OM' and OM" are lines with constant labor input/unit area ratios under two different levels of mechanization technology. Assume the holding expands its cropped area through land development from A_1 to A_2 (for example, through developing idle land or through higher

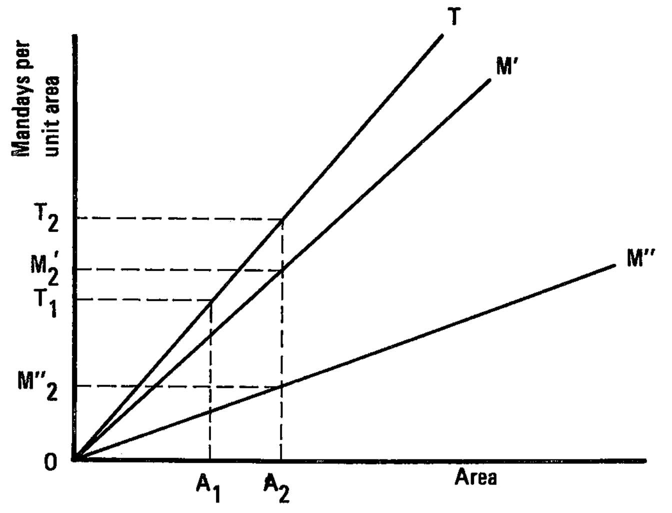


Figure 2.4. Effect of increase in area on employment under traditional technology (T) and different levels of mechanization (M' and M") under conditions of neutral yield effect.

cropping intensity). If cultivation continues in the same traditional manner, then T_1T_2 additional employment is created. If a low level of mechanization is introduced (M'), then $T_1M'_2$ additional employment is created, whereby $T_1M'_2 < T_1T_2$. If a high level of mechanization is used (M"), then total employment is reduced to OM''_2 and M''_2T_1 mandays are lost even though area is expanded. For Thailand, the situation represented by M' is typical. If, however, the holding increased its cropped area through merger of two farms with combined area OA_2 and labor input of OT_2, and not through land development or intensification, in the case of both M' and M" total employment will be reduced.

When including yield, the matter becomes even more complex because the labor input is affected by yield. Higher yielding varieties require more labor input for irrigation, fertilizing, crop care, harvesting and transport than traditional varieties. In Figure 2.4, the labor requirement for the holding was a function of area and mechanization technology only. In Figure 2.5, high-yielding technology is added. The OY lines represent a constant yield per unit area. Y_n (with tangent 1) represents a neutral yield effect on employment. The effect of

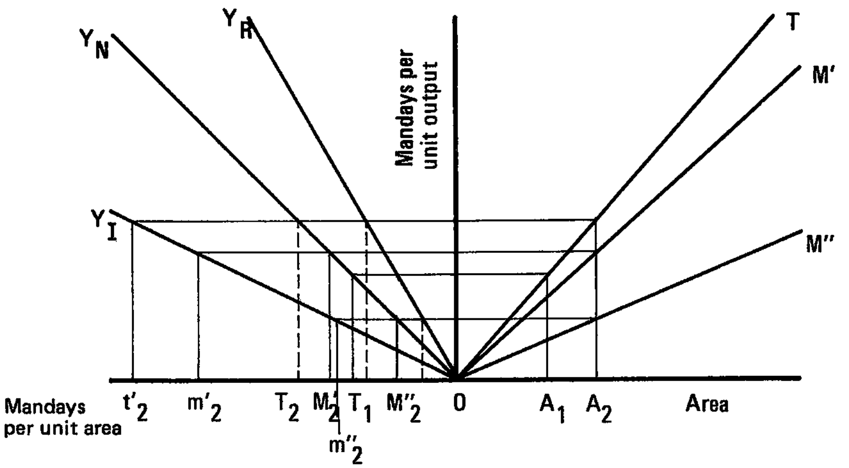


Figure 2.5. Effect of increase in area and yield on employment under traditional technology (T), different levels of mechanization (M' and M") and neutral yield (Y_N), increased yield (Y_I), or reduced yield (Y_R).

increased yield (Y_I) is in case of area expansion to A_2 and under M' mechanization technology an additional $M'_2m'_2$ man-days. Even area expansion to A_2 applying M" mechanization technology and higher yield increases the labor input (albeit marginally) by $T_1m"_2$ as compared with the original holding, whereas in the yield neutral case, labor input is reduced by $M"_2T_1$, even though area is increased. The effect of reduced yield (Y_R) represents extensification, for example, due to farm size increase, and shows the reduction in labor input for different levels of mechanization.

Figure 2.5 also shows that despite mechanization, if high-yielding technology is applied, total labor input can be higher on mechanized than on traditional farms. Assume OA_2 is a traditional farm applying farm power technology T and yield technology Y_n , thereby using OT_2 man-days of labor. Another farmer with the same area OA_2 applies M' mechanization technology and Y_I yield increasing technology. Despite applying a higher level of mechanical technology, he uses more labor on his farm than the traditional farmer, namely Om'_2. This does not imply that mechanization has increased yield or employment opportunity. If the traditional farmer continues to use traditional farm power technology T but switches to yield increasing technology Y_I , then $T_2t'_2$

additional man-days would be created, whereas under the mechanized system $m'_2t'_2$ potential employment opportunity has been lost. The case of the traditional farmer applying high-yielding technology only, thereby increasing his labor input from OT_2 to Ot'_2, conforms to the graph depicted in Figure 2.3.

Studies in Thailand indicate that mechanization did not have a negative effect on farm employment and that labor utilization per farm may increase. [88/] In Pakistan, on the other hand, a World Bank study estimated that tractors reduced job opportunity at about five jobs per tractor. [89/] Mechanization also changes the nature of the demand for rural labor. It is therefore inadequate to consider only the net effect of mechanization on total employment. [90/] Studies show less use of family labor but higher levels of hired labor on mechanized farms. This phenomenon may be related to feudal type social structures, or may be explained as follows: Innovative farmers with sufficient wealth to finance mechanization can also afford to release family members from farm work for other purposes (including education) and to hire labor instead. It is generally believed that mechanization has more impact on the displacement of female labor than on male. In Japan and the Republic of Korea, farm machinery is frequently operated by female workers and machinery training courses are given to female operators. A machine or technology in itself is not gender-specific or biased towards male workers, but country-specific social considerations may produce a bias, as is often the case in traditional farm operations.

The effect of mechanization on employment may be transferred to other geographical regions. [91/] In Thailand, migratory seasonal agricultural labor is commonly employed in the Central Region on cassava, sugarcane, and pineapple plantations, and for the harvest of dry season paddy. During the sugarcane harvest in the 1980-81 season in the Central Region, it was estimated that as many as 115,000 migrant laborers were mobilized, mostly from the Northeast, where during the cane harvest season (December-April) little farm work opportunity exists. [92/]

Although mechanization reduces employment in the farm sector, it creates employment in the industrial and services sector because of the need for the manufacture, sales, service, repair and maintenance of machinery. Several studies indicate that the creation of employment as a result of mechanization is much less than the labor substituted by machinery. Using Philippine data, Merrill estimated that creation of one man-year in this sector for production, sales and servicing of tractors would be accompanied by a reduction in on-farm employment of 20-30 man-years. [93/] In Thailand, it has been estimated that 10,000 full-time jobs are generated for repair and maintenance of agricultural machinery. [94] Recently, it was reported that at least 26,000 persons were employed for production and marketing of agricultural equipment in Thailand, [95] which is obviously much less than the labor substituted.

2.2.4 Mechanization and Social Change

Mechanization and other new technologies can contribute to positive social changes. For example, release of family labor may result in longer and higher school education; successful mechanization facilitates growth in rural income; and the introduction of machines may create interest in modern technology and provide practical training to operate, maintain and repair such machines. Tractors are frequently used in Pakistan and India to provide cheap rural transport and thus improve rural market systems. Similarly, in Thailand the rapid widespread introduction of the locally manufactured farm truck enables farmers to transport their paddy and cassava to farther markets or millers. [96] However, mechanization is also held responsible for adverse social implications in rural areas. [97] According to one study, the most striking change following the introduction of tractors in Pakistan was a 240 per cent increase in average farm size; and an estimated 4.5 farmers (tenants or owners) lost their occupation for each tractor introduced. [98] Similarly, in India and Malaysia it was found that tractors encouraged landowners to take over farming operations, thus converting renter-tenants into laborers. [99] One should be careful, however, to attribute these social changes exclusively to mechanization. New varieties, technologies, and prices may make farming more profitable and induce a trend towards owner-cultivation and land reclamation. [100]

There is no evidence that new agricultural technology in Thailand, including mechanization, has disadvantaged the small and marginal farmer. Larger farmers in more productive areas may be the early innovators of new technology because they have different opportunity costs for land, capital and labor than the small family farmer or subsistence farmer. Little doubt exists, however, that new technology also benefitted the small and marginal farmer in Thailand. Tractors provided the farm power required to expand crop areas rapidly when world market prices for food crops were very favorable, while the increased area provided additional employment for crop care and harvesting. Furthermore, about 90 per cent of Thai farm families are self-employed, and 73 per cent of the holdings are farmed by owner-operators rather than tenants. Cultivation of land mainly with hired labor is not very common except for large sugarcane and pineapple farms. [101/] There is therefore no evidence that tenants were evicted or that land concentration occurred because of mechanization.

2.2.5 Transfer of Mechanization Technology

In the 1960s and early 1970s, an increasing awareness emerged that the simple transfer of sophisticated Western technology had not benefitted the rural masses in developing countries. This awareness resulted in a search for new forms of technological development. A special kind of technology was considered necessary for developing countries, and terms such as *alternative technology*, *appropriate technology*, *intermediate technology*, and *light capital technology* emerged. These alternative technology movements emerged due to two basic reasons: [102/] (i) technology change was essential for the aims of developing countries; and (ii) much of the new technology introduced into developing countries failed to cause the desired economic and social change. As a result, institutions for alternative technology have been established and considerable efforts and funds have been allocated for research in alternative technology, but a significant contribution of the alternative technology movement to economic and social development has yet to materialize. In retrospect, the movement was probably too politically inspired, often overlooking economic and technical realities. [103/] Experiences with alternative technology suggests that reorientation and proper education of engineers involved in technology transfer is more relevant than a new type of technology.

2.2.6 Mechanization and Fossil Energy Consumption

The majority of developing countries import most of their commercial fuel requirements. Particularly after the energy crisis in the 1970s, the governments have been concerned with fuel shortages and rising prices. This concern is reflected by efforts to conserve energy and to develop alternative technology and energy sources. It is occasionally suggested that the agricultural sector should reduce fossil-energy consumption by putting more emphasis on draft animal technology rather than on fuel consuming mechanical power technology. However, the share of commercial energy consumption by the agricultural sector in the developing countries is low and the scope for fossil fuel conservation is limited. [104/] In 1984, Thai agriculture accounted for 10 per cent of total petroleum consumption at a total cost of $277 million (7.2 billion baht), 94 per cent in the form of diesel oil. [105/] An Asian Development Bank (ADB) study concluded that more (not less) energy should be expended in the agricultural sectors in most of its developing member countries, particularly in those with extreme land shortages relative to labor and population. [106/]

Statistics on energy are usually based on commercial energy consumption and hence underestimate total energy consumption in less developed countries. Consumption of non-commercial energy is more difficult to analyze because energy flow data in the developing countries is often fragmentary. Makhijani and Poole found that the total amount of energy (including human and animal) consumed in farming is surprisingly large, and calculated that rice production in India requires 250 per cent per ton more than the amount of energy used in Japan and the USA. [107/] Thai agriculture, however, appears energy efficient. Analysis of energy inputs and outputs of rice, maize and sugarcane showed that energy yield ratios (energy output divided by energy input, excluding solar energy) were three to five times higher in Thailand than in the USA. [108/] This may be explained by the fact that Thai farmers are low-input oriented, and low-input extensive farming systems are usually more efficient in terms of capital and labor input. [109/]

Nevertheless, some scope exists for slowing the growth in fossil fuel consumption through specific consumers in the agricultural sector. For example, better operation, repair and maintenance of farm machinery prolong its life span, and as such reduce the energy required for its manufacture and operation. The promotion of minimum tillage, whenever feasible, may reduce the need for fuel-consuming power. Conservation of agricultural waste into energy has been traditionally practiced in sugar and rice mills in Thailand, often utilizing old fashioned low cost technology (for example, locomotive steam engines fired by rice husk or baggase). In Thailand, the use of baggase and paddy husk in sugar and rice mills increased from 1979 to 1984 more than 500 per cent. In terms of crude oil equivalent, these by-product wastes accounted for 7 per cent (in 1970) and 18 per cent (in 1984) of Thai petroleum products consumption. [110/] The required technologies are readily available, but many of these technologies have become sophisticated and are subject to appreciable economies of scale and are therefore more appropriate to larger scale operations than to individual farmers or small rice mills.

2.3 REMARKS AND CONCLUSIONS

The social and economic consequences of mechanization have stirred much debate, and a large number of studies have been undertaken to assess the impact of mechanization on production, productivity, and socio-economic consequences, particularly employment. The discussion is not new to developing countries and also emerged during the early stages of mechanization in the highly mechanized countries. [111]

Governmental concern about unemployment and underemployment is understandable. Frequently, however, the agricultural sector is considered a labor absorber of the last resort. It is not unusual for development plans to project a minimum employment increase in the industrial and services sectors with the balance of the increased labor force conveniently absorbed by the agricultural sector, regardless of agriculture's requirements or the effect on labor productivity. [112] In Thailand, rural unemployment has not been a serious issue in the mechanization discussion because during the 1960s and 1970s, growth in cultivated areas outstripped population growth and agricultural labor force – a unique phenomenon in Asia. However, there is a physical limit to the output per unit of cultivated land with any given technology. Significant agricultural increases in countries with land shortage are unlikely to occur by increasing labor input alone. When new or improved technologies and production systems are adopted as well, however, increases are likely. With regard to the socio-economic issues, the costs per unit of production must also be considered. [113] Economic criteria should not be overruled by a "make-work" attitude; a country may be able to afford this in the short term, but such policies always have longer term adverse implications, including higher production costs, lower productivity, and delay in replacing obsolete production processes with more efficient ones. [114]

Many of the employment and other social issues associated with agricultural mechanization can be avoided if operations in need of mechanization are carefully identified and the technology is properly priced. A recent World Bank study reviewed the experience with agricultural mechanization in developing countries and stressed the need to eliminate bias towards mechanization in order to bring mechanization policy in line with development objectives. The principal recommendations of this study were (i) to cause exchange rates and interest rates for agricultural machinery to reflect market conditions; (ii) to reduce inconsistencies in policies governing the import of machines, spare parts, and implements; (iii) to reduce or eliminate bias against certain technology, particularly against draft animals; (iv) to reduce bias against small-scale firms; and (v) to implement industrial policies conducive to local adaptation, production and maintenance of machines. [115] This will require, however, development of an efficient mechanization strategy supported by proper policies. For most situations, a technically and socio-economically sound mechanization technology system is available. The mechanization process of Thailand is an excellent example in support of this view. The pattern of agricultural growth and the relatively high cost of capital have prevented the "evils of mechanization" from occurring in Thailand. [116] Thailand's local machinery industry is highly labor intensive and flexible and quickly responds to changing demand.

Many of the issues discussed in association with mechanization may be discounted in monetary terms and are non-issues when viewed in an economic context. It is of little relevance whether or not combine harvesters increase or decrease harvest losses as long as the machines increase net benefit. A harvester can no doubt be designed that reduces loss compared with existing methods or machines, but if that design is twice as expensive farmers will not use it. The loss percentage will be considered part of the operational costs of the existing machine. Scope for increasing cropping intensity as a result of mechanization is irrelevant in an economy where the price received for the increased output does not meet the cost of production (for example, in East Asia, where cost of labor has increased), or in a surplus situation where the increased output is not matched by demand. Similarly, a full employment policy may look good in a development plan, but has little meaning if the marginal labor productivity is close to zero. [117]

During the 1970s, pessimism concerning the ability of developing countries to feed their people in the future predominated. [118] Inefficiencies, particularly in the marketing systems, provided examples of high food losses. The matter attracted the attention of the international aid community which, in turn, meant increased budgets to reduce post-harvest loss. Since then, in many cases, post-harvest loss reduction has become an end in itself rather than a cost factor in the production and marketing system. It may not be economical or financially attractive to prevent a small loss, and it may be more effective to use a bit more fertilizer to compensate for the grain lost.

Development is accompanied by social change and may even cause social disruption for certain groups in the effort to achieve in a few years what took a generation in the industrialized world. The discussion should, therefore, not only focus on those affected by mechanization, but rather on whether those affected can be offered a better alternative. For example, for physical farm work, female labor virtually disappeared in most of the industrialized countries, but the displaced women did not express dissatisfaction, since other opportunities became available and living standards improved. Instead of highlighting the fact that mechanical rice transplanters are operated by males, for example, it may be more to the point to assume that women in developing countries prefer a decently paid job in a garment factory to working up to their ankles in mud. The discussion should focus on whether the garment factory is a realistic alternative for earning an income and whether the economic cost of the rice transplanter is balanced by the opportunity cost of female labor.

With reference to mechanization policy and strategy formulation, two crucial conclusions emerge in this chapter:

(i) The agricultural mechanization process is the result of induced innovation and is governed by changing relative prices for agricultural produce, cost of capital investment, and wage rates. The driving force for this process is the farmer's effort to increase or maintain income.

(ii) The net effects of mechanization on production and the society highly depend on the agricultural production system and socio-economic situation of the particular locality where mechanization is being applied. These effects must therefore be assessed on a case by case basis for a particular country, region, program or project.

NOTES AND REFERENCES TO CHAPTER 2

1/ See for example Meij 1960, Binswanger 1982, Herdt 1982.

2/ Anonymous 1954. The report deals with mechanization of small farms in Europe after World War II and includes topics similar to those in developing countries (such as need for land consolidation, improved draft animal technology, intensification of the small farm through mechanization, timeliness of operations and reduction of risk, and the need for training and extension). See also various chapters in Meij 1960 (particularly Chapter 2 by Mitchell, "Conditions for Mechanization in Europe", pp. 37-62). Mitchell questions the justification for mechanization given its effect on employment (p. 38), the advancement of mechanization ("Against the horse [as compared with the ox] it was held that its weight and the speed with which it pulled the plough through the ground would in the end have disastrous effects on tilth and soil structure", p. 40), mechanization as a means of land and labor saving, need for land consolidation (redistribution), the need and justification for small tractors, second-hand or new equipment, forms of machinery ownership, and contract services.

3/ Agricultural machinery existed in the early Chinese and Babylonian cultures for the drilling of seeds from 2000 BC.

4/ Slicher van Bath 1960.

5/ See for example Binswanger 1982, Herdt 1982, Heady 1960.

6/ This theory was first developed by Hicks 1932. For a more recent interpretation of agricultural innovation, see Binswanger, Ruttan, et al 1978.

7/ Slicher van Bath 1960, p. 4.

8/ Slicher van Bath 1960, p. 16. Agricultural diversification occurred in Western Europe only when cereals were imported in large quantities. The Baltic provinces had long been the granaries of Western Europe, but in the nineteenth century grain was imported from the Ukraine and the USA.

9/ Office of Agricultural Economics, *Agricultural Statistics of Thailand*, various issues.

10/ See for details Slicher van Bath 1960, Heady 1960.

11/ Binswanger 1982.

12/ Herdt 1982. For a comprehensive analysis of the different agricultural growth paths in the USA and Japan, see Hayami and Ruttan 1985, Part III. Publicly funded biological research was initiated in the 1870s in the United States, but it led to substantial yield increases only after 1930, when uncultivated land was no longer available and a high level of mechanization had been achieved.

13/ Tsuchiya 1972.

14/ Crop land area more than doubled during 1960-1980 (Rijk and van der Meer 1984). Average fertilizer nutrient consumption per unit of arable land and land under permanent crops during 1969-71 was 8 kg/ha for Thailand versus 21 kg/ha for Asia (excluding Japan). For 1979-81, these figures were 17 kg/ha for Thailand and 61 kg/ha for Asia (excluding Japan). For Thailand, 53 per cent of the fertilizer was applied to paddy (average 17 kg/ha for 1979-81 as compared with 34 kg/ha for the Philippines and 104 kg/ha for Malaysia) and 12 per cent to vegetables (van Ardenne 1983, Tables 7, 9, 11).

15/ Corsel 1986.

16/ The *resource exploitation model* is further described in Hayami and Ruttan 1985, pp. 41-45.

17/ The *staple model* was developed by Innis. See further Hayami and Ruttan 1985, p. 43.

18/ The *vent-for-surplus* model is further discussed under the *resource exploitation model* in Hayami and Ruttan 1985, pp. 42-45.

19/ On the system of contract operators in Thailand, see Chancellor 1970.

20/ Herdt 1982. See for a summary review Rijk 1983, pp. 8-14.

21/ Barker 1960.

22/ Hung 1969, pp. 101-121.

23/ In some cases, however, use of tractors for land preparation and threshing machines have preceded investments in water control as, for example, in Central Luzon, Philippines, and the Central Plain in Thailand. This may be explained by the fact that the farms in these areas are relatively large and investments in water control are uneconomical or technically infeasible.

24/ Rijk 1983. An exception to this hypothesis appears to be Central Luzon in the Philippines, where large power threshers have been used since before the 1950s. However, these threshers were introduced on big estates to facilitate easier control and checking of the share to laborers. (Personal communication with Bart Duff, IRRI.)

25/ Hayami and Ruttan 1985, p. 75.

26/ After Hicks 1932, as discussed in Hayami and Ruttan 1985, pp. 74-75.

27/ After Blaug 1963, as discussed in Sahal 1981, pp. 16-22. By its definition, an isoquant (or iso-product curve) traces out the combinations of any two or more inputs which give the same level of output. These combinations must be efficient (i.e., any point on the isoquant curve shows the minimum quantities of inputs needed to produce the given output). Isoquants are typically drawn as convex to the origin because of assumed substitutability of inputs. If inputs are complementary, the isoquant will be a perfect "L" shape. If substitutes are perfect, the isoquant will be a straight line.

28/ Binswanger 1982, p. 19. For other distinctions see also Nowacki 1968, who considered five stages in the agricultural mechanization process, namely: (i) primitive labor stage (zero mechanization); (ii) elementary mechanization stage using only manually operated tools; (iii) animal traction and initial motorization stage using a combination of animal and mechanical power; (iv) motorization stage using principally mechanical power; and (v) automation stage. Nowacki focuses on the use and type of machine rather than the production system. Curfs 1976, pp. 7-8 refers to Smerdon (1971) who visualizes three stages through which mechanization in developing countries progressess, namely, (i) Start of Agricultural Mechanization (Stage 1), (ii) Progress in Mechanization (Stage 2), and (iii) Towards Total Mechanization (Stage 3). Such distinction is, however, not a characteristic of agricultural mechanization and applies to any technological development.

29/ Hayami and Ruttan 1985, p. 78.

30/ Beets 1982, pp. 9-10.

31/ For example, a fully-mechanized farming system requires completely clean land clearing; fully mechanized paddy farming requires a well-developed irrigation and drainage system; and big and heavy machines require better access to plots, wide and strong rural roads and bridges, and large plots to obtain high operation efficiency. The higher the level of mechanization technology applied, the bigger investment has to be made in land clearing, field layout, drainage and access roads.

32/ Research experiments are ongoing in controlled traffic farming with automatic guidance systems. Such a system will relieve the operator of the monotonous task of making steering corrections.

33/ Syed 1966, pp. 344-357. See for summarized discussion Binswanger, Ruttan, et al 1978, pp. 26-29.

34/ Binswanger, Ruttan, et al 1978, pp. 18-19.

35/ For example, see Hayami and Ruttan 1971, pp. 54-56; Kindleberger and Herrick 1977, pp. 132-134.

36/ For example, Curfs list 13 specific objectives as a summary from 10 authors. These refer to area expansion, labor input reduction, increased total employment, conversion of animal power feed production areas to human food production, increased output per worker, increased land productivity, improved timing of operations, more intensive farming systems, reduced drudgery, improved dignity of the farmer, improved water supply, reduced wastage and losses, improved quality of produce, and improved marketing systems (Curfs 1976, pp. 3-4).

37/ Rijk 1983, p. 15. Sometimes combinations of the three effects occur simultaneously, even if the emphasis is on increasing land productivity.

38/ For example, in the industrial and services sectors in Europe, Japan, the Republic of Korea and the Republic of China. In the latter three, a deliberate mechanization policy was adopted to cope with the demand for labor in these sectors.

39/ USA in the 19th century, Australia, Northeast Thailand in the 1960s and 1970s. In the case of Malaysia, labor has migrated to urban areas, causing land to be left idle and decreasing farm production. Mechanization may reverse this trend and bring production back to its potential level.

40/ For example, by introducing pumpsets, or mechanized land preparation and harvest to reduce the time land is non-productive.

41/ For example, the Republic of Korea introduced mechanization in order to increase labor productivity, thereby both improving rural incomes and making labor available for industrial development (Gifford and Rijk 1980, pp. 46-52). At present, the Republic of China and Malaysia are facing an acute shortage of rural labor caused by more attractive labor opportunities outside the agricultural sector, and mechanization is required to maintain agricultural production. Indonesia has ample surplus of agricultural labor in Java, and therefore, requires mechanization technologies to increase land productivity. A power shortage may exist on its outer islands, however, especially in transmigration areas, and mechanization which increases labor and land productivity is required (Rijk 1979). In Bangladesh and Nepal, pumpsets are introduced to increase land productivity through higher yields and cropping intensity, thus providing additional employment.

42/ For example, crop failure, buffalo disease or buffalo theft.

43/ Binswanger 1978, p. 75.

44/ Moens, van Loon and Hoftijzer 1974; Dibbits 1975, p. 56. These two studies confirm that the operation of single-axle tractors places a heavy workload on the operator and may jeopardize his health. In Thailand, farmers complained about the strain of operating single-axle tractors, including arm pain and shoulder pain caused by vibration (personal discussion in Northern Thailand 1975). Also, at early stages of mechanization in the Netherlands, physical workload for the individual could reach the limit (for example, the bagging of the crop on combine harvesters or potato diggers), sometimes causing injury. Hazardous noise levels for machine operators have also been a cause for concern but only became a design criterion during the last 15 years. The mental workload of machine operators can be high. With the disappearance of gangs of farm workers, the machine operator often has a lonely and isolated job, and this is perceived as having removed much of the pleasure from farming (Wildenbeest 1987, pp. 6-10).

45/ In the USA between 1910 and 1956, the cost index of hired labor increased from 96 to 536. The price index for farm machinery increased from 100 to 330 over the same period, making machinery more competitive (Heady 1969, p. 69). In Thailand, a similar phenomenon is taking place (Figure 3.1). Between 1961 and 1976, the wage rate increased by about 700 per cent in Japan and by 1700 per cent in Korea. In Burma, the increase was only 40 per cent and in the Philippines 220 per cent over a comparable period. In 1978, wage rates in East Asia already exceeded US$8.00 per day compared with around US$1.00 per day in the rest of Asia, explaining the difference in use of mechanical technology (Herdt 1982).

46/ This is not necessarily always the case. Some high yielding varieties give higher yield than traditional varieties even without fertilizer. However, in the long run this may not be the case because of soil depletion. Also, some new varieties may be less prone to moisture stress and certain pests (Lipton and Longhurst 1985, Chapters 1 and 2).

47/ Herdt 1982.

48/ After Mellor 1963 as discussed in Mellor 1966, pp. 171-173.

49/ For a summary review, see Rijk 1983.

50/ Binswanger 1978, Chapter II.

51/ This is further demonstrated in Figure 2.5, Sub-section 2.2.3.

52/ For example: Inukai 1970, pp. 453-473. His area of study generally has better soil quality compared with the less mechanized areas. See also: Wicks and Buengsung 1984, p. 14.

53/ Rijk 1979. In his study, farm power shortage is observed as a constraint on the outer islands of Indonesia and has an adverse effect on the performance of transmigration projects. In Malaysia, the migration of rural labor to more attractive work results in irrigated land being left idle or not optimally utilized. In Pakistan and Thailand, tractors facilitate the rapid expansion of upland crop cultivation.

54/ Harvesting machines were already known in the third century AD but not further developed (Slicher van Bath 1960, p. 10).

55/ Personal observation and discussion, 1980-81, Northeast Thailand.

56/ Curfs and Moomaw 1971, p. 55. Curfs and Moomaw reported that deep tillage tests showed 5-10 per cent increase in paddy yield in 60 per cent of the cases, but many instances were identified with decreased production, and no effect was observed in the remainder. Raanan reported that cleared upland fields from jungle in Newalpur Valley (Nepal) produced for the first three years much lower yields when deeply plowed (30-35 cm) than those plowed with local plows (10-12 cm), even when fertilizers were used. The difference in maize yield was as high as 30 per cent (Raanan undated, p. 71).

57/ BAAC 1986a, p. 9.

58/ Wicks and Buengsung 1984, p. 14.

59/ Khan 1984b, pp. 30-31. However, Khan's study did not differentiate between two-axle tractors for upland preparation and single-axle tractors for paddy land preparation.

60/ Herdt 1982. Planting of the second grain crop on ricefields was an ancient practice in Japan in limited areas where soil and weather conditions permitted this practice. By 1950 (before the mechanization of Japanese agriculture) the multiple cropping index stood at 124. In 1956, the index peaked at 137, but thereafter declined gradually to 103 by the late 1970s despite rapid mechanization. In the Republic of China, the multiple cropping index was 176 in 1952, increased to its peak level of 189 in 1965, and thereafter declined steadily to the level of 142 in 1985 (Provincial Department of Agriculture and Forestry [PDAF] 1986). In the Republic of Korea, the multiple cropping index has shown no trend since 1956, fluctuating between 135 and 145.

61/ BAAC July 1986a. The study covered three provinces (Chiengrai, Khon Kaen, Prachinburi). The ADB-financed credit project assumed that the main benefit from the use of power tillers lay in extending the area planted to rice in the dry season, but this assumption proved invalid (p. 10). See also Wicks and Buengsung 1984, p. 14.

62/ See for example Chancellor and Singh 1974, p. 18. Chancellor and Singh investigated results on research stations and in farmers' fields in West Malaysia, Pakistan and India. They found little evidence to support the view that substitution of mechanical power for animal power gave significant increases in yields. Binswanger analyzed numerous studies on the impact of tractorization in India, Pakistan and Nepal and could find no evidence that tractors were responsible for significant increases in cropping intensity, yields or gross returns (Binswanger 1978). IRRI research results on five different soil tillage treatments did not support the hypothesis that mechanized land preparation increased rice yields, and the study indicated that farmers agree with this finding (Duff 1977). Another IRRI study found that in Central Luzon (in 90 per cent of the cases), yields were not higher on mechanized farms when adjusted for fertilizer use. A 1979-80 survey in Central Luzon concluded that irrigated farms with carabao land preparation and manual threshing had cropping intensities just as high as farms that used tractors and mechanized threshing (200 per cent) (Jayasuriya, Te, and Herdt 1982). A study on mechanical thresher adoption in Iloilo, Philippines, showed that thresher use had little influence on cropping patterns and intensity, although the full effects may not have been felt at the time of the study (Juarez and Duff 1979). A study on Bangladesh analyzed data from 4,000 plots and concluded that the effect of tractor cultivation on yields or cropping intensity is insignificant, but that other factors such as land height, flooding, and irrigation tend to demonstrate a significant relationship (Gill 1981). Studies in South Sulawesi and West Java, Indonesia, concluded that even in sparsely populated areas (South Sulawesi), almost no change occurred in cropping intensity on either rainfed or irrigated farms after the introduction of tractors for land preparation (Sinaga 1981a, Sinaga 1981b). A study on the impact of combine harvesters in India concludes that there is no social gain due to their use in terms of increase in cropping intensity or farm productivity (Laxminarayan, et al 1981).

63/ For a summary discussion on this matter, see Duff 1985, pp. 62-67.

64/ See Gill 1981, Sinaga 1981a, Sinaga 1981b.

65/ Jayasuriya, et al 1982.

66/ Duff 1985, p. 67.

67/ Binswanger 1978, p. 40.

68/ Personal communication with Lawrence Clark, Agrisystems.

69/ Hogue and Akanda 1980, p. 22. The shortest turn-around time is obtained through zero tillage. Hogue and Akanda found no significant difference in Bangladesh in grain yield of irrigated rice between zero tillage (one day turn-around time), minimum tillage (four-day turn-around time), and high intensity tillage (15-day turn-around time) with tillage cost of respectively $14.02, $60.93, and $71.63 per hectare, not including potential loss of growing period. Soya bean planted after irrigated rice produced higher yields in the Jatilahur irrigated area of Indonesia with zero tillage (Ismail, et al 1978).

70/ For example, in the USA in 1933, 23.9 million ha of land was required to feed horses and mules. This area was reduced to 3.6 million ha in 1956 (Heady 1960, Table 1).

71/ Binswanger 1978.

72/ See for example ADB 1981, Main Report, p. 17; and UNDP/FAO 1981.

73/ According to the FAO Programme for the Prevention of Food Losses, a post-harvest food loss in quantity or quality is defined as an economically avoidable decrease in food availability caused by the intervention of nature, pests or man himself. Post-harvest losses may be caused by micro-organisms, insects, rodents, harvesting and handling operations, or processing techniques. A variety of types of losses are to be considered: weight loss, nutritional loss, quality loss, and monetary loss.

74/ Greely 1980. His study on post-harvest losses in Bangladesh found that food losses, even in the wet season, are low in farm-level post-harvest operations with total physical losses below 7 per cent. Further, evidence indicated that technical changes occurring in threshing and milling actually increased food losses. The survey of Boxall and Gillett in Eastern Nepal demonstrated that farm level storage losses were approximately 5 per cent (much lower than previously reported [10-30 per cent]). Consequenly, tentative proposals for a program to reduce losses were considered unjustified (Boxall and Gillett 1982). Manandhar and Rijk surveyed farm storage at a number of locations in Nepal and found that storage techniques were generally very adequate but that the maize crop harvested in the hills during the rainy season suffered from serious insect attacks (Manandhar and Rijk 1980).

75/ DAE 1982.

76/ DAE 1982.

77/ Wanders reported losses with combine harvesters in Surinam of 3-18 per cent (Wanders 1969, pp. 55-57). Total grain losses with combine harvesting in Senegal were, for two varieties, 19 and 30 per cent, respectively (FAO 1976, p. 89). Combine harvesters in Indonesia (Sukhamandi seed farm) gave field losses of 25-30 per cent, especially at the cutter-bar (personal observation and communications with Wanders 1988). In Malaysia, combine harvester losses in some cases were so high that farmers did not have to replant paddy, but let the lost grain germinate to obtain the next crop (personal observation and discussion). In wet western European climates, mechanized harvesting may increase direct loss, but this loss is accepted, since manual harvest is no longer possible due to high labor costs and risk of indirect loss is high.

78/ Mechanical power threshers were widely adopted in the early 1970s in India after bad weather caused serious wheat harvest losses, since traditional methods could no longer accomplish the threshing to keep up with the increased production caused by the Green Revolution.

79/ Donovan and Rijk 1981. A low cost improved cardamom dryer introduced in Nepal was not accepted since the higher investment and cost of operation were not offset by a higher farmgate price for the farmer.

80/ Personal communication with Dr. Kwang-won Lee, Senior Agricultural Machinery Specialist, Council of Agriculture Executive Yuan, the Republic of China (April 1986).

81/ Duff 1985, pp. 71-73.

82/ BAAC 1986a, pp. 1-3.

83/ Rijk 1983, pp. 42-43.

84/ Personal interviews, May-June 1987; see also BAAC 1986a, pp. 1-3.

85/ FAO 1986, Table 3.

86/ ADB 1981, p. 27.

87/ Rijk 1983, pp. 22-27 provides for a summary of views and opinions held on the topic.

88/ Wicks and Buengsung 1984, p. 13; Khan 1984a. A survey reported that after single-axle tractor purchases, hired labor increased by 3.8 per cent in Khon Kaen and 13.2 per cent in Prachinburi province. (BAAC 1986a, p.9). Although the tractors reduced the amount of labor needed for land preparation, the increased area planted increased the need for hired labor during the harvest period.

89/ McInerney and Donaldson 1975, pp. 48-50. Introduction of tractors in Pakistan resulted in an increase in labor used per farm (allowing for the increase in farm size). Labor utilization per cultivated area, decreased by about 40 per cent, and it was estimated that each tractor replaced 7.5 to 11.8 full-time jobs. Some of these jobs were replaced by casual labor, and the overall net reduction in jobs was therefore estimated at about five per tractor.

90/ Rural societies consist of a variety of people: landless laborers, male and female labor, skilled and unskilled labor, family labor, hired labor, sharecroppers, tenants, etc. Certain categories of rural labor are displaced by mechanization (e.g., plowmen), while the demand for some skilled labor (e.g., drivers, mechanics) increases.

91/ Laxminarayan, et al 1981, p. 150. This study reveals that in Ludhiana district of Punjab, 73 per cent of the labor force for manual harvest of paddy is migratory casual labor, and introduction of combine harvesters seriously jeopardizes the employment opportunities of the casual labor force, particularly migrant laborers. The combine harvesters are mainly in demand by big farmers. The study therefore recommends that in order to alleviate their harvest labor shortage, the flow of migrant workers from labor surplus areas to labor scarcity areas during the harvest season must be better organized.

92/ Panpriemras and Krusuamsombat 1985, pp. 303-341. Many of the cane farmers have long-time arrangements with families in villages in Northeast Thailand which provide harvesting labor. Transport is arranged, and it is not unusual for cash payments to be made in advance to the laborer's family at the start of the harvest season. (Personal communication with Dr. Tongroj Onchan, May 1987).

93/ Merrill 1975.

94/ Donovan, et al 1986. The estimate is based on 380 hours per year mechanic time for large tractors and 34 hours on single-axle tractors (obtained from Chancellor 1970). The study suggests that this is high. In 1978 it was estimated that employment in the agricultural machinery industry would not exceed 5,000 workers (World Bank 1983, p. 70).

95/ Bergman 1986, p. 36.

96/ The farm truck (in Thai called *i-taen*) is made of used automotive parts (wheels, axles, transmission, steering wheel) and powered by a single piston diesel engine. The latter can be easily dismounted to power a locally made tractor, thresher, or pumpset.

97/ For a review of studies, see Rijk 1983, pp. 27-29.

98/ McInerney and Donaldson 1975, pp. 48-50.

99/ Alifuddin undated.

100/ Binswanger 1978, pp. 52-53. Binswanger recognizes that from 1966 to 1970 (when institutional credit for tractors became widely available), Pakistan experienced a period in which new varieties and changes in prices made farming much more profitable. Nevertheless, he considers it doubtful that in the absence of tractors the trend towards owner cultivation would have been so strong.

101/ Rijk and van der Meer 1984, pp. 27-28.

102/ World Bank 1978, p. 43.

103/ For a critical review of the appropriate technology movement, see Rybczynski 1980.

104/ FAO 1979, p. 56. In 1972-73, commercial energy for agriculture was estimated at 3.5 per cent at the world level, 4.0 per cent in the developing countries, and 5.3 per cent in the Far East. Developing countries (with two-thirds of the world's population) accounted for about 18 per cent of the total commercial energy used in agricultural production in 1972-73. It was estimated that this figure would rise to 28 per cent by 1985-86. The world's developing countries' share of commercial energy devoted to the manufacture and operation of farm machinery was expected to increase from 8 per cent in 1972-73 to no more than 15 per cent by 1985. In 1972-73, the manufacture and operation of farm machinery accounted for the largest share of commercial energy consumption in agricultural production, accounting for 51 per cent of the world level (Faidley 1977). In the Far East, however, it represented only 8 per cent and ranked a distant second after chemical fertilizer (84 per cent) in agricultural energy consumption. The manufacture and operation of irrigation equipment, pesticide production, and pesticide application each used only about 2 per cent of the total commercial energy input for agricultural production in 1972-73.

105/ World Bank 1986b, pp. 80-93.

106/ ADB 1981, p. 36. This study suggests that the increased energy application should be of two types: (i) increased input intensity; and (ii) land development and improvement, including irrigation development.

107/ Makhijani and Poole 1975.

108/ Singh and de los Reyes 1983.

109/ See also Ruthenberg 1980.

110/ World Bank 1986b, p. 78.

111/ See for example Mitchell 1960, p. 38.

112/ Gifford and Rijk 1980, p. 22. Also, the ADB's Sector Profile examines this phenomenon and cites Bangladesh as an example where between 1970 and 1979 almost the entire increase in the agricultural labor force (25 per cent) had to be absorbed by the agricultural sector because of lack of non-agricultural employment opportunities (ADB 1981).

113/ For example, depending on prices, a windmill may be more expensive per liter of water pumped than a small engine-powered pump. Also, there are generally economics of scale in machinery design and hence there usually is a cost in scaling it down. The cost per horsepower of farm tractors, for example, generally increases as horsepower is reduced, assuming equal levels of quality and sophistication. FAO gave as an example an internationally known conventional two-axle tractor of 45 hp costing about US$12,000 or $267/hp. A two-axle tractor of 18 hp from the same manufacturer cost about $5,000 or $277/hp, and a 10 hp single-axle tractor of equal sophistication and quality sold for US$5,000 or $500/hp (FAO, 1981).

114/ Limiting the introduction of a new harvest system for the sake of employment conflicts with the basics of economic development. For example, in Indonesia the change from the *bawon* harvest system using the *ani-ani* (a finger held knife) to the *tebasan* system using sickles increased harvest labor productivity by 78 per cent and reduced losses appreciably without any significant capital investment. Moreover, the *ani-ani* was considered unsuitable for harvesting new varieties (Gaiser and Esmay 1981).

115/ World Bank 1987, pp. 57-59.

116/ Despite parity of the Thai baht to the US dollar until recently, the interest rates in Thailand for borrowing have been significantly higher than for the US dollar money market.

117/ Because these statements sometimes appear trivial to an economic planner, these realities are frequently overlooked. Studies have analyzed and reported adverse social developments as a result of technology development, which nevertheless were economically justified and in some cases necessary. For example, the discussions on harvest systems in Indonesia (see note 114), the change from manual paddy hulling to rice mill units in Java, and the replacement of female labor for paddy hulling in Bangladesh with mechanical rice hullers (Greely 1980).

118/ See further Chapter 4, Section 4.3.

3

AGRICULTURAL MECHANIZATION IN THAILAND

3.1 INTRODUCTION

Driven by a demand for farm power resulting from area expansion and relative change in factor prices, the process of agricultural mechanization in Thailand can be considered a successful example of technology transfer and development. [1/] During the 1960s and 1970s, when world market prices were attractive for Thai farmers, new infrastructure and mechanization facilitated the rapid expansion of cultivated area. From 1960 to 1986, paddy area expanded on average by 1.9 per cent annually and upland food crops by 9.3 per cent. Yield-increasing technology played a limited factor in growth of agricultural output in Thailand. [2/] Since 1960, Thailand's area planted per agricultural worker increased by 55 per cent. This increase was largely facilitated by mechanization [3/]. The annual investment in agricultural equipment and fuel for operation has been about twice that of fertilizer. [4/] About 50 per cent of agricultural machinery is concentrated in the Central Region, whereas the Southern Region has relatively little machinery due to its predominantly perennial crops. [5/] Details on the mechanization subsector are provided in Appendix 1.

Traditionally, Thai farmers used simple tools and animal drawn implements. [6/] Mechanization with power technology began after the Second World War with the importation of water pumps. Subsequent milestones are summarized as follows. [7/]

1947 : Single-axle tractors with rotary hoes powered by 4.4 kW (6 hp) gasoline engines are imported. The low chassis are unsuitable for swampy fields.

Early 1950s	:	Government-operated mechanization centers are established for land preparation and threshing, but these centers are not financially viable and they soon cease operations. [8/] Large American-made threshing machines are imported, but this technology is not popular. [9/]
1957	:	AED is established within the Ministry of Agriculture and Cooperatives (MOAC) and releases the design of a low-lift axial flow pump to local manufacturers. The pump becomes very popular and is manufactured in large quantities.
1958	:	AED releases the design of a low-cost two-axle tractor (the "Iron Buffalo"), but commercial production does not catch on at that time.
1960-64	:	Ford and Massey Ferguson establish assembly lines for two-axle 44 kW (60 hp) tractors.
Mid-1960s	:	Workshops around Bangkok begin to manufacture simple single-axle tractors which quickly gain popularity.
1969	:	A single-axle tractor manufacturer in Ayudhaya starts producing a low-cost two-axle tractor powered by a single-piston imported diesel engine of 11 kW (15 hp) using a combination of V-belt and chain/sprocket transmission and second-hand car differential. Five years pass before a significant demand arises for these tractors.
1975	:	Three firms begin production of axial flow threshers based on the IRRI design and demand increases rapidly.
1976	:	Massey Ferguson introduces sugarcane harvesters, but this technology proves premature in Thailand.
1978	:	A 12-row power-operated rice transplanter is imported by a local manufacturer with the

objective of producing it locally, but until now the machine has not become popular. The same applies to manual transplanters.

1979 : The Board of Investment approves promotional privilege to three diesel engine (4.4-13.3 kW; 6-18 hp) manufacturers. Production of diesel engines starts in 1980.

1980- present : Locally-manufactured farm trucks rapidly gain popularity. Small second-hand tractors are imported from Japan.

1981 : Reaper harvesters are imported from the People's Republic of China to be copied and adopted by local manufacturers, but no significant market emerges for the machines.

1980-87 : Low crop prices and years with low yields cause demand for machines to stagnate and even decline.

The agricultural mechanization process in Thailand follows a pattern whereby *power-intensive* operations (pumping, land preparation, threshing) are being mechanized before *control-intensive* operations (weeding, planting, harvesting). A clear distinction must be made between the size and design of tractors and the type of work these tractors are used for in Thailand: [10]

(i) Single-axle tractors are locally built and used for flooded paddy land preparation, for transport, and as a stationary power source. These tractors are sold in large quantities (around 40,000 units per year) and are responsible for the rapid mechanization of paddy land preparation under flooded conditions. This tractor consists of a heavy frame and is powered by a 4.4-7.4 kW (6-10 hp) diesel engine equipped with a plow or simple comb-harrow. From the technical point of view, the tractor is a substitute for buffalo power and has not changed land preparation techniques. However, because of the deeper plowing capability of the tractor, the field is usually plowed only once (as compared with two to three times with the buffalo).

(ii) Power tillers of 7.4 kW (10 hp) have been imported since 1955 and are used in flooded paddy land and for vegetable cultivation. Their rotary tillers represent a technology unavailable with draft animals or locally built single-axle and two-axle tractors. Power tillers are expensive, and unlike in several other Asian countries, do not play a significant role in Thailand. An increase of import duties (up to 30 per cent) in 1980 has almost stopped imports since then.

(iii) Locally made two-axle tractors of less than 15 kW (20 hp) are used for flooded paddy land preparation in the same fashion as the single-axle tractor. [11/] These tractors have a higher capacity and cause less strain on the operator. They do not have the standard design features of imported tractors (for example, power take-off [PTO] and multiple speed gearbox). The locally made articulated two-axle tractor (which is developed from the single-axle tractor) is popular in some areas of the Central Plain and is included in this category.

(iv) Two-axle imported tractors of less than 33 kW (45 hp) (also referred to as *small tractors*) were imported until 1981, but few are imported at present. Significant quantities of second-hand units are imported from Japan at very low prices. Many of these tractors are within the 15-22 kW (20-30 hp) range and are not used for paddy cultivation but mainly in fruit and tree crops. [12/]

(v) Two-axle 33-63 kW (45-85 hp) imported tractors (also referred to as *big tractors*) are usually equipped with disc plows and disc tillers. These tractors are important to upland preparation and some specific work for sugarcane (ridging and stubble-shaving). The tractors are too heavy to prepare flooded or swampy paddy fields, but in the large fields of the Central Plain, in combination with a disc tiller these tractors are also used to prepare paddy land prior to the start of the monsoon rains. Equipped with a rotary tiller, they are also used for preparation of dry paddy land to grow high-value secondary crops (for example, vegetables and tobacco in the Chiang Mai Valley), and are used to power corn shellers. These tractors contributed to the rapid expansion of upland farming and planting of a secondary high-value crop. The big tractors are owned by farmers who also provide tractor-hire services. Despite their seasonality, these tractors obtain a high degree of annual utilization. [13/]

Given the weak data base, estimates on utilization of agricultural machinery and area covered in Thailand must be carefully treated and compared with other relevant information and data. Based on an annual 59.4 million rai (9.5 million ha) paddy land preparation, an estimated 54 per cent is at present completely or partly prepared with tractors. A draft buffalo population of about two million suggests the estimate of tractorized paddy land preparation is correct. 14/ There are about 28,000 big tractors in operational condition, having a capacity of 21 million rai (3.4 million ha) per year for upland preparation. Assuming 35.1 million rai (5.6 million ha) is plowed annually, 60 per cent of the upland area is prepared with tractors. 15/ In the Central Plain, most land is now prepared mechanically. Threshers have been rapidly introduced since 1975. The new technology made mechanical threshing very attractive when the cost of labor increased. Including treading by tractor, almost all the paddy crop in the Central Region is now threshed by machine. Since 25 per cent of the paddy crop is grown in the Central Region, it is estimated that at least 30 per cent of the paddy is mechanically threshed nationwide. Maize shelling and sorghum threshing are also mechanized in the commercial areas. Reapers, transplanters, planters, cane harvesters, combine harvesters, milking machines, and other advanced machines have been introduced in Thailand, although their use is not yet significant.

3.2 CHARACTERISTICS OF THE AGRICULTURAL MACHINERY INDUSTRY

Except for two-axle tractors and a few advanced technologies, most agricultural machinery used in Thailand is made domestically. Both the importation of two-axle tractors and domestic machinery manufacture are characterized by a highly competitive private sector (see Appendix 1 for further details). Distribution, maintenance and repair facilities are efficient and available nationwide. Machinery hire-services are widely offered at competitive rates and are a major force in rapid mechanization. In addition, the high cost of capital in Thailand means that agricultural machinery achieves high annual utilization and a long economic life.

The private sector in Thailand reacted to the demand for agricultural machinery by manufacturing low-cost machines suitable for Thai conditions. The industry is characterized by highly labor intensive production technologies with low capital investment, and can therefore adjust rapidly to fluctuating demands without the burden of high fixed capital costs. Production capacity was expanded mainly by adding more labor. Initially, most of the machinery manufacturers did not invest in better and more efficient production technology and improved designs, and when small second-hand two-axle tractors from Japan and single-axle tractors from the People's Republic of China were offered at very competitive prices, domestic manufacturers could not compete. Because of the increased competition, the manufacturers pressured the government to raise import duties and to restrict imports. In order to protect the local industry, the government imposed import quotas for single-axle tractors and two-axle tractors with engine capacity of less than 1,100 cc in 1982. In addition, import duties on tractors, rice combine harvesters, and transplanters were increased from 5 to 30 per cent on cost of insurance and freight (CIF)-included value. This effectively stopped the import of power tillers, new small two-axle tractors, transplanters and harvesters, even though these machines hardly competed with the local industry since they were not locally manufactured or were used for some specific operations for which local designs were not suitable.

Decreased demand in recent years caused a healthy shakeout in the large number of firms involved in tractor manufacturing, resulting in various improvements. Designs were improved, workshops were better laid out and maintained, and more productive and efficient manufacturing techniques were employed, including farming out production of parts to specialized factories. This improvement was part of the self-inspired development process, but was probably also induced by the United Nations Development Program (UNDP)/FAO Agricultural Machinery Production Project, the accreditation process of BAAC which included a scoring system for product quality and design, and the decreased total demand for agricultural machinery. (This latter development increased competition, resulting in product improvement.) Because of the labor intensive manufacturing process with little investment in production machinery and overhead, the manufacturing industry was able to contract and expand their production rapidly, or switch to producing other machines or engineering products. Because of depressed demand, prices tended to stabilize and manufacturers' and dealers' margins were low. Although in the middle of the 1980s the agricultural machinery industry was working at not more than 50 per cent of capacity, much of this was achieved by laying off labor. Many of the small rural workshops producing a few machines per year have stopped production and focus on other engineering work.

Local manufacture of diesel engines for use in agriculture has been protected from fully assembled imports through import duties, taxes and restrictions. Initially, the locally assembled engines may have been over 30 per cent more expensive than similar engines imported in ready-to-use fashion. The depreciation of the baht with respect to the yen in recent years makes the Thai-produced engines cheaper, and the possibility for export is being explored. Diesel engine parts are already shipped to Indonesia to be used in domestic manufacture.

The anticipation and competitiveness of the Thai machinery manufacturing industry facilitated the rapidly increased mechanization of Thai agriculture. Contrary to common belief, most of the machinery presently popular in Thailand is not a unique indigenous innovation: the single-axle tractor resembles the very early designs used in the early stage of mechanization in Japan, the farm truck was made in the Republic of China before it became popular in Thailand, the axial flow thresher was already commercially manufactured in the Philippines prior to its demonstration in Thailand, and implements used with big tractors are usually copied from imported machines. Thai manufacturers copy designs and adapt them to local conditions and low cost manufacturing technology very effectively. They are less adept at innovation. [16/] Although there are exceptions, the standard of workmanship is not always high, [17/] but the farm machinery produced in Thailand is competitive in price, and some manufacturers have successfully entered the export market.

3.3 INSTITUTIONAL SUPPORT

3.3.1 Research and Development

Total annual government expenditure on research and development, training, education and extension for mechanization is about 40 million baht ($ 1.5 million). [18/] With an annual investment of about 3.5 billion baht ($135 million) in new agricultural machinery alone (excluding replacement parts and fuel), only about 1 per cent of total agricultural machinery capital investment is matched by supporting institutional activities of research, training, extension and education. [19/] This overall percentage is low and justifies further increases in budget allocations, especially for research, extension and training. For comparison, the total budget of the Extension Department in 1986 was 1,503 million baht ($57.8 million). [20/] Much of the Extension Department's work deals with seed and fertilizer technology, even though mechanization has had a larger role in agricultural production increase.

3.3.2 Relevant Government Institutions

The government's most important agency involved in mechanization is AED within the Department of Agriculture of the MOAC. In addition, other public institutions and government departments and agencies are involved with agricultural mechanization. Bergman listed 28 offices/departments and institutions involved in various degrees and stages of agricultural mechanization. [21] The activities of nearly all MOAC Departments, as well as the office of the Under-Secretary of State, deal with agricultural mechanization in some way. It has been reported that inter-departmental and inter-ministerial cooperation on mechanization issues is lacking. [22] These conclusions are not new to Thailand, nor are they unique when compared with any other country.

In recent years, a number of institutional developments took place in AED, accelerated because of UNDP/FAO assistance to AED for the Agricultural Machinery Project and participation in the ESCAP/Regional Network for Agricultural Machinery (RNAM) project. Under the auspices of RNAM, national agricultural mechanization committees were established in the participating countries to serve as high-level policy-making advisory and coordinating bodies. In Thailand, this National Committee on Agricultural Machinery (NCAM) is chaired by the Permanent Secretary of State for Agriculture and Cooperatives, while secretariat responsibilities rest with the Director of AED. [23] Progress is being made in bringing all parties together in a forum, but coordination and cooperation at the operational level still need improvement, and the overlap between the various government departments and offices remains substantial.

The UNDP/FAO Project provided assistance to AED for the preparation of mechanization strategy guidelines, and prepared projects and programs for consideration in the Sixth Five-Year Development Plan (1987-92). As a result, the Sixth Five-Year Development Plan includes for the first time a significant section on farm mechanization which was approved by the National Economic and Social Development Board (NESDB) and adopted by the cabinet. This is an improvement over the past plans, but working out the programs and projects is still required.

