INFORMATION TO USERS

This reproduction was made from a copy of a document sent to us for microfilming. While the most advanced technology has been used to photograph and reproduce this document, the quality of the reproduction is heavily dependent upon the quality of the material submitted.

The following explanation of techniques is provided to help clarify markings or notations which may appear on this reproduction.

1. The sign or “target” for pages apparently lacking from the document photographed is “Missing Page(s)”. If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting through an image and duplicating adjacent pages to assure complete continuity.

2. When an image on the film is obliterated with a round black mark, it is an indication of either blurred copy because of movement during exposure, duplicate copy, or copyrighted materials that should not have been filmed. For blurred pages, a good image of the page can be found in the adjacent frame. If copyrighted materials were deleted, a target note will appear listing the pages in the adjacent frame.

3. When a map, drawing or chart, etc., is part of the material being photographed, a definite method of “sectioning” the material has been followed. It is customary to begin filming at the upper left hand corner of a large sheet and to continue from left to right in equal sections with small overlaps. If necessary, sectioning is continued again—beginning below the first row and continuing on until complete.

4. For illustrations that cannot be satisfactorily reproduced by xerographic means, photographic prints can be purchased at additional cost and inserted into your xerographic copy. These prints are available upon request from the Dissertations Customer Services Department.

5. Some pages in any document may have indistinct print. In all cases the best available copy has been filmed.
Netayaraks, Prayong

ECONOMIC ANALYSIS OF ALCOHOL PRODUCTION IN THAILAND AND ITS IMPLICATION ON TRADE WITH JAPAN

The Ohio State University

University Microfilms International

300 N. Zeeb Road, Ann Arbor, MI 48106
PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark √.

1. Glossy photographs or pages ______
2. Colored illustrations, paper or print ______
3. Photographs with dark background ______
4. Illustrations are poor copy ______
5. Pages with black marks, not original copy ______
6. Print shows through as there is text on both sides of page ______
7. Indistinct, broken or small print on several pages √
8. Print exceeds margin requirements ______
9. Tightly bound copy with print lost in spine ______
10. Computer printout pages with indistinct print ______
11. Page(s) ________ lacking when material received, and not available from school or author.
12. Page(s) ________ seem to be missing in numbering only as text follows.
13. Two pages numbered ________. Text follows.
14. Curling and wrinkled pages ______
15. Other__________________________________________________________________________
ECONOMIC ANALYSIS OF ALCOHOL PRODUCTION IN THAILAND
AND ITS IMPLICATION ON TRADE WITH JAPAN

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Prayong Netayaraks, B.A., M.A.

* * * * *

The Ohio State University
1983

Reading Committee: Approved by
Norman Rask
Donald W. Larson
Douglas Southgate

Norman Rask
Adviser
Department of Agricultural Economics
and Rural Sociology
Dedicated to My Parents
ACKNOWLEDGMENTS

I wish to express my gratitude and sincere appreciation to Dr. Norman Rask, my adviser and member of the Guidance Committee, for his dedication, patience, and encouragement throughout this study.

Gratitude is likewise due Drs. Donald W. Larson and Douglas Southgate, members of the Reading Committee, for their valuable suggestions and comments.

A special word of appreciation is extended to Dr. Fred J. Hitzhusen for serving on the Guidance Committee, Dr. Douglas H. Graham for his advice during the beginning of my graduate program, and Dr. Francis E. Walker for his help in solving computational problems.

I am greatly indebted to the following persons for their assistance in the data collection: Dr. Delane E. Welsch, University of Minnesota, Minnesota; Mr. Ta-Noo Vicharangsan, Secretary of Power Alcohol Committee, Bangkok, and Mr. Eiichi Hamanishi, The Japan Foundation, Tokyo.

I would like to thank the Japan Foundation which provided me the financial support to study at The Ohio State University, and the funds for my field trip to Thailand and Japan.
Thanks go to Mrs. Judy Petticord for her typing this research.

Finally, I owe my special thanks to my wife, Somphiang, and to my children, Peti and Pakorn, for their encouragement, patience, and sacrifice during my study in the graduate program.
May 21, 1945 ................ Born - Samutsakhon, Thailand

1970 ......................... B.A. (Hons.) Thammasat University, Bangkok, Thailand

1970-1973 ..................... Junior Instructor, Faculty of Economics, Thammasat University, Bangkok, Thailand

1973 ........................ M.A., Thammasat University, Bangkok, Thailand

1973-1977 ..................... Lecturer, Faculty of Economics, Thammasat University, Bangkok, Thailand

1977-1983 ..................... Assistant Professor, Faculty of Economics, Thammasat University, Bangkok, Thailand

FIELDS OF STUDY

Major Field: Agricultural Economics

Studies in Economic Theory. Professors Stephen A. McCafferty, Charles Cox, and Gene E. Mumy

Studies in Quantitative Methods. Professors Francis E. Walker, Leroy J. Hushak, Danny S. Wong, and Glenn W. Milligan

Studies in Resource Economics. Professors Frederick J. Hitzhusen, Leroy J. Hushak, and Douglas Southgate

Studies in Economic Development. Professors Douglas H. Graham and Albert Keidel

Studies in Production Economics. Professor Francis E. Walker
Studies in Agricultural Marketing. Professor Donald W. Larson

Studies in History of Modern Japan/Government and Politics in Japan. Professors James R. Bartholomew and Bradley M. Richardson
TABLE OF CONTENTS

Page

DEDICATION ............................................ 11
ACKNOWLEDGEMENTS ........................................ 111
VITA .......................................................... v
LIST OF TABLES ........................................ x
LIST OF FIGURES ......................................... xvii

Chapter

I. INTRODUCTION ........................................ 1
   1. The Problems ........................................ 1
   2. Alcohol Program .................................... 12
   3. Objectives of the Study ............................ 13

II. ENERGY, AGRICULTURE, AND TRADE WITH JAPAN .... 16
   1. Energy Consumption ............................... 16
   2. Energy Production ................................. 20
   3. Production, Consumption and Trade of
      Potential Energy Crops ............................ 27
   4. Agricultural and Alcohol Trade Between
      Thailand and Japan ............................... 32

III. DESCRIPTION OF THE STUDY AREA ................. 39
   1. Region 1: Extreme North .......................... 42
   2. Region 2: North Central .......................... 45
   3. Region 3: Northern Part of Northeast ........... 46

vii
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Region 4: Southern Part of Northeast...</td>
<td>47</td>
</tr>
<tr>
<td>5. Region 5: East.</td>
<td>48</td>
</tr>
<tr>
<td>6. Region 6: Central Plain</td>
<td>49</td>
</tr>
<tr>
<td>7. Region 7: South</td>
<td>50</td>
</tr>
<tr>
<td>IV. THEORY, METHODS, AND PROCEDURES.</td>
<td>51</td>
</tr>
<tr>
<td>1. Theoretical Framework.</td>
<td>51</td>
</tr>
<tr>
<td>2. Conceptual Framework of Crop and Alcohol Production Systems</td>
<td>54</td>
</tr>
<tr>
<td>2.1. Agricultural Production.</td>
<td>54</td>
</tr>
<tr>
<td>2.2. Transportation</td>
<td>55</td>
</tr>
<tr>
<td>2.3. Alcohol Production</td>
<td>56</td>
</tr>
<tr>
<td>2.4. Consumption</td>
<td>59</td>
</tr>
<tr>
<td>2.5. Crop and Alcohol Exports</td>
<td>61</td>
</tr>
<tr>
<td>3. Model Formulation.</td>
<td>62</td>
</tr>
<tr>
<td>4. Description of the Models and Data</td>
<td>66</td>
</tr>
<tr>
<td>4.1. Agricultural Production Activities</td>
<td>67</td>
</tr>
<tr>
<td>4.2. Processing Activities.</td>
<td>70</td>
</tr>
<tr>
<td>4.3. Transportation Activities.</td>
<td>71</td>
</tr>
<tr>
<td>4.4. Marketing Activities</td>
<td>72</td>
</tr>
<tr>
<td>V. EMPIRICAL ANALYSIS</td>
<td>75</td>
</tr>
<tr>
<td>1. Model Description.</td>
<td>75</td>
</tr>
<tr>
<td>1.1. Model A (Fixed Demand)</td>
<td>77</td>
</tr>
<tr>
<td>1.2. Model B (Variable Demand).</td>
<td>78</td>
</tr>
<tr>
<td>1.3. Models C and D (Blended Alcohol Consumption)</td>
<td>78</td>
</tr>
<tr>
<td>1.4. Models E and F (Pure Alcohol Consumption)</td>
<td>79</td>
</tr>
<tr>
<td>Chapter</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>1.5. Models G and H (Alternative Energy Crops)</td>
<td>80</td>
</tr>
<tr>
<td>1.6. Model I (Increased Cropland)</td>
<td>81</td>
</tr>
<tr>
<td>1.7. Models J and K (Alcohol Production in 1986)</td>
<td>81</td>
</tr>
<tr>
<td>2. Model Analysis</td>
<td>82</td>
</tr>
<tr>
<td>2.1. Alcohol Production in 1981</td>
<td>84</td>
</tr>
<tr>
<td>2.2. Regional Distribution of Alcohol Production and Use</td>
<td>93</td>
</tr>
<tr>
<td>2.3. Alcohol Production Impact</td>
<td>99</td>
</tr>
<tr>
<td>2.4. Alcohol Production in 1986</td>
<td>107</td>
</tr>
<tr>
<td>2.5. Alcohol Production from Alternative Energy Crops</td>
<td>116</td>
</tr>
<tr>
<td>2.6. Trade Consideration with Japan</td>
<td>121</td>
</tr>
<tr>
<td>VI. SUMMARY AND CONCLUSIONS.</td>
<td>129</td>
</tr>
<tr>
<td>1. Summary</td>
<td>129</td>
</tr>
<tr>
<td>2. Conclusions</td>
<td>131</td>
</tr>
<tr>
<td>3. Policy Implications</td>
<td>136</td>
</tr>
<tr>
<td>4. Study Limitations</td>
<td>138</td>
</tr>
<tr>
<td>5. Future Research</td>
<td>140</td>
</tr>
<tr>
<td>APPENDIXES</td>
<td></td>
</tr>
<tr>
<td>A. Coefficients for Programmed Activities</td>
<td>143</td>
</tr>
<tr>
<td>B. Models Output</td>
<td>161</td>
</tr>
<tr>
<td>BIBLIOGRAPHY.</td>
<td>178</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Thailand Oil Production, Trade and Inferred Consumption: Total Crude and Products in 1970-1979</td>
<td>3</td>
</tr>
<tr>
<td>1.2</td>
<td>Retail Prices of Petroleum Products Prior to and Post 1973 Oil Embargo—Bangkok, Thailand</td>
<td>5</td>
</tr>
<tr>
<td>1.3</td>
<td>Sugar Production, Domestic Consumption, Quota Export and Sugar in Storage in 1978</td>
<td>7</td>
</tr>
<tr>
<td>1.4</td>
<td>Thai Exports and Imports by Country in Selected Years</td>
<td>10</td>
</tr>
<tr>
<td>2.1</td>
<td>Potential Annual Energy Supply from Existing Forest and Biomass Waste</td>
<td>24</td>
</tr>
<tr>
<td>2.2</td>
<td>Investment Costs, Energy Crops Used and Amount of Alcohol Produced by the Investors who are Interested in Alcohol Production</td>
<td>26</td>
</tr>
<tr>
<td>2.3</td>
<td>Area, Production, Yield, Farm Price and Exports of Cassava in Selected Years in Thailand</td>
<td>28</td>
</tr>
<tr>
<td>2.4</td>
<td>Area, Production, Yield and Farm Price of Sugarcane, Sugar Production, and Exports in Selected Years in Thailand</td>
<td>31</td>
</tr>
<tr>
<td>2.5</td>
<td>Thai Shares in Japanese Agricultural Imports by Commodity, 1972-1981</td>
<td>35</td>
</tr>
<tr>
<td>2.6</td>
<td>Thailand's Principal Agricultural Exports to Japan by Commodity, 1970-1981</td>
<td>36</td>
</tr>
<tr>
<td>2.7</td>
<td>Japanese Ethyl Alcohol Imports by Country, 1975-1980</td>
<td>38</td>
</tr>
<tr>
<td>3.1</td>
<td>Regions, Zones, Provinces, Energy Crops and Other Agricultural Commodities in Thailand</td>
<td>41</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>3.2</td>
<td>Agricultural Land Holding by Region, 1977</td>
<td>43</td>
</tr>
<tr>
<td>3.3</td>
<td>Use of Cultivated Land for Specific Crops by Region in Crop Year 1978/79</td>
<td>44</td>
</tr>
<tr>
<td>5.1</td>
<td>Summary of the Specific Model Formulations</td>
<td>83</td>
</tr>
<tr>
<td>5.2</td>
<td>Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels--0 to 20 Percent Alcohol Substitution for Gasoline (Model D), 1981</td>
<td>86</td>
</tr>
<tr>
<td>5.3</td>
<td>Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels--0 to 100 Percent Alcohol Substitution for Gasoline (Model P), 1981</td>
<td>88</td>
</tr>
<tr>
<td>5.4</td>
<td>Alcohol Production Opportunity Costs and Gasoline Costs by Region and Assumed Energy Price Levels--0 to 100 Percent Alcohol Substitution for Gasoline, Models F and G, 1981</td>
<td>91</td>
</tr>
<tr>
<td>5.5</td>
<td>Regional Distribution of Alcohol Use and Supply at Energy Prices of +5 Percent--20 Percent Alcohol Substitution for Gasoline (Model D), 1981</td>
<td>94</td>
</tr>
<tr>
<td>5.6</td>
<td>Interregional Shipment of Alcohol Associated with Selected Energy Price Levels--0 to 20 Percent Alcohol Substitution for Gasoline (Model D), 1981</td>
<td>96</td>
</tr>
<tr>
<td>5.7</td>
<td>Interregional Shipment of Alcohol Associated with Selected Energy Price Levels--0 to 100 Percent Alcohol Substitution for Gasoline (Model P), 1981</td>
<td>97</td>
</tr>
<tr>
<td>5.8</td>
<td>Regional Distribution of Alcohol Use and Supply at Energy Prices of +30 Percent--100 Percent Alcohol Substitution for Gasoline (Model P), 1981</td>
<td>98</td>
</tr>
<tr>
<td>5.9</td>
<td>Regional Distribution of Alcohol Use and Supply at Energy Prices of +60 Percent--100 Percent Alcohol Substitution for Gasoline Plus Exports (Model P), 1981</td>
<td>99</td>
</tr>
</tbody>
</table>
Table 5.10  Impact of Alcohol Production on Land Use by Agricultural Product and Energy Price Level—0 to 20 Percent Alcohol Substitution for Gasoline (Model D), 0 to 100 Percent Alcohol Substitution for Gasoline (Model F), 1981  

Table 5.11  Impact of Alcohol Production on Agricultural Domestic Consumption—0 to 20 Percent Alcohol Substitution for Gasoline (Model D), 0 to 100 Percent Alcohol Substitution for Gasoline (Model F), 1981  

Table 5.12  Agricultural Price Index and Agricultural Product Price Changes Associated with Energy Price Increases—0 to 20 Percent Alcohol Substitution for Gasoline (Model D), 0 to 100 Percent Alcohol Substitution for Gasoline (Model F), 1981  

Table 5.13  Impact of Alcohol Production on Agricultural Product Exports—0 to 100 Percent Alcohol Substitution for Gasoline (Model F), 1981  

Table 5.14  Alcohol Production by Region and Energy Feedstock at Specified Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline and Constant Crop Yield (Model J), 1986  

Table 5.15  Alcohol Production by Region and Energy Feedstock at Specified Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline and Increased Crop Yield (Model K), 1986  

Table 5.16  Interregional Shipment of Alcohol Associated with Selected Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline and Constant Crop Yield (Model J), 1986  

Table 5.17  Regional Distribution of Alcohol Use and Supply at Energy Prices of +40 Percent—100 Percent Alcohol Substitution for Gasoline and Constant (1981) Crop Yield (Model J), 1986  

Table 5.18  Impact of Alcohol Production on Agricultural Product Exports—0 to 100 Percent Alcohol Substitution for Gasoline, Constant (1981) Crop Yield (Model J) and Increased (1981 plus 5 Percent) Crop Yield (Model K), 1986
<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.19</td>
<td>Alcohol Production in Total by Energy-Feedstock and Energy Price Level—0 to 100 Percent Alcohol Substitution for Gasoline; Fixed Demand Models E (Cassava), G (Sugarcane Only) and H (Sweet Sorghum Only), 1981</td>
</tr>
<tr>
<td>5.20</td>
<td>Alcohol Production from Cassava, Sweet Sorghum and Sugarcane by Region and Energy Price Level—0 to 100 Percent Alcohol Substitution for Gasoline; Fixed Demand Models E (Cassava), G (Sugarcane Only) and H (Sweet Sorghum Only), 1981</td>
</tr>
<tr>
<td>A.1</td>
<td>Energy Equivalents for Production of Agricultural Inputs</td>
</tr>
<tr>
<td>A.2</td>
<td>Agricultural Resources, Land and Labor by Type and Region, 1981 and 1986</td>
</tr>
<tr>
<td>A.3</td>
<td>Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 1, 1981</td>
</tr>
<tr>
<td>A.4</td>
<td>Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 2, 1981</td>
</tr>
<tr>
<td>A.5</td>
<td>Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 3, 1981</td>
</tr>
<tr>
<td>A.6</td>
<td>Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 4, 1981</td>
</tr>
<tr>
<td>A.7</td>
<td>Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 5, 1981</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>A.8</td>
<td>Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 6, 1981</td>
</tr>
<tr>
<td>A.9</td>
<td>Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 7, 1981</td>
</tr>
<tr>
<td>A.10</td>
<td>Sugar and Alcohol Production: Input/Output Coefficients and Non-Energy Costs by Production Process, 1981</td>
</tr>
<tr>
<td>A.11</td>
<td>Non-Energy Costs and Energy Inputs Per Ton of Raw Materials Transported from Farms to Processing Plants by Region, 1981</td>
</tr>
<tr>
<td>A.12</td>
<td>Non-energy Costs and Energy Inputs per Liter of Alcohol Transported from Distilleries to Consumption Centers and Among Regions, 1981</td>
</tr>
<tr>
<td>A.13</td>
<td>Agricultural Product Exports and Consumption by Region, 1981</td>
</tr>
<tr>
<td>A.14</td>
<td>Average Product Prices by Region, and Export Price, 1981</td>
</tr>
<tr>
<td>A.15</td>
<td>Own Price Elasticities of Domestic and Export Demands at Bangkok Wholesale Price.</td>
</tr>
<tr>
<td>A.16</td>
<td>Estimated Demand Equations by Agricultural Product—Regions 1, 2, 3 and 4, 1981</td>
</tr>
<tr>
<td>A.17</td>
<td>Estimated Demand Equations by Agricultural Product—Regions 5, 6, 7 and Export, 1981</td>
</tr>
<tr>
<td>B.1</td>
<td>Alcohol Wholesale Prices by Region in 1981.</td>
</tr>
<tr>
<td>B.2</td>
<td>Diesel Retail Prices by Region in 1981.</td>
</tr>
<tr>
<td>B.3</td>
<td>Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels—0 to 20 Percent Alcohol Substitution for Gasoline (Model C), 1981</td>
</tr>
<tr>
<td>B.4</td>
<td>Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline (Model E), 1981</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>B.5</td>
<td>Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline (Model I), 1981</td>
</tr>
<tr>
<td>B.6</td>
<td>Land Use by Region and Agricultural Product—Current Energy Prices, 18 Percent Alcohol Substitution for Gasoline (Model D), 1981</td>
</tr>
<tr>
<td>B.7</td>
<td>Land Use by Region and Agricultural Product—Energy Prices of +5 Percent, 20 Percent Alcohol Substitution for Gasoline (Model D), 1981</td>
</tr>
<tr>
<td>B.8</td>
<td>Land Use by Region and Agricultural Product—Energy Prices of +10 Percent, 20 Percent Alcohol Substitution for Gasoline (Model D), 1981</td>
</tr>
<tr>
<td>B.9</td>
<td>Land Use by Region and Agricultural Product—Energy Prices of +15 Percent, 20 Percent Alcohol Substitution for Gasoline Plus Exports (Model D), 1981</td>
</tr>
<tr>
<td>B.11</td>
<td>Land Use by Region and Agricultural Product—Current Energy Prices, 34 Percent Alcohol Substitution for Gasoline (Model F), 1981</td>
</tr>
<tr>
<td>B.12</td>
<td>Land Use by Region and Agricultural Product—Energy Prices of +10 Percent, 42 Percent Alcohol Substitution for Gasoline (Model F), 1981</td>
</tr>
<tr>
<td>B.13</td>
<td>Land Use by Region and Agricultural Product—Energy Prices of +20 Percent, 73 Percent Alcohol Substitution for Gasoline (Model F), 1981</td>
</tr>
<tr>
<td>B.14</td>
<td>Land Use by Region and Agricultural Product—Energy Prices of +30 Percent, 100 Percent Alcohol Substitution for Gasoline (Model F), 1981</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>B.15</td>
<td>Land Use by Region and Agricultural Product—Energy Prices of +60 Percent, 100 Percent Alcohol Substitution for Gasoline Plus Exports (Model F), 1981</td>
</tr>
<tr>
<td>B.16</td>
<td>Impact of Alcohol Production on Agricultural Product Exports—0 to 100 Percent Alcohol Substitution for Gasoline, Fixed Demand (Model E), Variable Demand with Increased Cropland (Model I), 1981</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Thailand's Agricultural Zones, Regions and Consumption Centers</td>
<td>40</td>
</tr>
<tr>
<td>4.1</td>
<td>Energy Crop Domestic and Export Market Equilibrium</td>
<td>53</td>
</tr>
<tr>
<td>4.2</td>
<td>Food Crop Domestic and Export Market Equilibrium</td>
<td>53</td>
</tr>
<tr>
<td>4.3</td>
<td>Simplified Process Flow Diagram of Alcohol Production</td>
<td>57</td>
</tr>
<tr>
<td>4.4</td>
<td>Simplified Process Flow Diagram of Sugar and Alcohol Production from Molasses</td>
<td>58</td>
</tr>
<tr>
<td>4.5</td>
<td>Simplified Process Flow Diagram of Alcohol Production from Cassava</td>
<td>60</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

Thailand's energy-food relationship is characterized by increasing energy imports (at higher prices), a persistent agricultural production surplus, a static or declining cassava market in Europe, and a perennial balance of trade deficit. This situation has led the government to incorporate an alcohol production program into Thailand's Fifth Five-Year National Economic and Social Development Plan: 1982-1986. The goal of the program is to use two energy crops, sugarcane and cassava, to produce 480 million liters per year of alcohol. This amount of alcohol production with its concomitant demand for energy-feedstocks can cause significant economic changes at the farm, regional, national and international trade levels as the various sectors adjust to the needs and uses of alcohol production.

1. The Problems

   Energy Problem: The demand for commercial fuels in Thailand has been rising rapidly due to population growth, commercialization of agriculture, and a growing manufacturing sector. Imported oil supplies have also risen substantially to fulfill increasing liquid fuel demands. This increase in
imported oil associated with the increase in its price has widened the balance of trade deficit and accelerated the inflation rate in the Thai economy.

Commercial energy (petroleum fuels, natural gas, electricity, coal, and hydropower) consumption increased from 1.2 million metric tons of oil equivalent in 1960 to 10.0 million metric tons in 1978. This amounts to an annual percentage increase of 15.5 from 1960 to 1973. The rate of increase slowed down after 1973, following the increases in energy prices that took place after that year. However, commercial energy consumption still continued to rise at an average annual rate of 5.1 (11).

Most of Thailand's commercial energy consumption is supplied by imported oil, which increased from 105 thousand barrels per day in 1970 to 205 thousand barrels per day in 1979 (Table 1.1).

The increase in oil prices plus the increase in quantity imported has caused oil import costs to rise from $113 million dollars in 1970 to $1,900 million dollars in 1979. Oil import costs, as a percentage of merchandise imports, increased from 10 percent in 1972 to 23 percent in 1976 (16). The country's oil import bill used up 12 percent of the export earnings in 1972, and 26 percent of the export earnings in 1978 (3).

The retail prices of fuels in Thailand have been rising. Regular gasoline price prior to the oil embargo
Table 1.1: Thailand Oil Production, Trade and Inferred Consumption: Total Crude and Products, 1970-1979

Unit: thousand barrels per day

<table>
<thead>
<tr>
<th>Year</th>
<th>Crude Production</th>
<th>Imports</th>
<th>Exports</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>--</td>
<td>105</td>
<td>1</td>
<td>104</td>
</tr>
<tr>
<td>1971</td>
<td>--</td>
<td>129</td>
<td>4</td>
<td>125</td>
</tr>
<tr>
<td>1972</td>
<td>--</td>
<td>151</td>
<td>9</td>
<td>142</td>
</tr>
<tr>
<td>1973</td>
<td>--</td>
<td>172</td>
<td>11</td>
<td>161</td>
</tr>
<tr>
<td>1974</td>
<td>--</td>
<td>164</td>
<td>3</td>
<td>161</td>
</tr>
<tr>
<td>1975</td>
<td>--</td>
<td>167</td>
<td>2</td>
<td>165</td>
</tr>
<tr>
<td>1976</td>
<td>--</td>
<td>175</td>
<td>1</td>
<td>174</td>
</tr>
<tr>
<td>1977</td>
<td>--</td>
<td>186</td>
<td>--</td>
<td>186</td>
</tr>
<tr>
<td>1978</td>
<td>--</td>
<td>218</td>
<td>1</td>
<td>217</td>
</tr>
<tr>
<td>1979</td>
<td>--</td>
<td>205</td>
<td>--</td>
<td>205</td>
</tr>
</tbody>
</table>

Source: Central Intelligence Agency of USA (9).
(July 1973) was 39 US $ per gallon. It increased to 73.3 and 215.8 US $ per gallon in 1977 and 1981, respectively. Retail prices of other fuels have also been rising significantly following the oil embargo (Table 1.2).

These increasing prices of fuels have pushed up the transportation costs and retail prices of goods and services. The consumer price index for the whole kingdom rose substantially after the oil embargo. The consumer price index was 119.6 in 1972, and it increased to 171.8 and 218.8 in 1974 and 1978 respectively (3). The rise in the price of imported oil has been a significant contributor to inflation in the Thai economy.

In order to lessen the impact of a large balance of trade deficit and inflation, the Thai government has decided to reduce oil imports while pursuing policies of energy conservation and increased domestic energy production in the country. The alcohol program is a key part of new energy production policy. The program will help not only to decrease oil imports, but also to solve the agricultural production surplus problem.

**Agricultural Production Surplus**: Agriculture is the most important sector in the Thai economy. It contributes a major share to gross domestic product and foreign exchange earnings. It accounted for 27 percent of gross domestic product (GDP) at current prices in 1978. Manufacturing, the second largest sector, contributed 13 percent of the total
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular gasoline (US$/gallon)</td>
<td>39.0</td>
<td>73.3</td>
<td>215.8</td>
<td>17.1</td>
<td>57</td>
</tr>
<tr>
<td>Premium gasoline (US$/gallon)</td>
<td>43.0</td>
<td>78.7</td>
<td>254.6</td>
<td>16.3</td>
<td>60</td>
</tr>
<tr>
<td>Household kerosene (US$/gallon)</td>
<td>36.0</td>
<td>50.0</td>
<td>117.6</td>
<td>8.6</td>
<td>83</td>
</tr>
<tr>
<td>Diesel fuel oil (US$/gallon)</td>
<td>19.9</td>
<td>49.2</td>
<td>139.9</td>
<td>25.4</td>
<td>79</td>
</tr>
<tr>
<td>Residual fuel oil (US$/42-gallon barrel)</td>
<td>504.0</td>
<td>1,260.8</td>
<td>--</td>
<td>25.8</td>
<td>98</td>
</tr>
</tbody>
</table>

GDP (52). The total value of agriculture, forestry and fishery exports contributing 75 and 66 percent of total exports in 1974 and 1978 respectively (29). There were about 13 categories of agricultural commodity exports in 1978. They include rice and rice products, food crops, oil seeds products, fiber crop products, garden crops and fruits, miscellaneous crops, tobacco and rubber, livestock and poultry, animal feed, livestock products, fishery products, textile material, and forestry products. Among these, rice and rice products, rubber, cassava, corn, and sugar were the top five export earners in 1978 (29).

There are several major problems related to agricultural exports. First, demand for Thai agricultural exports is unstable, due to supply fluctuations in the world market. Second, export prices are uncertain and are determined by world markets. Third, the demand for some export commodities, such as sugar and cassava, is limited by international trade agreements or regional trade restrictions. These problems have contributed significantly to price and income instability for farmers producing export commodities.

The most serious production surpluses have occurred with sugar and cassava which are among the top five agricultural exports. For instance, in 1978, Thailand received a quota from the International Sugar Agreement to export sugar up to 1.02 million tons and had to keep 0.44 million tons in storage (Table 1.3). It has been estimated that
Table 1.3: Sugar Production, Domestic Consumption, Quota Export and Sugar in Storage in 1978

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount (1,000 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar in storage at January 1, 1978</td>
<td>140</td>
</tr>
<tr>
<td>Sugar produced in crop year 1977/78</td>
<td>1,870</td>
</tr>
<tr>
<td>Total supply</td>
<td>2,010</td>
</tr>
<tr>
<td>Domestic consumption</td>
<td>500</td>
</tr>
<tr>
<td>Quota export</td>
<td>1,020</td>
</tr>
<tr>
<td>Reserve</td>
<td>50</td>
</tr>
<tr>
<td>Total demand</td>
<td>1,570</td>
</tr>
<tr>
<td>Sugar in storage in December, 1978</td>
<td>440</td>
</tr>
</tbody>
</table>

Source: Netayarak, Prayong (48).
Thailand had to reduce by one million rai (1 rai = 0.395 acre) its sugarcane planted area in order to absorb the production surplus (48).

Cassava products for the feed industry have been sent mostly to European Economic Community (EEC) countries. The total amount of pellet exports to EEC amounted to more than 90 percent of all Thai cassava exports. Although export statistics suggest that the potential for Thai cassava would continue to be bullish, one source (67) indicated that the European feed industries have voiced objections to the use of cassava from Thailand. These are based on nutritional and technological consideration. The high sand and cellulose content, plus high mould and bacteria growth in the Thai product make consumption in large quantities unsuitable unless a radical change is introduced into the planned feed formulation. Another reason for the limitation in Thai cassava exports to Europe is to protect EEC farmers who produce other agricultural products that compete with cassava in the feed industry.

If cassava exports are further reduced, a serious cassava production surplus will arise unless the domestic demand for cassava increases. A strong export market has been a key factor in the rapid expansion of cassava production. The increasing trend of planted area is partly associated with the simple cultivation methods used to produce cassava. It can be grown profitably in all parts of the
country, regardless of climatic condition or type of soil. In addition, it can be grown almost year round, and hence harvest can be conducted continuously. These suitable characteristics of cassava make a reduction of its production more difficult to achieve. An increase in domestic demand for cassava, therefore, is an attractive alternative solution to the production surplus problem.

Although the use of the alcohol program to solve the agricultural surplus problem and lessen the overall balance of trade deficit appears promising, the program may widen the trade deficit with Japan. Thailand has exported more agricultural commodities to Japan than to any other country. But, the trade deficit with Japan has been increasing and accounts for more than 50 percent of the total trade deficit. This problem has been of great concern to the Thai government.

**Trade Deficit with Japan:** The major source of foreign exchange earnings has come from agricultural commodity exports, and the major share of these exports have been to Japan. The Japanese share of foreign imports into Thailand is larger than from other countries (Table 1.4). This has contributed to the trade deficit with Japan. For instance, in 1970 the trade deficit with Japan was 6,337 million baht (1 baht = 0.05 US $), which accounted for 51 percent of the total trade deficit (4). The trade deficit with Japan
Table 1.4: Thai Exports and Imports by Country in Selected Years

<table>
<thead>
<tr>
<th></th>
<th>Exports</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>Malaysia</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Indonesia</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Singapore</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>United States</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Netherlands</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>W. Germany</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Italy</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Taiwan</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>India</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Australia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Bank of Thailand (3).
increased to 16,595 million baht in 1978, or 64 percent of the total (5).

In order to decrease the trade deficit with Japan, Thailand has tried to export more agricultural commodities to that country. There are some problems associated with this. Thai corn exports have to compete with the corn export from the US. The amount of Japanese rice imports from Thailand depends on domestic Japanese production. Rubber export has to compete with other exporting countries, such as Malaysia. Sugar export is limited by the International Sugar Agreement's quota system and by competition from other major exporting countries.

