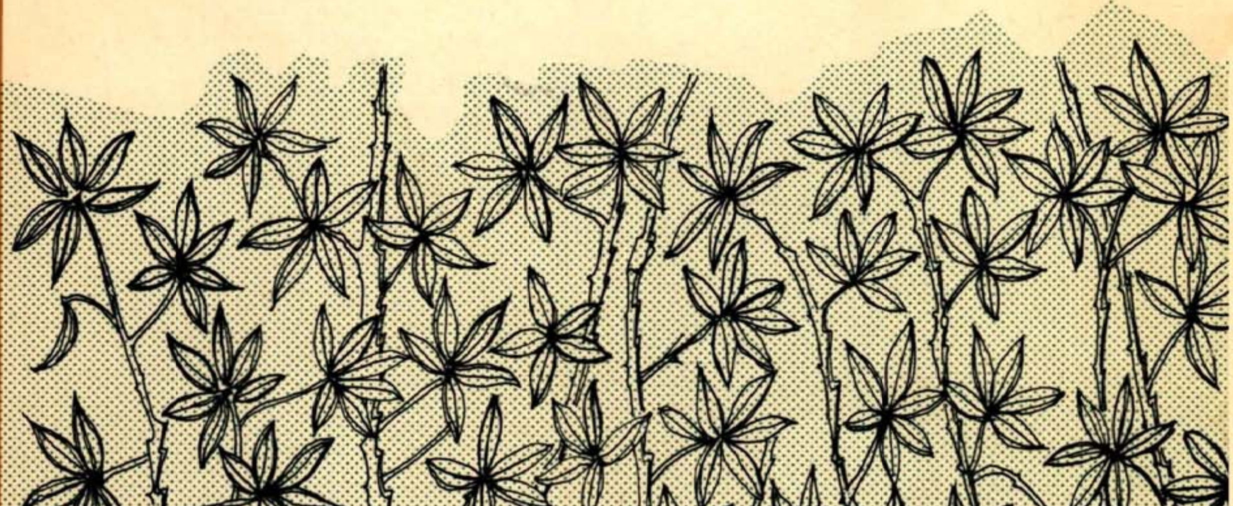
CASSAVA UTILIZATION AND POTENTIAL MARKETS

TRUMAN P. PHILLIPS



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Cassava Utilization and Potential Markets*

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Abstract

On behalf of CIAT (Centro Internacional de Agricultura Tropical, Cali, Colombia), and with the funding of IDRC (International Development Research Centre, Ottawa, Canada) this study was undertaken: (a) to assess the potential of the human, animal and industrial starch markets for cassava; (b) to relate these markets to producing countries in general, and Brazil and Thailand in particular; (c) to derive from the analyses economically based priorities for the cassava research program being mounted by CIAT.

The methodology of the report is to apply those techniques of analysis, be they descriptive or quantitative, which appear to be best suited to the problem at hand and to the data available. Quantitative results are, when possible, validated by best available information. If the results are shown to be untenable, adjustments are made to the data and/or techniques in order to produce an analysis which approximates a priori expectations. Where quantitative results are considered to be fallacious, they are dropped from the analysis.

The report is divided into three parts: the first contains the analyses of the three distinct markets for cassava which are reconciled with supply of cassava; the second deals with brief case studies of the position of cassava in the Brazilian, Thai, and Indian economies; and the third catalogues some areas requiring research. To a large degree each chapter is self-contained so that readers interested in specific topics need only consult the appropriate chapter(s) to glean the ideas and results contained in this report pertinent to the point in question. Chapter 2 treats the analysis of the human food market and the global supply of cassava. Chapter 3 considers the industrial starch market for cassava, primarily the United States, Canada, and Japan. The latter market is not studied in any detail, owing to a lack of available data. Chapter 4 presents the analysis of the European animal feed market. Attempts are made to assess the demand effects of cassava price and quality changes, as well as high protein feed price changes. Chapter 5 contains a summary of the supply and demand projections of Chapters 2 through 4, and an interpretation of these projections. Chapters 6, 7, and 8 present country-specific studies of the role of cassava in the economies of Brazil, Thailand, and India. The latter chapter was prepared by Angus Hone, Institute of Commonwealth Studies, Oxford University. Chapter 9 presents the research recommendations which were evolved from this study.