The UNDP/FAO Project has also contributed to improvements in design and manufacturing standards, and advised on institutional strengthening, particularly for AED. Within its limited financial and manpower resources, AED has assumed an important role in agricultural mechanization. AED has developed capability in research and development as well as in surveying, analyzing, and understanding the mechanization process. A matter for concern is the number of organizations directly involved in agricultural mechanization without much coordination. Khan listed the activities and concluded that at least four organizations are involved in the same type of activity without formal linkages. [24] Overlap of activities within MOAC has a historical background, but even within AED itself there is overlap of functions and facilities.

3.3.3 Rationalizing the Role of AED

In order to rationalize the role and function of AED, a clear distinction must be made between the development and utilization of agricultural machinery and its manufacture. Although very closely linked, they are to be treated as separate disciplines with unique development objectives. Ministries of agriculture, particularly agricultural engineering divisions, generally have no responsibility for developing the agricultural machinery industry, since this is usually part of the industrialization strategy and therefore the domain of industry ministries. In the case of Thailand, the development of the agricultural machinery industry is a role for the Regional Industrial Promotion Centers (RIPCs) under the Department of Industrial Promotion. AED activities therefore should be confined to the utilization aspects of agricultural machinery. Of course, agricultural engineers and industrial (extension) engineers should collaborate and discuss matters of common interest. Too much emphasis on domestic manufacturing may be counter- productive for the agricultural sector. The quota system for import of small second-hand two-axle tractors and single-axle tractors was established to protect domestic industry, but it increased the cost of machinery for farmers at the same time. Similarly, the limited volume of production for domestic diesel engine manufacture and the need for protection against imports initially caused engines to cost farmers about one-third more than similar imported ones.[25]

It is erroneous to assume that developing the machinery industry will automatically lead to rapid agricultural mechanization. [26] Demand for machinery depends on the relative cost of machinery versus the cost of labor and draft animals and on the cost of production versus the level of farm prices. Thus, through importation of appropriate designs, agricultural mechanization could also have proceeded in Thailand, as was the case with big tractor technology. [27] It needs to be ascertained whether imported machinery of similar simple design would be more expensive. The experience with import of single-axle tractors suggests that import may have been very competitive, while imported diesel engines were significantly cheaper than locally manufactured ones, and importation of sprayers suggests the same.[28] It is not suggested that a Thai agricultural machinery industry is unjustified. On the contrary, the agricultural machinery industry is labor intensive and is important in developing light engineering industry and repair and maintenance skills in rural and urban areas, thus contributing to overall economic development. [29/] The point is that mechanization strategy may be formulated independently of industrialization strategy, and mechanization may proceed without developing a local manufacturing industry. Therefore, activities relating to the utilization of machines are clearly an AED responsibility, but activities related to manufacture should rest with the Ministry of Industry through the RIPCs. The present arrangement whereby AED assumes an industrial extension responsibility is a duplication of RIPC responsibility and puts an extra strain on AED's limited budget and manpower resources. This duplication of responsibility possibly results from UNDP/FAO's Agricultural Machinery Production Project, and is unlikely to be very effective for the future. [30/]

UNDP/FAO experts prepared proposals for the reorganization and strengthening of AED, including additional field and training centers, and proposals for programs to be implemented by AED and other institutions. [31/] Because of the efforts by the government to control and limit its spending, many of the recommendations for institutional strengthening of AED have not been implemented. However, it is necessary that institutional support from the government for agricultural mechanization be improved, particularly for training, research and development, and policy and strategy formulation. Merging the workshops and streamlining AED, including establishing priorities and a clear delineation of role and responsibility among the various agencies, are more likely to result in efficient manpower and budget utilization than increasing its size. Reorganization can make the AED more efficient and increase its contribution to agricultural mechanization with minimum increase in budget and manpower. Assistance to the manufacturers should become the sole responsibility of the Ministry of Industries (MOI) through the Department of Industrial Promotion and RIPCs, thus freeing manpower for activities in machinery research, design, extension, and training.

3.4 INTERPRETATION OF THE MECHANIZATION PROCESS IN THAILAND

As earlier discussed, agricultural development in Thailand is characterized by rapid area expansion rather than intensification. The demand for agricultural machines and the development of the agricultural machinery industry responds mainly to the demand for more farm power as a result of rapid area expansion and change in the cost of machines versus labor and draft animals. [32/] In Thailand, the government has interfered little with mechanization compared with other developing countries, while adverse policies favoring mechanical technology at the expense of employment are insignificant. In fact, several government policies place mechanical technology at a disadvantage. For example, low-cost institutional credit for big machinery is absent, domestic tractor and engine manufacture are protected, and rice exports used to be heavily taxed.

Following the broad classification introduced in Sub-section 2.1.1, Thailand has largely completed Stage I (Stationary Power Substitution) and substantially proceeded into Stage II (Motive Power Substitution), while Stage III (Human Control Substitution) of mechanization is being tested. The Stage I and Stage II operations require high levels of physical effort and are highly seasonal, and therefore subject to a premium wage rate, while the machines substituting for muscle power are relatively cheap and simple to operate. For control-intensive operations (Stage III), more labor is available because it includes women and children, and therefore the wage rate is also lower for these operations. Also crop care, weeding and some harvesting (for example, cassava) are less peak demanding and are usually performed with own labor. Machines to perform control-intensive operations are usually more complicated and require more skill. These machines usually require farming techniques to be changed, while biological factors become important in the efficient use of the machines. Thus, relatively expensive machines such as (trans)planters, combine harvesters, and sugarcane harvesters are still insignificant. These machines also usually require better land preparation, water control, and certain modifications in cropping techniques. In recent years, a demand for control-intensive machinery has become notional. On the other hand, the demand for certain machines decreased rapidly when a saturation level was reached or the cost of production and farm prices became unfavorable. Demand for big tractors dropped when their prices increased and returns to crop production decreased, while local manufacturing of two-axle tractors nosedived, probably also because a saturation point was achieved. This saturation point became lower when paddy prices fell drastically.

The financing terms and conditions for machinery have not created an artificial bias towards capital as compared with labor. Mechanization has therefore had insignificant adverse social or economic effects but rather, because of the increase in cultivated area, has actually increased employment opportunity and income.[33/] Farmers have also benefitted from mechanization by increasing their off-farm income facilitated by mechanizing their farm work, or earning extra income from contractor work.[34/] Upland farmers benefitted from tractor hire services by expanding their cropped area. Single-axle tractors and threshers reduced the cost of production and facilitated higher cropping intensities and improved techniques once water control systems were constructed in the Central Plain. [35] However, cropping intensity was not increased by mechanization, since water was the limiting factor and this factor is already fully utilized before the introduction of mechanical land preparation. [36] Increase in area with a second paddy crop is therefore not a result of mechanization but of water control investments, particularly in the Central Region. On the other hand, higher demand for labor (because of double cropped paddy) increased the demand for mechanical technology, while investment in machinery also became more attractive due to higher annual utilization rates as a result of double cropping. That cropping intensity increased little despite the rapid increase of water pumps is explained by the fact that most of these pumps are small low-lift types used mainly to ensure timely water supply (or even drainage) rather than to facilitate an additional crop. After 1978, there was a rapid increase in threshers when suitable technology had been introduced and the cost of mechanical threshing decreased relative to the cost of labor (Figure 3.1).

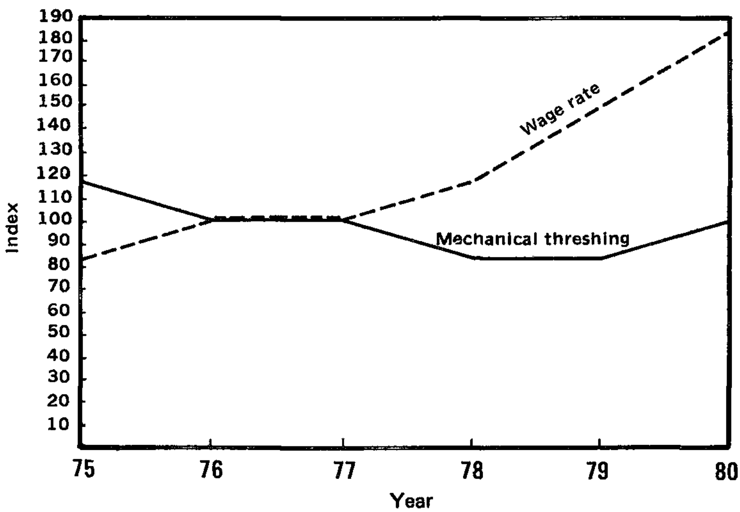


Figure 3.1. Cost index of mechanical threshing versus farm labor wage rate (1977 = 100).[37]

Mechanization contributed substantially to increased production in Thailand by facilitating the rapid expansion of upland area and increasing labor productivity. The rapid increases in production and export of upland cash crops in Thailand could not have been achieved without the availability of two-axle tractor hire services, often complementary to inputs such as seed, credit and a ready market. However, the Thai experience provides evidence for the hypothesis that merely introducing power technology does not increase land productivity.

NOTES AND REFERENCES TO CHAPTER 3

1/ See for example: World Bank 1983, pp. 62-70; Duncan 1984, p. 1.

2/ In the period 1960-83, 78 per cent of the growth of agricultural production was due to planted area expansion and 22 per cent to increase in land productivity (Corsel 1986).

3/ Rijk and van der Meer 1984, p. 87. See also Chapter 2, Section 2.1.

4/ In 1985, 1.15 million tons of fertilizer material (Office of Agricultural Economics, *Agricultural Statistics of Thailand*, Crop Year 1985/86) at an average price of 4,500 baht per ton, or total fertilizer expenditure of 5.2 billion baht. Locally manufactured farm equipment cost 1.7 billion baht (Table A1.2); 60,000 small diesel engines cost an average of 20,000 baht each; 326 newly imported tractors were an average of 386,000 baht each; 400 big second-hand units cost an average of 175,000 baht each; and 5,000 small second-hand tractors averaged 50,000 baht each. Thus, value of total equipment was 3.7 billion baht (including 10 per cent replacement parts). At 6.7 baht per liter, 1,153 million liters of diesel fuel amounted to 7.7 billion baht (World Bank 1986b, Vol. III: Statistical Appendix, p. 80).

5/ Office of Agricultural Economics 1986. See also Table A1.1.

6/ See also: Chancellor 1961.

7/ Compiled from various sources, namely: Chancellor 1970, USOM 1969, Taenkam 1980, and Sriboonchilla 1975.

8/ Chancellor 1970, p. 137.

9/ During the same period, the technology was adopted in the Philippines by large private estates in Central Luzon, suggesting that the technology was technically feasible.

10/ See also Rijk 1986. A *two-axle tractor* generally refers to a tractor with more than two wheels and with at least one axle at standard-tread. The term includes articulated, tandem and tricycle-type (row-crop) tractors. A *single-axle* tractor generally refers to a design which requires the operator to walk behind the tractor when tilling soil. The tractor may be pivoted upon its axle (for example, for lifting implements out of the soil). A *power tiller* usually refers to a single-axle tractor equipped with a power driven rotary cultivator. A *track-laying type tractor*, or *crawler tractor* travels on two chain belts.

11/ Mongkoltanatas, et al 1986.

12/ Mongkoltanatas, et al 1986. Although these second-hand tractors may be shipped from Japan with the rotary hoe attached, these implements are rarely used. The small disc plows, disc tillers, and rotary slashers are more popular. This is surprising because in Japan these tractors are widely used for paddy land preparation and when equipped with rotary hoe (or rotary tiller) are rather efficient. Two explanations have been suggested for this phenomenon. First, these tractors are heavier and easily bog down (most are fitted with high-lug paddy land type tires but are not equipped with the Japanese flotation type paddy wheels). Second, paddy farmers frequently use their local single- and two-axle tractors to drive pumps or other machinery by running a belt from the flywheel pulley, or the engine is switched to a thresher or farm truck. The Japanese two-axle tractors do not have belt pulleys, and PTO drive is more expensive and complicated.

13/ USOM 1969; Chancellor 1970, p. 84; personal discussions 1987.

14/ Office of Agricultural Economics, *Agricultural Statistics of Thailand*, Crop Year 1985/86. Total single-axle tractors and locally made two-axle tractors: 410,000 units @ 75 rai/season = 30.8 million rai. Big two-axle tractors used in the Central Plain for paddy land preparation: 15,000 units @ 1,000 rai/season = 1.5 million rai. Two million draft buffalo @ 12.5 rai/season = 25.0 million rai.

15/ Assuming an average of 750 rai upland preparation per big tractor per year, and a total upland area requiring tillage of 35.1 million rai. Although very high utilization rates have been reported (USOM 1969 and Chancellor 1970), high utilization is usually achieved only in the first few years of the tractor's life. After that, frequent breakdowns reduce annual utilization (Chancellor 1986). Second-hand small tractor imports have not been included in the calculation because they have far less impact. They are rarely used for contract work (Mongkoltanatas, et al 1986, p. 13), and many are used for secondary tillage including inter-row weeding and slashing in tree crops.

16/ It has been suggested that the educational and social systems limit the innovativeness of engineers (personal communication May 1988 with Dr. D. Gee-Clouch, AIT). Although further substantiation is needed, it appears that in for example the Philippines and the People's Republic of China innovation scores higher in the agricultural machinery industry.

17/ As compared with the Philippines, for example (personal observations).

18/ Estimate based on 1983-84 budget allocations as presented in Khan 1984b.

19/ See also Note 4. The institutional budget allocations for mechanical engineering support to the industry (for example, Industrial Services Institute [ISI], education, vocational training) are excluded, since these are part of industrial development rather than agricultural development.

20/ Office of Agricultural Economics, *Agricultural Statistics of Thailand*, Crop Year 1985/86, p. 225.

21/ Bergman 1986.

22/ Gifford 1981, p. 128; Khan 1984b, p. 39.

23/ The name of the committee suggests that the focus is on machinery rather than on mechanization. The latter is much more comprehensive and includes all aspects related to utilization of machinery, including credit policies, extension, etc.

24/ Khan 1984b, pp. 35-37.

25/ Interviews with dealers and manufacturers, Bangkok 1984.

26/ The local manufacture of rice transplanters but lack of demand is only one example which supports this statement.

27/ In some highly productive agricultural countries, many of the handtools, equipment and machinery are imported. Large numbers of the Land Master (the forerunner of the IRRI single-axle tractor design) were initially imported by Japan from England, suggesting that the machine had first to be imported prior to development of a large single-axle tractor industry in Japan.

28/ The retail price of imported four furrow disc plows made in the UK was 42,000 baht, only marginally more expensive than the price of a locally made plow (39,000 baht) (communication with Anglo Thai Tractors, May 1987).

29/ During the early stage of industrialization, the manufacture of agricultural tools, machinery and implements was also important in Japan, the Republic of Korea and the Republic of China.

30/ The name of the project implies that it should have been under ISI rather than AED. The Project preparation team included FAO (agricultural machinery utilization) and the United Nations Industrial Development Organization (UNIDO) (agricultural machinery manufacture) and proposed a single project in which both UNIDO-related type work and the FAO-related type work were combined. At the final stage of the project, the two activities were combined under one UNDP/FAO project assisting AED only. During the implementation of the project, an industrial extension unit was established within AED consisting of two full-time engineers from AED and a part-time engineer from ISI/RIPC.

31/ See Khan 1984b, Gifford 1981, Weaving 1986.

32/ For example, in terms of investment per unit of capacity, a single-axle tractor is now cheaper than animal draft power. A steel plow for animal traction is now cheaper than the traditional wooden one.

33/ Growth rate for area cultivated was higher than growth rate of the agricultural labor force. See also Khan 1984a; BAAC July 1986a; Saitorn 1983, pp. 138-171.

34/ BAAC July 1986a.

35/ Farmers switched from broadcast paddy to transplanted paddy, which give better yield and results in higher cropping intensity. However, in recent years, probably due to low rice prices and increasing labor costs, farmers have returned to broadcast paddy in areas with good water control.

36/ BAAC 1986a; Wicks and Buengsung 1984.

37/ Costs of mechanical threshing include the contractor's charge in Chachoengsao (Central Region) and the operator's fee. In 1978, the contractor's charge for mechanical threshing was 50 baht per ton, and 87 baht including labor. Cost of buffalo treading was at that time 193 baht, including labor cost (Pathnopas 1980, p. 93). Farm labor wage rate (Central Region) from Bertrand 1977, Table 18, for 1975 and 1976; Pathnopas 1980, p. 97 (for 1977), p. 37 (for 1978 and 1980).

4

MECHANIZATION POLICY AND STRATEGY FORMULATION

4.1 THE NEED FOR MECHANIZATION POLICY AND STRATEGY

To achieve increased agricultural production and productivity or to reduce the cost of production, technological changes in the agricultural production process are needed. Mechanization is a key factor under the category of labor-saving technology. The land-saving technologies (high-yielding variety [HYV] technology, irrigation and drainage) have received considerable attention in the development effort through implementation of projects and programs and provision of incentives. In contrast, labor-saving technologies (such as agricultural mechanization and new cropping practices which increase labor productivity) have received little support in many developing countries because of concern for rural employment. Nevertheless, the importance of certain labor-saving technologies has been increasingly recognized as an important factor for agricultural development. [1/] Adequate and appropriate farm power is important in programs to increase agricultural output and labor productivity. In several developing countries, annual investment and operational costs for mechanization are substantial and may exceed the annual fertilizer expenditure. [2/] In some countries, because of better opportunities in non-agricultural sectors, labor-saving technology is required to ensure that farm production levels are maintained. [3/] Farm mechanization will become increasingly important for resettlement projects; areas with rural labor shortages, land development, and irrigation projects; and crop intensification programs in newly industrialized and semi-industrialized countries. [4/] Because of rural unemployment and underemployment in many developing countries, and the relatively high investment and operational cost of mechanical technology, efficient mechanization policies and strategies must be formulated to avoid undesirable social and economic effects.

As explained in Chapter 2, there is no single solution to the mechanization issue which can be applied universally: the need for mechanization and its impact depend on technical, economic and social conditions which are location-specific and subject to change. Comprehensive strategy formulation, project design, and programs require an understanding of the historical mechanization process, including the effect of government policies on that process. Selecting the appropriate technology from the options available, including the manner of implemention, and a profound understanding of all aspects associated with a particular technology in the specific social and economic environment, is important for designing effective mechanization strategies and for project formulation. A study on seven countries participating in ESCAP's RNAM project showed that only two (India and the Republic of Korea) had reasonably well established processes for formulation and implemention of agricultural mechanization that reflected national development objectives and goals. The Republic of China and the People's Republic of China have also actively implemented mechanization strategies. [5/]

The need for planning of mechanization programs or the formulation of mechanization strategies requires further elaboration. It may be argued that no need exists for planning or mechanization strategy formulation because once overall economic policies are implemented (which provide incentives for agricultural production and eliminate distortions in prices of labor and capital), mechanization will take its proper place and adverse socio-economic effects will be automatically minimized. This view is only partly correct. First, price distortions are usually well entrenched and are often difficult to eliminate due to the complexity of the social, economic, and political environment. It is optimistic to assume that pricing policies can be easily adjusted and rationalized (as demonstrated by the agricultural policies of Japan and the EC, for example). Second, governments impose taxes and duties and may provide incentives through subsidies to achieve development goals or even political support or stability. An indiscriminate application of these instruments for all agricultural technology, in particular for all forms of mechanization, may be ineffective and will probably result in unwanted developments when specific goals are planned. Moreover, a laissez-faire attitude towards mechanization may delay technology innovation or may contribute to undesirable socio-economic developments when price distortions occur. Governmental ignorance of the need for mechanization (and of the need for incentives, programs and projects to stimulate the use of certain types of machinery) can adversely affect agricultural and overall development. [6/] But even if the proper economic incentives are established and price distortions eliminated, mechanization strategies and programs must be formulated which specify the required credit, educational and training programs, subject-matter extension specialists, and other components. [7/]

Opponents of mechanization strategy formulation argue that, while the developed countries never planned for mechanization or formulated mechanization strategies, in developing countries (such as in the People's Republic of China) active governmental involvement in development of mechanization strategy and the planning of mechanization programs caused mechanization to fail. [8/] The first argument is only partly true. The government of Japan has been actively involved in promoting mechanization, and Western governments had an active role in the training, extension and demonstration of mechanization technology. [9/] Numerous free or subsidized training programs were organized on machinery operation and maintenance, and agricultural mechanization became part of the curriculum at universities, colleges and vocational training centers. Moreover, patent rights, testing, and machinery safety standards were developed and enforced; extension services organized exhibitions, demonstrations, and field days; and mechanization became an important activity of government sponsored agricultural research and extension. There was less need, however, for Western governments to actively plan the process of mechanization because: (i) machinery development and mechanization took place in a gradual fashion, and the supporting infrastructure and institutions were gradually developed to a high level of sophistication over a period of about 100 years; [10/] (ii) the main purpose of mechanization in the developed countries was to increase labor productivity, and unemployment was usually not an important issue; and (iii) the engineering sector was sufficiently developed to undertake the unsophisticated research and development. Most machines were gradually developed and produced by rural blacksmiths. The private sector responded to new demands for machinery, design, manufacture, distribution and hire services.

The situation in most developing countries is different. Rather than a gradual invention and adoption of increasingly complicated machinery, highly sophisticated machinery may be available to unskilled or illiterate farmers. For example, farmers used to harvesting their crop with poor quality sickles may suddently be introduced to sophisticated harvesters. Such "technology jumps" are often made without taking into account various technical, social and economic considerations, or without considering more appropriate intermediate steps. [11/] The supporting infrastructure for the newly introduced complex technology may be weak or non-existent.

The conflicting objectives resulting in poor mechanization planning in the People's Republic of China, and its active but unsuccessful governmental involvement in implementation support the need for comprehensive mechanization strategy formulation. [12] This does not require extensive government involvement in all aspects of implementation. Too much public sector involvement in implementation usually gives adverse effects, and political factors may become predominant.

In particular, the governments of the Republic of Korea and the Republic of China have successfully pursued a mechanization strategy by identifying objectives, establishing the necessary policies and providing the institutional support to achieve these objectives. The manufacture and utilization of the machinery, however, was left to the private sector, which reacted to the favorable policy environment. In Thailand, the government had very little involvement in the design and promotion of low cost mechanization technology, and the mechanization process is therefore mainly the result of private sector initiative. Nevertheless, more government initiative is required in Thailand to promote mechanization into the next stages (see Chapter 7). India has also pursued mechanization through providing the necessary policy framework in which mechanization can prosper. However, the Indian government has directly interfered in the manufacturing of machinery through its general controls on the industrial entrepreneur and foreign collaboration through a system of licensing and protectionism in the agricultural machinery industry. This government involvement has resulted in numerous adverse developments, and the licensing system has proven to be an ineffective instrument for planning and pricing. [13] The import restrictions (through quota and high duty) of small second-hand tractors in Thailand also create more problems than they solve and are based on wrong assumptions. [14] The examples of the People's Republic of China and India confirm that in implementing a mechanization strategy, governmental contribution must be confined as much as possible to institutional support (research, training, education, credit, extension) while leaving the supply and use of the hardware to the private sector. [15]

The general experience with mechanization in developing countries is that many programs are implemented on an ad hoc basis, while the required policies and the institutions and infrastructure needed for successful implementation are not well established. This has constrained the effectiveness of mechanization and adversely affected the viability of successful mechanization programs or caused adverse effects. These difficulties arise from unsystematic application of mechanical power technology rather than from programs designed to increase agricultural production and productivity in the existing socio-economic environment. This suggests that mechanization is not only an engineering matter but equally an activity of agricultural sector development planning.

As a result of FAO efforts in recent years, several countries have become aware of the importance of agricultural mechanization policy and strategy formulation in the agricultural development planning process. Under the auspices of FAO and RNAM projects, several attempts at strategy formulation have been made in recent years. However, unlike strategy formulation in the Republic of Korea, the Republic of China, and India, these recent activities have not always resulted in governmental approval at the highest level. This is because mechanization strategy formulation: (i) takes place in isolation of the national development planning process; (ii) is overly controlled by engineers and agronomists with little input from economists; (iii) remains too broad and philosophical and lacks further quantification; and (iv) is too ambitious or fails to attract political support.

4.2 THE PLACE OF MECHANIZATION POLICY AND STRATEGY FORMULATION IN PLANNING

Since the end of the Second World War or following independence, most developing countries have prepared and published economic development plans, usually for five-year periods. In Thailand, a central planning body was created in 1959, presently called the National Economic and Social Development Board (NESDB). The first five-year national plan was prepared for 1961-1966, but its impact was limited. [16/] With FAO/UNDP assistance to AED, the Sixth Five-Year Plan (1988-92) for the first time includes a section on agricultural mechanization.

Planning is an attempt to coordinate economic decision making over the long run in order to direct a country's development. A multi-sectoral plan is usually built up from sectoral plans, including an agricultural sector plan and regional plans. Ideally, a development plan should not only provide realistic objectives and targets, but provide information on how these objectives and targets are to be met. In addition, the plan must quantify the required inputs, as well as the measures and policies needed to achieve the objectives. The objectives and targets are often optimistic, while the strategy, policies, and budgets required for achieving these targets are inadequate. Well designed policies are crucial. "The core of planning for higher productivity in the private sector lies in a set of policies which induce private persons to employ their time and resources more productively. The quality of a plan depends on the quality of its policies, rather than on the quality or quantity of its arithmetic". [17]

When governments are defining objectives and establishing goals and targets at the multi-sectoral economy-wide national level, agricultural mechanization is not a consideration. The focus for decision-making on agricultural mechanization should be at the level of subsector planning, in particular during the agricultural sector planning process. At this stage of planning, agricultural mechanization is one of the resources which must be organized and allocated to put the agricultural development plan into effect. Thus, agricultural mechanization becomes part of the strategy to achieve development objectives and targets, and it is more appropriate to think in terms of *mechanization strategy* in the development process rather than *mechanization plan*. Only after the mechanization strategy required to achieve sectorial objectives and targets has been formulated may the *mechanization policy formulation*, the *mechanization program*, and the *mechanization project preparation* be undertaken. [18] The outcome of this exercise results in a *mechanization plan*, but this terminology may lead to confusion as it suggests that mechanization is the objective rather than the means to achieve development objectives.

Many development policies relate directly or indirectly to agricultural mechanization, since it is not only an element in rural or agricultural development plans, but often in industrial development plans. A well-defined mechanization strategy helps avoid the effects of mechanization on overall development objectives, and the effects of national development policies on mechanization. Development policies on interest rates and import duties for agricultural machinery, for example, have a direct and immediate impact on mechanization. This influence may seemingly be changed easily without incurring long-term or undesirable side effects. [19] However, it has proven difficult politically to reverse previous decisions beneficial to the electorate. Thailand's import restrictions on small second-hand tractors are made at the cabinet level. New evidence indicates that these restrictions adversely affect agricultural production. Because cabinet approval is required, cancellation of the policy is a difficult procedure and unlikely to be attempted. [20] Other policies may appear to have less direct effect on farm mechanization but require a longer time span to implement or cancel, or may indirectly affect mechanization. [21]

4.3 GENERAL POLICY AND STRATEGY GUIDELINES FOR MECHANIZATION TECHNOLOGY

Agricultural development is driven by the process of technological innovation and its successful transfer. This innovation and transfer are influenced by prices for agricultural produce, factor scarcity, and factor prices. The important questions in relation to agricultural technology are when and what type of technology is required and how to apply the technology efficiently in farmers' fields. With presently available agronomic technologies, the yield potential of existing land and water resources could be more fully realized in many developing countries. This applies to both irrigated and rainfed farming systems. From the technical point of view, the scope for production increases based on crop intensification programs, including improved extension, quality seed, and increased application of fertilizer and other agro-chemicals, is large in Thailand and other countries with low crop yields and low fertilizer application rates. 22/ However, this view requires some further elaboration. In the 1960s and 1970s, pessimism concerning the developing world's future ability to feed its rapidly expanding populations was worldwide. 23/ World market prices went up rapidly in the first half of the 1970s, and the financial and economic rates of return on irrigation projects and intensification programs were high, particularly where fertilizer application had been low. With the low cost of labor, the lump sum of investment and operational costs for farm machinery other than pumpsets usually compared unfavorably with biological and chemical technologies in terms of yield increase.

With a gloomy future assuming widespread famine, national and international development efforts concentrated on yield increase, since most Asian countries had low land/man ratios, and area expansion was limited. 24/ Agricultural development experts, in an effort to demonstrate the potential of increased production, often presented research papers citing yield and input data from Japan or other high technology input agricultural systems, and compared the data with low input levels of developing countries. Looking at high input agricultural systems often provided the strategy for future research directions and developmental efforts. Wihtol refers to the "Japanese model for agricultural development" which puts heavy emphasis on irrigation, drainage, and other high-yielding technology investments. Apart from Japan, this model has also been applied to the Republic of Korea and the Republic of China. A measure of success of the model was a yield increase from one ton to over five tons per hectare, and the model was widely adopted as a blueprint for agricultural development in Asia. 25/ During this process, Japanese agricultural machinery was often imported. However, economic comparisons were rarely made, including the level of price support or subsidies that went into these highly productive agriculture systems. [26] Apart from economic considerations, Japanese machinery often proved technically unsuitable. [27]

Since 1980, the picture for Asia has drastically changed. Indonesia and India, once major importers, have become self-sufficient in rice. Other countries have also increased foodcrop production rapidly. The world market prices for traditional foodcrops rapidly fell in the first half of the 1980s. High agricultural subsidy schemes, trade barriers and support prices in EC and Japan have come increasingly under attack in the international political arena, and their consumers and taxpayers increasingly dissent. High support prices and direct and indirect subsidies have made the Japanese agricultural system an inefficient food producer in terms of labor and capital productivity. [28] At the same time, these subsidies are held responsible for adverse impacts on non-farming society, and are even considered a significant factor in the present worldwide economic instability. [29] The EC's pricing policies have led to excessive production at the cost of its taxpayers and consumers and of the developing countries. The latter may have a comparative advantage but are denied free competition in the protected markets. Thailand, however, taxed its paddy farmers heavily when prices were high and competed (and still competes) very efficiently in the world market. Despite its low fertilizer use and low crop yield, Thailand has a record of impressive economic and agricultural annual growth rates (the latter among the highest in the world). [30]

Agricultural development is not synonymous with high crop yield. Extensive farming systems (in terms of yield) may have higher labor productivity than intensive farming systems.[31] Although land scarcity is predominant in Asia, several countries still have large regions where labor is relatively scarce, where land is underutilized, and where some form of mechanization technology is required to achieve full land utilization. Therefore, although for most Asian countries agricultural technology strategy is likely to focus on increased land productivity, mechanization may have priority for Thailand and several other countries or regions. The choice of technology will differ between countries and even between regions within countries (for example, in Indonesia for Java versus the transmigration areas on the outer islands; Northern Thailand versus Northeast Thailand; wet versus dry regions) or between agricultural subsectors (for example, irrigated subsistence rice farming versus plantation type agriculture), depending on the agro-ecological conditions, socio-economic situations, relative scarcity and cost of labor and land, and the level of agricultural prices.

General, broad guidelines for the formulation of an agricultural technology strategy (which includes mechanization) may be summarized as follows. [32/]

(i) Where land is abundant but labor a limiting production factor, mechanization can increase production per worker and the area under cultivation (for example, Northeast Thailand, Malaysia, and transmigration projects in Indonesia).

(ii) Where land is scarce but labor is in surplus, biological and chemical technology such as HYVs and intensive cropping systems should be emphasized to raise land productivity. This situation occurs in many Asian regions (for example, Bangladesh, Sri Lanka, Java [Indonesia], Banawe [Philippines], Kathmandu Valley and the Hills of Nepal). In such cases, certain mechanization technology may be required as a supporting, complementary input to biological and chemical technology (for example, water pumps and pesticide applicators) or to reduce cost of production (for example, when cost for maintaining and operating draft animals is more expensive than mechanical land preparation).

(iii) Where both land and labor are underutilized due to distinct seasonality – for example, under marginal rainfed agricultural production systems as a result of poor soils and low rainfall, semi-arid areas in India, Barani areas in Pakistan, upland areas of Northeast Thailand, and on Flores in Indonesia – mechanization technology is required to eliminate labor shortage bottlenecks (usually for land preparation).

(iv) Where there is a shortage of both labor and land, a combination of labor-saving mechanization and biological and chemical technology should be applied to achieve high productivity of both labor and land (for example, the Republic of Korea and the Republic of China).

(v) Where the cost of traditional power sources such as human labor and draft animals has become high (for example, Malaysia, East Asia), mechanization is required to reduce costs of agricultural production.

(vi) In many developing countries, human labor and draft animals remain a major power source in agricultural production. Proper attention must be given to the introduction of more efficient tools and implements in conjunction with these power sources.

The contention of this chapter is that it is necessary for a developing economy to formulate mechanization policies and strategies to complement national-economic and agricultural development plans and strategies to safeguard the efficient utilization of scarce resources. The content and scope of these policies and strategies depend on the stage of socio-economic and agricultural development, as well as on development priorities. A profound knowledge of the mechanization process, both technical and economic, is a prerequisite in policy and strategy formulation.

In a dynamic economy, policies and strategies are usually subject to periodic review and adjustment. It is therefore futile to develop detailed mechanization strategies or programs beyond a five-year horizon. There is little need to consider policies and strategies of relevance to Stage IV (Cropping System Adaptation) of the mechanization process if the agricultural system is still at the level of Stage I (Stationary Power Substitution). In countries (such as Nepal or Bhutan) where laborers manually hammer stones into gravel for road construction, or where water lifting is done with manually operated scoops (for example, Bangladesh), it is premature to consider mechanized harvesting technology. Discussions concerning farmers' adoption of power rice threshers in Java become irrelevant if a quick calculation indicates that depreciation costs alone on a per hectare basis exceed the costs of manual threshing. Depreciation costs close to US$100 per hectare for a modern combine harvester [33/] may explain why grain harvest is still undertaken manually in Thailand.

NOTES AND REFERENCES TO CHAPTER 4

1/ To facilitate area expansion, adoption of labor productivity-increasing technology has been an important factor in Thailand in increasing agricultural production, in maintaining high agricultural growth rates, and in decreasing rural poverty. (Rijk and van der Meer 1984, pp. 15-16.) In Indonesia, shortages of farm power in several transmigration projects have limited their success. Land is available, but lack of sufficient farm power impedes land area utilization. Large estates, using tractors only for primary soil tillage have managed to attain high production in the same areas (Rijk 1979, pp. 11-12).

2/ For example, India (personal communication with B.K.S. Jain) and Thailand. For the latter see Section 3.1.

3/ Unlike the Republic of Korea and the Republic of China, in Malaysia rapid increase in real wages in the off-farm sector were not accompanied by a planned, vigorous introduction of labor productivity-increasing technology in the agricultural sector. Rapid migration of rural youth to urban areas for more remunerative employment has led to the structural problem of shortage of labor for food crop production. This shortage has led to significant underutilization and abandonment of cultivable land, including irrigated land, with serious consequences for food crop production. Data collected by the Ministry of Agriculture (Malaysia) in 1978 indicated a total of 880,000 hectares in Peninsular Malaysia either lying idle or not fully productive, comprising 154,000 hectares of paddy land (of which 106,000 hectares was totally abandoned) and 726,000 hectares of other cultivable land. Gross margin per hectare was in early 1980 less than one-half and one-third, respectively, compared with rubber and oil palm (Mustapha 1982, pp. 115-121).

4/ For example, labor shortages occur on Indonesia's outer islands in Sumatra, Sulawesi, and Kalimantan, particularly in transmigration areas (Rijk 1979). In NICs such as in the Republic of Korea and the Republic of China, labor-saving technology is becoming increasingly important to maintain cropping intensities or reduce cost of production.

5/ The seven RNAM participating countries are India, Indonesia, Pakistan, the Philippines, the Republic of Korea, Sri Lanka and Thailand. In the Republic of Korea, the government follows a deliberate mechanization policy to increase agricultural production and increase rural labor productivity in order to maintain rural incomes at a par with urban income levels (Gifford and Rijk 1980, p. 20). Also, the Republic of China has actively implemented a mechanization strategy, particularly in more recent years when labor shortages and government strategies for diversification away from rice amplified its need. Centrally planned economies of the USSR and the People's Republic of China have experienced extensive planning and implementation of mechanization programs.

6/ Both Japan and the Republic of Korea pursued a mechanization strategy successfully, including enaction of mechanization promotion laws. In Malaysia, on the other hand, little government attention was addressed to mechanization, resulting in acute labor shortages in rural areas. See also notes 1 and 3. For more examples and further discussion, see Rijk 1979, Gifford and Rijk 1980.

7/ There are many highly diverse components in a mechanization program, including training and education; organization of fuel, spare parts and other supply networks; establishment of local manufacture, land development and consolidation programs; provision of stable feed supplies and health services for draft animals; and development of a network of public or private dealers for the distribution, maintenance and repair of the agricultural machinery. See Stout and Downing 1975, Gifford and Rijk 1980.

8/ Stavis 1978; On Kit Tam 1985, p. 172.

9/ Some European government institutions did get involved at an early stage by importing machinery from more advanced countries like the USA for demonstration and testing. As early as 1870, Japan imported machinery for purposes of testing and evaluation, but it found that western machinery was not suited to Japanese conditions, and efforts were concentrated on biological and chemical technologies.

10/ See also Slicher van Bath 1960.

20/ See Section 3.2 and Appendix 1, Sub-section A1.2.1. Personal communication with Jaruwat Mongkoltanatas, May 1987.

21/ See Section 3.2 and Sub-section 7.2.2 (xii), (xiii).

22/ ADB 1981, Main Report, p. 44.

23/ See also ADB 1978, pp. 183-184. The Survey predicted a foodgrain deficit for the Bank's DMCs between 21 and 46 million tons in 1985.

24/ For the Thai farmer, investment in area expansion through upland development and mechanization was obviously more attractive than using fertilizer and other high yielding technology, as discussed in Sections 2.1 and 3.1. See also Rijk and van der Meer 1984, pp. 23-24.

25/ Withol 1988, pp. 63-66 and pp. 76-78.

26/ Gee-Clough 1985.

27/ Rijk 1983, p. 47. For example, Japanese made paddy transplanters and direct paddy seeders for areas with unreliable water supply, and paddy reaper-binders for varieties susceptible to shedding and lodging. Japanese machines for rice production have been developed for *Japonica* varieties, which have some significantly different properties from the *Indica* varieties confined to tropical monsoon areas.

28/ Van der Meer 1986; van der Meer and Yamada 1986; van der Meer and Yamada 1988.

29/ Critics argue that Japanese farmers' privileges (tax exemption and support prices resulting in high net income) come at the expense of their urban countrymen. Highly profitable agricultural land ownership results in high land prices, which in turn is held responsible for poor housing conditions. High costs of living and food leave less income to be spent on other consumer goods. The focus therefore is on industries for export markets, which in turn creates an excess balance of payments and a strong yen (Chira 1987, pp. 1-2).

30/ World Bank 1988, p. 224, Table 2.

31/ Rijk and van der Meer 1984, pp. 22-23. Usually more extensive farming systems yield higher labor productivity, and intensification of land use comes about under increasing population pressure. See also: Boserup 1965, Boserup 1981, Ruthenberg 1980.

32/ Rijk 1983, page 31. See also ADB 1981, main report p. 35. By reviewing agricultural mechanization in a number of countries over a period of time, Binswanger established a set of generalizations (Binswanger 1986).

33/ Yule, Copland, and O'Callaghan 1988, pp. 25-27. Their data refer to a large combine harvester operated in the United Kingdom.

5

A MODEL FOR MECHANIZATION POLICY AND STRATEGY FORMULATION

5.1 REVIEW OF EXISTING METHODOLOGIES

Planning methodologies have been developed for many sectors and subsectors of the economy, but little attention has been directed to systematic quantitative procedures for the formulation of mechanization policies, strategies, programs or projects for developing countries. Similarly, models have been applied to solve questions of economic policy and agricultural development, but little work has been directed towards models to support mechanization and policy strategy formulation for developing countries. This section reviews relevant work undertaken to establish the basic requirements for the proposed model.

Projections were made of future changes in agricultural mechanization for member countries of the United Nations Economic Commission for Europe (ECE). These projections are qualitative and based on extrapolation of trends and technological development. [1/] In order to obtain comparable information from a uniform approach, the ECE's Group of Experts on Mechanization of Agriculture adopted Nowacki's Energistic Method of Model Forecasting of Agricultural Mechanization Development at their 20th session (in 1974). [2/] His method evaluates the energy efficiency of mechanization at different mechanization levels. He characterizes the level of mechanization by an index (W) which represents the percentage of machine work relative to the sum of manual and machine work, expressed in energy units. Several characteristic parameters (for example, labor input, productivity of labor and machines) are described as a function of W, and the functions are subsequently solved on an electronic analog computer. The analog model provides quick and easy projection of changes in macro indicators, although it does not provide for experimentation with price variables and changes in technical coefficients as a result of innovation. Moreover, the approach assumes that energy inputs from different origins are of equal quality.

In order to support agricultural planning in developing countries, an approach emerged in the 1960s based on horsepower (or kilowatt) ratio per hectare. Fundamental to this approach was the view that the optimum level for farm power in developing countries was 0.37-0.59 kW (0.5-0.8 hp) per hectare.[3] It is strongly recommended that this approach be discontinued because of the following reasons:

(i) The kilowatt (or horsepower) per hectare measure as a power requirement is erroneous since it does not include a time dimension. It represents a *stock* concept rather than a *flow* concept. [4] Even if the approach in itself was appropriate, kilowatt-hours or joule should be used to represent the actual power input.

(ii) Manual, animal, and mechanical power do not produce power which has equal application for all operations. The timing constraint or power demand during a peak period may affect the choice of power source, while manual, animal and mechanical power represent different technologies and may result in different production methods.

(iii) The optimum of 0.37-0.59 kW per hectare was derived by plotting data from countries with different resource endowments and levels of economic development, erroneously assuming a causal relation between available power and yield. [5]

Moens and Wanders made a projection of the demand for agricultural machinery in Mali covering the period 1983-2000.[6] Machinery increase was projected on the basis of (i) the planned increase in food production laid down in the national development plan; (ii) the expected growth in population and urbanization; and (iii) the increase in area, yield and number of farms. Technical parameters (norms) were applied, particularly hectare coverage by machine and estimation of the percentage of farms expected to acquire the machines over the period under consideration. The study did not include economic factors (for example, change in relative cost of draft animals and labor versus mechanical technology) or relative changes in produce prices. This approach is typical for centrally planned economies, whereby the government (rather than the private sector) actively implements the mechanization program as part of the agricultural sector plan (or rather, implementing agencies pursue the quantitative goals set by the central government for the planning period).

In centrally governed economies, emphasis is put on organization of production factors to achieve centrally planned goals and production targets. For the latter, the required capital (machinery) can be calculated applying technical coefficients and levels of scarce resources. The development of the previously discussed Nowacki method in Poland may be seen in this context. This approach of planning for mechanization may not have the desired effects. It may even have adverse effects on social and economic development (see Chapter 4), or be unresponsive to changing economic conditions during the planning period. In a market economy, decision making by individual entrepreneurs (including farmers) is governed by income and profit maximization, while physical output level is of secondary consideration, such as is the case in Thailand. [7/]

For the short to medium term, the Moens and Wanders approach in Mali can also be used by manufacturers and dealers of machinery to estimate demand and to adjust production capacity. However, as experienced with investment in the power tiller manufacturing capacity in India (see Section 4.1), this method must be used with caution. The methodology should not be applied for periods covering more than a few years, and preferably only for marketing type studies to estimate sales prospects, with adjustments to be made periodically on actual achievements. When large investments are proposed in manufacturing capacity for new technology which does not yet have a proven (domestic) market, maximum flexibility should be maintained to avoid medium- to long-term implications of ill-conceived investments. Even in established markets (like Thailand), changes in economic conditions have significant effects on the demand for machines (see Chapter 3).

None of the above methods included evaluation of policy effects or experimentation with changes in economic conditions on the demand for machinery, mainly because non-use of computerized routines made it impractical to analyze alternative scenarios. Computers have also been used to analyze the effects of mechanization. In the early 1960s, LP techniques were applied for optimum allocation of resources in farm planning for developing countries, including economic evaluation of farm mechanization. [8/] Because of limitations on software and computer capacity, and also because of orientation towards farm management economics, the early LP models used for farm mechanization planning analyses assumed a limited choice of technologies and crops at the micro-level for a single farm. [9] These models usually do not explicitly incorporate substitution possibilities for a variety of machinery options or methods. They focus on maximizing monetary returns for a single farm, subject to a set of constraints on the available resources and the feasible cropping pattern, while mechanization technology choices are limited and implicitly incorporated. Typically, the objective function of these models contains profit per unit crop area assuming the use of a certain type of mechanization technology. Instead of maximizing farm income, some researchers have considered other objective functions. A model used by Muchiri in Kenya maximizes the production of maize. [10] Multiple-goal LP techniques have been developed to analyze the effect of a set of macro economic goals. [11]

Further development of software and increase in computer capacity have facilitated construction of larger models for mechanization analyses. In the Yuchen region in Shandong province of northern People's Republic of China, the University of Hawaii used an LP model for assessing machinery requirements to slacken the demand for labor during peak periods. [12] Van Niejenhuis developed an LP model to investigate economic advantages of cooperation between farms by sharing machinery and labor. [13] Goense used an LP model to optimize farm size and to study prospects for mechanized farming on a hypothetical farm in the Zanderij area of Suriname growing maize and groundnuts. [14] For the individual farm, integer LP techniques are applied to select an optimal set of equipment. [15] Other modeling techniques simulate machine systems and optimize machinery investments to support decision making at the operational level. [16] Simulation models for mechanization are typically designed for a single (model) farm with a limited flexibility in crop rotation or machinery and labor resources, and the models are applied for the scheduling of mechanized operations and to optimize the required machinery capacities or cropping patterns. [17]

Little work has been done on models which allow for the flexibility and analyses needed for agricultural mechanization policy and strategy formulation at the aggregated or sector level. Siswosumari applied a simulation model to formulate a farm mechanization plan for the Jatiluhur irrigation scheme (Indonesia). [18] His model ignored economic aspects, considered merely technical factors, and assumed that cropping intensities would be maximized from a technical point of view, with the power gap to be supplied by single-axle tractors.

5.2 THE MECHANIZATION MODEL (MECHMOD)

5.2.1 The Purpose of MECHMOD and Design Criteria

As explained in Chapter 2, the reasons for agricultural mechanization in a market environment are economic: namely, change in the cost of labor relative to the cost of using machines. In economic terminology, this causes a move along the isoquant for labor and capital (machinery) inputs, or factor substitution (see Figure 2.2, Sub-section 2.1.1). Innovations (technical change) will move the isoquant towards the origin (see Figure 2.1, Section 2.1).

In the first part of this chapter, a review of the methods used to assess progress with mechanization identified one or several of the following principal shortcomings: (i) most approaches are technically inspired and do not include the effect of economic changes; (ii) factor substitutions through alternative mechanization options are not explicitly included; (iii) the methods do not provide for a quick evaluation of changes in economic conditions or evaluation of policy effects; and (iv) the models are limited to a single farm or micro level farm management economics rather than evaluating the sector as a whole. In the remaining part of this chapter, a model is therefore formulated to overcome these shortcomings.

The purpose of a model should be clearly defined prior to selection of modeling technique and formulation, construction, and collection of required input data. A clear understanding of the model's purpose and its limitations may prevent the modeling exercise from exhausting available computer and personnel resources. In general, one or more of the following purposes of a model may be considered: (i) to describe the relationship between variables; (ii) to predict or project the value of variables into the future; (iii) to analyze the effects of policy scenarios (particularly global and indicative analysis); (iv) to support the decision making process for policy measures; and (v) to evaluate the effect of policy decisions and to make adjustments for inclusion of new and additional information. [19]

The objectives of developing the farm mechanization model (MECHMOD) are to better understand the process of mechanization and to analyze the effects of change in technical conditions (for example, innovation), economic variables, and crop area expansion on the demand for mechanization technology and labor utilization. MECHMOD will help explain farmers' reactions to external changes and will support the formulation of mechanization policy and strategy. [20] Rather than providing the optimal solution, given a set of limited resources, prices and available technology, MECHMOD's main purpose is to study the effect of change in technical and economic variables and policy measures on the agricultural mechanization process.

Keeping in mind the purpose of this study, some additional criteria for MECHMOD are important: (i) It must be possible to construct the major part of MECHMOD from data readily available. Further information and data may be required, but they should not require extensive surveying. (ii) MECHMOD's underlying principles should be understood by planners and decision makers, who should be able to experiment with it and interpret results. (iii) MECHMOD must provide meaningful answers to the common questions engineers, planners and decision makers are likely to ask. (iv) MECHMOD should have broad application and therefore be flexible and easily adjustable to a range of different situations, and new information should be easily included. [21/]

5.2.2 The Features and Rationale of MECHMOD

A model represents only part of a complex reality and aims at better understanding of the functioning of a complex system. A *mathematical* model is one of a large variety of models that can be distinguished. A distinction can be made between *simulation* and *optimalization* models, even though this distinction cannot always be clearly maintained. Another classification in models relates to time dimension. A *static* model does not interact with the outcome of the model at a later time. In a *dynamic* model, the present output of the model has an effect on future behavior or outcome. [22/] Another distinction important for this study relates to a model for a micro-unit (namely, a single production unit such as a farm) or a model for a region, or a sector or subsector.

MECHMOD is a *partial* model for the farm mechanization subsector. It is aggregated at the regional level and does not have the features of a comprehensive economic sector model. It does not include specification of the market environment (for example, product supply and demand functions, statements about price elasticities, variations in marketing and processing cost). Except for the effect of utilization rate on the cost of mechanization, input and output prices are exogenous variables to MECHMOD. [23/]

MECHMOD is a flexible mechanism for indicating how farmers' demand for mechanization technology is affected by increase or decrease in area, by changing technical coefficients (as a result of technical innovation), and by changing economic variables. These variables are an input for MECHMOD (*exogenous variables*). [24] The effect of changes of these exogenous variables on the demand for machinery and agricultural labor (*endogenous variables*) may be studied with MECHMOD. [25] The value of the exogenous variables may be estimated or obtained from projections or from other models – for example, from price projections for machinery and fuel (*uncontrollable exogenous variables*) – or given as policy decisions (*controllable exogenous variables*), such as interest rates on institutional credit, minimum wage rates, or subsidies or taxes on machinery. The farmers' aim is to maximize net revenue (*status variable*) to the farm household, assuming financial price expectations for inputs and outputs and an opportunity cost for family labor. In MECHMOD, the demand for labor, draft animals and machinery is specified according to major crops and key farm operations to be performed within a specified period of time. Within certain limitations, the farmholding family has several options (decision variables or endogenous variables): (i) working on their own farm versus off-farm work; (ii) hiring labor for farm operations; (iii) employing draft animals; and (iv) using various machinery.

The process outlined above is limited by available land. Availability of some types of farm power is also limited (for example, family labor), but the principal feature of MECHMOD is that it allows for factor substitution: Machinery may substitute for labor and draft animals.

A choice was necessary between modeling a representative farm unit or the aggregate regional farm sector. [26] MECHMOD's structure allows it to be used (with few modifications) for the smallest production unit. The regional farm sector type approach, however, is applied for the following reasons.

(i) Farm power is highly exchangeable, and the utilization of agricultural machinery in Thailand is seldom restricted to use on the owners' fields. A highly competitive machinery rental market exists, and the acquisition of machines to earn additional income through contract work is common. Farm labor is also highly exchangeable. The representative farm approach results in underutilization of machines. This in turn results in a higher fixed cost (an endogenous variable). Total machinery requirements are therefore more realistic in the case of the aggregate regional farm sector than the application of MECHMOD to a single representative farm.

(ii) It is rather difficult to group farms meaningfully by class. Thai agricultural statistics classify farms by size, but grouping farms based on land area is arbitrary since land type is more relevant to decision making than is farm size. Grouping according to technological opportunities (namely, crop production characteristics) is therefore more appropriate, and this approach has been followed in MECHMOD.

MECHMOD's features are typical for a *partial*, *normative* (or *prescriptive*), and *static* (or *single-stage*) model. [27] Given the type of data available and the formulation of the problem, LP is a logical choice of technique for agricultural models, and for MECHMOD in particular. [28] The advantage of an LP model is the fashion in which it presents technological and financial information and its flexibility once this information is modified. Parametric programming techniques provide the necessary evaluation under variable external conditions, change in technical coefficients, and impact of policy instruments. MECHMOD helps explain farmers' reaction to external changes and therefore may also be considered *positive* or *descriptive*. [29]

5.2.3 MECHMOD's Basic Structure

MECHMOD's basic structure consists of a LP tableau which imitates a multiple cropping system. Each crop requires certain period-specific field operations. These operations can be performed following certain methods, and each method requires a combination of men, draft animals, or machines (for further details, see Section 5.3). The principles and application of LP to agriculture are well documented and are not further discussed here. [30] A LP tableau consists of *activities*, *constraints*, and an *objective function*. The objective function is maximized in MECHMOD. For MECHMOD, typical LP activities include farm power technology choice (draft animals, hired labor, or machinery). Typical resource constraints are available land, available labor, and available draft animals. Although capital is scarce in the economic sense, it is mobile, and its scarcity is represented in MECHMOD by applying an exogenous lending rate. Since MECHMOD represents farmers' decision making, financial prices are used. Matrix coefficients (or input/output coefficients), represent the demand for farm machinery, labor, and draft animals. The multiple cropping farming system requires that the activities and resource constraints are specified by period.

In the LP tableau, a number of miscellaneous restrictions and equations (rows) are included. *Sequence rows* ensure that farm operations are performed in the proper sequence, *area balance rows* ensure that farm operations are balanced, and *supply and demand rows* assure that appropriate farm power is provided (hiring labor, off-farm work, and engaging machines; or *farm power transfer rows*). *Disposal* or *slack activities* are also included to allow for non-use of resources. Figure 5.1 represents a schematic simplification of the LP tableau. Appendix 2 provides a detailed mathematical formulation of the LP model. Section 5.3 discusses the data input for activities, resources, and objective function for MECHMOD's case study of the Central Region of Thailand.

5.2.4 The Software

Standard computer software is available to solve the LP tableau (matrix) and usually has options for post-optimality analysis. The modeller's major task is translating the problem into a matrix, including calculation of the matrix coefficients, and inputting the matrix elements to the software in a prescribed format. For models which include multiple cropping systems with different options on resource utilization and technologies and variation in timing of activities, the matrix becomes large and complex and is difficult to construct. [31/] The matrix may need to be modified frequently for models used for policy experiments under different economic and technological scenarios. Manual data input then becomes so time consuming and error prone that it becomes impractical. A matrix generator program may be written to calculate the coefficients from the basic input data (for example, resource availability, return per unit area, and input-output coefficients) and construct the matrix according to the model formulation. Writing the matrix generator software for a comprehensive model is a major task, usually provides for little flexibility, and therefore limits experimentation. It also requires vast experience in computer programming, and time and budget constraints become limiting factors. To reduce the problems in writing matrix generator software, special matrix generator languages have been developed. These languages drastically reduce the amount of computer code to be written, although they often have limitations in expressing model formulation as compared with standard computer programming languages. The main program for MECHMOD has been written in MGG [32/], a high-level language for mathematical programming. Running this MGG written program produces a matrix generator (MG) program in Formula Translator (FORTRAN) source code from an algebraic type formulation of MECHMOD. [33/] Because of the

Figure 5.1. Simplified schematic representation of MECHMOD's LP tableau for a single crop, one operation, three methods, and one period.