A policy of reducing imports from Japan has been tried without success. The value of imports from Japan is rising and is expected to rise at a faster pace in the future. Thailand needs capital goods for its economic development, and many goods from Japan are less expensive than those from other countries because of lower transportation costs.

However, the trade deficit may be improved by the alcohol program if Thailand can export alcohol to Japan. Japan imports a substantial amount of alcohol each year. For instance, in 1975 102.64 million liters were imported. The total imports increased to 237.33 million liters in 1980 (23).
2. Alcohol Program

On the first of May, 1980, Thailand announced a program regarding the production of fuel alcohol from agricultural products. The objectives of this program are to pursue a course of energy independence, to help ease the energy shortage problem, to improve balance of payments, to reduce car exhaust pollution, and to help stabilize the crop surplus situation (38). On January 21, 1981, the cabinet approved the incorporation of the alcohol production program in Thailand's Fifth Five-Year National Economic and Social Development Plan: 1982-1986. The goal of the program is to use sugarcane and cassava to produce alcohol at a production level of 480 million liters per year (5).

At present, there are more than 10 investors interested in setting up alcohol plants. They have proposed to use sugarcane, molasses, cassava, corn, sorghum and potatoes as feedstocks to produce alcohol totaling around 10.03 million liters per day (68).

The increase in production of energy crops for alcohol production may cause a reduction in production of food crops, fiber, and livestock products because of limited resources, such as land. The full implementation of the alcohol program can cause significant economic adjustments at the farm, regional, national, and international trade levels. The increase in trade deficit due to less agricultural commodity exports may or may not be offset by
reduction in the oil import bill. Thus, the competition for the use of basic resources for the production of energy crops and other agricultural products, and a trade-off between exporting them and importing oil, should be considered and determined. Price relationships will naturally be an important determinant of the allocation of these resources. Although alcohol production from agricultural products is technically possible, the economic feasibility of alcohol production still has to be proven, and the conditions and the price relationships which will make it feasible have to be determined.

The purpose of this study is to assess the viability of alcohol production from agricultural commodities in Thailand. This study does not attempt to provide an overall answer for the total energy problem as it relates to agriculture. It is intended to provide some insight into how the production of food crops, fiber, and livestock, and the production of energy crops and their prices will be affected by various levels of energy prices and quantities of alcohol produced. It also considers how agricultural trade with Japan will be affected by alcohol production.

3. Objectives of the Study

The overall objective of this study is to evaluate the economic impact of alcohol production on the agricultural sector and trade, with particular reference to trade with
Japan. The geographic area of this study encompasses the entire territory of Thailand. Energy crops—sugarcane, cassava, and sweet sorghum—are examined.

Specifically, the objectives of this study are the following:

1. To develop a regionalized integrated national agricultural programming model to include:
   a. resource constraints;
   b. agricultural and alcohol production, consumption, exports, and prices;
   c. transport linkages among energy and non-energy crop production, alcohol processing, and alcohol distribution.

2. To use the model to examine, under selected energy prices and agricultural policy conditions:
   a. the economic feasibility of alcohol production from sugarcane, cassava, and sweet sorghum in 1981 and 1986;
   b. the impact on agricultural production, consumption, exports, and prices;
   c. optimal regional resource allocation among agricultural commodity production;
   d. optimal location of alcohol plants.

3. To examine, under different energy prices and amounts of alcohol produced:
a. changes in quantities and prices of agricultural exports to Japan;
b. economic feasibility of exporting alcohol to Japan;
c. changes in the balance of trade with Japan.
CHAPTER II
ENERGY, AGRICULTURE, AND TRADE WITH JAPAN

This chapter is divided into four parts. A general discussion of energy consumption in Thailand is presented first. Energy consumption is categorized as commercial and traditional. Three main types of commercial energy consumption categories considered are energy used for transportation, tractors, and fertilizer. The second part deals with energy production from fossil, hydropower, and biomass sources. Alcohol production, which is a new energy source, is also considered in this part. Present production, consumption and exports for sugarcane and cassava (potential energy feedstocks) are discussed in the third part. A strong export market has been a key factor in the rapid expansion for these crops. Production increase for these "energy crops" has come largely from increase in area planted. The last part of this chapter is devoted to examining the importance of agricultural trade with Japan. Thirty percent of the principal agricultural commodities that Thailand exports go to the Japanese market.

1. Energy Consumption

Energy sources can be divided into traditional and commercial. The traditional fuels are wood, charcoal, crop
residues, and animal dung. The commercial energy comprises those energy forms for which there is a large international and domestic market, and which supply the needs of a modern industrial economy, i.e., petroleum fuels, natural gas, electricity, coal, and hydropower.

**Traditional Energy Consumption:** Both households and industries use traditional fuels. Households in rural and urban areas use traditional fuels primarily for cooking. Almost all (97 percent) of the population in Thailand used traditional fuels in 1972, and the national average for traditional fuel use was 14.7 gigajoules (GJ)\(^1\) per capita per year (21). In urban households, traditional fuels are commonly used together with commercial fuels, both of which are sold in organized markets. Charcoal is generally preferred to firewood in cities because of its convenience, compactness, and cleaner burning quality. In 1972, for example, the use of wood in Bangkok was estimated at 3 million cubic meters, or almost 2 cubic meters per inhabitant (11).

The industrial use of traditional fuels also appears to be quite extensive. Estimates of industrial consumption of traditional fuels were 153 and 869 thousand metric tons oil equivalent in 1967 and 1976, respectively. The percentage of all traditional fuel consumed by the industrial sector has risen from 52 percent in 1967 to 93 percent in 1976 (11).

\(^1\) A gigajoule is one billion \((10^9)\) joules or is approximately equivalent to 0.17 barrels of crude oil. A joule is one watt-second.
percent in 1976 (11). The industrial consumption of traditional fuels has been not only large but rising, due to the increasing price of fossil fuels.

However, the production of traditional fuels has been limited and has created a serious deforestation problem. More wood has been taken from forests every year (through fuelwood gathering, charcoal making, timber and pulpwood production, or clearing for agriculture) than the annual increment of forest growth, and eventually the forest could disappear. The decrease in the supply of traditional fuels may cause their prices to rise. This could lead to a substitution of commercial energy for wood fuels, depending on relative prices.

**Commercial Energy Consumption:** The increase in demand for commercial energy consumption in Thailand has been directly related to an expansion of the transportation sector and modernization of the agricultural sector.

Prior to 1950, no national road system existed in Thailand. Such roads as did exist were feeder roads for the railway, unpaved provincial roads largely used by bullock carts, and short stretches of road around Bangkok. Since 1950 a vigorous road-construction program has been carried out, and by 1971 most populated areas could be reached by roads. Truck and bus transport has increased sharply (22). These developments have contributed to a major increase in the demand for petroleum products. The transportation
activity consumed 43 and 42 percent of the total petroleum products used in Thailand in 1977 (16) and 1980 (45), respectively. Also, the percentage share of gasoline in petroleum product demand for transportation was 44 percent in 1977 (16) and 41 percent in 1980 (45).

The increase in numbers of tractors being used in agriculture is another significant source of commercial energy consumption. Starting from near-zero in 1950, the number of four-wheeled farm tractors rose to 17,500 in 1967, and to 25,000 in 1969 (56). The total number of tractors used in agriculture has increased steadily in spite of the rapid increase in the price of gasoline since 1973. The total number of farm tractors was 33,000 in 1978 (17).

Thai farmers have used tractors widely for land tilling. In 1976 about 60 percent of the paddy land in the central region was tilled by tractor, and even higher rates were reported for upland crops: corn, 96 percent; cotton, 64 percent; sugarcane, 72 percent; and sorghum, 75 percent (56).

The other important development in Thai agriculture, which is tied to the use of commercial fuels, is the use of fertilizer. Before 1966, chemical fertilizer was scarcely used at all in Thailand. Traditional rice farmers have relied on the enriching silt deposited in their paddy fields brought by annual flood waters, and on application of animal manure. Most chemical fertilizer was used for the rapidly
expanding cash crops, such as corn, kenaf, cassava, fruits, and vegetables. Total fertilizer consumption (nitrogen, phosphate, and potash) in 1961-1965 was only 61,423 metric tons (17). However, this increased significantly after 1966. There are two factors associated with increases in fertilizer use. First, high yielding varieties of rice and upland crops have been adopted. Second, the fertility of farmland has decreased rapidly. The amount of total fertilizer consumption rose from 105,100 metric tons in 1969 to 189,522 metric tons in 1974 (17).

2. Energy Production

There are very few types of fuels produced domestically, as energy resources are limited in Thailand. Forest and waste biomass have been the most important. However, energy production from these sources could become less important due to overexploitation. Alcohol production may become the new dominant source of energy production in the country if other sources continue to be overexploited. Some of these types of energy production and sources are discussed below.

**Oil Shale Reserve:** Thailand has a small oil shale reserve. The potentially exploitable deposits have been estimated to be 0.82 billion barrels (73).

**Coal:** Coal production was 0.2 million metric tons in 1977 and increased to 0.5 million metric tons in 1980 (16).
The amount of coal produced depends on geological resources, which have been estimated at 78 million tons (73).

Natural Gas and Its Use: Natural gas is a potential alternative source of energy. Its production has been projected initially at 200 million cubic feet per day (mid-1981 to mid-1983), and 500 million cubic feet per day thereafter (2). Although the government has proposed to use the entire gas production to replace imported oil in electricity generation, it has been suggested that this represents low-value use as compared to high-value uses in the production of urea fertilizer, steel, and petrochemicals (2). Another alternative use of natural gas is as an energy input into the production of alcohol.

Nuclear Option: Although nuclear power is used successfully in some developed countries, there are some problems relating to nuclear power in a developing country context. They include the following (16):

1. a very high capital cost,
2. a dependence on imported technology,
3. the fact that the smallest available power generating reactor is large in relation to the system size in most of the developing countries,

2/ Geological resources are defined as coal occurrences that at some time in the future may acquire an economic value.
4. the international agreements and restrictions on fuel supply.

The other problems that nuclear power plants create are the minor amounts of radioactivity in water and air used for cooling purposes, the potential of accidents or sabotage, and the serious problem of disposing of the highly radioactive spent fuel.

However, it is expected that Thailand may have one reactor with a total nuclear capacity of 0.6 NEP (net electrical power in gigawatt) by 1990 (16).

**Hydroelectric Power:** Hydroelectric power is a popular source of energy currently used in Thailand. The recent annual production of power is 451 MW (megawatt), and the annual energy output is 5,400 terajoules. The installable capacity has been estimated to be 6,242 MW of power or 81,302 terajoules of annual energy (11). Other benefits are stream flow control and provision of water for irrigation which continues to be very important in many areas.

However, there are some problems relating to the use of hydroelectric power. The variability of river flows often makes it difficult to utilize highly capital-intensive hydroelectric facilities economically. Furthermore, uneven flows tend to make the usual environmental and land-use problems associated with hydroelectric power even greater—especially direct flooding and destruction of habitats for
local species of flora and fauna. Finally, sedimentation problems can often be serious.

Forest and Biomass Waste: Forest and biomass waste have been the most popular domestic energy sources. They have been produced for traditional energy consumption. However, they could become less popular if their supply becomes more limited. The potential annual energy supplies from existing forest and waste biomass have been estimated, and are shown in Table 2.1.

Alcohol Production: Alcohol production is expected to be the most significant new domestic energy resource. The Thai government has planned to produce 480 million liters per day of alcohol from cassava and sugarcane in 1982-1986. This alcohol will be mixed with gasoline, and the mixture will be used in the transportation industry. The progress of alcohol production under the alcohol program can be divided into the following three steps (68):

1. One alcohol plant has been approved by the government. This plant will be built in Chonburi Province, in the eastern part of Thailand. The project plans propose to use cassava and sugarcane to produce alcohol at a rate of 0.65 million liters per day.

2. Next, three separate investors have proposed alcohol production projects to the government for approval. The first investor has proposed to use
### Table 2.1: Potential Annual Energy Supply from Existing Forest and Biomass Waste

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Energy Production (10^15 joules)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential energy from forest growth[^a/]</td>
<td>290 - 2,900</td>
</tr>
<tr>
<td>Potential energy from animal manure</td>
<td>205</td>
</tr>
<tr>
<td>Potential energy from crop residues</td>
<td>308</td>
</tr>
<tr>
<td>Total potential annual energy[^b/]</td>
<td>800 - 3,400</td>
</tr>
</tbody>
</table>

Source: Dunkerley, J., Ramsay, W., Gordon, L., Cecelski, E. (11).

[^a/]: Volume of timber assessed to be capable of increasing by 1-10 cubic meters per hectare; also, this assumes an energy content of 10 gigajoules per cubic meter.

[^b/]: Energy from theoretical incremental growth of forest product output plus energy from animal wastes and crop residues.
corn, sugarcane, cassava, sorghum, and potatoes to produce 0.2 million liters per day of alcohol. This plant will be located in Chachoengsao Province, in the central plain. The second investor has proposed to build an alcohol plant in Supanburi Province, in the central plain, and use sugarcane to produce 0.375 million liters per day of alcohol. The third investor has proposed to build a plant which has two sets of alcohol production processes. Each set will use sugarcane and sorghum to produce alcohol totaling around 0.22 million liters per day.

3. Lastly, another set of investors exist who are interested in alcohol production, but they have yet to propose formally their alcohol production projects to the government. Their proposed investment costs, energy crops used, and potential amounts of alcohol produced are presented in Table 2.2.

The proposed amount of alcohol production mentioned above can create a major shift in the demand schedule for energy crops. This increasing demand must be equilibrated by a domestic supply adjustment which accounts for the current production, consumption, and trade patterns for these potential energy crops.
Table 2.2: Investment Costs, Energy Crops Used and Amount of Alcohol Produced by the Investors who are Interested in Alcohol Production.

<table>
<thead>
<tr>
<th>Investor</th>
<th>Investment Costs (million baht)</th>
<th>Energy Crop Used</th>
<th>Alcohol Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japanese - sugarcane</td>
<td>--</td>
<td>sugarcane</td>
<td>5,000-10,000 liters per day</td>
</tr>
<tr>
<td>Japanese - cassava</td>
<td>50</td>
<td>cassava</td>
<td>--</td>
</tr>
<tr>
<td>Japanese - 120 sugarcane</td>
<td>120</td>
<td>cassava</td>
<td>3,000 million liters per year</td>
</tr>
<tr>
<td>Joint venture between Japanese and Thai</td>
<td>62</td>
<td>cassava</td>
<td>2,000 liters per day</td>
</tr>
<tr>
<td>Pioneer project funded by World Bank</td>
<td>500</td>
<td>cassava</td>
<td>50 million liters per year</td>
</tr>
</tbody>
</table>

Source: Tosakule, Kamolluk (68).
3. Production, Consumption, and Trade of Potential Energy Crops

Production of cassava and sugarcane has been rising rapidly because of availability of marginal land, road construction in the rural areas, and a strong export market. Planted areas have increased steadily while yields have scarcely changed. Roads have provided the people in the rural areas with an effective contact with outside markets. The roads have brought trucks, buses, and traders; and they have greatly reduced the cost of transportation. Studies of particular roads show large increases in agricultural output in the areas served by them (22). Statistics show that the energy crop exports have increased substantially almost every year. Currently, more than 70 percent of the production of these crops is exported.

Cassava: Cassava was first grown in Thailand in the South, primarily for human consumption, around 1850. It has become quite popular in the eastern seaboard provinces, namely, Chonburi, Rayong, and nearby areas, and many processing factories have been established there (70). Cassava growing has also spread to provinces in the northern, western and upper central parts of Thailand. In the last 18 years planted area for the kingdom has ranged from a low of about 0.767 million rai to a high of about 7.25 million rai (Table 2.3).
Table 2.3: Area, Production, Yield, Farm Price and Exports of Cassava for Selected Years, Thailand

<table>
<thead>
<tr>
<th>Year</th>
<th>Planted Area (1,000 rai)</th>
<th>Fresh Root Production (1,000 tons)</th>
<th>Yield (tons/rai)</th>
<th>Farm Price (baht/kg)</th>
<th>Exports^/ (1,000 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>767</td>
<td>2,077</td>
<td>2.71</td>
<td>n.a.</td>
<td>240</td>
</tr>
<tr>
<td>1965</td>
<td>656</td>
<td>1,557</td>
<td>2.37</td>
<td>n.a.</td>
<td>719</td>
</tr>
<tr>
<td>1967</td>
<td>814</td>
<td>1,892</td>
<td>2.32</td>
<td>n.a.</td>
<td>781</td>
</tr>
<tr>
<td>1969</td>
<td>1,066</td>
<td>2,611</td>
<td>2.45</td>
<td>0.33</td>
<td>975</td>
</tr>
<tr>
<td>1971</td>
<td>1,403</td>
<td>3,431</td>
<td>2.45</td>
<td>0.47</td>
<td>1,122</td>
</tr>
<tr>
<td>1973</td>
<td>2,093</td>
<td>3,952</td>
<td>1.89</td>
<td>0.47</td>
<td>1,836</td>
</tr>
<tr>
<td>1975</td>
<td>3,000</td>
<td>6,240</td>
<td>2.08</td>
<td>0.30</td>
<td>2,385</td>
</tr>
<tr>
<td>1977</td>
<td>4,373</td>
<td>10,137</td>
<td>2.32</td>
<td>0.46</td>
<td>3,954</td>
</tr>
<tr>
<td>1979</td>
<td>6,313</td>
<td>15,048</td>
<td>2.38</td>
<td>0.77</td>
<td>3,961</td>
</tr>
<tr>
<td>1980</td>
<td>7,250</td>
<td>16,540</td>
<td>2.28</td>
<td>0.75</td>
<td>5,218</td>
</tr>
</tbody>
</table>

Sources: Ministry of Agriculture and Co-operatives (28), (29), (35).

^/ Shredded, flour, pellets, waste, sago flour, and pearl.
Cassava has at least five attributes which favor its production. They are as follows (53):

1. It is easily propagated. Seeds or roots are not required, propagation being a simple matter of planting stalk cuttings.

2. It is relatively high yielding.

3. It is relatively inexpensive to produce. It is easily planted and harvested, and requires little or no weeding because of its leafy canopy. It does not have a critical planting or harvesting time, hence it is not season-bound.

4. It is a good risk-averse crop. Its hydrocyanic acid content makes it subject to minimal animal and pest attacks, and it is capable of growing in soils often considered too poor for other crops.

5. It is a reliable staple and an excellent source of carbohydrates.

A strong export market has also been a key factor in the rapid expansion of cassava production. Exports increased from 0.24 million tons of processed cassava in 1963 to 5.218 million tons in 1980 (Table 2.3). The annual domestic consumption, which was projected in the Third Five-Year Economic and Social Development Plan (1972-1975), was around 10 percent of the root production (49).

Sugarcane: Sugarcane production has increased greatly. The planted area increased from 0.345 million rai in 1963 to
2.927 million rai in 1981 (Table 2.4). Most of the production is from the central region. For instance, in 1977 the central region contained 69 percent of the total planted area. The second largest production (14 percent) was from the eastern region. Only 10 percent and 7 percent of the sugarcane area was located in the north and northeast regions respectively (48).

Promotion of the sugar industry, a strong export market, and a multi-year crop are the three main factors that have contributed to a rapid increase in sugarcane production. As part of the promotional effort, a company, the Sugar Industry of Thailand, was established. In addition, the Factory Act was passed to help the sugar industry. It exempted them from income tax and import duties on machinery and equipment. The sugar industry has evolved from a scattered cottage industry to one using a modern, highly mechanized technology in large mills.

The increase in sugar production has been a response to the increasing demand for sugar exports, which have increased about 120 thousand tons per year, from less than 50 percent of sugar production in the 1960's to 1,116 thousand tons, or 70 percent, in 1981 (Table 2.4).

Sugarcane is a multi-year crop. A three-year rotation is common in which three economic harvests can be made from the same plant, one in each of the first, second and third years. This can lower costs of the sugar production. In a
### Table 2.4: Area, Production, Yield and Farm Price of Sugarcane; Sugar Production and Exports in Selected Years in Thailand

<table>
<thead>
<tr>
<th>Year</th>
<th>Planted Area (1,000 rai)</th>
<th>Sugarcane Production (1,000 tons)</th>
<th>Yield (tons/rai)</th>
<th>Farm Price(^a/) (baht/ton)</th>
<th>Sugar Production (1,000 tons)</th>
<th>Sugar Exports(^b/) (1,000 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>345</td>
<td>1,695</td>
<td>4.91</td>
<td>119.80</td>
<td>125</td>
<td>90</td>
</tr>
<tr>
<td>1965</td>
<td>532</td>
<td>3,913</td>
<td>7.35</td>
<td>117.87</td>
<td>320</td>
<td>215</td>
</tr>
<tr>
<td>1967</td>
<td>361</td>
<td>2,535</td>
<td>7.01</td>
<td>161.18</td>
<td>232</td>
<td>77</td>
</tr>
<tr>
<td>1969</td>
<td>646</td>
<td>4,399</td>
<td>6.81</td>
<td>150.97</td>
<td>318</td>
<td>99</td>
</tr>
<tr>
<td>1971</td>
<td>862</td>
<td>6,586</td>
<td>7.69</td>
<td>144.90</td>
<td>532</td>
<td>146</td>
</tr>
<tr>
<td>1973</td>
<td>1,133</td>
<td>9,513</td>
<td>8.39</td>
<td>179.72</td>
<td>648</td>
<td>276</td>
</tr>
<tr>
<td>1975</td>
<td>1,935</td>
<td>13,413</td>
<td>6.93</td>
<td>298.66</td>
<td>1,060</td>
<td>597</td>
</tr>
<tr>
<td>1977</td>
<td>3,118</td>
<td>26,094</td>
<td>8.37</td>
<td>286.03</td>
<td>2,212</td>
<td>1,656</td>
</tr>
<tr>
<td>1979</td>
<td>3,190</td>
<td>20,561</td>
<td>6.45</td>
<td>278.00</td>
<td>1,795</td>
<td>1,190</td>
</tr>
<tr>
<td>1981</td>
<td>2,927</td>
<td>19,854</td>
<td>6.78</td>
<td>430.00</td>
<td>1,603</td>
<td>1,116</td>
</tr>
</tbody>
</table>

Sources: Sugar Institute (58), (35).

\(^a/\) Average farm price for the whole country.
\(^b/\) Sugar exports include raw sugar, refined sugar, and others.
normal year sugarcane growers get higher income than most other crop growers (48).

However, the sugarcane growers have been facing two major problems. First, the demand for Thai sugar exports is unstable and limited by the International Sugar Agreement. The world price is low and demand for Thai sugar decreases when there is an excess supply of sugar in the world market. As a result, the demand and price of sugarcane decrease. Sugarcane production also decreases with less land, fertilizer, water, or weeding. Second, sugarcane is sensitive to drought and flood. These two reasons are an explanation for the variations in sugarcane production and yield as shown in Table 2.4.

As demonstrated in the above discussion, the two potential energy crops are dependent on world demand and prices. Specifically, cassava exports depend on demand from EEC countries, while sugar exports are dominated by Japanese demand. More sugar, corn and other principal agricultural commodities have been exported to Japan than to any other countries. The importance of agricultural trade between Thailand and Japan is discussed in the next part.

4. Agricultural and Alcohol Trade Between Thailand and Japan

Japan is an industrialized country that consumes more agricultural products than it produces. Its agricultural
self-sufficient ratio (production/use) was 0.72 in 1976 (55).

The Japanese food deficit results from a decrease in food production (except rice) and increases in the demand for food. Two major goals under Japan's new food strategy (particularly as spelled out in the Basic Law of 1961) have created larger food deficits. One goal is to increase per capita supply of food in order to reduce nutritional deficiencies and, concurrently, satisfy demand. Another goal is to increase production of agricultural products with high income elasticities (livestock products, fruits, and vegetables) (25). This increase in livestock production has required the importation of more and more raw materials, especially feed grains and soybeans.

On the supply side, Japanese domestic production of all crops except rice has dropped dramatically in the last 20 years. The reason for this trend is a decline in the labor input into agricultural production. As the Japanese economy grew, the demand and need for labor has been such that many farmers secured relatively lucrative part-time jobs in construction and other industries during the off-season or winter months (25).

Because of food deficits, Japan has imported large quantities of food crops and other agricultural products from many countries, including Thailand. Thailand has been a long time supplier of corn to Japan, the origins of which
were formalized in 1961 when a Thai Corn Imports Cartel was formed in Japan. This cartel negotiates annually with the Thai government to purchase certain amounts of corn it then is committed to buy. The price of this corn is determined by the world market price. The amount that the importer's cartel commits itself to purchase is usually the maximum that Thai officials believe will be available for export. In 1972 Thai corn supplied 14 percent of Japan's total corn imports (Table 2.5). However, the Thai corn's share in Japan's total corn imports decreased to less than one percent in 1981. Other major Thai commodities exported to Japan are rice, cassava products, kenaf, jute, sugar, and rubber (Table 2.5). It should be noted that Thai kenaf, jute, and sugar exports to Japan have also decreased in recent years. Japan's total rice imports are less than fifty thousand tons per year.

As discussed earlier, Thailand exports more agricultural commodities to Japan than to other countries. The majority commodities are shown in Table 2.6. Although the shares of these commodity exports to Japan have decreased slightly, these shares (except those of cassava products and rice) are still larger than the shares of these commodity exports to other countries. The alcohol program, which may reduce the availability of potential energy crop and other principal agricultural exports will, therefore, affect the
Table 2.5: Thai Shares in Japanese Agricultural Imports by Commodity, 1972-1981

<table>
<thead>
<tr>
<th>Year</th>
<th>Rice (%)</th>
<th>Corn (%)</th>
<th>Cassava Products (%)</th>
<th>Sorghum (%)</th>
<th>Kenaf and Jute (%)</th>
<th>Sugar (%)</th>
<th>Rubber (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>87.77</td>
<td>14.24</td>
<td>n.a.</td>
<td>0.67</td>
<td>68.75</td>
<td>1.27</td>
<td>67.94</td>
</tr>
<tr>
<td>1973</td>
<td>81.44</td>
<td>4.98</td>
<td>n.a.</td>
<td>0.45</td>
<td>57.64</td>
<td>--</td>
<td>54.04</td>
</tr>
<tr>
<td>1974</td>
<td>44.89</td>
<td>11.45</td>
<td>n.a.</td>
<td>1.12</td>
<td>53.47</td>
<td>7.94</td>
<td>64.67</td>
</tr>
<tr>
<td>1975</td>
<td>36.48</td>
<td>1.31</td>
<td>n.a.</td>
<td>1.05</td>
<td>43.37</td>
<td>12.51</td>
<td>66.45</td>
</tr>
<tr>
<td>1976</td>
<td>55.54</td>
<td>13.47</td>
<td>78.91</td>
<td>--</td>
<td>44.51</td>
<td>27.18</td>
<td>72.18</td>
</tr>
<tr>
<td>1977</td>
<td>95.97</td>
<td>5.41</td>
<td>81.91</td>
<td>0.08</td>
<td>40.21</td>
<td>23.02</td>
<td>74.20</td>
</tr>
<tr>
<td>1978</td>
<td>29.51</td>
<td>3.82</td>
<td>99.92</td>
<td>--</td>
<td>28.50</td>
<td>16.94</td>
<td>72.05</td>
</tr>
<tr>
<td>1979</td>
<td>85.30</td>
<td>4.51</td>
<td>58.87</td>
<td>0.33</td>
<td>22.50</td>
<td>24.03</td>
<td>n.a.</td>
</tr>
<tr>
<td>1980</td>
<td>89.14</td>
<td>1.80</td>
<td>64.68</td>
<td>--</td>
<td>5.28</td>
<td>0.69</td>
<td>n.a.</td>
</tr>
<tr>
<td>1981</td>
<td>96.82</td>
<td>0.04</td>
<td>72.53</td>
<td>--</td>
<td>2.38</td>
<td>6.05</td>
<td>74.70</td>
</tr>
</tbody>
</table>

Source: Japan Tariff Association (23).
Table 2.6: Thailand's Principal Agricultural Exports to Japan by Commodity, 1970-1981.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rice</th>
<th>Cassava Products</th>
<th>Sugar</th>
<th>Corn</th>
<th>Mungbeans</th>
<th>Sorghum</th>
<th>Jute and Kenaf</th>
<th>Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>2.96</td>
<td>4.29</td>
<td>67.53</td>
<td>44.88</td>
<td>33.57</td>
<td>27.80</td>
<td>30.01</td>
<td>51.79</td>
</tr>
<tr>
<td>1971</td>
<td>1.93</td>
<td>5.25</td>
<td>18.86</td>
<td>49.39</td>
<td>38.59</td>
<td>16.45</td>
<td>19.40</td>
<td>52.51</td>
</tr>
<tr>
<td>1972</td>
<td>0.74</td>
<td>3.25</td>
<td>9.17</td>
<td>45.68</td>
<td>35.79</td>
<td>15.91</td>
<td>15.51</td>
<td>59.66</td>
</tr>
<tr>
<td>1973</td>
<td>2.22</td>
<td>4.47</td>
<td>n.a.</td>
<td>33.80</td>
<td>28.23</td>
<td>13.06</td>
<td>10.34</td>
<td>55.34</td>
</tr>
<tr>
<td>1974</td>
<td>2.30</td>
<td>7.81</td>
<td>55.08</td>
<td>42.51</td>
<td>29.95</td>
<td>30.18</td>
<td>13.06</td>
<td>49.16</td>
</tr>
<tr>
<td>1975</td>
<td>0.88</td>
<td>4.21</td>
<td>53.47</td>
<td>39.27</td>
<td>36.38</td>
<td>18.12</td>
<td>3.65</td>
<td>55.80</td>
</tr>
<tr>
<td>1976</td>
<td>0.35</td>
<td>2.55</td>
<td>61.66</td>
<td>40.91</td>
<td>48.04</td>
<td>0.78</td>
<td>10.35</td>
<td>51.75</td>
</tr>
<tr>
<td>1977</td>
<td>1.53</td>
<td>2.45</td>
<td>37.90</td>
<td>25.94</td>
<td>36.61</td>
<td>3.12</td>
<td>17.17</td>
<td>53.00</td>
</tr>
<tr>
<td>1978</td>
<td>1.18</td>
<td>1.50</td>
<td>39.55</td>
<td>27.65</td>
<td>28.67</td>
<td>0.36</td>
<td>3.15</td>
<td>55.82</td>
</tr>
<tr>
<td>1979</td>
<td>0.52</td>
<td>1.56</td>
<td>33.45</td>
<td>23.63</td>
<td>19.71</td>
<td>0.94</td>
<td>6.96</td>
<td>58.50</td>
</tr>
<tr>
<td>1980</td>
<td>0.47</td>
<td>1.16</td>
<td>17.71</td>
<td>5.10</td>
<td>17.29</td>
<td>0.03</td>
<td>1.97</td>
<td>65.91</td>
</tr>
<tr>
<td>1981</td>
<td>2.57</td>
<td>1.24</td>
<td>9.36</td>
<td>0.85</td>
<td>14.41</td>
<td>0.02</td>
<td>1.82</td>
<td>69.80</td>
</tr>
</tbody>
</table>

Sources: Bank of Thailand (3).  
Ministry of Commerce (42).
agricultural trade with Japan more than it will with other countries.