The qualified findings of the study are that the demand for cassava will grow in the 1970s. The greatest relative increase is expected to occur in the EEC animal feed market, with the human food and industrial starch markets displaying slower rates of growth. The indications are that future supply will be sufficient to meet these demands. It was, however, not possible within the scope of the study to assess the potential demand for cassava in the non-human food markets of producing countries. These markets coupled with other potential new markets may imply that future supply will not be sufficient to meet all demands if new varieties, production practices, and/or policies are not introduced.

Résumé

La présente étude a été entreprise pour le compte du CIAT (Centro Internacional de Agricultura Tropical, Cali, Colombie), financée par le CRDI (Centre de Recherches pour le Développement International, Ottawa, Canada), et elle a pour objet: (a) de déterminer les marchés potentiels de la fécule de manioc destinée à la consommation humaine, animale et industrielle; (b) d'établir les relations entre ces marchés et les pays producteurs en général et, en particulier le Brésil et la Thaïlande; (c) de déterminer à partir des analyses faites les priorités d'ordre économique intéressant le programme de recherche sur le manioc organisé par le CIAT.

La méthodologie indiquée dans le rapport consiste à utiliser les techniques d'analyse descriptives ou quantitatives qui semblent convenir le mieux aux problèmes existants et aux données disponibles. Chaque fois que cela est possible, les résultats quantitatifs sont confirmés par les renseignements les plus sûrs. Si les résultats se révèlent aberrants, les données, voire les techniques font l'objet de rectifications afin que l'analyse corresponde aux attentes. Lorsque les résultats quantitatifs sont considérés comme trompeurs, on les soustrait de l'analyse.

Ce rapport est divisé en trois: la première partie comporte l'analyse de trois marchés distincts pour le manioc, marchés qui correspondent à l'offre; la seconde analyse de brèves études par cas de la situation du manioc dans les économies brésilienne, thaïlandaise et indienne; la troisième répertorie certains domaines nécessitant des recherches. Dans une grande mesure, chacun de ces chapitres forme un tout, ce qui fait que le lecteur n'a qu'à consulter celui ou ceux portant sur les questions qui l'intéressent pour prendre connaissance des idées et des résultats exposés dans le rapport à ce sujet. Le chapitre 2 traite de l'analyse du marché de l'alimentation humaine et de l'offre globale en manioc. Le chapitre 3 étudie le marché industriel de la fécule de manioc, en particulier aux Etats-Unis, au Canada et au Japon. Ce dernier marché ne fait pas l'objet d'une étude détaillée, du fait du manque de données disponibles. Le chapitre 4 analyse le marché européen des aliments du bétail. Le rapport tente de déterminer les effets sur la demande du prix du manioc et des modifications de qualité ainsi que ceux des changements de prix des aliments du bétail à forte teneur en protéine. Le chapitre 5 contient un résumé des projections intéressant l'offre et la demande des chapitres 2 à 4 et présente une interprétation de ces projections. Les chapitres 6, 7 et 8 présentent des études particulières par pays de la place occupée par le manioc dans les économies du Brésil, de la Thaïlande et de l'Inde. Ce dernier chapitre a été rédigé par M. Angus Hone, du "Institute of Commonwealth Studies" de l'Université d'Oxford. Le chapitre 9 commente les recommandations en matière de recherche qui ont été formulées à partir de l'étude.