	Activities	Period 1						Animal/Machinery Required			
			Operation 1								
	Constraints	Area of Crop 1	Method 1 Manual	Method 2 Animal	Method 3 Tractor	Hours Off-farm Work	Hours Hired Labor	Total Draft Animals	Total Tractors	Total Plows	Right Hand Side
Period 1	Land	+1									≤ RR: Total Land Area
	Labor hours		$+RT^1$	$+RT^2$	$+RT^3$	+1	−1				≤ RR (TR): Total Family Labor
	Animal hours			$+RT^2$				−UT'			≤ 0 : TR
	Tractor hours				$+RT^3$				−UT"		≤ 0 : TR
	Plow hours				$+RT^3$					−UT"'	≤ 0 : RT
	Bounds	UB LB				UB	UB	UB			
	Objective	+$			−V$	+$	−$	−F$	−F$	−F$	= Maximized Income

Notes: + indicates use; − indicates supply
RT = *reference time*; UT = *usable time* (for definitions, see Sub-section 5.3.4)
UB is *upper bound* or maximum value of activity allowed or feasible
LB is *lower bound* or minimum value of activity allowed or feasible
+$ is cash income; −$ is cash cost; −V$ is variable cost; −F$ is fixed cost
RR is resource restriction; TR is a transfer row
See also Sub-sections 5.3.6 and 5.3.7.

conversion of the model formulation into a standard language (FORTRAN), complex formulations and front-end calculations can be included and the program can run on a large variety of computers. The MG program can read data files, calculate the matrix coefficients in front-end subroutines, and produce files in Mathematical Programming System (MPS) format. MPS provides the input for the LP matrix solver (in this case, Sciconic). In addition, MGG produces the framework of a report writer program (RW) which combines the output of Sciconic LP software and user-written subroutines to produce output in a readily accessible format. [34/] MECHMOD was developed and implemented on the DEC/VAX/VMS [35/] mainframe computer system of the Wageningen Agricultural University. Figure 5.2 provides the schematic application of the Scicon software, user written subroutines, input data, and output files. [36/] The WOFOST program generates a daily rainfall pattern and is discussed in Sub-section 5.3.4.

Input of additional programming expertise can make MECHMOD more user-friendly, so that the user does not require programming skills, knowledge of linear LP, or even understanding of MECHMOD's principles. The danger of this is that MECHMOD becomes a black box to a layman-user who, unaware of MECHMOD's strength and limitations, applies the package regardless of situation-specific requirements and, therefore, likely misinterprets its results.

5.3 APPLICATION OF MECHMOD TO THE CENTRAL REGION OF THAILAND

The basic geographical divisions in Thailand consist of the Northern, the Central, the Northeastern, and the Southern Regions. MECHMOD has been applied to the Central Region of Thailand to assess its performance and conduct experiments [37/] (see Map, p. 173). The Central Region contains one-fifth of the land area of Thailand and slightly over one-fifth of land in farm holdings. Of the total population of about 55 million, about 20 per cent live in the Central Region (excluding Bangkok Metropolis which accounts for slightly over 10 per cent of Thailand's population). Disaggregation to the regional level reduces the aggregation bias, and the Central Region was chosen since mechanization is most advanced in this region and accounts for about two-thirds of the land receiving dry season irrigation. Rural seasonal migration between the Northeastern and Central Region was accounted for in the model through the labor hiring and off-farm working activity. [38/] Other model constraints are considered confined to the region. In the early stage of mechanization, two-axle tractors often traveled widely,

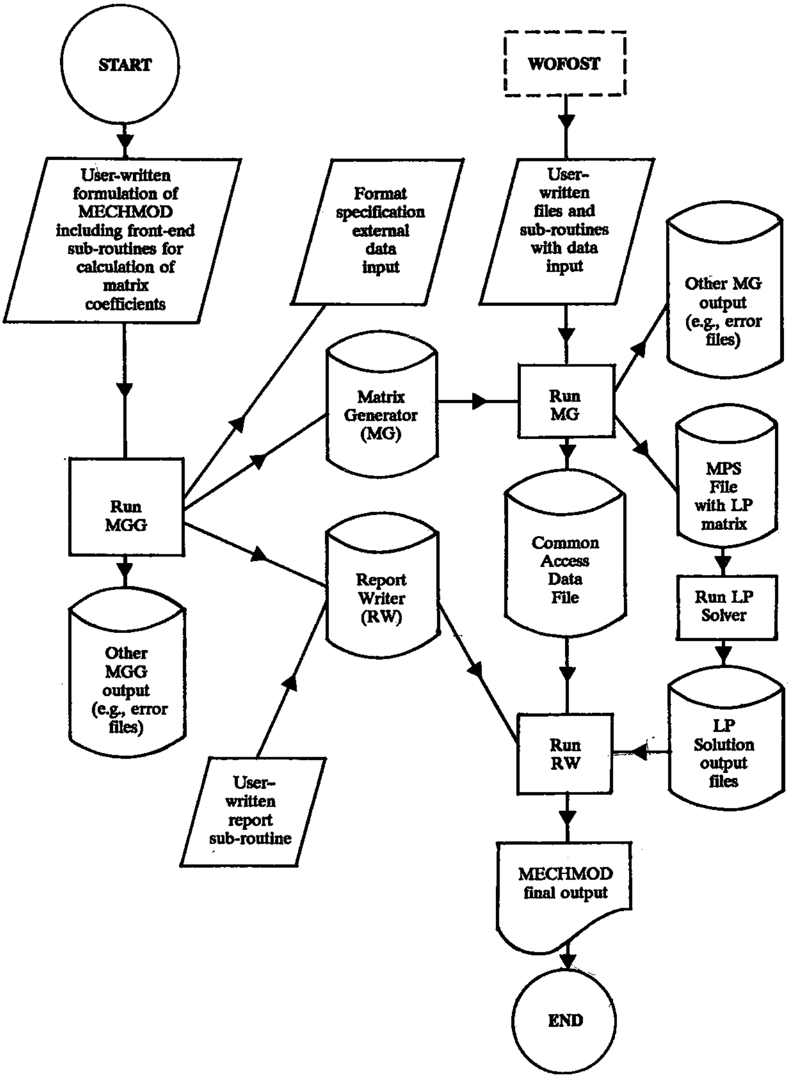


Figure 5.2. Flow chart for running MECHMOD using MGG/SCICONIC software, user-written sub-routines and data input.

crossing provincial borders to undertake contract work. [39] With the rapid expansion of machinery stock, however, this practice is no longer of relevance to the formulation of the model. [40] It is therefore superfluous to link the regions in MECHMOD through a multi-divisional LP model.

5.3.1 Crops Explicitly Considered

In order to keep the LP matrix within manageable proportions, only crops which occupy at least 5 per cent of total farm holding area are explicitly specified in the model. For the Central Region, these crops include paddy, maize, sorghum, cassava, and sugarcane. They are referred to as *model crops* and cover close to 90 per cent of the area studied. [41] Other products (not explicitly specified in MECHMOD) are referred to as *non-model crops* (fruits and vegetables, cotton, kenaf, livestock). For model crops, further subdivisions are made because of significantly different growing seasons, technologies, or cropping techniques. For example, a planted sugarcane crop has a different growing period, farmpower input, and yield compared with a ratoon crop. The planted cane and ratoon crops are therefore represented in the model as different crops. Thus, for the Central Region, 13 different crops are explicitly specified. Detailed information on these model crops is provided in Appendix 3.

5.3.2 Farm Operations, Working Methods, Labor, Draft Animal and Machine Requirements

MECHMOD represents the farmer decisions concerning selection of farm power input (specifically, the human, draft animal, or machinery). Given the specific farm operations required for a crop, MECHMOD selects the optimal method and specifies labor, draft animal, and machine requirements. For the Central Region, MECHMOD distinguishes a maximum of six different operations per crop; namely, paddy seedbed preparation, land preparation, planting, cropcare, harvest, and threshing. In addition, MECHMOD considers a total of 13 different methods and 21 different power sources. Taking into account the technical feasibility, certain combinations of laborers, draft animals, and machines (also called elements) are required to perform an operation following a certain method. [42] These methods and requirements represent key mechanization options for the Central Region, assuming certain simplifications. For example, for land preparation with two-axle tractors, only "plow" is specified without further distinction among disc plow, disc tiller (poly disc), or disc harrow. MECHMOD is highly flexible and can easily accommodate such specifications. However, because this rapidly increases computer run time and this detail is not required at the aggregate planning and policy level, "plow" simply refers to the group of land preparation implements used in combination with big two-axle tractors for primary land preparation. [43/] For each operation following a certain method on a specific crop, the input of an element in hours per unit area is obtained from farm management data, and total variable cost is calculated per unit area. Farm power input per element is therefore specified as to crop, operation, and method. These data are presented in Appendix 3.

5.3.3 Timing of Operations and Timeliness

Most field operations on crops have to be performed during a certain period. To cater for the temporal element of cropping and resource usage, MECHMOD divides a year into 24 calendar periods of equal lengths. For a region as a whole, the period during which an operation must be performed may be rather flexible (for example, two months), but on a certain field the optimum period for an operation may be much shorter, particularly if high cropping intensities must be achieved. For a single crop operation, comprehensive scheduling models are developed to support operational decisions at the farm level, [44/] but these scheduling techniques are complex and of little relevance to aggregated planning and policy models, such as MECHMOD.

Applying climatological factors and theoretical crop production models, the optimum date for a farm operation may be established. A function may be included to represent the economic benefit of timeliness. This function indicates the effect of reduction in crop value due to losses in yield, harvesting, marketing, and quality. [45/] The benefit of timely operation is compared with the higher costs associated with peak capacity. Inclusion of a timeliness function in MECHMOD requires detailed meteorological information and data concerning the effects of untimely operations on yield and loss. The timeliness function is highly specific to crop, variety, soil type, and other local conditions. In multiple cropping systems, particularly those with limited water supply, the possibility of growing an extra crop often affects timing of operations due to the dominant effect on total farm production. [46/] A single timeliness function for a crop in a regional model therefore becomes meaningless, and the date required to establish the timeliness function is unavailable. [47/] In MECHMOD, the calendar of farm operations is flexible within present farm management practices to allow for optimal allocation of power sources. MECHMOD schedules the operation within the allowed time period of the given cropping calendar (see Appendix 3).

5.3.4 Resources

Following LP terminology, MECHMOD considers three distinct resources: land, labor, and draft animals. [48] Although capital is also a resource, in MECHMOD capital for mechanization investment is available at the cost of the lending rate, an exogenous variable. This approach is acceptable, since investment in agricultural machinery in Thailand is insignificant compared with total capital investments, and therefore mechanization investments have no effect on the lending rate.[49] Within each of the three major resources, sub-resources are considered: for example, irrigated paddy land, deepwater paddy land, aggregate family labor, and male family labor. Because of the seasonality of agriculture and incidence of multiple cropping, these resource constraints are specified per calendar period.

Resources dedicated to farm activities not explicitly specified in MECHMOD (namely, non-model crops, general farm activities) are subtracted from total resources in front-end subroutines. For land resources, the area occupied by non-model crops can be obtained from agricultural statistics. For labor involved in crops, the average labor input per unit area of non-model crop is estimated. [50]

(a) Land

Four land capability types are distinguished in MECHMOD. [51]

Type I : Bunded lowland (paddy land) capable of producing only one crop per year (Major Rice). [52]

Type II : Irrigated bunded lowland capable of producing two paddy crops per year (Major Rice and Second Rice).

Type III : For the Central Region (and Lower North), paddy land subject to severe flooding and therefore suitable only for deepwater paddy must be distinguished from other paddy land. This flooding limits the choice of technology for farm operations (deepwater paddy is broadcast and cannot be harvested with heavy machines).

Type IV : Upland used for field crops (upland crops).

The various land resources are derived from crop area statistics and are presented in Table A4.1, Appendix 4. The area of each land type is not necessarily fixed over time because investments in land development and irrigation may transfer land from Type I to Type II, or from Type IV to Type I, while forest land may be developed into agricultural land. These trends in land development depend on economic and political factors (for example, EC cassava quota, government expenditure for irrigation projects) and are treated as exogenous variables. During the experiments, the effects of different land development scenarios on the demand for mechanization are explored.

(b) Labor

The labor resource is of paramount importance to MECHMOD since its availability and cost are a main cause for mechanization. MECHMOD assumes that farming is usually undertaken with family labor. The family farm is a dominant characteristic of the Thai agricultural sector. [53] Family labor constraints may be relaxed by hiring labor or machines.

The National Statistical Office provides information on the agricultural labor force in its Agricultural Census and semi-annual Labor Force Surveys. Several studies have been undertaken to estimate labor input in Thai agriculture. Corsel reviewed these studies and assessed the number of employed persons in agriculture by region. [54] Rather than concentrating on the number of employed persons, MECHMOD focuses on the man-hours available per period for crop production. Studies on labor utilization provide these man-hour estimates. [55] For some farm operations, the physical or mental workload is such that labor from men, women, children, or aged workers cannot be considered equally. It is therefore proposed that weighting factors be applied. Other operations require skill rather than strength. In these cases, the application of weighting factors would underestimate the labor resource. Since there is no general agreement as to the value of weighting factors, some authors recommend applying the actual working hours indiscriminately, unadjusted for sex or age.[56] In MECHMOD, however, heavy physical work (such as sugarcane harvesting or working with draft animals) and machine operation are performed by male workers 25-54 years of age. Therefore, a distinction is made between ***aggregate family labor*** (total family labor in the Central Region) and ***male family labor*** (25-54 years), each with a different opportunity cost. [57/] The same distinction is made for hired labor and off-farm work.

The definition of agricultural labor force is broad in Thailand. Farm households provide most labor by far, with little employee contribution. [58/] The definition of a farmer or holder includes all those operating areas of two or more rai (0.32 ha), or who have 100 or more chickens or ducks. [59/] The distinction between family and hired labor therefore has limited value, since much of the family labor may work a large part of the time on other farms as exchange labor or casual labor, or as part-time labor in the non-agricultural sector. For many Thai farmers, agriculture is more of a part-time occupation than in other Asian countries. [60/] The agricultural labor resource is highly flexible, since it depends largely on seasonal earning opportunities and on wage rate differential with non-agricultural work. Furthermore, during the slack season (January to May), the family labor force decreases by 30 per cent due to voluntary dropout from the labor force by young and female workers. [61/] Seasonal migration labor is employed for specific agricultural work from January to April.

For macro-economic or regional planning, it is not unusual to assume that agricultural (family) labor has an opportunity cost or shadow price close to zero, particularly for developing countries with high unemployment. Schultz has argued that this doctrine of agricultural labor of zero value rests on a shaky concept and is inconsistent with relevant data. [62/] These two different views are characteristic of the, respectively, classical and neo-classical view of the role of the agricultural labor force in developing countries. [63/] This matter is of interest to the macro-economic or regional development planner, but not to MECHMOD, since it has little relevance to the private farmer. MECHMOD uses financial prices and assumes that mechanization is a function of wage rate, including opportunity cost of family labor. The rationale for this requires further elaboration and supporting evidence. In Thailand, open unemployment is not significant. Off-farm earning activity is substantial, and too low an opportunity labor cost has often been assumed in the past for project economic analysis. [64/] The underestimation of off-farm earning opportunities was partly responsible for unsuccessful irrigation projects in the 1960s in the Northeastern Region. It was estimated that during the 1972 dry season, only 1.6 per cent of the irrigable land in the Northeast was actually used to grow crops, and similar findings were reported for the Central Plain. [65/] Although technical factors may be partly responsible for this phenomenon [66], farmers' economic rationale is probably the principal cause. A study of a representative irrigation project in Northeast Thailand showed that the average dry season off-farm wage rate was 25 baht per day, while the marginal productivity of labor in dry season irrigated farming was approximately 10 baht per day. [67] The results of the study indicated that earnings derived from activities other than irrigated farming exert a significant and negative influence on the amount of dry season cropping. This is also the case with peanut, a dry season but highly labor intensive crop. In the 1970s, area under peanut decreased despite a doubling in price due to a switch to less labor intensive crops or off-farm employment. From 1977 to 1986, the farmgate price of peanut increased 65 per cent, yet the planted area remained virtually unchanged. [68] This phenomenon may be explained by a more than doubling of the farm wage rate over the same period, as well as the absence of suitable cost-effective mechanization technology. This matter is explained graphically in Figure 5.3.

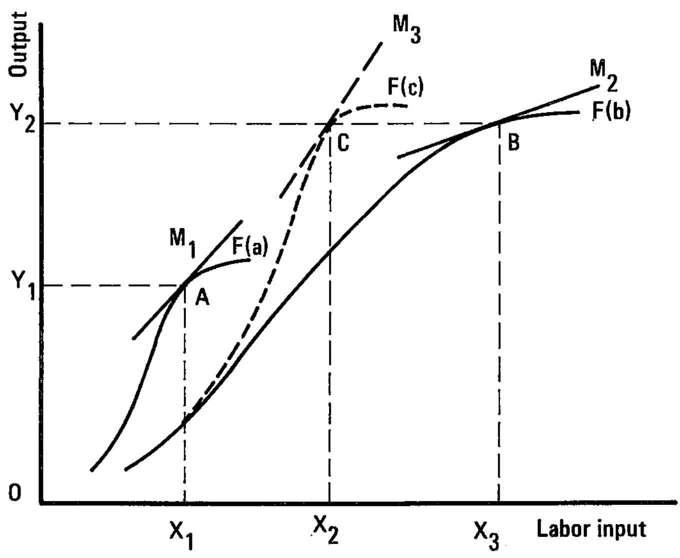


Figure 5.3. Hypothetical production function of different farming systems: traditional farming system F(a); high-yielding technology without mechanization F(b); high-yielding technology with mechanization F(c); and effect on marginal productivity of labor (M).

In Figure 5.3, F(a) represents the hypothetical relationship between labor input and output per unit area under conditions of a traditional or low input technology farming system, such as upland farming in Thailand. F(b) represents the production function under conditions of new technology, such as irrigation and HYVs. For reasons similar to those explained in Figure 2.3, F(b) is, at least initially, less steep than F(a). The tangents M_1 in A and M_2 in B represent the marginal returns to labor. The irrigation scheme may still yield positive financial returns at B, but if returns to labor M_2 are less than what can be earned off-farm, farmers will not adopt the new technology. If, however, labor-saving technology is introduced together with irrigation, thereby changing F(b) to F(c), and if marginal return to labor M_3 is equal or higher than the off-farm wage rate, the new technology is likely to be adopted.

On the basis of the above, in MECHMOD part of the family labor may also opt for working off-farm to earn a cash wage. Since MECHMOD uses financial prices, the opportunity cost of this *exchangeable family labor* is the exogenous wage rate less 10 per cent to reflect the cost of mobilization. Excluded are family members reported in the Agricultural Census who work only on their own farm and are therefore unavailable for off-farm work. These family members have an opportunity wage rate of zero for off-farm work. [69] This portion of the family labor is further referred to as *core family labor*. Data on the agricultural labor force are presented in Table A4.2, Appendix 4.

(c) Draft Animals

In Thailand, swamp buffalo are the only animals used for paddy and field crop production, and traditionally only for land preparation. Unlike in other countries, bullocks in Thailand are used for rural transport but not for fieldwork. The draft buffalo population has rapidly declined since 1978, and census data in this study are therefore adjusted to 1986 figures (Table A1.1, Appendix 1). Increase in draft buffalo population is limited through their natural rate of reproduction, reported at one per cent per annum. [70]

(d) Available Time and Workability

Capacities of the power sources are operation specific and specified in hours per unit area or volume of product (see Appendix 3). Because of the requirements dictated by the cropping calendar, an operation is time-specific and the aggregate demand for the power resources is specified in hours per period. Farm power resources (labor, draft animals, and machines) are therefore transformed to available hours per period. This process includes certain adjustments. Several definitions of time may be considered for comprehensive scheduling models: effective time, waiting time, actual time, set-up time, operating time, service and repair time, total time, and workable time. [71/] This detail of information is unavailable for most of the specific farm operations in developing countries. For MECHMOD, irrelevant time elements have therefore been removed. [72/] MECHMOD applies the following concepts of time.

(i) *Available Time*: the time (in hours) during a period laborers, animals, and machines are available for work, assuming regular hours plus overtime. [73/]

(ii) *Reference Time*: the time (in hours) a person, animal, or machine is required per unit area or volume (rate of operation) under normal circumstances to complete a specific operation. The reference time has been obtained from a large number of studies and is listed in Appendix 3.

(iii) *Machine Availability Factor*: the percentage of the available time that a machine can be operated in the field due to reductions for machine reallocation, service and repair (Appendix 4).

(iv) *Workability Factor*: the percentage of available time the laborers, animals, or machines can work because of weather related factors. The workability factor is period and operation specific [74/] (Appendix 5).

(v) *Usable Time*: the hours per period the power sources can actually be put to work, taking into account the available time to be corrected by the machine availability factor (if applicable) and the workability factor.

The available time (in hours) of family labor per period is derived at as follows. Per annum 1,800 hours are available from a worker (35 hours per week), with 20 per cent overtime allowed for labor during the peak periods of planting and harvesting.[75/] To allow for the high proportion of children in the labor force, 20 percent of the family labor force works only half time.

Due to weather factors, the power source may not be put to use in the field. For example, laborers will not work in the field when it rains, machinery may not be able to operate because of the soil condition (for example, plowing upland fields) or the condition of the crop (for example, moisture content of grain). The usable time of a particular machine may be significantly reduced during the rainy season, and this factor must be considered when establishing machinery requirements.[76/] Also affected is the annual utilization of the machine, thereby increasing its fixed cost per unit area, and thus making it become financially less attractive. For operational scheduling and micro-level mechanization planning models, a differentiation in physical condition is usually made according to soil moisture content and moisture content of product. [77/] This information (differentiated by soil type and product) is usually unavailable in developing countries, and is not relevant to MECHMOD. [78/]

In MECHMOD, correction of available time for weather related factors is obtained as follows. Depending on machinery used and method applied, three *Workability Classes* per period are distinguished. Using rainfall data from Lop Buri (Central Region), a daily rainfall pattern is generated applying WOFOST computer software. [79/] Based on this rainfall pattern, for each period and workability class, a workability factor is calculated, assuming certain rainfall criteria. Depending on working method, one of these three workability factors applies as a measure of workability for a certain period (see Appendix 5).

The machine availability factor (when applicable) and the workability factor reduce the available time, resulting in usable time. Total available time for the family labor resource is further corrected in a front-end subroutine for labor spent on general farm activities, including non-direct production related work such as repair, marketing, and raising livestock. Time spent on general farm activities is estimated at 20 per cent of available time from family labor. [80/] Time spent on care of draft animals is, however, explicitly accounted for in MECHMOD since it is a cost associated with the use of draft animal technology. Total available time for the family labor resource must also be corrected for labor devoted to the production of non-model crops through applying the weighted average labor input required per unit area per period. [81/] For the Central Region, the total area grown to non-model crops is known, and the man-hours required are deducted from per period available time of family labor.

5.3.5 Data Input, Base Year and Projection Period

Published data and other information are considered (for example, agricultural statistics, agricultural census data, and farm management studies), but the availability and reliability of the required input data and other information are subject to severe limitations. Statistics on land resources, land use, crop area, and irrigated area should be treated with caution in Thailand. The description of data may be confusing, data presented by different agencies may be inconsistent, and large annual fluctuations may occur which are unexplained. Land use and crop area are also often underreported. These phenomena relate to existence of significant area of fallow land, the non-registration of squatters, and political factors. Climatological vagaries and changes in crop prices contribute to significant fluctuations in the annually planted area.[82] Data on irrigation should be treated with caution because privately developed schemes may not be included.[83] Many irrigation schemes provide only for supplementary water, rather than facilitating an additional crop.[84] As discussed in Appendix 1, statistical data on agricultural machinery are deficient, and their utilization may easily lead to incorrect conclusions. In many cases, scarcity or non-existence of reliable data requires estimation supported by expert advise. The *base year* run assumes input data of 1986. Whenever required, data are adjusted to the base year, the year for which MECHMOD is validated.

MECHMOD is a static model, but because strategy decisions extend over a period of time, experimentation with MECHMOD includes future projections. Therefore, the resources can be adjusted over the projected time for expected annual growth rates. These growth rates have been varied to show their effect on mechanization over a specified time period.

5.3.6 Matrix Coefficients

The schematic LP tableau (Figure 5.1) is self-explanatory for the position of the non-zero coefficients and their signs. For the "Operation" columns, the coefficients represent the labor, animal, or machine inputs in hours per unit area (reference time) for a specific operation and method. For some operations (namely, shelling and threshing) the reference time is given in hours per ton. For these operations, during the matrix generation process the reference time is transformed to a per unit area basis given the crop yield. Under the "total units animal/machine" columns, the coefficients in the animal supply and demand rows represent usable time from one unit in a specific period.

5.3.7 Objective Function Coefficients

The Objective Function coefficients are expressed in baht (1 dollar is equivalent to about 26 baht depending on exchange rate fluctuations). Yield, farmgate price and cost for inputs are exogenous input variables. MECHMOD assumes that in Thailand the mere use of machinery does not affect yield (see Sub-section 2.2.1). For Thailand's major crops, farmgate prices depend largely on world market prices, and this is an additional factor for assuming the farmgate price exogenous. [85/] For the purpose of future projections, average yield growth rates are applied based on World Bank estimates. [86/] The coefficient under the "crop area" column represents the average yield in physical terms (tons per rai) multiplied by the average farmgate price, minus cost of cash inputs (such as seed, fertilizer and pesticides), but excluding the costs of labor and farm power.

The costs of labor and farm power are explicitly included in the objective function coefficients. The cost of using machinery is broken down in the objective function into variable costs and fixed costs to allow endogenous economies of scale for machinery utilization. The coefficient under the "Operation" columns represents depreciation and the variable costs of a machine (or combination of machines) per unit area, such as cost of fuel, oil and lubricant, repair and service.[87/] The annual fixed cost of draft animal and machine are kept under the columns for total animal and machine requirements. The fixed cost calculation assumes a salvage value of the animal and machines. Interest cost is calculated over average value of the investment. Taxes, subsidies, insurance and shelter assume a percentage of the purchase price. For interest cost calculations, three different sources of finance are considered, each with different interest rates: own finance (savings), institutional credit from BAAC, and suppliers' credit (including hire-purchase arrangements). Institutional credit is available only to finance the investment in locally-made small-scale farm equipment for up to 60 per cent. [88/] Two-axle tractors and other imported equipment are financed through arrangements with suppliers at 40 per cent down payment. [89/] During model experiments, the effect of change in these interest rates and ratios of finance from the three resources is studied. Details on the underlying assumptions for cost calculations and interest rates are presented in Appendix 4.

The opportunity cost for family labor available for off-farm work is included in MECHMOD through the "Off-Farm Work" column (income earning activity). Its coefficient in the objective function represents the exogenous off-farm wage rate per hour. Similarly, the coefficients under the "Hired Labor" column represent the costs of hired labor per hour. The hourly wage rate is differentiated according to period (slack season versus peak season) and puts a premium on male labor 25-54 years old. During the peak season, the wage rate increases by 45 per cent. [20/] Male labor wage rate is an average of 44 per cent higher.[21/]

5.3.8 Flexibility Constraints

Costs, prices and yields are in principle easily quantified, but factors such as lack of knowledge, uncertainty and lethargy defy direct quantification. In order to avoid creating a model too complicated for implementation, Henderson introduced so-called *flexibility constraints*. These include upper and lower limits (also called bounds) on allowable changes for variables due to technical or behavioral factors not explicitly taken into account in the model. [22/] Technical factors include shortage of processing capacity or draft animals (in the short and medium term) and limits on differentiation of land types. Limits reflecting behavioral factors such as lack of know-how, uncertainty, and subjective preferences are more complex. Flexibility constraints are particularly relevant to models which apply recursive programming.

The Centre for World Food Studies (SOW) gives the following rationale using bounds: The natural rate of perennial crop reproduction; limiting processing capacities (for example, sugar mills); some crops require very specific land quality but only a few land types are distinguished in the model; and seed availability and speed of learning process limit the rate of area expansion for certain crops. [23/] In MECHMOD, the annual growth rates allowed for crop area expansion and draft animal population assume the role of flexibility constraints in certain experiments.

5.4 AGGREGATION BIAS AND RELAXATION

In the transition from farm-level to sector-level analysis, an aggregation bias arises because all farms are not alike. Ideally, to cause the aggregation to be correct, a model should be constructed for every individual farm, and the individual models linked together to form a sector model. Since in practice this is infeasible, two approaches may be considered: (i) the sector model is based on representative farms; or (ii) the model assumes aggregate regional or farm type models. [94/] The first approach involves classification of the universe of farms into a smaller number of homogeneous groups, and applies a model for a representative farm from each group. The models' outcomes are then aggregated in the sector model using the number of farms in each group as weights. To limit aggregation bias, this procedure places a high demand on the proper definition of the representative farms and their weighting procedures. The aggregate regional approach involves consolidation of the region's resources and applying the model to these resources as if it were a single large farm.

Modelling the single large farm overstates resource mobility by enabling farms to combine resources in proportions unavailable to them individually. It also carries the implicit assumption that all aggregated farms have equal access to the same production technologies. Aggregation bias therefore always occurs in the upward direction. In order to avoid or minimize aggregation bias, farms are classified into groups or regions defined according to rigid requirements of homogeneity. Day established a comprehensive set of conditions or criteria for classification to avoid aggregation bias: (i) *technological homogeneity*, which means that each farm in a class has the same production possibilities, the same types of resources and constraints, the same levels of technology, and the same levels of managerial ability; (ii) *pecunious proportionality*, which demands that individual farms in a class hold expectations concerning unit activity returns that are proportional; and (iii) *institutional proportionality*, which requires that the constraint vector of the model for each farm be proportional to the constraint vector of the average or aggregate farm. [95/]

Day's requirements are very demanding, and several authors have proposed less stringent conditions. [96/] Some of these are based on the reasoning that an optimal solution of a LP model can be stable even when several coefficients are distorted. This concept is supported by post-optimality analyses which will indicate a range for each coefficient above which it can vary without causing a change in the optimal basis. As long as the farms included in a group have coefficients within the tolerated range of the solution basis of the average farm model, their optimal solution vectors will remain proportional. This approach is experiment-specific because the acceptable ranges for the coefficients are unique for a single optimal solution. Other approaches have been sought to provide methods which minimize rather than eliminate aggregation bias. In practice, the aggregation criteria are usually reduced following a few simple rules. Buckwell and Hazell, for example, suggest grouping farms by agroclimatically similar area or by the type of products produced to ensure a reasonable degree of conformity to Day's requirements of technological and pecunious homogenity.[97] In MECHMOD, these rules result into differentiation by region, family versus hired labor, aggregate versus male labor, land capability type, and crops grown. Moreover, experiments with MECHMOD emphasize relative changes rather than absolute values. For the Central Region study, the aggregation issue is favorably influenced by three factors: (i) Small farm households obtain a significant part of their income from non-farm work, while in general low levels of cash inputs are used, thus reducing the difference in risk perception for farm classes.[98] (ii) No clear evidence exists that small farmers assume a significantly different production process merely because their farms are small. For both rainfed and irrigated rice and even for sugarcane (which requires relatively high cash input), neither yields nor labor and technology usage are significantly related to farm size, while profits per man-day are roughly equal on all farm sizes.[99] (iii) At the regional level, farm size is fairly uniform, and large farm operators are significant only in case of a few typical plantation crops.[100]

As seen in Figure 5.1, the technique of *relaxation* in MECHMOD is applied to the LP tableau,[101] meaning the individual farm power elements (namely, labor, draft animals, and machines) assume the role of LP decision variables rather than the method (or gang). Relaxation reduces the number of decision variables and the number of constraints. However, the solution of a relaxed scheduling model may in some cases be technically infeasible and has led to the conclusion that for operational use, non-relaxed models are preferred.[102] MECHMOD is not meant as a comprehensive scheduling model for operational decisions of the individual farm. MECHMOD provides the number of hours demanded from each power source per half-monthly period at the aggregate level, and it is left to the individual farmer to decide on the hourly scheduling of labor, animal or machine. Moreover, the issue is of little relevance to MECHMOD, since very few machines may be used for operations with different workability factors during the same period. (This is the situation when the infeasibility may occur.) Relaxation is preferred for MECHMOD because it reduces the size of the LP tableau and the computer run time. This is an important consideration, since different scenarios and sensitivities to policy variables require frequent rerunning of MECHMOD.

5.5 DATA VERIFICATION AND MODEL VALIDATION

Input data verification and reconciliation are important prior to the model's validation process. As earlier explained, in most developing countries (including Thailand), data corresponding to MECHMOD's variables may be unreliable, inconsistent, or simply non-existent. However, the experiments performed with MECHMOD focus on relative changes, and therefore consistency of data input is emphasized rather than absolute value. Data consistency relates in particular to technical coefficients of farm power input per unit area, supply of farm power per unit per period, and the costs of farm power. [103/] Farm management studies provide many of the required data, but some data do not exist. For example, mechanized maize harvesting is not at present practiced in Thailand. This means that only estimates can be made on hourly capacity, labor substitution, and operation cost of a maize combine harvester, or data from other countries may be used. In these cases, MECHMOD output must be interpreted as follows: maize harvesters become significant in demand only when the industry supplies a machine with the capacity of "a" rai per hour, cost of "b" baht, and requiring "c" man-hours, whereby, a, b, and c are the estimates. Parametric programming can provide the sensitivity of MECHMOD to a range of these estimates if required.

The validation of MECHMOD involves: (i) comparing MECHMOD's outcome with the actual situation; (ii) improvements of MECHMOD as a consequence of the comparison; and (iii) judgment on MECHMOD's reliability for its stated purposes, including its limitations. [104/] The validation of MECHMOD includes a capacity test (to verify whether or not the constraints and numbers of different machines allow the observed output levels of all crops), the comparison of the marginal costs of different methods, and comparing MECHMOD's farm power input with actual input usage. During this process two distinct phases may be identified: *technical verification* and *behavioral validation*. The first phase involves the elimination of errors made in the formulation of MECHMOD, data files, and user-written front-end input subroutines. Verification of MECHMOD's LP tableau must take place after running MGG, but checking the MPS-formatted output file is tedious and time consuming. Therefore, a program in FORTRAN was written to convert this MPS-file into an output file visualizing the LP formulation into columns, rows and non-zero elements similar to Figure 5.1. The second phase, validation of MECHMOD's behavior, relates to its imitation of the actual situation. For this phase, the LP tableau must be solved, and its solution file transformed into meaningful information. To compare MECHMOD output with actual information and observation, comprehensive output information (written with the report writer sub-routine software) and a complete understanding of the internal mechanism and the effect of input variables are needed. This is time consuming, but the strengths and limitations of MECHMOD become apparent during this process, as further discussed in Sections 5.6 and 7.1.

For comparing the marginal costs of the different methods, the *dual price* of the solution is important. Theoretically, the dual price applies at the equilibrium point and is valid only for infinitely small changes, and therefore has limited value. An example of the dual price for draft animals and various agricultural machinery is presented in Table A6.3. A high dual price of a power source may indicate a bottleneck in the farm power supply, but further analysis is required.

Key input parameters for MECHMOD represent an average situation. For example, the reference time of mechanized land preparation for sugarcane is 1.5 hours. In reality, a range of situations exists: a sugarcane farmer on drought-prone land who wants to plow deep, for example, requires more time per unit area. During a year with delayed rain, land preparation and planting are compressed into a shorter time and thus likely result in more overtime or less thorough tillage than if performed under average conditions. Similarly, the cropping calendar represents the main period during which crops are grown during a common year. It can be expected that some farmers will grow crops outside the intervals dictated by the cropping calendar. [105/] This leads to two conclusions. First, if MECHMOD is applied to an individual farm, the specific data and information of this farm must be used rather than averaged data. Second, additional information on the utilization of sources of farm power may improve or expand the use of MECHMOD, provided this information can be included meaningfully. However, a more complex or larger model does not necessarily give better information, and caution should be exercised when embarking on extensive data collection activities. In Thailand, several detailed farm management studies (including time and motion studies) have been undertaken to provide information on labor expenditure in the agricultural production process. [106/] These data are usually very situation-specific and impractical or too detailed for use in an aggregated model. Moreover, extensive data collection is time consuming and costly. It is not unusual that by the time these data have been collected, the budget has been exhausted and actual analyses are not undertaken, or the data collection exceeds the actual need. [107/] A balance must be maintained between time devoted to detailed farm management studies or baseline surveys, and the analyses and interpretation of the data collected. For the latter, interviews with relevant farmers and relevant key personnel are important to interpret and use statistical data properly.

Increasing the number of subdivisions for crops may also reduce the bias caused by averaging input parameters. For example, paddy crops may be further divided into photoperiod and non-photoperiod varieties, and crops planted over a long time period may be separated into early and late crops. For an irrigated double-cropped area, a subdivision may be made according to timing of irrigation water supply. This requires, however, additional information not readily available. The flexibility of MECHMOD allows such refinements to be included easily, but it should be further ascertained whether the resulting model provides better information or justifies the cost of data collection and computer time.

The validation process includes MECHMOD's outcome to match the actual situation. This requires reliable statistics and other data on the relevant input (for example, statistics on machinery stock) and output information (for example, machinery utilization). Thai agricultural statistics have severe shortcomings, while information on draft animals and machinery utilization is not readily available. This puts a limitation on the validation process. The difficulties encountered with validation may explain why LP techniques are often applied for hypothetical situations or model farms by applying standard data, thereby circumventing many problems of validation by historical data. On the other hand, it can be argued that, rather than aiming at model outcomes which represent reality, in some cases it is more interesting to compare outcomes of the normative models with the actual situation and identify the reasons for differences between optimal model behavior and reality. During the validation process, changes in coefficients or model constraints should be rational and justified. In models for policy analysis, it may often be inappropriate to put constraints on the level of goal variables because it may jeopardize the interpretation of the results. [108/] The same caution applies to inclusion of flexibility constraints which have the purpose of forcing the model to mimic the real world.

For the validation of MECHMOD in the base year run, the values of the input data are presented in Appendices 3 and 4. In Table 5.1, key agricultural statistics on typical agricultural machinery are compared with MECHMOD's output for 1986 (base year).

Considering that MECHMOD explicitly covers about 90 per cent of the crop area reported in the statistics (the remainder are non-paddy crops), the outcome for tractors matches well. The output for threshers and shellers also matches the statistics, which combine all types of threshers and shellers into one figure. Sprayers do not match for two reasons. MECHMOD specifies only motorized back-pack sprayers for herbicide application. Most sprayers reported in the statistics are used for pesticide application, while the motorized sprayers are especially relevant to fruit and tree crops. The draft animal (swamp buffalo) population is about 65 per cent of the number reported in the statistics. Of the total draft animal population reported in the statistics, not all are available for work because female animals are not used when pregnant, and a buffalo can be used for draft purposes only after the third to fourth year.[109] Also, the draft animal population has been rapidly declining in the Central Region (about 10 per cent annually) and many buffalo may already be underutilized. In addition, draft animals are less mobile between farms (little contract work) and therefore prone to aggregation bias.

Table 5.1. MECHMOD's outcome compared to statistical data.

	Statistics [a]	MECHMOD [b]
Draft Animal	140,000	91,766
Single-axle Tractor	172,027	172,657
Big Two-axle Tractor	16,085	13,568
Motor Sprayer	78,908	45,143
Thresher and Sheller	19,496	21,274 [c]

Notes and References:

a/ OAE 1986. Data corrected for base year (1986).
b/ See Appendix 6.
c/ Consisting of 13,990 paddy threshers, 6,301 maize shellers, and 983 sorghum threshers.

The output relating to application of machinery is presented in Appendix 6 for assessing the validity of MECHMOD in the base year. Statistical data do not exist on the application of machinery, but this MECHMOD output is not in disagreement with the broad information contained in various reports, estimates, and expert views. [110/]

5.6 STRENGTH AND LIMITATIONS OF MECHMOD

The strength of MECHMOD lies in its flexibility and its easily understood mechanism. Because of linear programming, MECHMOD emphasizes technical and financial relations, resource constraints, and rationality. However, unlike econometric forecasting, the parameters of the LP model are obtained from various sources independently of the optimization model itself. For example, if farmgate prices of crops or production costs change relative to each other, a shift in cropping pattern may occur or upland may be developed into bunded paddy land. MECHMOD was formulated to allow land utilization to be endogenously optimized together with power sources application. Utilizing this feature, however, proved difficult.

Since crop prices are assumed to be exogenous variables to MECHMOD, an expected price ought to be provided. This projection of the expected crop price requires econometric analysis beyond the scope of this study. Further, it is doubtful whether meaningful crop price forecasting for the short and medium term is feasible for Thailand, where farmgate prices depend largely on the world market and the vagaries of the Thai climate. Forecasting commodity prices is equally difficult. [111/] Also, only a limited number of crops are considered in MECHMOD, while in reality individual farmers react differently to price expectations for a given crop depending on their specific situation. Knowledge and information on price- and cross-elasticities of demand are also not readily available for crops grown in Thailand. Therefore, at the aggregate level, it is impractical (if not impossible) to include a realistic optimization of the cropping pattern endogenously (as an endogenous equilibrium variable). However, the option of optimizing cropping patterns has been retained in MECHMOD and used in Series III experiments (explained in Chapter 6). In other experiments the crop area is an exogenous variable.

The sensitivity of MECHMOD to key variables is reported in Chapter 6. Most LP computer software includes a facility for post-optimality analysis to provide information concerning the stability of the solution. This stability is tested under a condition whereby the effect of a single coefficient is considered, keeping all other coefficients constant, and refers to the degree of variation in the coefficient that can be absorbed before a change in the basis (LP solution) occurs. [112/] Applying this facility to MECHMOD provides a large output of information, but its practical application is limited for two reasons. First, key input variables (for example; fuel price, interest rate and depreciation) are implicitly included in the objective coefficients and applied at different rates for a large number of specific technology options and operations. The calculation of these coefficients takes place in internal front-end sub-routines prior to setting up the LP matrix. Calculating the range for a key input variable after the post-optimality analysis from the coefficient's range proved impractical from a programming point of view because of its implicit occurrence in a large number of coefficients and because of the application of the variable at different rates. One solution to circumvent this problem is to include the input variable explicitly in the LP tableau in a separate column. However, because of its linkage to a large number of methods, the basis will change frequently over a short range of the variable studied, while the information on fixed costs of technology and variable costs of methods is lost. The second reason is that the formulation of MECHMOD (which imitates a multiple cropping system) requires inclusion of a large number of logical constraints (for example, *sequence rows*) and definition constraints (for example, *area balance rows*). The output from the post-optimality analysis also refers to these constraints, but this information is of little practical use. The sensitivity of MECHMOD to changes in key exogenous variables is therefore tested by increasing or decreasing the variable over fixed intervals and rerunning the LP solver. However, with this fixed interval approach, linear interpolations between adjacent solutions may be misleading. [113/]

MECHMOD does not provide information on income to farmers or groups of farmers. This information may be obtained outside the model from farm management studies for representative farms. The objective function value of the solution may give an indication of returns to labor input compared with working off-farm, but it would be speculative to attach a practical meaning to its absolute value because not all costs and returns of farm activities (for example, marketing, growing non-model crops, raising animals) are included in MECHMOD. The relative change of the objective function value of different scenarios gives an indication of the effect on returns to labor input. Similarly, the ratio of crop area to hours-labor-input indicates a trend, but should not be confused with labor productivity, which refers to production and includes yield effects.

The data input file for labor into MECHMOD is in stock terms and distinguishes family labor, hired, aggregate and male labor. Internally, MECHMOD works with farm power input in hours per unit area (reference time) in terms of flow, and power supply in hours per period (usable time) in terms of stock. Thus, the solution file produces information in actual hours input per period and provides information for comparing relative changes of the different scenarios. Transition of this information to employment of the different labor groups has not been attempted because of the explanation provided in Sub-section 5.3.4 regarding labor expenditures not explicitly included in MECHMOD. Therefore, MECHMOD provides information comparing relative changes in labor input (flow concept) of different scenarios, but no absolute information on employment of the different labor groups.

NOTES AND REFERENCES TO CHAPTER 5

1/ Dellenbach and Lehockzky 1973, United Nations 1981.

2/ Nowacki 1968, Nowacki 1978.

3/ UNIDO 1969, pp. 18-25; Giles 1975.

4/ *Stock* represents the availability (potential capacity) at a certain moment in time of a production factor (for example, agricultural land, agricultural labor force). *Flow* refers to actual utilization of the production factor (for example, correction for cropping intensity in the case of land, hours worked per year in agriculture).

5/ Gifford and Rijk 1980, pp. 20-21.

6/ Moens and Wanders 1983. Their projection was initiated ad hoc because an existing study for Mali was considered controversial in the methodology used (personal communication with A. A. Wanders, May 1988).

7/ Adulavidhaya, et al 1979.

8/ Clayton 1963; Odero-Oqwel and Clayton 1973; Heyer 1971, p. 55-67; Adema 1980; Muteba 1979; Kinsey 1980.

9/ For example, the LP model used by Adema was limited to a maximum of only 100 columns and 50 rows (Adema 1980, p. 45).

10/ Muchiri 1980.

11/ De Wit, et al 1988; Spronk and Veneklaas 1983.

12/ Singh, Nagarajan and Wang 1984.

13/ Van Niejenhuis 1981.

14/ Goense 1987.

15/ Rahman and Wicks 1985.

16/ Singh 1978, van Elderen 1977, Kjelgaard and Wu 1983, Ozkam and Edwards 1983.

17/ Van Elderen 1987, Wijngaard 1988.

18/ Siswosumario 1983.

19/ Oskam 1985.

20/ More specific output wanted from MECHMOD may include: At what levels of wage rates, borrowing costs, operation costs, or acquisition costs may a new technology be widely adopted? What is the effect of interest rate and fuel price on the demand for mechanical technology and labor absorption? What is the maximum price farmers are willing to pay for a machine with certain technical specifications? What is the effect of technical innovation on the process of mechanization? What is the effect of extension and better repair and maintenance on the machinery stock? What is the effect of a minimum wage rate on the labor/machine substitution process?

21/ Wicks 1979.

22/ Oskam and Thijssen 1987.

23/ An additional justification for the latter is that in Thailand, farmgate prices are not considered endogenous at the regional level for the crops included in MECHMOD because they are major export crops and therefore their farmgate price depends largely on demand and supply of the world market.

24/ *Endogenous variables* are variables inside the system boundary. *Exogenous variables* are outside the system boundary but act on the system. See Ward 1985, pp. 1-3.

25/ This may be considered a form of simulation (Agrawal and Heady 1972, pp. 80-84 and pp. 262-263),

26/ Aggregate or aggregation in this study means the collective, or sum of items, units, or areas into the whole (see *Webster's Ninth New College Dictionary* 1984, p. 69). It therefore has a broader meaning than Wijngaard's definition, which refers only to extension of the length of the planning period for scheduling models (see p. 2 in Wijngaard 1988).

27/ For a *normative* or *prescriptive* model, a set of norms is formulated, including incorporation of the farmers' objectives or decision rules, which in the case of MECHMOD is maximization of family income. A *positive* model does not require prior definition of norms, but attempts to simulate what farmers actually do through estimation of coefficients from empirical data (Wicks 1979, pp. 2-3). Unlike a *static* or *single-stage* model, a *recursive programming* model can be defined as "a sequence of optimization problems in which one or more parameters or coefficients in any problem in the sequence are functionally dependent on the optimal variables of preceding members of the sequence" (Day 1963b).

28/ Hazell and Norton 1986, pp. 3-4.; Wicks 1979. Following the conditions for an LP model, there are eight assumptions concerning the nature of the production process: (i) *Optimization*. An objective function is either maximized or minimized. (ii) *Fixedness*. At least one constraint has a non-zero right-hand side coefficient. (iii) *Finiteness*. There is a finite number of activities and constraints to be considered. (iv) *Determinism*. All matrix coefficients in the model are assumed to be known constants. (v) *Continuity*. Resources can be used and activities produced in quantities that are fractional units. (vi) *Homogenity*. All units of the same resource or activity are identical. (vii) *Additivity*. The activities are assumed to be additive in the sense that when two or more are used, their total product is the sum of their individual products. This means no interaction effects between activities are permitted. (viii) *Proportionality*. The gross margin and resource requirements per unit of activity are assumed to be constant regardless of the level of the activity used. However, while these stringent assumptions must hold for all rows and columns of an LP model, they do not have to hold for describing the farm production process, and ingenious methods exist to increase the flexibility of an LP model without violating the above assumptions (see for example Hazell and Norton 1986, pp. 13-14).

29/ Hazell and Norton 1986, p. 5, Section 7.2, and Chapter 12.

30/ Hadley 1973, Hillier and Lieberman 1969, van Beek and Hendriks 1983, Beneke and Winterboer 1973, Agrawal and Heady 1972, Hazell and Norton 1986.

31/ Depending on the experiment performed, MECHMOD's LP tableau consists of about 1,000 rows by 1,200 columns. Much effort has been made to make MECHMOD's tableau as compact as possible.

32/ MGG originates from Matrix-Generator-Generator.

33/ SCICON 1985.

34/ SCICON 1986. For further details on the development of the user-written software and implementation of MECHMOD, see Kavelaars 1988.

35/ DEC is an abbreviation for Digital Equipment Corporation, VAX for Virtual Address Extention, VMS for Virtual Memory Operating System.

36/ The complete program and input data files are available at the Department of Agricultural Engineering and Physics, Wageningen Agricultural University, Netherlands.

37/ The regional boundaries for MECHMOD follow the common classification in Thailand: Northeastern, Northern, Central and Southern (see Map, p. 173).

38/ Panpiemras and Krusuansombat 1985, pp. 303-341. Seasonal migration between the Northeastern and Central Regions has been estimated at 150,000 laborers during certain periods.

39/ Chancellor 1970.

40/ Personal discussion with Anglo-Thai Tractors, 1987. Contractors may even enforce their claim on an area of operation. Also, the border-crossing takes place in two directions and is less significant at the regional level.

41/ OAE, *Agricultural Statistics of Thailand*, Crop Year 1985/86. Sorghum occupies less than 5 per cent of total farm holding area but is an important crop and is often grown as a second crop after maize.

42/ This set may be called a *gang* and the laborers, draft animals and machines in a gang are called *gang-requirements* or *elements* (Oving 1971).

43/ Similarly, *toolbar* summarizes all implements used with a two-axle tractor to make furrows prior to planting, to ridge the soil in the standing crop, or to weed in between the rows. *Single-axle tractor* represents all the types of locally made tractors with simple implements used for preparation of a flooded paddy field. *Draft animal* includes the plow and comb harrow the animal pulls.

44/ Van Elderen 1977.

45/ Hunt and Patterson 1968, pp. 18-21. Other terminology include: (i) *timeliness of operation* – the "ability to perform an activity at such a time that quality and quantity of product are optimized," in ASAE 1974, pp. 293-294; (ii) *timeliness function* – the recoverable value ($ per ha, kg, or cow) of a material as a function of time; and (iii) *urgency* – value ($ per hour) obtained by preventing a delay in processing a material or in executing an operation (see van Elderen 1977, pp. 16-24).

46/ See Sub-section 2.2.1.

47/ The SOW agricultural production model for Thailand previously included a module (based on data from crop production theory) for the effect of timing on crop yield, but this facility was later on deleted (personal communication with C. van Diepen, September 1987, SOW/Centre for Agrobiological Research, Wageningen).

48/ These resource constraints are not really absolute and may be expanded within certain limits (for example, irrigation development may increase double cropped area, upland may be further expanded, draft animal population may increase through natural growth). For example, during 1960-86, total crop land area expanded at the rate of about 3.5 per cent per year.

49/ For illustration, in 1988 Thailand's Board of Investment approved investments totalled 190 billion baht (about $7.3 billion) for projects with promotional privileges alone. Total annual investment for mechanization amounts to less than 2 per cent (Sub-section 3.3.1) of this amount.

50/ Hazell, et al 1986, p. 274.

51/ The *Agricultural Statistics of Thailand* distinguishes eight land use categories as farm holding land, including non-productive land. Not all of these categories are of relevance to MECHMOD (for example, non-productive land, tree crops). OAE, *Agricultural Statistics of Thailand*, Crop Year 1985/86, Table 121.

52/ Bunded lowland refers to level plots surrounded by small dikes (about 30-50 cm high) to keep the plot flooded. In the terminology used in the *Agricultural Statistics of Thailand* (OAE), *Major Rice* refers to rainy season rice crop, while *Second Rice* refers to irrigated dry season rice crop.

53/ Even for the more commercialized Central Plain in Thailand, employees account for only about 10 percent of the agricultural labor force (Bertrand 1980, p. 12). For the family-operated farm, exchange labor (farmers helping each other with planting and harvesting) is an important characteristic.

54/ Corsel 1986, p. 100.

55/ See Bertrand 1980, Corsel 1986, SOW 1980. For MECHMOD experiments, 1,800 hours per year from a male laborer has been assumed, with 20 per cent overtime during May/July and November/December. Children work only half the number of hours of other labor (Bertrand 1980, p. 9).

56/ Van Heemst 1986, pp. 251-259.

57/ Further reference in the text to *male (family) labor* implies 25-54 years of age.

58/ Bertrand 1980, p. 12; NSO 1985, p. 14.

59/ NSO 1983, p. 3

60/ Lewis 1988.

61/ Bertrand 1980, p. 5.

62/ Schultz 1964. To prove his point, Schultz cites examples from Peru, Brazil, and India.

63/ For a discussion on this topic, see Jorgenson 1965, Chapter 11, pp. 320-360.

64/ OAE, *Agricultural Statistics of Thailand*, Crop Year 1985/86, Tables 127 and 131; Brannon, Russel, et al 1980, pp. 191-200; Bertrand 1980, p. 2-10.

65/ Royal Irrigation Department 1973; Small 1982. It must be further assessed whether this extremely low utilization rate is merely the result of low financial returns for dry season cropping or whether other (technical) factors also play a role. (Some of the irrigated area only provides for supplementary water and does not allow a second paddy crop.) Nevertheless, the phenomenon discussed here is generally acknowledged.

66/ World Bank 1986a, pp. 6-7.

67/ Brannon, et al 1980, pp. 191-200. See also Bertrand 1980, p. 4.

68/ OAE, *Agricultural Statistics of Thailand*, various issues. Personal communication with A. de Jong, Bangkok, May 1987.

69/ NSO 1983, Chapter 4, Table 5.

70/ SOW 1980, p. 66.

71/ Van Elderen 1977, p. 164, lists the following definitions:

time	–	a duration
actual time	–	the time a gang is available for use after setup: *effective time* plus *waiting time*
available time	–	the time men are available for work during regular hours and overtime in a period or season
effective time	–	the time a gang uses its effective field capacity (*field time*)
operating time	–	the time needed for the operation of a field with interruptions due to weather and other operations
total time	–	the time a gang is used: *operating time* plus time for service and repair
waiting time	–	the time a gang has to wait with processing until another gang starts delivering after the completion of its set-up time
workable time	–	the time a material is ready for processing during the regular hours or the available time in a period or season

72/ Van Elderen 1987, p. 22 .

73/ Beveridge uses the term *available time* to include weather-related factors (in this study termed *usable time*). His definition is erroneous and confusing when assuming different workability classes (Beveridge 1974, pp. 9-10).

74/ Workability is defined as the possibility of applying a working method with respect to the condition of the material, the soil, and the atmosphere (Goense 1987, p. 37).

75/ See note 55.

76/ Goense 1987, Ph.D. Thesis Theorem 4.

77/ Goense 1987, p. 37; Wijngaard 1988, pp. 7-8.

78/ In MECHMOD, for reasons similar to those for the timeliness function (Subsection 5.3.3), this detailed differentiation would not be practical.

79/ WOFOST Rainfall Generator Version 4.0, Centre for World Food Studies (SOW), Wageningen, March 1987. The method is described in Geng, de Vries, and Supit, pp. 363-376.

80/ Estimation based on de Jong 1980, p. 98; van de Zande 1988.

81/ Based on data from von Fleckenstein 1980.