The impact of the alcohol program upon balance of trade with Japan could be minimal or positive if alcohol is made from cassava and exported to Japan, since only about 2 percent of cassava exports now go to Japan. This is a possibility, since Japan now imports a substantial amount of ethyl alcohol each year. Although Thailand exports more alcohol for industrial use to Japan than to other countries (85 percent), this represents only 5 percent of Japanese alcohol imports (Table 2.7). Japanese investors are also interested in some joint ventures with Thai alcohol plants.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiwan</td>
<td>3.30</td>
<td>12.10</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Philippines</td>
<td>6.76</td>
<td>--</td>
<td>8.22</td>
<td>5.01</td>
<td>4.40</td>
</tr>
<tr>
<td>Indonesia</td>
<td>4.75</td>
<td>4.51</td>
<td>5.23</td>
<td>4.44</td>
<td>4.36</td>
</tr>
<tr>
<td>Pakistan</td>
<td>10.67</td>
<td>4.02</td>
<td>8.73</td>
<td>3.36</td>
<td>4.30</td>
</tr>
<tr>
<td>USA</td>
<td>2.69</td>
<td>3.56</td>
<td>1.85</td>
<td>1.61</td>
<td>0.95</td>
</tr>
<tr>
<td>Cuba</td>
<td>2.98</td>
<td>--</td>
<td>6.31</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Brazil</td>
<td>37.71</td>
<td>35.49</td>
<td>1.94</td>
<td>22.83</td>
<td>42.54</td>
</tr>
<tr>
<td>Argentina</td>
<td>10.39</td>
<td>16.70</td>
<td>33.83</td>
<td>26.89</td>
<td>17.78</td>
</tr>
<tr>
<td>Australia</td>
<td>20.25</td>
<td>17.67</td>
<td>22.36</td>
<td>18.89</td>
<td>11.63</td>
</tr>
<tr>
<td>Singapore</td>
<td>0.50</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>India</td>
<td>--</td>
<td>5.95</td>
<td>5.16</td>
<td>9.90</td>
<td>5.13</td>
</tr>
<tr>
<td>Thailand</td>
<td>--</td>
<td>--</td>
<td>4.11</td>
<td>6.54</td>
<td>3.92</td>
</tr>
<tr>
<td>Bolivia</td>
<td>--</td>
<td>--</td>
<td>1.66</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Burma</td>
<td>--</td>
<td>--</td>
<td>0.38</td>
<td>0.24</td>
<td>0.21</td>
</tr>
<tr>
<td>France</td>
<td>--</td>
<td>--</td>
<td>0.22</td>
<td>0.29</td>
<td>0.52</td>
</tr>
<tr>
<td>Netherlands</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>4.26</td>
</tr>
<tr>
<td><strong>Total (percent)</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
</tr>
<tr>
<td><strong>Total (million liters)</strong></td>
<td><strong>102.64</strong></td>
<td><strong>145.23</strong></td>
<td><strong>185.84</strong></td>
<td><strong>210.66</strong></td>
<td><strong>237.33</strong></td>
</tr>
</tbody>
</table>

Source: Japan Tariff Association (23).
CHAPTER III
DESCRIPTION OF THE STUDY AREA

Thailand has a geographic area of 321.25 million rai. Administratively, the country is divided into 72 provinces (Changwad). However, for the purposes of agricultural development planning, the 72 provinces have been grouped into 19 agro-economic zones, as shown in Figure 3.1. These zones have been defined according to homogeneous land types and climatic conditions. They are used as regional division in the national crop model of Thailand. Within this model, land is classified into four types as follows (57): land type I is suitable only for production of floating rice; land type II is suitable for production of crops under controlled irrigation; land type III is suitable for rainfed-irrigated crop production; and land type IV is suitable only for upland crops.

For the purpose of this study, the zones have been aggregated into 7 regions (Figure 3.1 and Table 3.1). The criteria used to define these regions are (1) similarity in patterns of agricultural production, (2) potential for producing energy crops, (3) spatial location of major consumption centers and collecting points for agricultural
Figure 3.1: Thailand's Agricultural Zones, Regions and Consumption Centers.
Table 3.1: Regions, Zones, Provinces, Energy Crops and Other Agricultural Commodities in Thailand

<table>
<thead>
<tr>
<th>Region</th>
<th>Zone</th>
<th>Province</th>
<th>Energy Crop</th>
<th>Other Commodity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9,10</td>
<td>Sukhothai, Uttaradit, Phrae, Nan, Lampang, Lamphun, Chaingmai, Chaingrai, Maehongson</td>
<td>sugarcane</td>
<td>tobacco, cotton, corn, soybeans, cattle, rice, buffaloes</td>
</tr>
<tr>
<td>2</td>
<td>6,7,8</td>
<td>Nakhonsawan, Uthaithani, Loei, Phetchabun, Lopburi, Saraburi, Tak, Kamphaengphet, Phichit, Phitsanulok</td>
<td>sugarcane</td>
<td>mungbeans, corn, groundnuts, soybeans, rice, cotton, tobacco, sorghum</td>
</tr>
<tr>
<td>3</td>
<td>1,2,3</td>
<td>Nongkai, Sakonnamphok, Udonthani, Nakhonphanom, Yasothon, Ubonratchathani, Kalasin, Roiet, Khonkaen, Mahasarakham</td>
<td>cassava</td>
<td>rice, tobacco, corn, kenaf, silk, buffaloes, cattle</td>
</tr>
<tr>
<td>4</td>
<td>4,5</td>
<td>Nakhonratchasima, Chaiyaphum, Buriram, Surin, Sisaket</td>
<td>cassava</td>
<td>kenaf, rice, corn, cotton, silk, castor, cattle, buffaloes</td>
</tr>
<tr>
<td>5</td>
<td>13,15,16</td>
<td>Prachinburi, Chachoengsao, Chonburi, Rayong, Chanthaburi, Trat</td>
<td>sugarcane</td>
<td>rice, coconut, corn, para-rubber, fruit trees, buffaloes, marine fisheries</td>
</tr>
<tr>
<td>6</td>
<td>11,12,14</td>
<td>Bangkok, Ayutthaya, Pathumthani, Nonthaburi, Nakhonnayok, Angthong, Nakhonpathom, Chainat, Singburi, Suphanburi, Kanchanaburi, Ratchaburi, Kanchanaburi, Ratchaburi, Phetchaburi, Prachuapkhiri Khan, Samutsakorn, Samutsongkhram, Samutprakan</td>
<td>sugarcane</td>
<td>rice, cotton, corn, castor, coconut, vegetables, cattle, marine fisheries</td>
</tr>
<tr>
<td>7</td>
<td>17,18,19</td>
<td>Chumphon, Ranong, Suratthani, Phuket, Phangnga, Nakhonsithammarat, Krabi, Trang, Pattani, Phatthalung, Satun, Songkhla, Yala, Narathiwat</td>
<td>sugarcane</td>
<td>rice, coconut, coffee, para-rubber, fruit trees, cattle, buffaloes, marine fisheries</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture and Cooperatives (63).
products, and (4) transportation linkages among regions, and between regions and the export port.

There are 113.80 million rai of agricultural land in Thailand, or 35 percent of the total area. Forest land occupies 26 percent, and the rest (39 percent) is classified as other land (31). Based on land use criteria, the agricultural land use patterns have been classified as paddy field, upland crop area, land under permanent crops, vegetable and flower, pasture, housing area, idle land, and other land. The share of each type of land use is shown in Table 3.2. The table shows that paddy field dominates the land use in regions 1 through 6. The second largest use of agricultural land (except region 7) is devoted to upland crops. Table 3.2 also shows that idle land exists, and it can be used for agricultural production purposes. This land may be used to produce energy crops. Specific characteristics of each region are presented below.

1. **Region 1: Extreme North**

Region 1 is located in the extreme north. Its topography is a mixture of level land and very hilly land. A total of 8.857 million rai of the agricultural farmland are included in the region. The average farm size is 13 rai, the smallest in the whole kingdom (31).

Sugarcane is the only energy crop produced in region 1 (Table 3.3). Five sugar mills are located within this
Table 3.2: Agricultural Land Holding by Region, Thailand, 1977

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(1,000 rai)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paddy field</td>
<td></td>
<td>6,220</td>
<td>11,143</td>
<td>21,715</td>
<td>12,948</td>
<td>4,110</td>
<td>10,448</td>
<td>4,912</td>
<td>71,496</td>
</tr>
<tr>
<td>Upland crop area</td>
<td></td>
<td>1,761</td>
<td>6,569</td>
<td>4,848</td>
<td>4,202</td>
<td>2,869</td>
<td>2,892</td>
<td>94</td>
<td>23,325</td>
</tr>
<tr>
<td>Land under permanent cropsa/</td>
<td></td>
<td>374</td>
<td>443</td>
<td>235</td>
<td>170</td>
<td>960</td>
<td>992</td>
<td>6,911</td>
<td>10,085</td>
</tr>
<tr>
<td>Vegetable and flower land</td>
<td></td>
<td>40</td>
<td>51</td>
<td>59</td>
<td>17</td>
<td>17</td>
<td>15</td>
<td>25</td>
<td>333</td>
</tr>
<tr>
<td>Idle landb/</td>
<td></td>
<td>81</td>
<td>121</td>
<td>1,541</td>
<td>353</td>
<td>280</td>
<td>124</td>
<td>603</td>
<td>3,103</td>
</tr>
<tr>
<td>Pasture</td>
<td></td>
<td>2</td>
<td>39</td>
<td>138</td>
<td>67</td>
<td>7</td>
<td>47</td>
<td>324</td>
<td></td>
</tr>
<tr>
<td>Housing areae/</td>
<td></td>
<td>309</td>
<td>364</td>
<td>618</td>
<td>367</td>
<td>157</td>
<td>426</td>
<td>451</td>
<td>2,692</td>
</tr>
<tr>
<td>Other landf/</td>
<td></td>
<td>70</td>
<td>162</td>
<td>435</td>
<td>581</td>
<td>467</td>
<td>378</td>
<td>353</td>
<td>2,446</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>8,857</td>
<td>18,982</td>
<td>29,589</td>
<td>18,705</td>
<td>8,882</td>
<td>15,393</td>
<td>13,396</td>
<td>113,804</td>
</tr>
</tbody>
</table>

(Percent)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy field</td>
<td></td>
<td>70</td>
<td>59</td>
<td>73</td>
<td>69</td>
<td>46</td>
<td>68</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Upland crop area</td>
<td></td>
<td>20</td>
<td>35</td>
<td>16</td>
<td>23</td>
<td>33</td>
<td>19</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Land under permanent cropsa/</td>
<td></td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>11</td>
<td>6</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Vegetable and flower land</td>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Idle landb/</td>
<td></td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Pasture</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Housing areae/</td>
<td></td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Other landf/</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture and Cooperatives (31).

a/ Area which was devoted to orchard and trees which are over one year of age, e.g., coconuts, rambutan, durian, para-rubber, etc.
b/ Area which is not utilized.
c/ Area which was devoted to houses, storage, pond, farm building and area around the houses.
d/ Area which was devoted to roads, cartway, fish pond, watering place, etc., and was not included in above categories.
### Table 3.3: Use of Cultivated Land for Specific Crops by Region, Thailand, Crop Year 1978/79

<table>
<thead>
<tr>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1,000 rai)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>654</td>
<td>5,672</td>
<td>716</td>
<td>1,332</td>
<td>98</td>
<td>166</td>
<td>23</td>
<td>8,661</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>168</td>
<td>234</td>
<td>273</td>
<td>15</td>
<td>584</td>
<td>1,916</td>
<td>--</td>
<td>3,190</td>
</tr>
<tr>
<td>Cassava</td>
<td>--</td>
<td>150</td>
<td>1,792</td>
<td>2,419</td>
<td>1,742</td>
<td>204</td>
<td>--</td>
<td>6,313</td>
</tr>
<tr>
<td>Rice</td>
<td>5,074</td>
<td>9,674</td>
<td>18,463</td>
<td>9,358</td>
<td>3,279</td>
<td>8,603</td>
<td>3,959</td>
<td>58,410</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>311</td>
<td>2,113</td>
<td>28</td>
<td>45</td>
<td>12</td>
<td>86</td>
<td>43</td>
<td>2,638</td>
</tr>
<tr>
<td>Soybeans</td>
<td>565</td>
<td>373</td>
<td>37</td>
<td>3</td>
<td>7</td>
<td>25</td>
<td>--</td>
<td>1,010</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>305</td>
<td>79</td>
<td>48</td>
<td>93</td>
<td>97</td>
<td>9</td>
<td>2</td>
<td>660</td>
</tr>
<tr>
<td>Cotton</td>
<td>46</td>
<td>168</td>
<td>50</td>
<td>91</td>
<td>45</td>
<td>29</td>
<td>--</td>
<td>429</td>
</tr>
<tr>
<td>Kenaf</td>
<td>3</td>
<td>9</td>
<td>1,203</td>
<td>759</td>
<td>29</td>
<td>--</td>
<td>--</td>
<td>2,003</td>
</tr>
<tr>
<td>Total</td>
<td>7,126</td>
<td>18,472</td>
<td>22,610</td>
<td>14,115</td>
<td>5,893</td>
<td>11,038</td>
<td>4,060</td>
<td>83,314</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>(Percent)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>9</td>
<td>31</td>
<td>3</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>10</td>
<td>17</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cassava</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>17</td>
<td>29</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rice</td>
<td>71</td>
<td>52</td>
<td>82</td>
<td>66</td>
<td>56</td>
<td>78</td>
<td>98</td>
<td>0</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>4</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Soybeans</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cotton</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kenaf</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture and Cooperatives (29).
region, and an alcohol plant has been proposed. The energy source recommended for alcohol processing is bagasse.

Other major upland crops produced in the region are corn, mungbeans, soybeans and groundnuts. Fifty-six percent of total soybean planted area in the kingdom and forty-six percent of total groundnut planted area in the country are from this region (29). Hence, they are the main non-energy crop competitors for the upland area.

The climate in the region is dry in winter (November, December, January and February) and rainy in summer (July, August, September and October). The temperature in the coldest month is below 6 degrees C, the lowest in the country. The mean annual temperature lies between 23 degrees C and 25 degrees C. The annual rainfall ranges between 1,000 to 2,200 mm (29).

Chiangmai is the largest city in this region, and is the second largest city in Thailand. The second international airport is also located in this city. Chiangmai, therefore, is the most appropriate energy consumption center in region 1.

2. **Region 2: North Central**

Region 2 is located in North Central Thailand. There are three modes of transportation between this region and Bangkok. A highway, connecting Bangkok with region 1, and a railway both pass through this region. Also, four rivers
from the north join together in Nakhonsawan Province in this region, forming an important river route through Bangkok to the Gulf of Thailand. The river not only provides the main source of irrigation water for farmers in this region and region 6, but also becomes an important transportation route between region 2 and Bangkok.

Region 2 has a mixture of level and hilly land. Two energy crops, cassava and sugarcane, are produced here. Corn and mungbeans are important crops in this region, accounting for 65 and 80 percent of the total planted area in the country for these crops (Table 3.3). Three sugar refineries are located in the region. The energy source available to produce alcohol from cassava is casuarina junghuhniana (wood). Nakhonsawan Province is a big regional consumption center.

3. Region 3: Northern Part of Northeast

Region 3 is located in the northern part of northeast Thailand. There is a highway going from Bangkok through region 4 to this region. Khonkean Province, in zone 3, is the most important city. It is an important collecting point for agricultural products before they are shipped to Bangkok for export. Khonkean Province, therefore, is chosen as a consumption center for this region.

Land quality in this region is considered to be the poorest in the country. Lack of water is another problem
faced by farmers in the region. However, the area planted
to cassava is the second largest (28 percent) of total
cassava area planted in the country. It occupies 8 percent
of the total cultivated land in the region. This region
also produces significant amounts of corn (8 percent of
total corn planted area) and sugarcane (9 percent of total
sugarcane planted area). Four sugar mills are located here
and an alcohol plant has been proposed for this region.
Casuarina junghuhniana (wood) and bagasse may be used as
energy sources for the alcohol plant.

Region 3 has the largest number of farms, 1.097
million. The average farm size is 27 rai, which is near the
national average (26 rai) [31].

4. **Region 4: Southern Part of Northeast**

Region 4 is located in the southern part of the
northeast. Agricultural crop production patterns are simi-
lar to region 3. However, the soil is more fertile. It is
the most important cassava producing region (38 percent of
total cassava area planted). Corn is another important
crop. It is second in area planted (15 percent) in the
country. However, only one sugar refinery is located within
the region, resulting in only a small amount of sugarcane
being produced. The energy source available for producing
alcohol for cassava is casuarina junghuhniana (wood).
Nakhonratchasima Province, in zone 5, is the biggest city and the most important collecting point for agricultural products. This study will use it as a consumption center.

5. Region 5: East

Region 5 is located in the east of Thailand. It is close to Bangkok and connected to the Gulf of Thailand. It has a mixture of level and hilly land. A total of 8.882 million rai of agricultural farmland are included in this region. This land is used as paddy fields (42 percent), upland crop area (32 percent), land under permanent crops (11 percent), and other land uses (15 percent) (Table 3.2).

Sugarcane area in this region is the second largest (18 percent) in the country. Nine sugar mills are located in the region. Cassava is another major energy crop produced. It occupies 30 percent of the cultivated land in region 5. Presently, cassava production is sold to factories in the region which produce shredded cassava, flour, and pellets for exports. Some mechanization and hired labor are used to produce sugarcane and cassava. The region has experienced a labor shortage during sugarcane and cassava harvesting seasons. The average farm size is 38 rai, the largest in the country.

Two alcohol plants will be built, and they plan to produce alcohol from sugarcane and cassava. The cassava alcohol can be produced using casuarina junghuhniana (wood) as
an energy input. Chonburi Province is a small regional consumption center located within the region. However, Bangkok can be considered as an alternative consumption center.

6. Region 6: Central Plain

Region 6 is located in the central plain. It contains around 60 percent of the total sugarcane planted area in Thailand. Twenty-three sugar refineries are in the region. Most of them are located along the Mae Klong River in zone 12. Also, rice is another major crop produced in the region. The land is level and mechanization is also used for some rice and sugarcane production. The farms hire more labor than other regions and have experienced labor shortages in past sugarcane harvesting seasons. The land in some part of this region is too wet for upland crops, thus it can be used only for rice production.

A sugarcane based alcohol plant will be built to produce alcohol totaling 0.375 million liters per day. Another energy crop produced is cassava. It is expected that natural gas being produced in the south, region 7, will be delivered to this region. Therefore, it may be a major energy source, other than casuarina junghuhniana (wood), for producing alcohol from cassava.

Bangkok, the capital of Thailand, is located in this region. It is the biggest food and energy consumption center in the country. It is also the export and import
center. It is the hub of the transportation system linked to the northeast, the north, the east and the south of Thailand.

7. Region 7: South

Region 7 is located in the south of Thailand. The western side lies along the Indian Ocean, and the eastern side is open to the Gulf of Thailand. It has land types and climatic conditions that are suitable for growing para-rubber which has been one of the major export crops. The other crop is rice which uses up 98 percent of the cultivated land in region 7. However, it is the only region that consumes more rice than it produces (30).

Although there is no significant amount of energy crops produced in the region, it is an important region and should be included in the study. It has to import rice from other regions. It may be an alcohol importer from other regions. It also is a major exporter of natural gas to region 6. Nakhonsithammaret is considered to be the consumption center in this region.
CHAPTER IV
THEORY, METHODS, AND PROCEDURES

This chapter is divided into four parts. In the first part, a theoretical discussion of the effects of alcohol production on agricultural output, consumption, and trade is presented. The second part discusses a conceptual structure of crop and alcohol production systems. The system includes: agricultural production, energy crop processing, alcohol and crop consumption, and agricultural commodity and alcohol exports. The third part deals with the mathematical model formulation. Linear programming models are used. The models maximize the objective functions subject to sets of linear constraint functions. A description of the objective and constraint functions are presented in the fourth part.

1. Theoretical Framework

The purpose of this part is to explain theoretically how alcohol production affects agricultural output, consumption and exports. To simplify the analysis it is assumed that only energy crops and food crops are produced. Perfect competition is assumed for agricultural production and marketing. Total resource supplies are fixed but can be
shifted between crops. Under this situation farmers compete with each other for factors of production, land, labor and capital. Each farmer can control a set of production factors, and he uses these factors in the most efficient manner to maximize his profits. Farmers are price takers, and the prices paid or received by them are determined by market demand and supply forces. It is assumed that perfect competition exists in the export market. Exporters' demand is downward sloping. Transportation costs and trade barriers are assumed not to exist for simplicity of this theoretical analysis.

Under the above situation the increase in demand for energy crops, resulting from alcohol production, can cause changes in prices and quantities of energy crops and food crops produced, consumed, and exported. This is illustrated in Figures 4.1 and 4.2. Before alcohol fuel is produced, equilibrium prices and quantities of energy and food crops are $Q^6_o$, $P^6_o$ and $Q^f_o$, $P^f_o$, while equilibrium export prices and quantities of energy and food crops are $Q^1_o$, $P^1_o$ and $Q^{11}_o$, $P^{11}_o$ respectively. The alcohol production shifts the demand for energy crops to the right, from $D^6_o$ to $D^1_o$, and shifts supply of energy crop export to the left, from $S^1_o$ to $S^{11}_o$. The energy crop price increases to $P^1_e$, which is equal to $P^{11}_1$ in the energy crop export market. Ceteris paribus, farmers respond to the higher price by producing more energy crops from $Q^6_o$. 
Figure 4.1: Energy Crop Domestic and Export Market Equilibrium.

Figure 4.2: Food Crop Domestic and Export Market Equilibrium.
to $Q^e_1$. As a result, less food crop is produced ($Q^f_o$ to $Q^f_1$), less food crop is exported ($Q^{11}_o$ to $Q^{11}_1$), and food price increases from $P^f_o$ to $P^f_1$ or food export price increases from $P^{11}_o$ to $P^{11}_1$. The increase in food price will induce farmers to produce more food crops (more food crop export) and less energy crops (less energy crop export). The new equilibria in energy and food crop domestic and export markets are ($Q^e_2$, $P^e_2$), ($Q^f_2$, $P^f_2$), ($Q^1_2$, $P^1_2$) and ($Q^{11}_2$, $P^{11}_2$) respectively. The post-alcohol production shows that more energy crops ($Q^f_o$ to $Q^f_2$) and less food crops ($Q^f_o$ to $Q^f_2$) are produced, more energy crops (a to b) and less food crops (c to d) are consumed, and less energy crops ($Q^1_o$ to $Q^1_2$) and food crops ($Q^{11}_o$ to $Q^{11}_2$) are exported. Both food crop and energy crop prices increase. The above analysis implies that the decreases in cassava (energy crop) export to EEC, and sugar export, as limited by ISA, are satisfied by the increase in alcohol production.

2. Conceptual Framework of Crop and Alcohol Production Systems

The conceptual framework of crop and alcohol production systems includes agricultural production; crop and alcohol transportation; energy crop processing; crop and alcohol demands or consumption; and crop and alcohol exports.

2.1. Agricultural Production

Food crops and livestock are produced in all regions of Thailand. Energy crops are produced in regions 1 through 6.
Agricultural production patterns may change following the implementation of the alcohol program, as shown earlier. In addition, the government can use some policies to stimulate energy crop production. The possible policies are subsidies paid directly to farmers in the purchase of agricultural inputs such as fertilizer, support prices for energy crops, and concessional agricultural credit.

Land and labor are the limiting resources, while all other resources are unconstrained. Resource prices are determined internally by the models. The energy input price is adjusted in line with alcohol output price within the models.

2.2 Transportation

Although alcohol plants are located near the energy crop production areas, energy crops have to be transported to the plants. Energy inputs from outside or within the region need to be shipped to the alcohol distilleries. Alcohol fuels produced are also sent to the consumption centers in each region, and from the production surplus regions to the production deficit regions and to the export port.

Energy and non-energy crops are not produced in sufficient quantities to meet demands in all regions. In some regions surpluses are produced. Transportation activities allow these crops to be shipped from surplus to deficit regions and to the export port. This study assumes that trucks are the only transportation mode for all commodities
discussed above. The capacity of a truck is determined and fixed. The transportation costs include loading, unloading, operating costs, and energy consumption in diesel oil equivalents. The costs are categorized as non-energy and energy costs. Prices for non-energy items are assumed to be determined in competitive markets and fixed. Energy costs are calculated by using the energy prices that are set (and adjusted) with alcohol output prices within the models.

2.3. Alcohol Production

Alcohol is produced from three possible energy sources—sugarcane, cassava, and sweet sorghum. Sugarcane is processed and transformed into alcohol and sugar products. It is possible to produce alcohol directly from sugarcane (Figure 4.3) or from molasses, which is a by-product of the sugar production process (Figure 4.4). Under free market conditions, the quantity of sugar and alcohol produced are determined by their relative prices. However, government policy intervention may set the minimum quantity of sugar produced for domestic consumption and the maximum amount of sugar exported to equal the quota allocated by ISA.

Cassava and sweet sorghum processes are different from the sugarcane process because no major competing products exist at the processing stage. Nevertheless, there are other alternative commercial uses for these crops. Cassava is a major crop export to the EEC, while sorghum can be used
Figure 4.3: Simplified Process Flow Diagram of Alcohol Production from Sugarcane/Sweet Sorghum Juice.

Source: Mattuella, Juvir L. (20).
Figure 4.4: Simplified Process Flow Diagram of Sugar and Alcohol Production from Molasses.

Source: Mendes, Luiz G. (21).
to feed animals. Thus, the decision to direct these crops for alcohol production is dependent on relative prices. The price of alcohol less its production costs has to be equal to or greater than the prices of these products for alternative commercial uses to induce alcohol production. The alcohol production processes for cassava and sweet sorghum are shown in Figures 4.3 and 4.5.

2.4. Consumption

Energy and non-energy crops are consumed in all regions. In the theoretical discussion earlier, it was indicated that under competitive situations, alcohol production can affect consumption levels for these crops. The changes in consumption of these crops depend on their demand and supply elasticities and shift their demand and supply curves. However, government intervention may set a minimum consumption for these crops in each region.

At the consumption centers, alcohol can be consumed in two forms: gasohol and pure alcohol. Gasohol is formed by blending alcohol with gasoline at the rate of 20:80. This study also allows alcohol to be substituted for 100 percent of gasoline consumption. Although pure alcohol and gasohol can be substituted for gasoline, their consumption depends on their prices compared to the price of gasoline. The high price of alcohol due to high costs of alcohol production can cause the pure alcohol and gasohol prices to be higher than
Figure 4.5: Simplified Process Flow Diagram of Alcohol Production from Cassava.

Source: Adams, Reinaldo I. (1).
the gasoline price. Government policy intervention may subsidize the alcohol production so that it can compete with gasoline. Other forms of subsidies to alcohol consumers are lower interest rates and long term repayment to finance the purchase of alcohol cars, and cheaper annual certificate of registration costs for driving alcohol cars.

This study assumes that (1) consumers are utility maximizers and price takers, (2) gasoline and gasohol are perfect substitutes, (3) pure alcohol can be substituted for gasoline at the rate of 1.2:1, (4) energy market structure is constant, and (5) the excess production of alcohol can be sold to Japan.

2.5 **Crop and Alcohol Exports**

Thailand exports a substantial amount of both energy and non-energy crops. Export activities are included in the model to allow the production surplus of these crops to be exported. The export demands for these crops are also incorporated into the crop demand model. This provides the export prices and quantities to be affected by alcohol production. Another way to incorporate the energy and non-energy crop export demands into the fixed point demand model is to assume that these crops are exported at fixed prices, i.e., they have perfectly elastic export demand schedules (small country assumption). In this case alcohol production affects the quantities of crop exports only.
As discussed in Chapter II, strong export markets have been a key factor in the rapid expansion of cassava and sugar production and exports. Nevertheless, these crop exports have been restricted in recent years. Under a competitive market situation, cassava and sugar exports can decrease as a result of an increase in alcohol production. Maximum amounts of cassava and sugar exports can also be set in the model.

Alcohol export activity is also included in the models. This allows alcohol to be exported to Japan if such export is feasible. Japan imports a substantial amount of alcohol each year. The possibility that Thailand can export alcohol to Japan depends on competition with other exporting countries and the amount of Japanese alcohol imports. Japan is also a major petroleum and gasoline importer. The model allows alcohol fuel exports from Thailand to Japan if its price can compete with Japanese gasoline import prices.

3. Model Formulation

Two different modified linear programming models are used. The first model (A) is the fixed point demand model. This model has been extensively used and largely discussed by Heady and Canler (75), Beneke and Winterhoer (76), Dorfman et al. (77) and Dantzig (78). The second model (B) was modified by Duloy and Norton (67) to incorporate a demand function in the basic linear programming model.
Duloy and Norton have applied this model to Mexican agriculture.

**Model A: Fixed Point Demand Model:** The mathematical form of this model can be expressed as follows:

\[
\begin{align*}
\text{Max. } Z &= \sum_{i=1}^{7} p_i Q_i + \sum_{i=1}^{7} r_i Y_i - \sum_{i=1}^{7} c_i X_i - \sum_{i=1}^{7} d_i S_i - \sum_{i=1}^{7} e_i T_i - \sum_{i=1}^{7} f_i Y_i \\
&- \sum_{i=1}^{7} \tau_i Q_i
\end{align*}
\]

Subject to

\[
\begin{align*}
A_i X_i &\leq R_i \\
B_i X_i &\geq Q_i + T_i \\
C_i S_i &\leq T_i \\
D_i S_i &\geq Y_i \\
Q^u &\geq Q \geq Q^l \\
Y^u &\geq Y \geq Y^l \\
S, Q, X, Y &\geq 0
\end{align*}
\]

where: 
- \( Z \) = objective function,
- \( i = 1, 2, \ldots, 7 \) (regions) and export port for products \( Q \) and \( Y \),
- \( Q \) = vector of agricultural products except those that are used as raw materials in processing activities,
- \( p \) = vector of domestic and export prices for agricultural products,
- \( Y \) = vector of processed products,
- \( r \) = vector of domestic and export prices for processed products,
$X =$ vector of agricultural production activities,
$c =$ vector of production costs for agricultural production activities,
$S =$ vector of energy crop processing activities,
$d =$ vector of costs for energy crop processing activities,
$T =$ vector of raw materials transported from farms to processing plants,
$e =$ vector of transportation costs for raw materials transported from farms to processing plants,
$f =$ vector of transportation costs for processed products,
$t =$ vector of transportation costs for agricultural products,
$A =$ matrix of technical coefficients for agricultural production activities,
$R =$ vector of land and labor resources,
$B =$ vector of agricultural products per unit of agricultural production activities,
$C =$ matrix of technical coefficients for energy crop processing activities,
$D =$ vector of processed products per unit of energy crop processing activities,
Model B: Crop Demand Model: This model is a modification of Model A. Its mathematical form is the following:

\[
\text{Max } U = \sum_{i=1}^{n} W_i + \sum_{i=1}^{n} Y_i - \sum_{i=1}^{n} c_i X_i - \sum_{i=1}^{n} d_i S_i - \sum_{i=1}^{n} e_i T_i - \sum_{i=1}^{n} f_i Y_i - \sum_{i=1}^{n} g_i Q_i
\]

Subject to

\[
\begin{align*}
\sum_{i=1}^{n} \alpha_i X_i &\leq R_i \\
B_i X_i &\geq Q_i + T_i \\
C_i S_i &\leq T_i \\
D_i S_i &\geq Y_i \\
S, Q, X, Y &\geq 0
\end{align*}
\]

where: \( U = \text{objective function} \),

\( W = \text{vector of linear approximation of economic surplus} \), and

\( V = \text{vector of linear approximation of gross revenue} \).

It should be noted that the major difference between the two models is their objective functions. The objective
function of Model A is total revenue minus total costs, while the objective function of Model B is the area under the demand curve plus processed products sold minus total costs. The function representing the area under the demand curve is defined as \( W = Q'(a + 0.5bQ)^2 / \), where \( a \) is a vector of demand intercepts, and \( b \) is a negative semidefinite matrix of demand slopes. From this equation, the value of \( W \) can then be computed by substituting the value of \( Q \).

Another difference between Model A and B is that Model B includes income constraint \( \sum_i (\pi V_i - \pi c_i X_i - \pi t_i Q_i) \geq 0 \) in its constraint set. The purpose of this inclusion is to guarantee that a farmer will get total revenue at least equal to total costs. The total revenue function can be written as \( V = Q'(a + bQ) \), which is the product price \( P = a + bQ \) times the quantity sold. Again, the value of \( V \) can be calculated by substituting the value of \( Q \).

4. Description of the Models and Data

This part provides a full description of the models and data used in the analysis. It is divided into four sections. In the first section, agricultural production which includes agricultural commodities, resources, technical coefficients, and production costs is presented. The second section discusses energy crop processing, energy-feedstocks, energy-fuels, and energy-utilization.
output, and processing costs. The third section describes transportation activities and costs. The fourth section presents agricultural product and alcohol consumption, exports, and prices, and the procedure used to estimate the demand for agricultural commodities.

4.1. Agricultural Production Activities

Commodities: Agricultural products included in the models are corn, cassava, sugarcane, rice, sweet sorghum, sorghum, soybeans, mungbeans, groundnuts, cotton, kenaf, vegetables and flowers, other crops, cattle, buffaloes and casuarina junghuhniana (wood). Permanent crops which have over one year of age such as coconuts, para-rubber, and fruits, are not included in the models. Other livestock production such as pork, chicken, egg, and dairy production activities are also excluded from this study. But, quantities of crops used in these livestock production are included in the domestic crop consumption.