Le résultat significatif de cette étude est que la demande en manioc va augmenter au cours de la décennie actuelle. Proportionnellement parlant, l'augmentation la plus importante se situera sans doute dans le marché des aliments du bétail de la CEE, celui de l'alimentation humaine et celui de la fécule industrielle croissant à un rythme plus lent. Selon toutes indications, l'offre future sera suffisante pour satisfaire la demande. Il n'a cependant pas été possible dans le cadre de cette étude de déterminer la demande potentielle en manioc des marchés autres que celui de l'alimentation humaine dans les pays producteurs. L'existence de ces marchés jointe aux possibilités d'autres marchés nouveaux peut conduire à penser que l'offre future ne sera pas suffisante pour satisfaire l'ensemble de la demande si l'on ne fait pas appel à de nouvelles variétés et méthodes de production voire à de nouvelles politiques.

Acknowledgments

In many ways, this report is a compilation of the ideas communicated to the author by cassava researchers, traders, producers–processors, and officials of governments and international organizations. The helpfulness and interest of all these individuals made this report possible, and these great contributions are gratefully acknowledged. Some of these individuals, in addition to giving their time to meet with the author, kindly assisted with the arrangements for other meetings. The aid of these persons is sincerely appreciated: Barry L. Nestel, IDRC, Bogota; Carmen Norhe, ERS, USDA, Washington, D.C.; Tony Leeks, Commodity and Trade Division, FAO, Rome; Robert de Viana, ITC, UNCTAD/GATT, Geneva; Angus Hone, Institute of Commonwealth Studies, Oxford University; Mathew Meulenburg, Department of Agricultural Economics, University of Wageningen; Per Pinstrup-Andersen, CIAT, Cali; Marion Frazao, USAID, Rio de Janeiro; Wolf Darnell, CIDA, Brasilia; Deja Tulananda, Bank of Bangkok, Bangkok; Siraphon, Bank of Bangkok, Bangkok; Prajak Kumjim, Thai Tapioca Trade Association, Bangkok; Robert Stanton and Tan Koonlin, University of Malaya; Otavio de Almeida Braga, Brascan Nordeste, Recife, Brazil; Arthur Coffing, ERS, USDA, Washington, D.C.; Raffaello Marsili, World Bank, Washington, D.C.; A. M. Morgan Rees, Economics and Planning Department, Tropical Products Institute, London; Policarpo Vitti, Institute of Food Technology, Campinas, Sao Paulo, Brazil; and Enche Zulkifli M. Noor, Program Development Division, Malaysian Agricultural Bank, Kuala Lumpur.

Special acknowledgment is owing to Rafael O. Diaz, economist, CIAT, who travelled with me to Brazil and who collected much of the data used in chapter 6; to William Hendricks, graduate student, University of Guelph, who assisted with the analysis of the Industrial Starch Market (chapter 3); and to Brinda Murti, research associate, who assisted greatly with the analysis of the Human Food Market (chapter 2) as well as looking after many points of detail in other sections of the study.

This publication also benefited from commentary resulting from a 2-day IDRC workshop, held in Ottawa, which dealt with the preliminary report. The participants of that workshop are to be thanked for their interest in the study and their cogent observations. Additionally, Ian Sturgess, Department of Agricultural Economics, University of Newcastle, England, and Dr John C. Flinn, International Institute of Tropical Agriculture, Ibadan, Nigeria, were kind enough to provide detailed and pertinent remarks. All these contributions are greatly valued. It is hoped that they have been satisfactorily incorporated into this publication.

A word of thanks to the women in my life: Doreen Nicklin and Judy Gartley of the School of Agricultural Economics and Extension Education, University of Guelph, and Ann Barnes, IDRC, who produced the preliminary report with a smile even under duress. Furthermore, Doreen is to be thanked for the order which she was able to wrought from my disorder.

Finally, my wife and best friend, Michelle, is to be thanked and credited with any success this report may achieve. Not only did Michelle pose thought-provoking questions and ideas during the course of the study, she compensated for my lack of linguistic ability by providing translating services in French, Italian, Spanish, Portuguese and Chinese, her only failure being an inability to speak Thai.