82/ Rijk and van der Meer 1984, pp. 22-24; MOAC 1976, p. 20.

83/ SOW 1980, p. 42. This is of particular relevance to the mountainous Northern Region, but of less consideration for the Central Region.

84/ For Thailand as a whole, 15 per cent of arable land is irrigated. Only one quarter of the presently irrigated area is provided with water during the dry season (World Bank 1986a, pp. iv-v).

85/ For example, cassava is almost exclusively exported, rice over 20 per cent, and maize 60 per cent. The EC import quota for Thai cassava may become a dominating factor for the cassava farmgate price.

86/ World Bank 1982.

87/ Depreciation is associated with wear and tear only, and is therefore a variable cost. For details on cost calculation, see Appendix 4.

88/ This percentage has been derived from data presented in BAAC 1986 and estimates of annual sales (Table A1.3).

89/ This percentage is an estimate based on expert advise and personal communications (May 1987) and Patnopas 1980.

90/ Bertrand 1980, p. 12-15; de Jong 1980. The percentage applied is an average, and the peak season rate may increase in some cases to 30-150 per cent.

91/ NSO Labor Force Survey Tapes, as reported in World Bank 1986b.

92/ Henderson 1959; Day 1963, pp. 10-11.

93/ SOW 1981.

94/ Hazell and Norton 1986, pp. 143-145.

95/ Day 1963a, pp. 797-813.

96/ For a discussion of some of these approaches, see Hazell and Norton 1986, pp. 146-148.

97/ Hazell and Norton 1986, p. 147: Buckwell and Hazell 1972.

98/ OAE, *Agricultural Statistics of Thailand*, Crop Year 1985/86, Tables 127 and 131. Total farm household income may consist of 30 per cent (Central Region) to 55 per cent (South) non-farm income.

99/ Bot 1981, pp. 20, 27, 29, and 52.

100/ For example, according to NSO *1983 Intercensal Survey of Agriculture*, 54 per cent of holdings are in the Central Region between 1.6 and 6.4 ha (10-39.9 rai) and 21 per cent are over 6.4 ha. The remainder of the holdings are below 1.6 ha. Since no distinction is made in the data between paddy farms and upland farms, the holdings' uniformity is even more favorable.

101/ The meaning of *relaxation* here follows the definition by Wijngaard 1988, p. 60.

102/ Wijngaard 1988, pp. 60 to 67.

103/ Hazell and Norton 1986, p. 267. For an agricultural sector model, Hazell considered four principle consistency dimensions for the data set: (i) the product-product dimension, which refers to supply-demand balances; (ii) the product-input dimension; (iii) the product-price dimension; and (iv) the technical coefficients dimension.

104/ Hazell and Norton 1986, pp. 269-274.

105/ For example, this may be particularly true for the maize and sorghum crops. Sorghum is more drought tolerant than maize, and is assumed in MECHMOD to be grown as a second crop after maize. However, a farmer may decide to grow sorghum as a first crop in a drought year or on land which is more prone to moisture stress. However, since maize and sorghum require almost identical power input and the sorghum area is less than 5 per cent of total model crop area, the matter is of marginal consideration.

106/ See Bot 1981, Fleckenstein 1980, de Jong 1980, and the compilation of information in van de Zande 1987.

107/ For example, the data collected in the Lam Pao Irrigation Project (Northeast Thailand) by the Mekong Committee. The objective of the data collection was to obtain detailed information on farm labor utilization and physical limitations of land resources to be used for a crop production model in the command area. Comprehensive data collection (daily recording) was undertaken over a period of three years. By the time all data were put on tape, the project was discontinued and the analyses were never made (personal communication with A. de Jong).

108/ Hazell and Norton 1986, pp. 285-286.

109/ Toet 1983, Appendix III.

110/ See for example RID/ILACO 1986a; RID/ILACO 1986b; NSO 1985; OAE Agricultural Statistic Reports, and expert estimates.

111/ See for example the various issues of the *World Bank Commodity Price Projections* compared with actual prices materialized. The inherent difficulty with agricultural commodity price projections is that they are valid in principle for a point in time only because a significant price increase for one crop usually increases production for that crop, thereby creating a new price equilibrium.

112/ See further Hazell 1986, pp. 125-127 for details on this topic.

113/ Hazell 1986, pp. 126-127.

6

MODEL EXPERIMENTS

Experiments performed with MECHMOD are of a *comparative static* nature and may be summarized into three main series.

Series I Experiments. In these experiments the effect of a change in one exogenous variable on the capital stock for draft animals and machinery (further referred to as "capital stock") is studied while keeping all other exogenous variables constant. The effect of the following key variables is studied in this series:

(i) wage rate,

(ii) price of fuel,

(iii) acquisition cost of mechanization technology,

(iv) interest rate,

(v) size of agricultural labor force, and

(vi) size of exchangeable family labor force. [1/]

Series II Experiments. The combined effect on the capital stock of a simultaneous change in key variables, namely, crop area, labor force, and wage rate, is studied. Their combined change may amplify or dampen the effect of a single variable on the capital stock.

Series III Experiments. In these experiments, within certain limits on flexibility crop area is also an endogenous variable together with various technology options. Certain changes in key exogenous variables are assumed. The purpose of this series is to study the effect of wage rate increase on capital stock and changes in agricultural production (particularly area expansion or contraction), the role of mechanization in this process, and the effect of certain policy changes.

The outcome of these experiments is compared with the outcome for the base year. The base year run assumes input data of 1986, the year for which MECHMOD has been validated (see Section 5.5). Four distinct changes in the progress of mechanization technology adoption can be considered. These are: (i) the introduction of a new technology or method, for example, a mechanical sugarcane harvester; (ii) a change in the capital stock without change in area coverage or application; (iii) a change in area covered by a specific method, while total crop area remains the same; and (iv) a combination of both change in the capital stock and change in area covered by the method. In the case of (i), *technical innovation* has taken place. When (iii) or (iv) occurs, a change in *technology* (or *method*) *application* has taken place. It can be argued, however, that in the case of the individual farmer, innovation has also taken place because he may have shifted, for example, from draft animals to tractors.

In the case of (ii), the stock in draft animal/machinery changes without a change in area covered by the relevant technology, and a change in utilization rate of the draft animal or machine has occurred rather than a change in technology application. The *stock* and *flow* concepts apply here.[2/] Higher capital cost stimulates higher machine utilization (increased *flow*). A higher wage rate may increase the *stock* of machines (although flow from individual machines may remain the same or even decrease), and thus utilize the cheaper (core) family labor more efficiently. The application of technology or method therefore does not necessarily change. These two cases illustrate the principle that in a low income economy, the mechanization process is *machine-centered.* [3/] That is, it focuses on cost effective use of machinery. However, when per capita income rises (and subsequently the wage rate), the use of machines centers around the optimal utilization of manpower, and thus becomes *manpower-centered.* This phenomenon occurs in various experiments and is further referred to as *machine-centered* and *manpower-centered mechanization.* These two phenomena often occur simultaneously. For example, a reduction in acquisition cost of tractors increases the area plowed with tractors (an increase in technology application or method), because it becomes cheaper relative to draft animal technology. Because the cost of tractors becomes cheaper relative to labor, manpower-centered mechanization also takes place. The annual utilization of the tractors may therefore decrease, thereby amplifying the effect of increase in method on tractor stock.

For the interpretation of MECHMOD's results, the exogenously supplied wage rate, interest rate, acquisition cost and other costs of owning and operating draft animals and machinery ought to be distinguished from the cost incurred internally in MECHMOD (endogenous cost) for applying the technology. Even when the exogenously supplied cost data do not change, the endogenous per unit area cost may change. For example, using more family labor instead of hired labor (hired labor is more expensive), scheduling more work in slack season (when labor is cheaper), or higher annual utilization of a machine (which reduces the fixed annual cost on a per unit area basis) will reduce the cost of technology used on a per unit area basis.

The outcome of the experiments is summarized graphically in the main text with details provided in Appendix 7.[4/] The bar graphs represent the value of the capital stock in a certain group of technology, indicating the level of mechanization. The abbreviated legend in the bar graphs refers to the following:

BY	–	base year
DA	–	draft animals and associated implements
ST	–	single-axle tractors with implements
STT	–	small two-axle tractors with implements (only relevant in Series III experiments)
BT	–	big tractors with implements
THRES	–	paddy and sorghum threshers and maize shellers
CONTR	–	control-intensive mechanization technology (planters, sprayers, harvesting machinery)

In Table A6.3, the dual solution (in terms of dual prices in baht per hour) for labor, draft animals and machinery is given for the base year run. In particular, the dual price for labor is of interest, since it indicates the slack or surplus of labor during a certain period. Because of the mobility in labor and substantial off-farm earning activities (as discussed in Chapter 5), the dual price of labor approximately equals the opportunity cost of family labor and is therefore not reported for most experiments. However, in the analysis of the effect of different sizes of exchangeable family labor force (Sub-section 6.1.6), the dual price of labor varies markedly from the opportunity cost when the exchangeable family labor force is reduced (Figure 6.9).[5/] The dual price for land is of interest in Series III experiments and is listed in Table 6.6. The evaluation of MECHMOD and the interpretation of the results and recommendations are described in Chapter 7.

6.1 EFFECT OF ONE KEY EXOGENOUS VARIABLE ON MECHANIZATION (SERIES I EXPERIMENTS)

6.1.1 Wage Rate

The effect of different wage rates over a range from –25 per cent to +25 per cent at 5 per cent intervals from the base year (BY) situation (represented in the figures by the bar with 0 per cent variation) is shown in Figure 6.1 with details provided in Table A7.1, Appendix 7. A change in wage rate has greatest effect on the method of land preparation and has more effect on the substitution process of draft

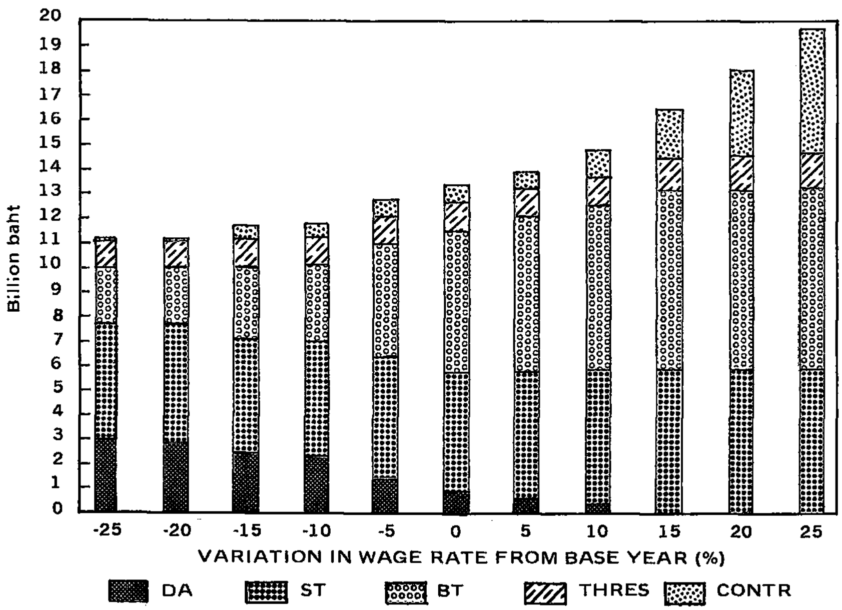


Figure 6.1. Effect of variation in wage rate on capital stock.

animals for big two-axle tractors than on the single-axle tractors. This phenomenon occurs because big tractors have a higher labor substitution effect than single-axle tractors. For example, in terms of hours of labor input per unit area for paddy land preparation, this ratio for the big tractor/draft animal is 0.42, whereas for the single-axle/draft animal, it is 0.66.

The change in stock of big two-axle tractors also changes the stock of their associated equipment (plows and maize shellers). Up to 10 per cent higher wage rates show an intermediate stage of mechanized paddy land preparation whereby initial plowing is undertaken by big tractors accompanied by puddling with draft animals, although single-axle tractors also substitute for draft animals. At a 15 per cent higher wage rate, both paddy land and upland preparation are fully mechanized, while a shift from the single-axle to the more labor efficient big tractor also exists for paddy land preparation where this is technically feasible.

There is no significant change in threshing technology within the range of 25 per cent higher or lower wage rates, although the stock of threshing machines may change due to change in tractors (such change can directly effect tractor-powered maize shellers). The higher stock of tractors reduces peak demands for threshers, thereby causing more even utilization. The substitution effect between rice threshers and trampling of paddy by single-axle tractors is only marginal. Only a substantially lower wage rate effects threshing technology: at a 50 per cent lower wage rate, the traditional method of trampling with draft animals substitutes for almost 50 per cent of mechanical threshing.[6/]

Chemical weed control is rapidly reduced when the wage rate decreases by 10 per cent or more, but increases are less pronounced in both upland and rice crops when the wage rate increases. The latter can be explained from the fact that part of the core family labor weeds manually even when the wage rate increases because the opportunity cost of core family labor is zero (for off-farm work). The reduction in chemical weed control and mechanical land preparation caused by the lower wage rate increases the total labor input through a reduction in off-farm work and an increase in hired labor.

At a 10 per cent increase in wage rate, mechanical sugarcane harvesting and mechanical cutting of paddy (reaper technology) become attractive on a limited scale. A wage rate increase to 15 per cent, however, suggests rapid adoption of the reaper. The rapid increase of reaper technology is explained because capital investment is low and it has a high labor substitution effect. For example, the labor requirement per unit area for rainfed paddy for harvesting with a reaper is 41 per cent of the labor requirement for manual harvesting. The situation is similar to that of the single-axle tractor and axial-flow thresher, which were also rapidly introduced when low-cost technology became available. Although mechanical cane harvesters have a high investment cost, they also have a high labor substitution effect. (For planted cane, the labor requirement for mechanized harvesting is only 9 per cent that of manual harvesting and loading.) The harvester is therefore attractive to initially replace the more costly (seasonal migrant) hired labor force.

Even at an increase in wage rate of 25 per cent, grain combine harvesters, planting machinery, and cassava harvesters are not attractive propositions. The capital cost of a grain combine is high, and its labor substitution effect is reduced once the cheaper threshing and reaper technologies are introduced, while a larger and cheaper labor force is available for harvest of grain crops since females and youngsters are included in this work. For similar reasons, planting machinery and cassava harvesters are not in demand. [7/] For weed control and cassava harvesting, timing is less demanding and the labor input may be spread over a longer period. Therefore, adequate core family labor may be available over an extended period when few other farm activities are performed.

Rice combine harvesters substitute for labor, rice threshers and reapers. Both indigenous thresher and reaper technologies are cheap compared with similar imported technologies. In Malaysia, low-cost thresher and reaper technologies were never widely introduced, but a large technology leap to combine harvesters was made once wage rates increased and large irrigation schemes were developed. If reapers are not readily available when wage rates increase by 20 per cent, the question arises whether combines will be introduced to Thailand earlier. To answer this question, MECHMOD was rerun with a wage rate increase of 20 per cent, but with the option of reaper technology excluded. The experiment revealed that combine-harvester technology is still not attractive under these circumstances.[8/]

The experiments indicate that mechanical threshing is much less affected by lower wage rate than mechanical land preparation, suggesting that threshing would be mechanized prior to land preparation (conform to the mechanization stages identified in Sub-section 2.1.1). In Thailand, however, the mechanization of paddy production focused initially on land preparation and later on threshing, contrary to historical development. The explanation for this is that low cost machinery for land preparation became available in Thailand much earlier than low cost threshing technology, which was introduced through the IRRI industrial extension program only after 1976.

Interpretation of results must acknowledge that a change in the agricultural real wage rate of 5 per cent or more (while all other prices remain the same) might be rather high for a developing economy, even under the Thai agricultural conditions of near full employment. In addition, these static experiments assume no change in size of the labor force or its composition. If the real wage rate increases in the industrial and services sector, the return to labor in the agricultural sector must also increase (for example, through higher crop prices or productivity increases). Otherwise, the agricultural labor force will move to better earning sectors. Thus, an increase of 25 per cent in wage rate will likely be accompanied by a change in size and/or composition of the agricultural labor force. The magnitude of this change depends on the profitability of farming; that is, wage rate development versus returns to agricultural labor. This matter is further explored in Series III experiments.

6.1.2 Price of Fuel

The price of diesel fuel has been varied between −40 per cent and +60 per cent from the base year price of $ 0.25 per liter (6.5 baht per liter). [9/] The results show that mechanical land preparation is affected most by the fuel price (Figure 6.2, details in Table A7.2). This is a power-intensive operation, and fuel constitutes a considerable portion of the variable cost of mechanized land preparation. For example, for upland maize preparation with two-axle tractor, the cost of fuel (at $0.25 [6.5 baht] per liter) and lubricant amounts to 35 per cent of its variable cost, including depreciation. This explains the rapid shift from gasoline to diesel powered single-axle tractors when fuel prices increased after 1977. However, the effect of the fuel price is much larger on the stock of big tractors than on single-axle tractors, the latter being more fuel efficient per unit area covered. For example, rainfed paddy land preparation with single-axle tractors requires 3.8 liters per rai, while the big tractor requires 6.5 liters per rai (see Table A3.1 and A4.3). [10/]

Even a drastic decrease in fuel cost of 40 per cent does not result in adoption of new mechanical technology since power-intensive operations are already largely mechanized, while fuel cost is relatively low for control intensive operations. This is even the case when the machinery is equipped with powerful engines (such as grain combine harvesters and cane harvesters). For example, the fuel cost per unit area for a rice combine amounts to less than 7 per cent of the variable

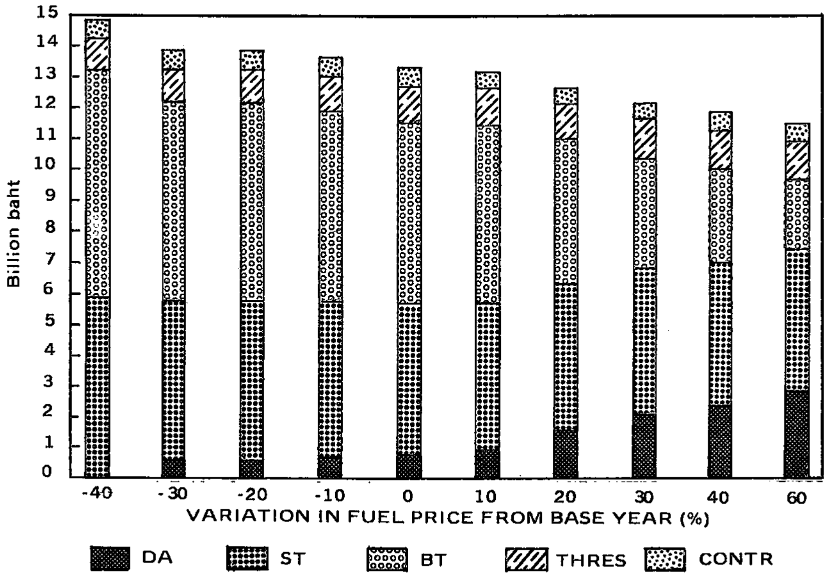


Figure 6.2. Effect of variation in fuel price on capital stock.

cost. [11/] For the same reason, the area threshed mechanically is not affected by the fuel price experiment. Decrease in rice threshers and maize sheller stock when fuel is cheaper is attributable to the higher stock of tractors. The increase in tractors reduces the peak demand for threshers, particularly since big tractors are needed to power maize shellers.

6.1.3 Acquisition Cost of Mechanical Technology

Change in the acquisition cost (or procurement price) of machinery may result from changes in taxes, import duties, subsidies, exchange rates, or manufacturing costs. The effect of differences in machinery acquisition costs over a range of plus or minus 20 per cent in steps of 5 per cent from base year prices is shown in Figure 6.3 (details in Table A7.3). In Figure 6.3, the value of the capital stock is readjusted to the base year price to maintain comparability in terms of number of units (capacity) between the bars. The last three columns of Table A7.3 indicate the effect if acquisition cost of draft animals also changes proportionally.

A higher procurement price severely affects the stock of big tractors, with mechanical upland preparation suffering most. This phenomenon was also experienced in the early 1980s, when tractor prices increased and sales almost came to a halt (see Appendix 1). However, because of the time-lag effect on the depreciation of existing tractor stock, the reduced sales will not immediately affect the mechanically prepared area, and the economic life of equipment may also change. Draft animals and single-axle tractors substitute for big tractors in paddy land preparation, although the stock of single-axle tractors also declines due to higher acquisition cost.

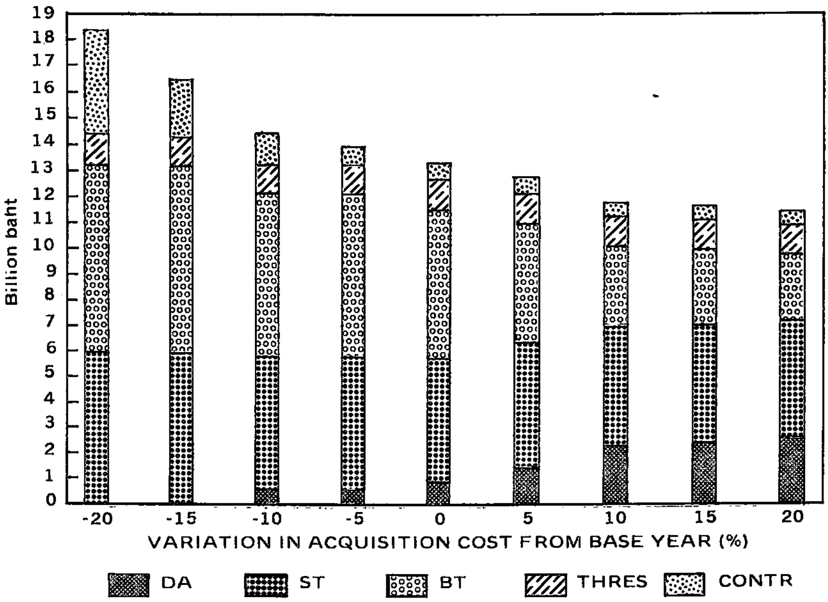


Figure 6.3. Effect of variation in acquistion cost on capital stock.

A decrease in procurement price causes a rapid substitution of draft animals by both single-axle and big two-axle tractors. Both paddy reapers and cane harvesters become attractive at lower prices. The high increase in rice threshers at a 20 per cent decrease in acquisition cost without a change in threshed area is caused partly by a shift from single-axle tractor trampling to threshers, but also by the shift to manpower-centered mechanization.

Because of the interest rate differentiation for various machines, this experiment should be interpreted with caution. The single-axle tractor is less sensitive to change in acquisition cost and appears therefore more capital efficient. However, the high ratio of cheap institutional credit for the single-axle tractor against none for the big two-axle tractor causes a change in acquisition cost to have a greater effect on the big two-axle tractor.

6.1.4 Interest Rate

The interest cost of machinery investment is considerable, especially in countries with high interest rates. Drastic reduction of interest cost through concessional credit has significantly affected the mechanization process in several developing countries. [12/] Under present BAAC policy, in practice only locally manufactured small-scale mechanization technology is eligible for BAAC credit. This policy discriminates against the more capital-intensive imported technology (see Appendix 1). Three different experiments with interest rates were performed: (i) a proportional variation in the opportunity cost for own capital, and interest rates on institutional credit from BAAC and on suppliers' credit; (ii) the effect of non-discriminating interest rates; and (iii) the effect of non-discriminating interest rates with limited funds available from BAAC.

(i) Proportional Variation in Interest Rates

Under this experiment, the opportunity cost of own capital, and interest rates on BAAC and suppliers' credit are changed over a range of plus or minus 40 per cent in steps of 10 per cent[13/] (Figure 6.4 and Table A7.4). Because of the reduction in annual fixed cost, lower interest rates cause substitution of tractors for draft animals. At 30 per cent reduction in interest rates, both reapers and cane harvesters become financially, though marginally, attractive. The difference in maize sheller stock is caused by more optimal utilization and is facilitated by the increased availability of big tractors. Rice threshing technology is only marginally affected due to substitution of threshers for trampling with single-axle tractors. Even at a 40 per cent lower credit cost, typical control-intensive operations such as mechanical planting and combine harvesting are not financially attractive.

A proportional increase in the interest rates causes farmers to substitute draft animals for big tractors. The area mechanically threshed hardly changes, but the stock of threshers achieves higher utilization (the higher capital cost causes a shift to machine-centered mechanization).

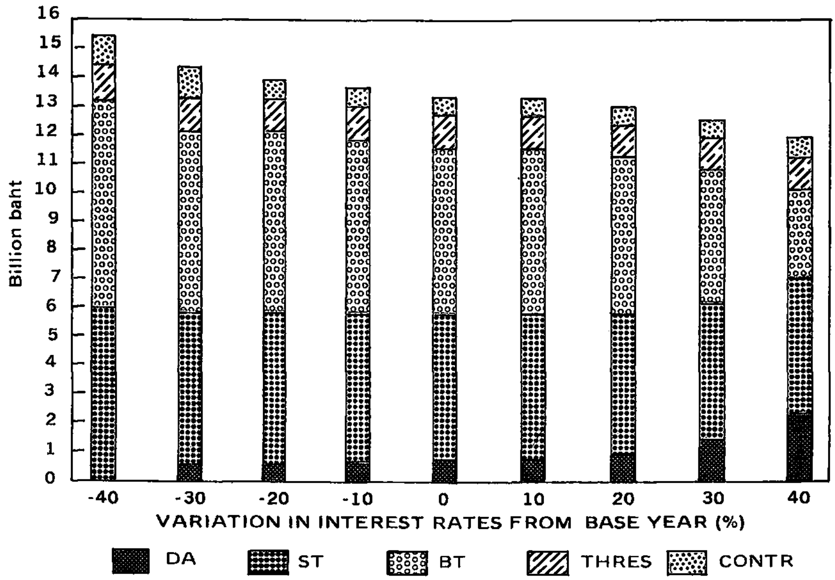


Figure 6.4. Effect of proportional variation in interest rates on capital stock.

(ii) Effect of Non-discriminating Interest Rate Policy

During these experiments, all capital investments, including draft animals, are subject to the same interest rate while 40 per cent of the capital stock is financed using own funds with an opportunity rate of 11 per cent. Experiments are conducted with different rates (10 to 40 percent in increments of 5 percentage points) (Figure 6.5 and Table A7.5). Up to a 15 per cent interest rate, reapers and cane harvesters are financially viable, but other control intensive machinery such as (trans)planters and cassava harvesters are not. Up to a 25 per cent interest rate, draft animal technology is totally replaced by mechanical technology, but higher interest rates make draft animal technology financially competitive. The higher labor input associated with draft animal technology becomes less a dominant factor relative to the higher capital cost of mechanical power. Compared with the lower interest rate situations, the higher labor input associated with draft animal technology is made available through hiring additional labor, reduction of off-farm work, and increase in chemical weed control in sugarcane, thereby freeing the labor required for the shift to draft animal technology. Thus, at higher cost of capital (interest rate), labor and chemical technology substitute for capital.

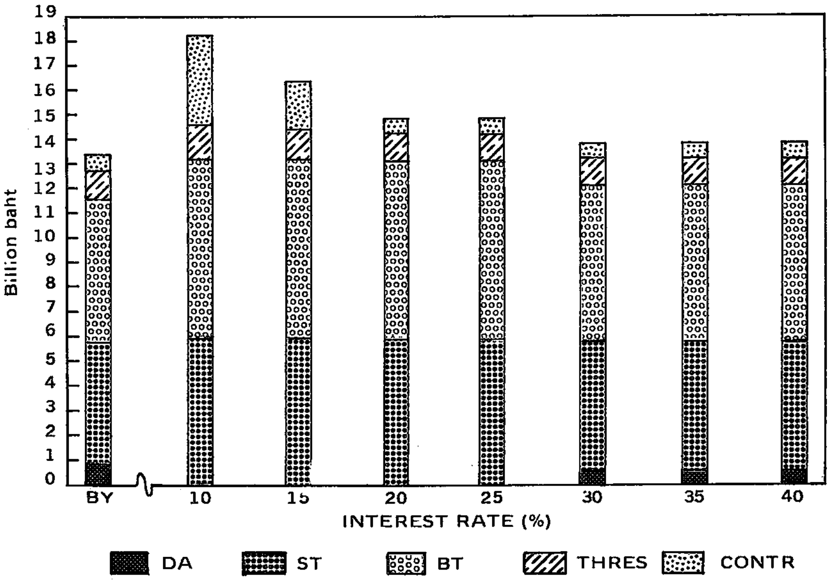


Figure 6.5. Effect of non-discriminating interest rates on capital stock.

The constant technology mix of draft animal, single-axle tractor, and big two-axle tractor over the 30 to 40 per cent interest rate range can be explained as follows. In the base year run, draft animal technology is subject to only 11 per cent interest, whereas machinery is subject to substantially higher rates (Table A4.4). In this particular experiment, draft animals and machinery are subject to the same rates. Subsequently, interest costs for machinery become relatively lower than for draft animals, and the level of mechanization increases compared to the base year. At 30 to 40 per cent interest range, the relative change is less than at the lower interest rates.

These experiments show that manipulation of the interest rate for the financing of machinery can affect mechanization significantly. Ample provision of cheap institutional credit can cause rapid introduction of machines, as experiences in the Republic of Korea and Pakistan have shown. In some countries, institutional credit is supplied at subsidized rates which do not reflect the real cost of capital or cost to the lending institution. Subsidized institutional credit for agricultural machinery may cause misallocation of a scarce resource and jeopardize the objectives of institutional credit, and is therefore not recommended.[14]

The BAAC rate in Thailand is about 14 per cent, compared with the commercial bank rate of around 18 per cent. [15] The above experiments show that a non-discriminate rate of 20 per cent would still increase the degree of mechanization and increase (albeit marginally) the return to the farmer under the conditions assumed. Therefore, the discriminating policy whereby BAAC finances only indigenous small-scale machinery at a lower than market rate is a disadvantage to the agricultural sector, particularly to upland farmers. The productivity of the agricultural sector can be increased through increases in the volume of non-subsidized institutional credit, whereby the rates may be increased to commercial rates without affecting the demand for machinery or its financial attraction. Such arrangements would be at the expense of the private money lender and would require sufficient funds from BAAC or other banks. In the case of a 20 per cent non-discriminating interest rate, the capital stock for machinery would have a replacement value of 14.8 billion baht (Figure 6.5). Assuming 40 per cent of this amount to be self-financed, and assuming machinery were replaced every 10 years, annual lending for machinery replacement is about 0.9 billion baht ($34 million), which may be further increased by an annual growth in capital stock of about 7 per cent. This does not compare unfavorably with BAAC's present lending operation of slightly less than one billion baht ($39 million) per year for machinery. [16] Also, at commercial rates commercial banks could play a more active role in the financing of machinery.

(iii) Effect of Non-discriminating Interest Rate Policy with Limited Funds Available from BAAC

Let us assume that BAAC policy maintains a limit on financing mechanization technology, though financing would be available without preferential treatment concerning the type of technology. Table A7.6 and Figure 6.6 show the effect on mechanization of various shares of BAAC financing. These experiments assume draft animals fully financed from own savings (opportunity cost 11 per cent), machinery financed with 30 per cent down payment from own savings (opportunity cost 11 per cent), BAAC share (at interest rate of 14 per cent) varying from zero to 70 per cent, and the remaining financing to be provided

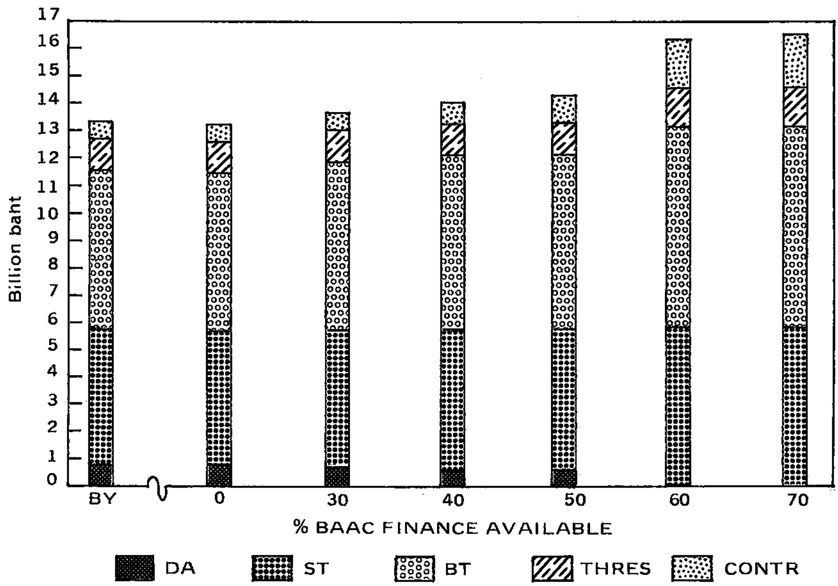


Figure 6.6. Effect of variation in ratio of non-discriminating BAAC credit on capital stock.

from suppliers' credit (at 36 per cent interest). At 60 per cent BAAC share, the capital stock in machinery is about 16.4 billion baht (Figure 6.6), and assuming the machinery stock is replaced over 10 years, BAAC's annual lending operation for machinery replacement would be about one billion baht ($38 million) (the present BAAC level). A salient finding is that under the present circumstances, if BAAC credit is unavailable, mechanization is hardly affected. This is explained by the fact that principally only single-axle tractors, motor sprayers and threshers are financed with BAAC credit. These technologies are financially much superior to draft animal and manual technology at given wage rate and are therefore insignificantly affected by higher interest rates.

6.1.5 Size of Agricultural Labor Force

In MECHMOD, the agricultural labor force is differentiated into family labor and hired labor (including seasonal migration). For both, a sub-category is included for male labor 25-54 years of age. During this experiment, the base year agricultural labor force, the hired labor, and seasonal labor force change in size by –30 per cent to +20 per cent, the results of which are shown in Figure 6.7 and Table A7.7. During the experiment, the size of the family labor force which may work off-farm (exchangeable family labor) is constant. Therefore, the core family labor force changes more than proportionally in size when the total labor force is changed.

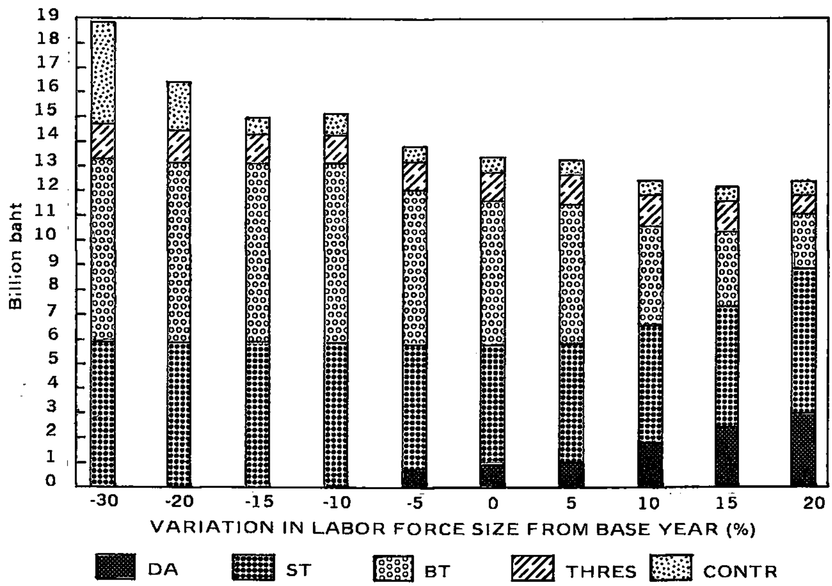


Figure 6.7. Effect of variation in size of labor force on capital stock.

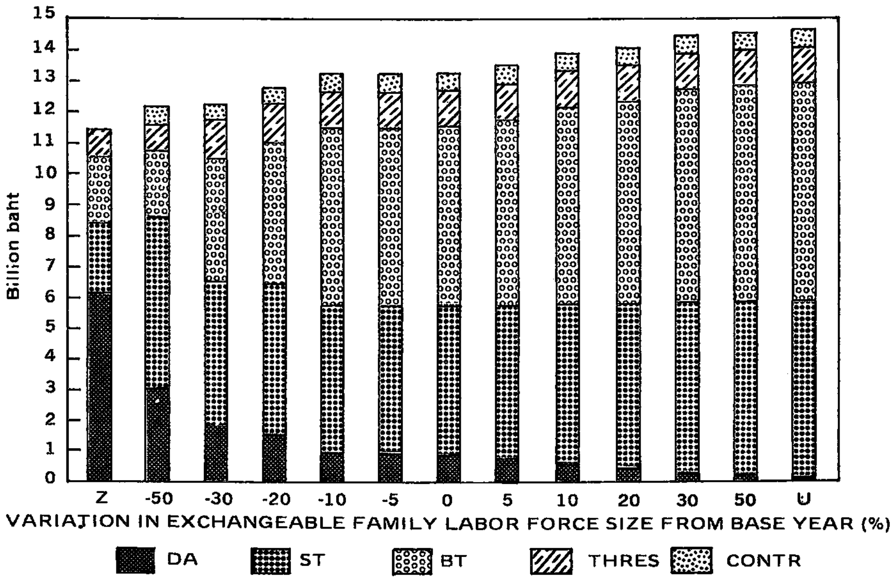
A decrease in the labor force causes a shift in land preparation technology by substitution of tractors for draft animals, a process completed when the total labor force is reduced by 10 per cent. At that point, mechanical reapers are deployed and chemical weed control of sugarcane is slightly increased to cope with the labor force reduction. At a 15 per cent decrease, a few mechanical cane harvesters are needed to overcome the male labor shortage during harvest, and chemical weed control is further increased. Pressure on the paddy harvest is relaxed as a result, and fewer reapers are required. At 20 per cent decrease, mechanical reapers as well as cane harvesters are used heavily.

In this experiment, the decrease in labor force causes a shift towards mechanization because the labor scarcity increases the dual price of labor. This dual price increase occurs because less core family labor is available (with zero opportunity cost for off-farm work), less work can be scheduled in slack periods (when labor is cheaper), and more labor must be hired (which is more expensive than family labor). The reduced labor force decreases the hours worked off-farm, and although less hired labor is available, the hiring takes place over a longer period, and total time of hired labor therefore increases.

Increasing the agricultural labor force decreases the dual price of labor, thus substituting labor for capital. For example, the area under mechanical land preparation is reduced. (Rice threshers increase initially to offset the effect of fewer tractors.) At 20 per cent increase in labor force, core family labor is no longer gainfully employed and is left idle over a significant period of time, resulting in a dual price for labor of zero. A drastic shift toward land preparation with draft animals occurs. Manual weed control in sugarcane further increases, and sorghum is no longer threshed mechanically. Because of the effect of labor force size on the dual price of labor (endogenous cost of labor), Figure 6.7 mirrors Figure 6.1 (effect of wage rate). However, the experiment assumes a constant exchangeable family labor force. A zero dual price for labor is unlikely in Thailand at present because core family labor would probably become exchangeable labor. This matter is further analyzed in the next experiment and in Series III experiments.

6.1.6 Size of Exchangeable Family Labor Force

In the previous experiment, the size of the family labor force, which may opt to work in the non-agriculture sector (exchangeable family labor) has been kept constant. Depending on the off-farm wage rate relative to the return to working on the farm, more or fewer persons may seek employment outside agriculture. Higher off-farm wage rates will increase the ratio of exchangeable family labor force to core family labor force. Ultimately, the exchangeable family labor force may become permanently employed outside agriculture, causing the agricultural labor force to decline. This process is part of the agricultural development and commercialization of agriculture in Thailand.[17/] The effect of changing the limit on family labor available for non-agricultural work (exchangeable family labor) has been explored with the results shown in Table A7.8 and Figure 6.8. In this experiment, the total agricultural labor force is kept constant (meaning the sum of core family labor and exchangeable family labor is constant).



Z ("zero") represents a situation whereby family labor is not exchangeable with non-agricultural work. U ("unlimited") represents a situation whereby family labor is fully exchangeable with non-agricultural work, under the condition that land remains fully utilized.

Figure 6.8. Effect of variation in size of exchangeable family labor force on capital stock.

Increasing the size of the exchangeable family labor force (thereby decreasing the size of the core family labor force) increases the area of mechanical land preparation at the expense of draft animal technology. At the given prices, the cost of mechanical land preparation compares favorably with the off-farm earning opportunity of family labor. Decreasing the size of the exchangeable labor force (thereby increasing the size of the core family labor force) has an opposite effect: the opportunity for family labor to earn off-farm income is less, and because of the lower opportunity cost of labor (lower dual price), mechanical technology loses its competitive edge. Interaction is likely between changes in total agricultural labor force, exchangeable family labor force, wage rate, and opportunity cost of family labor, and simultaneous changes are studied in the Series II experiments.

The effect on the dual price for aggregate family labor during the year is presented in Figure 6.9. Only the most characteristic runs are included in the figure, and the 24 half-monthly periods are transformed to 12 monthly periods to simplify graphic presentation. [18] If the family labor force is fully exchangeable for off-farm work, the dual price for aggregate labor is higher in peak periods than the actual wage rate for

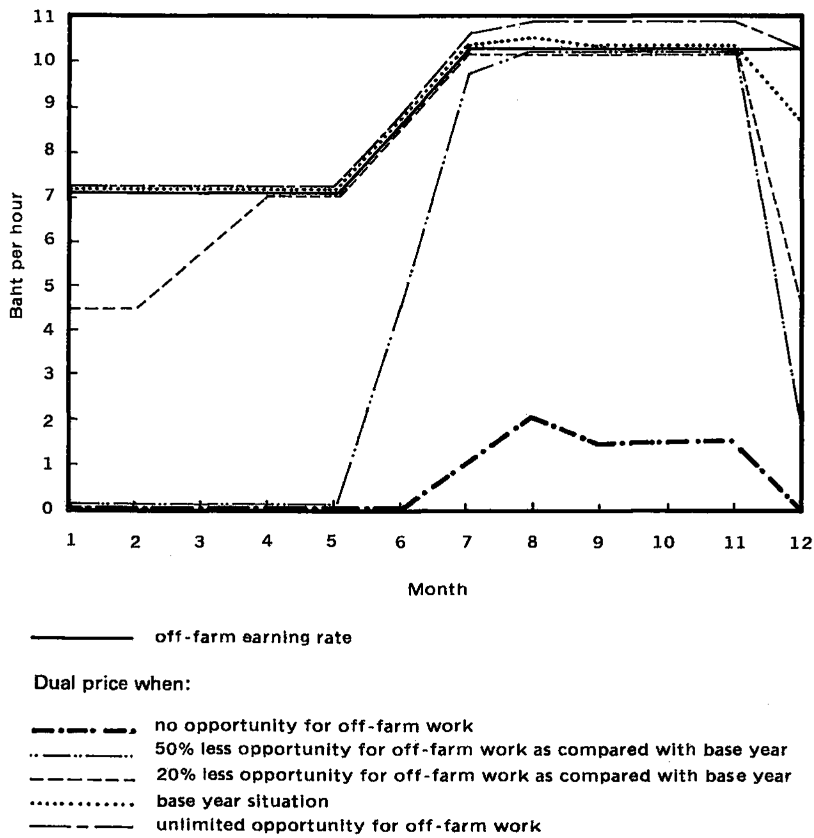


Figure 6.9. Effect of variation in exchangeable family labor force on dual price for aggregate family labor.

aggregate labor, because it substitutes for male labor which earns a premium off-farm wage rate.

6.2 EFFECT OF DIFFERENT SCENARIOS FOR CROP AREA, LABOR FORCE AND WAGE RATE ON MECHANIZATION (SERIES II EXPERIMENTS)

6.2.1 Introduction

In this series of experiments, the effects on mechanization of different combinations of crop area, agricultural labor force, and wage rate are studied. These combinations represent the effect of different annual growth rates for crop area, labor force and wage rate projected over a period of five years. The maximum and minimum growth rates for crops and land are presented in Table 6.1, and for labor and wage rate in Table 6.2. The size of exchangeable family labor force is assumed to increase at 25 per cent over the five year period for all scenarios.[19] Since core family labor equals total family labor minus exchangeable family labor, the size of the core family labor changes when the size of the labor force changes. For yield increase, an average rate has been assumed since, except for threshing and shelling, it has no other effect on the experiments (Table 6.3). Other exogenous variables have been kept at the base year level.

The combinations of land, labor and wage growth rate scenarios studied in this series of experiments are listed in Table 6.4. The effect of extreme but possible scenarios is studied first, and several other feasible combinations are subsequently considered.

In the Series II experiments, the difference between the low and high crop area growth scenarios is not merely area expansion at different paces of growth. With relevance to Table 6.1 and Table A7.9, under the low crop area growth scenario, the total harvested rice area increases by 0.67 per cent and the upland cropped area increases by 1.4 per cent annually, whereas under the high crop area growth scenario these percentages are 1.37 per cent and 4.2 per cent per annum, respectively. Therefore, the different crop area scenarios not only represent a different growth rate in area expansion but a different type of area expansion. Under the high crop area growth scenario, upland crop growth is faster than paddy crop growth as compared with the low crop area growth scenario. This difference is reflected in the experiments through a shift in mechanization pattern. A salient feature of the Series II experiments is that crop area always increases faster than the agricultural labor force. This phenomenon is unusual in many

Table 6.1. Series II experiments: Crop area expansion.[a/]

	Annual Growth Rate (%)		
	Low	**Medium**	**High**
Rainfed Paddy [b/]	0.3	0.45	0.6
Doubled Cropped Paddy [c/]	1.25	1.9	2.5
Flooded (Deepwater) Paddy[d/]	–1.0	–0.5	0.0
Upland [e/]	1.4	2.1	4.2
Non-model Crops [f/]	1.0	1.75	2.5

Notes and References:

a/ Actual expansion rates largely depend on future profitability of agriculture. See also World Bank 1982; and Rijk and van der Meer 1984, p. 30.

b/ Based on annual growth rates from *Agricultural Statistics*; period 1975-83 (0.38 per cent); 1975-86 (0.43 per cent); 1983-86 (0.55 per cent). See World Bank 1982, Report 3705a-TH.

c/ Assuming that under the high scenario a potential of 4.55 million rai will be developed by year 2001. World Bank 1986a, Report No. 5847, p. 83.

d/ No expansion of deepwater paddy area is expected, but rather a decline through reclamation, conversion to fishponds, etc.

e/ Assuming that under the high scenario, total area of 16.8 million rai suitable for maize, sugar and cassava will be under cultivation by year 2001 (excluding marginal land). Based on the Thai University Research Association (TURA) study as reported in World Bank 1983, Vol. II, pp. 12-13; and Rijk and van der Meer 1984, pp. 226-227. For individual crops see World Bank 1982. In the Series II experiments, areas with maize, sorghum, sugar and cassava are expanding at same rate as upland area.

f/ These crops (tree, fruit, vegetables and other crops) are not explicitly included in MECHMOD, but resource availabilities are corrected for these crop areas. The growth rate has been estimated based on the data in *Agricultural Statistics* 1985/86, p. 201.

Table 6.2. Series II experiments: Agricultural labor force and wage rate increase.

	Annual Growth Rate (%)		
	Low	Medium	High
Agricultural Labor Force [a]	0.2	0.45	0.7
Wage Rate [b]	0.0	0.75	1.5
Seasonal Migration [c]	0.0	0.9	1.8

Notes and References:

a/ Based on Corsel 1986, p. 28; Central Region 1960-70 (1.4 per cent); 1960-83 (1 per cent); 1970-83 (0.7 per cent).

b/ Based on World Bank 1986b, Report 6036-TH. Changes in real wages in agricultural season over 1978-81 (0.0 per cent); 1981-1983 (2.6 per cent).

c/ Base year 150,000 persons (Panayotou 1985). "Low" assumes no further increase. "High" assumes proportional increase with growth of agricultural labor force in Northeastern Region (see Corsel 1986, p. 28).

Table 6.3. Series II experiments: Yield increase for crops.

Yield Increase [a]	Annual Growth Rate (%)
Paddy	1.6
Deepwater Paddy	0.5
Maize	2.0
Sorghum	2.0
Sugarcane	1.5
Cassava	1.5

Notes and References:

a/ Estimates based on: World Bank 1982, Report No. 3705a-TH, Appendix 9.

Table 6.4. Series II experiments: Combinations of crop area, agricultural labor and wage rate growth scenarios.

Run	Bar Graph[a]	Crop Area[b]	Agricultural Labor[c]	Wage Rate	Projection[d]
		Annual Growth Rates			
01	LLL	Low	Low	Low	5
02	LHL	Low	High	Low	5
03	LLH	Low	Low	High	5
04	LHH	Low	High	High	5
05	HLL	High	Low	Low	5
06	HHL	High	High	Low	5
07	HLH	High	Low	High	5
07Y[e]	-	High	Low	High	5
07A	-	High	Low	High	10
08	HHH	High	High	High	5
09	MML	Medium	Medium	Low	5
10	MMM	Medium	Medium	Medium	5
11	MMH	Medium	Medium	High	5
12	ZZH	Zero	Zero	High	5

Notes and References:

a/ See Figure 6.10.
b/ For Growth Rate see Table 6.1.
c/ For Growth Rate see Table 6.2.
d/ In years.
e/ No limit on exchangeable family labor. This means all family labor may work off-farm.

developing countries but typical of agricultural development in Thailand. In some of the runs, the total labor available for the model crops and for off-farm work may decline because the growth rate of the non-model crop area is higher than that of the labor force. The non-model crops, particularly fruits and vegetables, are not mechanized, and their demand for labor is proportional to non-model crop area increase (see Subsection 6.2.3). The results of Series II experiments have been detailed in Table A7.9. Figure 6.10 shows the effect of the different scenarios on capital stock.

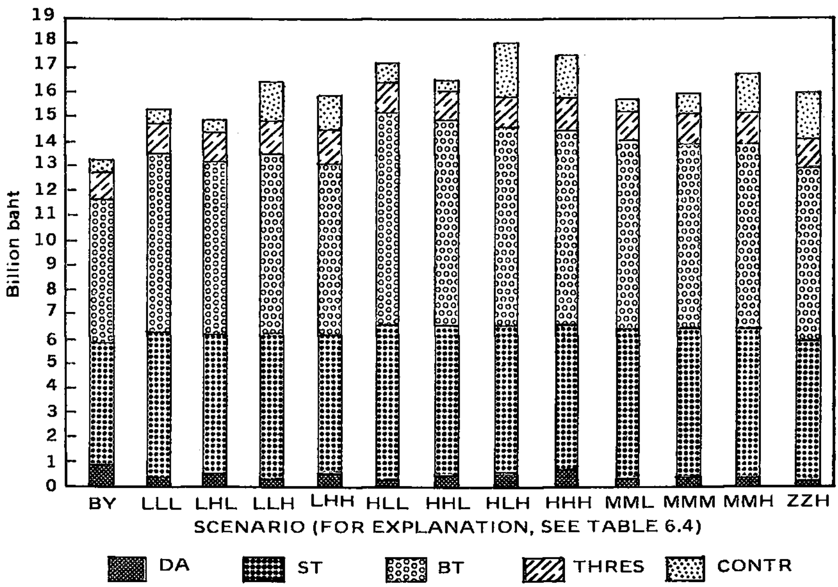


Figure 6.10. Effect of different crop area, labor force and wage rate scenarios on capital stock.

6.2.2 Low Crop Area Expansion and High-Low Labor Force and Wage Rate Growth Scenarios

Run 01: Low Crop Area, Low Agricultural Labor Force, and Low Wage Rate Growth

Under this scenario, rainfed paddy area increases by 0.3 per cent per year, double cropped paddy area by 1.25 per cent per year, deepwater paddy land decreases by 1.0 per cent per year, and all upland crops increase by 1.4 per cent per year. The non-model crops increase by 1.0 per cent per year. The agricultural labor force increases by only 0.2 per cent per annum, but seasonal migration does not increase. Zero growth in real wage rate has been assumed for this run (see Tables 6.1 and 6.2).

Typical of this scenario is that there is no increase in cost of labor nor in the cost of owning and operating draft animals and machinery. The run merely shows the effect of the labor force increase (at 0.2 per cent per annum) lagging behind the increase in cropped area (at 0.94 per cent per year [Table A7.9]). It also shows the effect of yield increase (which affects the stock of threshers and shellers). There is a slight decrease in total labor input (on-farm and off-farm) to the model because non-model crop area expansion is higher than labor force increase.

The results of Run 01 show that the substitution of tractors for draft animals is occurring more rapidly than in recent years to cope with the further decline in growth rate of agricultural labor (Table A7.9). The major change in mechanization is a further increase in mechanical land preparation. Land preparation with draft animals is giving way to a first plowing by big two-axle tractors with a subsequent harrowing (puddling) by draft animals (although in terms of area coverage this method remains insignificant). This intermediate method of land preparation is a typical transition stage prior to fully mechanized systems.

The slight decrease in maize shellers can be explained by their higher utilization rate facilitated by an increase in big tractors, which allows for smoothening of peak demands. The use of herbicides in the rice crop lags behind compared with manual weeding. In upland crops, an increase in chemical weed control occurs due to sugarcane. Because of the increase in single-axle tractors for land preparation, an increase in threshing (trampling) with tractors occurs, although this method remains insignificant when considering the total area threshed.

The growth in labor force at 0.2 per cent per annum lags behind the model crop area expansion which is 0.94 per cent per annum (see Table A7.9). This is reflected in a reduction in labor input of 0.34 per cent for model crop area and an increase in capital stock of 3.8 per cent per annum.

The Run 01 scenario represents a situation with a low labor force increase which should increase labor scarcity, and is therefore unlikely to be compatible with the zero wage rate increase. Depending on return to agricultural labor, at a low (or zero) increase in off-farm wage rate, the agricultural labor force may be expected to increase at a higher rate and vice versa. These scenarios are explored in Run 02 and Run 03.

Run 02: Low Crop Area, High Agricultural Labor Force, and Low Wage Rate Growth

In Run 02, the crop area increases annually at the same rate as in Run 01, and the wage rate does not increase. Therefore, no change in the exogenous cost of manual, draft animal, or mechanical technology occurs. The agricultural labor force, however, increases by 0.7 per cent per annum with seasonal migration increasing at 1.8 per cent (see Table 6.2). Except for this higher increase in agricultural labor force, Run 02 is similar to Run 01, but in Run 02 the agricultural labor force lags less behind crop area expansion. Consequently, the change to mechanical land preparation occurs at a lower pace than in Run 01, although draft animal population is still reduced by close to 10 per cent per annum. The principal difference from Run 01 is that Run 02 has a larger core family labor force (which has an off-farm opportunity cost of zero). This core labor family force is employed before mechanical power replaces exchangeable family labor, which has an opportunity cost close to off-farm wage rates.[20/] Apart from land preparation, no other significant change in technology application or innovation occurs. The increase in rice threshers and maize shellers is due to increases in area and yield, but also the change in the stock of tractors may have an effect (single-axle tractors can be used for trampling; big tractors are used in combination with maize shellers).

Run 03: Low Crop Area, Low Agricultural Labor Force, and High Wage Rate Growth

Under this scenario, crop area and agricultural labor force have the same annual growth rates as in Run 01. The salient feature of this run is that wages increase at 1.5 per cent annually, while there is no increase in cost of draft animals or mechanical power. This relative change in factor prices in favor of the wage rate causes a substitution of machines for men. Apart from high increases in mechanical land preparation and chemical weed control (change in technology application), new technologies are also introduced, namely, mechanical reapers and sugarcane harvesters. Because of the increase in labor saving technology, labor productivity increases, the hiring of labor is reduced, and the attractive wage rate increase results in more hours off-farm work, facilitated by mechanization.

Run 03 is one of the likely scenarios for the next 5 years. Rapid industrialization and expansion of the services sector will increase the real wage rate, causing a drain on the agricultural labor force, particularly if crop prices remain low (thus giving low returns to agricultural labor). This, in turn, will be a disincentive for crop area expansion, represented by the low crop area growth rate.