Sweet sorghum is not commercially grown in Thailand. The purpose of including it in the models is to test its potential as an energy crop. Vegetables and flowers are grouped together because they have similar techniques of production and use the same land resource. Minor crops are classified as other crops. They include sesame, castor beans and tobacco. All commodities except rice are considered as produced once a year. Rice in the irrigated area can be grown in the wet and dry seasons.
Land: Cropland used in the model is obtained by subtracting housing areas, roads, cartways, fish ponds, watering places, and land under permanent crops from total agricultural land. The cropland is classified into 7 categories. They are upland crop areas, irrigated paddy land for single cropping (wet season), irrigated paddy land for multiple cropping (wet and dry seasons), ordinary paddy land, vegetable and flower land, pasture, and idle land. Land is a constraint resource in the models. Data on land by type and region are shown in Table A.2 in Appendix A.

Upland crops are grown in both upland crop areas and irrigated land. Ordinary paddy land, which is calculated by subtracting irrigated paddy land from total paddy land, is used for growing rice only. This type of land cannot be used to grow upland crops because it has too much water in the wet season and too little water in the dry season. In the base models, cattle and buffaloes are allowed to use idle land instead of pasture land. This represents the fact that farmers sometimes raise their buffaloes and cattle on idle land. In one model, idle land is made available for crop production to test crop and alcohol production response to an increase in available cropland.

Labor: The labor resource used in this study is that of an economically active agricultural labor force between the ages of 15-65. Labor for forestry and fishing is excluded. Labor is measured in man-days and is considered
mobile within the region but immobile among regions. Farm labor is calculated by assuming that a worker works 25 days per month and 8 hours per day (definition used in the National Crop Model). Labor is a restricted resource in the models. Data on labor resource in 1981 and the projected labor resource in 1986 are shown in Table A.2 in Appendix A.

**Energy:** Energy input for agricultural commodity production is considered to be an unrestricted resource in the models. The energy components of all inputs except land and labor are converted to liters of diesel oil equivalents. The total energy input is composed of direct and indirect energy use. The energy used directly in the production process is gasoline, diesel oil, combustible oil, and nitrogen fertilizers. The energy used in machinery production, insecticides, herbicides, etc., is classified as indirect energy use. By using the information in Table A.1 in Appendix A, direct and indirect energy use is converted to liters of diesel oil equivalents.

**Technical Coefficients and Production Costs:** Technical coefficients and production costs for each crop in each region are shown in Tables A.3 through A.9 in Appendix A. Labor and energy inputs for each commodity production are per unit of land (rai). The data used to calculate these inputs are from the Ministry of Agriculture and Cooperatives and a field survey by the author. The inputs used vary from crop to crop and from region to region. Output per rai
(yield) for each commodity is the five-year average for the period 1977-1981. Labor and energy inputs and output per rai of each crop are considered to be the same for all types of land.

Costs of production for each crop are also calculated based on a unit of land (rai). The total production costs are divided into two groups: energy and non-energy costs. Energy costs are determined by the prices given to the energy inputs, which are allowed to vary when alcohol production and price change. Labor costs are in the non-energy cost category. Due to lack of costs of production data for other crops, vegetables, flowers, cattle, and buffaloes, it was assumed that the prices of these commodities are equal to their costs of production. Production costs per rai of each crop are also considered equal for all types of land.

4.2. Processing Activities

Sugarcane, cassava, and sweet sorghum are processed into sugar and alcohol as major products; stillage and bagasse are the residuals. There are five types of processing activities included in this study. They are: (1) sugar production primarily, with some alcohol produced from molasses with bagasse as the energy input; (2) alcohol production only from sugarcane, using bagasse as the energy input; (3) alcohol production from cassava as raw material
using casuarina junghuhniana (wood) as the energy source; (4) alcohol production from sweet sorghum stems, using bagasse as the energy source; and (5) alcohol production from sugarcane and cassava, using bagasse and wood as the energy sources. The capacity of processing plants is considered fixed at 150,000 liters of alcohol production per day for the first three types of processing activities. The capacity of the plants for sorghum processing and sugarcane/cassava processing are 120,000 and 66,000 liters of alcohol production per day, respectively. It is also assumed that sugarcane processing plants operate 150 days per year, while other crop processing plants operate 300 days.

Total processing costs are categorized as non-energy costs and energy input in liters of diesel oil equivalents. These costs are considered to be the same for all regions. All by-products of energy crop processing are excluded from the models. The input/output coefficients and non-energy costs for these energy crop processing activities are presented in Table A.10 in Appendix A.

**4.3. Transportation Activities**

All transportation activities included in the models can be summarized as follows: energy crops transported from farms to distilleries; alcohol shipped from distilleries to consumption centers; crops and alcohol transported among
regions; and crops and alcohol shipped to the export port. Non-energy costs and energy input requirement for these activities were calculated and are presented in Tables A.11 and A.12 in Appendix A.

4.4. Marketing Activities

Alcohol Consumption, Exports and Price: Two alternative maximum levels of alcohol demand are specified in each region in the two models. They are blended and pure alcohol demand capacities. The blended alcohol demand capacity is considered to substitute for 20 percent of gasoline demand in each region, while the pure alcohol demand substitutes for 120 percent of annual gasoline consumption. The two models also allow alcohol produced in each region to be exported to Japan if it is economically viable. Both alcohol wholesale and export prices were computed and are parameterized at various levels in the analysis.

Agricultural Consumption, Exports and Prices: In the fixed point demand model (A) the amounts of all crops (except vegetables, flowers, other crops, cattle, and buffaloes) consumed in each region are restricted to actual consumption in 1981. The consumption of vegetables, flowers, other crops, cattle and buffaloes is assumed equal to regional production because of lack of data on consumption of these commodities. Consumers are assumed to buy all commodities at farm prices in the same year. Crops are
exported at Bangkok wholesale prices. The maximum amount of each crop exported is also fixed at the actual export level in 1981. Data on regional consumption, exports and prices are presented in Tables A.13 and A.14 in Appendix A.

Demand for Agricultural Products: The fixed consumption and maximum exports in the fixed point demand model (A) were replaced by domestic and export crop demands in the crop demand model (B). Because of the unavailability of exporters' demand equations for agricultural products at the Bangkok wholesale price level in Thailand, the estimation of demand functions in this study used Mattuella's procedure (46), which is as follows:

a) It is assumed that the quantity demanded for a specific product is determined solely by its own price and that these price-quantity relationships can be expressed by a linear function in the form of: $Q = a + bP$.

b) Using available data on demand-price elasticity and the average price and quantity, the slope and intercept of the export demand equation at the Bangkok wholesale price level can be determined as follows:

$$E = \frac{\delta Q}{\delta P} P^*; \quad \frac{\delta Q}{\delta P} = EQ^* = b$$

and $a = Q^* + bP^*$

where: $E =$ demand-price elasticity at Bangkok wholesale price level,

$P^* =$ average price at Bangkok wholesale price level,
Q* = average quantity at Bangkok wholesale price level,

b = demand slope,

a = demand intercept.

The estimation of regional demand for agricultural products at the farm level also follows the above two steps, with the exception that average price, quantity, and price elasticity are at the farm level. George and King's method was used to derive the elasticity at the farm level from the elasticity at the Bangkok wholesale price level. It assumes constant absolute spread between the Bangkok wholesale and farm prices. Then, the elasticity at the farm price level is obtained as a product of elasticity at the Bangkok wholesale price and the proportion of farm price and the Bangkok wholesale price. This can be represented mathematically as:

\[ E_{ij} = e_{ij} \frac{p_{ij}^f}{p_{ij}^w} \]

where:

- \( E_{ij} \) = demand-price elasticity of commodity \( J \) at farm price level,
- \( e_{ij} \) = demand-price elasticity of commodity \( J \) at Bangkok wholesale price,
- \( p_{ij}^f \) = farm price of commodity \( J \), and
- \( p_{ij}^w \) = Bangkok wholesale price of commodity \( J \).

Data on demand elasticities at Bangkok wholesale prices and the estimated export and regional demand equations are presented in Tables A.15, A.16 and A.17 in Appendix A.
CHAPTER V
EMPIRICAL ANALYSIS

This chapter is divided into two main parts. In the first part the eleven models used in the empirical analysis are described. The model analysis is presented in the second part. This includes the results and forecasts of alcohol production and distribution in 1981 and 1986; the viability of alcohol production from alternative crops; regional location of alcohol plants; the impact of alcohol production on other agricultural commodity production, consumption, exports, prices and land use; the feasibility of alcohol export to Japan; and the impact of alcohol production on agricultural exports to Japan.

1. Model Description

Eleven specific models were developed. They are identified by letters A through K. Each model represents a different agriculture situation and policy alternative for the development of an alcohol production program. These situations and policy alternatives are: fixed crop output levels and prices; variable crop output levels with prices and quantities determined by demand and supply in the free market; two levels of alcohol demand; three alternative
energy crops; increased cropland availability; and alcohol production based on 1986 demand projections for agricultural commodities.

Models A (fixed demand) and B (variable demand) are base models. Models C through K include alcohol production and were parameterized at various energy price levels—including both diesel retail price and alcohol wholesale price; the parameterization is based on energy prices in 1981. The current price of diesel is the retail price at the consumption center of each region. The wholesale price of alcohol at each consumption center was calculated by adding the ex-refinery price of gasoline (assuming that alcohol and gasoline are perfect substitutes) and the transportation cost from the refinery to the consumption center. The price of alcohol exported to Japan was computed by assuming that the ex-refinery prices of gasoline in Thailand and Japan are equal; thus, the alcohol export price is the ex-refinery price minus the transportation cost between Thailand and Japan. Results of the calculation are shown below.

<table>
<thead>
<tr>
<th>Region</th>
<th>Alcohol Wholesale Price (baht/liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.99</td>
</tr>
<tr>
<td>2</td>
<td>7.13</td>
</tr>
<tr>
<td>3</td>
<td>7.50</td>
</tr>
<tr>
<td>4</td>
<td>7.15</td>
</tr>
<tr>
<td>5</td>
<td>6.64</td>
</tr>
<tr>
<td>6</td>
<td>6.67</td>
</tr>
<tr>
<td>7</td>
<td>8.51</td>
</tr>
<tr>
<td>Export</td>
<td>5.80</td>
</tr>
</tbody>
</table>
In developing all eleven models plus the energy price parameterization of Models C through K, a total of 61 runs were made. Each of the eleven models is described below.

1.1. Model A (Fixed Demand)

This is a base model developed to represent the agricultural production, consumption and trade situation in 1981. Seven types of available land, including idle land, were incorporated in the model. However, the only use permitted for idle land was cattle and buffalo production.

Thirteen primary agricultural products (corn, cassava, sugarcane, rice, sorghum, soybeans, mungbeans, groundnuts, cotton, kenaf, cattle, buffaloes, vegetables and flowers) and two processed products (sugar and alcohol) were included in the model. Crops in the model are not energy suppliers and the only alcohol production is from molasses, a by-product of sugar production. The above commodities are not produced in all seven regions. Therefore, transportation linkages were incorporated to allow these commodities to flow among regions and to the export port.

Lower limits for cassava and sugarcane production were included so that sugar and cassava factories would not be kept idle in the short run due to lack of raw materials. Sugar production is limited to current mill capacity. An upper limit for export of each crop was also set.

Domestic consumption of the commodities in the model was fixed at the 1981 consumption levels. Thus, consumption
demand is not affected by implementation of the alcohol plan. This condition is relaxed in Model B.

1.2. **Model B (Variable Demand)**

Model B is a second base model with the same basic structure as Model A, except that demand schedules were substituted for fixed quantities of some commodities in Model A: corn, rice, soybeans, mungbeans, groundnuts, cotton, kenaf, and sugar. The demand schedules were computed at the farm level, except for sugar, which was computed at the sugar mill level. Export demand schedules for corn, cassava, rice, mungbeans, kenaf, and sugar were also incorporated into the model. These demands were calculated at Bangkok wholesale price levels.

This model allows the domestic and export demands and prices to be determined endogenously by the model. Domestic crop demands can decrease to the minimum limits (lower bounds of demand curves), while exports can be reduced to zero.

1.3. **Models C and D (Blended Alcohol Consumption)**

Models C and D are modifications of Models A and B, respectively. Both models feature molasses, cassava and sugarcane as energy-feedstocks, and both include casuarina junghuhniana, a wood crop which is used to fuel cassava alcohol distilleries. Alcohol transport costs between regions and to the export port were also incorporated into
the models. Alcohol demand capacity for the consumption center in each region was restricted to 20 percent of the gasoline consumption in 1981. However, an unlimited amount of alcohol export to Japan was allowed if export was feasible.

The only difference between these two models is that Model C allows only the quantities of crop exports to be affected by the increase in alcohol production, while Model D allows domestic crop consumption, exports and prices to adjust to the new equilibrium.

Energy prices—diesel price at retail levels and alcohol wholesale price—were parameterized at the following levels for both models: current price, +5 percent, +10 percent, +15 percent, and +20 percent above current prices.

1.4. Models E and F (Pure Alcohol Consumption)

The basic structures of Models E and F are the same as Models C and D respectively, with the exception that gasoline in all consumption centers in 1981 was allowed to be replaced completely by alcohol. Since pure alcohol is only about 80 percent as efficient as gasoline, the total pure alcohol fuel consumption was assumed to be 20 percent more than the total gasoline consumption. However, as alcohol production increased, the models would blend alcohol with gasoline at the rate of 20:80; then, if alcohol production increased further, they would allow consumption of pure alcohol.
alcohol. In other words, as the demand for pure alcohol increased, the demand for blended alcohol would decrease. Finally, if the supply of alcohol increased still more, all cars would convert to pure alcohol fuel, and the excess supply of alcohol would be exported to Japan. Again, an unlimited amount of alcohol was allowed for export.

Energy prices of Models E and F were parameterized at seven levels, as follow: current price, +10 percent, +20 percent, +30 percent, +40 percent, +50 percent, and +60 percent above current prices.

1.5. Models G and H (Alternative Energy Crops)

Models G and H have the same characteristics as the fixed demand model (A) with the following alternative sources of energy; G, sugarcane and molasses only; and H, sweet sorghum and molasses only. In formulating Model H, both alcohol and sorghum grain selling activities were included. The sorghum grain is assumed to have the same value as corn and the grain can be sold for domestic consumption; sorghum stems are used to fuel the alcohol processing plant.

The energy price sensitivity analysis for these two models determines the price levels at which alcohol production from these crops is feasible and the quantity of alcohol that can be produced. The location of the alcohol distilleries for these crops can also be determined. Thus, a comparison between these two models and with Model E can
be made. Seven levels of energy prices are parameterized: +10 percent, +20 percent, +30 percent, +40 percent, +50 percent, +60 percent, and +70 percent above current prices.

1.6. Model I (Increased Cropland)

This model is an extension of Model F, with more land available for crop production. Land typically idle (3 percent of total cropland) is made available only for cattle and buffalo production in the other models. In this model only 2 percent is reserved for idle land. The rest (1 percent or 1.4 million rai) is allowed to be used for crop production. Although there is not much idle land to include in the model, the model is used to determine to what extent the impact of alcohol fuel production on agriculture would be reduced and how much more alcohol can be produced if cropland were increased. The energy prices were parameterized at the same levels as Model F.


The basic structure of these two models is the same as that of Model E. They were formulated to represent the situation of alcohol production in 1986. The specific changes included in the models are: (1) cassava exports (fresh root) decrease to 16 million tons due to anticipated limitation of exports to the EEC; (2) other crop exports increase by 10 percent; (3) domestic crop demand and labor
supply increase in proportion to projected population growth; and (4) crop yields are constant in Model J and increased by 5 percent in Model K. In addition, costs of production of primary and processed products and their prices are assumed to increase at the same rate as inflation. The technical coefficients of primary and processed agricultural activities are assumed to be unchanged. The projected gasoline consumption is used to set the upper limit for pure alcohol demand in the two models. Energy prices were also parameterized at the same levels as those in Model E.

The various models discussed above are summarized in Table 5.1.

2. Model Analysis

This part is divided into six sections. The first section presents alcohol production in 1981, discusses the production of alcohol to fulfill two levels of demand—20 and 100 percent substitution for gasoline—plus alcohol exports, and analyzes the opportunity costs of alcohol production. Section two describes the interregional shipment and use of alcohol. Alcohol production impacts, which include the impacts on agricultural land use, domestic crop demand, prices, and exports, are analyzed in section three. Section four projects alcohol production in 1986: two production situations, constant and increased crop yields, are considered, as well as the regional distribution of alcohol
### Table 5.1: Summary of the Specific Model Formulations

<table>
<thead>
<tr>
<th>Model</th>
<th>Demand</th>
<th>Molasses</th>
<th>Cassava</th>
<th>Sugarcane</th>
<th>Sweet Sorghum</th>
<th>Maximum Domestic Demand as % of Gasoline Consumption</th>
<th>Export</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Fixed</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Variable</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Fixed</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>20</td>
<td>Unlimited</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Variable</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>20</td>
<td>Unlimited</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Fixed</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>120</td>
<td>Unlimited</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Variable</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>120</td>
<td>Unlimited</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>Fixed</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>120</td>
<td>Unlimited</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Fixed</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>120</td>
<td>Unlimited</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Variable</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>120</td>
<td>Unlimited</td>
<td>Increased cropland</td>
</tr>
<tr>
<td>J</td>
<td>Fixed 1986</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>120</td>
<td>Unlimited</td>
<td>Crop Yields at 1981 levels</td>
</tr>
<tr>
<td>K</td>
<td>Fixed 1986</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>120</td>
<td>Unlimited</td>
<td>Crop Yield Increased by 5%</td>
</tr>
</tbody>
</table>
production and use, and the alcohol production impact on crop exports in 1986. Section five compares the competitiveness of alcohol produced from three alternative energy crops (cassava, sweet sorghum, and sugarcane). In the last section, the viability of alcohol exports to Japan and the alcohol production impact on trade with Japan are analyzed.

2.1. Alcohol Production in 1981

The potential for alcohol production was estimated under different hypothetical situations and energy price levels. The different situations were: fixed and variable demands for agricultural commodities with alcohol substituting for 20 percent of gasoline consumption (Models C and D); fixed and variable crop demands with 0 to 100 percent alcohol substitution for gasoline (Models E and F); and variable demand with increased cropland and alcohol substituting for 100 percent of annual gasoline consumption (Model I). The energy-feedstocks included in these models are molasses, cassava, and sugarcane.

Results of the price parameterization indicate that alcohol produced from molasses and cassava is competitive in all models. The amount of alcohol produced at each price and potential alcohol demand level is similar across models: the only difference is that the variable demand model produces slightly more alcohol than the fixed demand model, and
more alcohol is produced when available cropland is increased. However, alcohol production increases substantially when the potential alcohol demand increases from 20 to 100 percent substitution for gasoline.

For the analysis that follows, two models, D and P, were selected. They represent variable crop demands and the two potential alcohol-gasoline substitution levels, 20 and 100 percent. Alcohol production results from other models (C, E and I) are presented in Appendix Tables B.3, B.4, and B.5. Energy price levels used in this analysis are shown in Appendix Tables B.1 and B.2.

Alcohol-Gasoline Blend (Model D): Alcohol produced from molasses (a by-product of sugar production) and cassava is competitive at current energy price levels (Table 5.2). All regions except regions 4 and 7 produce molasses alcohol. Region 6, a major sugar-producing region, produces two thirds of the alcohol from molasses, which in turn accounts for approximately 68 percent of the total alcohol demand of 433 million liters (20 percent blend with gasoline). The rest (32 percent) is supplied by cassava alcohol, which is produced in Region 3 only. Nevertheless, the amount of alcohol produced from molasses, which is dependent on sugar production, is constant throughout the energy price range.

Alcohol produced from cassava varies positively with energy prices. Domestic demand (20 percent blend) is met
### Table 5.2: Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels—0 to 20 Percent Alcohol Substitution for Gasoline (Model D), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Energy - Feedstock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Molasses</td>
</tr>
<tr>
<td></td>
<td>All Energy Price Levels</td>
</tr>
<tr>
<td></td>
<td>Current</td>
</tr>
<tr>
<td></td>
<td>(10^6 liters)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>Molasses</th>
<th>Cassava</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>89</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>140</td>
</tr>
<tr>
<td>3</td>
<td>140</td>
<td>269</td>
</tr>
<tr>
<td>4</td>
<td>140</td>
<td>745</td>
</tr>
<tr>
<td>5</td>
<td>140</td>
<td>745</td>
</tr>
<tr>
<td>6</td>
<td>269</td>
<td>745</td>
</tr>
<tr>
<td>7</td>
<td>745</td>
<td>745</td>
</tr>
<tr>
<td>All Regions</td>
<td>293</td>
<td>382</td>
</tr>
<tr>
<td>Total (Including Molasses)</td>
<td>--</td>
<td>433A/</td>
</tr>
</tbody>
</table>

a/ Maximum domestic demand at 20 percent blend with gasoline.
when energy prices are 5 percent above present levels. The production rises significantly when alcohol exports become competitive at the energy price of +15 percent.

**Alcohol-Gasoline Blend and Pure Alcohol (Model F):** Alcohol production increases substantially when the maximum domestic alcohol demand increases to 2,587 million liters (100 percent substitution for gasoline). At this amount of production all regions produce cassava alcohol, and cassava is the single major alcohol source, providing 89 percent of the total alcohol production (Table 5.3). The other energy-feedstock is molasses, which supplies 11 percent of the total.

Only Region 3 produces alcohol from cassava at current energy prices. It should be noted that Region 3 is located in the northern part of Northeast Thailand, where soil quality is considered to be the poorest in the country. Lack of water is another major problem faced by farmers in this region. Consequently, Region 3 is more suitable for growing cassava than for other crops. Moreover, this region is the only region that has unused upland crop area. Region 4, which is located in the southern part of the Northeast, is another major cassava alcohol producing region. However, its production is more competitive at higher energy prices than that of Region 3, because Region 4 is a major corn-producing area. It appears that at low energy prices
Table 5.3: Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline (Model P), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Molasses</th>
<th>Energy - Feedstock</th>
<th>Cassava</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Energy Price Levels</td>
<td>Current</td>
<td>+10%</td>
</tr>
<tr>
<td></td>
<td>(10^6 liters)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12 (11)a/</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>--</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>586</td>
<td>745</td>
</tr>
<tr>
<td>4</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5</td>
<td>47 (46)c/</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>192</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>All Regions</td>
<td>293</td>
<td>586</td>
<td>805</td>
</tr>
<tr>
<td>Total (Including Molasses)</td>
<td>--</td>
<td>879</td>
<td>1,098</td>
</tr>
</tbody>
</table>

a/ Molasses alcohol at energy prices of +60 percent.

b/ Sugarcane - cassava alcohol.

c/ Molasses alcohol at energy prices of +20 percent - +60 percent.

d/ Maximum domestic demand at 100 percent substitution for gasoline.
cassava cannot compete with corn, which has a strong export demand.

Between the energy price ranges of +30 and +50 percent, alcohol production is stable. This is because the domestic alcohol demand is fulfilled and the alcohol exports are not competitive. The production increases sharply at the energy prices of +60 percent to satisfy the export demand. At this energy price level, Region 6 becomes the major alcohol producer. Its production is mainly for its own regional consumption, which is the largest in the country. Regions 3 and 4 become alcohol exporters.

Alcohol Production Opportunity Costs: Alcohol production in any region depends on alcohol production opportunity costs, alternative fuel price (gasoline), and costs of alcohol transport from production site to consumption centers, both within the region and from other regions. Alcohol production opportunity costs are the values necessary to attract the use of scarce resources to alcohol production, or alternatively the costs of a loss of production of another commodity as a result of the production of one more unit of alcohol. Alcohol is assumed to be sold at the same price as gasoline. Thus, it is profitable to produce alcohol from energy crops if the alcohol production opportunity costs plus transportation costs are less than gasoline prices. The opportunity costs of alcohol production from
cassava and sugarcane, and the gasoline price in each region are presented in Table 5.4.

At current energy prices, in Regions 1, 2, 3, and 4 the cassava-alcohol production opportunity costs plus transportation costs within the regions are less than the respective gasoline prices. Production opportunity costs (plus transportation) in Regions 5-7 are greater than the gasoline prices. However, in Regions 5 and 6 they are very close to being competitive with gasoline prices. Although, at this current energy price level, alcohol production from cassava in Regions 1, 2, and 4 is profitable, it is even more profitable for these regions to import alcohol from Region 3, which has the lowest alcohol production opportunity costs.

As energy prices are increased, the cassava-alcohol production opportunity costs increase more slowly than gasoline prices, since energy costs are only part of the total production costs. Thus, total alcohol production increases as it becomes profitable in more regions. For example, as the energy prices are increased 20 percent above current prices, Regions 2, 3, and 4 produce cassava alcohol, and at the energy prices of +30 percent or above, all regions produce alcohol.

Sugarcane is less competitive than cassava as an energy feedstock since it has higher alcohol production opportunity costs in all regions. However, at the energy prices of +30 percent or lower, the differences between the opportunity
Table 5.4: Alcohol Production Opportunity Costs\(^a\) and Gasoline Costs\(^b\) by Region and Assumed Energy Price Level—0 to 100 Percent Alcohol Substitution for Gasoline; Models F and G, 1981

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current +10% 20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>7.14 7.99 7.74 8.79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>6.67 7.13 7.26 7.84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>5.66 7.50 6.21 8.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>6.17 7.15 6.81 7.87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>6.67 6.64 7.33 7.30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>6.68 6.67 7.34 7.34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>8.72 8.51 9.36 9.36</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Alcohol Production\(^c\)/
- Cassava 586 805 1,584
- Sugarcane

As Percent of Total\(^d\)/
- Cassava 27 37 73
- Sugarcane

\(^a\) Minimum liquid fuel price necessary to attract energy crop production. Sugarcane and cassava values are not derived from joint production in the same model. Sugarcane values were obtained from model G, which excluded cassava as an energy feedstock.

\(^b\) Ex-refinery price plus transportation costs from the refinery to the consumption centers.

\(^c\) Alcohol production in million liters from energy crops—cassava and sugarcane.

\(^d\) Alcohol produced from energy crops as percent of total gasoline consumption.
Table 5.4, continued

<table>
<thead>
<tr>
<th>Region</th>
<th>Cassava Alcohol Opportunity Costs</th>
<th>Sugarcane Alcohol Opportunity Costs</th>
<th>Gasoline Costs</th>
<th>Cassava Alcohol Opportunity Costs</th>
<th>Sugarcane Alcohol Opportunity Costs</th>
<th>Gasoline Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.71</td>
<td>10.38</td>
<td>10.39</td>
<td>9.14</td>
<td>12.31</td>
<td>12.78</td>
</tr>
<tr>
<td>2</td>
<td>8.57</td>
<td>9.39</td>
<td>9.27</td>
<td>9.19</td>
<td>11.32</td>
<td>11.41</td>
</tr>
<tr>
<td>3</td>
<td>7.44</td>
<td>9.76</td>
<td>9.75</td>
<td>7.94</td>
<td>11.14</td>
<td>12.00</td>
</tr>
<tr>
<td>4</td>
<td>8.08</td>
<td>10.66</td>
<td>9.30</td>
<td>8.65</td>
<td>11.35</td>
<td>11.44</td>
</tr>
<tr>
<td>5</td>
<td>8.60</td>
<td>8.67</td>
<td>8.63</td>
<td>9.23</td>
<td>10.50</td>
<td>10.62</td>
</tr>
<tr>
<td>6</td>
<td>8.65</td>
<td>8.74</td>
<td>8.67</td>
<td>9.29</td>
<td>10.64</td>
<td>10.67</td>
</tr>
<tr>
<td>7</td>
<td>10.96</td>
<td>--</td>
<td>11.06</td>
<td>11.90</td>
<td>--</td>
<td>13.62</td>
</tr>
</tbody>
</table>

Alcohol Production^c/
--- Cassava 2,295 3,483
--- Sugarcane 1 1,547

As Percent of Total^d/
--- Cassava 106 161
--- Sugarcane 0 72

--- Minimum liquid fuel price necessary to attract energy crop production. Sugarcane and cassava values are not derived from joint production in the same model. Sugarcane values were obtained from model G, which excluded cassava as an energy feedstock.

--- Ex-refinery price plus transportation costs from the refinery to the consumption centers.

--- Alcohol production in million liters from energy crops—cassava and sugarcane.

--- Alcohol produced from energy crops as percent of total gasoline consumption.
costs of sugarcane and cassava are very close in Region 5 and 6, the traditional sugarcane regions. Therefore, the choice between cassava and sugarcane as alcohol feedstocks in these two regions is less important than in other regions.

2.2. Regional Distribution of Alcohol Production and Use

The focus of this section is on regional alcohol demand and interregional shipment of alcohol. Two levels of alcohol demand are examined: blended alcohol demand (0 to 20 percent substitution for gasoline) and pure alcohol demand (0 to 100 percent substitution for gasoline).

Under the blended alcohol demand, the total demand is 433 million liters per year (Table 5.5). Region 6, in which the capital of Thailand is located, has the highest demand capacity, absorbing 55 percent of the total production. The demand capacity of other regions ranges from 19 to 50 million liters annually. At the energy prices of +5 percent, alcohol demands of all regions are fulfilled. At this price level, Region 6 imports alcohol from Regions 3 and 5. Region 3 is the most important alcohol supplier, since it transports alcohol to all other regions except Region 5. Region 7, which produced no alcohol, is the biggest importer; however, this region does not import alcohol at current energy prices, because the transportation costs are too high compared to the alcohol price at the consumption
Table 5.5: Regional Distribution of Alcohol Use and Supply at Energy Prices of +5 percent--20 Percent Alcohol Substitution for Gasoline (Model D), 1981

<table>
<thead>
<tr>
<th>Destination (Region)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>16</td>
<td>7</td>
<td>19</td>
<td>38</td>
<td>50</td>
<td></td>
<td>433</td>
</tr>
<tr>
<td>22</td>
<td>22</td>
<td>31</td>
<td>19</td>
<td>9</td>
<td>192</td>
<td>50</td>
<td></td>
<td>433</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td>31</td>
<td>19</td>
<td>9</td>
<td>192</td>
<td>50</td>
<td></td>
<td>433</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>22</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>29</td>
</tr>
<tr>
<td>31</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>31</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>38</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>22</td>
<td>160</td>
<td></td>
<td>47</td>
<td>192</td>
<td></td>
<td>433</td>
</tr>
</tbody>
</table>
center of this region (Table 5.6). Region 3 supplies not just other regions, but is also a major alcohol exporter to Japan. It begins to export alcohol at the alcohol price of 6.67 baht per liter. Region 5, which ships a small amount of alcohol to Region 6, becomes another alcohol exporter at the alcohol price of 6.96 baht per liter. The volume of alcohol trade among regions accounts for 32 percent of the total domestic demand.