Foreword

Cassava (*Manihot esculenta* Crantz) is a traditional subsistence crop of low-income families living in the humid tropics. It is bulky, high in energy, low in protein and, unless processed, deteriorates rapidly after harvesting. Because it does not grow in temperate climates, and is unattractive to most western palates, it is a crop that has been relatively neglected by research workers.

In spite of this, cassava is one of the world's most important staple food crops. It is particularly valued because of its drought tolerance, its ability to grow on poor soils, and its relative resistance to weeds and insect pests. These characteristics, plus the fact that it can be left in the ground without harvesting for a long period of time, mean that it is a very useful crop as a security against famine.

Cassava also possesses certain characteristics which make it of particular interest to the biologist and the economist concerned with resource development in tropical areas. First and foremost of these is the fact that, in terms of calories per unit land area per unit time, cassava appears to be able to outproduce all other staple food crops. This situation exists in spite of the limited efforts that have been made to bring about genetic improvement in cassava and it suggests that, given a research input comparable to that devoted to other major crops, it should be possible to bring about a considerable increase in the productivity of cassava.

In the past 5 years, two major new international agricultural research centres have been created which include cassava amongst the commodities they are studying. At the Centro Internacional de Agricultura Tropical (CIAT) in Colombia, cassava is a main program activity and a team of international scientists is concentrating activities on this commodity. At the International Institute for Tropical Agriculture (IITA) in Nigeria, a program of somewhat similar magnitude is being mounted to study both cassava and yams. The formulation and structuring of these two new international programs, which are devoting far more resources to cassava than have been available previously, have posed a number of important questions on research policy.

Paramount amongst these is that of identifying the potential for increasing the utilization of cassava. Traditionally this crop has been used mainly as human food with animal feed and industrial starch being subsidiary uses. In the last decade a major trade has developed in dried cassava products used as animal feed. This trade serves as an important source of export earnings for some Asian countries, especially Thailand.

IDRC invited the School of Agricultural Economics and Extension Education of the University of Guelph to make available the services of Dr Truman Phillips to carry out a study on the utilization and potential markets for cassava. Dr Phillips was asked to examine the growth potential of this feed market, and to relate it to the prospects for the increased utilization of cassava as human food or as industrial starch, thus providing economically based priorities for the cassava research program of CIAT. This study was funded by a grant which IDRC received from the Canadian International Development Agency (CIDA) for Canadian-based research related to the cassava program of CIAT.

On behalf of IDRC, Dr Angus Hone of the Institute of Commonwealth Studies at Oxford carried out a specific study on cassava in the State of Kerala, India.

These two studies were presented in draft form at a Workshop, held in Ottawa on 26–27 June 1973, attended by a group of people concerned with cassava marketing. As a result of the workshop discussions, the original drafts were revised in the form presented in this report.

The report is the fourth in a series relating to IDRC-sponsored workshops dealing with cassava. Earlier reports have dealt with research priorities (published by CIAT), mosaic disease (published by IITA), and chronic cyanide toxicity (published by IDRC). As in the case of the earlier reports, IDRC is indebted not only to the authors of the working papers (Drs Phillips and Hone) but also to the workshop participants for the time, effort, and expertise they contributed towards making the workshops successful.

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Manihot esculenta Crantz, commonly called cassava, manioc, mandioca, tapioca, or yuca.

Chapter 1. Introduction

Cassava is apparently emerging from its obscurity in the Tropics and is marching northward and southward to fill new roles in temperate climates.

FRANKLIN W. MARTIN

Cassava, manioc, tapioca, mandioca, and yuca are common regional names[1] of the shrubby perennial tropical root crop *Manihot esculenta* Crantz. Cassava is thought to have originated in tropical Brazil, from where it spread to other parts of Latin America (archeologists have found traces of cassava dating as early as 800 BC on the Colombia-Venezuela border; Smith 1968, p. 259) and in post-Columbian times, to other regions of the tropics.