Run 04: Low Crop Area, High Agricultural Labor Force, and High Wage Rate Growth

This run is similar to Run 03, except that the labor force in agriculture increases at a high rate of 0.7 per cent per year and seasonal migration at 1.8 per cent per year. For reasons similar to those explained in Run 01, this scenario is somewhat unrealistic. If wages increase rapidly due to industrialization and crop area expansion is low, the rural area will supply this labor, and growth in the agricultural labor force will decline (rather than remain high as this run assumes). Even if farming remains attractive because of high crop prices, agricultural labor will increasingly shift to non-farm work, with the power gap on the farm filled with mechanical technology, which becomes cheaper relative to labor.

Since the core family labor increase is larger than in Run 03, the cost of labor decreases,[21] and the pace of mechanization is slower than in Run 03. The return per hour worked is also lower than in Run 03. Since the off-farm wage rates in Run 03 and Run 04 are the same, the tendency is that more agricultural labor is likely to seek non-agricultural work. How fast this process comes about will largely depend on the differential between return per hour in agriculture (which depends on prices and yields) and wage rate. These issues are further explored in Series III experiments.

6.2.3 High Crop Area Expansion and High-Low Labor Force and Wage Rate Growth Scenarios

Run 05: High Crop Area, Low Agricultural Labor Force, and Low Wage Rate Growth

Under this scenario, annual increases for rainfed paddy are 0.6 per cent, double cropped paddy 2.5 per cent, deepwater paddy 0 per cent, upland 4.2 per cent and non-model crops 2.5 per cent. Agricultural labor force increases only by 0.2 per cent, but the size of the seasonal migrant labor force and cost of labor remain constant. This run has no relative change in exogenous cost of technologies, but a more rapid widening of the gap between area expansion and labor force when compared with the runs previously mentioned in Series II. Total crop area expands at 2.46 per cent compared with a decline of 0.71 per cent in labor available for model crops. This absolute decline is caused by an annual increase in non-model crop area of 2.5 per cent compared with an agricultural labor increase of only 0.2 per cent. This assumes that there is no increase in labor productivity in non-model crops in terms of hours input per unit area. This is not unrealistic because the non-model crops are more difficult to mechanize (fruits and vegetables), and any gain in productivity per unit output of non-model crops may be offset by yield increase, thereby maintaining levels of labor input per unit area.

The widening gap in farm power occurring in this run is closed by reducing the hours worked off-farm (more specialization of the labor force), hiring more labor, and mechanization. The last focuses on increase in mechanical land preparation and initiation of mechanical paddy reaping and sugarcane harvesting. Like Run 01 and Run 02, this run (and also Run 06) shows the effect of area expansion and the lagging behind of the labor force. However, as explained in Sub-section 6.2.2, the combination of a low increase of agricultural labor force and a low wage rate is an unlikely scenario. Run 06 and Run 07 are therefore more relevant.

Run 06: High Crop Area, High Agricultural Labor Force, and Low Wage Rate Growth

Like Run 05, there is no change in the exogenous cost of different technologies. Because of the higher labor force increase, the power gap (labor versus area expansion) widens less rapidly than in Run 05. Therefore, the endogenous cost of labor remains lower because the core family labor force is larger than in Run 05. The shift to mechanical land preparation is therefore less rapid, although the rate is still high (draft animal population is decreasing at a rate of 12.8 per cent). The mechanization process remains limited principally to power intensive operations, especially mechanization of land preparation.

Run 07: High Crop Area, Low Agricultural Labor Force, and High Wage Rate Growth

This scenario is the most dramatic in terms of the mechanization process. Total crop area grows at 2.46 per cent per annum, but labor force grows at only 0.2 per cent per year,[22] and the wage rate increases at 1.5 per cent per annum. Labor therefore becomes more expensive than other power sources. Capital stock for mechanical technology rapidly increases at 7.2 per cent per annum, and labor input per unit area decreases at 1.35 per cent. Chemical weed control is further expanded. A remarkable feature of this run is the rapid introduction of reaper and sugarcane harvesting technology, causing the rate of mechanized land preparation to decrease in relation to some of the previously mentioned Series II runs. Under conditions of rapid labor cost increase, control-intensive mechanization will be initiated sooner at the expense of the pace of mechanized land preparation. This phenomenon is further explained below.

Comparing the high labor, low wage rate scenarios of Run 02 and Run 06 versus the low labor, high wage rate scenarios of Run 03 and Run 07 under both low crop area and high crop area growth leads to the following conclusion: Mere expansion of area accompanied by a lagging behind of the agricultural labor force without a change in cost of technologies causes mainly mechanization of land preparation (power-intensive operations). An increase in wage rate (or change in the cost of manual technology relative to mechanical power) results in more chemical weed control and the mechanization of sugarcane and paddy harvest (control-intensive operations). This behavior of MECHMOD is consistent with the theory that power-intensive operations are mechanized prior to control-intensive operations. The lower pace of the mechanization of land preparation in Run 07 is not inconsistent with this theory. Because mechanization occurs in other operations (reaping, sugarcane harvest), more core family labor is available during specific periods, making some land preparation with draft animals attractive to employ the core family labor gainfully. To verify this explanation, Run 07 is carried out with full mobility of family labor to non-agricultural work. Under this condition, land preparation is indeed fully mechanized (Run 07Y). The growth rates of Run 07 are also projected over a period of 10 years (Run 07A), indicating that continuation of the rates result in fully mechanized land preparation, and about half of the paddy and sorghum crop are mechanically reaped, and more than half of the sugarcane crop is mechanically harvested after 10 years.

The above finding reconfirms that the simultaneous existence of draft animal technology and mechanical technology in a locality does not necessarily mean that one farmer is more efficient or cost-effective than others, or that a farmer is constrained by lack of credit, training, education, or other reasons limiting his access to modern technology. Because of different opportunity costs, various farmers may use different technologies with equal efficiency. In this context, the stages of mechanization technology hypothesized in Sub-section 2.1.1 reflect the behavior of the individual farm. For the whole agricultural sector, a certain degree of overlap in the stages exists, reflecting various resource endowments and opportunity costs for the individual firm.

Run 08: High Crop Area, High Agricultural Labor Force, and High Wage Rate Growth

This scenario is similar to Run 07 except that the agricultural labor force increases at 0.7 per cent annually and seasonal migration labor at 1.8 per cent. Since core family labor increases faster in Run 08 than in Run 07, the mechanization process is slower for reasons similar to those explained in Run 06. A high wage rate increase combined with a high agricultural labor force increase will materialize only if returns to labor in agriculture keep up with wage rate development in other economic sectors. This may, for example, happen if the demand for labor in other sectors stagnates and prices for agricultural produce become attractive which, in turn, would result in high growth in crop area.

6.2.4 Some Additional Scenarios

Run 09: Medium Crop Area, Medium Agricultural Labor Force, and Low Wage Rate

Under this scenario, crop area expands annually as follows: rainfed paddy, 0.45 per cent; double cropped paddy, 1.9 per cent; deepwater rice, –0.5 per cent; upland crops, 2.1 per cent; and non-model crops 1.75 per cent. The agricultural labor force increases by 0.45 per cent per annum, and seasonal migration by 0.9 per cent. The wage rate does not increase and, therefore, in this run there is no relative change in cost of various technologies. Model crop area increases by 1.43 per cent, while total crop area increases by 1.47 per cent. Under this scenario, there is a rapid shift towards mechanical land preparation, but no control-intensive mechanization is introduced except for a slight increase in the proportion of area under chemical weed control.

Run 10: Medium Crop Area, Medium Agricultural Labor Force, and Medium Wage Rate Growth

In this run, crop area expands at the same rate as in Run 09, but the wage rate increases at a rate of 0.75 per cent per annum. Therefore, cost of labor increases relative to cost of machinery, and this is reflected in further mechanization of land preparation and a marginal introduction of control-intensive mechanization (specifically, reapers and cane harvesters).

Run 11: Medium Crop Area, Medium Agricultural Labor Force, and High Wage Rate Growth

This run is similar to Run 09 except for a higher increase in wage rate at 1.5 per cent per annum. This causes a more rapid increase in control-intensive mechanization, but for reasons similar to those explained in Run 07, the mechanization of land preparation proceeds at a slower pace than in Run 10.

Run 12: Zero Crop Area, Zero Agricultural Labor Force, and High Wage Rate

In this run, there is no increase in crop area, yield or agricultural labor force. However, the exchangeable family labor force increases by 25 per cent over the projection period, and this causes an increase in off-farm work. Further rapid mechanization of land preparation occurs, accompanied by widespread introduction of mechanical reaping and cane harvesting. This scenario represents a high demand for labor in the industrial and services sectors, resulting in a rapid wage increase. At the same time, return to agriculture may not increase, causing an outflow of agricultural labor to the more rewarding sectors while agricultural crop area expansion stagnates. This scenario represents the opposite development studied in Run 08 with regard to crop area and labor force.

6.2.5 Conclusions from Series II Experiments

Some important conclusions emerge from the Series II experiments. The experiments show that increasing crop area at a higher rate than the agricultural labor force without increasing wage rates, leads to a rapid increase in mechanical land preparation (power-intensive operations). However, increasing the wage rate leads to the introduction of mechanization for control-intensive operations. The slower pace of mechanical land preparation under the high wage rate scenarios results from the use of more core family labor for land preparation once certain control-intensive machines have been acquired.[23]

Another important finding involves the existence of different levels of mechanization technology simultaneously next to each other. The MECHMOD experiments show, for example, that in a particular run, draft animal technology is applied for upland preparation, while at the same time tractors are used for the same purpose. Both manual weeding and herbicide application take place in sugarcane, and cane is harvested manually as well as mechanically. These differences in adoption of agricultural technology are frequently explained in terms of early innovation versus slow adoption by individual farmers; unequal access to modern technology as a result of varying access to education, extension, or institutional credit; or other social and economic differences. Because these behavioral differentiations are not included in MECHMOD, another reason is as follows: An optimum technology mix is adopted because the opportunity cost and dual price of the different technologies change at different levels of utilization and periods of application. This situation occurs because, for example, one farm family consists of several working members while another depends entirely on hired labor, or because of costs associated with size of operation, draft animal technology is financially more attractive than mechanical technology. Apart from technical reasons, this phenomenon does not support the view that small two-axle tractors should be made available to cater to the needs of small farmers.[24] In fact, the uneducated farmer may have a better understanding of economic principles like opportunity cost than generally acknowledged.

Combine harvesters substitute for cutting and threshing labor, but the technology is not even financially attractive under the high land, high wage rate scenarios. The combine technology assumed in MECHMOD is the small Japanese-type machine tested in Thailand by FAO under a post-harvest technology project. One reason for the non-selection of the combine may be that the low cost threshing technology introduced by IRRI has retarded the combine adoption. This hypothesis would explain why in Malaysia, where the cost efficient threshing technology was not promoted, combines are widely used in large irrigation schemes. To test this hypothesis, the investment cost of the thresher is made higher than that of the combine. However, the combine is still not selected, and MECHMOD shows that traditional threshing by trampling is the alternative. This indicates that the combine technology is still too expensive at the going wage rate and an investment cost of 330,000 baht ($12,700). Even with institutional credit (70 per cent BAAC, 30 per cent own private finance), increased wage rates (by 7.5 per cent to 8.51 baht [$0.33] per hour), and an investment subsidy of 40 per cent, the Japanese mini-combine proved unattractive. Private combine operators in Malaysia prefer European-type large combine harvesters rather than the Japanese technology. MECHMOD therefore was rerun with the data on rice combine technology obtained in Malaysia. [25/] Although the European combine technology is more cost efficient, adopting this combine technology requires institutional credit (70 per cent BAAC, 30 per cent own finance) and also an investment cost reduced by 25 per cent (either through reduction of taxes and duties or as government subsidy) at a wage rate of 8.51 baht ($0.33) per hour.[26/] Other complementary investments required to facilitate working with the heavy combines are not considered. Therefore, it is unlikely that combines will become an economic proposition in the near future in Thailand, unless the technology is heavily subsidized.

Both Series I and Series II experiments show that mechanized paddy land preparation with new small two-axle tractors and mechanical paddy transplanters are not financially attractive even when made available with 70 per cent of the investment financed at BAAC interest rates.[27/]

6.3 EFFECT OF WAGE RATE ON PRODUCTION AND MECHANIZATION, AND CONTRIBUTION OF POLICY CHANGES (SERIES III EXPERIMENTS)

6.3.1 Introduction

In this series of experiments, certain potential maximum growth rates for land are assumed while family labor is fully mobile for non-farm work.[28/] Whether this potential crop area expansion will actually be realized depends on off-farm wage rate development relative to returns to agricultural work. By extrapolating the growth rates over five years, the upper limits (flexibility constraints) for land (crop) area and labor are established for MECHMOD. In the experiment, the wage rate is gradually increased while the effects of other measures are explored. Thus crop area is also an endogenous variable within the limitations on flexibility in crop and land area imposed. This means that, in addition to increase or decrease in crop area and change in technology, the cropping pattern may also change (including a shift from transplanting to broadcasting and vice versa) in an effort to maintain or increase family income when relative prices change. Maximum increases in land of various suitability classes and crop areas are listed in Table 6.5. Increase in agricultural labor and seasonal migration are allowed to expand at the maximum annual rates applied in the Series II experiments (Table 6.2). Yield is assumed to increase at the rates presented in Table 6.3.

A main objective of these Series III experiments is to investigate the consequences of rapid increases in wage rates on crop area expansion and mechanization. The experiments particularly aim to investigate whether a rapid increase in wage rates and a stagnation of crop prices or low returns to agricultural labor will cause land to be left fallow and ultimately return to bush, or whether further mechanization will arrest this process. Table 6.6 provides the dual prices of land for the various runs. The dual price shows how much the aggregated family income increases if one additional unit of land is farmed and indicates the pressure on the land frontier. Appendix 7, Tables A7.10A to A7.12B provides detailed results of the Series III experiments. These are summarized in Figure 6.11.

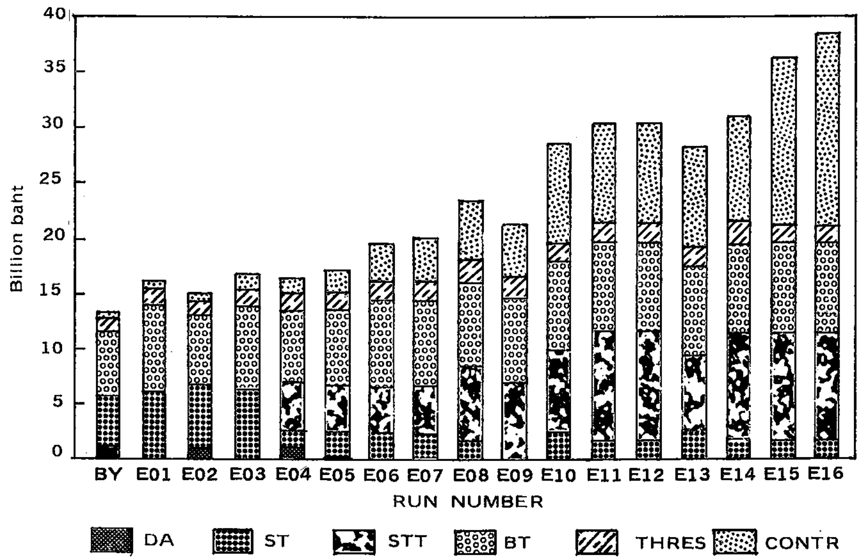


Figure 6.11. Summary of Series III experiments
(for description of the runs, see Sub-sections 6.3.2 to 6.3.4).

Table 6.5. Potential crop areas for Series III experiments.

	Maximum		
	Base Year[a] ('000 Rai)	After 5 Years[b] ('000 Rai)	Increase (%) Over 5 Years
Total Rainfed Paddy Area			
Transplanted	9,097	9,303.4	2.27
Broadcast	5,458		
Total Double Cropped Paddy Area			
First Transplanted	1,257		
First Broadcast	1,886		
Second Transplanted	1,257		
Second Broadcast	1,886		
Deepwater Paddy Area	218	218.0	0
Total Upland Area[c]	9,072	10,065.4	10.95
Maize	3,315	3,678.0	10.95
Sorghum	890	987.5	10.95
Sugarcane	2,403	2,666.1	10.95
Cassava	2,553	2,832.6	10.95
Non-model crops	3,800	4,144.3	9.06

Notes:

a/ Source: Table A3.13 and Table A4.1.
b/ Assuming the medium growth rates from Table 6.1.
c/ Total upland area does not equal sum of maize, sorghum, sugarcane and cassava area because of double cropping and the growing period for sugarcane is longer than one year.

Table 6.6. Series III experiments: Dual price for land (in baht per rai).

Run	E01	E02	E03	E04	E05	E06	E07	E08	E09	E10	E11A	E11	E12	E13	E14	E15	E16
Rainfed Paddy Land	0	21.43	0	21.68	9.54	4.67	0	0	0	3.83	0	34.36	41.56	3.55	60.07	68.35	0
Double Cropped Paddy Land																	
First Crop	475.41	474.84	442.25	414.38	403.86	428.17	401.87	486.09	421.74	468.97	437.66	529.04	572.46	581.19	507.57	628.79	689.86
Second Crop	326.89	364.70	301.15	320.24	297.78	291.85	262.73	295.35	294.32	324.95	290.85	375.22	401.69	387.01	258.82	297.61	208.45
Deepwater Paddy Land	114.52	134.52	101.01	132.67	114.93	113.30	93.97	90.77	98.06	107.29	88.01	127.89	130.39	98.56	25.57	27.11	0
Upland	1.17	47.46	0	0	0	5.71	0	0	0	51.11	36.95	127.48	169.34	152.64	39.87	52.24	0

6.3.2 Effect of Wage Rate Only

In Run E01, the wage rate and other prices and costs remain unchanged from the base year run. The difference in the model's outcome is therefore the result of increased mobility of family labor to non-farm work, a relative shift in cropping patterns (including transplanted versus broadcast paddy), and the option of leaving land idle within the limitations of the flexibility constraints. These flexibility constraints are assumed as follows: The maximum paddy crop area is limited by maximum suitable land area, while the minimum area is kept at the base year level. For upland crops, the flexibility of the crop area lies within the range of base year and maximum crop area (Table 6.5).

The main finding of this run is that draft animal technology has totally disappeared in favor of mechanical land preparation, but no other mechanical (control-intensive) technology is introduced. For rainfed conditions, transplanted paddy area remains unchanged from the base year and broadcast paddy has not fully expanded, leaving about 1.5 per cent of the maximum potential land area idle (Table A7.10A). For the higher yielding irrigated crops, land is fully utilized and transplanting maximized because the higher yield of transplanted paddy more than offsets the higher labor costs associated with transplanting. Of course, this phenomenon depends largely on the cost of labor and returns (particularly price of paddy) per rai. 29/ All upland crops are grown to their maximum possible area, but the dual prices for land suggest little pressure for further upland area expansion (Table 6.6). The prices of the upland crops assumed in the experiments are, except for cassava, rather low, and therefore little pressure on the land frontier is exerted.

In Run E02, the basic wage rate decreases by 5 per cent to 7.51 baht ($0.30) per hour, but all other prices and costs remain unchanged. The lower cost of labor favors a more labor-intensive production system while land is fully utilized because return to farm work compares favorably with non-farm wage earnings. The dual prices for rainfed paddy land and upland remain low. The lower opportunity cost for labor makes animal draft technology more competitive, but machinery stock increases due to area expansion and the limits imposed on animal population growth rate, 30/ higher yield, and the mobility of family labor to off-farm work.

Run E03 assumes a 5 per cent increase in wage rate to 8.30 baht ($0.33) per hour. Under the price levels assumed, the crop area does not expand to its maximum on account of rainfed paddy and sugarcane. The higher wage rate results in complete mechanized land preparation and chemical weed control in sugarcane, while mechanical cane harvesters are also introduced. In this run, only the minimum area imposed on rainfed transplanted paddy has been planted (base year level), indicating transplanting is not attractive. A shift to broadcast paddy may be expected. (This process has been facilitated in Run E09 and beyond by removing the minimum limit constraint on the individual paddy crops.) Similarly, idle sugarcane areas may be planted to more profitable crops. [31/]

6.3.3 Policy Proposals to Counteract the Effect of Higher Wages

In Run E03, the idle area indicates that rainfed paddy and sugarcane no longer give an attractive return when compared with off-farm earning. Introduction of new, cost-effective technology may reverse this trend. Tractorization of land preparation is an efficient way to increase labor productivity, and the potential of further gains with this farm operation should be examined. As previous runs indicate, all land in the Central Region will soon be prepared mechanically, and more of the same technology will no longer reduce production cost. A more efficient land preparation technology (in terms of labor productivity) should be introduced. The substitution of the single-axle tractor for buffalo power has a dramatic effect on labor input for rice production, but is still labor-intensive compared with two-axle tractors. However, in poorly drained and permanently irrigated paddy land, big two-axle tractors are generally technically infeasible due to frequent bogging down and destruction of the hard pan. Small lightweight (30-45 hp, 22-33 kW) two-axle tractors are alternatives, provided they are equipped with special wheel extensions (paddy puddle wheels) and a light single-row disc harrow. Newly imported, these tractors, with suitable implements for wet paddy field preparation, are too expensive compared with single-axle and big two-axle tractors and are therefore not in demand in Thailand. [32/] Cheap second-hand small tractors are imported from Japan, but these are not yet used in wet paddy fields. [33/]

Run E04 assesses the effect of introducing these small second-hand two-axle tractors with proper attachments for paddy land preparation, including their lower purchase price and an adjustment for remaining operational life (see Table A4.3). Run E04 shows that this technology is more cost-effective than present technology, and introduction on a large scale makes the transplanted rainfed paddy crop attractive again. In this run, because of BAAC policy, second-hand tractors do not obtain institutional credit (compared with 60 per cent for single-axle tractors). Since the technology is suitable only for paddy, it does not change the profitability of sugarcane, a crop for which area remains contracted. Introduction of this new technology also affects the mechanization process in other ways. The small second-hand tractors not only compete successfully with single-axle tractors, but also with big two-axle tractors for paddy land preparation. Subsequently, big tractor annual utilization is reduced and their fixed cost must be recovered from smaller areas, thereby increasing their cost for land preparation. The use of draft animal technology for upland plowing is thus greater than in Run E03, but the production cost of upland crops is also increased. One important finding emerging from this run is therefore that the big tractors should be used over an extended season (multiple crop use) to keep their annual fixed cost low on a per unit area basis. [34/] Under the conditions of Run E04, a beginning is made with mechanical reaping. Weed control in sugarcane is fully chemical, and mechanical cane harvesters are being used.

In Run E05, the basic wage rate is increased by 10 per cent to 8.69 baht ($0.36) per hour, with all other exogenous variables the same as in Run E04. In these Series III experiments, all measures, changes or modifications remain in upward runs. Therefore, second-hand tractors remain an option. All paddy land is utilized to its maximum, but, similar to Run E04, sugarcane and maize area are planted at their lower limits, indicating they are not attractive crops at the prevailing farmgate prices and costs of production. As explained in Run E04, the introduction of small second-hand tractors contributes to an increase in the production cost of sugarcane and maize. Mechanized paddy and cane harvesting has further increased.

Run E06 is similar to Run E05 except that the effect of a policy change on institutional credit is studied; specifically, machinery used for upland crop production can be financed up to 70 per cent of purchase price with BAAC credit, regardless of type of technology or origin. This reduces production costs, and in Run E06 all upland crops become attractive again with land utilized to its maximum. The policy measure has direct effect on the mechanization of sugarcane planting and harvesting, while land preparation is fully mechanized.

In Run E07, wage rate is further increased to 9.09 baht ($0.36) per hour, 15 per cent over basic wage rate. The effect of the previous policy measures (namely, second-hand small tractors and institutional credit) is cancelled out, and rainfed paddy and sugarcane again no longer provide attractive returns compared with alternative earning opportunities. The increase in labor cost causes a further shift from single-axle to small two-axle tractors for land preparation, and reaper technology rapidly expands.

In Run E08, all agricultural machinery, regardless of its use, type, origin, and new or second-hand condition, is financed for 70 per cent with BAAC credit. This policy measure increases the stock of small second-hand tractors and reapers. However, the policy does not sufficiently decrease production costs to achieve full utilization of paddy and upland area potential.

For Run E09, all flexibility constraints on individual paddy crop area are removed to assess the long-term implications should returns to labor in paddy production lag behind the non-farm earning opportunities. This removal of flexibility constraints allows for a complete shift from transplanted to broadcast paddy and vice versa. The effect on the rainfed paddy crop is dramatic: The rainfed transplanted paddy crop totally disappears, and rainfed broadcast paddy is reduced. Subsequently, rainfed paddy land is left idle. At the prevailing farmgate price and paddy production cost, farm labor moves to more rewarding employment outside agriculture, similar to the phenomenon experienced in Malaysia. At this stage, further mechanization is too expensive to substitute for labor. To prevent land from being abandoned, either the cost of mechanization must decrease (to lower the cost of production) or returns must increase (through higher yield or farmgate price).

In Run E10, the price of all machinery is reduced by 10 per cent.[35/] This reduction in acquisition cost may be the result of a policy measure (for example, reduction of taxes or duties) or more efficient manufacture, a combination of these, or other cost reducing developments. The outcome of this run indicates a further rapid increase in the small second-hand two-axle tractor technology, mechanical reaping, and sugarcane harvest. The lower investment cost (as compared with wage rate) also makes the mechanization of cassava planting attractive, albeit on a limited area (less than 15 per cent), while inter-row weeding in cassava with tractors is also introduced.

6.3.4 Effect of Low Yields and Low Crop Prices on Mechanization

In Run E11A, the basic wage rate is increased by 20 per cent to 9.48 baht ($0.38) per hour. Consequently, the rainfed paddy area dropped by more than 50 per cent of its potential. Therefore, a general farmgate price increase of 5 per cent (for all crops) is also applied for Run E11 to maintain full land utilization. When comparing Run E11 with Run E10, no new mechanization technology is introduced, suggesting resistance to further investment in more sophisticated technology. The higher crop prices are needed merely to offset the higher production cost caused by the increase in labor cost.

In Run E12, the basic wage rate increases by 30 per cent to 10.7 baht ($0.41) per hour, but to keep rainfed paddy land fully utilized, crop prices are increased by 10 per cent. Also in this run, no change in mechanization occurs.

In Run E13, the basic wage rate increases by 50 per cent to 11.85 baht ($0.47) per hour, and in order to maintain full utilization of land, crop prices are increased by 15 per cent.[36/] The existing mechanization technology is applied over a wider crop area, but no innovation occurs. Even at the 50 per cent wage rate increase, rice transplanters, maize and sorghum planters, cassava harvesting equipment, or combine harvesters are not financially viable.

In Run E14, the basic wage rate is increased by 75 per cent to 13.83 baht ($0.55) per hour. At the 15 per cent increase of all crop prices maintained from Run E13, only one-third of the rainfed paddy area remains occupied, but the upland is fully utilized.[37/] Rather than a further increase of farmgate prices for all crops, several changes are made. The yield of rainfed paddy is increased by 15 per cent, and increases in farmgate prices are maintained at 15 per cent over the base year prices for all crops (except for cassava, which is kept at 600 baht per ton [base year level]). Under these conditions, the only new mechanization technology introduced is the cassava harvester. Machines may increase in number due to manpower-centered mechanization. The 15 per cent yield increase on rainfed paddy also directly affects the number of rice threshers, since reference time for threshing is related to yield. For this reason, a 15 per cent yield increase shows a different result from a 15 per cent farmgate price increase.

In Run E15, the basic wage rate is increased by 100 per cent to 15.8 baht ($0.63) per hour. To maintain full utilization of rainfed paddy land, farmgate prices are increased by 25 per cent over base year price except for cassava, which is increased by only 10 per cent.[38/] In this scenario, rice combine harvesters are financially viable and almost one-third of the paddy crop is harvested with a combine.

In Run E16, the basic wage rate is increased by 150 per cent to 19.75 baht ($0.79) per hour, with farmgate prices increased by 35 per cent except for cassava, which is increased by 20 per cent. Rainfed paddy land and upland remain underutilized, the latter because cassava production is no longer attractive. The effect of further wage rate or farmgate price increases is not studied because this wage rate scenario

NOTES AND REFERENCES TO CHAPTER 6

1/ The *exchangeable family labor force* equals total family labor minus the core family labor force. The opportunity cost of the exchangeable family labor is 90 per cent of the hired labor wage rate. The *exchangeable family labor* is family labor available for off-farm work. This definition should not be confused with exchange labor, which refers to farm families helping each other for mutual benefit during peak seasons without payment. The core family labor does not work off-farm and has an opportunity cost for off-farm work of zero. *Labor* refers to agricultural labor, while *wage rate* refers to *basic wage rate*, i.e., wage paid to hired labor (see also Sub-section 5.3.4).

2/ For explanation, see Section 5.1, note 4.

3/ Dovring 1966, pp. 289-290; as referred to in Hayami and Ruttan 1971, p. 179.

4/ The computer printouts with further details of each run are available on request.

5/ Also, the experiment with size of labor force described in Sub-section 6.1.5 shows significant variation in dual price for labor. Because exchangeable family labor is constant, the core family labor force changes substantially, giving the same effect as that described in Sub-section 6.1.6.

6/ Run F-50, the results of which are not listed in the table and graph, since a decrease in wage rate to this level is unlikely.

7/ Recently, tractor-operated sugar planters have become in demand in Thailand. However, these machines perform the furrowing and planting in one operation, unlike the machine considered in MECHMOD, which assumes two separate operations (see Table A3.11) and is now considered obsolete (or, in terms of MECHMOD, the technical coefficients have changed significantly). When discussing mechanical sugarcane planting, the old technology is referred to, but it is likely that the new technology is ready for widespread adoption. Additional runs showed that rice transplanters and cassava harvesters became attractive at a wage rate increase of 125 per cent, while rice combines needed a wage increase of 600 per cent before being economically attractive. However, because of the static nature of the experiment, the outcome of these wage levels should be interpreted with caution.

8/ The experiment was performed in Run F20A (results not reported).

9/ In agriculture, diesel fuel is used predominantly.

10/ The higher fuel consumption of the big tractor may be explained by higher working speed, rolling resistance of front wheels, and deeper plowing.

11/ The variable cost per rai (including depreciation) of combine harvesting rainfed paddy amounts to 289.81 baht, of which fuel and lubricant costs amount to only 21 baht or around 7 per cent.

12/ For example, in the Philippines under the World Bank credit scheme, in Nepal under the ADB project with the Agricultural Development Bank of Nepal, and particularly in Pakistan through World Bank/International Development Association (IDA) loans to the Agricultural Development Bank of Pakistan (ADBP) for financing of two-axle tractors, and more recently the financing of wheat combine harvesters by ADBP.

13/ Because of different rates for the three sources of capital, a change in cost of credit (interest rate) is given as a percentage of the three rates applied to the base year run, rather than in percentage points.

14/ These issues are discussed in several studies on agricultural credit (see for example Moll 1989).

15/ These are the rates at the time of the field research (1987). In May 1989, the prime lending rate stood at 12 per cent.

16/ Total disbursement in 1986 was 23.2 billion baht ($893 million) (BAAC 1986b, p. 11).

17/ For the Central Region, farm exchange labor is becoming less important. The percentage of core family labor is rapidly declining (NSO 1983, Table 5, p. 26).

18/ Although the dual prices are discrete, graphs are drawn for the purpose of illustration.

19/ Five per cent has been assumed based on data presented in NSO 1983, Table 5, p. 26.

20/ Wage rate for exchangeable family labor is 90 per cent of the cost of hired labor on account of mobilization cost.

21/ For similar reasons to those explained in Run 02.

22/ Because of increase in non-model crop area of 2.5 per cent annually, labor available to model crops decreases in absolute terms, as explained in Run 05.

23/ See Run 07 for explanation.

24/ ADBP advocates this strategy and persuaded the government of Pakistan to make small two-axle tractors available. These tractors, however, gained little popularity.

25/ Lock Chin Kong 1984.

26/ These experiments with combine technology are undertaken in Run M10 and Run M10A, respectively (results not reported).

27/ Run 28B (results not reported).

28/ In runs where a minimum area is grown because of limits on flexibility, labor is needed even when its return is less than that of working off-farm.

29/ After completion of the irrigation and drainage schemes in the Central Plain in the 1970s, farmers shifted from broadcast paddy to transplanted paddy when the price of rice was high. In the 1980s, this trend reversed when wages increased and rice price was low. This phenomenon has also been observed in other schemes. See also RID/ILACO 1986a, RID/ILACO 1986b.

30/ Draft animal population can increase maximally at 1 per cent per year. See Sub-section 5.3.4.

31/ However, area expansion of these crops may reduce their farmgate prices and, therefore, profitability. This option is therefore not considered further, since it requires information on price elasticities. At the prices assumed, an additional run showed that allowing full substitution of individual upland crops quickly reduces or even eliminates most upland crops in favor of cassava, occupying 83 per cent of upland area (Run D10, not reported). This confirms that cassava remains a very attractive crop to the Thai farmer.

32/ This is studied in Run E04A (results not reported) and also in Series I and Series II experiments, but no change occurred on account of these new small tractors when included in the options.

33/ See Section 3.1.

34/ The mechanization pattern in Run 04 is different from the pattern obtained in Run E03. For example, in the latter, reaper technology was not yet introduced. This requires further analysis of the detailed printout. In order to compare the effect of the second-hand small tractor with the outcome of Run E03, an additional Run (D05A) was made with UBDA=0 (upper bound on draft animals), meaning no draft animals were allowed in the solution. Under those circumstances, maize area is contracted because of the higher production cost (results not listed). The mechanical reapers are introduced in an effort to offset the effect of the higher cost of big tractors. (See also Run E05.)

35/ At this junction, lower acquisition cost for draft animals proves irrelevant, since they are no longer competitive with tractors. As discussed in Sub-section 6.1.3, when the acquisition cost is changed, the value of the capital stock is readjusted in the bar graphs to base year prices to maintain comparability in terms of number of units (capacity) between the bars.

36/ A 10 per cent increase in crop prices was insufficient to keep rainfed paddy land fully planted (Run E13A, results not reported).

37/ Run D 141, results not reported. In fact, this 15 per cent farmgate price in Run E13 is needed only to maintain maximum area utilization for sugarcane, maize, sorghum and rainfed paddy.

38/ At a 20 per cent farmgate price increase, rainfed paddy land remained underutilized.

39/ This experiment is undertaken in Run D09AA. Since no change in the solution takes place when compared with Run E09, the detailed results have not been reported.

7

INTERPRETATION OF FINDINGS AND CONCLUSIONS

Two aspects of this study should be distinguished in interpretating the MECHMOD experiments. First, MECHMOD was developed to analyze the process of mechanization and to provide a tool for country-specific mechanization policy and strategy formulation. Therefore, the first section of this chapter assesses the applicability of MECHMOD, including its suitability for application to other countries and situations. Second, the results of the experiments are interpreted and conclusions are provided concerning the formulation of mechanization policy and strategy for Thailand.

7.1 APPLICABILITY OF MECHMOD

The purpose of MECHMOD, its design criteria and its features are described in Sub-sections 5.2.1 and 5.2.2. Applying LP techniques emphasizes MECHMOD's normative characteristics. The technical and supply and demand relations are explicitly presented, and these can be easily adjusted to area- or country-specific requirements, or quickly modified if new information becomes available. MECHMOD's performance adhered to general principles and theories such as factor substitution as a result of changes in the cost of manual, draft animal and mechanical power; the application of opportunity cost and economies of scale; a shift from machine-centered to manpower-centered type mechanization when the wage rate increases and vice versa; adoption of cost-effective technology (technical innovation); and the theory of power-intensive versus control-intensive mechanization or staged development in mechanization. Experimenting with MECHMOD provides better insight into the impact of policy decisions and economic changes, and improves the understanding of the mechanization process.

It is once more emphasized that MECHMOD is a partial and static model and not a general equilibrium model. This implies that the wage rate and supply of labor are externally supplied variables. Therefore, when specifying a particular economic development scenario exogenously, MECHMOD reveals the implications for mechanization. In Series III experiments, MECHMOD is used to identify the implications of low yields and low farmgate prices on mechanization and agricultural production when the cost of labor continues to increase. MECHMOD provides the proper picture of future mechanization in Thailand, however, only if the exogenous data input represent the actual economic development scenario. In a general equilibrium model, this scenario is established endogenously, demanding knowledge of future prices and price elasticities, accurate and comprehensive data, and substantial inputs of manpower and computer time. Because of the complexities involved (as discussed in Chapter 5), obtaining results of these equilibrium models is time consuming and results are often of limited validity, even when substantial resources are allocated for data collection and model construction.[1/]

For the purpose of mechanization policy and strategy formulation, the equilibrium models are not practical tools for agricultural planners and mechanization experts engaged for limited periods of time. The advantage of MECHMOD for these applications is that it is easily understood and highly flexible, and can be quickly adjusted for application in other localities or conditions. Different clientele may demand different information from MECHMOD. This can be quickly accommodated in MECHMOD provided the required input data are available. Concomitantly, the formulation, development and experiments with MECHMOD also adhere to a precept put forth by Hazell and Norton.

> *Building an applied model is a process, and the most successful models evolve through time to take into account new findings. There never is a definite version, but rather at any moment in time the model represents a kind of orderly data bank that reflects both the strengths and limitations of the available quantitative information.* [2/]

Apart from absorbing quick changes in input data, MECHMOD itself can easily incorporate additional features. For example, for an irrigation project area, limitations on water resources and water requirements can be quickly included. If applicable and available, a timeliness function can be incorporated for a confined and homogenous project area. However, using MECHMOD and modifying it to include special features require an understanding of LP techniques, a good knowledge of Sciconic software applications, and the ability to program computers in FORTRAN. It must also be stressed that MECHMOD could not have been developed within a limited time frame, nor could its degree of flexibility have been achieved without the application of high-level computer software (such as described in Sub-section 5.2.4) and its development and implementation on a mainframe computer. However, to have practical and widespread application, MECHMOD should be implemented on a personal computer. With conversion for personal computer application in mind, considerable effort has been made to keep the LP tableau compact. [3/] Nevertheless, the size of the LP matrix is still in the order of 1,000 rows and 1,200 columns. After initial runs, the number of activities may be reduced when certain technology options or methods (for example, threshing by animal trampling) become irrelevant for the experiments conducted. Nevertheless, the numbers of rows and columns remain in the order of 800 x 1,000 during most experiments, which is still too large to be run on personal computers. [4/]

Further work to adapt MECHMOD for use with personal computers is recommended. Three ways to drastically reduce the size of the LP tableau and computer run time should be further explored: (i) Calendar periods for cropping may be increased from half-monthly to monthly. This would reduce the number of rows by about half, although the effect on the performance and validity of MECHMOD should be further ascertained. (ii) The workability class of a particular method is period-specific and is represented in MECHMOD through additional constraints (rows) when a machine is used in more than one workability class. An alternative method is to correct the reference time for weather-related factors. This reduces the number of constraints, but the objective function coefficient should be adjusted with a reciprocal factor to maintain the correct per unit area variable cost. A disadvantage of this approach is that the information from sensitivity analyses can no longer be used without applying a method and period-specific correction. (iii) MGG facilitates the quick deletion or inclusion of certain machinery, methods or operations through flagging the relevant index in the external data file. Certain options may be relevant only over a limited range of an external policy or economic variable. For example, at lower wage rates, expensive mechanization technology is not a viable option, and combine harvesters may therefore be flagged for elimination in the tableau. Since the combine harvesting activity is included per period and per crop, the numbers of columns and rows are significantly reduced. Similarly, when the cost of labor increases, draft animal technology may be excluded when it is no longer a viable option. This approach requires some indication of the range over which certain technologies are relevant. This information may be obtained through sensitivity analysis. [5/]

7.2 FUTURE MECHANIZATION IN THAILAND

7.2.1 Outlook for Agricultural Development and Consequences for Mechanization

The selection of the proper mechanization scenario out of Series II experiments and the recommended mechanization strategy will depend on the correct forecasting of economic development, particularly in the agricultural sector. The World Bank attempted to project area expansion and yield increase of important crops. [6/] The main contribution of this study was its indication of potential achievement through area expansion and technical progress (for example, improved seed, more fertilizer usage, and other technology). However, these projections paid little attention to the dynamic nature of Thai agriculture and its capability of responding quickly to increased farmgate prices for certain crops, which cause farmers to shift rapidly from one crop to another. This situation makes farmgate price projections for individual crops very difficult, [7/] and policies on quotas in overseas markets (for example, the EC quota for cassava import) and other restrictions (for example, standards on aflatoxin for maize exported to Japan and the Republic of China) exacerbate attempts at accurate projections. Projecting area expansion and agricultural growth for Thailand is, therefore, rather difficult.

Although Thailand's agricultural development was highly successful up to 1980, pessimism concerning further growth prevailed in the early 1980s. [8/] A study conducted at the end of 1983 was fairly optimistic about the outlook for Thai agriculture because the depressed prices would not affect Thailand's comparative advantage as an agricultural producer, and signs existed that prices for many agricultural commodities were already recovering. [9/] The latter view proved rather premature: In 1987 prices for several Thai export crops had been severely depressed for several years, and returns to farmers had been equally poor, due to adverse weather conditions. Subsequently, sales of agricultural machinery plummeted and at the time of field research for this study (1987), there was little cause for optimism. A year later, the world market price for sugar doubled, while the prices for maize and rice increased by 70 and 40 per cent, respectively. [10/]

Another claim is that the malaise in the world market for agricultural commodities is a permanent phenomenon, and the recent upturn in prices will not endure. [11] The basis for this claim is that the protection of agriculture in the industrialized countries has been capitalized into the value of land, and that politically and socially these countries cannot afford to substantially lower their protection. In addition, the developing countries which have been importers in the past are increasingly self-sufficient, and some may even become competitors in the world market. [12] Long-term commodity price projections also suggest that the pre-1982 prices for agricultural commodities will not return at least for the next decade.[13] Thailand will not be able to compete in subsidies or support prices with Japan, the EC, or the US. With these high subsidies and support prices in other countries, Thailand's comparative advantage becomes ineffective. Since prices for agricultural commodities highly affect the profitability of farming, rates of expansion for crop area will depend highly on farmgate prices affecting mechanization. Because of the difficulties with projecting commodity prices, the expected growth rates in agricultural employment, labor cost, crop area expansion, and other relevant developments are discussed to indicate scenarios that may likely materialize.

The experiments in this study show that area expansion is a dominant force for increasing power-intensive mechanization. However, area expansion will cease because the burgeoning phase of international markets for traditional Thai export crops is over, while expanding the land frontier is increasingly costly and less rewarding. Disagreement may exist as to the question of how much cultivable land can or will still be developed, but it is most unlikely that the rate of area expansion of the last 30 years can be maintained, since the limits of the land frontier are in sight. [14] Similarly, an increase in double cropping through expansion of irrigated areas is technically feasible, but with the low crop prices, the investments are no longer financially attractive. Rice prices dropped from over $400 per ton in the 1970s to $180 in 1986. Subsequently, although rice prices have improved since 1986, the high prices of the 1970s are unlikely to return, and little investment in expansion of irrigated land will take place. [15]

Assuming that the markets for major Thai agricultural export commodities remain depressed in the future due to overproduction in the world's agriculture, a possible solution for Thailand is to switch to high-value crops, particularly fruits and vegetables. Export of these crops has grown very rapidly in recent years[16]; but most of these crops are highly perishable, quality requirements in foreign markets are strict, and demand for individual crops is limited. These high-value crops are usually grown on irrigated land, but alternatives exist for upland agriculture (for example, fruit trees and commercial tree production for fuel, timber or pulp). Experiments show that for these high-value crops most control-intensive mechanization technology is not financially viable in the near to medium future, while power-intensive operations will be reduced once perennial crops are established. [17]

Unlike intensification, area expansion was important in absorbing the incremental labor force in the 1960s and the 1970s. As explained above, area expansion will slow down or stagnate, while falling world market prices will have a negative effect on the returns to agricultural labor, thereby depressing wage rates. However, Thai labor statistics indicate that numerous people included in the census under agricultural labor force obtain a significant portion of their income from outside the sector, and this will cushion the effect of diminishing returns to agriculture as well as labor absorption. Siamwalla considers two possible scenarios for the agricultural labor force. First, non-agricultural employment opportunity may expand rapidly, causing agricultural labor to leave the sector. Second, if non-agricultural employment fails to expand sufficiently, farmers will attempt to avoid a drop in income either by additional area expansion, or because of the limits on the land frontier, by intensification. [18] Which of these two scenarios will materialize depends primarily on the pace of expansion of the non-agricultural sector. A scenario explored in Series III experiments whereby land is left idle will come about if returns to agricultural labor stagnate compared with the non-agricultural sector. At least initially, the process of abandoning land will be confined to marginally productive agricultural land for which the higher levels of mechanization are not financially viable. Whether this phenomenon will actually occur will depend on whether it will be profitable to transform the marginal farming systems into higher yielding systems. This depends largely on price incentives, although decreases in cost of production through technology development (for example, low-cost chemical and biological innovations) and structural changes (for example, larger farms and fields) should have a similar effect, but the scope for these scenarios is likely to be limited.

Land abandonment will further depend on the pace of economic development, particularly the pace of industrialization in Thailand [19] and level of farmgate prices. At low farmgate prices, farmers will abandon marginal land earlier. The pace of industrialization largely depends on the economic development taking place in other countries, in particular, how fast other countries (for example, People's Republic of China, India, Sri Lanka) can penetrate markets vacated by the original NICs [20] when wages in these NICs catch up with productivity. Also, the economic growth in Organization for Economic Cooperation and Development (OECD) countries will affect aggregate imports from the third world, including from Thailand. [21/] Similarly, because of the strengthening of the yen relative to the dollar and baht, Japanese companies are increasingly investing in Thailand, not only for import substitution manufacture, but increasingly for export to other markets.

The expanding manufacture, construction and service sectors will increasingly entice labor away from agriculture, especially around greater Bangkok, where part-time seasonal farmers who earn a larger part of their income off-farm are already common. Lewis identified the non-subsidized mechanization of rice farming to allow workers to cease full-time farming as a component of rural development.[22/] However, this process has occurred spontaneously for several years, and there is little reason to limit it to rice farming, nor does there appear to be any need for active government involvement through an enhanced rural development program.

With reference to above, the following scenario is likely: Zero to low growth rates in area planted with traditional crops, low to medium agricultural labor force growth rates, and medium to high wage rate increases will occur. With reference to Series II experiments, Run 03, with low growth rates for crop area and agricultural labor and high growth rates for wages, and Run 12, with zero growth rates for crop area and agricultural labor and high growth rates for wages, are relevant to this scenario. If agricultural commodity prices remain attractive, Run 11, with medium growth rates for crop area and labor force and high growth rates for wages, is also applicable. These runs confirm that land preparation in the Central Region will soon be fully mechanized, while mechanized reaping of paddy and mechanical sugarcane harvesting will soon be adopted. Several other runs confirm that mechanical land preparation will become fully mechanized in the short to medium term, while adoption rates of mechanical reaping and sugarcane harvesting will largely depend on whether the cost of labor increases and whether agriculture remains an important labor absorber. Under these scenarios, annual increase in machinery capital stock in the Central Region will be between 5 and 6 per cent, much lower than that experienced in the 1970s (Table A1.1). However, this growth rate has a higher base, while replacement of equipment will become an important market for the domestic agricultural machinery industry. Therefore, there is little reason to be pessimistic concerning the future demand for agricultural machinery and the future of the industry, since a shake-out has already reduced the number of participants. Also, other regions are still in a much less advanced stage of mechanization and should achieve higher rates of investment in mechanization technology.

7.2.2 Specific Conclusions and Recommendations for Mechanization Strategy and Policy Formulation

The analysis in this study produces specific information and shows the implications of several variables concerning the process of mechanization in Thailand. This information is summarized in the following conclusions and recommendations:

(i) Increase in crop area at a higher rate than the agricultural labor force without a relative change in the cost of manual, draft animal or mechanical technology leads mainly to further mechanization of land preparation. Only if labor cost increases relative to mechanical technologies may mechanization of control-intensive operations become significant.

(ii) With the exception of chemical weed control, mechanical reaping and cane harvesting, Thailand's mechanization process will not proceed significantly into Stage III (Human Control Substitution) during the next 5 to 10 years.[23/] Farm operations to be mechanized during Stage III are control-intensive operations,[24/] which are expensive to mechanize and may save relatively little labor. A substantial increase in wage rate is therefore required before grain combine harvesters, cassava harvesters, planting equipment and mechanical or chemical weed control for maize, sorghum and cassava are widely adopted.[25/] Some advanced technologies, particularly rice combine harvesters, require investment in land development which will make these technologies even less likely to be adopted soon.[26/]

(iii) Once power-intensive operations are fully mechanized in Thailand, mechanization will be only a limited solution to offset the increasing cost of labor due to the high cost of more sophisticated machinery. Unless returns per unit area increase through higher farmgate prices, higher yields, or a combination of both, ultimately the marginal farming systems (in terms of yield) will be incapable of financially supporting more advanced and costly control-intensive mechanization technology. Therefore, if the increasingly higher labor cost is not accompanied by higher returns, land with marginal farming systems will be left fallow.

(iv) In addition to (ii) and (iii) above, the experiments show that highly mechanized farming systems from industrialized countries will not be adopted in Thailand unless the real wage rate at least doubles and farmgate prices or yields increase substantially. In this context, the combination of high wage rates, subsidized machinery, and much higher farmgate prices in Eastern Asian countries explains the level of mechanization in these countries.

(v) Implementation of certain policy changes can reduce agricultural production costs without the need for government subsidy or support prices. These policy changes include the provision of credit from BAAC without preference to type of technology, its origin, or its utilization (see [vi] below). Another major cost-reducing policy is the promotion of small, second-hand, two-axle tractors imported from Japan and equipped with appropriate equipment for paddy land preparation. The implementation of this program requires: (a) reversal of the controversial controls on second-hand tractor imports from Japan (see Section 3.2);[27] (b) introduction (local manufacture and demonstration) of the single-row disc harrow developed in other countries for use in paddy fields, and paddy puddle wheels; and (c) development and manufacture of a low-cost flat belt power-take-off for the Japanese-made tractors to facilitate driving stationary equipment (for example, pumps and threshers) with this tractor. The technical requirements should not cause any problem in Thailand once a sample has been developed and demonstrated. The reduced demand for Thai manufactured tractors may be offset by the manufacture of implements for these tractors and parts.

(vi) No justification exists for the present policy of making credit from BAAC available only for small-scale indigenous machinery. Experiments in Sub-section 6.1.4 show that these technologies are the least in need of this institutional credit.[28] The policy may be beneficial to the local machinery industry, but the preferential interest rate for small-scale technology (which is relevant only to paddy production) puts the upland farmer at a disadvantage, including the small farmer who depends on contractor services. The opinion that this institutional credit for more sophisticated and high capacity machines benefits only the large farmer is at least in the case of Thailand erroneous. With BAAC credit available for financing contractor rental fees, small farmers will increasingly demand the services of contractors. Because of the efficient and competitive machinery contracting services, a reduction in cost of credit for investment in big tractors will reduce machinery contracting rates and thus benefit the small farmer. Moreover, abolishing the preferential scheme may be accompanied by an increase in BAAC rates to the level of commercial bank rates without affecting the agricultural sector's productivity (Section 6.1.4). This would also allow BAAC to raise its deposit rates and assume an important force in rural saving mobilization. [29/]

(vii) In addition to (vi) above, subsidized credit is not recommended as a policy instrument to promote mechanization. Although lowering interest rates is effective in stimulating agricultural mechanization, subsidized credit usually jeopardizes the purpose of the credit scheme and the financial viability of credit institutions.[30/]

(viii) The wage rate affects the draft animal/two-axle tractor substitution process more than draft animal/single-axle tractor substitution because of the higher labor substitution effect of the two-axle tractor in terms of man-hours per unit area. Although irrelevant to the Central Region of Thailand, it can be recommended that in countries or areas where draft animal power rather than labor is a constraint (either because of high investment or maintenance cost, diseases, or lack of fresh water in swampy coastal areas), mechanization of paddy land preparation should focus on low cost single-axle tractors rather than on two-axle tractors.

(ix) Paddy land preparation with single-axle tractor and power threshing technology as applied in Thailand is highly cost effective. This explains the rapid adoption of power threshers over a period of five years. Mechanical paddy reapers are likely next in line for rapid adoption provided low-cost designs are promoted and adapted to Thai conditions.[31/]

(x) A second effort (the first in the mid 1970s failed) to mechanize sugarcane harvest may succeed if the real wage rate increases by 5 to 10 per cent. Initially, these machines will replace the seasonally hired migratory labor force. However, it is recommended that an intermediate mechanization level of sugarcane harvest be studied, especially the mechanization of cane loading in the field.

(xi) Changes in the price of fuel mainly affect mechanical land preparation, particularly for upland crops with big tractors.

Differentiation of fuel price for the agricultural sector is an efficient policy instrument for the mechanization of land preparation provided an economic justification exists. However, history has shown that such price differentiation is difficult to implement and quickly results in misuse, and is therefore not recommended.[32/]

(xii) Reasonable protection of local industry may be required for specific machinery initially to promote its domestic manufacture and to establish a farm machinery industry. This has been done successfully in the Republic of Korea and the Republic of China, and, once firmly established, these countries managed to produce competitively and obtain an important share of the export market. The same may soon occur with diesel engines of Japanese design (already manufactured in Thailand) if the baht/yen exchange rate remains favorable for Thailand. However, if protectionist policies occur, all aspects of import restrictions must be fully considered, and the cost of protectionist measures should not be transferred to farmers who, with depressed crop prices, will have difficulty absorbing these additional costs. Proper policies such as tax holidays for manufacturers rather than protectionism through artificial high prices for imports must be identified to support the development of the machinery industry at minimum cost to the farmer.

(xiii) Experiments indicate that taxation or subsidy on specific machinery is an efficient instrument to guide the mechanization process in a desired direction. The Republic of Korea and the Republic of China have used this policy to selectively stimulate agricultural mechanization. Similarly, in Thailand, import duties and sales taxes on cane harvesters could be reduced to make the sugar industry more competitive. These discriminating policies, however, can cause economic inefficiencies. For example, an artificial advantage to sugarcane production may be provided, while a shift to other crops may be more beneficial to the economy. On the other hand, rice production was taxed heavily in Thailand when world prices were high. Under these circumstances, subsidies for machinery used for rice production may be justified. Also, preferential policies for stimulating domestic diesel engine manufacture initially resulted in higher engine prices than those imported from Japan, with farmers actually subsidizing the industrial sector. Therefore, a subsidy on these engines was a logical conclusion, but the strong yen has now eliminated this price disadvantage. Nevertheless, a major conclusion of this study remains that governments should not interfere in the market mechanism for supply and demand of mechanization technology, but limit their role to provide the required institutional support.

(xiv) Small rice combine harvesters and new, small two-axle tractors are less cost effective than bigger harvesters and tractors. Although this matter should be further explored, the experiments suggest that machinery developed for East Asian countries may not always be suitable for Thailand for both economic and technical reasons (for the latter, see Section 4.3).

(xv) Traditionally, draft animals in Thailand were used only for paddy land cultivation, and no suitable draft animal implements have been commercially introduced for upland farmers. Experimental work and demonstrations in the past with improved animal-drawn implements for upland farming were promising. [33/] However, the MECHMOD experiments clearly indicate that draft animal technology is rapidly on its way out in the Central Region, and this trend will continue in the less advanced regions. Therefore, there is little justification for further research and development on improved draft animal technology in Thailand.

(xvi) The experiments in Chapter 6 have convincingly shown that mechanical paddy transplanters are unlikely to become in demand. An increase in labor cost will cause a shift toward broadcast paddy, and therefore research and development efforts should not be spent on mechanical transplanting technology.