Alcohol distribution patterns and use change when alcohol is allowed to substitute completely for the total gasoline demand. At current energy prices Region 3 is the only alcohol supplier. It transports alcohol to Regions 1, 2, and 4 (Table 5.7). Although Region 4 imports alcohol from Region 3 at low energy prices, it becomes a major alcohol exporter at high energy prices. For instance, at the energy price of +30 percent Region 4 exports alcohol to Regions 6 and 7 (Table 5.8). Region 6, which has the highest potential demand, is the biggest importer, importing alcohol from Regions 3 and 4. Region 7, which has the highest transportation cost, starts to import alcohol after the demands of all other regions are fulfilled. It is noted that as energy prices rise, the deficit regions tend to produce more alcohol for their own needs. At the energy prices of +60 percent, only Region 7 imports alcohol from Region 6 (Table 5.9). The volume of interregional alcohol trade decreases from 66 to 12 percent of the total demand as the energy
Table 5.6: Interregional Shipment of Alcohol Associated with Selected Energy Price Levels—0 to 20 Percent Alcohol Substitution for Gasoline (Model D), 1981

<table>
<thead>
<tr>
<th>Destination (Region)</th>
<th>Origin (Region)</th>
<th>Energy Price Level</th>
<th>Energy Price Level</th>
<th>Energy Price Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Current(^a)/ 3 5</td>
<td>+5(^{o})/ 3 5</td>
<td>+20(^{o})/ 3 5</td>
</tr>
<tr>
<td></td>
<td>(10° liters)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>--</td>
<td>16</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>--</td>
<td>6</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>--</td>
<td>19</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>9</td>
<td>37</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>--</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Export</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>596 9</td>
</tr>
</tbody>
</table>

\(^a\)/ 18 percent substitution of alcohol for gasoline.
\(^b\)/ 20 percent substitution of alcohol for gasoline.
\(^c\)/ 20 percent substitution of alcohol for gasoline plus exports.
Table 5.7: Interregional Shipment of Alcohol Associated with Selected Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline (Model F), 1981

<table>
<thead>
<tr>
<th>Origin (Region)</th>
<th>Energy Price Level</th>
<th>Destination (Region)</th>
<th>Current(^a/) (10^6 liters)</th>
<th>+30(^b/)</th>
<th>+60(^c/)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>154</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>150</td>
<td>90</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>116</td>
<td>--</td>
<td>116</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>--</td>
<td>489</td>
<td>366</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>--</td>
<td>--</td>
<td>297</td>
</tr>
<tr>
<td>Export</td>
<td></td>
<td></td>
<td>--</td>
<td>--</td>
<td>579</td>
</tr>
</tbody>
</table>

\(^a/\) 34 percent substitution of alcohol for gasoline.
\(^b/\) 100 percent substitution of alcohol for gasoline.
\(^c/\) 100 percent substitution of alcohol for gasoline plus exports.
Table 5.8: Regional Distribution of Alcohol Use and Supply at Energy Prices of +30 Percent—100 Percent Alcohol Substitution for Gasoline (Model F), 1981

<table>
<thead>
<tr>
<th>Destination (Region)</th>
<th>Origin (Region)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(10^6 liters)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>166</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>166</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>82</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>172</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>185</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>185</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>116</td>
<td></td>
<td></td>
<td></td>
<td>116</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>225</td>
<td></td>
<td></td>
<td>225</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>565</td>
<td></td>
<td>1,420</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>297</td>
<td></td>
<td>5</td>
<td>302</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>166</td>
<td>82</td>
<td>764</td>
<td>779</td>
<td>225</td>
<td>565</td>
<td>5</td>
<td>2,586</td>
</tr>
</tbody>
</table>
Table 5.9: Regional Distribution of Alcohol Use and Supply at Energy Prices of +60 Percent--100 Percent Alcohol Substitution for Gasoline plus Exports (Model P), 1981

<table>
<thead>
<tr>
<th>Destination (Region)</th>
<th>Origin (Region)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>166</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>--</td>
<td>172</td>
</tr>
<tr>
<td>3</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Export</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>166</td>
<td>172</td>
</tr>
</tbody>
</table>
prices increase from +30 to +60 percent, respectively. Two factors are responsible for this tendency. First, at high alcohol price the energy crop production can compete more efficiently with the food crops; and second, high transportation costs discourage the deficit regions from importing alcohol.

Regions 3 and 4 begin to export alcohol to Japan at the alcohol price of 9.28 baht per liter (Table 5.9). This price is higher than the viable export price under the blended alcohol demand discussed earlier (6.67 baht per liter), because resources become more limited when alcohol production increases. A high alcohol price is required to draw the resources from other production activities, especially from food production. Consequently, the impact of alcohol production on agriculture at high energy prices is greater than at low energy prices.

2.3. Alcohol Production Impact

The agricultural impacts of various levels of alcohol production associated with energy price changes are analyzed in the following order. First, land use changes are examined. Second, the impact on agricultural demand is described. Third, the impact on agricultural prices is discussed. Finally, the impact on crop exports is presented.

Land Use Changes: Data on land use changes as a result of alcohol production to substitute for 20 and 100 percent
of gasoline demand (Models D and F) are presented in Table 5.10. Additional data on land allocation by region and for each energy price level of these two models are shown in Appendix Tables B.6 through B.15.

Entries for cassava refer to the acreage for the production of both energy and non-energy uses. Casuarina junghuhniana (wood) acreage refers to the production of wood energy inputs used in the cassava alcohol processing activity. Thus, its acreage varies positively with cassava production. The cassava and casuarina junghuhniana acreages also vary in the same direction with the energy prices, while other crop acreages change in the opposite direction.

Table 5.10 indicates that the total land use increases as energy prices are increased. This is because there is unused cropland in Regions 3 and 4. However, as the energy prices increase further, from +30 to +60 percent, the total land use decreases, from 92 to 91 million rai, as a result of high energy input costs which reduce the profitability of certain crop production. The impact of alcohol production and energy price changes on cropland use varies from product to product; the larger the amount of alcohol produced, the greater the changes in acreage; and cropland use changes more at high energy prices than at low energy prices. These outcomes are expected because the model formulation allows for agricultural production costs to vary as energy prices increase. Consequently, production costs are also affected
<table>
<thead>
<tr>
<th>Model</th>
<th>Energy Price</th>
<th>Total Land</th>
<th>Corn</th>
<th>Cassava</th>
<th>Sugar-cane</th>
<th>Rice</th>
<th>Sorghum</th>
<th>Soy-beans</th>
<th>Mung-beans</th>
<th>Ground-nuts</th>
<th>Cotton</th>
<th>Kenaf (Wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>Current</td>
<td>86,389</td>
<td>11,078</td>
<td>8,243</td>
<td>2,922</td>
<td>56,096</td>
<td>1,348</td>
<td>1,134</td>
<td>2,489</td>
<td>726</td>
<td>1,090</td>
<td>1,259</td>
</tr>
<tr>
<td></td>
<td>+5%</td>
<td>86,453</td>
<td>11,058</td>
<td>8,377</td>
<td>2,920</td>
<td>56,095</td>
<td>1,348</td>
<td>1,125</td>
<td>2,452</td>
<td>723</td>
<td>1,090</td>
<td>1,259</td>
</tr>
<tr>
<td></td>
<td>+15%</td>
<td>86,669</td>
<td>11,031</td>
<td>8,719</td>
<td>2,918</td>
<td>56,041</td>
<td>1,348</td>
<td>1,114</td>
<td>2,421</td>
<td>721</td>
<td>1,090</td>
<td>1,254</td>
</tr>
<tr>
<td></td>
<td>+20%</td>
<td>87,307</td>
<td>10,835</td>
<td>9,979</td>
<td>2,914</td>
<td>55,694</td>
<td>1,346</td>
<td>1,076</td>
<td>2,391</td>
<td>706</td>
<td>1,080</td>
<td>1,254</td>
</tr>
<tr>
<td>F</td>
<td>Current</td>
<td>87,292</td>
<td>11,010</td>
<td>9,557</td>
<td>2,921</td>
<td>55,863</td>
<td>1,346</td>
<td>1,109</td>
<td>2,397</td>
<td>715</td>
<td>1,090</td>
<td>1,259</td>
</tr>
<tr>
<td></td>
<td>+10%</td>
<td>87,630</td>
<td>10,927</td>
<td>10,137</td>
<td>2,918</td>
<td>55,740</td>
<td>1,346</td>
<td>1,080</td>
<td>2,393</td>
<td>708</td>
<td>1,090</td>
<td>1,256</td>
</tr>
<tr>
<td></td>
<td>+20%</td>
<td>88,813</td>
<td>10,763</td>
<td>12,201</td>
<td>2,916</td>
<td>55,910</td>
<td>460</td>
<td>1,060</td>
<td>2,389</td>
<td>711</td>
<td>1,080</td>
<td>1,254</td>
</tr>
<tr>
<td></td>
<td>+30%</td>
<td>91,669</td>
<td>10,741</td>
<td>14,138</td>
<td>2,914</td>
<td>56,775</td>
<td>460</td>
<td>1,097</td>
<td>2,384</td>
<td>731</td>
<td>1,080</td>
<td>1,249</td>
</tr>
<tr>
<td></td>
<td>+60%</td>
<td>90,632</td>
<td>9,953</td>
<td>17,293</td>
<td>2,914</td>
<td>54,066</td>
<td>96</td>
<td>1,042</td>
<td>2,372</td>
<td>680</td>
<td>816</td>
<td>1,249</td>
</tr>
</tbody>
</table>

Table 5.10: Impact of Alcohol Production on Land Use by Agricultural Product and Energy Price Level—0 to 20 Percent Alcohol Substitution for Gasoline (Model D); 0 to 100 Percent Alcohol Substitution for Gasoline (Model F), 1981.
by energy price changes. Small reductions in crop production, caused by an increase in costs of production, occur at low energy price levels. At high energy prices, both alcohol production and agricultural production costs are responsible for the decrease in production of the non-energy crops. At high energy prices, regions 1, 2 and 6 produce more alcohol for their own consumption instead of importing from Regions 3 and 4 (Table 5.9). This substantially affects food production in these three regions because they are major food producing areas. Sorghum, produced mostly in Region 6, is highly affected, low productivity and high energy input costs being the principal factors affecting its production.

Agricultural Demand Changes: Variable demands for consumption of cassava, sorghum, vegetables, flowers, cattle, buffaloes and other minor crops were not included in the models and thus are not affected by the alcohol production and energy price changes. The agricultural demand for the major crops (Table 5.11) decreases as alcohol production and energy prices increase. Changes in total consumption under 100 percent alcohol substitution for gasoline (Model F) are greater than under 20 percent substitution (Model D), and the consumption changes are greater at high energy prices than at low energy prices. Rice consumption is maintained at 12.23 million tons merely because of a minimum consumption constraint. Demand for these commodities is relatively
<table>
<thead>
<tr>
<th>Model</th>
<th>Energy Price</th>
<th>Total Consumption</th>
<th>Agricultural Product[^a]/ (1,000 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Corn</td>
<td>Rice</td>
</tr>
<tr>
<td>D</td>
<td>Current</td>
<td>13,739.1</td>
<td>663.4</td>
</tr>
<tr>
<td></td>
<td>+5%</td>
<td>13,729.6</td>
<td>656.0</td>
</tr>
<tr>
<td></td>
<td>+10%</td>
<td>13,719.3</td>
<td>656.0</td>
</tr>
<tr>
<td></td>
<td>+15%</td>
<td>13,702.6</td>
<td>648.6</td>
</tr>
<tr>
<td></td>
<td>+20%</td>
<td>13,587.9</td>
<td>595.6</td>
</tr>
<tr>
<td>F</td>
<td>Current</td>
<td>13,696.1</td>
<td>645.1</td>
</tr>
<tr>
<td></td>
<td>+10%</td>
<td>13,630.8</td>
<td>621.7</td>
</tr>
<tr>
<td></td>
<td>+20%</td>
<td>13,552.6</td>
<td>576.7</td>
</tr>
<tr>
<td></td>
<td>+30%</td>
<td>13,540.8</td>
<td>570.7</td>
</tr>
<tr>
<td></td>
<td>+60%</td>
<td>13,437.6</td>
<td>525.5</td>
</tr>
</tbody>
</table>

[^a]: Only products that have demand schedules.
[^b]: Minimum consumption constraint.
inelastic. Thus, the percentage changes in quantities demanded are less than the percentage changes in prices.

**Agricultural Price Changes:** In order to measure the impact of alcohol production on crop prices, the crop price changes were calculated using the Laspeyres Index. The Laspeyres Index was originally developed to measure the cost, relative to the base period, of purchasing the base-year quantities at the given prices (18). For this study the "base period" is defined as the run with current energy prices and no alcohol production. The "given year prices" are the market equilibrium prices of various runs. Results of the computation are presented in Table 5.12.

Alcohol production and energy price changes cause agricultural prices to increase. The agricultural price index increases in both 20 and 100 percent alcohol substitutions for gasoline. However, the crop prices are affected by the pure alcohol demand more than by the blended alcohol demand, and the prices change less at low energy prices than at high energy price levels. Table 5.12 shows that the impact on agricultural prices also varies from crop to crop. Cotton and kenaf prices rise less than the prices of other products, such as soybeans, mungbeans, groundnuts, rice, and corn.

**Agricultural Export Changes:** There is no impact on agricultural commodity exports under the 20 percent alcohol
Table 5.12: Agricultural Price Index and Agricultural Product Price Changes Associated with Energy Price Increases—0 to 20 Percent Alcohol Substitution for Gasoline (Model D); 0 to 100 Percent Alcohol Substitution for Gasoline (Model F), 1981

<table>
<thead>
<tr>
<th>Model</th>
<th>Energy Price</th>
<th>Price Index</th>
<th>Corn</th>
<th>Rice</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Groundnuts</th>
<th>Cotton</th>
<th>Kenaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>Current (no alcohol)</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Current</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>+ 5%</td>
<td>100.4</td>
<td>100.8</td>
<td>100.4</td>
<td>101.2</td>
<td>100.7</td>
<td>100.2</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>+10%</td>
<td>100.5</td>
<td>100.8</td>
<td>100.5</td>
<td>101.2</td>
<td>101.2</td>
<td>101.5</td>
<td>100.0</td>
<td>100.6</td>
</tr>
<tr>
<td></td>
<td>+15%</td>
<td>101.7</td>
<td>101.4</td>
<td>101.8</td>
<td>103.0</td>
<td>103.9</td>
<td>102.2</td>
<td>100.0</td>
<td>100.8</td>
</tr>
<tr>
<td></td>
<td>+20%</td>
<td>106.7</td>
<td>105.7</td>
<td>107.2</td>
<td>107.5</td>
<td>105.7</td>
<td>101.8</td>
<td>101.8</td>
<td>100.8</td>
</tr>
<tr>
<td>F</td>
<td>Current (no alcohol)</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Current</td>
<td>102.3</td>
<td>101.7</td>
<td>102.5</td>
<td>103.6</td>
<td>102.3</td>
<td>103.2</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>+10%</td>
<td>105.5</td>
<td>103.7</td>
<td>106.0</td>
<td>106.9</td>
<td>104.7</td>
<td>105.2</td>
<td>100.0</td>
<td>100.6</td>
</tr>
<tr>
<td></td>
<td>+20%</td>
<td>107.9</td>
<td>107.6</td>
<td>108.4</td>
<td>109.8</td>
<td>106.4</td>
<td>105.9</td>
<td>101.8</td>
<td>100.8</td>
</tr>
<tr>
<td></td>
<td>+30%</td>
<td>108.1</td>
<td>108.3</td>
<td>108.4</td>
<td>113.7</td>
<td>108.7</td>
<td>107.4</td>
<td>101.8</td>
<td>101.7</td>
</tr>
<tr>
<td></td>
<td>+60%</td>
<td>108.6</td>
<td>112.3</td>
<td>108.4</td>
<td>120.9</td>
<td>112.4</td>
<td>108.1</td>
<td>105.3</td>
<td>102.8</td>
</tr>
</tbody>
</table>

a/ Only products that have demand schedules.
substitution for gasoline and the energy price parameterization range from current prices to +20 percent (Model D).

Total crop exports decrease as the alcohol substitution for gasoline increases to 100 percent (Table 5.13). However, individual crop exports are affected in various ways. Cassava, soybean, groundnut, kenaf, and sugar exports are stable throughout the energy price range under study. Corn and cotton exports change at the energy prices of +60 percent, rice exports decrease at the energy prices of +20 percent and sorghum exports decrease the most.

It is noted that the increase in cropland (Model J) has no effect on crop exports, except for a little increase in sorghum exports at the energy prices of +30 percent (Table B.16 in Appendix). There is a greater reduction in crop exports if domestic agricultural demand is not affected by alcohol production and energy price changes (Model E).

2.4. Alcohol Production in 1986

This section assesses alcohol production under hypothetical situations in 1986, regional distribution of alcohol production and use, and alcohol production impact on crop exports. The production is considered under two different situations, constant and increased crop yields, with alcohol substituting for 100 percent of projected gasoline demand in 1986 plus exports (Models J and K).
Table 5.13: Impact of Alcohol Production on Agricultural Product Exports—0 to 100 Percent Alcohol Substitution for Gasoline (Model F), 1981

<table>
<thead>
<tr>
<th>Energy Price</th>
<th>Total Exports</th>
<th>Corn (1,000 tons)</th>
<th>Cassava</th>
<th>Rice</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Groundnuts</th>
<th>Cotton</th>
<th>Kenaf</th>
<th>Sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>27,059.5</td>
<td>2,700.0</td>
<td>18,000</td>
<td>4,700.0</td>
<td>225.0</td>
<td>5</td>
<td>190.0</td>
<td>16</td>
<td>44</td>
<td>19.5</td>
<td>1,160</td>
</tr>
<tr>
<td>+10%</td>
<td>27,059.5</td>
<td>2,700.0</td>
<td>18,000</td>
<td>4,700.0</td>
<td>225.0</td>
<td>5</td>
<td>190.0</td>
<td>16</td>
<td>44</td>
<td>19.5</td>
<td>1,160</td>
</tr>
<tr>
<td>+20%</td>
<td>26,885.0</td>
<td>2,700.0</td>
<td>18,000</td>
<td>4,684.8</td>
<td>65.7</td>
<td>5</td>
<td>190.0</td>
<td>16</td>
<td>44</td>
<td>19.5</td>
<td>1,160</td>
</tr>
<tr>
<td>+30%</td>
<td>26,885.0</td>
<td>2,700.0</td>
<td>18,000</td>
<td>4,684.8</td>
<td>65.7</td>
<td>5</td>
<td>190.0</td>
<td>16</td>
<td>44</td>
<td>19.5</td>
<td>1,160</td>
</tr>
<tr>
<td>+60%</td>
<td>25,815.9</td>
<td>2,542.4</td>
<td>18,000</td>
<td>3,891.2</td>
<td>--</td>
<td>5</td>
<td>181.8</td>
<td>16</td>
<td>--</td>
<td>19.5</td>
<td>1,160</td>
</tr>
</tbody>
</table>

\(a/b\) Maximum export constraints.
Alcohol Production: Sensitivity analysis on energy prices of the constant and increased crop yield models (J and K) shows that alcohol produced from molasses and cassava is competitive under conditions specified in the models (Table 5.14 and 5.15). The alcohol production patterns are similar to the patterns in 1981 (Model P); that is, Region 3, again, produces alcohol from cassava at current energy prices, while other regions produce cassava alcohol at higher energy price levels. Regions 3 and 4 are the major cassava alcohol producing regions. At high energy prices, the alcohol deficit regions produce more alcohol for their own regional consumption, especially Region 6, which produces more cassava alcohol than other regions at the energy prices of +60 percent.

Alcohol production is constant between the energy prices of +40 and +50 percent because the potential domestic alcohol demand is exhausted. The production increases substantially as alcohol exports become competitive at energy prices of +60 percent. A comparison between the constant and increased crop yield models indicates that more alcohol is produced under the increased crop yield situation.

Regional Distribution of Alcohol Production and Use: The interregional shipment of alcohol in 1986 (Table 5.16) follows the shipment patterns of 1981 (Table 5.7). At current energy prices Region 3 is the only alcohol exporter,
Table 5.14: Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline and Constant Crop Yield (Model J), 1986

<table>
<thead>
<tr>
<th>Energy-Feedstock</th>
<th>All Energy Price Levels</th>
<th>Cassava</th>
<th>Molasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>Current +10% +20% +30% +40% - +50% +60%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>179</td>
<td>179</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>679</td>
<td>744</td>
</tr>
<tr>
<td>4</td>
<td>--</td>
<td>779</td>
<td>779</td>
</tr>
<tr>
<td>5</td>
<td>52</td>
<td>207</td>
<td>207</td>
</tr>
<tr>
<td>6</td>
<td>215</td>
<td>264</td>
<td>602</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>58</td>
<td>85</td>
</tr>
<tr>
<td>All Regions</td>
<td>324</td>
<td>1,003</td>
<td>1,126</td>
</tr>
<tr>
<td>Total (Including Molasses)</td>
<td>1,003</td>
<td>1,126</td>
<td>1,965</td>
</tr>
</tbody>
</table>

a/ Maximum domestic demand at 100 percent substitution for gasoline.
Table 5.15: Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline and Increased Crop Yield (Model K), 1986

<table>
<thead>
<tr>
<th>Region</th>
<th>Molasses</th>
<th>Energy-Feedstock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Energy Price Levels</td>
<td>Current</td>
</tr>
<tr>
<td></td>
<td>(10^6 liters)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>677</td>
</tr>
<tr>
<td>4</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5</td>
<td>213</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>52</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>65</td>
</tr>
<tr>
<td>All Regions</td>
<td>324</td>
<td>677</td>
</tr>
<tr>
<td>Total (Including Molasses)</td>
<td>--</td>
<td>1,001</td>
</tr>
</tbody>
</table>

a/ Maximum domestic demand at 100 percent substitution for gasoline.
Table 5.16: Interregional Shipment of Alcohol Associated with Selected Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline and Constant Crop Yield (Model J), 1986

<table>
<thead>
<tr>
<th>Destination (Region)</th>
<th>Origin (Region)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current +40% +60%</td>
</tr>
<tr>
<td></td>
<td>3 3 4 3 4 6</td>
</tr>
<tr>
<td></td>
<td>(10^6 liters)</td>
</tr>
<tr>
<td>1</td>
<td>179 -- -- -- --</td>
</tr>
<tr>
<td>2</td>
<td>176 116 -- -- --</td>
</tr>
<tr>
<td>4</td>
<td>134 -- 134 -- 134</td>
</tr>
<tr>
<td>6</td>
<td>-- 438 382 -- 1,636</td>
</tr>
<tr>
<td>7</td>
<td>-- -- 263 -- 5 258</td>
</tr>
<tr>
<td>Export</td>
<td>-- -- -- 536 640 --</td>
</tr>
</tbody>
</table>

a/ 34 percent substitution of alcohol for gasoline.
b/ 100 percent substitution of alcohol for gasoline.
c/ 100 percent substitution of alcohol for gasoline plus exports.
shipping alcohol to Regions 1, 2, and 4. As energy prices increase to +40 percent Region 4 becomes another exporter, transporting alcohol to Regions 6 and 7. At this energy price Region 5 is the major alcohol importer, with the total import into Region 6 accounting for 50 percent of its total consumption (Table 5.17). The alcohol distribution pattern changes as the energy prices increase further. Region 6 becomes another alcohol exporter at the energy prices of +60 percent, exporting alcohol to Region 7. Region 7 is the only alcohol deficit region, and imports alcohol from Regions 4 and 6. At this level Regions 3 and 4 begin to export alcohol to Japan. Region 5 is the only region that is not involved in alcohol trade throughout the energy price range under study.

**Alcohol Production Impact on Crop Exports:** Total crop exports are less than the export targets in 1986, and the changes in exports depend on three main factors: individual commodity, energy price levels, and crop yields, Table 5.18. Exports of cassava, mungbeans, groundnuts, cotton and sugar are not affected by alcohol production and energy price changes in both constant and increased crop yield situations. Sorghum exports decrease the most. Other crop exports change at high energy prices more than at low energy prices, especially at the energy prices of +60 percent, where alcohol exports are viable. This confirms the previous findings that increases in alcohol production and crop
Table 5.17: Regional Distribution of Alcohol Use and Supply at Energy Prices of +40 Percent--100 Percent Alcohol Substitution for Gasoline and Constant (1981) Crop Yield (Model J), 1986

<table>
<thead>
<tr>
<th>Destination (Region)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Region)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(10^6 liters)</td>
</tr>
<tr>
<td>1</td>
<td>191</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>191</td>
</tr>
<tr>
<td>2</td>
<td>--</td>
<td>82</td>
<td>116</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>198</td>
</tr>
<tr>
<td>3</td>
<td>--</td>
<td>--</td>
<td>213</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>213</td>
</tr>
<tr>
<td>4</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>134</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>134</td>
</tr>
<tr>
<td>5</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>260</td>
<td>--</td>
<td>--</td>
<td>260</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>--</td>
<td>438</td>
<td>382</td>
<td>--</td>
<td>816</td>
<td>--</td>
<td>1,636</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>263</td>
<td>--</td>
<td>--</td>
<td>85</td>
<td>348</td>
</tr>
<tr>
<td>Total</td>
<td>191</td>
<td>82</td>
<td>767</td>
<td>779</td>
<td>260</td>
<td>816</td>
<td>85</td>
<td>2,980</td>
</tr>
</tbody>
</table>
Table 5.18: Impact of Alcohol Production on Agricultural Product Exports—0 to 100 Percent Alcohol Substitution for Gasoline, Constant (1981) Crop Yield (Model J) and Increased (1981 plus 5 percent) Crop Yield (Model K), 1986

<table>
<thead>
<tr>
<th>Energy Price</th>
<th>Total Exports</th>
<th>Corn (1,000 tons)</th>
<th>Cassava</th>
<th>Rice (1,000 tons)</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Groundnuts</th>
<th>Cotton</th>
<th>Kenaf</th>
<th>Sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>Current</td>
<td>25,673.5</td>
<td>2,844.0</td>
<td>16,000</td>
<td>5,170.0</td>
<td>--</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>+10%</td>
<td>25,673.5</td>
<td>2,844.0</td>
<td>16,000</td>
<td>5,170.0</td>
<td>--</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>+20%</td>
<td>24,255.0</td>
<td>2,833.4</td>
<td>16,000</td>
<td>3,762.1</td>
<td>--</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>+30%</td>
<td>23,771.5</td>
<td>2,830.4</td>
<td>16,000</td>
<td>3,281.6</td>
<td>--</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>+40%</td>
<td>23,499.2</td>
<td>2,830.4</td>
<td>16,000</td>
<td>3,009.3</td>
<td>--</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>+60%</td>
<td>21,972.3</td>
<td>1,901.2</td>
<td>16,000</td>
<td>2,439.1</td>
<td>--</td>
<td>--</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>--</td>
</tr>
<tr>
<td>K</td>
<td>Current</td>
<td>26,020.1</td>
<td>2,970.0</td>
<td>16,000</td>
<td>5,170.0</td>
<td>220.6</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>+10%</td>
<td>25,944.6</td>
<td>2,970.0</td>
<td>16,000</td>
<td>5,170.0</td>
<td>145.1</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>+20%</td>
<td>25,782.5</td>
<td>2,953.0</td>
<td>16,000</td>
<td>5,170.0</td>
<td>--</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>+30%</td>
<td>25,776.3</td>
<td>2,946.8</td>
<td>16,000</td>
<td>5,170.0</td>
<td>--</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>+40%</td>
<td>25,593.3</td>
<td>2,946.8</td>
<td>16,000</td>
<td>4,987.0</td>
<td>--</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>+60%</td>
<td>22,787.5</td>
<td>2,098.4</td>
<td>16,000</td>
<td>3,029.6</td>
<td>--</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
</tr>
<tr>
<td>Export Targeta/</td>
<td>26,047.0</td>
<td>2,970.0</td>
<td>16,000</td>
<td>5,170.0</td>
<td>247.5</td>
<td>5.5</td>
<td>290</td>
<td>17.6</td>
<td>48.4</td>
<td>22</td>
<td>1,276</td>
</tr>
</tbody>
</table>

a/ Crop exports except cassava are projected to increase 10 percent above the 1981 exports; cassava exports decrease from 18 million tons in 1981.
production costs cause more non-energy crop production to decrease at high energy price levels, hence more decreases in exports. However, changes in these exports are less if crop yields increase. It can be concluded that the increase in crop yields significantly affects crop exports and alcohol production. Improvement in crop production technology in the next few years should be encouraged as part of the alcohol plan implementation.

2.5. Alcohol Production from Alternative Energy Crops

The previous findings indicate that only alcohol produced from molasses and cassava is competitive throughout the energy price parameterization range. In order to assess the competitiveness of alcohol produced from sugarcane and sweet sorghum, Models G and H were developed from the fixed demand Model A. Model G has sugarcane and molasses as energy-feedstocks and Model H has sweet sorghum and molasses. The two models have the same potential alcohol demand: 100 percent alcohol substitution for gasoline. Results of the parameterization for Models G and H are shown in Table 5.19. For comparison, alcohol produced from molasses and cassava of the fixed demand Model E is also presented in Table 5.19.

Alcohol production from sweet sorghum is less competitive than that from cassava and molasses but more competitive than that from sugarcane. Molasses alcohol is
Table 5.19: Alcohol Production in Total by Energy-Feedstock\textsuperscript{a/} and Energy Price Level--0 to 100 Percent Alcohol Substitution for Gasoline; Fixed Demand Models E (Cassava), G (Sugarcane Only) and H (Sweet Sorghum Only), 1981

<table>
<thead>
<tr>
<th>Alcohol Source</th>
<th>Energy Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current</td>
</tr>
<tr>
<td>Molasses (all models)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>296</td>
</tr>
<tr>
<td>Cassava (Model E)</td>
<td>586</td>
</tr>
<tr>
<td>Sweet Sorghum alone (Model H)</td>
<td>436</td>
</tr>
<tr>
<td>Sugarcane alone (Model G)</td>
<td>1</td>
</tr>
</tbody>
</table>

\textsuperscript{a/} Cassava was the only feedstock selected in multi-feedstock models. Models H and G are single feedstock models, sweet sorghum and sugarcane respectively, to test competitive positions of these crops individually.
produced at current energy prices and the production is stable throughout the energy price range. The amount of alcohol produced from cassava increases as the energy prices rise from current prices to +30 percent. The production is constant between the energy prices of +30 and +50 percent, since the potential alcohol demand is fulfilled. Cassava alcohol production increases again when alcohol exports are viable, at energy prices of +60 percent. Alcohol produced from sweet sorghum is competitive at energy prices of +10 percent. At energy prices lower than +40 percent, less alcohol is produced from sweet sorghum than from cassava. However, sweet sorghum alcohol production increases substantially for exports at energy prices of +60 percent.

Although alcohol produced from sugarcane is viable at the energy prices of +20 percent, only a small amount is produced; significant production occurs at energy prices of +50 percent. It is noted that at the energy prices of +70 percent the sugarcane plus molasses alcohol is still not sufficient to meet domestic consumption.

Alcohol produced from sugarcane is less competitive than that from cassava, due to the relatively low yield of sugarcane production and high yield of cassava production. The 1981 yield of sugarcane in Thailand was 38.75 tons per hectare, a yield lower than both that of Brazil (54.89 tons per hectare) and the world average (56.10 tons/hectare).
But, cassava yield in Thailand was 17.05 tons per hectare, a yield higher than both that of Brazil (11.97 tons/hectare) and the world average (9.06 tons/hectare) in the same year (17). Although alcohol production from sweet sorghum is more competitive than that from sugarcane, that is basically a result of its dual use for both grain and alcohol. When grain use is limited, then its competitiveness for alcohol production in relation to sugarcane may be reduced.

The regional location of alcohol production from the three energy crops discussed above is summarized in Table 5.20. Region 3 produces cassava alcohol at current energy prices. Alcohol produced from cassava in Regions 2 and 4 is competitive at the energy prices of +10 and +20 percent respectively. At the energy prices of +30 percent all regions produce cassava alcohol.

Regions 1, 3, and 4 begin to produce alcohol from sweet sorghum at the energy prices of +10 percent. However, at high energy prices Region 5 becomes competitive and it produces more than 50 percent of the total alcohol production from sweet sorghum. At high energy prices all regions except 7 produce alcohol from sweet sorghum. As discussed in Chapter 3, Region 7 located in the south of Thailand, has a climate and soil quality unsuited to sugarcane and sweet sorghum; at present, the region produces no sweet sorghum or sugarcane.
Table 5.20: Alcohol Production from Cassava, Sweet Sorghum and Sugarcane  
by Region and Energy Price Level—0 to 100 Percent Alcohol  
Substitution for Gasoline; Fixed Demand Models E (Cassava),  
G (Sugarcane Only) and H (Sweet Sorghum Only), 1981

<table>
<thead>
<tr>
<th>Alcohol Source</th>
<th>Energy Price Level</th>
<th>Current</th>
<th>+10%</th>
<th>+20%</th>
<th>+30%</th>
<th>+40%</th>
<th>+50%</th>
<th>+60%</th>
<th>+70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava (E)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>154</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>--</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>150</td>
<td>2,452</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>--</td>
<td>745</td>
<td>745</td>
<td>745</td>
<td>745</td>
<td>745</td>
<td>745</td>
<td>1,765</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>586</td>
<td>--</td>
<td>779</td>
<td>779</td>
<td>779</td>
<td>779</td>
<td>1,638</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>--</td>
<td>--</td>
<td>174</td>
<td>174</td>
<td>174</td>
<td>175</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>374</td>
<td>374</td>
<td>374</td>
<td>1,466</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>302</td>
<td></td>
</tr>
<tr>
<td>Sweet Sorghum (H)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>--</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>154</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>--</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>1,326</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>--</td>
<td>116</td>
<td>116</td>
<td>116</td>
<td>116</td>
<td>1,289</td>
<td>1,343</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>--</td>
<td>174</td>
<td>1,322</td>
<td>1,322</td>
<td>1,322</td>
<td>1,343</td>
<td>1,343</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>--</td>
<td>--</td>
<td>110</td>
<td>384</td>
<td>384</td>
<td>1,990</td>
<td>3,137</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Sugarcane (G)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>--</td>
<td>1</td>
<td>1</td>
<td>12</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>962</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>369</td>
<td>663</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>
Alcohol produced from sugarcane is less competitive than alcohol from cassava and sweet sorghum in all regions. As the energy prices increase, Region 1 is the first region to produce sugarcane alcohol. This is because Region 1 has an alcohol price higher than these in all other regions except Region 7. Nevertheless, at high energy prices Regions 5 and 6 become dominant producers. These two regions, at present, are the major sugarcane growing regions. In Regions 4 and 7 alcohol production from sugarcane is not viable within the price levels studied.