Today cassava is successfully grown in zones ranging from latitudes 30° north and south and at elevations of up to 2000 m (6500 ft); it is tolerant of temperatures of 18–35 C (65–85 F), precipitation of 50–500 mm (20–200 in) (Jones 1959, p. 15), and soils with a pH range of 5–9 (Rogers and Appon 1972, p. 12).

This ecological zone, the "Cassava Belt," coincides roughly with many FAO Economic Class 2, or less developed, countries (LDCs). This belt accounts for 46% of world arable land, 47% of world population, and only 13% of world Gross Domestic Product (GDP) (FAO 1971, 1972).

Cassava production amounts to 57% of tropical root and tuber production while utilizing only 54% of tropical root and tuber acreage (FAO 1972). The crop's preeminence in less-developed tropical countries is explained by its aforementioned ecological adaptability and its appropriateness to the agricultural conditions which often obtain in the Cassava Belt. The main attributes which favour the production of cassava are:

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 is not season-bound;
4 It is a good risk-aversion crop—its hydrocyanic acid content makes it subject to minimal animal and pest attacks; it is capable of growing on soils often considered too poor for other crops; and
5 It is a reliable staple and an excellent producer of carbohydrates.[2]

These five attributes make cassava well suited to small-scale, subsistence agriculture. Propagation of cassava by cuttings means that in terms of net yield, cassava is relatively more productive than grains and many other root crops which require witholding a proportion of seeds or tubers for future planting. Moreover, as a root crop, cassava is biologically more efficient than grain since it does not require an elaborate structure to support its edible portion (63–85% of dry weight of cassava is edible, compared with 36% for wheat; Coursey and Haynes 1970, p. 265).

[1]The plant is called cassava in English-speaking regions of North America, Europe, and Africa. In French-speaking areas it is called manioc. It is referred to as tapioca in English-speaking parts of Southeast Asia, as mandioca in Brazil, and as yuca in Spanish-speaking regions of South America.

[2]Coursey and Haynes (1970, p. 265) calculated the production of kilocalories per hectare per day of some major crops to be: cassava 250; maize 200; rice 176; sorghum 114; and wheat 110.

The cost of cassava production is low—lower perhaps than is commonly recognized because labour,[3] the main input, tends to be improperly costed at average wage rates. Since the crop is not season-bound, the farmer is able to undertake planting and harvesting after other more crucial tasks are completed and at times when his opportunity cost of labour is, if not zero, very low. Moreover, cassava's almost weed-free growth and resistence to drought, pest, and disease[4] mean that labour and other requirements for nurture are minimal.

Cassava's high yields mean that whether it is grown as a staple or risk-aversion crop, a relatively small land base is required for its cultivation. This last point requires qualification, however. The practice of leaving roots in the ground until required (mature roots may be left in the ground for up to 2 years without any serious deterioration) is space-consuming, and it is estimated that as much as 20% of total cassava acreage is used solely for root storage (R. Booth, Tropical Products Institute, personal communication). Thus, despite high yields, the small farmer may, because of risk aversion, incur substantial costs in terms of lost production opportunities[5] (although development of an alternative, inexpensive, space-economizing method of storage could free land for profitable uses while providing producers with a stock of cassava).

Interestingly, despite these attributes, production of cassava has not been encouraged. Several commonly held but inaccurate beliefs account for this fact. First, cassava has historically been discounted as a human food because of its high starch and low protein content. Second, cassava is considered to be an inferior food (implying, in economic terms, a backward sloping (negative) income demand schedule). Third, cassava is regarded as a soil-depleting crop. Fourth, it is looked upon as a low-value crop, and fifth, it is believed to incur high production costs because of large labour requirements relative to value.