(xvii) Contrary to the experience in many developing countries, a bias towards mechanical technology at the expense of labor has not been experienced in Thailand. In fact, several government policies have put mechanical technology at a disadvantage: for example, the absence of credit from BAAC for the more advanced imported machinery, protection of domestic tractor and engine manufacture, and heavy taxation of rice exports. Labor-saving technology will become increasingly important for Thailand, and the government must eliminate policies which cause a bias against mechanization.

(xviii) In Thailand, as in the industrialized countries, research and development on agricultural machinery is undertaken largely by the private sector. However, it is doubtful whether the Thai private sector will be able to maintain this momentum. Technically, the machinery manufacturing industry is still at an early stage and has been innovative mainly in its application of low cost, labor-intensive production technology rather than in inventing new machinery (see Section 3.2). Many manufacturers lack the agronomical knowledge and research and development capability to develop the sophisticated machinery needed, particularly for control-intensive operations. In most cases, the required investment in the development of this machinery is not financially attractive for the individual Thai manufacturer. The cost of skilled labor and design engineers is likely to increase rapidly, and more labor-productive manufacturing technology will require capital and know-how. Asian NICs and other developing countries usually establish their agricultural machinery industry in collaboration with foreign companies. Sophisticated machinery is presently produced by large companies on a global scale. Therefore, a sustainable and competitive agricultural machinery manufacturing industry for both domestic and export markets is likely to come about only with the collaboration of foreign manufacturers.

(xix) Agricultural mechanization will become increasingly important and sophisticated to offset increasing wage rates. Given the limitations of the private sector on research and development, AED must assume a stronger but clearly defined role. The need to rationalize the role of AED was discussed in Sub-section 3.3.3, and efforts to invent new machines must be avoided. AED should (a) focus on assessment of bottlenecks in the agricultural production system which may be eliminated through mechanization; (b) import samples of potentially suitable machinery to serve as prototypes; (c) undertake (either by itself or under contract with research institutions) extensive testing and modification of these prototypes; and (d) recommend alternative farming practices required for the efficient utilization of these machines. Once a suitable machine or solution has been obtained, promotional work, extension and advisory services on mechanization should be provided or initiated by AED. A recent project on the mechanization of the peanut crop could be considered a test case on how successful the government will be in providing new mechanization technology to the farmers.[34/]

NOTES AND REFERENCES TO CHAPTER 7

1/ For example, one of the principal objectives of IRRI's Consequences of Mechanization Project was to integrate the data collected into a model which would subsequently be used to make projections of the impact of mechanization on employment, incomes, and income distribution (Wicks 1979, p. 1). A comprehensive data collection exercise was undertaken in three countries, but the model was not constructed by the time project funding was terminated (personal communication with J.A. Wicks, Manila, October 1988). Since early 1980, SOW had allocated substantial resources to develop a general equilibrium model for the agricultural sector in Thailand, but a satisfactory version is not yet available and the approach has been subject to critical debate.

2/ Hazell and Norton 1986, p. 272.

3/ For example, because of the multiple cropping imitation in the LP tableau, land occupation must be period-specific. To accommodate this, a usual formulation would increase MECHMOD's tableau by 24 (periods) times 4 (land types), or 96 columns. In MECHMOD's formulation, no extra columns are required, because land occupation is combined with columns which represent field operations (namely, land preparation and harvest). For details, see Kavelaars 1988, Appendix VI, pp. 146-149.

4/ The personal computer versions of the mainframe software used are MGG and MICRO LP (the LP solver) by Scicon Ltd., Milton Keynes, UK. MICRO LP can solve only non-integer problems with up to 300 rows by 500 columns. Other LP solvers for personal computers claim to solve much larger matrices, but because of limited core memory size, computer run time becomes excessive. In principle, however, it should be possible to use these LP solvers in combination with MGG.

5/ An additional recommendation for reducing the size of the LP tableau is to formulate flexibility constraints as bounds rather than as constraints whenever applicable. However, not all LP software for personal computers include a facility for using bounds.

6/ World Bank 1982.

7/ This is demonstrated by, for example, sugarcane. Based on the assumption that yields would continue to improve by about 2.5 per cent per year and that the area under sugarcane would remain constraint (due to export limitations under the sugar agreement), NESDB projected an increase in production from 21.6 million tons in 1981 to 24.5 million tons by 1986. However, this level of production was already achieved by 1982 (Rijk and van der Meer 1984, p. 41).

8/ Three basic arguments for this pessimism were the depressed world market prices for agricultural produce, limits on the land frontier being approached, and the government agencies for supporting services required for agricultural intensification and development being unable to provide the support needed to maintain high agricultural growth rates (Rijk and van der Meer 1984, p. 97).

9/ Rijk and van der Meer 1984, p. 97.

10/ Far Eastern Economic Review 1988, p. 72. The World Bank projected in its October 1986 commodity projection report for 1987 and 1988 maize prices of $117 and $123, respectively, per ton, compared with an actual price of $275 for August 1988. For rice, these prices were $220, $243, and $310, respectively (World Bank 1986c, Volume II, p. 169).

29/ Institutional credit rates lower than the market rates are frequently held responsible for agricultural credit institutions being unable to mobilize rural savings. It has also been recommended that BAAC be allowed to raise its rates and become a force in rural savings mobilization (ADB 1988, p. 14).

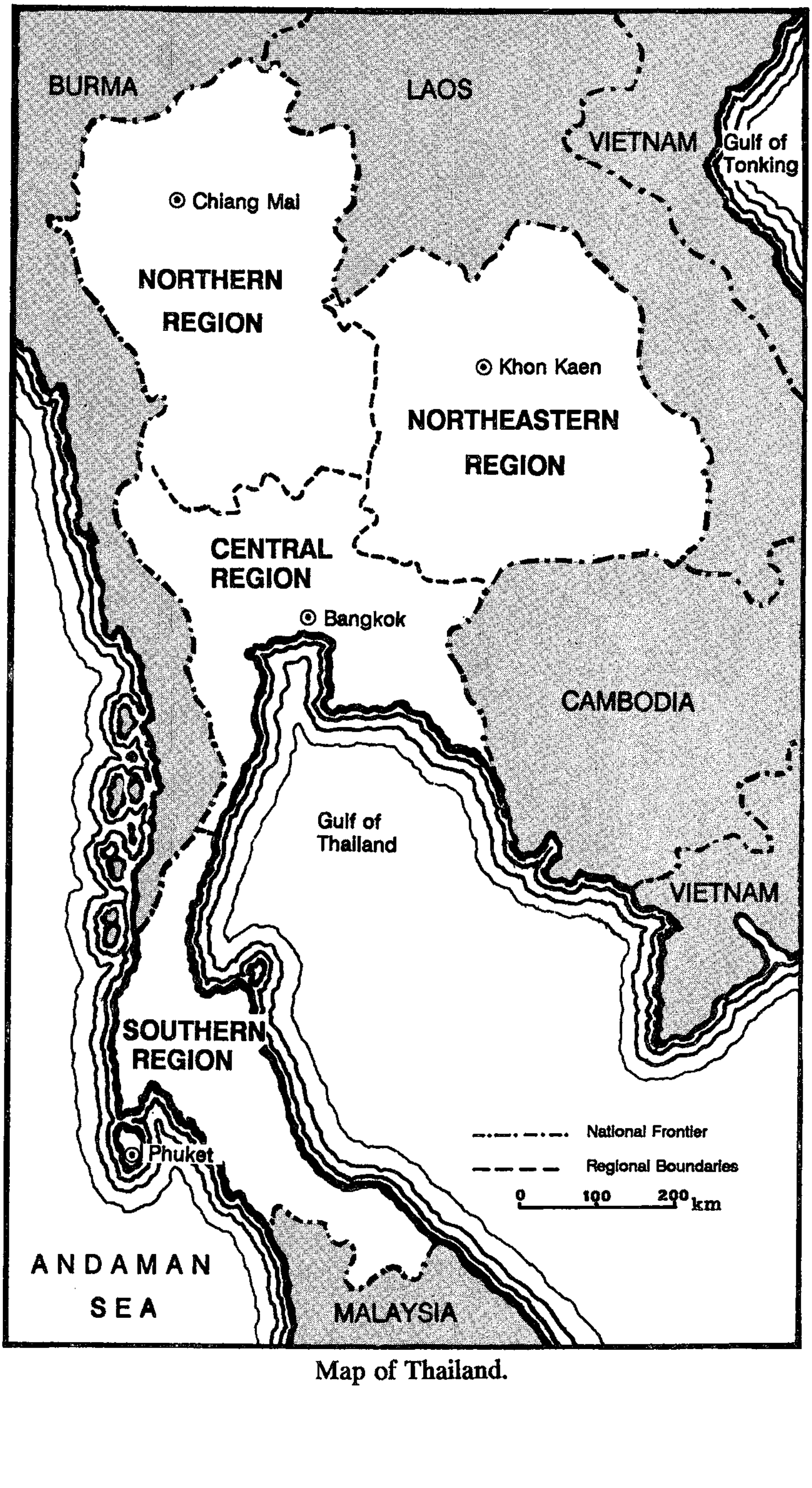
30/ For a discussion on this matter, see for example Moll 1989.

31/ Research at IRRI and the Chinese Academy for Agricultural Mechanization (CAAM) resulted in the development of low-cost reaper technology which is already adopted in Pakistan. An important issue is whether the rapid and widespread introduction of reaper technology requires agronomical changes in Thailand. Some varieties may be shatter- or lodging-prone, creating difficulties for mechanical reaping. The pace of the adoption process may therefore slacken because of the requirement to change to varieties more suitable to mechanical reaper technology. See also Juarez 1989.

32/ When domestic cooking gas became subsidized in Thailand, motor rickshaws and taxes in Bangkok were quickly converted to take advantage of its price differential with gasoline. Similarly, because of the subsidized and extremely low lamp oil (kerosene) price in Indonesia for family use only, it was quickly put to use for industrial purposes (for example, cement factories), and engines were converted to run on kerosene.

33/ For example, the Thai-Australian Land Development Project (TALD) in Northern Thailand and the Dutch-assisted Integrated Development Project (IDP) in Northeast Thailand.

34/ Mongkoltanas 1988, p. 23.



Map of Thailand.

APPENDIX 1

DETAILS ABOUT THE MECHANIZATION SUBSECTOR

A1.1 THE DATA BASE FOR AGRICULTURAL MECHANIZATION

In Thailand, reliable statistical data on agricultural machinery imports, local manufacture and utilization are difficult to obtain because of the language barrier. Beyond this constraint, however, careful examination and interpretation are needed to gather meaningful data for analysis. For example, the Customs Department import data for plows include discs which are imported as parts for the domestic manufacture of disc plows, disc tillers (poly-disc plows) and disc harrows, or as replacement parts for these implements. Import data on water pumps do not specify type or usage, and many of the pumps are probably used for domestic water supply in urban areas. Statistics on import of tractors are unspecified, and they do not match the quantities reported by importers. Motor vehicle registration data of the Police Department list tractors but provide no details, and actual numbers are inconsistent. With the import of large quantities of cheap single-axle tractors in 1981 from the People's Republic of China and the import of Japanese second-hand two-axle tractors, import data for tractors became meaningless, since no distinction was made between type and size. Most other reports and statistics for tractors do not distinguish between locally manufactured and imported tractors, although they have different usage (see Section 3.1). Statistics on imports for new big tractors can be obtained from importers, but data on second-hand small tractors imported from Japan are unreliable, since these are shipped in containers (and sometimes shipped in parts), often without counting the units, since import duties are paid over total value. Because of import quotas on these tractors, dealers are very reluctant to disclose the quantity annually imported. Statistics on sprayers may include hand operated knapsack sprayers, including those for non-agricultural use, engine-driven knapsack sprayers and dusters, tractor-drawn boom (field) sprayers, and spray-lance type machines for orchards.

Until a few years ago, statistics published by the Office of Agricultural Economics (OAE) on the stock of machinery, particularly big two-axle tractors, were around 50 per cent overestimated. The OAE data were obtained through extrapolation of data from an earlier agricultural census, and applied too high a growth rate when tractor imports and sale of other machinery fell drastically after 1980. Similar problems as above are encountered with statistics on other machinery. Since the statistical data are usually unexplained, without verification and double checking erroneous conclusions may easily be drawn.

An OAE report provides 1985 census data on the number of draft animals, single-axle and two-axle tractors, water pumps, sprayers, and threshers owned by farmers (Table A1.1). The data give the number of single-axle tractors and big two-axle tractors, but do not include two-axle locally made and second-hand imported small tractors. Cross checking these data with various other sources of information, the data presented in Table A1.1 appear accurate. Table A1.2 provides data on domestic machinery manufacture.

The manufacture and utilization of agricultural machinery have become increasingly important in industrial and agricultural development. In order to facilitate decision making by planners and entrepreneurs, reliable statistics are of paramount importance. An urgent task for the National Committee on Agricultural Machinery (NCAM) is to provide guidelines and a standard format for the collection and presentation of statistical data on agricultural machinery importation, manufacture, and utilization, including those for the agricultural census. The development of guidelines and procedures for reliable data collection could be taken up with assistance or expertise from FAO or RNAM. A meaningful and standardized format could be used to compare and exchange data with other countries, and to facilitate common analysis. This could greatly assist planners, manufacturers, and the domestic and international trade, particularly within the Southeast Asian countries.

A1.2 SUPPLY OF AGRICULTURAL MACHINERY

A1.2.1 Import of Machinery

A major shortcoming of the statistics on agricultural machinery imports is that no differentiation is made between type and size, new or

Table A1.1. Stock of draft animals and machinery.

Item	Region	1978	1981	1985	Annual Growth Rate (%) 1978-85
Draft Bullock	Northeast	522,030		508,190	-0.4
	North	428,634		188,872	-11.0
	Central	208,683		103,903	-9.5
	South	372,361		141,611	-12.9
	Thailand	1,531,708		942,576	-6.7
Draft Buffalo	Northeast	2,389,869		1,778,942	-4.1
	North	765,278		301,143	-12.5
	Central	325,566		157,012	-9.9
	South	133,133		80,834	-6.9
	Thailand	3,613,846		2,317,931	-6.1
Single-axle Tractor	Northeast	13,196	20,879	38,790	16.7
	North	45,172	74,739	139,785	17.5
	Central	106,497	140,782	172,027	7.1
	South	17,108	27,146	51,480	17.0
	Thailand	181,973	263,546	402,082	12.0
Two-axle Tractor > 45 hp	Northeast	2,152	3,422	4,950	12.6
	North	4,078	5,812	9,296	12.5
	Central	6,614	10,906	16,082	13.5
	South	439	684	1,087	13.8
	Thailand	13,283	20,824	31,415	13.1
Water Pump (Agr. use only)	Northeast	45,352	67,568	95,579	11.2
	North	74,725	116,993	164,324	11.9
	Central	159,240	236,688	327,995	10.9
	South	10,510	17,133	26,893	14.4
	Thailand	289,827	438,382	614,791	11.3
Motor Sprayer	Northeast	3,894		6,010	6.4
	North	9,483		19,199	10.6
	Central	24,930		78,908	17.9
	South	921		2,094	12.5
	Thailand	39,228		106,211	15.3
Manual Sprayer	Northeast	38,285		218,245	28.2
	North	106,613		457,885	23.1
	Central	105,822		377,493	19.9
	South	6,688		58,439	36.6
	Thailand	257,408		1,112,062	23.2
Thresher/Sheller	Northeast	1,216		2,631	11.7
	North	4,339		7,841	8.8
	Central	15,236		19,496	3.6
	South	202		794	21.6
	Thailand	20,993		30,762	5.6
Farm Truck	Northeast			13,708	
	North			16,556	
	Central			14,561	
	South			621	
	Thailand			45,446	
Trailer for Tractor	Northeast			18,261	
	North			112,302	
	Central			139,938	
	South			19,153	
	Thailand			289,654	

Source: Office of Agricultural Economics 1986.

Table A1.2. Domestic production of key agricultural machinery.

Item	Annual Production 1980-81	Annual Production 1985-86	Increase %	No. of Firms 1980-81	No. of Firms 1985-86	Increase %	Average Sale Price (baht) 1985-86	Value (Million Baht) 1985-86	Comments
1 Single-Axle Tractor	50,000	40,000	−20	25	30	20	10,000	400	Excl. engine
2 Two-Axle Tractor	5,000	500	−90	12	3	−75	50,000	25	Excl. engine
3 Disc Plow for 1	n.a	30,000	-	n.a.	20	-	3,000	90	
4 Disc Plow - Big Tractor	3,000	3,000	0	20	15	−25	18,000	54	
5 Ridger for Big Tractor	500	2,000	300	5	15	200	10,000	20	
6 Plowframe for Animal	15,000	150,000	900	10	30	200	150	22.5	
7 Plowshares for 6	300,000	400,000	33	10	20	100	18	7.2	Incl. replacement parts
8 Water Pump (all types)	5,000	25,000	400	10	20	100	4,000	100	
9 Paddy Thresher	3,500	4,000	14	20	28	40	35,000	140	Excl. engine
10 Other Thresher	200	500	150	8	10	25	30,000	15	
11 Maize Sheller	1,500	1,500	0	20	20	0	10,000	15	Incl. hand operated
12 Peanut Sheller	60	50	−17	2	2	0	9,000	0.45	
13 Rice Mill	1,000	5,000	400	20	50	150	85,000	425	Small type incl. engine
14 Coffee Husker	20	200	900	1	7	600	8,000	1.6	Engleberg excl. engine
15 Winnower	500	1,000	100	10	8	−20	2,000	2	
16 Cassava Slicer	1,000	700	−30	6	5	−17	7,000	4.9	Excl. engine
17 Small Rotary Mower	n.a.	5,000	-	n.a.	6		n.a.		Handpush, incl. engine
18 Trailer	3,000	4,000	33	10	10	0	5,000	20	Single-axle
19 Farm Truck	1,500	4,000	167	2	20	900	80,000	320	Incl. engine
Total								1,662	Million baht

Note: n.a. = not available.

Sources:

- Mongkoltanatas 1981.
- Data based on a survey by AED in June 1985 - March 1986, and reported in AED 1986.
- Average prices, collected from reports, BAAC, manufacturers, and dealers.

second-hand. Two-axle tractor imports during 1974-81 averaged about 2,300 units annually, and the majority of these tractors were of the 33-64 kW (45-85 hp) size. In the case of single-axle tractors (including power tillers), it is estimated that less than 5 per cent of the total annual demand was ever imported. Since 1981, import has totally stopped because of high duties. [1/] During 1981, tractor imports increased to 12,862 units because of a sudden increase in imports of single-axle tractors from the People's Republic of China and second-hand two-axle tractors from Japan and Europe. Most of the second-hand two-axle tractors imported from Japan were initially in the 10-18 kW (14-25 hp) range. Under pressure from manufacturers, the Government restricted the import of single-axle and small Japanese tractors by imposing higher import duties and placed a quota on the import of tractors with less than 1,100 cc engine capacity. The small Japanese tractors are used for totally different work than the locally made two-axle tractors. Therefore, these tractors do not compete for the same market, and the government restrictions only resulted in higher cost to the farmers.[2/] The restrictions also shifted second-hand imports to the 15-26 kW (20-35 hp) range. The importation of the single-axle tractors reduced rapidly as a result of the import restrictions, and they are no longer brought into the country. In 1986, it was estimated that at least 5,000 small, second hand two-axle tractors were imported from Japan in the 15-26 kW (20-35 hp) range with prices of about 50,000 baht ($1,900) (15 kW/20 hp) to 80,000 baht ($3,000) (26 kW/35 hp) for tractors with often no more than 500 hours of operation. [3/] By comparison, the locally built two-axle tractor equipped with a 13 kW (18 hp) engine sold for nearly 100,000 baht ($3,800) and had fewer technical capabilities. Kubota, Ford and Massey Ferguson offered models (made in Japan) of about 29 kW (40 hp), but prices of 300,000 baht ($11,500) made these tractors prohibitively expensive compared with second-hand imports or larger two-axle tractors. Subsequently, new two-axle tractors less than 33 kW (45 hp) are now rarely imported.

There has been severe competition in the limited market for new 33-63 kW (45-85 hp) tractors, and over 10 major international tractor manufacturers are represented in Thailand. [4/] Since 1970, the market has been dominated by Ford and Massey Ferguson (with about equal market shares and 80 per cent of the total market) and John Deere, which entered the market after 1975. During the 1970s, the big tractor market was a sellers' market, with buyers having little bargaining power. However, sales decreased rapidly after 1981 to fewer than 500 units annually compared with around 2,300 units during the 1970s. Rising tractor prices (partly as a result of the unfavorable exchange rate for baht to the British pound), importation of second-hand tractors, bad crop years (1979-80 and 1980-81) due to drought, and depressed crop prices, were the main factors causing the decline in demand. In addition, hire purchase operations of the major tractor importers suffered severely. Subsequently, reorganizations and changes of ownership took place. One importer had a market share of close to 90 per cent or 341 units in 1986. During the last few years, Japanese manufacturers tried to increase their market share for big tractors with limited success because of the depressed demand and unfavorable exchange rate of the yen. Russian-and the Republic of China-made big tractors have also been marketed but are not popular. Demand improved during 1986, and 1987 was even better. [5/] Excess liquidity (and therefore more financing activity from the banks) and the higher prices for cassava may have caused this increase in sales.

The major importers of big tractors and equipment are part of large companies involved in a number of activities. These companies showed flexibility and buoyancy when the market for big tractors collapsed and when huge losses from tractor financing had to be absorbed. Nevertheless, their business operations were drastically reduced, and in some cases they were sold off to other companies. [6/] Because of the depressed sales, big two-axle tractors are no longer locally assembled. Distributors/importers shifted to reconditioning of repossessed and second-hand imported tractors, which sold at about one-third ("as is, where is") to 80 per cent (top quality with guarantee) of the price of a new tractor.

A1.2.2 Local Manufacture

The agricultural machinery industry in Thailand is generally an import-substituting industry. Because local designs were cheaper and suited to local conditions, imports of machinery during the 1970s were low, while local manufacture increased rapidly. Traditionally, hand tools and animal-drawn implements are produced by village blacksmiths and small workshops, but hoes and steel animal-drawn plows are also manufactured in larger factories. Single-axle, small two-axle and low lift pumps are produced in large quantities (Table A1.2). Soil tillage implements and most other machinery used in farm production are locally manufactured except for a few more sophisticated machines used on big farms, dairies, and government farms. Some components may be imported for use in locally manufactured implements, particularly discs and disc bearings for disc plows and disc tillers. In the 1970s, about 100 rotary cultivators were imported annually, but these are rarely imported at present because of their high price, and few are locally manufactured.

Other locally produced items are rice threshers, farm trucks, rice-milling machinery, maize shellers, cassava processing machinery, and some implements for big tractors. Prime movers (engines) are usually imported, but since 1980 three joint ventures have been established for the production of 4.4 - 13.3 kW (6-18 hp) single-piston diesel engines. Importation of this engine size is controlled by the government. [7/] Pesticide application machinery is produced locally but is also still imported in large quantities.

The rapid growth of the machinery industry began in the late 1960s and early 1970s. In early 1980, it was estimated that there were 130 agricultural machinery manufacturers. The industry is predominantly family-owned and-managed. Actual tractor production is presently 40,000 single-axle and 500 small two-axle tractors per year, but capacity is almost double the production (Table A1.2). The number of people employed in this manufacturing subsector is estimated at about 10,000, with 16,000 additional people employed in the sales and servicing sectors. [8/] The larger manufacturers are concentrated in the Central Plain, where farm mechanization is most evident. The large firms have started to export products to other Asian countries (in particular Laos), but the value of exports is still small. For 1985, total free on board (FOB) value for machinery and parts amounted to $0.9 million (23.4 million baht). [9/] Machinery manufacturers are organized in an association, and two export firms have been formed by groups of manufacturers to promote export.

During the 1970s, manufacture increased very rapidly, but the producers made little progress with product improvement and design or introduction of more efficient manufacturing and management techniques. Since 1980, however, quality and design have improved, and many single-axle tractors are now equipped with steering clutches and forward and reverse gears. The two-axle tractor design has also improved and now includes hydraulics and steering brakes. Most locally-made tractors are now equipped with small disc plows for flooded paddy land preparation rather than the traditional moldboard plow, since disc plows cut better through rice straw stubble. Factories have become better managed and organized, and fixtures and dies are now commonly used.[10/] However, demand has decreased and production of agricultural machinery declined in 1985 by about 30 per cent. [11/] Severe competition has forced many small producers out of production, while margins have become very small. [12/]

A1.2.3 Distribution, Maintenance and Repair System

Unique among developing countries, Thailand has both efficient and adequate distribution of agricultural machinery and fuel, and a good maintenance and repair system.[13/] One important contributing factor to this phenomenon is the extensive and well maintained road network and efficient transport system. Another is the active involvement of the private sector in supply and maintenance. Importers and distributors can easily reach potential customers directly from Bangkok or from branches offices and dealers in other cities. However, because of low sales volume, branch offices for big tractors have been reduced over the last few years.

Local manufacturers have various systems for handling sales and distribution of their products, depending on the size of the firm. Large manufacturers in the Central Region may have established dealership networks in the North and Northeastern Regions. Smaller manufacturers sell through agents, who often handle a wide range of agricultural inputs and usually have one or two salesmen who contact potential buyers. Small manufacturers also sell directly from their workshops to farmers. BAAC branch offices stock agricultural machinery for financing under the credit for kind system, and have become significant retailers.

The manufacture and maintenance system has adjusted to local conditions and practices. Domestically manufactured machinery is simple and easy to repair in rural workshops. Parts for diesel engines and big tractors are readily available. The most commonly sold big two-axle tractor is popular for its unsophisticated design and interchangeability of parts with earlier models. Turbo-charged models are undesirable because of problems experienced under less favorable conditions. Second-hand big tractor importers specify the preferred type and model which have proven reliable. They do not import tractors equipped with the more technically advanced options commonly used in Europe. One previous assembler of big two-axle tractors used power-train parts of a higher horsepower model to better withstand the severe conditions under which these tractors are operated in new upland areas. Other parts are reinforced. To reduce down time from tire puncture when plowing upland fields, a standard eight-ply tire is often reinforced by bolting an old tire inside the landside rear tire. About 80 per cent of fast moving parts for imported tractors are made locally by about 300 parts manufacturers. Because of over capacity in the domestic automobile parts industry, a variety of replacement parts are also produced locally at competitive prices.

Concern has been voiced regarding importation of small, second-hand two-axle tractors, since no established dealer network existed, nor were parts imported. A study, however, found that no serious problem existed and that users were satisfied. [14] Also, given the experience with other second-hand imports (for example, diesel engines, construction machinery, and truck axles in Thailand; and diesel engines and trucks in the Philippines), it is unlikely that serious problems will occur. The local workshops and the engineering industry are highly capable of making parts, while importation of parts for second-hand equipment and cannibalization are also practiced.

The common belief is that in developing countries agricultural machines have low utilization rates and short technical life spans due to poor operation and maintenance. In Thailand the opposite is true. Domestic manufacture, low labor costs relative to cost of capital, high capability for maintenance and repair, and widespread availability of replacement parts result in agricultural machinery achieving high annual utilization and long economic life. Tractors 20 years old are often still in working condition.

A1.3 Financing Arrangements

To finance agricultural machinery, farmers may obtain credit from BAAC (especially through the credit in kind program), private commercial banks, dealers, local money lenders, or relatives and friends. Also, farm machinery may be financed from farmers' own savings. [15] As a provider of credit to farmers, BAAC through its network of 61 branches, 500 field offices, and staff of 5,000 field unit officers has traditionally been involved in financing machinery for farmers. However, because of more demanding collateral requirements for bigger machines (including big tractors), BAAC financing is limited to locally made tractors, threshers, sprayers, pumps and farm trucks.

BAAC's lending operations for machinery have rapidly expanded. In 1985, equipment loans decreased substantially despite an infusion from an ADB loan for BAAC's equipment in kind scheme (Table A1.3). Total disbursement by BAAC for farm machinery was about 750 million baht ($29 million) in fiscal year 1986, with total lending operations (disbursements) of 23.2 billion baht ($892 million) for fiscal year 1986. [16] Less than 5 percent of BAAC's credit operation is for agricultural machinery, and it is estimated that BAAC financing is about 25 per cent of the value of all farm machinery sold, although this share varies per region. [17] Through its equipment in kind scheme, BAAC has assumed an important role in the distribution of farm machinery. The

Table A1.3: Disbursement by BAAC for agricultural machinery.

Item	1981		1982		1983		1984		1985		1986		1987	
	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value
1. Engines	12,918	163.46	16,486	257.11	21,288	348.64	38,388	438.06	21,686	386.28	22,195	419.6	27,582	562.0
2. Single-axle Tractors	8,923	138.85	9,297	84.25	13,238	106.73	19,875	147.84	24,475	135.29	27,584	155.9	31,005	198.9
3. Locally-made Two-axle Tractors	734	38.36	437	20.27	339	19.38	556	29.39	787	20.01	1,509	31.9	1,051	24.5
4. Farm Trucks	-	-	968	31.66	2,171	64.56	6,988	59.73	2,040	39.56	3,131	87.4	3,877	118.8
5. Threshers/ Milling Machines	306	6.99	205	6.71	409	13.00	815	23.50	839	16.55	782	19.7	642	17.3
6. Sprayers	-	-	-	-	2,588	5.74	4,138	8.47	4,780	8.75	11,756	8.5	12,236	18.2
7. Water Pumps	-	-	-	-	-	-	-	454	3.75	27,366	5.45	-	-	12.1
8. Mowers	-	-	-	-	-	-	16	1.28	361	1.44	2,485	-	-	2.3
9. Miscellaneous	-	-	-	21.56	-	21.21	-	21.23	-	3.28	-	n.a.	-	6.9
Total		347.66		421.56		579.26		733.25		616.61		723.0		961.0

Note: Value in million baht.
Sources:

- BAAC as reported in AED 1986.
- BAAC 1986b.
- BAAC as reported in Mongkoltanatas 1989, Table 6, for 1987.

scheme was introduced for fertilizer and machinery to avoid diversion of loan funds extended in cash. Because of the stringent BAAC accreditation process, which uses measures of price, quality and after-sales services, the scheme has had a price lowering effect and has been a contributing factor in improved quality standards in the local industry.

In addition to the credit in kind scheme, BAAC also extends loans on a cash basis for agricultural machinery. BAAC does not use machines as collateral, and personal or group guarantees are accepted for less than 60,000 baht ($2,300). Higher amounts require land as collateral. The equipment loans are usually to be repaid within five years. BAAC may even finance up to 100 per cent of the price of the equipment, depending on the financial position or collateral of the borrower. Recognizing the need for financing mechanized land preparation, BAAC started a pilot scheme in 1986 in Nakhon Sawan for short-term credit for land preparation. The scheme proved successful and is being extended.

Commercial banks have recently become involved by extending loans for farm machinery to dealers and farmers. Hire-purchase is available from rural dealers and through arrangements with banks. For locally made single- and two-axle tractors, farm trucks, water pumps and threshers, 30-50 per cent down payment is usually required, while interest rates from informal credit sources are 3 per cent per month, but may go up to 5 per cent for high-risk borrowers. The repayment period varies from six months to three years. [18/] Although these informal rates may appear high, they represent the substantial risk borne by the lender, as explained below.

Prior to the 1980s, the three major tractor importers (representing Ford, Massey Ferguson and John Deere) had their own hire-purchase operations with funds borrowed from abroad to finance the schemes. Iseki tried to capture a market share with a similar scheme in the early 1980s but did not succeed. In the second half of the 1970s, the demand for these tractors was high and business highly profitable. Subsequently, competition increased, and to capture a larger market share, very favorable financing conditions were offered with down payments of only 10-20 per cent and repayment in three years (as compared with the previous 35 per cent and 18 months). [19/] This drastically lowered the financial threshold for buying a tractor. Farmers with little experience in the tractor operation and rental business and financially too weak to absorb any risk or cash flow deficit bought tractors on these easy financing terms. Particularly in the Northeast, farmers often pay for tractor services after selling the crop, but the tractor owners have to make cash payments for fuel, wages, repairs and monthly installments. Thus, under these conditions, the first installments often had to be postponed until after the harvest. When farmers could not pay contractors due to bad crop years (severe drought during 1979-80 and 1980-81) and low crop prices, the financing system quickly broke down, with the importer having to reschedule the payments or ultimately to repossess the tractor. But under the attractive financing terms, repossession proved a heavy loss for the financier, since the recovered tractors were in poor condition. In many cases, repossession also proved to be difficult, since the importer/financier in Bangkok had to trace the tractor in the rural areas. In addition, the importers suffered from unfavorable exchange fluctuations over the funds borrowed overseas. All the importers who provided financing incurred heavy losses. One importer incurred a loss of over 1 billion baht ($39 million), while another claimed he had to repossess about 40 per cent of the tractors sold in the Northeast. As a result of this experience, importers stopped financing tractors to farmers, and only Kubota and Massey Ferguson continued to extend credit to their dealers. The rural tractor dealers now have their own financing schemes. It has even been suggested that their major income is the 2.5 to 3.5 per cent monthly interest charge from financing a tractor, since they have hardly any margin on its sale. Because of their knowledge of local money lending practices, local conditions and population, and probably strong influence and efficient supervision, rural dealers have little problems collecting payments. [20/]

A1.4. SUPPORTING INSTITUTIONAL ARRANGEMENTS

Several institutions under different ministries are involved in institutional aspects of farm mechanization through research, development, education, training and extension.

A1.4.1 Agricultural Engineering Division

The government's most important agency involved in mechanization is AED. AED was established in 1957 within the Department of Agriculture of the Ministry of Food and Agriculture. AED is headed by a director and is composed of two research groups and five sections, with a total manpower of around 500 persons. The role and responsibilities of each unit as well as budget and manpower allocations are clearly delineated. Priority is placed on service, repair and maintenance of the government's vehicles and equipment. About 35 per cent of AED staff is involved in agricultural mechanization research. Development and training account for another 21 per cent. Budget allocations for research and development and for training represent 28 per cent and 27 per cent, respectively, of the AED budget.[21/]

The Agricultural Machinery Research Group's activities include development of new tools and machinery, testing and evaluation of imported and locally developed machines, field demonstration and participation in agricultural fairs, surveys on various aspects of farm mechanization, and acting as the secretariat of NCAM. Through this Group, AED provides the necessary backstopping, feedback and information to government's planners and policy makers.

The Group has a workshop with about 1,000 sq m floor area for prototype development. All staff are stationed in Bangkok but travel frequently the countryside. Some staff may be temporarily stationed in Chiang Mai, where AED has been allocated office space at the Northern Region Agricultural Development Centre (NADC). Through the Group, AED collaborates with RNAM and IRRI. The group was assisted by the UNDP/FAO Agricultural Machinery Production Project which terminated in 1986. Machinery improvement and development include single- and two-axle tractors, axial flow pumps and maize shellers. Through collaboration programs and projects, the Group has also worked on numerous imported or locally developed machines, including reapers, animal drawn plows, ridgers, planters and weeding tools, peanut diggers and power tiller attachments.

The Storage and Processing Technology Research Group is involved in improvement of post-harvest practices and equipment, development and introduction of new techniques and technologies, collection of data, and training of personnel in post-harvest technology. The Group works on the quality of grain, drying equipment, and methods and improvement of small rice milling machines. Government concern about aflatoxin in maize and about the quality of other export commodities has prioritized improvement of post-harvest technology to remain competitive in a depressed world market. Several projects have been financed by external donors. The Group's facilities are in Klong Luang, about 35 km north of Bangkok, and include a small machine shop (250 sq m) for improvement and development of equipment. Its administrative office accommodation was recently completed at the main AED complex in Bangkok.

The Workshop and Service Section was responsible for repairing equipment belonging to the Department of Agriculture, including airconditioners and electrical appliances. This duty was subsequently transferred to the Repair and Maintenance Section. The Workshop and Service Section now works solely on multiplication of prototypes for field testing and on design improvements in collaboration with private manufacturers. The Section provides industrial extension services, including upgrading manufacturing capability. It has a workshop area of 1,200 sq m located in the AED premises. The Section's achievements include a survey of farm machinery manufacturers and the organization of training courses for technicians of manufacturers in collaboration with the Industrial Service Institute. The distinction between this Section and the Agricultural Machinery Research Group is vague; there is significant overlap in the roles and functions of the two units, and the two workshops are located next to each other, working on the same types of machinery.

The Training Section operates three centers for the training of farmers and government staff (including extension officers) in the operation, repair and maintenance of agricultural machinery. The three training centers are located at Klong Luang (Patumtani), about 35 km north from Bangkok; Takfa (Nakorn Sawan) in the Central Plain; and Pattalung in the South. Two more centers have been proposed: one in the Northeast (Khon Kaen) and one in the North (Lampang). Training courses last for 1 week, 2 weeks, 3 weeks, and 110 days. About 70 per cent of the time consists of practical training (for which a range of machinery is available), and the remainder of the time is spent in the classroom. At the time of field research for this study, three batches each of 75 trainees were trained annually at Klong, and training was provided to about 450 persons annually for all three centers. Instruction and lodging are free, while the government provides 20 baht ($0.77) per day per trainee to the Section to provide three daily meals. The main thrust of the Section is on training farmers to operate, repair, and maintain agricultural machinery. Participants are selected through the Department of Agricultural Extension (DAE). Some training is also provided on appropriate technology including bio-gas and brick-making.

The Heavy Equipment Section undertakes land development on experimental farms of the Department of Agriculture and occasionally on farms of DAE. The section owns and operates a number of different types of heavy earthmoving equipment. The main station/workshop is located in Bangkhen (Bangkok), with a sub-station at Lampang.

The Repair and Maintenance Section, like the Heavy Equipment Section, has a service function and is responsible for repair and maintenance of vehicles, equipment and machinery of the various institutes and divisions of the Department of Agriculture all over the country. In addition to a central workshop, the Section operates mobile repair units.

A1.4.2 Farm Mechanization Subdivision of DAE

DAE was established in the 1970s with assistance from the World Bank. The main objective of this new department was to consolidate all extension activities previously carried out by the various departments of MOAC. This objective has not yet fully been achieved, and several departments still have their own extension networks. DAE is mainly involved in crop production of particular seed and fertilizer technology. The Farm Mechanization Subdivision is under the Administrative Development Division of DAE and consists of a Pre-Harvest Section and a Post-Harvest Section. In addition, it operates a Farm Mechanization Promotion Centre (FMPC) in Chainat (Central Region). For mechanization, DAE has one coordinator per province, but subject matter specialists for mechanization do not yet exist. [22/]

Much of the pre-harvest section's work is related to on-farm water management, while other activities include training, demonstration, organization of field days and plowing contests, and promotional pilot schemes and projects. The latter include village rice mill programs, windmill demonstrations, soybean thresher promotion, machinery safety campaigns, and a fully mechanized paddy production system in a Central Region village. The post-harvest section includes a pilot project with a mobile dryer and an anti-aflatoxin campaign. A mobile training unit annually trains about 1,000 machinery-owning farmers in the villages for three days on maintenance. The most promising farmers are selected for one-week training programs at the provincial level to assume roles as village mechanics. At the FMPC, in-service training of subject matter specialists is conducted mainly for on-farm water management. The Subdivision obtained assistance from several bilateral and multilateral sources (including FAO) for a Food Losses Prevention Project completed in 1982.

A1.4.3 Department of Industrial Promotion

The Department of Industrial Promotion (DIP) was established in 1941 under the Ministry of Industry. Under this Department, two ISIs – one in Bangkok and another in Chiang Mai – were established with UNDP/UNIDO assistance in 1966 and 1973. Extension, training, consultancy and advice to the industry are DIP's primary activities

Through reorganization of DIP, the existing ISIs have become Regional Industrial Promotion Centres (RIPCs). Additional RIPCs were established in Khon Kaen (Northeast) and Songkhla (South). Responsibility for technical advice and assistance to the agricultural machinery manufacturers resides in principle with the Metal Industry Development Section of the RIPCs. Because of shortage of funds and manpower, however, little assistance has been extended by DIP to the agricultural machinery industry. Fortunately, the RIPCs are sufficiently well equipped to undertake this activity.

A1.4.4 Education

There are three universities in Thailand where a BSc degree in agricultural engineering can be obtained; namely, Kasetsart University (with campuses in Bangkok and Kampangsaen), Khon Kaen University, and Chiang Mai University. Although there are 43 agricultural colleges, they do not include agricultural mechanization as a specialized curriculum. The Agricultural Engineering Training College at Pathum Thani (Bangkok) was established with German assistance and trains agricultural college teachers in repair, maintenance and operation of agricultural equipment.

Kasetsart University was established in 1943. In 1955, the Irrigation Training School – already in existence since 1938 – was transferred to the University to become the Faculty of Irrigation Engineering. Its name was changed to the Faculty of Engineering in 1967. The Department of Agricultural Engineering was established the same year. In 1979, the Department of Agricultural Engineering moved to the new campus extension in Kampangsaen (Nakorn Patom), about 120 km from Bangkok. The total number of students at Kasetsart University is about 10,000, of which 150 study agricultural engineering. Very few research activities are undertaken on agricultural mechanization because of manpower and budget constraints. Within the Kasetsart University Research and Development Institute, the Agricultural Machinery Centre was established in 1980 with Japanese assistance. Its functions are to undertake research on agricultural machinery; undertake testing and evaluation of imported and locally manufactured machinery; provide training to farmers, students, government staff and technicians from the private sector; and render advisory service on agricultural mechanization.

Khon Kaen University was established in 1964 and presently has about 5,000 students, of which about 1,000 are enrolled in the Faculty of Engineering. The Department of Agricultural Engineering has a total of about 130 students and resides under the Faculty of Engineering. It includes two divisions: Farm Machinery, and Soil and Water. Teaching is the most important function of the Department, and research has been rather limited because of limitations on funds.

Chiang Mai University was established in 1960 and has an enrollment of about 10,000 students, of which about 450 students are enrolled in the Faculty of Engineering. Under this Faculty resides the Division of Agricultural Engineering. This Division is not really a separate entity and does not have its own building or permanent staff. The Division is under the Department of Mechanical Engineering, and proposals to develop the Division as an independent Department of Agricultural Engineering have not materialized yet. The Faculty of Agriculture has a Farm Mechanization Section responsible for maintenance and operation of the Faculty's farm machinery. Little linkage exists between the Faculty of Engineering and the Faculty of Agriculture. Almost no research is undertaken by the Division of Agricultural Engineering.

A1.4.5 Research, Development, Training and Extension by the Private Sector

Research in the private machinery manufacturing sector is very limited. The private manufacturing sector has been very successful in copying existing technology and adopting imported designs to local conditions, including modifications to facilitate low-cost labor intensive manufacture. However, the private sector has invented few new or unique machines. Only in recent years has a clear improvement been effected in quality standards and addition of design features such as clutch, forward and reverse speeds, and steering clutches for single-axle tractors. Modification of the axial flow thresher for use with other crops grown in Thailand took place only recently after the work was initiated by AED.

Training in repair and maintenance has traditionally been given by tractor importers to mechanics in their dealer network. Anglo-Thai motors operates a training center which trains about 3000 farmer/mechanics per year for two to three days. The Massey-Ferguson training school for tractor operators no longer operates, but mechanics of dealers receive on-the-job training. Importers occasionally introduce new machinery and arrange demonstrations to popularize and stimulate demand. For example, Anglo-Thai motors organized tours for sugarcane farmers to Queensland, Australia, and Kubota demonstrated a low cost technique for raising rice seedling mats to be used with its transplanter. Sugarcane harvesters were demonstrated and introduced by importers, and another company imported 35 rice combines. However, these technologies have generally not been adopted due to the high investment and operational costs involved, and also because of the need to change cropping practices.

NOTES AND REFERENCES TO APPENDIX 1

1/ Staff of Kubota Thailand estimated that around 10,000 units over the years had been imported. Because of government's import policy, power tillers are presently hardly imported.

2/ See Section 3.1 and also Mongkoltanatas, et al 1986.

3/ Personal observation and interviews, May 1987.

4/ See also USOM 1969.

5/ In 1986, a total of 341 new big tractors were sold by Anglo-Thai (Ford), of which about 25 per cent had four-wheel drive. In 1987, about 400 were sold. In addition, 320 second-hand big tractors were imported and sold by the same importer, while another 500 units were imported by other parties. Leonowens (Massey-Ferguson) sold 50 new big tractors in 1986.

6/ East Asiatic sold its tractor operations (John Deere) to Charoen Pokphan Agri-Industry Co.; Ford Tractors became part of the Inchcape company; Kubota tractors and Kubota engine manufacture became part of the Siam Cement Group. Iseki went out of business in Thailand.

7/ In early 1979, the Board of Investment promoted investment in the local manufacture of small (4.4-13.3 kW; 6-18 hp) single piston diesel engines. Kubota,Yanmar and Mitsubishi established manufacturing operations, and local content (in terms of value) increased rapidly to its present level of about 80 per cent, much of it manufactured by outside suppliers. The annual sale of engines is about 60,000 units (1986), of which Kubota supplies 65 per cent. About 50 per cent of the engines sold are in the 5.9 kW (8 hp) class. Kubota began manufacturing single-axle tractors in 1987.

8/ Bergman 1986, p. 36.

9/ Department of Customs, as reported in AED 1986, Table 4.

10/ Weaving 1986.

11/ AED 1986.

12/ One source reported that 300 baht profit was made on a single-axle tractor frame of 9,000 baht. Similarly, margins on second-hand tractor importation are low. Several big tractor importers sold their stocks at heavily discounted prices in 1986 when demand stagnanted. Retailers/dealers of big two-axle tractors make little profit on the sale, but rather on their financing operation with interest charges of 2.5-3.5 per cent per month.

13/ Personal observations and experience. See also Gifford 1981, Wicks 1984, and Khan 1984.

14/ Mongkoltanatas et al 1986.

15/ Pathnopas 1980.

16/ BAAC 1986b, pp. 17-18 and 84-85. The estimate for lending operations is crude, since lending to cooperatives and farm associations is not specified according to item. At any rate, less than 5 per cent of BAAC's annual disbursements are for agricultural machinery.

17/ See Section 3.1, note 4.

18/ Pathonopas 1980.

19/ Chancellor 1986, p. 303.

20/ Personal communication in May 1987 with Anglo-Thai Tractors; Leonowens (Massey-Ferguson); and Mr. Chamnong Sukontrasawadi (Kamol Trading Co.).

21/ Khan 1984b.

22/ For comparison, DAE has in total over 10,000 staff, including 5,000 extension workers and 2,000 subject matter specialists.

APPENDIX 2

DESCRIPTION OF THE LP TABLEAU FORMULATION

To solve the LP tableau with SCICONIC software, its matrix input file must be prepared in standard MPS format. This MPS input file is prepared with the Matrix Generator (MG). The latter consists of a computer program in FORTRAN code written by MGG an ultra-high-level language for mathematical programming. By applying this programming language, the LP tableau can be formulated in a natural, mathematical and flexible fashion and then translated by MGG into a comprehensive FORTRAN program (the Matrix Generator). The LP tableau formulation follows the notation as prescribed by the MGG manual.[1/]

(i) Suffixes

Variables (or LP activities) may use the same name, but are differentiated by using suffixes. Suffixes are always written between brackets when used with subscribed variables. The following suffixes are used:

- C for Crop, with C = 1 .... 14 (Although the MECHMOD includes only 13 crops, an extra crop is specified. It is used only for the purpose of testing and verification.)
- P for Period, with P = 1 ... 24
- O for Operation, with O = 1 ... 6
- M for Method with M = 1 ... 15

- R for Aggregate Labor (R = 1), Male Labor (R = 2), Draft Animal (R = 3), or type of Equipment with R = 4 ... 21
- L for Land Suitability Class, with L = 1 ... 4
- W for Workability Class with W = 1 ... 3

A particular suffix may be further prescribed by adding a single digit, for example, O1 refers to "for O = 1."

(ii) Elements

In the SCICONIC software, elements refer to coefficients in the Objective Function and the Constraints (Equations). Elements cannot be distinguished by suffixes. Therefore, the elements have either an externally-supplied value, or (if a function of suffixes) are to be calculated in a FORTRAN statement or in a FORTRAN written function. For example, with reference to the Objective Function C01 = Yield (C) * Price (C) – Casex (C)

With:

Yield (C)	=	Yield in metric tons per rai for crop C
Price (C)	=	Farmgate price per metric ton for crop C
Casex (C)	=	Cost of pesticides and fertilizer per rai for crop C

Yield (C), Price (C), and Casex (C) are exogenous variables.

C02 = –FUVARC ( )

FUVARC ( ) is a user written FORTRAN function in which the variable cost of a particular field operation O, in period P, using method M is calculated for crop C.

(iii) Model Variables

TOCRA(C) : Total Area of Crop C

OPRA(C,O,P,M)	:	Area of crop C on which operation O is performed in period P using technology or method M. To reduce the size of the matrix, infeasible OPRAs are eliminated through the logical function FUOPRA: NOT IF (FUOPRA .EQ. 0)[2/]
HL(P)	:	Man-hours of aggregate hired labor in period P
HML(P)	:	Man-hours of male hired labor in period P
DA	:	Draft animals required in heads
MACH1(R)	:	Units of a particular machine required, with R = 4 ... 21
FLBO(P)	:	Man-hours of aggregate family labor earning off-farm income in period P
MFLBO(P)	:	Man-hours of male family labor earning off-farm income in period P

Depending on the model experiments performed, the range of the above variables may be limited by upper and/or lower bounds.

(iv) The Objective Function [3/]

Maximize for all C,O,P,M:

SUM(C) C01 * TOCRA(C)+ SUM(C,O,P,M) C02 * OPRA(C,O,P,M) + SUM (P) C03 * HL(P) + SUM (P) C04 * HML(P) + C05 * DA + SUM (R) C06 * MACH1(R) + SUM (P) C07 * FLBO(P) + SUM(P) C08 * MFLBO(P)

With:

C01	=	Yield * farmgate price – cost of pesticides and fertilizer, for crop C
C02	=	Cost of operation OPRA (C,O,P,M) (excluding cost of labor)

C03 = Cost per hour of aggregate hired labor in period P

C04 = Cost per hour of male hired labor in period P

C05 = Fixed annual cost of draft animal per head

C06 = Fixed annual cost of machine R

C07 = Wage earned by aggregate labor for off-farm work

C08 = Wage earned by male labor for off-farm work.

(v) The Equations

(a) Resource Constraints

OLARE(L,P): Land suitability class L in period P. Defined as:

SUM(C,L,P1,M) C14 * OPRA (C,O1,P1,M) + SUM (C,L,P1,M) C15 * OPRA (C,O2,P1,M) – SUM (C,L,P1,M) C16 * OPRA (C,O5,P1,M) .LE. R01

P1 = SQUARE [4/]

C14 = SBED/100 or 0, depending whether seedbed is required. SBED is percentage of area of transplanted paddy used for seedbed.

C15 = 1 or 0, depending whether crop may occupy land suitability class L in period P

C16 = 1 or 0 depending whether harvest may take place in period P

O1 = Seedbed preparation

O2 = Land preparation

O5 = Harvest

R01 = Land resource area of class L

ATFLB(P,R,W): Aggregate Family Labor (R = 1) for period P, in workability class W. Defined as:

SUM (C,O,M) T02 * OPRA(C,O,P,M) – HL(P) – HML(P) + T05 * FLBO(P) + T05 * MFLBO(P) + T04 * DA .LE. R02

T02	=	Labor time in hours required per unit area for particular operation (reference time)
T04	=	Labor time spent per period P on care of one draft animal
T05	=	1 (if W = 1 only) or 0
R02	=	Available aggregate labor in hours in workability class W in period P (usable time)

AMFLB(P,R,W): Male Family Labor (R = 2) for period P in workability class W. Defined as:

SUM (C,O,M) T03 * OPRA(C,O,P,M) – HML(P) + T05 * MFLBO(P) .LE. R03

T03	=	Labor time in hours required per unit area for operation requiring male labor (reference time)
T05	=	1 (if W = 1 only) or 0
R03	=	Available aggregate labor in hours in workability class W, in period P (usable time)

(b) Transfer Rows

DAC(P,R,W): Draft animal (R = 3) for period P in workability class W; NOT IF (FUDMAC .EQ. 0). Defined as:

SUM (C,O,M) T01 * OPRA(C,O,P,M) – D01 * DA .LE. 0

T01	=	Draft animal hours required per unit area for particular operation (reference time)
D01	=	Hours available from one DA in period P and workability class W (usable time)

MACHC(P,R,W): Machinery (R = 4 ... 21) for period P in workability class W; NOT IF (FUDMAC .EQ. 0). Defined as:

SUM(C,O,M) T01 * OPRA(C,O,P,M) – D02 * MACH1(R) .LE. 0

T01 = Machine hours required per unit area for particular operation (reference time)

D02 = Hours available from machine R in period P and workability class W (usable time)

(c) Logical Constraints

SEQRW (C,O,P): Sequence row which ensures proper sequence of overlapping consecutive operations; NOT IF (FUSEQ .EQ. 0). Defined as:

SUM (M) C09 * OPRA(C,O1,P1,M) – SUM (M) C09 * OPRA(C,O,P1,M) .GE. 0

C09 = 1 or 0, depending on whether overlap in operations is technically flexible

P1 = SQUARE

O1 = O – 1 (previous operation)

AB(C,O): Area balance row which ensures that the total area covered under one operation (regardless of method) is equal to the total area with crop C. For seedbed preparation (O = 1) and for threshing and shelling (O = 6), different constraints apply; NOT IF (FUAB .EQ. 0). Defined as follows:

TOCRA(C) – SUM (P,M) OPRA(C,01,P,M) .EQ. 0

O1 .GT. 1

ABSB(C,O): Area balance row for seedbed preparation of transplanted rice. NOT IF (FUABS .EQ. 0). Defined as:

TOCRA(C) – SUM(P,M) C10 * OPRA(C,O,P,M) .EQ. 0

O	=	1
C10	=	100/SBED

ABTS(C,O): Area balance row for threshing and shelling (O = 6). When combine harvester is used no threshing or shelling operation is required. NOT IF (FUABTS .EQ. 0). Defined as:

SUM (P,M) C11 * OPRA(C,O5,P,M) – SUM (P,M) OPRA(C,O6,P,M) .EQ. 0

O	=	5 (harvest)
O5	=	5 (harvest)
O6	=	6 (threshing or shelling)
C11	=	1 or 0 depending on whether threshing or shelling is required (not in case a combine harvester is used)

ABOP(C,O,P): Flexibility constraint which represents the minimum area of operation to be performed in a certain period. The constraint is excluded if the operation is not applicable NOT IF (FUABOP .EQ. 0). Defined as:

B08 * TOCRA(C) – SUM(M) OPRA(C,O,P,M) .LE. 0

B08	=	FUB08 : calculates the lower bound for an operation, assuming 50 per cent of the crop area to be covered by a certain operation is equally distributed over the feasible periods.

O .GT. 2

ABOPS(C,O,P): Similar to ABOP (C,O,P) but for seedbed preparation of transplanted rice. Defined as:

B08 * TOCRA(C) – SUM(M) C10 * OPRA(C,O,P,M) .LE. 0

O	=	1
C10	=	100/SBED

SAB1(C,O,P): The area with planted sugarcane must equal the area of first ratoon crop and the land must continue to be occupied. NOT IF (FUSAB .EQ. 0). Defined as:

SUM(M) OPRA(C1,O5,P,M) – SUM(M) OPRA(C2,O2P,M) .EQ. 0

C = 11 (planted sugar)

O = 5 (harvest)

C1 = 11 (planted sugar)

O5 = 5 (harvest)

C2 = 12 (first ratoon crop)

O2 = 2 (first operation after harvest)

SAB2(C,O,P): Similar to above, the area under first ratoon sugar must be equal to the area under second ratoon, and the land must continue to be occupied. Defined as:

SUM(M) OPRA(C1,O5,P,M) – SUM(M) OPRA(C3,O2,P,M). EQ. 0

C = 12 (first ratoon sugar crop)

O = 5 (harvest)

C1 = 12 (first ratoon sugar crop)

O5 = 5 (harvest)

C3 = 13 (second ratoon sugar crop)

NOTES AND REFERENCES TO APPENDIX 2

1/ SCICON Ltd. 1985. MGG-User Guide Version 2.1, London.