2.6. Trade Consideration with Japan

The discussion in this section concerns alcohol exports to Japan, crop exports, and alcohol production impact on the balance of trade of Thailand in general and with Japan in particular.

Alcohol Exports to Japan: In order to assess the feasibility of alcohol exports to Japan, an alcohol export activity was incorporated into all models used in the analysis. The alcohol export price was computed, as were the costs of transportation linkages between production areas and the export port. Results of the energy price parameterization, indicating at what price and how much alcohol is exported to Japan, are summarized in Table 5.21.

It is feasible to export alcohol to Japan. However, the amount of alcohol exported and the export price depend

<table>
<thead>
<tr>
<th>Model</th>
<th>Maximum Domestic Alcohol Demand as Percent of Gasoline Consumption</th>
<th>Energy Price</th>
<th>Quantity (million liters)</th>
<th>Price (baht/liter)</th>
<th>Value (million baht)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Demand (D)</td>
<td>20% +15%</td>
<td>129</td>
<td>6.67</td>
<td>860</td>
<td></td>
</tr>
<tr>
<td>Variable Demand (D)</td>
<td>20% +20%</td>
<td>604</td>
<td>6.96</td>
<td>4,204</td>
<td></td>
</tr>
<tr>
<td>Variable Demand (F)</td>
<td>120% +60%</td>
<td>1,193</td>
<td>9.28</td>
<td>11,071</td>
<td></td>
</tr>
<tr>
<td>Variable Demand (I) (Increased Cropland)</td>
<td>120% +60%</td>
<td>1,296</td>
<td>9.28</td>
<td>12,027</td>
<td></td>
</tr>
<tr>
<td>Fixed Demand 1986 (J) (Constant Crop Yield)</td>
<td>120% +60%</td>
<td>1,194</td>
<td>9.28</td>
<td>11,080</td>
<td></td>
</tr>
<tr>
<td>Fixed Demand 1986 (K) (Increased Crop Yield)</td>
<td>120% +60%</td>
<td>2,320</td>
<td>9.28</td>
<td>21,530</td>
<td></td>
</tr>
</tbody>
</table>
on several factors. If the domestic demand for alcohol is restricted at 20 percent substitution for gasoline, alcohol exports are competitive at the energy prices of +15 percent or an alcohol price of 6.67 baht per liter (1.10 US$/gallon). Under the 100 percent alcohol substitution for gasoline, the viable alcohol export price is 9.28 baht per liter (1.53 US$/gallon). This price is slightly lower than the F.O.B. price (10.21 baht per liter) of ethyl alcohol for industrial use that Thailand exported to Japan in 1981 (42). The volume of alcohol exports under variable crop demand is greater than under the fixed crop demand situation. Alcohol exports increase significantly as crop yields increase.

The discussion in Chapter II reveals that Japan imports a substantial amount of ethyl alcohol from various countries including Thailand. Japan is also a major energy importer. If Thai alcohol can compete with the gasoline imports into Japan, the amount of alcohol exports to Japan would increase. This would help to remedy Thailand's balance of trade deficit with Japan. However, improvement in the balance of trade also depends on the extent to which Thai agricultural commodity exports to Japan are affected by the increases in alcohol production and energy prices.

Changes in Crop Exports to Japan: The previous findings show that crop exports are not affected by alcohol production and energy price changes under 20 percent alcohol
substitution for gasoline. As alcohol substitution for gasoline increases to 100 percent, however, some commodity exports decrease. Corn, mungbean, and cotton exports change at the energy prices of +60 percent (Table 5.13). Rice and sorghum exports decrease at the energy prices of +20 percent and above. All of these except cotton figure in Thailand's exports to Japan. Corn exports to Japan comprised approximately 24 percent of the total corn exports in 1979 and decreased to less than one percent in 1981. Sorghum exports accounted for less than one percent of the total exports in 1981, while rice exports rose from 0.5 to 2.57 percent in 1979 and 1981 respectively (42). Nevertheless, some commodity exports to Japan are not affected by the alcohol production: cassava, kenaf, groundnuts and sugar. Thus, it can be concluded that the impact of alcohol production and energy price changes on agricultural trade between Thailand and Japan would be minimal.

**Alcohol Production Impact on Balance of Trade:** The changes in balance of trade resulting from alcohol production stem, in this study, from three main sources: alcohol exports, reduction of gasoline or petroleum imports, and decrease in crop exports. The value of alcohol exports is the value of the alcohol exports to Japan from the Bangkok port. In order to calculate how much export earnings are saved by the reduction of gasoline imports, it is assumed
that reduction of gasoline imports is equal to the amount of gasoline replaced by alcohol, and the ex-refinery price of gasoline is used to compute the value of gasoline imports. Reduction of the export earnings due to the decrease in crop exports is calculated by the following formula:

\[ \text{Export earnings foregone} = P_0 Q_0 - P_r Q_r \]

where:

- \( Q \) = quantity of agricultural commodity exports,
- \( P \) = export price,
- \( i \) = agricultural product exports (corn, cassava, rice, sorghum, soybeans, mungbeans, groundnuts, cotton, kenaf and sugar),
- \( o \) = the base Models A and B and target exports for Models J and K,
- \( r \) = energy price parameterization run.

Results of the computation are shown in Table 5.22. The net change in the balance of trade is positive for all models used in this analysis. The variable demand with increased cropland (Model I) makes the greatest contribution to the balance of trade in 1981. The balance of trade in 1986 increases significantly if crop yields increase. The value of alcohol exports exceeds the export earnings foregone in all situations except the fixed demand with constant crop yields (Model J). This implies that the impact of

<table>
<thead>
<tr>
<th>Model</th>
<th>Maximum Domestic Alcohol Demand as Percent of Gasoline Consumption</th>
<th>Energy Price</th>
<th>Export Earnings Increased by Alcohol Exports</th>
<th>Export Earnings Saved by Reduction of Gasoline Imports&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Export Earnings Decreased by Reduction of Crop Exports</th>
<th>Net Change in Balance of Trade&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)=(1)+(2)-(3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(million baht)</td>
<td>(million baht)</td>
<td>(million baht)</td>
<td></td>
</tr>
<tr>
<td>Variable Demand (D)</td>
<td>20%</td>
<td>+15%</td>
<td>860</td>
<td>2,782</td>
<td>0</td>
<td>3,642</td>
</tr>
<tr>
<td>Variable Demand (D)</td>
<td>20%</td>
<td>+20%</td>
<td>4,204</td>
<td>2,782</td>
<td>0</td>
<td>6,986</td>
</tr>
<tr>
<td>Variable Demand (F)</td>
<td>120%</td>
<td>+60%</td>
<td>11,071</td>
<td>13,912</td>
<td>2,643</td>
<td>22,340</td>
</tr>
<tr>
<td>Variable Demand (I) (Increased Cropland)</td>
<td>120%</td>
<td>+60%</td>
<td>12,027</td>
<td>13,912</td>
<td>2,643</td>
<td>23,296</td>
</tr>
<tr>
<td>Fixed Demand 1986 (J) (Constant Crop Yield)</td>
<td>120%</td>
<td>+60%</td>
<td>11,080</td>
<td>16,024</td>
<td>14,796</td>
<td>12,308</td>
</tr>
<tr>
<td>Fixed Demand 1986 (K) (Increased Crop Yield)</td>
<td>120%</td>
<td>+60%</td>
<td>21,530</td>
<td>16,024</td>
<td>11,737</td>
<td>25,817</td>
</tr>
</tbody>
</table>

<sup>a</sup> Calculated by using ex-refinery price of gasoline (6.44 baht/liter).

<sup>b</sup>
alcohol production on the balance of trade of Thailand with Japan is also positive.

In summary, alcohol production from cassava is more competitive than that from sweet sorghum and sugarcane, and alcohol produced from molasses and cassava is sufficient to substitute for annual domestic gasoline consumption in 1981 and 1986 plus some exports. An increase of 5 percent in energy prices would provide enough incentive to supply alcohol equal to 20 percent of current gasoline consumption. And energy price rises of 30 and 40 percent would provide enough alcohol to substitute for all gasoline use in 1981 and 1986 respectively.

Regions 3 and 4 (northeast Thailand) are major alcohol producers and exporters to deficit regions and Japan. At high energy prices the deficit regions tend to produce more alcohol for their own regional consumption, especially Region 6, a major food producing region. This situation significantly affects non-energy crop production, consumption, exports, and prices. Domestic consumption of agricultural commodities, agricultural exports, and agricultural prices all change as energy prices increase. Increase in alcohol production and increase in energy-related costs of agricultural production cause these changes.

The impact on domestic crop demand, exports, and prices also depends on the potential alcohol demand and varies from crop to crop. There is no change in agricultural exports
under 20 percent alcohol substitution for gasoline. The crop exports decrease as the alcohol substitution increases to 100 percent, and sorghum exports decrease the most. Domestic crop demand and prices change more under 100 percent alcohol substitution than under 20 percent. The balance of trade for Thailand changes as a result of alcohol exports, a decrease in gasoline imports, and a reduction in crop exports. This study shows that in all hypothetical situations the impact on the balance of trade is indeed positive.
CHAPTER VI
SUMMARY AND CONCLUSIONS

6.1. Summary

Increasing energy imports and persistent surpluses of potential energy crops (cassava and sugarcane) have led the Thai government to incorporate an alcohol production program into Thailand's Fifth Five-Year National Economic and Social Development Plan: 1982-1986. At present, more than 10 investors are interested in setting up alcohol distilleries. They have proposed to produce alcohol at the rate of around 10.03 million liters per day. This amount of alcohol production would potentially cause changes in resource allocation, non-energy crop production, consumption, prices, and exports, especially crop exports to Japan, the principal export market for Thai agricultural commodities.

The principal objective of this research was to evaluate the economic impact of alcohol production on agriculture output and price and on trade with Japan. The specific objectives were to develop a regionalized, integrated, national agricultural programming model and to use the model to examine the following issues: the economic feasibility of alcohol production from sugarcane, cassava and sweet
sorghum in 1981 and 1986; optimal agricultural resource allocation and location of alcohol plants; the impact of alcohol production on agricultural output, consumption, prices, and exports to Japan; and the viability of alcohol exports to Japan.

The geographic area of this study encompasses the entire territory of Thailand. The country was divided into 7 regions based on (1) similarity in patterns of agricultural production; (2) potential for producing energy crops; (3) spatial location of major consumption centers and collecting points for agricultural products; and (4) transportation linkages among regions, and between each region and the export port.

Two base models were developed to represent different situation and agricultural policy alternatives: a fixed demand model which allows only crop exports to be affected by alcohol production and energy price changes, and a variable demand model in which crop consumption, exports, and prices freely adjust to changes in alcohol production and energy prices. Based on these two models, nine additional models were formulated to incorporate two levels of alcohol demand capacity (up to 20 and up to 100 percent alcohol substitution for gasoline to represent blended and pure fuel use respectively), three energy crop alternatives (sugarcane, cassava, and sweet sorghum), increased cropland availability, and future alcohol production impacts (1986)
under constant and increased crop yields. All of these models were parameterized at various energy price levels.

Results of the energy price parameterization show that alcohol produced from both molasses (a by-product of sugar production) and cassava is competitive at current energy price levels. Further, when molasses and cassava are available options for alcohol production, they are the only feedstocks selected throughout all energy price levels studied. However, when cassava is not considered as an alcohol option, alcohol produced from sweet sorghum and sugarcane is viable as energy prices are increased 10 and 20 percent above current prices, respectively.

With cassava as a primary source and at current energy prices, the northern part of the northeast region, which has the lowest cassava-alcohol production opportunity costs, is the only cassava alcohol producer and supplies surplus alcohol to the other north and northeast regions. As energy prices are increased, more alcohol is produced and eventually each region except the south becomes self-sufficient in alcohol production, while the northeast exports surplus alcohol to Japan. Alcohol exports occur only after domestic demand has been satisfied.

6.2. Conclusions

1. Alcohol production is a viable energy option in Thailand. Alcohol production from molasses, a by-product of sugar production, is competitive at all energy price levels
studied and could contribute 68 percent of the alcohol supply for a 20 percent blend with gasoline, or 11 percent of the pure alcohol for a complete substitution for gasoline. The remainder of alcohol production would come from competition between energy crops and food crops, and the specific quantity of alcohol produced would depend on the price of alcohol (gasoline) and the opportunity costs of alcohol production. Alcohol from energy crops would be produced if the price of alcohol is greater than alcohol production opportunity costs plus transportation costs from the production site to consumption centers. More alcohol would be competitively produced as energy prices are increased because alcohol price increases faster than alcohol production opportunity costs.

When energy prices are increased 5 percent above current prices, the amount of alcohol produced from energy crop feedstocks plus molasses is sufficient to blend with gasoline at the maximum rate of 20 percent.

To provide pure alcohol substitution for gasoline (from 20 to 100 percent), further increase in energy prices will be necessary. For example, a 10 percent energy prices increase would allow 42 percent substitution for gasoline, while 20 and 30 percent increase would result in 73 and 100 percent substitution. In addition to the energy prices and the opportunity costs of alcohol production, several other factors can contribute to increases in alcohol production.
They include potential alcohol demand, variable domestic and export commodity demands, and increases in cropland and crop yields.

2. **Cassava is superior to sugarcane as an energy-feedstock in Thailand.** Alcohol produced from cassava is more competitive than from sugarcane. The opportunity costs of alcohol production from cassava are lower than those from sugarcane at all energy price levels studies. However, in traditional sugarcane areas, cassava is only marginally less costly than sugarcane. Cassava alcohol production is feasible at current energy price levels, and only cassava is selected as an energy-feedstock in all energy price parameterization ranges. When cassava is not considered as an energy option, alcohol produced from sugarcane is competitive only if energy prices are increased 20 percent above current prices. However, the amount of alcohol produced is less than one percent of the total pure alcohol demand. Significant alcohol production from sugarcane occurs only at a very high energy price level (50 percent above current price). Even at energy prices 70 percent above current price, sugarcane plus molasses alcohol is still not sufficient to substitute for annual gasoline consumption.

Alcohol produced from sugarcane is less competitive than cassava due to relatively low yields of sugarcane and high yields of cassava. Moreover, sugarcane is grown mainly in the central plain, a major food producing and intensive
land use area. Thus, it has to compete with food crop production. While cassava is produced in the northeast, an area of limited rainfall, underutilized land resource and low intensity of food crop production. These factors result in higher opportunity costs of alcohol production from sugarcane than those of cassava.

3. **Alcohol production is region specific.** Northeast Thailand would be the major cassava alcohol producer and supplier. It can produce alcohol from cassava at lower production opportunity costs than can other parts of the country. Alcohol produced in this region can be sold within the region at a price lower than the regional gasoline price. It is also profitable for this region to export cassava alcohol to other parts of the country, except the east, which has the lowest gasoline price and where petroleum refinery plants are located. The northeast has a comparative advantage to grow cassava for energy feedstock because of its poor soil and drought conditions. Given the soil and weather conditions, food is less intensively produced compared to the central and north regions of Thailand, and land is not fully utilized. The increase in cassava production at low energy prices comes from the slack land resource. Therefore, it does not have to compete for land from food crops. In addition, potential alcohol demand in this region is low, only 12 percent of the total country
demand. The northeast would, thus, be the major alcohol exporter to central, northern, and southern of Thailand.

However, the central plain and the eastern region, the traditional sugarcane areas, would be major alcohol producers and suppliers if alcohol is produced from sugarcane. The opportunity costs of alcohol production from sugarcane in these two regions are lower than in other regions. They are also not significantly different from the opportunity costs of alcohol production from cassava in the same regions. Thus, the amount, cost, and feedstock source selected for alcohol production have important regional implications for Thailand.

4. Alcohol production has only minimal impact on exports. Agricultural commodity exports are not affected by alcohol production under the blended alcohol demand and low energy prices. This is because alcohol is produced mainly from the northeast, which has slack land and less competition from food production. Although, as cassava production increases further, it has to compete with food production for more land resource, and a small reduction in crop exports is found. For example, as the alcohol production increases to substitute completely for annual gasoline demand, sorghum exports decrease substantially and rice exports decrease slightly, while other crop exports including sugar and cassava, do not change.
5. **The impact of alcohol production on balance of trade is positive.** A slight reduction in crop exports results in a marginal loss of foreign exchange earnings. This is more than offset, however, by the savings from lower petroleum imports. The balance of trade becomes even more positive when alcohol production levels allow for exports.

6.3. **Policy implications**

Alcohol production in Thailand is feasible, the impact of alcohol production on agricultural commodity exports is minimal, and the impact on balance of trade is positive. These are all positive elements supporting alcohol fuel production in Thailand. How much alcohol should be produced, where the alcohol plants should be built, and the necessary supporting public policies are important questions that should be addressed.

The maximum amount of alcohol production may be set at 20 percent substitution for gasoline. This alcohol-gasoline blended fuel can be used without any engine modification. A small increase (+5 percent) in energy price above the current price is needed to provide an incentive to produce alcohol at this 20 percent rate. Production above this level, then, would be exported. Pure alcohol cars or 100 percent alcohol substitution for gasoline is another policy alternative. At this level of alcohol production, the country would be more independent of petroleum imports.
However, some engine modification is needed. This adds more costs to the pure alcohol car consumers, unless the additional costs are subsidized by the government. Higher energy prices (+30 percent) are needed to provide enough incentive to produce alcohol at this 100 percent substitution level. Thus, there would be greater impacts on agricultural commodity exports, agricultural domestic consumption and prices, and resource allocation between energy crop and food crop production. These impacts would be minimized if crop yields increase. This suggests that research should be focused on increasing output and less energy intensive technology.

Under 433 million liters of alcohol demand (20 percent substitution for gasoline), molasses alcohol would supply 293 million liters and the rest (140 million liters) would be supplied by cassava alcohol. One alcohol plant would be needed to produce this amount of alcohol, and the plant should be located in the northern part of the northeast (Region 3). This plant would supply alcohol within the region and export to the north, the central and the south of Thailand.

In order to supply 2,587 million liters of alcohol (100 percent substitution for gasoline), several alcohol plants would be built in the northeast, and at least one plant would be located in each of the other regions. The plants in the northeast, the north and the south would use cassava
as an energy feedstock. While the plants in the central and eastern regions could produce alcohol from either cassava or sugarcane. Although the opportunity costs of alcohol production from cassava are slightly lower than those from sugarcane in these two regions, sugarcane might be preferred to cassava as an energy feedstock. The central and eastern regions are major sugarcane producing areas and, at present, 32 sugar mills are located within the regions.

The locations of the plants suggested above fall within a more general framework. The specific locations of alcohol plants are important in relation to alcohol price, the opportunity costs of alcohol production and transportation costs within regions and from production sites to consumption centers in other regions. These plants should therefore be located in areas for which transportation costs and the opportunity costs of production are at their minimum. However, future research is still needed in order to determine the specific locations of these alcohol plants within each region.

6.4 Study Limitations

The limitations of this study are related to model formulation and data used. The model was formulated under some restrictive assumptions. These were (1) linear relationships between input and output; (2) perfect competition in agricultural and alcohol production, marketing and exports;
and (3) uniform production units, and homogeneous land and labor inputs within each region. The major limitations on data used are outlined below:

1. Inputs other than land and labor are unconstrained, although it is known that storage facilities, working capital (cash costs), machinery, and equipment are limited for many farmers in some areas.

2. Sweet sorghum is not commercially produced. Its costs of production and transportation are assumed to be equal to those of sugarcane. Yield is projected from experimental plots, and the grain price is assumed to be equal to corn price.

3. Alcohol fuel is not at this time produced in Thailand. Alcohol production costs, and input and output coefficients of the processing activities used in this study are based on feasibility studies. These studies refer to alcohol production experience in other countries, especially Brazil. Thus, the alcohol production costs, inputs used, and output may be over- or under-estimated.

4. The regional consumption of vegetables, flowers, other crops, cattle, and buffaloes is assumed to be equal to that regional production, although it is known that these commodities are traded among regions and some are exported.
5. The crop demand is estimated under the assumption that the quantity demand of a crop is a linear function of its own price, and the cross effect is excluded. If the cross effect is also included in the estimated demand equation, the result might more accurately represent the actual demand. It has been found that some farmers substitute broken rice for corn when relative prices of corn increase.

6. The crop consumption in 1986 is estimated under the assumption that consumption increases in proportion to population growth. If real income per capita increases during this 1981-1986 period, the estimated consumption would be less than actual consumption.

6.5. **Future Research**

Additional research is needed in four major areas.

1. Alcohol produced from cassava is more competitive than that produced from other energy crops. However, cassava-alcohol processing is not well developed, compared to that of sugarcane. Technical research on cassava-alcohol processing is thus needed. The energy input recommended for cassava processing in this study is wood. Other inputs, such as natural gas and lignite, may be as
useful; economic evaluation of alternative uses of natural gas and lignite as energy sources for cassava alcohol production should be done.

2. Sweet sorghum-alcohol processing is also not well developed, and it is considered to be the same as sugarcane-alcohol processing. The results of research done to improve sweet sorghum processing technology may increase its competitiveness, reduce the processing costs, and increase the alcohol output. Sorghum grain utilization and its value should also be studied so that more precise conclusions can be drawn.

3. Experience from other countries, especially Brazil, indicates that alcohol produced from sugarcane is viable. Alcohol production from sugarcane in Thailand is not competitive, however, due to its relatively low yield. The competitiveness of sugarcane as an energy feedstock would increase if yield of sugarcane increases. Also, increases in crop yields of other major agricultural commodities contribute significantly to the increase in alcohol production and minimize the impact on agricultural product exports. Research to improve yields of major crops including sugarcane should, therefore, be encouraged.
Locations of alcohol plants are sensitive to costs of intra and interregional shipment of alcohol and alcohol production opportunity costs. The plants should be located in such a way that these costs are minimized. Thus, the optimal locations of alcohol plants should be carefully determined before the alcohol production program is implemented.
APPENDIX A

COEFFICIENTS FOR PROGRAMMED ACTIVITIES
Table A.1: Energy Equivalents for Production of Agricultural Inputs

<table>
<thead>
<tr>
<th>Input</th>
<th>Unit</th>
<th>Kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Oil</td>
<td>liter</td>
<td>9,371</td>
</tr>
<tr>
<td>Gasoline</td>
<td>liter</td>
<td>8,398</td>
</tr>
<tr>
<td>Absolute Alcohol</td>
<td>liter</td>
<td>5,500</td>
</tr>
<tr>
<td>Hydrated Alcohol</td>
<td>liter</td>
<td>5,400</td>
</tr>
<tr>
<td>Machinery</td>
<td>kg</td>
<td>33,096</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>kg</td>
<td>18,480</td>
</tr>
<tr>
<td>Phosphoric</td>
<td>kg</td>
<td>3,344</td>
</tr>
<tr>
<td>Potassium</td>
<td>kg</td>
<td>2,310</td>
</tr>
<tr>
<td>Insecticides</td>
<td>kg</td>
<td>24,200</td>
</tr>
<tr>
<td>Herbicides</td>
<td>kg</td>
<td>24,200</td>
</tr>
<tr>
<td>Firewood</td>
<td>kg</td>
<td>2,550</td>
</tr>
<tr>
<td>Bagasse</td>
<td>kg</td>
<td>1,910</td>
</tr>
</tbody>
</table>

Sources: (1) and (44).
Table A.2: Agricultural Resources, Land and Labor, by Type and Region, 1981 and 1986

<table>
<thead>
<tr>
<th>Region</th>
<th>Total (1,000 rai)</th>
<th>Upland Crop (1,000 rai)</th>
<th>Irrigated Paddy (Wet Season) (1,000 rai)</th>
<th>Ordinary Paddy (Dry Seasons) (1,000 rai)</th>
<th>Vegetables and Flowers (1,000 rai)</th>
<th>Pasture (1,000 rai)</th>
<th>Idle (1,000 rai)</th>
<th>Labor (1,000 man-days) 1981</th>
<th>Labor (1,000 man-days) 1986</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8,730.9</td>
<td>2,036.0</td>
<td>1,127.5</td>
<td>634.1</td>
<td>4,724.9</td>
<td>35.1</td>
<td>11.7</td>
<td>161.6</td>
<td>776,301</td>
</tr>
<tr>
<td>2</td>
<td>19,946.1</td>
<td>7,297.9</td>
<td>2,517.8</td>
<td>431.9</td>
<td>9,295.2</td>
<td>55.7</td>
<td>135.1</td>
<td>212.5</td>
<td>592,507</td>
</tr>
<tr>
<td>3</td>
<td>29,360.1</td>
<td>5,446.3</td>
<td>1,231.5</td>
<td>537.3</td>
<td>20,427.3</td>
<td>53.8</td>
<td>158.0</td>
<td>1,505.9</td>
<td>1,359,399</td>
</tr>
<tr>
<td>4</td>
<td>18,687.9</td>
<td>4,454.7</td>
<td>399.4</td>
<td>169.2</td>
<td>13,121.7</td>
<td>23.6</td>
<td>56.4</td>
<td>462.9</td>
<td>758,984</td>
</tr>
<tr>
<td>5</td>
<td>7,675.5</td>
<td>3,398.8</td>
<td>2,970.5</td>
<td>155.0</td>
<td>1,879.8</td>
<td>11.9</td>
<td>51.4</td>
<td>208.1</td>
<td>229,117</td>
</tr>
<tr>
<td>6</td>
<td>13,408.1</td>
<td>3,021.0</td>
<td>6,199.1</td>
<td>2,725.2</td>
<td>1,176.7</td>
<td>110.7</td>
<td>62.4</td>
<td>113.0</td>
<td>693,284</td>
</tr>
<tr>
<td>7</td>
<td>5,414.2</td>
<td>103.1</td>
<td>1,578.1</td>
<td>128.8</td>
<td>3,132.0</td>
<td>23.7</td>
<td>48.0</td>
<td>400.5</td>
<td>664,394</td>
</tr>
<tr>
<td>Total</td>
<td>103,222.8</td>
<td>25,757.8</td>
<td>15,023.9</td>
<td>4,781.5</td>
<td>53,757.6</td>
<td>314.5</td>
<td>523.0</td>
<td>3,064.5</td>
<td>5,073,986</td>
</tr>
</tbody>
</table>

a/ All irrigation area is assumed to be completed in 1981.
b/ Ordinary paddy land = total paddy land - irrigated paddy land.
c/ Economically active labor force between the ages of 15-64; a worker works 25 days per month and 8 hours per day.

Sources: (32), (33), (41) and (61).
Table A.3: Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 1, 1981

<table>
<thead>
<tr>
<th>Agricultural Activity</th>
<th>Total Labor (man days)</th>
<th>Energy Inputs (DOE) (liters)</th>
<th>Non-Energy Production Costs (baht)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>8.99</td>
<td>12.17</td>
<td>469.27</td>
<td>0.28</td>
</tr>
<tr>
<td>Cassava</td>
<td>14.11</td>
<td>7.73</td>
<td>832.43</td>
<td>2.11</td>
</tr>
<tr>
<td>Rice - First Crop</td>
<td>13.77</td>
<td>18.05</td>
<td>637.75</td>
<td>0.43</td>
</tr>
<tr>
<td>Rice - Second Crop</td>
<td>15.85</td>
<td>28.90</td>
<td>1,086.16</td>
<td>0.65</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>31.71</td>
<td>42.33</td>
<td>1,767.10</td>
<td>5.48</td>
</tr>
<tr>
<td>Sweet Sorghum</td>
<td>31.71</td>
<td>42.33</td>
<td>1,767.10</td>
<td>8.00/a/</td>
</tr>
<tr>
<td>Sorghum</td>
<td>2.65</td>
<td>6.55</td>
<td>239.78</td>
<td>0.15</td>
</tr>
<tr>
<td>Soybeans</td>
<td>13.69</td>
<td>22.38</td>
<td>653.73</td>
<td>0.17</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>8.99</td>
<td>16.32</td>
<td>469.35</td>
<td>0.11</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>19.02</td>
<td>11.96</td>
<td>1,046.81</td>
<td>0.20</td>
</tr>
<tr>
<td>Cotton</td>
<td>23.83</td>
<td>18.66</td>
<td>1,740.20</td>
<td>0.14</td>
</tr>
<tr>
<td>Other Crops</td>
<td>25.46</td>
<td>21.21</td>
<td>2,634.00</td>
<td>0.13</td>
</tr>
<tr>
<td>Vegetables and Flowers</td>
<td>34.41</td>
<td>40.58</td>
<td>3,711.44</td>
<td>0.78</td>
</tr>
<tr>
<td>Casuarina Junghuhniana</td>
<td>1.29</td>
<td>1.08</td>
<td>17,184.69</td>
<td>54.72/b/</td>
</tr>
<tr>
<td>Cattle</td>
<td>45.00</td>
<td>2.02</td>
<td>57,127.00</td>
<td>20.00/c/</td>
</tr>
<tr>
<td>Buffaloes</td>
<td>45.00</td>
<td>2.02</td>
<td>133,912.00</td>
<td>20.00/d/</td>
</tr>
</tbody>
</table>

a/ Sweet sorghum production is of stalks and grains.
b/ In m³.
c/d/ In heads.

Sources: (7); (34), (35), (37) and field survey by the author.
Table A.4: Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 2, 1981

<table>
<thead>
<tr>
<th>Agricultural Activity</th>
<th>Total Labor (man days)</th>
<th>Energy Inputs (DOE) (liters)</th>
<th>Non-Energy Production Costs (baht)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>8.26</td>
<td>13.44</td>
<td>437.85</td>
<td>0.31</td>
</tr>
<tr>
<td>Cassava</td>
<td>14.11</td>
<td>8.39</td>
<td>921.30</td>
<td>2.32</td>
</tr>
<tr>
<td>Rice - First Crop</td>
<td>11.67</td>
<td>26.99</td>
<td>662.03</td>
<td>0.31</td>
</tr>
<tr>
<td>Rice - Second Crop</td>
<td>13.59</td>
<td>28.59</td>
<td>1,099.61</td>
<td>0.58</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>31.58</td>
<td>48.55</td>
<td>1,903.78</td>
<td>6.71</td>
</tr>
<tr>
<td>Sweet Sorghum</td>
<td>31.58</td>
<td>48.55</td>
<td>1,903.78</td>
<td>8.00/.482/</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3.14</td>
<td>6.75</td>
<td>269.15</td>
<td>0.17</td>
</tr>
<tr>
<td>Soybeans</td>
<td>10.40</td>
<td>19.90</td>
<td>676.79</td>
<td>0.14</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>8.26</td>
<td>18.05</td>
<td>413.54</td>
<td>0.10</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>21.50</td>
<td>11.70</td>
<td>1,180.18</td>
<td>0.19</td>
</tr>
<tr>
<td>Cotton</td>
<td>25.63</td>
<td>20.04</td>
<td>1,605.29</td>
<td>0.18</td>
</tr>
<tr>
<td>Kenaf</td>
<td>23.21</td>
<td>7.90</td>
<td>899.21</td>
<td>0.13</td>
</tr>
<tr>
<td>Other Crops</td>
<td>25.46</td>
<td>21.21</td>
<td>2,638.03</td>
<td>0.14</td>
</tr>
<tr>
<td>Vegetables and Flowers</td>
<td>34.41</td>
<td>40.58</td>
<td>3,719.07</td>
<td>0.78</td>
</tr>
<tr>
<td>Casuarina Junghuhniana</td>
<td>1.29</td>
<td>1.08</td>
<td>17,184.89</td>
<td>54.722/</td>
</tr>
<tr>
<td>Cattle</td>
<td>45.00</td>
<td>2.02</td>
<td>57,127.00</td>
<td>20.002/</td>
</tr>
<tr>
<td>Buffaloes</td>
<td>45.00</td>
<td>2.02</td>
<td>133,913.00</td>
<td>20.003/</td>
</tr>
</tbody>
</table>

a/ Sweet sorghum production is of stalks and grains.
b/ In m³.
c/ In heads.
d/ In heads.