These five points, which have been responsible for a lack of interest in the crop on the part of governments, investors, traders, and researchers, are certainly questionable if not completely misleading. For example, great attention has been given by research organizations and institutions to the study of protein sources to meet a predicted future world protein shortage. However, there are now indications that future food shortages in LDCs may, in fact, take the much more alarming form of a carbohydrate gap (Abbott 1972). In this context, adaptable, resilient, high-yielding starch sources, such as cassava, take on a new importance. The assumption that demand for cassava, as an inferior food, will decrease as incomes in LDCs increase overlooks the fact that more than half of FAO estimates of cassava income demand elasticities (examined in detail in the next chapter) are greater than zero! Cassava is often criticized for being a soil-depleting plant. However, its ability to grow in areas too exhausted to support other crops is hardly an expected attribute of a soil depleter. Cassava's low value has been criticized. It is true that value per unit weight of cassava is low. However, high per unit land value, owing to high yield, does allow cassava to compete with other commercial crops (in Thailand, where market forces primarily determine agricultural prices, cassava returns per unit land are lower only than kapok, tobacco, and coconuts). And finally, as already argued, low or negligible opportunity costs of labour mean low, not high, production costs for cassava cultivation, where labour is the primary input.

This study takes as its point of departure the present very interesting situation in which conventional wisdoms regarding cassava are confronted by emerging markets, new contexts, and reassessments. The situation is economically and politically interesting because it, of necessity, invokes (hopefully accurate) speculation on future trends of cassava production and marketing. Most important, the situation is humanly interesting because it involves the food source and livelihood of many millions of people living within the Cassava Belt.

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[3]Estimates of labour input for cassava production vary from 370 man-hours/ha for 10 tons to 1867 man-hours/ha for 25 tons (Brannen 1972, p. 226).

[4]Tropical crops are reported to be subject to five to ten times as many diseases as non-tropical crops. Cassava, however, is generally reputed for its resilience. One of its unique properties is that it does not appear to suffer from the ravages of migratory locusts (Lehman 1972).

[5]Dr J. C. Flinn, IITA, Ibadan, Nigeria, points out, however, that in much of West Africa cassava is to be followed by bush fallow and as such there is no loss of production.

This report examines three distinct markets for cassava:

- the human food market
- the industrial starch market
- the animal feed market in the European Economic Community

Case studies of the Brazilian, Thai, and Indian cassava economies are presented. Potential supplies of cassava are examined, and future demand for the crop is projected. Finally, recommendations regarding market potentials and research needs are presented.

55 million tons of cassava are consumed annually in the tropics. A major proportion is still processed by simple labour-intensive techniques.

Chapter 2. Cassava as Human Food

All modern methods for processing manioc roots derived from Indian methods, and the ancient processes are still employed in many parts of the tropics. In fact, some of the tapioca of commerce is prepared by methods very little improved over those used in South America before the arrival of the Europeans. The Indian then removed the prussic acid by leeching, rotting, and heating, or by various combinations of these processes, and produced four principal kinds of food products: meal, flour, starch, and a stock for sauces and soups.

WILLIAM O. JONES

The role of cassava in the human diet is inextricably related to general world food conditions. This chapter therefore prefaces the analysis of the human demand for cassava by a discussion of the world food situation.

World Food Situation

This analysis concentrates on past and possible future trends in world demand for food.[6] The post-1960 demand for food may be considered to be a function of population, income, prices, and food supply. Whereas all these factors are influential, emphasis is on the first two factors since: (1) population and income are considered to be the most important in determining long-run consumption patterns; (2) price data are not available in most instances; and (3) discussion of global food supply exceeds the scope of this study.

[6]The time horizon of this analysis is approximately 1960–85, but a few futuristic statements regarding the possibilities for the end of this century will be made.