2/ The prefix "FU..." refers to user-written functions in FORTRAN code where calculations may be made or logical statements verified.

3/ In SCICONIC code, for example, SUM (C,O) OPRA (C,O) means

$$\sum_{C=1}^{C\ max} \sum_{O=1}^{O\ max} \text{OPRA (C,O), etc.}$$

4/ SQUARE refers to a so-called non-standard suffix; a SCICONIC-MGG feature to formulate square matrixes (or parts thereof). Square matrixes are used where the row suffix is not directly related to the column suffix.

LE means "Less or Equal"
NE means "Not Equal"
GE means "Greater or Equal"
GT means "Greater Than"

Appendix 3

CROP SPECIFIC DATA INPUT TO MECHMOD

Table A3.1. Rainfed transplanted paddy: Data on timing and farm power input per operation and method.

Operation	Timing [a] From-Until	Method	Power Source Required [a] Description	Hours per Rai [c]
Seedbed Preparation (incl. manual broadcasting of seed, etc.)	May 2 - Jul 2	Plowing and puddling with draft animal	Male labor	29.0
			Draft animal	19.0
		Plowing and puddling with single-axle tractor	Male labor	19.5
			Single-axle tractor	4.75
		Plowing and puddling with two-axle tractor (<45 hp)	Male labor	13.0
			Two-axle tractor (<45 hp)	1.5
Land Preparation	Jun 1 - Aug 1	Plowing and puddling with draft animal	Male labor	14.4
			Draft animal	14.4
		Plowing and puddling with single-axle tractor	Male labor	9.5
			Single-axle tractor	4.75
		Plowing and puddling with two-axle tractor (<45 hp)	Male labor	3.0
			Two-axle tractor (<45 hp)	1.5
		First plowing with tractor (> 45 hp); puddling with draft animal	Male labor	6.0
			Tractor (>45 hp)	0.5
			Plow	0.5
			Draft animal	5.0
		First plowing with tractor (>45 hp); puddling with single-axle tractor	Male labor	4.2
			Tractor (>45 hp)	0.5
			Plow	0.5
			Single-axle tractor	1.6
Transplanting (including preparation of seedlings)	Jun 2 - Aug 2	Manual transplanting	Labor	28.8
		Transplanting machine	Labor	11.6
			Male labor	2.5
			Transplanter	2.5
Crop Care	Jul 1 - Oct 1	Manual weeding	Labor	22.7
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	14.7
			Male labor	2.0
			Sprayer	2.0
Reaping	Sept 2 - Nov 2	Manual	Labor	20.7
		Mechanical reaper with manual collection/bunding	Labor	6.0
			Male labor	2.4
			Reaper	1.2
		Small Japanese type combine harvester	Male labor	3.0
			Combine harvester	1.5
		European type combine harvester	Male labor	0.42
			Combine harvester	0.21
Threshing (including cleaning and bagging)	Sept 2 - Dec 1	Treading with draft animals	Labor	38.8
			Draft animal	22.0
		Treading with single-axle tractor	Labor	19.3
			Male labor	2.6
			Single-axle tractor	2.6
		Mechanical threshing	Labor	8.47
			Male labor	0.77
			Thresher	0.77

For Notes and Sources, see Table A3.13.

Table A3.2. Rainfed broadcast paddy: Data on timing and farm power input per operation and method.

Operation	Timing [a] From-Until	Method	Power Source Required [b] Description	Hours per Rai [c]
Land Preparation	May 2 - Jul 1	Plowing and puddling with draft animal	Male labor	14.4
			Draft animal	14.4
		Plowing and puddling with single-axle tractor	Male labor	9.5
			Single-axle tractor	4.75
		Plowing and puddling with two-axle tractor (<45 hp)	Male labor	3.0
			Two-axle tractor (<45 hp)	1.5
		First plowing with tractor (>45 hp); puddling with draft animal	Male labor	6.0
			Tractor (>45 hp)	0.5
			Plow	0.5
			Draft animal	5.0
		First plowing with tractor (>45 hp); puddling with single-axle tractor	Male labor	4.2
			Tractor (>45 hp)	0.5
			Plow	0.5
			Single-axle tractor	1.6
Seed (incl. preparation of seed)	Jun 2 - Jul 2	Manual broadcasting	Labor	2.9
Crop Care	Jul 2 - Oct 2	Manual weeding	Labor	26.5
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	15.2
			Male labor	2.0
			Sprayer	2.0
Reaping	Oct 2 - Nov 2	Manual	Labor	20.7
		Mechanical reaper with manual collection/ bundling	Labor	6.0
			Male labor	2.0
			Reaper	1.0
		Small Japanese type combine harvester	Male labor	3.0
			Combine harvester	1.5
		European type combine harvester	Male labor	0.42
			Combine harvester	0.21
Threshing (incl. cleaning and bagging)	Oct 2 - Dec 1	Treading with draft animals	Labor	38.8
			Draft animal	22.0
		Treading with single-axle tractor	Labor	19.3
			Male labor	2.6
			Single-axle tractor	2.6
		Mechanical threshing	Labor	8.47
			Male labor	0.77
			Thresher	0.77

For Notes and Sources, see Table A3.13.

Table A3.3. First crop irrigated transplanted paddy: Data on timing and farm power input per operation and method.

Operation	Timing [a] From-Until	Method	Power Source Required [b] Description	Hours per Rai [c]
Seedbed Preparation (including manual broad-casting of seed, etc.)	May 2 - Jul 2	Plowing and puddling with draft animal	Male labor	29.0
			Draft animal	19.0
		Plowing and puddling with single-axle tractor	Male labor	19.5
			Single-axle tractor	4.75
		Plowing and puddling with two-axle tractor (<45 hp)	Male labor	13.0
			Two-axle tractor (<45 hp)	1.5
Land Preparation	Mar 1 - Mar 2	Plowing and puddling with draft animal	Male labor	15.4
			Draft animal	15.4
		Plowing and puddling with single-axle tractor	Male labor	9.5
			Single-axle tractor	4.75
		Plowing and puddling with two-axle tractor (<45 hp)	Male labor	3.0
			Two-axle tractor (<45 hp)	1.5
Transplanting (including preparation of seedlings)	Mar 2 - Apr 2	Manual transplanting	Labor	28.8
		Transplanting machine	Labor	11.6
			Male labor	2.5
			Transplanter	2.5
Crop Care	Apr 2 - May 2	Manual weeding	Labor	26.9
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	18.9
			Male labor	2.0
			Sprayer	2.0
Reaping	Jun 1 - Jun 2	Manual	Labor	20.7
		Mechanical reaper with manual collection/ bundling	Labor	5.0
			Male labor	2.2
			Reaper	1.1
		Small Japanese type combine harvester	Male labor	3.0
			Combine harvester	1.5
		European type combine harvester	Male labor	0.42
			Combine harvester	0.21
Threshing (including cleaning and bagging)	Jun 1 - Jul 1	Treading with draft animals	Labor	38.8
			Draft animal	22.0
		Treading with single-axle tractor	Labor	17.4
			Male labor	2.4
			Single-axle tractor	2.4
		Mechanical threshing	Labor	7.7
			Male labor	0.7
			Thresher	0.7

For Notes and Sources, see Table A3.13.

Table A3.4. First crop irrigated broadcast paddy: Data on timing and farm power input per operation and method.

Operation	Timing [a] From-Until	Method	Power Source Required [b] Description	Hours per Rai [c]
Land Preparation	Feb 2 - Mar 1	Plowing and puddling with draft animal	Male labor	15.4
			Draft animal	15.4
		Plowing and puddling with single-axle tractor	Male labor	9.5
			Single-axle tractor	4.75
		Plowing and puddling with two-axle tractor (< 45 hp)	Male labor	3.0
			Two-axle tractor (<45 hp)	1.5
Seedling (including preparation of seed)	Feb 2 - Mar 1	Manual broadcasting	Labor	2.9
Crop Care	Mar 2 - May 1	Manual weeding	Labor	30.1
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	19.4
			Male labor	2.0
			Sprayer	2.0
Reaping	May 2 - Jun 2	Manual	Labor	20.7
		Mechanical reaper with manual collection/ bundling	Labor	5.0
			Male labor	2.2
			Reaper	1.1
		Small Japanese type combine harvester	Male labor	3.0
			Combine harvester	1.5
		European type combine harvester	Male labor	0.42
			Combine harvester	0.21
Threshing (including cleaning and bagging)	Jun 1 - Jul 1	Treading wih draft animals	Labor	38.8
			Draft animal	22.0
		Treading with single-axle tractor	Labor	17.4
			Male labor	2.4
			Single-axle tractor	2.4
		Mechanical threshing	Labor	8.25
			Male labor	0.75
			Thresher	0.75

For Notes and Sources, see Table A3.13.

Table A3.5. Second crop irrigated transplanted paddy: Data on timing and farm power input per operation and method.

Operation	Timing [a/] From-Until	Method	Power Source Required [b/] Description	Hours per Rai [c/]
Seedbed Preparation (including manual broad-casting of seed, etc.)	Jul 2 - Aug 2	Plowing and puddling with draft animal	Male labor	22.7
			Draft animal	12.7
		Plowing and puddling with single-axle tractor	Male labor	16.4
			Single-axle tractor	3.2
		Plowing and puddling with two-axle tractor (<45 hp)	Male labor	12.0
			Two-axle tractor (<45 hp)	1.0
Land Preparation	Jun 1 - Aug 1	Plowing and puddling with draft animal	Male labor	9.6
			Draft animal	9.6
		Plowing and puddling with single-axle tractor	Male labor	5.5
			Single-axle tractor	2.75
		Plowing and puddling with two-axle tractor (<45 hp)	Male labor	2.0
			Two-axle tractor (<45 hp)	1.0
Transplanting (including preparation of seedlings)	Aug 2 - Sept 2	Manual transplanting	Labor	28.8
		Transplanting machine	Labor	11.6
			Male labor	2.5
			Transplanter	2.5
Crop Care	Sept 1 - Nov 2	Manual weeding	Labor	20.7
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	15.3
			Male labor	2.0
			Sprayer	2.0
Reaping	Nov 2 - Dec 2	Manual	Labor	20.7
		Mechanical reaper with manual collection/ bundling	Labor	5.0
			Male labor	2.2
			Reaper	1.1
		Small Japanese type combine harvester	Male labor	3.0
			Combine harvester	1.5
		European type combine harvester	Male labor	0.42
			Combine harvester	0.21
Threshing (including cleaning and bagging)	Nov 2 - Jan 1	Treading with draft animals	Labor	38.8
			Draft animal	22.0
		Treading with single-axle tractor	Labor	17.4
			Male labor	2.4
			Single-axle tractor	2.4
		Mechanical threshing	Labor	7.7
			Male labor	0.7
			Thresher	0.7

For Notes and Sources, see Table A3.13.

Table A3.6. Second crop irrigated broadcast paddy: Data on timing and farm power input per operation and method.

Operation	Timing a/ From-Until	Method	Power Source Required b/: Description	Power Source Required b/: Hours per Rai c/
Land Preparation	Jul 2 - Aug 2	Plowing and puddling with draft animal	Male labor	9.6
			Draft animal	9.6
		Plowing and puddling with single-axle tractor	Male labor	5.5
			Single-axle tractor	2.75
		Plowing and puddling with two-axle tractor (<45 hp)	Male labor	2.0
			Two-axle tractor (<45 hp)	1.0
Seedling (including preparation of seed)	Jul 2 - Aug 2	Manual broadcasting	Labor	2.9
Crop Care	Sept 1 - Nov 1	Manual weeding	Labor	25.0
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	17.9
			Male labor	2.0
			Sprayer	2.0
Reaping	Nov 2 - Dec 1	Manual	Labor	20.7
		Mechanical reaper with manual collection/ bundling	Labor	5.0
			Male labor	2.2
			Reaper	1.1
		Small Japanese type combine harvester	Male labor	3.0
			Combine harvester	1.5
		European type combine harvester	Male labor	0.42
			Combine harvester	0.21
Threshing (including cleaning and bagging)	Nov 2 - Dec 2	Treading with draft animals	Labor	38.8
			Draft animal	22.9
		Treading with single-axle tractor	Labor	17.4
			Male labor	2.4
			Single-axle tractor	2.4
		Mechanical threshing	Labor	7.7
			Male labor	0.7
			Thresher	0.7

For Notes and Sources, see Table A3.13.

Table A3.7. Deepwater paddy: Data on timing and farm power input per operation and method.

Operation	Timing [a] From-Until	Method	Power Source Required [b] Description	Hours per Rai [c]
Land Preparation	May 1 - Jun 2	Plowing and puddling with draft animal	Male labor	14.4
			Draft animal	14.4
		Plowing and puddling with single-axle tractor	Male labor	9.5
			Single-axle tractor	4.75
		Plowing and puddling with two-axle tractor (<45 hp)	Male labor	3.0
			Two-axle tractor (<45 hp)	1.5
		First plowing with tractor (>45 hp); puddling with draft animal	Male labor	6.0
			Tractor (>45 hp)	0.5
			Plow	0.5
			Draft animal	5.0
		First plowing with tractor (>45 hp); puddling with single-axle tractor	Male labor	4.2
			Tractor (>45 hp)	0.5
			Plow	0.5
			Single-axle tractor	1.6
Seeding (including preparation of seedlings)	Jun 1 - Jul 2	Manual broadcasting	Labor	2.9
Crop Care	Jul 1 - Aug 2	Manual weeding	Labor	11.3
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	7.3
			Male labor	1.5
			Sprayer	1.5
Reaping	Nov 2 - Jan 1	Manual	Labor	20.7
		Mechanical reaper with manual collection/bundling	Labor	7.0
			Male labor	2.4
			Reaper	1.2
		Small Japanese type combine harvester	Male labor	3.0
			Combine harvester	1.5
Threshing (including cleaning and bagging)	Dec 1 - Jan 2	Treading with draft animals	Labor	38.8
			Draft animal	22.0
		Treading with single-axle tractor	Labor	19.3
			Male labor	2.6
			Single-axle tractor	2.6
		Mechanical threshing	Labor	12.0
			Male labor	1.5
			Thresher	1.5

For Notes and Sources, see Table A3.13.

Table A3.8. Maize: Data on timing and farm power input per operation and method.

Operation	Timing [a] From-Until	Method	Power Source Required [b] Description	Hours per Rai [c]
Land Preparation	Mar 2 - May 1	Plowing with draft animal	Male labor	14.8
			Draft animal	14.8
		Plowing with tractor (> 45 hp)	Male labor	2.0
			Tractor (>45 hp)	1.0
			Plow	1.0
Planting	Apr 2 - May 2	Manual	Labor	1.6
		Tractor (>45 hp) with tractor-drawn planter	Male labor	0.6
			Tractor (>45 hp)	0.3
			Planter	0.3
Crop Care	May 1 - Jul 1	Manual weeding	Labor	19.2
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	9.6
			Male labor	2.0
			Sprayer	2.0
		Interrow-weeding with tractor (>45 hp)/manual weeding	Labor	10.0
			Male labor	1.5
			Tractor (>45 hp)	0.75
			Toolbar	0.75
Harvest	Jul 2 - Aug 1	Manual picking of cobs	Labor	23.0
		Combine harvester	Male labor	0.9
			Combine	0.3
Shelling (including cleaning and bagging)	Aug 2 - Sept 2	Mechanical sheller	Labor	2.5
			Male labor	0.5
			Tractor (>45 hp)	0.5
			Sheller	0.5

For Notes and Sources, see Table A3.13.

Table A3.9. Sorghum: Data on timing and farm power input per operation and method.

Operation	Timing [a/] From-Until	Method	Power Source Required [b/] Description	Hours per Rai [c/]
Land Preparation	Aug 2 - Sept 2	Plowing with draft animal	Male labor	13.0
			Draft animal	13.0
		Plowing with tractor (>45 hp)	Male labor	1.6
			Tractor (>45 hp)	0.8
			Plow	0.8
Planting	Sept 1 - Sept 2	Manual	Labor	1.6
		Tractor (>45 hp) with tractor drawn planter	Male labor	0.6
			Tractor (>45 hp)	0.4
			Planter	0.4
Crop Care	Sept 2 - Nov 1	Manual weeding	Labor	17.0
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	8.5
			Male labor	2.0
			Sprayer	2.0
		Interrow-weeding with tractor (>45 hp)/manual weeding	Labor	7.1
			Male labor	1.5
			Tractor (>45 hp)	0.75
			Toolbar	0.75
Reaping	Dec 1 - Jan 1	Manual cutting and bundling	Labor	20.0
		Mechanical reaper/manual bundling	Labor	6.0
			Male labor	2.4
			Reaper	1.2
		Combine harvester	Male labor	0.9
			Combine	0.3
Threshing (including cleaning and bagging)	Dec 1 - Jan 1	Mechanical thresher	Labor	4.2
			Male labor	0.7
			Sorghum thresher	0.7

For Notes and Sources, see Table A3.13.

Table A3.10. Cassava: Data on timing and farm power input per operation and method.

Operation	Timing [a] From-Until	Method	Power Source Required [b] Description	Hours per Rai [c]
Land Preparation	Dec 1 - Feb 2	Plowing with draft animal	Male labor	15.0
			Draft animal	15.0
		Plowing with tractor (< 45 hp)	Male labor	1.8
			Tractor (>45 hp)	0.9
			Plow	0.9
Planting (including preparation of stakes)	Dec 1 - Mar 2	Manual	Labor	18.6
		Tractor (>45 hp) with cassava planter	Labor	3.0
			Male labor	1.5
			Tractor (>45 hp)	0.75
			Cassava planter	0.75
Crop Care	Sept 2 - Nov 1	Manual weeding	Labor	24.0
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	8.0
			Male labor	1.5
			Sprayer	1.5
		Interrow-weeding with tractor (>45 hp)/manual weeding	Labor	8.0
			Male labor	1.2
			Tractor (>45 hp)	0.6
			Toolbar	0.6
Harvest	Oct 2 - Mar 2	Manual	Labor	44.8
		Tractor (>45 hp) with cassava lifter; manual collection	Labor	16.0
			Male labor	4.0
			Tractor (>45 hp)	2.0
			Cassava lifter	2.0

For Notes and Sources, see Table A3.13.

Table A3.11. Planted sugarcane: Data on timing and farm power input per operation and method.

Operation	Timing [a/] From-Until	Method	Power Source Required [b/] Description	Hours per Rai [c/]
Land Preparation	Mar 1 - Apr 1	Plowing and furrowing with draft animal	Male labor	21.0
			Draft animal	21.0
		Plowing and furrowing with tractor (>45 hp)	Male labor	3.0
			Tractor (>45 hp)	1.5
			Plow	1.0
			Toolbar	0.5
Planting (including preparation of planting material)	Apr 1 - Jun 2	Manual	Labor	44.8
		Tractor (>45 hp) with cane planter	Labor	19.8
			Male labor	1.9
			Tractor (>45 hp)	0.95
			Cane planter	0.95
Crop Care	May 1 - Nov 1	Manual weeding	Labor	71.0
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	29.6
			Male labor	3.0
			Sprayer	3.0
		Interrow-weeding with tractor (>45 hp)/manual weeding	Labor	55.0
			Male labor	2.0
			Tractor (> 45 hp)	1.0
			Toolbar	1.0
Harvest (including loading)	Dec 1 - Feb 1	Manual	Male labor	75.6
		Mechanical cane harvester	Male labor	0.68
			Cane harvester	0.34

For Notes and Sources, see Table A3.13.

Table A3.12. First ratoon sugarcane crop: Data on timing and farm power input per operation and method.

Operation	Timing [a/] From-Until	Method	Power Source Required [b/] Description	Hours per Rai [c/]
Stubble shaving and ridging	Dec 1 - Feb 2	Tractor (>45 hp) with equipment	Labor	2.0
			Male labor	1.2
			Tractor (> 45 hp)	0.6
			Toolbar	0.6
Crop Care	Dec 1 - Jun 1	Manual weeding	Labor	66.2
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	29.6
			Male labor	2.0
			Sprayer	2.0
		Interrow-weeding with tractor (>45 hp)/manual weeding	Labor	50.0
			Male labor	1.5
			Tractor (> 45 hp)	0.75
			Toolbar	0.75
Harvest (including loading)	Dec 2 - Apr 2	Manual	Male labor	71.2
		Mechanical cane harvester	Male labor	0.68
			Cane harvester	0.34

For Notes and Sources, see Table A3.13.

Table A3.13. Second ratoon sugarcane crop: Data on timing and farm power input per operation and method.

Operation	Timing [a] From-Until	Method	Power Source Required [b] Description	Hours per Rai [c]
Stubble Shaving	Dec 2 - Apr 2	Tractor (>45 hp) with equipment	Labor	2.0
			Male labor	1.2
			Tractor (> 45 hp)	0.6
			Toolbar	0.6
Crop Care	Dec 2 - May 2	Manual weeding	Labor	48.1
		Chemical weed control with motorized backpack sprayer/manual weeding	Labor	26.6
			Male labor	2.0
			Sprayer	2.0
		Interrow-weeding with tractor (>45 hp)/manual weeding	Labor	36.3
			Male labor	1.5
			Tractor (>45 hp)	0.75
			Toolbar	0.75
Harvest (including loading)	Dec 2 - Apr 1	Manual	Male labor	64.1
		Mechanical cane harvester	Male labor	0.68
			Cane harvester	0.34

Notes and Sources to Tables A3.1 to A3.13:

With reference to section 3.1 and Appendix 1 (Section A1.2), two-axle tractor (< 45 hp) refers to relatively small and light Japanese designs of 30 hp (22 kW) and two-axle tractor (> 45 hp) refers to larger tractors of European design of 65 hp (48 kW).

a/ Crop calendar specifies half-monthly periods. Therefore, May 2 means second half of May, etc.
b/ For technical specification of machinery, see Table A4.3.
c/ The crop specific data on timing and time requirements have been derived from: Abeygoonawardana 1977; Bot 1981; Celocia 1983; Curfs 1979; Curfs 1976; FAO 1976; Jong 1980; Lock 1984; Krochmal 1966; Panpiemras, et al 1985; Pathnopas 1980; RID/ILACO 1986a; RID/ILACO 1986b; Rijk 1975; Sharma 1978; Singh 1980; Sriboonchilla 1975; Taenkam 1980, p. 88; Toet 1983; de Vries 1980; World Bank 1986a (5847-TH), Appendix 1; van de Zande 1987.

Table A3.14. Data on crop area, yield, farmgate price and cost of inputs. [a]

Crop	Area ('000 rai)	Yield (tons/ rai)	Farm-gate Price (baht/ ton)	Cost of Inputs	
				Herbi-cide[b]	Others[c]
Rainfed Transplanted Paddy	3,639	0.365	2,735	30.0	94.00
Rainfed Broadcast Paddy	5,458	0.328	2,735	42.0	136.96
First Crop Irrigated Transplanted Paddy	1,257	0.608	2,735	30.0	362.50
First Crop Irrigated Broadcast Paddy	1,886	0.536	2,735	42.0	392.00
Second Crop Irrigated Transplanted Paddy	1,257	0.544	2,735	30.0	276.72
Second Crop Irrigated Broadcast Paddy	1,886	0.480	2,735	30.0	359.68
Deepwater Paddy	218	0.272	2,735	30.0	54.72
Maize	3,315	0.427	2,290	50.0	55.00
Sorghum	890	0.228	2,513	50.0	40.00
Cassava	2,553	2.176	600	100.0	30.00
Planted Sugarcane	801	7.900	320	100.0	1,112.00
First Ratoon Sugarcane	801	7.110	320	100.0	668.90
Second Ratoon Sugarcane	801	6.000	320	100.0	668.90
Non-Model Crops	3,800				

Notes and Sources:

a/ Estimates for base year (1986).
b/ Cost of herbicide in baht per rai.
c/ Cash expenditure in baht per rai for seed, fertilizer, pesticide, etc.

Farmgate prices 1983-84 - 85-86 average (OAE, *Agricultural Statistics of Thailand*, Crop Year 1985/86). Other data derived from: BOT 1981; OAE 1986; RID/ILACO 1986a; RID/ILACO 1986b; World Bank 1986a, Appendix 1; World Bank 1985; World Bank, 1984, Vol. II.

Appendix 4

DATA ON RESOURCES FOR BASE YEAR

Table A4.1. Land type resources used in MECHMOD for the Central Region.

Land Type	Description	'000 Rai
Type I	Bunded lowland (paddy land) with only one paddy crop per year	9,096.9
Type II	Irrigated bunded lowland capable of producing two paddy crops per year	3,142.9
Type III	Deepwater paddy land	218.0
Type IV	Land used for upland field crops	9,071.9

References:

- OAE, *Agricultural Statistics of Thailand*, Crop Year 1985/86.
- World Bank 1985b, p. 54.
- World Bank 1982, Vol. III, p. 33.

Table A4.2. Agricultural labor resources in the Central Region.

Farm Holdings[a/]	834,000
Agricultural Labor Force [b/]	
	('000 persons)
Family Labor:	
1 - Member > 11 years [c/]	3,248
2 - Engaged only on holding [c/] (core family labor)	1,918
3 - Economically inactive [c/]	524
4 - Active aggregate family labor ([1]-[3])	2,724
5 - Exchangeable family labor for off-farm work ([1]-[2]-[3]) [c/]	806
6 - Male family labor, 25-54 years [d/]	665
7 - Exchangeable male labor for off-farm work [e/]	193
Hired Labor:	
8 - Male migration labor [f/]	150
9 - Upper limit hired aggregate labor [g/]	200
10 - Upper limit hired male labor [g/]	55

Notes and References:

a/ NSO 1983, Table 1, Chapter 4. Holdings refer to holdings with land and is adjusted for 1986 assuming average annual rate of growth 1978-83.
b/ NSO 1983, NSO 1985. Total labor force 5.6 million. See also: Vanderveen 1987, p. 132; Corsel 1986, p. 28.
c/ NSO 1983, Table 5, Chapter 4, adjusted for rate of growth.
d/ NSO 1983, Table 5.2, Statistical Tables.
e/ Estimated pro rata.
f/ Estimated on the basis of information in Panpiemras 1985.
g/ Estimated based on NSO 1983, NSO 1985.

For MECHMOD, (4), (5), (6), (7), (8), (9), and (10) have been specified in the input data files.

Table A4.3. Machinery specific input data to MECHMOD.

Short Description	Technical/ Design Details	Retail Price[a/] ('000 baht)	Estimated Life[b/] (hours)	Available Time[c/] (hours/ week)	Machine Availability Factor[b/] (%)	Fuel Consumption[b/] (liter/ hour)	Repair and Maintenance Cost[b/] (%)
Single-axle Tractor	Single-axle tractor, 6 hp, locally-made cage wheels, no gears, no steering clutches, with mold-board plow and comb harrow	29	3,000	21	60	0.8	70
Two-axle Tractor (30 hp)	Two-axle tractor, 30 hp, Japanese type with paddy wheels and paddy disc harrow	290 (new) 115 (2nd-hand)	5,000 (new) 4,000 (2nd-hand)	24	60	4.9	100
Two-axle Tractor (65 hp)	Two-axle tractor, 65 hp, European type standard design	388	8,000	54	60	10.4	120
Plow	Disc plow 3 furrow/ disc tiller for dry field conditions and 65 hp tractor	30	2,000	54	60	-	150
Toolbar	Interrow weeder/ridger for 65 hp tractor	30	2,000	54	60	-	100
Trans-planter	Rice transplanter self-propelled, Chinese design 12 row semi-automatic	50	1,500	42	40	0.9	120
Planter	4-row maize/sorghum planter for 65 hp tractor	30	1,500	54	60	-	80
Sprayer	Backpack motor sprayer/ duster	10	1,000	42	50	0.3	60
Reaper	Reaper, IRRI/CAAMS design, 1 m cutting width attached to single-axle tractor	50	1,200	42	50	1.1	120
Rice Thresher	IRRI based design axial flow thresher, 10 hp	65	2,000	48	50	1.8	100

(continued)

Table A4.3 (continued)

Short Descript-tion	Technical/ Design Details	Retail Price[a/] ('000 baht)	Estim-ated Life[b/] (hours)	Avail-able Time[c/] (hours/ week)	Machine Avail-ability Fac-tor[b/] (%)	Fuel Con-sump-tion[b/] (liter/ hour)	Repair and Mainte-nance Cost[b/] (%)
Small Rice Combine	Small rice combine, Japanese design, Kubota NX 1300, full track, 0.75 m cutting width	330	2,000	54	60	1.9	60
Large Rice Combine	European design, half	2,050	2,500	54	60	13.9	60
Combine	European design combine equipped for sorghum and maize, 4 m working width	2,000	2,500	54	60	12.5	60
Maize Sheller	Maize sheller including cleaner, powered by 65 hp tractor	30	2,500	54	60	-	100
Cane Planter	Sugar cane planter, semi-automatic for 65 hp tractor, two-row	31	2,000	54	60	-	80
Cane Harvester	Self-propelled cane harvester with topper	2,250	2,000	54	60	17.5	80
Sorghum Thresher	Sorghum thresher with cleaner, 10 hp	50	2,000	48	60	1.7	100
Cassava Planter	Cassava planter, semi-automatic, two-row for 65 hp tractor	28	2,000	54	60	-	80
Cassava Lifter	Single-row cassava lifter, attached to 65 hp tractor	25	2,000	54	60	-	70

Notes and References:

a/ Retail prices are 1986 average prices including taxes and derived from Cholburi Muang Thong Co., 1986 price list, Anglo-Thai Tractors Ltd. price list, BAAC price list, interviews. Average price for two-axle tractor (65 hp) takes into account price of reconditioned tractors. For machines not yet sold in Thailand, prices have been obtained from comparable countries.

b/ Estimated life, efficiency, fuel consumption, repair and maintenance cost data have been obtained from ASAE 1987; Hunt 1973; Deere 1975; Elsevier 1981, pp. 546-549; or estimated and adjusted for Thailand based on expert advice. Machine Availability Factor is measured in a percentage and converts the Available Time per week for time lost in transport, adjustments, repair and maintenance. Repair and maintenance cost during the total expected life of the machine is given in a percentage for retail price.

c/ Available Time (hours per week) has been estimated based on various sources (Toet 1983, Chancellor 1961, and interviews). For single-axle tractor and two-axle tractors (30 hp), it has been assumed that these tractors are available for fieldwork only 50 per cent of the time, with the remainder used to power stationary machinery or pumpsets, or for transport.

1 horsepower = 0.736 kilowatt

Table A4.4. Other external variables for MECHMOD.

MECHMOD Variable	Base Year Value	Description
SBED	8.0	Seedbed area for transplanted rice in percentage of transplanted area
GFW	20	Percentage of family labor spent on general farm work and livestock
USLMIN	6.1	Hours per week per rai spent on non-model crops
BWAGE	7.9	Basic wage rate (baht/hour)
TFLDA	5.2	Hours spent per week on care of draft animals (DA)
THEFT	2.0	Risk of theft of draft animals (%)
DEAD	3.6	Risk of mortality of draft animals (%)
HCARE	50	Cost of health care for draft animals in baht per year
ELDYR	12	Economic life of DA in years
SVDA	60	Salvage value of DA in percentage of procurement price
AVDAP	15	Working hours available from one DA per week assuming 50 per cent efficiency for total herd
PPDA	9,000	Procurement price of DA in baht, including implements
PFUEL	6.5	Price of diesel fuel in baht per liter
PREM	0.5	Annual insurance premium (or risk borne by the owner) for machinery as percentage of its procurement price
SHEL	1.5	Annual cost of shelter of machinery in percentage of its procurement price
SVMA	10	Salvage value for machinery as a percentage of its procurement price
CIRDA	11.0	Interest rate over DA (opportunity cost of own capital)
CIR1	11.0	Interest rate over own capital
CIR2	14.0	Interest rate for machinery financed by BAAC
CIR3	36.0	Interest rate for machinery financed through supplier's credit
RAT1	30.0	Ratio of own finance applied for machinery (%)
RAT2	60.0	Ratio (%) of BAAC finance available only for single-axle tractor and sprayer. For rice thresher, sorghum thresher and maize sheller RAT2 is 20
RAT3		Ratio (%) of finance from supplier's credit. RAT3 = 100 - (RAT1 + RAT2). In case RAT2 = 0, RAT1 is 40 per cent

References:

- For GFW and USLMIN, see Sub-section 5.3.4.
- BWAGE based on data from Department of Labor and information in Sub-section 5.3.7.
- On draft animal, Sriboonchilla 1975; Bunyawanichkul 1981; Toet 1983, Appendix III.
- On machinery, see notes and references Table A4.3.
- On interest rates and financing ratios, see Appendix 1.

Appendix 5

WORKABILITY FACTORS APPLIED IN MECHMOD

Depending on machinery used and method applied, three *Workability Classes* per period are distinguished. Applying rainfall data from Lop Buri (Central Region), a daily rainfall pattern was generated over a period of 30 years with WOFOST computer software.[1/] Based on this rainfall pattern, for each period and workability class, a *Workability Factor* has been calculated in the user written program WFACTOR. [2/] The workability factor for a certain period and class is defined as the number of days that satisfy the criteria on workability estabished for that class, divided by the total number of days in the period. The criteria for a day to belong to a workability class are as follows: [3/]

Class I : Day with less than 10 mm rain

Class II : Day with less than 5 mm rain, less than 10 mm on the preceding day, and total rainfall over these two days of less than 10 mm

Class III: Day with less than 2 mm, less than 5 mm on the preceding day, and total rainfall over these two days of less than 4.5 mm

Field operations and methods have been allocated to the workability classes.

Workability Class I

Paddy Crops

- Seedbed preparation with draft animal and single-axle tractor
- Land preparation with draft animal, single-axle tractor, and small two-axle tractor
- Transplanting and broadcasting of seed
- Crop care

Upland Crops

- Land preparation with draft animal
- Manual planting
- Manual and chemical crop care
- Manual harvesting of cassava
- Manual harvesting of sugarcane

Workability Class II

Paddy Crops

- Land preparation with big two-axle tractor
- Manual and mechanical reaping

Upland Crops

- Land preparation with big two-axle tractor
- Planting with tractor-pulled planting machine
- Crop care with tractor-pulled interrow cultivator
- Manual and mechanical reaping of grain crop
- Mechanized harvesting of cassava
- Mechanical cane harvesting

Workability Class III

Paddy Crops

- Combine harvesting
- Threshing

Upland Crops

- Grain combine harvesting
- Threshing and shelling

The workability factors are written in file WEERDAT. WEERDAT is read during running MGG by IWEERFAC, a user-written front-end subroutine. The workability factors are listed in Table A5.1.

Table A5.1. Workability factors per period and class.

	Class		
Period	I	II	III
1	0.98	0.95	0.94
2	0.98	0.96	0.95
3	0.98	0.94	0.90
4	0.97	0.92	0.88
5	0.97	0.92	0.87
6	0.96	0.92	0.89
7	0.94	0.85	0.79
8	0.91	0.79	0.72
9	0.84	0.63	0.51
10	0.84	0.66	0.53
11	0.86	0.65	0.52
12	0.86	0.69	0.56
13	0.85	0.63	0.50
14	0.85	0.66	0.50
15	0.81	0.58	0.44
16	0.79	0.54	0.41
17	0.72	0.46	0.34
18	0.66	0.40	0.28
19	0.84	0.68	0.56
20	0.86	0.67	0.59
21	0.90	0.76	0.68
22	0.97	0.93	0.89
23	0.97	0.94	0.93
24	1.00	0.99	0.99

NOTES AND REFERENCES TO APPENDIX 5

1/ WOFOST Rainfall Generator Version 4.0, March 1987. Centre for World Food Studies (SOW), Wageningen. The rainfall data for Lop Buri are included in the computer data files of SOW.

2/ For further details and the FORTRAN written WFACTOR program, see Kavelaars 1988, p. 128.

3/ These criteria were established using expert advise and information from Klooster 1979, Donk 1983, and Goense 1987.

Appendix 6

OUTPUT FOR BASE YEAR

Table A6.1. Base year: Capital stock and labor input.

Capital Stock:	Million Baht
Draft Animal and Machinery	13,240
Draft Animal	826
Machinery	12,414
Draft Animal/Machinery:	Units
Draft Animal	91,766
Single-axle Tractor	172,657
Big Tractor	13,568
Plow for Big Tractor	13,568
Paddy Transplanter	0
Motor Sprayer	45,143
Reaper	0
Rice Thresher	13,990
Rice Combine Harvester	0
Maize/Sorghum Planter	0
Toolbar	4,548
Maize/Sorghum Combine Harvester	0
Maize Sheller	6,301
Sugarcane Planter	0
Sugarcane Harvester	0
Sorghum Thresher	983
Cassava Planter	0
Cassava Harvester	0
Total Annual:	Million Hours
Aggregate Labor Hours Available	2,489.0
Male Labor Hours Available	519.7
Hours On-Farm Work	1,764.3
Hours Off-Farm Work	724.8
Hours Hired Labor	49.8
Hours Male Input on Model Crops	342.4
Total Hours Input on Model Crops	1,814.1
Return/Hour	10.03 baht
Labor Input per Rai	73.3 hours

Table A6.2. Base year: Area by operation and method.

Crop	Operation	Method	'000 Rai	Percent-age of Crop
Paddy	Mechanical Paddy Land Preparation Ratio		14,186.2	90.9
	Land Preparation	Draft Animal	1,414.8	9.1
		Single-axle Tractor	6,990.9	44.8
		Big Tractor	7,163.7	45.9
		Big Tractor/ Draft Animal	31.6	0.2
		Small Tractor		0.0
	Planting	Manual	6,153.0	39.4
		Transplanter	0.0	0.0
		Broadcasting	9,448.0	60.6
	Crop Care	Manual	10,143.0	65.0
		Chemical	5,458.0	35.0
	Harvest	Manual	15,601.0	100.0
		Reaper	0.0	0.0
		Combine	0.0	0.0
	Threshing	Draft Animal	0.0	0.0
		Single-axle Tractor	384.7	2.5
		Thresher	15,216.2	97.5
Maize/ Sorghum	Land Preparation	Draft Animal	508.1	12.1
		Big Tractor	3,696.9	87.9
	Planting	Manual	4,205.0	100.0
	Crop Care	Manual	4,205.0	100.0
		Chemical	0.0	0.0
	Harvest	Manual	4,205.0	100.0
		Combine	0.0	0.0
	Shelling	Threshing	4,205.0	100.0
Sugarcane	Land Preparation [a]	Draft Animal	267.0	11.1
		Big Tractor	534.0	22.2
	Stubble Shaving/ Furrowing	Big Tractor	1,602.0	66.7
	Planting	Manual	801.0	33.3
		Big Tractor	0.0	0.0
	Crop Care	Manual	801.0	33.3
		Chemical	1,602.0	66.7
	Harvest	Manual	2,403.0	100.0
		Mechanical Harvester	0.0	0.0
Cassava	Land Preparation	Draft Animal	777.4	30.5
		Tractor	1,775.6	69.5
	Planting	Manual	2,553.0	100.0
	Crop Care	Manual	2,553.0	100.0
		Big Tractor/Toolbar	0.0	0.0
		Chemical	0.0	0.0
	Harvest	Manual	2,553.0	100.0
		Big Tractor	0.0	0.0
Total Upland to be Plowed:			7,559.0	
Mech. Upland Plowing Ratio:			79.5	

Note:

[a] Because of two ratoon crops, only one-third of total sugarcane area needs land preparation.

Table A6.3. Base year: Dual prices for labor, draft animals, and machinery (baht/hour).

Period	Aggregate Labor	Male Labor	Draft Animal	Single-Axle Tractor	Big Tractor	Plow	Sprayer	Rice Thresher	Tool-bar	Maize Sheller	Sorghum Thresher
1 Jan	7.11	11.38	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.7
2	7.11	11.38	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 Feb	7.11	11.38	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	7.11	11.38	8.8	21.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 Mar	7.11	11.38	8.8	21.6	0.0	0.0	0.0	0.0	75.7	0.0	0.0
6	7.11	11.38	18.5	0.0	210.1	0.0	0.0	0.0	0.0	0.0	0.0
7 Apr	7.11	11.38	19.9	0.0	210.1	0.0	0.0	0.0	0.0	0.0	0.0
8	7.11	10.24	19.6	0.0	212.4	0.0	0.0	0.0	0.0	0.0	0.0
9 May	7.11	7.11	22.8	0.0	218.6	0.0	3.1	0.0	0.0	0.0	0.0
10	7.11	10.24	6.1	7.9	82.4	0.0	0.0	0.0	0.0	0.0	0.0
11 Jun	7.11	10.24	6.1	7.9	0.0	82.4	0.0	127.7	0.0	0.0	0.0
12	10.31	14.19	2.2	0.0	74.5	0.0	0.0	88.6	0.0	0.0	0.0
13 Jul	10.31	14.19	2.2	0.0	74.5	0.0	0.0	88.5	0.0	0.0	0.0
14	10.34	14.85	1.4	0.0	42.7	24.4	1.6	0.0	0.0	0.0	0.0
15 Aug	10.34	14.85	1.4	0.0	67.1	0.0	1.6	0.0	0.0	0.0	0.0
16	10.34	14.85	0.0	0.0	0.0	0.0	1.6	0.0	0.0	47.8	0.0
17 Sep	10.31	14.84	0.0	0.0	0.0	0.0	1.8	0.0	0.0	47.9	0.0
18	10.31	10.31	4.4	0.0	9.1	0.0	6.4	0.0	0.0	43.4	0.0
19 Oct	10.31	10.31	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0
20	10.31	10.31	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0
21 Nov	10.31	10.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	10.31	10.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 Dec	10.22	11.29	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	7.11	14.85	0.0	0.0	0.0	0.0	0.0	30.7	0.0	0.0	61.1

Notes:
- Base year run (Run 00A) uses data and information from 1986.
- Basic wage rate equals 7.9 baht/hour (aggregate labor) (1986).
- Male labor (25-54 year) wage rate is 44 per cent higher.
- During peak season (June - December), wage rate is 45 per cent higher.
- Labor which is available for off-farm work is assumed to have a net earning of 90 per cent of wage rate.

An example of comparing the marginal costs of different methods is as follows: The dual prices are in baht per hour net-available from an animal or machine obtained from the base year solution (Run 00A). For period 9 (first half of May), the dual price for a big tractor is 218.60 baht/hour, for draft animal 22.80 baht/hour, and for male labor 7.11 baht/hour. The variable cost (including depreciation) of plowing maize land with a tractor is 209.40 baht/rai and requires 1 hour/rai tractor time and 2 hours male labor. With draft animal and one male labor, it requires 14.8 hours. Applying the dual prices, both plowing by draft animal and tractor costs 442 baht/rai (marginal cost). MECHMOD shows that in Period 9, 169,000 rai are plowed with animal traction, while 600,000 rai are plowed with tractors. In the case of land preparation for cassava in Period 24 (second half of December), the dual price for tractors and draft animals is both 0.0 baht. For male labor it is 14.85 baht per hour, and applying the variable costs and time required per rai, tractor plowing costs 215.27 baht/rai, and draft animal plowing costs 222.75 baht. Subsequently, plowing cassava land in Period 24 is performed only with tractors.

Appendix 7

OUTPUT FROM EXPERIMENTS

Table A7.1. Series I: Effect of wage rate on capital stock. [a]

Parameter	Variation in Wage Rate from Base Year [b]									
	-25%	-20%	-15%	-10%	-5%	+5%	+10%	+15%	+20%	+25%
Capital Stock (Value):										
DA and Machinery [c]	-15.6	-15.5	-12.3	-11.3	-4.2	5.6	12.0	24.6	36.6	49.5
Machinery	-33.8	-33.7	-26.8	-24.8	-10.0	8.5	17.0	32.9	45.7	59.4
DA/Machinery (Units):										
DA	258.1	258.1	204.7	191.7	82.9	-38.9	-62.8	-100.0	-100.0	-100.0
Single-axle Tractor	-3.5	-3.5	-7.2	-6.3	-1.0	7.6	12.3	19.5	19.5	19.5
Big tractor	-62.5	-62.5	-49.5	-46.4	-20.1	9.8	16.5	26.1	26.2	27.9
Plow for Big Tractor	-62.5	-62.5	-49.5	-46.4	-20.1	9.8	16.5	26.1	26.2	27.9
Motor Sprayer	-84.4	-82.7	-24.2	-16.1	0.0	0.0	0.0	0.0	0.0	41.7
Reaper [d]							1,417	22,024	50,829	56,023
Rice Thresher	0.2	0.2	1.7	0.2	0.2	-3.2	0.2	0.2	12.5	12.5
Toolbar	-44.7	-44.8	-43.3	-42.9	-36.4	0.0	0.0	6.5	1.3	20.8
Maize Sheller	-19.2	-19.2	0.0	0.0	0.0	-19.2	-19.2	-19.2	-19.2	-19.2
Cane Harvester [d]						85	234	247	268	771
Sorghum Thresher	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-19.0	-19.0	-19.0
Hours On-Farm Work	7.67	7.73	6.65	6.13	2.71	-1.77	-3.24	-6.89	-12.19	-19.78
Hours Off-Farm Work	-18.68	-18.81	-16.19	-14.92	-6.59	4.31	7.89	16.77	29.68	48.16
Hours Hired Labor Input	175.34	163.03	73.45	68.86	33.05	-32.65	-80.54	-100.00	-100.00	-100.00
Hours Male Labor Input	28.94	29.26	25.62	24.73	12.78	-7.00	-14.58	-16.93	-13.60	-29.15
Total Hours Input and Labor Input per Rai	12.27	11.99	8.49	7.85	3.54	-2.62	-5.36	-9.44	-14.60	-21.99
Return/Hour Fam. Labor	-4.84	-4.10	-3.20	-2.26	-1.21	0.71	2.71	4.28	5.89	7.77
Area by Operation and Method										
Paddy:										
Mech. Land Preparation Ratio [e]	65.2	65.2	70.4	72.0	85.0	94.0	98.9	100.0	100.0	100.0
Land Prep. DA	284.1	284.1	226.6	209.0	65.7	-53.2	-71.6	-100.0	-100.0	-100.0
Land Prep. 2-W Tractor	11.8	11.8	6.4	6.6	7.9	3.9	0.5	-1.1	-1.4	-2.3
Land Prep. Big Tractor (BT)	-67.2	-67.2	-50.6	-47.3	-20.2	-1.3	8.9	21.2	21.6	22.5
Land Prep BT & DA	-100.0	-100.0	-100.0	-100.0	-100.0	1,816	1,064	-100.0	-100.0	-100.0
Crop Care Manual	51.8	46.3	13.5	9.0	0.0	0.0	-8.3	-8.3	-8.3	-53.3
Crop Care Chemical	-96.2	-86.0	-25.1	-16.8	0.0	0.0	15.4	15.4	15.4	99.1
Harvest Manual	0.0	0.0	0.0	0.0	0.0	0.0	-2.0	-26.4	-70.3	-84.8
Harvest Reaper [f]							306	4,116	10,961	13,236
Threshing Tractor	48.1	48.1	22.5	-1.5	-1.5	23.8	5.6	5.6	-92.9	-92.9
Mechanical Thresher	-1.2	-1.2	-0.6	0.0	0.0	-0.6	-0.1	-0.1	2.3	2.3
Upland:										
Mech. Upland Preparation Ratio [e]	14.6	14.6	23.5	25.0	47.5	87.5	91.4	100.0	100.0	100.0
Maize & Sorghum Mech. Land Preparation	-71.3	-71.3	-60.7	-58.1	-36.5	5.4	8.7	13.7	13.7	13.7

(continued)

Table A7.1 (continued)

Parameter	Variation in Wage Rate from Base Year b/									
	-25%	-20%	-15%	-10%	-5%	+5%	+10%	+15%	+20%	+25%
Sugarcane:										
Mech. Land Preparation	-92.4	-92.4	-78.6	-75.2	-40.0	19.1	31.2	50.0	50.0	50.0
Crop Care Manual	0.0	0.0	0.0	0.0	0.0	-82.7	-100.0	-100.0	-100.0	-100.0
Crop Care Chemical	0.0	0.0	0.0	0.0	0.0	41.4	50.0	50.0	50.0	50.0
Harvest Manual	0.0	0.0	0.0	0.0	0.0	-6.7	-18.5	-19.5	-21.1	-60.8
Harvest Mechanized f/						161.5	444.0	468.6	507.9	1,460.8
Cassava:										
Mech. Land Prep.	-100.0	-100.0	-88.0	-88.0	-48.3	17.0	23.4	43.8	43.8	43.8
Crop Care Manual	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.1
Crop Care Chemical 6/										232

Notes:

a/ Effects are listed in percentage change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The indicator has not been listed if no change took place during the experiments.
b/ Wage rate at base year is 7.90 baht per hour.
c/ For draft animal alone, see under DA units.
d/ In units (base year = 0).
e/ Ratios in percentage of crop area.
f/ In '000 rai (base year = 0).

Table A7.2. Series I: Effect of fuel price on capital stock. [a]

Parameter	Variation in Fuel Price from Base Year [b]								
	-40%	-30%	-20%	-10%	+10%	+20%	+30%	+40%	+60%
Capital Stock (Value):									
DA and Machinery [c]	11.5	4.1	4.1	2.6	-0.6	-4.2	-8.0	-10.2	-12.7
Machinery	19.0	7.0	7.0	4.3	-1.0	-10.0	-19.5	-24.3	-30.7
DA/Machinery (Units):									
DA	-100.0	-38.9	-38.9	-23.5	5.3	82.9	163.7	201.8	258.1
Single-axle Tractor	19.5	7.6	7.6	4.6	-1.0	-1.0	-4.5	-7.0	-7.4
Big Tractor	25.4	9.8	9.8	5.9	-1.3	-20.1	-39.6	-48.8	-62.5
Plow for Big Tractor	25.4	9.8	9.8	5.9	-1.3	-20.1	-39.6	-48.8	-62.5
Motor Sprayer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	18.2
Rice Thresher	-3.3	-3.2	-3.2	-3.2	0.2	0.2	12.4	12.4	12.5
Toolbar	0.0	0.0	0.0	0.0	0.0	-36.4	-41.8	-43.2	-45.5
Maize Sheller	-19.2	-19.2	-19.2	0.0	0.0	0.0	0.0	0.0	-19.2
Hours On-Farm Work	-2.42	-0.89	-0.89	-0.59	0.37	2.71	4.93	5.75	7.31
Hours Off-Farm Work	5.88	2.18	2.18	1.43	-0.91	-6.59	-12.00	-13.99	-17.79
Hours Hired Labor Input	-38.29	-14.18	-14.18	-8.11	1.75	33.05	59.18	72.35	83.37
Hours Male Labor Input	-10.89	-3.97	-3.97	-2.59	1.82	12.78	22.68	26.07	31.64
Total Hours Input and Labor Input per Rai	-3.40	-1.26	-1.26	-0.79	0.41	3.54	6.42	7.58	9.40
Return/Hour Family Labor	1.70	1.30	0.78	0.46	-0.44	-0.82	-1.15	-1.42	-1.94
Area by Operation and Method									
Paddy:									
Mech. Land Prep. Ratio [d]	100.0	95.8	95.8	94.7	90.4	85.0	75.4	70.7	64.4
Land Prep. DA	-100.0	-53.3	-53.3	-41.5	5.8	65.7	171.1	222.7	292.1
Land Prep. 2W-Tractor	-3.2	3.9	3.9	2.2	0.2	7.9	7.1	6.4	10.2
Land Prep. Big Tractor (BT)	23.3	-1.2	-1.2	-4.1	-1.1	-20.2	-40.3	-49.8	-67.2
Land Prep. BT & DA	-100.0	814.7	1,814.7	2,296.3	-58.4	-100.0	-100.0	-100.0	-100.0
Threshing Tractor	25.7	23.8	23.8	23.8	-1.5	-1.5	-99.1	-99.1	-100.0
Thresher	-0.7	-0.6	-0.6	-0.6	0.0	0.0	2.5	2.5	2.5
Upland:									
Mech. Upland Preparation Ratio [d]	100.0	87.5	87.5	84.3	73.5	47.5	28.3	23.9	16.1
Maize & Sorghum Mech. Land Prep.	13.7	5.4	5.4	3.3	-11.1	-36.5	-52.5	-60.1	-71.3
Sugar Cane:									
Mech. Land Prep.	50.0	19.1	19.1	11.4	0.0	-40.0	-68.0	-77.9	-92.4
Cassava:									
Mech. Land Prep.	43.8	17.0	17.0	10.3	-2.3	-48.3	-88.0	-88.0	-93.4

Notes:

[a] Effects are listed in percentage change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The indicator has not been listed if no change took place during the experiments.

[b] Fuel price in base year is 6.50 baht per liter.

[c] For draft animal alone, see under DA units.

[d] Ratios in percentage of crop area.