Sources: (7), (34), (35), (37) and field survey by the author.
Table A.5: Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 3, 1981

<table>
<thead>
<tr>
<th>Agricultural Activity</th>
<th>Total Labor (man days)</th>
<th>Energy Inputs (DOE) (liters)</th>
<th>Non-Energy Production Costs (baht)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>10.96</td>
<td>9.99</td>
<td>466.24</td>
<td>0.23</td>
</tr>
<tr>
<td>Cassava</td>
<td>14.10</td>
<td>6.17</td>
<td>754.81</td>
<td>2.21</td>
</tr>
<tr>
<td>Rice - First Crop</td>
<td>15.93</td>
<td>13.20</td>
<td>572.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Rice - Second Crop</td>
<td>17.06</td>
<td>13.21</td>
<td>323.03</td>
<td>0.43</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>22.72</td>
<td>39.18</td>
<td>1,512.03</td>
<td>5.56</td>
</tr>
<tr>
<td>Sweet Sorghum</td>
<td>22.71</td>
<td>39.18</td>
<td>1,512.03</td>
<td>8.00/4.88/</td>
</tr>
<tr>
<td>Soybeans</td>
<td>13.78</td>
<td>15.49</td>
<td>815.67</td>
<td>0.13</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>10.96</td>
<td>14.31</td>
<td>536.26</td>
<td>0.11</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>23.40</td>
<td>7.36</td>
<td>1,061.67</td>
<td>0.16</td>
</tr>
<tr>
<td>Cotton</td>
<td>27.67</td>
<td>17.18</td>
<td>1,903.72</td>
<td>0.14</td>
</tr>
<tr>
<td>Kenaf</td>
<td>23.47</td>
<td>7.47</td>
<td>890.59</td>
<td>0.16</td>
</tr>
<tr>
<td>Other Crops</td>
<td>25.46</td>
<td>21.21</td>
<td>2,630.33</td>
<td>0.24</td>
</tr>
<tr>
<td>Vegetables and Flowers</td>
<td>34.41</td>
<td>40.58</td>
<td>3,715.91</td>
<td>0.78</td>
</tr>
<tr>
<td>Casuarina Junghuhniana</td>
<td>1.29</td>
<td>1.08</td>
<td>17,184.81</td>
<td>54.72/</td>
</tr>
<tr>
<td>Cattle</td>
<td>45.00</td>
<td>2.02</td>
<td>57,127.00</td>
<td>20.00/</td>
</tr>
<tr>
<td>Buffaloes</td>
<td>45.00</td>
<td>2.02</td>
<td>133,913.00</td>
<td>20.00/</td>
</tr>
</tbody>
</table>

a/ Sweet sorghum production is of stalks and grains.

b/ In m³.
c/,d/ In heads.

Sources: (7), (34), (35), (37) and field survey by the author.
Table A.6: Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 4, 1981

<table>
<thead>
<tr>
<th>Agricultural Activity</th>
<th>Energy Inputs (DOE) (liters)</th>
<th>Non-Energy Production Costs (baht)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>11.13</td>
<td>478.55</td>
<td>0.29</td>
</tr>
<tr>
<td>Cassava</td>
<td>7.06</td>
<td>812.16</td>
<td>2.21</td>
</tr>
<tr>
<td>Rice - First Crop</td>
<td>12.26</td>
<td>583.64</td>
<td>0.20</td>
</tr>
<tr>
<td>Rice - Second Crop</td>
<td>20.17</td>
<td>796.08</td>
<td>0.44</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>39.18</td>
<td>1,535.59</td>
<td>5.53</td>
</tr>
<tr>
<td>Sweet Sorghum</td>
<td>39.18</td>
<td>1,535.59</td>
<td>8.00/0.48⁴</td>
</tr>
<tr>
<td>Sorghum</td>
<td>10.30</td>
<td>305.90</td>
<td>0.18</td>
</tr>
<tr>
<td>Soybeans</td>
<td>19.71</td>
<td>734.76</td>
<td>0.13</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>15.20</td>
<td>450.10</td>
<td>0.11</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>13.70</td>
<td>1,101.40</td>
<td>0.18</td>
</tr>
<tr>
<td>Cotton</td>
<td>16.71</td>
<td>2,159.58</td>
<td>0.19</td>
</tr>
<tr>
<td>Kenaf</td>
<td>8.29</td>
<td>893.73</td>
<td>0.17</td>
</tr>
<tr>
<td>Other Crops</td>
<td>21.21</td>
<td>2,636.76</td>
<td>0.14</td>
</tr>
<tr>
<td>Vegetables and Flowers</td>
<td>40.58</td>
<td>3,716.72</td>
<td>0.78</td>
</tr>
<tr>
<td>Casuarina Junghuhniana</td>
<td>1.08</td>
<td>17,184.83</td>
<td>54.72³</td>
</tr>
<tr>
<td>Cattle</td>
<td>2.02</td>
<td>57,127.00</td>
<td>20.00⁵</td>
</tr>
<tr>
<td>Buffaloes</td>
<td>2.02</td>
<td>133,913.00</td>
<td>20.00⁶</td>
</tr>
</tbody>
</table>

a/ Sweet sorghum production is of stalks and grains.

b/ In m³.

c/,d/ In heads.

Sources: (7), (34), (35), (37) and field survey by the author.
Table A.7: Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 5, 1981

<table>
<thead>
<tr>
<th>Agricultural Activity</th>
<th>Total Labor Inputs (man days)</th>
<th>Energy Inputs (DOE) (liters)</th>
<th>Non-Energy Production Costs (baht)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>8.81</td>
<td>11.33</td>
<td>550.47</td>
<td>0.28</td>
</tr>
<tr>
<td>Cassava</td>
<td>12.10</td>
<td>7.40</td>
<td>841.50</td>
<td>2.36</td>
</tr>
<tr>
<td>Rice - First Crop</td>
<td>7.38</td>
<td>29.97</td>
<td>538.74</td>
<td>0.27</td>
</tr>
<tr>
<td>Rice - Second Crop</td>
<td>9.80</td>
<td>37.66</td>
<td>1,071.16</td>
<td>0.48</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>23.02</td>
<td>46.46</td>
<td>1,556.85</td>
<td>7.16</td>
</tr>
<tr>
<td>Sweet Sorghum</td>
<td>23.02</td>
<td>46.46</td>
<td>1,556.85</td>
<td>8.00/48a</td>
</tr>
<tr>
<td>Soybeans</td>
<td>10.32</td>
<td>16.78</td>
<td>703.45</td>
<td>0.15</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>8.14</td>
<td>15.73</td>
<td>462.49</td>
<td>0.10</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>16.20</td>
<td>15.35</td>
<td>1,038.94</td>
<td>0.18</td>
</tr>
<tr>
<td>Cotton</td>
<td>25.74</td>
<td>22.28</td>
<td>2,021.05</td>
<td>0.17</td>
</tr>
<tr>
<td>Kenaf</td>
<td>22.78</td>
<td>8.29</td>
<td>889.47</td>
<td>0.17</td>
</tr>
<tr>
<td>Other Crops</td>
<td>25.46</td>
<td>21.21</td>
<td>2,640.57</td>
<td>0.14</td>
</tr>
<tr>
<td>Vegetables and Flowers</td>
<td>34.41</td>
<td>40.58</td>
<td>3,724.02</td>
<td>0.78</td>
</tr>
<tr>
<td>Casuarina Junghuhniana</td>
<td>1.29</td>
<td>1.08</td>
<td>17,185.02</td>
<td>54.72b</td>
</tr>
<tr>
<td>Cattle</td>
<td>45.00</td>
<td>2.02</td>
<td>57,127.00</td>
<td>20.00c</td>
</tr>
<tr>
<td>Buffaloes</td>
<td>45.00</td>
<td>2.02</td>
<td>133,913.00</td>
<td>20.00d</td>
</tr>
</tbody>
</table>

a/ Sweet sorghum production is of stalks and grains.
b/ In m³.
c/,d/ In heads.

Sources: (7), (34), (35), (37) and field survey by the author.
Table A.8: Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 6, 1981

<table>
<thead>
<tr>
<th>Agricultural Activity</th>
<th>Total Labor Inputs (DOE) (man days)</th>
<th>Energy Inputs (DOE) (liters)</th>
<th>Non-Energy Production Costs (baht)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>8.16</td>
<td>11.40</td>
<td>515.44</td>
<td>0.23</td>
</tr>
<tr>
<td>Cassava</td>
<td>12.83</td>
<td>8.34</td>
<td>853.84</td>
<td>2.36</td>
</tr>
<tr>
<td>Rice – First Crop</td>
<td>8.13</td>
<td>34.73</td>
<td>639.23</td>
<td>0.30</td>
</tr>
<tr>
<td>Rice – Second Crop</td>
<td>10.44</td>
<td>29.80</td>
<td>1,131.48</td>
<td>0.61</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>21.14</td>
<td>49.48</td>
<td>1,858.03</td>
<td>7.56</td>
</tr>
<tr>
<td>Sweet Sorghum</td>
<td>21.14</td>
<td>49.48</td>
<td>1,858.03</td>
<td>8.00/480</td>
</tr>
<tr>
<td>Sorghum</td>
<td>4.32</td>
<td>9.97</td>
<td>319.66</td>
<td>0.18</td>
</tr>
<tr>
<td>Soybeans</td>
<td>11.90</td>
<td>14.89</td>
<td>743.09</td>
<td>0.15</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>8.16</td>
<td>16.31</td>
<td>455.62</td>
<td>0.10</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>20.40</td>
<td>13.98</td>
<td>1,007.27</td>
<td>0.18</td>
</tr>
<tr>
<td>Cotton</td>
<td>24.08</td>
<td>19.31</td>
<td>2,085.23</td>
<td>0.16</td>
</tr>
<tr>
<td>Other Crops</td>
<td>25.46</td>
<td>21.21</td>
<td>2,642.06</td>
<td>0.14</td>
</tr>
<tr>
<td>Vegetables and Flowers</td>
<td>34.41</td>
<td>40.58</td>
<td>3,726.86</td>
<td>0.78</td>
</tr>
<tr>
<td>Casuarina Junghuhniana</td>
<td>1.29</td>
<td>1.08</td>
<td>17,185.10</td>
<td>54.72b/</td>
</tr>
<tr>
<td>Cattle</td>
<td>45.00</td>
<td>2.02</td>
<td>57,127.00</td>
<td>20.00c/</td>
</tr>
<tr>
<td>Buffaloes</td>
<td>45.00</td>
<td>2.02</td>
<td>133,913.00</td>
<td>20.00d/</td>
</tr>
</tbody>
</table>

a/ Sweet sorghum production is of stalks and grains.
b/ In m³.
c/d/ In heads.

Sources: (7), (34), (35), (37) and field survey by the author.
Table A.9: Technical Coefficients, Costs and Production per Rai for Agricultural Activities in Region 7, 1981

<table>
<thead>
<tr>
<th>Agricultural Activity</th>
<th>Total Labor (man days)</th>
<th>Energy Inputs (DOE) (liters)</th>
<th>Non-Energy Production Costs (baht)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava</td>
<td>12.90</td>
<td>6.30</td>
<td>888.30</td>
<td>1.78</td>
</tr>
<tr>
<td>Rice - First Crop</td>
<td>12.55</td>
<td>22.19</td>
<td>718.99</td>
<td>0.28</td>
</tr>
<tr>
<td>Rice - Second Crop</td>
<td>9.74</td>
<td>41.87</td>
<td>735.22</td>
<td>0.43</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>8.44</td>
<td>16.40</td>
<td>444.57</td>
<td>0.10</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>21.46</td>
<td>10.68</td>
<td>1,137.26</td>
<td>0.20</td>
</tr>
<tr>
<td>Vegetables and Flowers</td>
<td>34.41</td>
<td>40.58</td>
<td>3,738.52</td>
<td>0.78</td>
</tr>
<tr>
<td>Casuarina Junghuhniana</td>
<td>1.29</td>
<td>1.08</td>
<td>17,184.77</td>
<td>54.72&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cattle</td>
<td>45.00</td>
<td>2.02</td>
<td>57,127.00</td>
<td>20.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Buffaloes</td>
<td>45.00</td>
<td>2.02</td>
<td>133,913.00</td>
<td>20.00&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> In m³.
<sup>b</sup>,<sup>c</sup> In heads.

Sources: (7), (34), (35), (37) and field survey by the author.
Table A.10: Sugar and Alcohol Production: Input/Output Coefficients and Non-Energy Costs by Production Process, 1981

<table>
<thead>
<tr>
<th>Input and Output</th>
<th>Sugar from Sugarcane</th>
<th>Alcohol from Sugarcane</th>
<th>Alcohol from Cassava</th>
<th>Alcohol from Sweet Sorghum</th>
<th>Alcohol from Sugarcane and Cassava</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Energy Costs (baht)</td>
<td>322.94</td>
<td>214.90</td>
<td>489.60</td>
<td>243.10</td>
<td>282.94</td>
</tr>
<tr>
<td>Sugarcane (ton)</td>
<td>1.00</td>
<td>1.00</td>
<td>--</td>
<td>--</td>
<td>0.70</td>
</tr>
<tr>
<td>Cassava (ton)</td>
<td>--</td>
<td>--</td>
<td>1.00</td>
<td>--</td>
<td>0.30</td>
</tr>
<tr>
<td>Sweet Sorghum (ton)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1.00</td>
<td>--</td>
</tr>
<tr>
<td>Casuarina Junghuhniana (m³)</td>
<td>--</td>
<td>--</td>
<td>0.38</td>
<td>--</td>
<td>0.065</td>
</tr>
<tr>
<td>Sugar (ton)</td>
<td>0.083</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Alcohol (liter)</td>
<td>14.00</td>
<td>70.00</td>
<td>160.00</td>
<td>65.00</td>
<td>97.00</td>
</tr>
<tr>
<td>Bagasse (ton)</td>
<td>0.012</td>
<td>0.015</td>
<td>--</td>
<td>0.007</td>
<td>--</td>
</tr>
<tr>
<td>Stillage (liter)</td>
<td>156.00</td>
<td>910.00</td>
<td>1,827.00</td>
<td>910.00</td>
<td>1,185.10</td>
</tr>
</tbody>
</table>

Sources: Estimated from information contained in: (24), (26), (39), (46), (64), (65), and (66).
Table A.11: Non-Energy Costs and Energy Inputs Per Ton of Raw-Material Transported from Farms to Processing Plants by Region, 1981

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Energy Costs (baht)</td>
<td></td>
<td>78.80</td>
<td>78.80</td>
<td>78.80</td>
<td>78.80</td>
<td>75.55</td>
<td>75.55</td>
<td>--</td>
</tr>
<tr>
<td>Energy-DOE (liters)</td>
<td></td>
<td>3.45</td>
<td>3.45</td>
<td>3.45</td>
<td>3.45</td>
<td>3.22</td>
<td>3.22</td>
<td>--</td>
</tr>
<tr>
<td>Cassava</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Energy Costs (baht)</td>
<td></td>
<td>90.80</td>
<td>90.80</td>
<td>84.79</td>
<td>84.79</td>
<td>84.79</td>
<td>90.80</td>
<td>131.91</td>
</tr>
<tr>
<td>Energy-DOE (liters)</td>
<td></td>
<td>4.05</td>
<td>4.05</td>
<td>3.65</td>
<td>3.65</td>
<td>3.65</td>
<td>4.05</td>
<td>5.67</td>
</tr>
<tr>
<td>Sweet Sorghum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Energy Costs (baht)</td>
<td></td>
<td>78.80</td>
<td>78.80</td>
<td>78.80</td>
<td>78.80</td>
<td>75.55</td>
<td>75.55</td>
<td>--</td>
</tr>
<tr>
<td>Energy-DOE (liters)</td>
<td></td>
<td>3.45</td>
<td>3.45</td>
<td>3.45</td>
<td>3.45</td>
<td>3.22</td>
<td>3.22</td>
<td>--</td>
</tr>
<tr>
<td>Casuarina Junghuhniana</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Energy Costs (baht)</td>
<td></td>
<td>65.64</td>
<td>65.64</td>
<td>65.64</td>
<td>65.64</td>
<td>65.64</td>
<td>65.64</td>
<td>65.64</td>
</tr>
<tr>
<td>Energy-DOE (liters)</td>
<td></td>
<td>4.60</td>
<td>4.60</td>
<td>4.60</td>
<td>4.60</td>
<td>4.60</td>
<td>4.60</td>
<td>4.60</td>
</tr>
</tbody>
</table>

Sources: Calculated from Data Contained in: (10), (40), (62) and field survey by the author.
Table A.12: Non-Energy Costs and Energy Inputs Per Liter of Alcohol Transported from Distilleries to Consumption Centers and Among Regions, 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Destination Center</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Export</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region 1</td>
<td>Non-Energy Costs (baht)</td>
<td>.116</td>
<td>.642</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1.035</td>
</tr>
<tr>
<td>Region 1</td>
<td>Energy-DOE (liters)</td>
<td>.011</td>
<td>.062</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>.099</td>
</tr>
<tr>
<td>Region 2</td>
<td>Non-Energy Costs (baht)</td>
<td>.642</td>
<td>.116</td>
<td>--</td>
<td>.624</td>
<td>--</td>
<td>.393</td>
<td>--</td>
<td>.393</td>
</tr>
<tr>
<td>Region 2</td>
<td>Energy-DOE (liters)</td>
<td>.062</td>
<td>.011</td>
<td>--</td>
<td>.059</td>
<td>--</td>
<td>.038</td>
<td>--</td>
<td>.038</td>
</tr>
<tr>
<td>Region 3</td>
<td>Non-Energy Costs (baht)</td>
<td>.985</td>
<td>.706</td>
<td>.116</td>
<td>.335</td>
<td>.771</td>
<td>.751</td>
<td>2.075</td>
<td>.751</td>
</tr>
<tr>
<td>Region 3</td>
<td>Energy-DOE (liters)</td>
<td>.093</td>
<td>.067</td>
<td>.011</td>
<td>.032</td>
<td>.072</td>
<td>.071</td>
<td>.201</td>
<td>.071</td>
</tr>
<tr>
<td>Region 4</td>
<td>Non-Energy Costs (baht)</td>
<td>1.033</td>
<td>.624</td>
<td>.335</td>
<td>.116</td>
<td>.436</td>
<td>.416</td>
<td>1.740</td>
<td>.416</td>
</tr>
<tr>
<td>Region 4</td>
<td>Energy-DOE (liters)</td>
<td>.098</td>
<td>.059</td>
<td>.032</td>
<td>.011</td>
<td>.041</td>
<td>.039</td>
<td>.169</td>
<td>.039</td>
</tr>
<tr>
<td>Region 5</td>
<td>Non-Energy Costs (baht)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>.092</td>
<td>.197</td>
<td>--</td>
<td>.197</td>
</tr>
<tr>
<td>Region 5</td>
<td>Energy-DOE (liters)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>.009</td>
<td>.018</td>
<td>--</td>
<td>.018</td>
</tr>
<tr>
<td>Region 6</td>
<td>Non-Energy Costs (baht)</td>
<td>--</td>
<td>.393</td>
<td>--</td>
<td>.416</td>
<td>.197</td>
<td>.116</td>
<td>1.373</td>
<td>.116</td>
</tr>
<tr>
<td>Region 6</td>
<td>Energy-DOE (liters)</td>
<td>--</td>
<td>.038</td>
<td>--</td>
<td>.039</td>
<td>.018</td>
<td>.011</td>
<td>.130</td>
<td>.011</td>
</tr>
<tr>
<td>Region 7</td>
<td>Non-Energy Costs (baht)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1.373</td>
<td>.116</td>
<td>1.373</td>
</tr>
<tr>
<td>Region 7</td>
<td>Energy-DOE (liters)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>.130</td>
<td>.011</td>
<td>.130</td>
</tr>
</tbody>
</table>

Sources: (40) and field survey by the author.
Table A.13: Agricultural Product Exports and Consumption by Region, 1981

<table>
<thead>
<tr>
<th>Region and Export</th>
<th>Agricultural Product</th>
<th>Vegetables</th>
<th>Cattle Buffaloes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corn</td>
<td>Cassava</td>
<td>Rice</td>
</tr>
<tr>
<td>1</td>
<td>81.47</td>
<td>25.93</td>
<td>1,444.00</td>
</tr>
<tr>
<td>2</td>
<td>89.93</td>
<td>26.91</td>
<td>2,498.00</td>
</tr>
<tr>
<td>3</td>
<td>23.55</td>
<td>45.68</td>
<td>2,543.00</td>
</tr>
<tr>
<td>4</td>
<td>15.05</td>
<td>28.72</td>
<td>1,599.00</td>
</tr>
<tr>
<td>5</td>
<td>75.59</td>
<td>12.81</td>
<td>713.00</td>
</tr>
<tr>
<td>6</td>
<td>329.41</td>
<td>55.82</td>
<td>3,108.00</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>27.72</td>
<td>1,543.00</td>
</tr>
<tr>
<td>Total</td>
<td>611.00</td>
<td>223.57</td>
<td>12,448.00</td>
</tr>
</tbody>
</table>

Exports 2,700.00 18,000.00 4,700.00 225.00 5.00 190.00 16.00 44.00 20.00 -- -- 1,160.00 -- --

Sources: (34), (35), (36) and (61).
<table>
<thead>
<tr>
<th>Region and Export</th>
<th>Agricultural Product</th>
<th>Other Crops</th>
<th>Vegetables and Flowers</th>
<th>Sugar</th>
<th>Cattle Buffaloes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corn</td>
<td>Cassava</td>
<td>Rice</td>
<td>Sorghum</td>
<td>Soybeans</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2,475</td>
<td>530</td>
<td>2,350</td>
<td>2,700</td>
<td>6,750</td>
</tr>
<tr>
<td>2</td>
<td>2,703</td>
<td>530</td>
<td>2,710</td>
<td>2,740</td>
<td>6,910</td>
</tr>
<tr>
<td>3</td>
<td>2,340</td>
<td>450</td>
<td>2,270</td>
<td>--</td>
<td>6,930</td>
</tr>
<tr>
<td>4</td>
<td>2,625</td>
<td>575</td>
<td>2,390</td>
<td>2,760</td>
<td>6,970</td>
</tr>
<tr>
<td>5</td>
<td>2,573</td>
<td>580</td>
<td>2,890</td>
<td>--</td>
<td>7,500</td>
</tr>
<tr>
<td>6</td>
<td>2,760</td>
<td>580</td>
<td>2,930</td>
<td>2,850</td>
<td>7,500</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>530</td>
<td>2,790</td>
<td>--</td>
<td>7,950</td>
</tr>
<tr>
<td>Export</td>
<td>2,985</td>
<td>880</td>
<td>3,877</td>
<td>3,380</td>
<td>7,902</td>
</tr>
</tbody>
</table>

Sources: (34), (35), (36) and (37).
<table>
<thead>
<tr>
<th>Commodity</th>
<th>Domestic Demand</th>
<th>Exporters' Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>2.2000</td>
<td>1.9900</td>
</tr>
<tr>
<td>Rice</td>
<td>0.1174</td>
<td>1.3136</td>
</tr>
<tr>
<td>Soybeans</td>
<td>0.8830</td>
<td>--</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>0.3690</td>
<td>1.2660</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>0.1440</td>
<td>--</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.6795</td>
<td>--</td>
</tr>
<tr>
<td>Kenaf</td>
<td>0.5448</td>
<td>1.5200</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.2676</td>
<td>0.4029</td>
</tr>
<tr>
<td>Cassava</td>
<td>--</td>
<td>0.2600</td>
</tr>
</tbody>
</table>

Sources: (6), (27), (36), (71) and (72).
Table A.16: Estimated Demand Equations by Agricultural Product – Regions 1, 2, 3, and 4, 1981

<table>
<thead>
<tr>
<th>Agricultural Product</th>
<th>Region 1 Intercept</th>
<th>Region 1 Price Coefficient</th>
<th>Region 2 Intercept</th>
<th>Region 2 Price Coefficient</th>
<th>Region 3 Intercept</th>
<th>Region 3 Price Coefficient</th>
<th>Region 4 Intercept</th>
<th>Region 4 Price Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>230,096.8</td>
<td>60.05</td>
<td>252,923.9</td>
<td>62.30</td>
<td>65,247.0</td>
<td>17.65</td>
<td>44,191.5</td>
<td>11.10</td>
</tr>
<tr>
<td>Rice</td>
<td>1,546,671.5</td>
<td>43.69</td>
<td>1,510,276.3</td>
<td>4.53</td>
<td>2,717,699.2</td>
<td>76.96</td>
<td>1,610,519.8</td>
<td>4.82</td>
</tr>
<tr>
<td>Soybeans</td>
<td>33,848.8</td>
<td>2.20</td>
<td>36,151.8</td>
<td>2.28</td>
<td>61,444.10</td>
<td>3.87</td>
<td>38,704.1</td>
<td>2.43</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>10,866.9</td>
<td>0.39</td>
<td>11,460.2</td>
<td>0.40</td>
<td>19,068.2</td>
<td>0.68</td>
<td>12,025.5</td>
<td>0.43</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>77,412.1</td>
<td>5.26</td>
<td>77,015.0</td>
<td>5.00</td>
<td>25,449.4</td>
<td>0.34</td>
<td>16,083.1</td>
<td>0.21</td>
</tr>
<tr>
<td>Kenaf</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>148,515.2</td>
<td>8.77</td>
<td>95,623.2</td>
<td>5.55</td>
</tr>
<tr>
<td>Sugar</td>
<td>80,138.7</td>
<td>1.82</td>
<td>83,891.3</td>
<td>1.89</td>
<td>141,799.4</td>
<td>3.20</td>
<td>89,455.6</td>
<td>2.01</td>
</tr>
</tbody>
</table>
Table A.17: Estimated Demand Equations by Agricultural Product – Regions 5, 6, 7 and Export, 1981

<table>
<thead>
<tr>
<th>Agricultural Product</th>
<th>Region 5</th>
<th>Region 6</th>
<th>Region 7</th>
<th>Export</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept</td>
<td>Price</td>
<td>Intercept</td>
<td>Price</td>
</tr>
<tr>
<td>Corn</td>
<td>218,928.8</td>
<td>55.71</td>
<td>999,513.4</td>
<td>242.8</td>
</tr>
<tr>
<td>Rice</td>
<td>775,395.1</td>
<td>21.59</td>
<td>3,383,683.7</td>
<td>94.09</td>
</tr>
<tr>
<td>Soybeans</td>
<td>16,745.0</td>
<td>1.09</td>
<td>78,150.0</td>
<td>4.75</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>5,484.9</td>
<td>0.19</td>
<td>24,485.0</td>
<td>0.83</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>7,294.0</td>
<td>0.09</td>
<td>31,924.0</td>
<td>0.41</td>
</tr>
<tr>
<td>Cotton</td>
<td>--</td>
<td>--</td>
<td>252,380.6</td>
<td>8.92</td>
</tr>
<tr>
<td>Kenaf</td>
<td>--</td>
<td>--</td>
<td>41,680.9</td>
<td>2.37</td>
</tr>
<tr>
<td>Sugar</td>
<td>39,963.0</td>
<td>0.90</td>
<td>174,578.2</td>
<td>3.91</td>
</tr>
<tr>
<td>Cassava</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>
APPENDIX B

MODELS OUTPUT
Table B.1: Alcohol Wholesale Price by Region in 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Current</th>
<th>+5%</th>
<th>+10%</th>
<th>+15%</th>
<th>+20%</th>
<th>+30%</th>
<th>+40%</th>
<th>+50%</th>
<th>+60%</th>
<th>+70%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(baht/liter)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7.13</td>
<td>7.49</td>
<td>7.84</td>
<td>8.20</td>
<td>8.56</td>
<td>9.27</td>
<td>9.98</td>
<td>10.70</td>
<td>11.41</td>
<td>12.12</td>
</tr>
<tr>
<td>3</td>
<td>7.50</td>
<td>7.88</td>
<td>8.25</td>
<td>8.63</td>
<td>9.00</td>
<td>9.75</td>
<td>10.50</td>
<td>11.25</td>
<td>12.00</td>
<td>12.75</td>
</tr>
<tr>
<td>4</td>
<td>7.15</td>
<td>7.51</td>
<td>7.87</td>
<td>8.22</td>
<td>8.58</td>
<td>9.30</td>
<td>10.01</td>
<td>10.73</td>
<td>11.44</td>
<td>12.16</td>
</tr>
<tr>
<td>5</td>
<td>6.64</td>
<td>6.97</td>
<td>7.30</td>
<td>7.64</td>
<td>7.97</td>
<td>8.63</td>
<td>9.30</td>
<td>9.96</td>
<td>10.62</td>
<td>11.29</td>
</tr>
<tr>
<td>6</td>
<td>6.67</td>
<td>7.00</td>
<td>7.34</td>
<td>7.67</td>
<td>8.00</td>
<td>8.67</td>
<td>9.34</td>
<td>10.01</td>
<td>10.67</td>
<td>11.34</td>
</tr>
<tr>
<td>7</td>
<td>8.51</td>
<td>8.94</td>
<td>9.36</td>
<td>9.79</td>
<td>10.21</td>
<td>11.06</td>
<td>11.91</td>
<td>12.77</td>
<td>13.62</td>
<td>14.47</td>
</tr>
<tr>
<td>Export</td>
<td>5.80</td>
<td>6.09</td>
<td>6.38</td>
<td>6.67</td>
<td>6.96</td>
<td>7.54</td>
<td>8.12</td>
<td>8.70</td>
<td>9.28</td>
<td>9.86</td>
</tr>
<tr>
<td>Region</td>
<td>Current</td>
<td>+5%</td>
<td>+10%</td>
<td>+15%</td>
<td>+20%</td>
<td>+30%</td>
<td>+40%</td>
<td>+50%</td>
<td>+60%</td>
<td>+70%</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>-----</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>7.50</td>
<td>7.88</td>
<td>8.25</td>
<td>8.63</td>
<td>9.00</td>
<td>9.75</td>
<td>10.50</td>
<td>11.25</td>
<td>12.00</td>
<td>12.75</td>
</tr>
<tr>
<td>2</td>
<td>7.31</td>
<td>7.68</td>
<td>8.04</td>
<td>8.41</td>
<td>8.77</td>
<td>9.50</td>
<td>10.23</td>
<td>10.97</td>
<td>11.70</td>
<td>12.43</td>
</tr>
<tr>
<td>3</td>
<td>7.39</td>
<td>7.76</td>
<td>8.13</td>
<td>8.50</td>
<td>8.67</td>
<td>9.61</td>
<td>10.35</td>
<td>11.09</td>
<td>11.82</td>
<td>12.56</td>
</tr>
<tr>
<td>4</td>
<td>7.37</td>
<td>7.74</td>
<td>8.11</td>
<td>8.48</td>
<td>8.84</td>
<td>9.58</td>
<td>10.32</td>
<td>11.06</td>
<td>11.79</td>
<td>12.53</td>
</tr>
<tr>
<td>5</td>
<td>7.19</td>
<td>7.55</td>
<td>7.91</td>
<td>8.27</td>
<td>8.63</td>
<td>9.35</td>
<td>10.07</td>
<td>10.79</td>
<td>11.50</td>
<td>12.22</td>
</tr>
<tr>
<td>6</td>
<td>7.12</td>
<td>7.78</td>
<td>7.83</td>
<td>8.19</td>
<td>8.54</td>
<td>9.26</td>
<td>9.97</td>
<td>10.68</td>
<td>11.39</td>
<td>12.10</td>
</tr>
<tr>
<td>7</td>
<td>7.42</td>
<td>7.79</td>
<td>8.16</td>
<td>8.53</td>
<td>8.90</td>
<td>9.65</td>
<td>10.39</td>
<td>11.13</td>
<td>11.87</td>
<td>12.61</td>
</tr>
</tbody>
</table>
Table B.3: Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels—0 to 20 Percent Alcohol Substitution for Gasoline (Model C), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Molasses</th>
<th>Cassava</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Energy</td>
<td>Energy Price Level</td>
</tr>
<tr>
<td></td>
<td>Current</td>
<td>+5%</td>
</tr>
<tr>
<td>(10^6 liters)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5</td>
<td>51</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>192</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>All regions</td>
<td>297</td>
<td>85</td>
</tr>
<tr>
<td>Total (Including molasses)</td>
<td>--</td>
<td>382</td>
</tr>
</tbody>
</table>

a/ Maximum demand consumption.
Table B.4: Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline (Model E), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Molasses (10^6 liters)</th>
<th>Cassava Energy Price Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current +10% +20% +30% - +50% +60%</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>-- -- -- 154 154</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>-- 60 60 60 150</td>
</tr>
<tr>
<td>3</td>
<td>20 (21)\textsuperscript{a/}</td>
<td>586 745 745 745 745</td>
</tr>
<tr>
<td>4</td>
<td>--</td>
<td>-- -- 779 779 779</td>
</tr>
<tr>
<td>5</td>
<td>51 (50)\textsuperscript{b/}</td>
<td>-- -- -- 174 175</td>
</tr>
<tr>
<td>6</td>
<td>192</td>
<td>-- -- -- 373 1,466</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>-- -- -- 5 5</td>
</tr>
<tr>
<td>All regions</td>
<td>297</td>
<td>586 805 1,584 2,290 3,474</td>
</tr>
<tr>
<td>Total</td>
<td>(Including molasses)</td>
<td>883 1,102 1,881 2,587\textsuperscript{c/} 3,771</td>
</tr>
</tbody>
</table>

\textsuperscript{a/} Molasses alcohol at the energy prices of +60 percent.
\textsuperscript{b/} Maximum demand consumption.
Table B.5: Alcohol Production by Region and Energy-Feedstock at Specified Energy Price Levels—0 to 100 Percent Alcohol Substitution for Gasoline (Model I), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Molasses</th>
<th>Cassava</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Energy</td>
<td>Energy Price Level</td>
</tr>
<tr>
<td></td>
<td>Price Levels</td>
<td>Current</td>
</tr>
<tr>
<td>1</td>
<td>12 (11)(^a/)</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>586</td>
</tr>
<tr>
<td>4</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5</td>
<td>47 (46)(^d/)</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>192</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>All regions</td>
<td>293</td>
<td>586</td>
</tr>
<tr>
<td>Total (Including molasses)</td>
<td>879</td>
<td>1,160</td>
</tr>
</tbody>
</table>

\(^a/\) Molasses alcohol at energy prices of +60 percent.
\(^b/\) Sugarcane-cassava alcohol.
\(^c/\) Molasses alcohol at energy prices of +20 percent - +60 percent.
\(^d/\) Maximum demand consumption.
Table B.6: Land Use by Region and Agricultural Product—Current Energy Prices, 18 Percent Alcohol Substitution for Gasoline (Model D), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Corn (1,000 ha)</th>
<th>Cassava</th>
<th>Rice</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Groundnuts</th>
<th>Cotton</th>
<th>Kenaf</th>
<th>Vegetables</th>
<th>Other Crops</th>
<th>Cattle Crops</th>
<th>Buffalo</th>
<th>Casuarina</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>384.6</td>
<td>12.3</td>
<td>154.0</td>
<td>7,120.6</td>
<td>42.0</td>
<td>1,065.6</td>
<td>160.7</td>
<td>138.7</td>
<td>--</td>
<td>34.6</td>
<td>78.1</td>
<td>26.5</td>
<td>35.8</td>
<td>28,232.6</td>
</tr>
<tr>
<td>2</td>
<td>8,232.6</td>
<td>173.0</td>
<td>238.0</td>
<td>10,159.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,090.0</td>
<td>--</td>
<td>55.1</td>
<td>82.1</td>
<td>23.2</td>
<td>30.8</td>
</tr>
<tr>
<td>3</td>
<td>104.1</td>
<td>2,127.0</td>
<td>252.0</td>
<td>11,792.9</td>
<td>--</td>
<td>--</td>
<td>913.6</td>
<td>144.6</td>
<td>--</td>
<td>603.3</td>
<td>52.6</td>
<td>137.6</td>
<td>93.2</td>
<td>119.0</td>
</tr>
<tr>
<td>4</td>
<td>2,086.4</td>
<td>2,217.0</td>
<td>--</td>
<td>7,779.9</td>
<td>19.0</td>
<td>--</td>
<td>445.2</td>
<td>--</td>
<td>--</td>
<td>655.7</td>
<td>23.1</td>
<td>86.5</td>
<td>24.1</td>
<td>60.9</td>
</tr>
<tr>
<td>5</td>
<td>270.0</td>
<td>2,553.5</td>
<td>468.7</td>
<td>4,160.3</td>
<td>--</td>
<td>68.1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>11.5</td>
<td>38.6</td>
<td>12.8</td>
<td>11.1</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>1,144.4</td>
<td>1,809.0</td>
<td>10,115.6</td>
<td>1,287.0</td>
<td>--</td>
<td>953.2</td>
<td>369.9</td>
<td>--</td>
<td>--</td>
<td>110.3</td>
<td>168.1</td>
<td>17.6</td>
<td>11.5</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>15.6</td>
<td>--</td>
<td>4,967.7</td>
<td>--</td>
<td>15.9</td>
<td>71.6</td>
<td>--</td>
<td>--</td>
<td>23.1</td>
<td>--</td>
<td>39.6</td>
<td>13.5</td>
<td>3.9</td>
</tr>
<tr>
<td>Total</td>
<td>11,077.7</td>
<td>8,242.8</td>
<td>2,921.7</td>
<td>56,096.0</td>
<td>1,348.0</td>
<td>1,133.7</td>
<td>2,488.6</td>
<td>725.8</td>
<td>1,090.0</td>
<td>1,259.0</td>
<td>310.3</td>
<td>591.0</td>
<td>197.0</td>
<td>282.6</td>
</tr>
</tbody>
</table>
Table B.7: Land Use by Region and Agricultural Product—Energy Prices of +5 Percent,
20 Percent Alcohol Substitution for Gasoline (Model D), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Corn</th>
<th>Cassava</th>
<th>Sugar-cane</th>
<th>Rice</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Ground-nuts</th>
<th>Cotton</th>
<th>Kenaf</th>
<th>Flowers</th>
<th>Other</th>
<th>Crops</th>
<th>Cattle</th>
<th>Buffaloes</th>
<th>Casuarina</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>376.8</td>
<td>12.3</td>
<td>154.0</td>
<td>7,120.6</td>
<td>42.0</td>
<td>1,058.6</td>
<td>160.7</td>
<td>153.5</td>
<td>--</td>
<td>34.6</td>
<td>78.1</td>
<td>26.5</td>
<td>35.8</td>
<td>--</td>
<td>--</td>
<td>1,058.6</td>
</tr>
<tr>
<td>2</td>
<td>8,232.6</td>
<td>173.0</td>
<td>238.0</td>
<td>10,159.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,090.0</td>
<td>--</td>
<td>55.1</td>
<td>82.1</td>
<td>30.8</td>
<td>--</td>
<td>--</td>
<td>1,090.0</td>
</tr>
<tr>
<td>3</td>
<td>104.1</td>
<td>2,127.0</td>
<td>252.0</td>
<td>11,792.9</td>
<td>--</td>
<td>--</td>
<td>977.9</td>
<td>144.6</td>
<td>--</td>
<td>603.3</td>
<td>52.6</td>
<td>137.6</td>
<td>53.2</td>
<td>119.0</td>
<td>6.1</td>
<td>1,287.0</td>
</tr>
<tr>
<td>4</td>
<td>1,805.3</td>
<td>2,217.0</td>
<td>7,779.9</td>
<td>19.0</td>
<td>--</td>
<td>--</td>
<td>726.3</td>
<td>--</td>
<td>655.7</td>
<td>23.1</td>
<td>86.5</td>
<td>24.1</td>
<td>60.9</td>
<td>--</td>
<td>--</td>
<td>2,452.3</td>
</tr>
<tr>
<td>5</td>
<td>538.9</td>
<td>2,288.0</td>
<td>466.8</td>
<td>4,160.3</td>
<td>--</td>
<td>66.6</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>11.5</td>
<td>38.6</td>
<td>12.8</td>
<td>11.1</td>
<td>--</td>
<td>--</td>
<td>603.3</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>1,543.9</td>
<td>1,809.0</td>
<td>10,114.1</td>
<td>1,287.0</td>
<td>--</td>
<td>571.5</td>
<td>353.6</td>
<td>--</td>
<td>110.3</td>
<td>168.1</td>
<td>17.6</td>
<td>11.5</td>
<td>--</td>
<td>--</td>
<td>2,452.3</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>15.6</td>
<td>--</td>
<td>4,957.7</td>
<td>--</td>
<td>15.9</td>
<td>71.6</td>
<td>--</td>
<td>23.1</td>
<td>--</td>
<td>39.6</td>
<td>13.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>603.3</td>
</tr>
<tr>
<td>Total</td>
<td>11,057.7</td>
<td>8,376.8</td>
<td>2,919.8</td>
<td>56,094.5</td>
<td>1,348.0</td>
<td>1,125.2</td>
<td>2,452.3</td>
<td>723.3</td>
<td>1,090.0</td>
<td>1,259.0</td>
<td>310.3</td>
<td>591.0</td>
<td>197.0</td>
<td>282.6</td>
<td>6.1</td>
<td>1,090.0</td>
</tr>
</tbody>
</table>

(1,000 rai)
Table 8.8: Land Use by Region and Agricultural Product—Energy Prices of +10 Percent, 20 Percent Alcohol Substitution for Gasoline (Model D), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Corn</th>
<th>Cassava</th>
<th>Sugar-cane</th>
<th>Rice</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Nuts</th>
<th>Cotton</th>
<th>Kenaf</th>
<th>Flowers</th>
<th>Crops</th>
<th>Cattle</th>
<th>Buffaloes</th>
<th>Casuarina</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1,000 rai)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>376.8</td>
<td>12.3</td>
<td>154.0</td>
<td>7,120.6</td>
<td>42.0</td>
<td>1,098.6</td>
<td>160.7</td>
<td>153.5</td>
<td>--</td>
<td>--</td>
<td>34.6</td>
<td>78.1</td>
<td>26.5</td>
<td>35.8</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>8,232.6</td>
<td>173.0</td>
<td>238.0</td>
<td>10,159.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,090.0</td>
<td>--</td>
<td>55.1</td>
<td>82.1</td>
<td>23.2</td>
<td>30.8</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>104.1</td>
<td>2,127.0</td>
<td>252.0</td>
<td>11,792.9</td>
<td>--</td>
<td>--</td>
<td>946.6</td>
<td>144.6</td>
<td>--</td>
<td>603.3</td>
<td>52.6</td>
<td>137.6</td>
<td>53.2</td>
<td>119.0</td>
<td>6.1</td>
</tr>
<tr>
<td>4</td>
<td>1,803.8</td>
<td>2,217.0</td>
<td>--</td>
<td>7,779.9</td>
<td>19.0</td>
<td>--</td>
<td>727.8</td>
<td>--</td>
<td>--</td>
<td>652.4</td>
<td>23.1</td>
<td>86.5</td>
<td>24.1</td>
<td>60.9</td>
<td>--</td>
</tr>
<tr>
<td>5</td>
<td>540.4</td>
<td>2,288.0</td>
<td>465.2</td>
<td>4,160.4</td>
<td>--</td>
<td>66.6</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>11.5</td>
<td>38.6</td>
<td>12.8</td>
<td>11.1</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>1,544.3</td>
<td>1,809.0</td>
<td>10,082.7</td>
<td>1,287.0</td>
<td>--</td>
<td>603.3</td>
<td>352.8</td>
<td>--</td>
<td>--</td>
<td>110.3</td>
<td>168.1</td>
<td>17.6</td>
<td>11.5</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>15.6</td>
<td>--</td>
<td>4,967.7</td>
<td>--</td>
<td>--</td>
<td>15.9</td>
<td>71.6</td>
<td>--</td>
<td>--</td>
<td>23.1</td>
<td>--</td>
<td>39.6</td>
<td>13.5</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>11,057.7</td>
<td>8,377.2</td>
<td>2,918.2</td>
<td>56,063.2</td>
<td>1,348.0</td>
<td>1,125.2</td>
<td>2,454.3</td>
<td>722.5</td>
<td>1,090.0</td>
<td>1,255.7</td>
<td>310.3</td>
<td>591.0</td>
<td>197.0</td>
<td>282.6</td>
<td>6.1</td>
</tr>
</tbody>
</table>

VO
<table>
<thead>
<tr>
<th>Region</th>
<th>Corn</th>
<th>Cassava</th>
<th>Sugar-cane</th>
<th>Rice</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Ground-nuts</th>
<th>Cotton</th>
<th>Kenaf</th>
<th>Flowers</th>
<th>Crops</th>
<th>Cattle</th>
<th>Buffalo</th>
<th>Casuarina</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>376.8</td>
<td>12.3</td>
<td>154.0</td>
<td>7,120.6</td>
<td>42.0</td>
<td>1,047.2</td>
<td>159.3</td>
<td>166.3</td>
<td>--</td>
<td>--</td>
<td>34.6</td>
<td>78.1</td>
<td>26.5</td>
<td>35.8</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>8,232.6</td>
<td>173.0</td>
<td>238.0</td>
<td>10,159.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,090.0</td>
<td>--</td>
<td>55.1</td>
<td>82.1</td>
<td>23.2</td>
<td>30.8</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>96.4</td>
<td>2,127.0</td>
<td>252.0</td>
<td>11,792.9</td>
<td>--</td>
<td>--</td>
<td>1,200.1</td>
<td>144.6</td>
<td>--</td>
<td>603.3</td>
<td>52.6</td>
<td>137.5</td>
<td>53.2</td>
<td>119.0</td>
<td>11.7</td>
</tr>
<tr>
<td>4</td>
<td>1,784.0</td>
<td>2,217.0</td>
<td>--</td>
<td>7,779.9</td>
<td>19.0</td>
<td>--</td>
<td>747.6</td>
<td>--</td>
<td>--</td>
<td>650.9</td>
<td>23.1</td>
<td>86.5</td>
<td>24.1</td>
<td>60.9</td>
<td>--</td>
</tr>
<tr>
<td>5</td>
<td>541.1</td>
<td>2,288.0</td>
<td>464.6</td>
<td>4,160.3</td>
<td>--</td>
<td>66.6</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>11.5</td>
<td>38.6</td>
<td>12.8</td>
<td>11.1</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>1,885.6</td>
<td>1,809.0</td>
<td>10,060.9</td>
<td>1,287.0</td>
<td>--</td>
<td>--</td>
<td>298.5</td>
<td>338.1</td>
<td>--</td>
<td>110.3</td>
<td>168.1</td>
<td>17.6</td>
<td>11.5</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>15.6</td>
<td>4,967.7</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>15.9</td>
<td>71.6</td>
<td>--</td>
<td>23.1</td>
<td>--</td>
<td>39.6</td>
<td>13.5</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>11,030.9</td>
<td>8,718.5</td>
<td>2,917.6</td>
<td>56,041.3</td>
<td>1,348.0</td>
<td>1,113.8</td>
<td>2,421.4</td>
<td>720.6</td>
<td>1,090.0</td>
<td>1,254.2</td>
<td>310.3</td>
<td>591.0</td>
<td>197.0</td>
<td>282.6</td>
<td>11.7</td>
</tr>
</tbody>
</table>
Table B.10: Land Use by Region and Agricultural Product—Energy Prices of +20 Percent,
20 Percent Alcohol Substitution for Gasoline (Model D), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Agricultural Product</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corn</td>
</tr>
<tr>
<td>1</td>
<td>333.9</td>
</tr>
<tr>
<td>2</td>
<td>8,223.6</td>
</tr>
<tr>
<td>3</td>
<td>96.4</td>
</tr>
<tr>
<td>4</td>
<td>1,990.8</td>
</tr>
<tr>
<td>5</td>
<td>190.4</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>10,835.1</td>
</tr>
</tbody>
</table>
Table B.11: Land Use by Region and Agricultural Product—Current Energy Prices, 34 Percent Alcohol Substitution for Gasoline (Model F), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Corn</th>
<th>Cassava</th>
<th>Sugar-cane</th>
<th>Rice</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Cotton</th>
<th>Kenaf</th>
<th>Flowers</th>
<th>Other Crops</th>
<th>Cattle</th>
<th>Buffaloes</th>
<th>Casuarina</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>355.4</td>
<td>12.3</td>
<td>154.0</td>
<td>7,120.6</td>
<td>20.6</td>
<td>1,046.5</td>
<td>157.8</td>
<td>211.3</td>
<td>--</td>
<td>--</td>
<td>34.6</td>
<td>78.1</td>
<td>26.5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8,213.7</td>
<td>173.0</td>
<td>238.0</td>
<td>10,159.0</td>
<td>18.9</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,090.0</td>
<td>--</td>
<td>55.1</td>
<td>82.1</td>
<td>23.2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>104.1</td>
<td>2,127.0</td>
<td>252.0</td>
<td>11,792.9</td>
<td>--</td>
<td>--</td>
<td>1,798.6</td>
<td>144.6</td>
<td>--</td>
<td>603.3</td>
<td>52.6</td>
<td>137.6</td>
<td>53.2</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2,106.6</td>
<td>2,217.0</td>
<td>--</td>
<td>7,779.9</td>
<td>19.0</td>
<td>--</td>
<td>425.0</td>
<td>--</td>
<td>--</td>
<td>655.7</td>
<td>23.1</td>
<td>86.5</td>
<td>24.1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>230.2</td>
<td>4,271.4</td>
<td>468.0</td>
<td>2,488.1</td>
<td>--</td>
<td>62.9</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>11.5</td>
<td>38.6</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>--</td>
<td>740.9</td>
<td>1,809.0</td>
<td>11,554.6</td>
<td>1,287.0</td>
<td>--</td>
<td>--</td>
<td>287.6</td>
<td>--</td>
<td>110.3</td>
<td>168.1</td>
<td>17.6</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>--</td>
<td>15.6</td>
<td>--</td>
<td>4,967.7</td>
<td>--</td>
<td>--</td>
<td>15.9</td>
<td>71.6</td>
<td>--</td>
<td>23.1</td>
<td>--</td>
<td>39.6</td>
<td>13.5</td>
</tr>
<tr>
<td>Total</td>
<td>11,010.0</td>
<td>9,557.2</td>
<td>2,921.0</td>
<td>55,862.8</td>
<td>1,345.5</td>
<td>1,109.4</td>
<td>2,397.3</td>
<td>715.1</td>
<td>1,090.0</td>
<td>1,259.0</td>
<td>310.3</td>
<td>591.0</td>
<td>197.0</td>
<td>282.6</td>
</tr>
<tr>
<td>Region</td>
<td>Corn (1,000 rai)</td>
<td>Cassava</td>
<td>Sugar-cane</td>
<td>Rice</td>
<td>Sorghum</td>
<td>Soybeans</td>
<td>Mungbeans</td>
<td>Ground-nuts</td>
<td>Cotton</td>
<td>Kenaf</td>
<td>Flowers</td>
<td>Crops</td>
<td>Cattle</td>
<td>Buffaloes</td>
</tr>
<tr>
<td>--------</td>
<td>------------------</td>
<td>---------</td>
<td>------------</td>
<td>------</td>
<td>---------</td>
<td>----------</td>
<td>-----------</td>
<td>------------</td>
<td>--------</td>
<td>-------</td>
<td>---------</td>
<td>-------</td>
<td>--------</td>
<td>-----------</td>
</tr>
<tr>
<td>1</td>
<td>333.9</td>
<td>12.3</td>
<td>154.0</td>
<td>7,120.6</td>
<td>20.6</td>
<td>1,079.6</td>
<td>77.2</td>
<td>280.3</td>
<td>--</td>
<td>--</td>
<td>34.6</td>
<td>78.1</td>
<td>26.5</td>
<td>35.8</td>
</tr>
<tr>
<td>2</td>
<td>8,211.1</td>
<td>173.0</td>
<td>238.0</td>
<td>10,159.0</td>
<td>18.9</td>
<td>--</td>
<td>--</td>
<td>1,090.0</td>
<td>--</td>
<td>55.1</td>
<td>82.1</td>
<td>23.2</td>
<td>30.8</td>
<td>2.6</td>
</tr>
<tr>
<td>3</td>
<td>104.1</td>
<td>2,127.0</td>
<td>252.0</td>
<td>11,792.9</td>
<td>--</td>
<td>--</td>
<td>2,118.0</td>
<td>157.5</td>
<td>--</td>
<td>603.3</td>
<td>52.6</td>
<td>137.6</td>
<td>53.2</td>
<td>119.0</td>
</tr>
<tr>
<td>4</td>
<td>2,087.9</td>
<td>2,217.0</td>
<td>--</td>
<td>7,779.9</td>
<td>281.1</td>
<td>--</td>
<td>181.6</td>
<td>--</td>
<td>--</td>
<td>652.4</td>
<td>23.1</td>
<td>86.5</td>
<td>24.1</td>
<td>60.9</td>
</tr>
<tr>
<td>5</td>
<td>190.4</td>
<td>4,384.9</td>
<td>465.2</td>
<td>2,480.1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>11.5</td>
<td>38.6</td>
<td>12.8</td>
<td>11.1</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>1,207.4</td>
<td>1,809.0</td>
<td>11,439.7</td>
<td>1,024.9</td>
<td>--</td>
<td>--</td>
<td>198.1</td>
<td>--</td>
<td>110.3</td>
<td>168.1</td>
<td>17.6</td>
<td>11.5</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>15.6</td>
<td>--</td>
<td>4,967.7</td>
<td>15.9</td>
<td>71.6</td>
<td>--</td>
<td>23.1</td>
<td>--</td>
<td>39.6</td>
<td>33.5</td>
<td>13.5</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>10,927.4</td>
<td>10,137.2</td>
<td>2,918.2</td>
<td>55,739.9</td>
<td>1,345.5</td>
<td>1,079.6</td>
<td>2,392.7</td>
<td>707.5</td>
<td>1,090.0</td>
<td>1,255.7</td>
<td>310.3</td>
<td>591.0</td>
<td>197.0</td>
<td>282.6</td>
</tr>
<tr>
<td>Region</td>
<td>Corn (1,000 rai)</td>
<td>Cassava</td>
<td>Sugar-cane</td>
<td>Rice</td>
<td>Sorghum</td>
<td>Soybeans</td>
<td>Mungbeans</td>
<td>Ground-nuts</td>
<td>Cotton</td>
<td>Kenaf</td>
<td>Flowers</td>
<td>Other</td>
<td>Cattle</td>
<td>Buffaloes</td>
</tr>
<tr>
<td>--------</td>
<td>------------------</td>
<td>---------</td>
<td>------------</td>
<td>------</td>
<td>---------</td>
<td>----------</td>
<td>-----------</td>
<td>-------------</td>
<td>--------</td>
<td>-------</td>
<td>---------</td>
<td>-------</td>
<td>--------</td>
<td>-----------</td>
</tr>
<tr>
<td>1</td>
<td>312.5</td>
<td>12.3</td>
<td>154.0</td>
<td>7,120.6</td>
<td>20.6</td>
<td>1,060.0</td>
<td>76.3</td>
<td>322.2</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>0,221.1</td>
<td>173.0</td>
<td>238.0</td>
<td>10,159.0</td>
<td>18.9</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,080.0</td>
<td>--</td>
<td>--</td>
<td>55.1</td>
<td>82.1</td>
<td>23.2</td>
</tr>
<tr>
<td>3</td>
<td>96.4</td>
<td>2,127.0</td>
<td>252.0</td>
<td>11,792.9</td>
<td>--</td>
<td>--</td>
<td>1,297.0</td>
<td>235.5</td>
<td>--</td>
<td>603.3</td>
<td>52.6</td>
<td>137.6</td>
<td>53.2</td>
<td>119.0</td>
</tr>
<tr>
<td>4</td>
<td>2,132.9</td>
<td>2,217.0</td>
<td>--</td>
<td>8,716.6</td>
<td>383.9</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>650.9</td>
<td>23.1</td>
<td>86.5</td>
<td>24.1</td>
<td>60.9</td>
</tr>
<tr>
<td>5</td>
<td>--</td>
<td>4,577.9</td>
<td>462.6</td>
<td>2,480.1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>11.5</td>
<td>38.6</td>
<td>12.8</td>
<td>11.1</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>3,078.3</td>
<td>1,809.0</td>
<td>10,672.7</td>
<td>37.0</td>
<td>--</td>
<td>--</td>
<td>82.1</td>
<td>--</td>
<td>110.3</td>
<td>168.1</td>
<td>17.6</td>
<td>11.5</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>15.6</td>
<td>--</td>
<td>4,967.7</td>
<td>--</td>
<td>16.1</td>
<td>71.4</td>
<td>--</td>
<td>--</td>
<td>23.1</td>
<td>--</td>
<td>39.6</td>
<td>13.5</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>10,762.9</td>
<td>12,201.1</td>
<td>2,915.6</td>
<td>55,909.6</td>
<td>460.4</td>
<td>1,060.0</td>
<td>2,389.4</td>
<td>711.2</td>
<td>1,080.0</td>
<td>1,254.2</td>
<td>310.3</td>
<td>591.0</td>
<td>197.0</td>
<td>282.6</td>
</tr>
</tbody>
</table>
Table B.14: Land Use by Region and Agricultural Product—Energy Prices of +30 Percent, 100 Percent Alcohol Substitution for Gasoline (Model F), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Corn (1,000 rai)</th>
<th>Cassava</th>
<th>Rice (1,000 rai)</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Groundnuts</th>
<th>Cotton</th>
<th>Sunflowers</th>
<th>Other Crops</th>
<th>Cattle</th>
<th>Buffaloes</th>
<th>Casuarina</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>291.0</td>
<td>468.5</td>
<td>154.0</td>
<td>7,120.6</td>
<td>20.6</td>
<td>803.6</td>
<td>79.7</td>
<td>137.8</td>
<td>--</td>
<td>--</td>
<td>34.6</td>
<td>78.1</td>
<td>26.5</td>
</tr>
<tr>
<td>2</td>
<td>8,221.1</td>
<td>173.0</td>
<td>238.0</td>
<td>10,159.0</td>
<td>18.9</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,080.0</td>
<td>--</td>
<td>55.1</td>
<td>82.1</td>
<td>23.2</td>
</tr>
<tr>
<td>3</td>
<td>96.4</td>
<td>2,127.0</td>
<td>252.0</td>
<td>11,792.9</td>
<td>254.5</td>
<td>2,307.9</td>
<td>235.5</td>
<td>--</td>
<td>597.8</td>
<td>52.6</td>
<td>137.6</td>
<td>53.2</td>
<td>119.0</td>
</tr>
<tr>
<td>4</td>
<td>2,132.9</td>
<td>2,217.0</td>
<td>--</td>
<td>11,311.4</td>
<td>383.9</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>650.9</td>
<td>23.1</td>
<td>86.5</td>
<td>24.1</td>
<td>60.9</td>
</tr>
<tr>
<td>5</td>
<td>--</td>
<td>4,533.1</td>
<td>461.0</td>
<td>2,480.1</td>
<td>38.6</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>11.5</td>
<td>38.6</td>
<td>12.8</td>
<td>11.1</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>4,587.1</td>
<td>1,809.0</td>
<td>8,942.8</td>
<td>37.0</td>
<td>--</td>
<td>--</td>
<td>287.0</td>
<td>--</td>
<td>110.3</td>
<td>168.1</td>
<td>17.6</td>
<td>11.5</td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>32.3</td>
<td>--</td>
<td>4,967.7</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>70.6</td>
<td>--</td>
<td>23.1</td>
<td>39.6</td>
<td>13.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Total</td>
<td>10,741.4</td>
<td>14,138.0</td>
<td>2,914.0</td>
<td>56,774.5</td>
<td>460.4</td>
<td>2,383.6</td>
<td>730.9</td>
<td>1,080.0</td>
<td>1,248.7</td>
<td>310.3</td>
<td>591.0</td>
<td>197.0</td>
<td>282.6</td>
</tr>
</tbody>
</table>
Table B.15: Land Use by Region and Agricultural Product—Energy Prices of +60 Percent, 100 Percent Alcohol Substitution for Gasoline (Model F), 1981

<table>
<thead>
<tr>
<th>Region</th>
<th>Agricultural Product</th>
<th>Sugar-cane</th>
<th>Cassava</th>
<th>Rice</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Ground-nuts</th>
<th>Cotton</th>
<th>Kenaf</th>
<th>Vegetables</th>
<th>Other Crops</th>
<th>Cattle</th>
<th>Buffaloes</th>
<th>Casuarine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Corn</td>
<td>154.0</td>
<td>7,120.6</td>
<td>20.6</td>
<td>799.3</td>
<td>75.7</td>
<td>214.9</td>
<td>--</td>
<td>--</td>
<td>34.6</td>
<td>78.1</td>
<td>26.5</td>
<td>35.8</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8239.6</td>
<td>414.8</td>
<td>238.0</td>
<td>10,159.0</td>
<td>18.9</td>
<td>--</td>
<td>--</td>
<td>815.8</td>
<td>--</td>
<td>55.1</td>
<td>82.1</td>
<td>23.2</td>
<td>30.8</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>88.7</td>
<td>2,127.0</td>
<td>252.0</td>
<td>11,792.9</td>
<td>--</td>
<td>242.5</td>
<td>1,163.5</td>
<td>462.0</td>
<td>--</td>
<td>597.8</td>
<td>52.6</td>
<td>137.6</td>
<td>53.2</td>
<td>119.0</td>
<td>32.3</td>
</tr>
<tr>
<td>4</td>
<td>1,398.2</td>
<td>2,217.0</td>
<td>--</td>
<td>11,208.6</td>
<td>56.0</td>
<td>--</td>
<td>1,062.5</td>
<td>--</td>
<td>--</td>
<td>644.9</td>
<td>23.1</td>
<td>86.5</td>
<td>24.1</td>
<td>60.9</td>
<td>33.8</td>
</tr>
<tr>
<td>5</td>
<td>--</td>
<td>4,862.0</td>
<td>461.0</td>
<td>2,189.8</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>11.5</td>
<td>38.6</td>
<td>12.8</td>
<td>11.1</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>7,178.9</td>
<td>1,809.0</td>
<td>6,627.1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>110.3</td>
<td>168.1</td>
<td>17.6</td>
<td>11.5</td>
<td>64.1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>32.7</td>
<td>4,967.7</td>
<td>--</td>
<td>70.2</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>23.1</td>
<td>--</td>
<td>39.6</td>
<td>13.5</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9,953.2</td>
<td>17,292.6</td>
<td>2,914.0</td>
<td>54,065.7</td>
<td>95.5</td>
<td>1,041.8</td>
<td>2,371.9</td>
<td>676.9</td>
<td>815.8</td>
<td>1,242.7</td>
<td>310.3</td>
<td>591.0</td>
<td>197.0</td>
<td>282.6</td>
<td>151.2</td>
</tr>
</tbody>
</table>
Table B.16: Impact of Alcohol Production on Agricultural Product Exports—0 to 100 Percent Alcohol Substitution for Gasoline, Fixed Demand (Model E) and Variable Demand with Increased Cropland (Model I), 1981

<table>
<thead>
<tr>
<th>Energy</th>
<th>Total Exports (1,000 tons)</th>
<th>Corn</th>
<th>Cassava</th>
<th>Rice</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Mungbeans</th>
<th>Groundnuts</th>
<th>Cotton</th>
<th>Kenaf</th>
<th>Sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Price</td>
<td>Energy</td>
<td>Total Exports</td>
<td>Corn</td>
<td>Cassava</td>
<td>Rice</td>
<td>Sorghum</td>
<td>Soybeans</td>
<td>Mungbeans</td>
<td>Groundnuts</td>
<td>Cotton</td>
</tr>
<tr>
<td>E</td>
<td>Current</td>
<td>27,060.0</td>
<td>2,700.0</td>
<td>18,000</td>
<td>4,700.0</td>
<td>225.0</td>
<td>5.0</td>
<td>190.0</td>
<td>16</td>
<td>44</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>+30%</td>
<td>25,851.3</td>
<td>2,700.0</td>
<td>18,000</td>
<td>3,525.3</td>
<td>191.0</td>
<td>5.0</td>
<td>190.0</td>
<td>16</td>
<td>44</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>+60%</td>
<td>24,485.9</td>
<td>2,045.7</td>
<td>18,000</td>
<td>3,028.3</td>
<td>--</td>
<td>1.9</td>
<td>190.0</td>
<td>16</td>
<td>44</td>
<td>--</td>
</tr>
<tr>
<td>I</td>
<td>Current</td>
<td>27,059.5</td>
<td>2,700.0</td>
<td>18,000</td>
<td>4,700.0</td>
<td>225.0</td>
<td>5.0</td>
<td>190.0</td>
<td>16</td>
<td>44</td>
<td>19.5</td>
</tr>
<tr>
<td></td>
<td>+30%</td>
<td>26,897.2</td>
<td>2,700.0</td>
<td>18,000</td>
<td>4,684.8</td>
<td>77.9</td>
<td>5.0</td>
<td>190.0</td>
<td>16</td>
<td>44</td>
<td>19.5</td>
</tr>
<tr>
<td></td>
<td>+60%</td>
<td>25,815.9</td>
<td>2,542.4</td>
<td>18,000</td>
<td>3,891.2</td>
<td>--</td>
<td>5.0</td>
<td>181.8</td>
<td>16</td>
<td>--</td>
<td>19.5</td>
</tr>
</tbody>
</table>


17. FAO, Production Year Book (several issues).


55. Rask, Norman. "Using Agricultural Resources to Produce Food or Fuel—Policy Intervention or Market Choice?" Department of Agricultural Economics and Rural Sociology, The Ohio State University, Columbus, Ohio, 1979 (mimeo).


60. Japan Statistical Yearbook, Tokyo, Japan, 1981.