Table A7.3. Series I: Effect of acquisition cost on capital stock. [a]

Parameter	Mechanical Technology Only								DA and Mechanical Technology		
	Variation in Acquisition Cost from Base Year										
	-20%	-15%	-10%	-5%	+5%	+10%	+15%	+20%	-10%	+10%	+20%
Capital Stock (Value):											
DA and Machinery (incl. tax)	11.1	5.9	-1.2	0.5	0.0	-4.2	-1.8	-0.7	-1.6	5.3	5.4
DA and Machinery (excl. tax) [b]	38.9	24.6	9.3	5.6	-4.2	-11.3	-12.1	-13.8	9.3	-4.3	-12.1
DA/Machinery (Units):											
DA	-100.0	-100.0	-36.3	-38.0	82.9	191.6	204.6	232.0	-36.3	84.4	204.6
Single-axle Tractor	19.5	19.5	7.1	7.4	-1.0	-6.3	-7.2	-8.4	7.1	-1.0	-7.2
Big Tractor	26.4	26.0	9.7	9.6	-20.1	-46.4	-49.5	-56.2	9.7	-20.4	-49.5
Plow for Big Tractor	26.4	26.0	9.7	9.6	-20.1	-46.4	-49.5	-56.2	9.7	-20.4	-49.5
Motor Sprayer	0.0	0.0	0.0	0.0	0.0	-16.1	-14.8	-14.5	0.0	0.0	-15.7
Reaper [c]	56,022	22,024	1,849	0	0	0	0	0	1,849	0	0
Rice Thresher	12.5	1.7	0.2	-1.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Toolbar	1.8	7.0	0.7	0.0	-36.4	-42.9	-43.3	-45.6	0.77	-37.1	-43.3
Maize Sheller	-19.2	-19.2	-19.2	-19.2	0.0	0.0	0.0	-5.6	-19.2	0.0	0.0
Cane Harvester [c]	282	245	254	86	0	0	0	0	254	0	0
Sorghum Thresher	-19.0	-19.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hours On-Farm Work	-13.09	-6.40	-1.86	-1.54	2.70	6.06	6.30	7.07	-1.86	2.75	6.42
Hours Off-Farm Work	31.87	15.58	4.54	3.75	-6.57	-14.76	-15.34	-17.21	4.54	-6.68	-15.62
Hours Hired Labor Input	-100.00	-100.00	-75.04	-33.25	33.05	69.12	76.49	80.24	-75.04	33.61	73.41
Hours Male Labor Input	-13.48	-16.37	-12.92	-7.07	12.75	24.43	25.93	28.51	-12.92	12.95	25.90
Total Hours Input and Labor Input per Rai	-15.48	-8.97	-3.87	-2.41	3.53	7.79	8.23	9.08	-3.87	3.59	8.25
Return/Hour Fam. Labor	4.07	2.68	1.76	0.70	-0.88	-1.45	-2.05	-2.52	1.79	-1.58	-2.86
Area by Operation and Method											
Paddy:											
Mech. Land Prep. Ratio [d]	100.0	100.0	95.6	95.7	85.2	72.0	70.4	67.1	95.6	84.8	71.1

(continued)

Table A7.3 (continued)

Parameter	Mechanical Technology Only								DA and Mechanical Technology		
	Variation in Acquisition Cost from Base Year										
	-20%	-15%	-10%	-5%	+5%	+10%	+15%	+20%	-10%	+10%	+20%
Land Prep. DA	-100.0	-100.0	-51.3	-52.6	63.7	208.9	226.4	262.4	-51.3	67.6	226.4
Land Prep. 2W-Tractor	-2.3	6.0	3.6	3.9	8.3	6.6	6.4	7.1	3.6	7.9	7.9
Land Prep. Big Tractor (BT)	22.4	14.3	-1.7	-1.6	-20.2	-47.3	-50.5	-58.3	-1.7	-20.6	-50.5
Land Prep. BT & DA	-100.0	-100.0	1,897.3	1,841.6	-100.0	-100.0	-100.0	-100.0	1,897.3	-100.0	-100.0
Crop Care, Manual	-8.3	-8.3	0.0	0.0	0.0	9.0	8.3	8.1	0.0	0.0	8.8
Crop Care, Chemical	15.4	15.4	0.0	0.0	0.0	-16.7	-15.4	-15.1	0.0	0.0	-16.4
Harvest, Manual	-82.3	-26.4	-2.6	0.0	0.0	0.0	0.0	0.0	-2.6	0.0	0.0
Harvest, Reaper c/	12,840	4,123	399						399		
Threshing Tractor	-92.9	-12.9	5.6	10.2	-1.5	-1.5	41.0	41.0	5.6	-1.5	41.0
Thresher	2.3	0.3	-0.1	-0.3	0.0	0.0	-1.0	-1.0	-0.1	0.0	-1.0
Upland:											
Mech. Upland Preparation Ratio d/	100.0	100.0	85.2	87.3	47.5	26.1	23.6	20.2	85.2	47.2	23.6
Maize & Sorgh. Mech. Land Prep.	13.7	13.7	5.1	5.3	-36.5	-58.1	-60.7	-66.1	5.1	-36.8	-60.7
Sugarcane:											
Crop Care Manual	-43.1	-77.9	-63.6	-59.1	0.0	0.0	0.0	0.0	-63.6	0.0	0.0
Crop Care Chemical	21.5	38.6	31.8	29.5	0.0	0.0	0.0	0.0	31.8	0.0	0.0
Mech. Land Prep.	50.0	50.0	17.8	18.7	-40.0	-75.2	-78.6	-85.6	17.8	-40.8	-78.6
Harvest Mech. e/	534.2	463.8	480.6	163.1	0.0	0.0	0.0	0.0	480.6	0.0	0.0
Cassava:											
Mech. Land Prep.	43.8	43.8	8.7	16.7	-48.3	-83.8	-88.0	-88.9	8.7	-48.7	-88.0

Notes:

a/ Effects are listed in percentage change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The indicator has not been listed if no change took place during the experiments.

b/ The acquisition cost is kept constant at base year prices.

c/ In units (base year = 0).

d/ Ratios in percentage of crop area.

e/ In '000 rai (base year = 0).

Table A7.4. Series I: Effect of proportional variation in interest rates on capital stock. [a]

Paramater	Variation in Interest Rates from Base Year							
	-40%	-30%	-20%	-10%	+10%	+20%	+30%	+40%
Capital Stock (Value):								
DA and Machinery [b]	16.5	8.3	4.2	2.6	-0.3	-2.4	-6.0	-10.5
Machinery	24.3	11.2	7.0	4.2	-0.4	-4.1	-11.8	-24.0
DA/Machinery (Units):								
DA	-100.0	-35.2	-37.4	-22.0	0.9	22.9	80.8	192.3
Single-axle Tractor	19.5	6.9	7.3	4.3	-0.2	-3.3	-6.0	-6.4
Big Tractor	25.9	9.5	9.4	5.5	-0.2	-5.5	-19.6	-46.6
Plow for Big Tractor	25.9	9.5	9.4	5.5	-0.2	-5.5	-19.6	-46.6
Motor Sprayer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2
Reaper [c]	2,279	1,661	0	0	0	0	0	0
Rice Thresher	12.5	1.7	0.2	0.2	-3.2	-3.2	-3.2	-2.3
Toolbar	0.0	0.0	0.0	0.0	0.0	0.0	-17.7	-42.9
Maize Sheller	-19.2	-19.2	-19.2	0.0	0.0	0.0	0.0	0.0
Cane Harvester [c]	165	197	0	0	0	0	0	0
Hours On-Farm Work	-2.7	-1.2	-0.9	-0.6	0.0	0.6	2.2	5.3
Hours Off-Farm Work	6.6	2.9	2.2	1.4	-0.1	-1.5	-5.2	-12.9
Hours Hired Labor	-80.8	-61.0	-13.7	-7.7	0.4	8.0	30.2	69.3
Total Hours Male Labor	-15.8	-10.9	-3.8	-2.4	0.1	2.6	9.5	23.3
Total Hours Input and Labor Input per Rai	-15.8	-2.9	-1.2	-0.8	0.1	0.8	2.9	7.0
Return/Hour Fam. Labor	2.2	1.6	1.1	0.5	-0.4	-1.0	-1.5	-2.0
Area by Operation and Method								
Paddy:								
Mech. Land Preparation Ratio [d]	100.0	95.5	95.7	94.6	90.8	88.8	84.4	76.8
Land Prep. DA	-100.0	-50.4	-52.1	-40.3	0.9	23.9	72.2	155.8
Land Prep. 2W-Tractor	11.5	3.6	4.0	2.4	0.0	1.0	6.0	17.6
Land Prep. Big Tractor (BT)	8.9	-2.1	-1.9	-4.7	-0.2	-5.3	-19.7	-47.5
Land Prep. BT & DA	-100.0	1,930.6	1,862.3	2,345.1	-9.7	-100.0	-100.0	-100.0
Harvest, Manual	-3.2	-2.3	0.0	0.0	0.0	0.0	0.0	0.0
Harvest, Reaper [e]	491.7	358.4	0.0	0.0	0.0	0.0	0.0	0.0
Threshing Tractor	-92.9	-20.0	-1.5	-1.5	23.8	23.8	23.8	17.4
Thresher	2.3	0.5	0.0	0.0	-0.6	-0.6	-0.6	-0.4
Upland:								
Mech. Upland Preparation Ratio [d]	100.0	85.0	87.1	84.0	79.3	74.4	59.6	28.7
Maize & Sorghum Mech. Land Prep.	13.7	4.9	5.2	3.1	-0.2	-5.5	-20.7	-58.2
Sugarcane:								
Mech. Land Preparation	50.0	17.3	18.4	10.6	0.0	0.0	-19.4	-75.4
Mechanical Harvest [e]	313.1	374.0	84.1	0.0	0.0	0.0	0.0	0.0
Cassava:								
Mech. Land Preparation	43.8	8.2	16.4	9.6	-0.4	-10.0	-35.4	-72.1

Notes:

a/ Effects are listed in percentage change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The indicator has not been listed if no change took place during the experiments.

b/ For draft animal alone, see under DA units.

c/ In units (base year = 0).

d/ Ratios in percentage of crop area.

e/ In '000 rai (base year = 0).

Table A7.5. Series I: Effect of non-discriminating interest rates on capital stock. [a]

Parameter	Interest Rate 10%	15%	20%	25%	30%	35%	40%
Capital Stock (Value):							
DA and Machinery [b]	38.2	24.0	11.6	11.5	4.1	4.1	4.1
Machinery	47.3	32.2	19.0	19.0	7.0	7.0	7.0
DA/Machinery (Units):							
DA	-100.0	-100.0	-100.0	-100.0	-39.3	-39.3	-39.4
Single-axle Tractor	19.5	19.5	19.5	19.5	7.7	7.7	7.7
Big Tractor	26.2	25.9	25.4	25.4	9.8	9.8	9.8
Plow for Big Tractor	26.2	25.9	25.4	25.4	9.8	9.8	9.8
Reaper [c]	56,023	22,024	0	0	0	0	0
Rice Thresher	12.5	12.5	-2.5	-3.3	-3.2	-3.2	-3.5
Toolbar	7.6	0.0	0.0	0.0	0.0	0.0	0.0
Maize Sheller	-19.2	-19.2	-19.2	-19.2	-19.2	-19.2	-19.2
Cane Harvester [b]	235	165	0	0	0	0	0
Hours On-Farm Work	-8.86	-5.27	-2.14	-2.13	-1.13	-0.99	-0.99
Hours Off-Farm Work	21.55	12.82	5.21	5.19	2.75	2.42	2.42
Hours Hired Labor Input	-100.00	-80.80	-38.29	-38.29	-13.57	-13.57	-13.59
Hours Male Labor Input	-13.49	-13.80	-9.42	-9.43	-3.88	-3.18	-3.19
Total Hours Input and Labor Input per Rai	-11.36	-7.34	-3.13-	-3.13	-1.47	-1.34	-1.34
Return/Hour Fam. Labor	3.38	1.84	0.53	-0.89	-2.01	-3.27	-4.44
Area by Operation and Method							
Paddy:							
Mech. Land Preparation Ratio [d]	100.00	100.00	100.00	100.00	95.80	95.80	95.80
Land Prep. DA	-100.00	-100.00	-100.00	-100.00	-53.55	-53.55	-53.66
Land Prep. 2W-Tractor	9.61	9.68	10.42	10.34	3.93	3.93	3.91
Land Prep. Big Tractor (BT)	10.81	10.75	10.02	10.10	-1.21	-1.23	-1.15
Land Prep. BT & DA	-100.00	-100.00	-100.00	-100.00	1,803.30	1,803.30	1,798.84
Harvest Manual	-57.55	-25.54	0.0	0.0	0.0	0.0	0.0
Harvest Reaper [e]	8,978.00	3,984.00	0.0	0.0	0.0	0.0	0.0
Threshing Tractor	-92.92	-92.92	18.51	25.74	23.76	23.76	33.15
Thresher	2.35	2.35	-0.47	-0.65	-0.60	-0.60	-0.84
Upland:							
Mech. Upland Preparation Ratio [d]	100.0	100.0	100.0	100.0	87.5	84.8	84.8
Maize & Sorghum Land Prep.	13.74	13.74	13.74	13.74	5.46	-0.25	-0.20
Sugarcane:							
Mech. Land Preparation	50.00	50.00	50.00	50.00	19.31	19.31	19.38
Chemical Crop Care	0.0	0.0	0.0	0.0	11.66	11.66	11.66
Mech. Harvest [e]	444.5	313.1	0.0	0.0	0.0	0.0	0.0
Cassava:							
Mech. Land Preparation	43.78	43.78	43.78	43.78	17.19	17.19	17.25

Notes:

a/ Effects are listed in percentage change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The indicator has not been listed if no change took place during the experiments.

b/ For draft animal alone, see under DA units.

c/ In units (base year = 0).

d/ Ratios in percentage of crop area.

e/ In '000 rai (base year = 0).

Table A7.6. Series I: Effect of variation in ratio of non-discriminating BAAC credit on capital stock. [a]

Parameter	Percentage Financed with BAAC Credit [b] 0%	30%	40%	50%	60%	70%
Capital Stock (Value):						
DA and Machinery [c]	-0.8	2.6	5.7	8.3	24.0	25.3
Machinery	-1.3	4.2	8.5	11.2	32.2	33.7
DA/Machinery (Units):						
DA	5.3	-22.0	-36.4	-35.2	-100.0	-100.0
Single-axle Tractor	-1.0	4.3	7.1	6.9	19.5	19.5
Big Tractor	-1.3	5.5	9.4	9.5	25.9	26.2
Plow for Big Tractor	-1.3	5.5	9.4	9.5	25.9	26.2
Motor Sprayer	-0.3	0.0	0.0	0.0	0.0	0.0
Reaper [d]	0	0	0	1,731	22,024	22,024
Rice Thresher	-3.2	0.2	0.2	1.7	12.5	12.5
Toolbar	0.0	0.0	0.0	0.0	0.0	7.6
Maize Sheller	0.0	0.0	-19.2	-19.2	-19.2	-19.2
Cane Harvester [d]	0	0	87	197	165	235
Hours On-Farm Work	0.17	-0.57	-0.94	-1.22	-5.27	-5.27
Hours Off-Farm Work	-0.42	1.39	2.29	2.98	12.82	12.83
Hours Hired Labor Input	1.87	-7.69	-34.70	-60.98	-80.80	-100.00
Hours Male Labor Input	0.62	-2.43	-7.23	-10.87	-13.80	-16.60
Total Hours Input and Labor Input per Rai	0.22	-0.77	-1.87	-2.86	-7.34	-7.87
Return/Hour Fam. Labor	-0.73	0.16	0.65	1.18	1.76	2.41
Area by Operation and Method						
Paddy:						
Mech. Land Preparation Ratio [e]	90.40	94.60	95.60	98.70	100.00	100.00
Land Prep. DA	6.13	-40.33	-51.37	-50.46	-100.00	-100.00
Land Prep. 2W-Tractor	0.12	2.39	3.85	10.77	9.68	9.61
Land Prep. Big Tractor (BT)	-0.88	-4.72	-1.96	-2.08	10.75	10.81
Land Prep. BT & DA	-100.00	2,345.09	1,892.63	1,929.68	-100.00	-100.00
Crop Care Chemical	-0.36	0.0	0.0	0.0	0.0	0.0
Harvest Manual	0.0	0.0	0.0	-2.39	-25.54	-25.55
Harvest Reaper [f]	0.0	0.0	0.0	373.40	3,984.00	3,986.00
Threshing Tractor	23.76	-1.46	-1.46	-20.01	-92.92	-92.92
Thresher	-0.60	0.04	0.04	0.51	2.35	2.35
Upland:						
Mech. Upland Preparation Ratio [e]	78.30	84.00	86.90	85.00	100.00	100.00
Maize & Sorghum Mech. Land Prep.	-1.27	3.10	5.07	4.91	13.74	13.74
Sugarcane:						
Mech. Land Preparation	0.0	10.57	17.87	17.27	50.00	50.00
Mech. Harvest [f]	0.0	0.0	164.50	373.90	313.10	444.50
Cassava:						
Mech. Land Preparation	-2.33	9.62	15.94	8.17	43.78	43.78

Notes:

a/ Effects are listed in percentage change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The indicator has not been listed if no change took place during the experiments.

b/ At 14 per cent interest per year.

c/ For draft animal alone, see under DA units.

d/ In units (base year = 0).

e/ Ratios in percentage of crop area.

f/ In '000 rai (base year = 0).

Table A7.7. Series I: Effect of size of agricultural labor force on capital stock. a/

Parameter	Variation in Labor Force from Base Year b/								
	-30%	-20%	-15%	-10%	-5%	+5%	+10%	+15%	+20%
Capital Stock (Value):									
DA and Machinery c/	42.1	24.0	13.1	14.4	3.7	-0.4	-6.8	-8.7	-7.0
Machinery	51.6	32.2	20.6	22.0	6.0	-1.3	-15.7	-22.7	-25.5
DA/Machinery (Units):									
DA	-100.0	-100.0	-100.0	-100.0	-31.7	13.6	126.6	200.7	270.1
Single-axle Tractor	19.5	19.5	19.5	19.5	6.2	-1.0	-5.2	-2.1	17.0
Big Tractor	27.4	24.9	24.9	24.9	7.9	-2.9	-30.5	-48.4	-62.5
Plow for Big Tractor	27.4	24.9	24.9	24.9	7.9	-2.9	-30.5	-48.4	-62.5
Motor Sprayer	57.5	9.7	0.0	0.0	5.3	0.0	0.0	0.0	0.0
Reaper d/	52,471	21,393	1,840	7,468	0	0	0	0	0
Rice Thresher	12.5	0.2	1.7	0.2	0.2	7.6	12.5	12.5	-34.0
Toolbar	14.3	0.0	0.0	0.0	0.0	-3.9	-41.8	-50.3	-54.4
Maize Sheller	-19.2	-19.2	-19.2	-19.2	-19.2	0.0	0.0	0.0	-19.2
Cane Harvester d/	382	222	31	0	0	0	0	0	0
Sorghum Thresher	64.2	64.2	64.2	0.0	0.0	-19.0	-19.0	-16.9	-100.0
Hours On-Farm Work	-23.42	-15.02	-9.88	-5.50	-1.66	1.24	6.26	11.39	16.32
Hours Off-Farm Work	-84.12	-57.59	-46.59	-33.59	-19.45	20.47	31.73	42.93	50.30
Hours Hired Labor Input	274.56	211.41	209.56	37.75	21.02	-27.43	-15.42	-28.09	-67.37
Hours Male Labor Input	-16.34	-15.34	-10.78	-8.42	-3.16	1.99	15.99	24.73	32.17
Total Hours Input and Labor Input per Rai	-15.24	-8.80	-3.86	-4.32	-1.04	0.45	5.67	10.30	14.03
Return/Hour Fam. Labor	-0.15	1.07	0.81	0.81	0.47	-0.52	-1.21	-2.19	-2.85
Area by Operation and Method:									
Paddy:									
Land Mech. Preparation Ratio e/	100.0	100.0	100.0	100.0	95.3	92.3	81.4	76.8	68.2
Land Prep. DA	-100.0	-100.0	-100.0	-100.0	-47.8	-15.3	104.7	155.4	250.3
Land Prep. 2W-Tractor	7.3	6.0	6.6	10.5	4.7	6.2	11.0	19.6	18.6
Land Prep. Big Tractor (BT)	13.1	14.3	13.7	10.0	-4.2	-18.2	-30.9	-49.4	-67.2
Land Prep. BT & DA	-100.0	-100.0	-100.0	-100.0	2,039.9	3,458.3	-100.0	-100.0	-100.0
Planting Manual	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planting Broadcast	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crop Care Manual	-27.1	-5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crop Care Chemical	50.4	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Harvest Manual	-68.9	-32.7	-3.0	-10.3	0.0	0.0	0.0	0.0	0.0
Harvest Reaper f/	10,753.0	5,107.0	472.0	1,611.0	0.0	0.0	0.0	0.0	0.0
Threshing Tractor	-92.9	-1.5	-20.0	-1.5	-1.5	-56.3	-43.3	301.8	1,300.1
Thresher	2.3	0.0	0.5	0.0	0.0	1.4	1.1	-7.6	-32.9

(continued)

Table A7.7 (Continued)

Parameter	Variation in Labor Force from Base Year b/								
	-30%	-20%	-15%	-10%	-5%	+5%	+10%	+15%	+20%
Upland:									
Mech. Upland Preparation Ratio e/	100.0	100.0	100.0	100.0	86.0	74.6	42.5	22.1	13.2
Maize & Sorghum Mech. Land Prep.	13.7	13.7	13.7	13.7	4.4	-4.3	-35.0	-59.9	-73.7
Maize Chem. Crop Care f/	663.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sorghum Mech. Threshing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-100.0
Sugarcane:									
Mech. Land Preparation	50.0	50.0	50.0	50.0	15.5	-4.3	-46.0	-77.6	-95.5
Chem. Crop Care	13.6	2.3	2.3	1.1	0.0	2.3	-26.3	-78.0	-85.5
Mech. Harvest	724.6	421.3	57.8	0.0	0.0	0.0	0.0	0.0	0.0
Cassava:									
Mech. Land Preparation	43.8	43.8	43.8	43.8	13.9	-10.6	-70.5	-96.1	-100.0

Notes:

a/ Effects are listed in percentage change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The indicator has not been listed if no change took place during the experiments.

b/ Change in total labor force size, male labor, hired and seasonal migration labor force.

c/ For draft animal alone, see under DA units.

d/ In units (base year = 0).

e/ Ratios in percentage of crop area.

f/ In '000 rai (base year = 0).

Table A7.8. Series I: Effect of size of exchangeable family labor force on capital stock. a/

Parameter	Variation in Exchangeable Family Labor Force from Base Year b/											
	"Zero"	-50%	-30%	-20%	-10%	-5%	+5%	+10%	+20%	+30%	+50%	"Un-limited"
Capital Stock (Value):												
DA and Machinery c/	-13.7	-8.7	-7.5	-3.7	-0.4	-0.5	1.6	4.6	6.1	8.8	9.7	10.2
Machinery	-57.0	-27.0	-16.8	-9.9	-0.8	-0.9	2.5	7.5	9.9	14.5	15.9	16.9
DA/Machinery (Units):												
DA	637.2	266.0	132.3	89.7	5.3	5.3	-13.1	-39.1	-51.2	-77.2	-84.4	-89.4
Single-axle Tractor	-52.5	11.7	-6.6	-1.0	-1.0	-1.0	2.6	7.6	10.0	15.1	16.5	17.4
Big Tractor	-62.5	-62.5	-31.8	-21.6	-1.0	-1.3	3.3	9.7	12.8	19.2	21.0	22.3
Plow for Big Tractor	-74.3	-62.5	-31.8	-21.6	-1.0	-1.3	3.3	9.7	12.8	19.2	21.0	22.3
Motor Sprayer	-100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rice Thresher	-30.6	-30.4	12.5	12.5	1.9	1.7	0.2	0.2	0.2	-3.2	-4.0	-4.0
Toolbar	-61.5	-57.2	-39.4	-39.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maize Sheller	-19.2	-19.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-10.4	-19.2	-19.2
Sorghum Thresher	-19.0	0.0	-19.0	-19.0	-19.0	-4.1	0.0	0.0	0.0	6.4	64.2	64.2
Hours On-Farm Work	24.09	12.40	5.79	2.79	0.21	0.39	-0.19	-1.10	-1.39	-2.24	-2.38	-2.51
Hours Off-Farm Work	-100.00	-35.51	-14.09	-6.80	-0.50	-0.96	0.46	2.67	3.37	5.46	5.80	6.10
Hours Hired Labor Input	69.26	56.35	40.50	32.77	-1.95	0.50	-3.23	-10.92	-12.23	-18.19	-20.10	-21.33
Hours Male Labor Input	46.44	31.67	16.29	11.32	0.65	1.81	-0.46	-4.37	-5.17	-8.50	-8.98	-9.44
Total Hours Input and Labor Input per Rai	25.33	13.60	6.74	3.62	0.15	0.40	-0.27	-1.37	-1.68	-2.68	-2.87	-3.02
Return/Hour Fam. Labor	-5.46	-2.52	-1.27	-0.66	-0.25	-0.24	-0.03	0.20	0.25	0.57	0.61	0.78
Area by Operation and Method:												
Paddy:												
Mech Land Preparation Ratio d/	13.2	68.7	80.8	84.7	91.9	91.0	92.2	95.8	96.2	98.9	99.3	99.5

(continued)

Table A7.8 (continued)

	Variation in Exchangeable Family Labor Force from Base Year b/											
Parameter	**"Zero"**	**-50%**	**-30%**	**-20%**	**-10%**	**-5%**	**+5%**	**+10%**	**+20%**	**+30%**	**+50%**	**"Un-limited"**
Land Prep. DA	857.4	245.6	111.8	68.7	-10.8	-0.9	-14.5	-53.5	-58.4	-88.3	-92.0	-94.5
Land Prep. 2W-Tractor	-89.0	19.6	10.9	8.8	3.2	1.5	-0.5	0.5	-1.6	-0.6	-0.2	0.2
Land Prep. Big Tractor (BT)	-82.0	-67.2	-32.3	-21.8	-10.2	-4.9	2.6	2.1	9.3	12.0	14.4	16.0
Land Prep. BT & DA	-100.0	-100.0	-100.0	-100.0	2,082.0	810.4	162.8	1,807.2	876.0	1,350.8	891.1	575.8
Crop Care Manual	53.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crop Chemical	-100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Theshing 2W-Tractor	1,153.3	1,171.0	-43.3	-43.3	-14.4	-12.9	-1.5	-1.5	-1.5	23.8	23.0	23.0
Thresher	-29.2	-29.2	1.1	1.1	0.4	0.3	0.0	0.0	0.0	-0.6	-0.6	-0.6
Upland:												
Mech. Upland Plowing Ratio d/	0.0	13.6	41.4	53.6	78.1	73.5	78.2	87.5	87.8	95.7	96.5	97.6
Maize & Sorghum Mech. Land Prep.	-100.0	-72.9	-37.2	-24.3	-1.4	-11.1	-6.2	5.4	2.5	11.4	10.2	11.3
Sugar Cane:												
Mech. Land Preparation	-100.0	-94.4	-43.4	-43.5	0.0	0.0	6.1	19.2	25.4	38.5	42.1	44.6
Chem. Crop Care	-100.0	-85.5	-55.0	-8.1	1.5	0.0	0.0	0.0	0.0	2.3	2.3	2.3
Cassava:												
Mech. Land Prep.	-100.0	-100.0	-71.4	-46.5	-2.9	-2.3	5.8	17.1	22.4	33.8	38.7	40.3

Notes:

a/ Total labor force size remains constant. Effects are listed in percentage change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The indicator has not been listed if no change took place during the experiments.

b/ Total labor force size remains constant. Percentage change applies to aggregate and male family labor force. "Zero" means no family labor is involved in off-farm work. "Unlimited" means that all family labor can be fully employed off-farm, under the condition that land is fully utilized.

c/ For draft animal alone, see under DA units.

d/ Ratios in percentage of crop area.

Table A7.9. Series II: Effect of different crop area, labor force and wage rate scenarios on capital stock. [a/]

Run	LLL 01	LHL 02	LLH 03	LHH 04	HLL 05	HHL 06	HLH 07	HLH 07Y	HLH 07A	HHH 08	MML 09	MMM 10	MMH 11	ZZH 12
	Scenario [b/]													
Capital Stock (Value):														
DA and Machinery [c/]	2.8	2.4	4.5	3.8	5.4	4.6	6.5	7.5	6.9	5.7	3.5	3.9	4.8	3.9
Machinery	3.8	3.0	5.5	4.4	6.5	5.5	7.2	8.9	7.6	6.3	4.5	4.8	5.8	5.1
DA/Machinery (Units):														
DA	-18.8	-9.2	-19.2	-9.7	-21.6	-12.8	-7.6	g/	g/	-5.1	-19.1	-16.3	-16.0	-30.6
Single-axle Tractor	3.8	2.9	3.8	2.9	5.3	4.6	4.1	6.2	4.3	3.8	4.5	4.3	4.3	3.1
Big Tractor	4.6	3.5	4.6	3.6	7.9	7.1	6.5	9.0	6.7	6.1	5.4	5.1	5.1	3.9
Plow for Big Tractor	4.6	3.5	4.6	3.6	7.9	7.1	6.5	9.0	6.7	6.1	5.4	5.1	5.1	3.9
Motor Sprayer	0.6	0.3	0.3	0.3	0.8	1.9	3.5	2.1	2.7	2.1	0.5	0.5	0.5	0.0
Reaper [d/]	0	0	11,887	9,915	2,739	0	15,018	8,652	38,938	10,022	0	1,539	8,963	19,866
Rice Thresher	1.3	2.0	1.5	1.5	1.6	1.6	2.1	1.6	2.5	2.1	1.6	1.6	1.8	-0.6
Toolbar	1.4	1.4	1.7	1.4	4.2	4.2	5.0	5.6	6.6	4.5	2.1	2.1	2.4	1.3
Maize Sheller	-0.9	2.7	-0.9	-0.9	1.9	1.9	1.9	1.9	4.0	1.9	-0.2	-0.2	-0.2	-4.2
Cane Harvester [d/]	0	0	292	251	87	0	408	507	1,351	335	0	128	303	254
Sorghum Thresher	3.4	3.4	3.4	3.4	6.2	6.2	6.2	7.2	6.3	6.2	4.1	4.1	4.1	0.0
Hours On-Farm Work	0.51	0.71	-0.21	0.12	1.52	1.91	0.98	0.87	0.95	1.30	0.94	0.65	0.34	-1.40
Hours Off-Farm Work	-1.65	0.28	0.15	1.70	-7.18	-5.39	-5.38	-5.03	-6.74	-3.49	-2.64	-1.84	-1.02	3.12
Hours Hired Labor Input	3.63	2.52	-9.89	-11.60	13.87	12.94	4.30	-3.68	-6.53	4.92	6.37	2.69	-5.12	-23.23
Hours Male Labor Input	-0.35	0.21	-2.45	-1.46	0.91	1.86	-0.57	2.77	-2.65	0.01	0.20	-0.65	-1.88	-3.47
Total Hours Input	0.60	0.76	-0.43	-0.14	1.95	2.29	1.08	0.76	0.80	1.41	1.11	0.71	0.21	-1.79
Labor Input per Rai	-0.34	-0.18	-1.36	-1.07	-0.49	-0.17	-1.35	-1.66	-1.67	-1.02	-0.32	-0.71	-1.21	-1.79
Return/Hour Fam. Labor	2.09	1.99	2.45	2.30	2.41	2.32	2.67	2.71	2.83	2.60	2.16	2.32	2.50	0.52

(continued)

Table A7.9 (continued)

Run	Scenario [b] LLL 01	LHL 02	LLH 03	LHH 04	HLL 05	HHL 06	HLH 07	HLH 07Y	HLH 07A	HHH 08	MML 09	MMM 10	MMH 11	ZZH 12
Rainy Season Rice	0.52	0.52	0.52	0.52	1.08	1.08	1.08	1.08	1.10	1.08	0.81	0.81	0.81	0.0
Dry Season Rice	1.25	1.25	1.25	1.25	2.50	2.50	2.50	2.50	2.50	2.50	1.90	1.90	1.90	0.0
Total Rice Area	0.67	0.67	0.67	0.67	1.37	1.37	1.37	1.37	1.40	1.37	1.03	1.03	1.03	0.0
Upland Crop Area	1.40	1.40	1.40	1.40	4.20	4.20	4.20	4.20	4.20	4.20	2.10	2.10	2.10	0.0
Total Model Crop Area (A)	0.94	0.94	0.94	0.94	2.46	2.46	2.46	2.46	2.52	2.46	1.43	1.43	1.43	0.0
Non-Model Crop Area (B)	1.00	1.00	1.00	1.00	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	0.0
Total Crop Area (A+B)	0.95	0.95	0.95	0.95	2.46	2.46	2.46	2.46	2.51	2.46	1.47	1.47	1.47	0.0
Area by Operation and Method														
Paddy:														
Mech. Land Prep. Ratio [e]	98.4	97.1	98.4	96.0	98.7	97.8	97.1	100.0	100.0	96.6	98.5	98.2	98.1	99.2
Land Prep. DA	-28.9	-19.8	-29.2	-14.4	-31.4	-23.6	-19.1	-100.0	-100.0	-16.9	-29.1	-26.7	-26.5	-39.0
Land Prep. 2W-Tractor	0.8	0.5	0.8	0.6	1.8	1.6	1.4	2.2	1.5	1.3	1.4	1.4	1.4	0.0
Land Prep. Big Tractor (BT)	1.9	0.4	2.0	1.5	2.8	1.6	0.6	4.5	3.2	0.0	2.1	1.8	1.7	2.7
Land Prep. BT & DA	86.4	106.2	85.5	79.9	79.8	100.2	112.0	-100.0	-100.0	117.7	85.7	92.0	92.7	58.7
Crop Care Manual	0.9	0.9	0.9	-0.5	1.8	1.8	1.8	1.0	1.3	1.8	1.3	1.3	1.3	0.0
Crop Care Chemical	0.3	0.3	0.3	2.6	0.6	0.6	0.6	2.1	1.5	0.6	0.5	0.5	0.5	0.0
Harvest Manual	0.7	0.7	-3.0	-2.2	-36.6	1.4	-3.8	-1.5	-5.5	-2.0	1.0	0.5	-1.8	-6.2
Harvest Reaper [f]	0.0	0.0	2,744	2,139	703	0	3,855	2,221	9,060	2,573	0	395	2,169	4,286
Threshing Tractor	9.4	6.5	9.3	9.3	15.2	15.2	13.7	15.2	9.9	13.7	12.1	11.7	11.6	4.4
Thresher	0.4	0.5	0.4	0.4	0.9	0.9	1.0	0.9	1.1	1.0	0.7	0.7	0.7	-0.1
Upland:														
Mech. Upland Preparation Ratio [e]	92.6	86.1	94.0	88.0	94.6	90.7	89.8	100.0	100.0	88.4	92.9	93.1	93.0	97.0
Maize & Sorghum Mech. Land Prep.	2.6	1.5	3.5	2.6	5.9	5.1	5.9	6.9	5.6	5.8	3.4	4.1	4.1	2.3
Sorghum Mech. Reaper [f]									574.0					

(continued)

Table A7.9 (continued)

	Scenario b/													
	LLL	LHL	LLH	LHH	HLL	HHL	HLH	HLH	HLH	HHH	MML	MMM	MMH	ZZH
Run	01	02	03	04	05	06	07	07Y	07A	08	09	10	11	12
Sugarcane:														
Mech. Land Preparation	10.0	5.3	7.5	5.5	11.1	9.7	8.5	13.0	8.5	7.8	8.3	7.8	7.8	7.2
Chem. Crop Care	1.9	1.9	10.0	10.0	4.7	4.7	13.0	13.0	8.5	13.0	2.6	10.7	10.7	8.2
Mech. Harvest f/	0.0	0.0	554.3	476.0	165.8	0.0	773.6	960.9	2,560.2	635.2	0.0	243.1	573.7	480.6
Cassava:														
Mech. Land Preparation	7.3	5.3	6.8	4.6	10.8	9.9	8.0	12.0	8.1	7.4	8.2	7.2	7.1	6.5

Notes:

a/ Effects are listed in percentage annual change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The indicator has not been listed if no change took place during the experiments.

b/ LLL means low crop Area, low labor force and low wage rate growth rates. See further Table 6.4.

c/ For draft animal alone, see under DA units.

d/ In units (base year = 0).

e/ Ratios in percentage of crop area.

f/ In '000' Rai (base year = 0).

g/ In Run 07Y and Run 07A, draft animals were totally replaced by tractors over the projection period assumed.

Table A7.10A. Series III: Change in capital stock, labor input, and crop area [a/] (Run E01 To Run E06).

	Base Year	Run E01	E02	E03	E04	E05	E06
	Mil Baht						
Capital Stock:							
DA and Machinery	13,240	20.3	12.8	25.5	22.5	27.5	45.8
DA	826	-100.0	5.1	-100.0	0.0	-85.1	-100.0
Machinery	12,414	28.3	13.3	33.8	24.0	35.0	55.5
Corrected for Subsidy	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Units						
DA/Machinery:							
DA	91,766	-100.0	5.1	-100.0	0.0	-85.1	-100.0
Single-axle Tractor	172,657	24.8	17.5	24.8	-63.4	-54.4	-51.9
Small Tractor [b/c/]	n.a.	n.a.	n.a.	n.a.	38,734	37,102	36,622
Big Tractor	13,568	38.6	12.4	36.9	11.9	21.2	38.6
Plow for Big Tractor	13,568	38.6	12.4	36.9	11.9	21.2	38.6
Motor Sprayer	45,143	1.6	4.1	0.5	3.6	3.6	4.1
Reaper [b/]	0	0	0	0	2,195	6,378	10,359
Rice Thresher	13,990	5.6	6.9	5.2	31.8	34.2	34.2
Rice Combine	0	0	0	0	0	0	0
Toolbar	4,548	11.0	-13.7	4.6	-13.3	18.3	37.7
Maize Sheller	6,301	-1.0	-1.0	-1.0	-1.0	-10.8	-1.0
Cane Planter	0	0	0	0	0	0	1,452
Cane Harvester [b/]	0	0	0	353	273	413	948
Sorghum Thresher	983	31.0	31.0	31.0	31.0	31.0	31.0
Cassava Planter	0	0	0	0	0	0	0
Cassava Harvester	0	0	0	0	0	0	0
	Mil Hours						
Hours On-Farm Work	1,764.3	7.27	7.27	1.01	1.73	-2.28	-4.53
Hours Off-Farm Work	724.8	-9.80	-18.54	-3.29	-5.04	4.71	10.19
Hours Hired Labor Input	49.8	26.87	60.76	-73.35	-58.84	-100.00	-100.00
Hours Male Labor Input	342.4	-2.49	11.65	-21.64	-21.66	-32.53	-46.20
Total Hours Input	1,814.1	7.81	8.74	-1.03	0.07	-4.96	-7.15
Labor Input per Rai	73.3 hours	1.31	1.63	-5.94	-5.54	-9.03	-13.22
Return/Hour Family Labor	10.23 baht	8.88	10.59	13.16	13.62	15.05	17.44
Crop Area	'000 Rai						
Paddy:							
Rainfed Transplanted (T)	3,639.0	0.00	0.00	0.00	0.00	0.00	0.00
Rainfed Broadcasted (B)	5,458.0	1.18	3.78	0.52	3.78	3.78	3.78
First Crop Irrigated T	1,257.0	24.67	24.67	24.67	24.67	24.67	24.67
First Crop Irrigated B	1,886.0	0.00	0.00	0.00	0.00	0.00	0.00
Second Crop Irrigated T	1,257.0	24.67	24.67	24.67	24.67	24.67	24.67
Second Crop Irrigated B	1,886.0	0.00	0.00	0.00	0.00	0.00	0.00
Deepwater Paddy	218.0	0.00	0.00	0.00	0.00	0.00	0.00
Maize	3,315.0	10.95	10.95	10.95	10.95	0.00	10.95
Sorghum	890.0	0.00	0.00	0.00	0.00	0.00	0.00
Sugarcane	2,403.0	10.95	10.95	0.00	0.00	0.00	10.95
Cassava	2,553.0	10.95	10.95	10.95	10.95	10.95	10.95

(continued)

Table A7.10A (continued)

	Base Year	Run					
		E01	E02	E03	E04	E05	E06
	'000 Rai						
Total Rainfed Paddy	9,315.0	0.69	2.22	0.31	2.22	2.22	2.22
Double Crop Paddy	6,286.0	9.86	9.86	9.86	9.86	9.86	9.86
Total Paddy Area	15,601.0	4.39	5.30	4.16	5.30	5.30	5.30
Upland Crops	9,161.0	9.89	9.89	7.01	7.01	3.05	9.89
Total Model Crop Area	24,762.0	6.42	7.00	5.21	5.93	4.47	7.00
Idle Area (% of Upper Limit) d/							
Rainfed Paddy Land	0.0	1.5	0.0	1.9	0.0	0.0	0.0
Double Crop Paddy Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deepwater Paddy Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upland	0.0	0.0	0.0	3.5	3.5	7.1	0.0

Notes:

a/ Effects are listed in percentage change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The rice transplanter, maize and sorghum combine harvester have not been listed since these machines are not adopted during any of the experiment's runs.

b/ In units (base year = 0).

c/ Second-hand, only included as an option in Run 04 and upwards.

d/ See Table 6.5.

n.a. - not applicable.

Table A7.10B. Series III: Change in area by operation and method (Run E01 to Run E06).

	Base Year		Run					
	'000 Rai	Ratio	E01	E02	E03	E04	E05	E06
Paddy:		Ratio (% of Total Paddy Crop)						
Total Mechanical Land Preparation	14,186	90.9	100.0	94.3	100.0	98.9	99.8	100.0
Land Preparation								
DA	1,415	9.1	0.0	5.7	0.0	1.1	0.2	0.0
Single-axle Tractor	6,991	44.8	46.4	50.5	46.6	6.4	8.0	8.3
Small Tractor	n.a.	n.a.	n.a.	n.a.	n.a.	51.3	49.3	48.8
Big Tractor (BT)	7,164	45.9	53.6	37.4	53.4	22.7	39.8	42.9
BT & DA	32	0.2	0.0	6.3	0.0	18.4	2.7	0.0
Planting								
Manual	6,153	39.4	41.6	41.2	41.7	41.2	41.2	41.2
Broadcasting	9,448	60.6	58.4	58.8	58.3	58.8	58.8	58.8
Crop Care								
Manual	10,143	65.0	66.1	65.5	66.2	65.5	65.5	65.5
Chemical	5,458	35.0	33.9	34.5	33.8	34.5	34.5	34.5
Harvest								
Manual	15,601	100.0	100.0	100.0	100.0	96.6	90.0	83.8
Reaper	0	0.0	0.0	0.0	0.0	3.4	10.0	16.2
Combine	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Threshing								
Single-axle Tractor	385	2.5	4.6	4.4	4.7	0.4	0.0	0.0
Thresher	15,216	97.5	95.4	95.6	95.3	99.6	100.0	0.0
			Ratio (%) of Total Crop)					
Maize & Sorghum:								
Mech. Land Preparation	3,696.9	87.9	100.0	80.4	100.0	92.2	98.7	100.0
Chemical Crop Care	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sorghum Mech. Reaper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sugarcane:								
Mech. Land Preparation	534.0	22.2	33.3	17.3	33.3	16.5	30.8	33.3
Mech. Planting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Chemical Crop Care	1,602.0	66.7	68.2	68.2	100.0	100.0	100.0	100.0
Mech. Harvest	0.0	0.0	0.0	0.0	27.3	21.5	31.6	63.5
Cassava:								
Mech. Land Preparation	1,775.6	69.5	100.0	63.8	100.0	79.4	96.9	100.0
Mech. Planting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mech. Crop Care	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemical Crop Care	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mech. Harvest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Upland to be Plowed	7,559.0		9.7	9.7	8.5	8.5	3.7	9.7
Total Mech. Upland Plowing Ratio (%)		79.5	100.0	71.7	100.0	83.6	97.4	100.0

Note:
n.a. - not applicable.

Table A7.11A. Series III: Change in capital stock, labor input, and crop area [a] (Run E07 to Run E11).

	Base Year	Run E07	E08	E09	E10	E11A	E11
	Mil Baht						
Capital Stock:							
DA and Machinery	13,240	50.5	76.2	60.4	92.9	55.4	104.9
DA	826	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
Machinery	12,414	60.5	88.0	71.0	105.7	65.8	118.5
Corrected for Subsidy	n.a.	n.a.	n.a.	n.a.	128.6	84.2	142.8
	Units						
DA/Machinery:							
DA	91,766	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
Single-axle Tractor	172,657	-55.5	-71.1	-100.0	-52.4	-100.0	-68.0
Small Tractor [b/] [c/]	n.a.	38,334	59,554	59,900	64,842	59,900	86,994
Big Tractor	13,568	38.9	38.9	38.9	42.2	42.2	42.2
Plow for Big Tractor	13,568	38.9	38.9	38.9	42.2	42.2	42.2
Motor Sprayer	45,143	0.0	0.0	-22.7	68.1	-22.3	68.1
Reaper [b/]	0	24,740	59,672	47,648	95,483	53,048	95,483
Rice Thresher	13,990	34.2	34.2	35.2	38.3	35.2	38.3
Rice Combine	0	0	0	0	0	0	0
Toolbar	4,548	26.1	26.1	26.1	15.5	15.5	15.5
Maize Sheller	6,301	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Cane Planter	0	1,309	1,309	1,309	1,452	1,452	1,452
Cane Harvester [c/]	0	907	907	907	1,407	1,407	1,407
Sorghum Thresher	983	31.0	31.0	31.0	31.0	31.0	31.0
Cassava Planter	0	0	0	0	2,183	2,183	2,183
Cassava Harvester	0	0	0	0	0	0	0
	Mil Hours						
Hours On-Farm Work	1,764.3	-9.73	-15.27	-32.17	-27.62	-40.10	-28.37
Hours Off-Farm Work	724.8	22.84	36.34	77.47	66.40	96.78	68.23
Hours Hired Labor	49.8	-100.00	-100.00	-100.00	-100.00	-100.00	-100.00
Hours Male Labor	342.4	-50.84	-50.29	-60.84	-56.58	-70.86	-58.38
Total Hours Input	1,814.1	-12.20	-17.60	-34.03	-29.61	-41.75	-30.34
Labor Input per Rai	73.3 hours	-16.46	-21.60	-22.56	-34.21	-32.46	-34.89
Return/Hour Family Labor	10.23 baht	19.21	21.00	23.49	26.37	28.99	35.70
Crop Area	'000 Rai						
Paddy:							
Rainfed Transplanted (T)	3,639.0	0.0	0.0	-100.00	-100.00	-100.00	-100.00
Rainfed Broadcasted (B)	5,458.0	0.0	0.0	-23.66	70.45	-23.66	70.45
First Crop Irrigated T	1,257.0	24.67	24.67	59.25	171.63	59.25	171.63
First Crop Irrigated B	1,886.0	0.0	0.0	-23.05	-97.95	-23.05	-97.95
Second Crop Irrigated T	1,257.0	24,67	0.0	0.53	-100.00	-100.00	-100.00
Second Crop Irrigated B	1,886.0	0.0	16.44	16.09	83.09	83.09	83.09
Deepwater Paddy	218.0	0.0	0.0	0.0	0.0	0.0	0.0

(continued)

Table A7.11B. Series III: Change in area by operation and method (Run E07 to Run E011).

	Base Year		Run					
	'000 Rai	Ratio	E07	E08	E09	E010	E011	E012
Paddy:			Ratio (% of Total Paddy Crop)					
Mechanical Land Preparation	14,186.2	90.9	100.0	100.0	100.0	100.0	100.0	100.0
Land Preparation								
DA	1,415.0	9.1	0.0	0.0	0.0	0.0	0.0	0.0
Single-axle Tractor	6,991	44.8	7.8	0.0	0.0	0.0	0.0	0.0
Small Tractor	n.a.	n.a.	51.5	75.2	100.0	100.0	100.0	80.4
Big Tractor (BT)	7,164.0	45.9	40.7	24.8	0.0	0.0	0.0	19.6
BT & DA	32	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Planting								
Manual	6,153	39.4	41.8	39.8	28.9	28.9	17.7	20.8
Broadcasting	9,448	60.6	58.2	60.2	71.1	71.1	82.3	84.7
Crop Care								
Manual	10,143	65.0	66.4	66.4	63.1	63.1	63.1	43.4
Chemical	5,458	35.0	33.6	33.6	36.9	36.9	36.9	56.6
Harvest								
Manual	15,601	100.0	61.5	25.3	25.7	25.7	4.5	1.0
Reaper	0	0.0	38.5	74.7	74.3	74.3	95.5	99.0
Combine	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Threshing								
Single-axle Tractor	385	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Thresher	15,216	97.5	100.0	100.0	100.0	100.0	100.0	100.0
Maize & Sorghum:			Ratio (% of Total Crop)					
Mech. Land Preparation	3,696.9	87.9	100.0	100.0	100.0	100.0	100.0	100.0
Chemical Crop Care	0.0	0.0	0.0	0.0	0.0	0.0	16.1	16.1
Sorghum Mech. Reaper	0.0	0.0	2.0	10.1	6.9	10.1	6.9	10.1
Sugarcane:								
Mech. Land Preparation	534.0	22.2	33.3	33.3	33.3	33.3	33.3	33.3
Mech. Planting	0.0	0.0	2.8	2.8	2.8	8.1	8.1	8.1
Chemical Crop Care	1,602.0	66.7	100.0	100.0	100.0	100.0	100.0	100.0
Mech. Harvest	0.0	0.0	71.6	71.6	71.6	100.0	100.0	100.0
Cassava:								
Mech. Land Preparation	1,775.6	69.5	100.0	100.0	100.0	100.0	100.0	100.0
Mech. Planting	0.0	0.0	0.0	0.0	0.0	13.9	13.9	13.9
Mech. Crop Care	0.0	0.0	0.0	0.0	0.0	77.3	77.3	77.3
Chemical Crop Care	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mech. Harvest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Upland to be Plowed	7,559.0		8.5	8.5	8.5	9.7	9.7	9.7
Total Mech. Upland Plowing Ratio (%)		79.5	100.0	100.0	100.0	100.0	100.0	100.0

Note:
n.a. - not applicable.

Table A7.12A. Series III: Change in capital stock, labor input and crop area [a] (Run E12 to Run E16).

	Base Year	Run E12	E13	E14	E15	E16
	Mil Baht					
Capital Stock:						
DA and Machinery	13,240	104.9	90.8	109.3	145.1	160.8
DA	826	-100.0	-100.0	-100.0	-100.0	-100.0
Machinery	12,414	118.5	103.4	123.2	161.4	178.1
Corrected for Subsidy	12,414	142.8	126.0	148.0	190.5	209.0
	Units					
DA/Machinery:						
DA	91,766	-100.0	-100.0	-100.0	-100.0	-100.0
Single-axle Tractor	172,657	-68.0	-48.5	-67.0	-67.0	-70.8
Small Tractor [b/c]	n.a.	86,994	59,341	85,573	85,573	85,573
Big Tractor	13,568	42.2	42.2	44.5	44.5	49.1
Plow for Big Tractor	13,568	42.2	42.2	32.7	32.7	37.4
Motor Sprayer	45,143	68.1	68.1	110.9	110.9	84.1
Reaper [b]	0	95,483	95,788	95,788	73,538	43,173
Rice Thresher	13,990	38.3	34.3	49.2	27.0	-22.0
Rice Combine	0	0	0	0	3,208	5,318
Toolbar	4,548	15.5	39.8	18.3	18.3	31.8
Maize Sheller	6,301	-1.0	-1.0	-1.0	-1.0	-1.0
Cane Planter	0	1,452	4,983	6,120	6,120	6,120
Cane Harvester [b]	0	1,407	1,407	1,407	1,407	1,407
Sorghum Thresher	983	31.0	31.0	31.0	31.0	31.0
Cassava Planter	0	2,300	2,300	5,648	5,648	4,985
Cassava Harvester	0	0	0	4,827	5,475	4,935
	Mil Hours					
Hours On-Farm Work	1,764.3	-28.91	-34.24	-41.34	-44.65	-51.79
Hours Off-Farm Work	724.8	69.53	82.50	99.79	107.84	125.23
Hours Hired Labor Input	49.8	-100.00	-100.00	-100.00	-100.00	-100.00
Hours Male Labor Input	342.4	-58.10	-54.51	-49.44	-52.48	-58.30
Total Hours Input	1,814.1	-30.86	-36.04	-42.95	46.17	-53.11
Labor Input per Rai	73.3 Hours	-35.38	-40.22	-46.68	-49.68	-52.08
Return/Hour Family Labor	10.23 Baht	47.49	64.42	81.17	109.14	152.30
Crop Area	**'000 Rai**					
Paddy:						
Rainfed Transplanted (T)	3,639.0	-100.00	-100.00	-100.00	-100.00	-100.00
Rainfed Broadcasted (B)	5,458.0	70.45	70.45	70.45	70.45	38.03
First Crop Irrigated T	1,257.0	171.63	25.69	-100.00	-100.00	-100.00
First Crop Irrigated B	1,886.0	-97.95	-0.68	83.09	83.09	83.09
Second Crop Irrigated T	1,257.0	-100.00	-100.00	-100.00	-100.00	-100.00
Second Crop Irrigated B	1,886.0	83.09	83.09	83.09	83.09	83.09
Deepwater Paddy	218.0	0.00	0.00	0.00	0.00	-100.00
Maize	3,315.0	10.95	10.95	10.95	10.95	10.95
Sorghum	890.0	0.00	0.00	0.00	0.00	0.00
Sugarcane	2,403.0	10.95	10.95	10.95	10.95	10.95
Cassava	2,553.0	10.95	10.95	10.95	10.95	0.00

(continued)

Table A7.12A (continued)

	Base Year	Run				
		E12	E13	E14	E15	E16
	'000 Rai					
Total Rainfed Paddy	9,315.0	2.22	2.22	2.22	2.22	-19.12
Double Crop Paddy	6,286.0	9.86	9.86	9.86	9.86	9.86
Total Paddy Area	15,601.0	5.30	5.30	5.30	5.30	-7.44
Upland Crops	9,161.0	9.89	9.89	9.89	9.89	6.83
Total Model Crop Area	24,762.0	7.00	7.00	7.00	7.00	-2.16
Idle Area (% of Upper Limit) d/						
Rainfed Paddy Land	0.0	0.0	0.0	0.0	0.0	19.0
Double Crop Paddy Land	0.0	0.0	0.0	0.0	0.0	0.0
Deepwater Paddy Land	0.0	0.0	0.0	0.0	0.0	100.0
Upland	0.0	0.0	0.0	0.0	0.0	2.8

Notes:

a/ Effects are listed in percentage change from base year situation (see Table A6.1 and A6.2) unless otherwise noted. The rice transplanter, maize and sorghum combine harvester have not been listed since these machines are not adopted during any of the experiment's runs.

b/ In units (base year = 0).

c/ Second-hand, only included as an option in run 04 and upwards.

d/ See Table 6.5.

n.a. - not applicable.

Table A7.12B. Series III: Change in area by operation and method (Run E12 to Run E016).

	Base Year '000 Rai	Base Year Ratio	Run E12	Run E13	Run E14	Run E15	Run E16
Paddy:			Ratio (% of Total Paddy Crop)				
Total Mechanical Land Preparation	14,186.2	90.9	100.0	100.0	100.0	100.0	100.0
Land Preparation							
DA	1,415.0	9.1	0.0	0.0	0.0	0.0	0.0
Single-axle Tractor	6,991	44.8	0.0	0.0	0.0	0.0	0.0
Small Tractor	n.a.	n.a.	80.4	68.5	79.8	79.8	89.9
Big Tractor (BT)	7,164	45.9	19.6	31.5	20.2	20.2	10.1
BT & DA	32	0.2	0.0	0.0	0.0	0.0	0.0
Planting							
Manual	6,153	39.4	20.8	9.6	0.0	0.0	0.0
Broadcasting	9,448	60.6	79.2	90.4	100.0	100.0	100.0
Crop Care							
Manual	10,143	65.0	43.4	26.1	1.3	1.3	0.0
Chemical	5,458	35.0	56.6	73.9	98.7	98.7	100.0
Harvest							
Manual	15,601	100.0	1.0	0.0	0.0	0.0	0.0
Reaper	0	0.0	99.0	100.0	100.0	69.3	50.0
Combine	0	0.0	0.0	0.0	0.0	30.7	50.0
Threshing							
Single-axle Tractor	385.0	2.5	0.0	0.0	0.0	0.0	0.0
Thresher	15,216	97.5	100.0	100.0	100.0	69.3	50.0
Maize & Sorghum:			Ratio (% of Total Crop)				
Mech. Land Preparation	3,696.9	87.9	100.0	100.0	100.0	100.0	100.0
Chemical Crop Care	0.0	0.0	16.1	28.3	100.0	100.0	100.0
Sorghum Mech. Reaper	0.0	0.0	10.1	19.5	19.5	19.5	19.5
Sugarcane:							
Mech. Land Preparation	534.0	22.2	33.3	33.3	33.3	33.3	33.3
Mech. Planting	0.0	0.0	8.1	20.9	27.8	27.8	33.3
Chemical Crop Care	1,602.0	66.7	100.0	100.0	100.0	100.0	100.0
Mech. Harvest	0.0	0.0	100.0	100.0	100.0	100.0	100.0
Cassava:							
Mech. Land Preparation	1,775.6	69.5	100.0	100.0	100.0	100.0	100.0
Mech. Planting	0.0	0.0	14.3	49.9	100.0	100.0	100.0
Mech. Crop Care	0.0	0.0	77.3	71.0	77.3	77.3	77.3
Chemical Crop Care	0.0	0.0	22.7	29.0	22.7	22.7	26.6
Mech. Harvest	0.0	0.0	0.0	0.0	22.2	22.7	41.7
Total Upland to be Plowed	7,559.0		9.7	9.7	9.7	9.7	6.0
Total Mech. Upland Plowing Ratio (%)		79.5	100.0	100.0	100.0	100.0	100.0

Note:
n.a. - not applicable.

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