Population Population has been and is expected to remain the major factor determining food demand, owing to the low income demand elasticities for food. (For example, ceteris paribus, "population demand elasticity" for all food equals 1, while income demand elasticities are normally less than 1, except for high protein foods in LDCs; Table 1.) It is anticipated that between 1970 and 1985 "... half (of the increased demand for food) will be due to increase in population ..." (FAO 1971). In LDCs it is estimated that population

TABLE 1. Income elasticities for specified food groups by selected subregions ranked in declining order of per capita income, 1960–62 (source: US Dept. of Agriculture, World Food Budget, 1970).

Subregion	Per caput income ($US)	Cereal	Vegetables	Milk	Meat	Eggs	Fish
USA	2342	0.50	0.25	0.05	0.35	0.00	0.30
Canada	1482	0.50	0.35	0.10	0.40	0.15	0.30
Japan	395	0.17	0.50	2.00	1.70	1.00	0.50
River Plate	365	0.30	0.60	0.40	0.15	0.10	0.40
Brazil	211	0.15	0.50	0.90	0.70	1.00	0.60
S. Africa	360	0.10	0.50	0.60	0.50	0.50	0.60
N. Africa	112	0.20	0.60	1.00	1.20	1.20	1.00
India	69	0.50	1.00	1.70	1.40	2.20	1.50
Pakistan	69	0.50	0.90	1.70	1.60	2.20	1.50
Indonesia	82	0.50	0.90	3.00	1.60	2.00	1.00

growth will account for 70% of the increased demand for food (FAO 1971). Table 2 indicates past population changes (since 1960) as well as expected future changes. Clearly, the substantial variability in population growth rates (viz 0.8% in Western Europe compared with 2.9% in Latin America and the Near East) will alter the distribution of world population (Fig. 1). The major

TABLE 2. World population by economic class and region: past and projected levels (*millions*) (source: FAO, Agricultural Commodity Projections 1970–80, Vol. 2, Rome, 1971).

Region	1960	1970	1980	Growth compounded (%/*yr*) 1965–70	1970–80
World	3038	3719	4575	2.0	2.1
Economic Class 1	651	727	805	1.0	1.0
North America	199	227	254	1.1	1.1
Western Europe	326	356	384	0.8	0.8
Oceania	13	15	19	1.8	2.0
Other developed market economies	113	129	149	1.4	1.4
Economic Class 2	1358	1760	2306	2.7	2.7
Africa	221	282	372	2.6	2.8
Latin America	213	283	376	2.9	2.9
Near East	128	167	223	2.7	2.9
Asia and Far East	793	1023	1330	2.6	2.6
Other developing market economies	3	4	5	–	–
Economic Class 3	1029	1232	1464	1.8	1.7
Asian central plural economies	717	884	1079	2.1	2.0
USSR and Eastern Europe	313	348	384	0.9	0.9

TABLE 3. Per capita gross domestic product at 1970 constant market prices, by economic class and region, past and projected levels (source: FAO, Agricultural Commodity Projections 1970–80, Vol. 2, Rome, 1971).

Region	1960	1970	1980	Growth compounded (%/*yr*) 1965–70	1970–80
World	599	803	1111	3.0	3.4
Economic Class 1	1960	2838	4245	3.6	4.2
North America	3547	4674	6333	2.4	3.2
Western Europe	1423	2076	3066	3.6	4.0
Oceania	2037	2830	4055	4.2	3.7
Other developed market economies	710	1719	3747	10.4	8.3
Economic Class 2	173	219	319	2.8	4.0
Africa	125	140	188	1.5	3.0
Latin America	438	543	797	2.5	4.0
Near East	230	344	515	4.2	4.2
Asia and Far East	105	130	186	2.8	3.8
Other developing market economies	231	299	400	3.3	3.0
Economic Class 3	301	437	636	4.3	3.9
Asian central plural economies	91	97	124	1.0	2.6
USSR and Eastern Europe	782	1299	2071	5.9	4.9

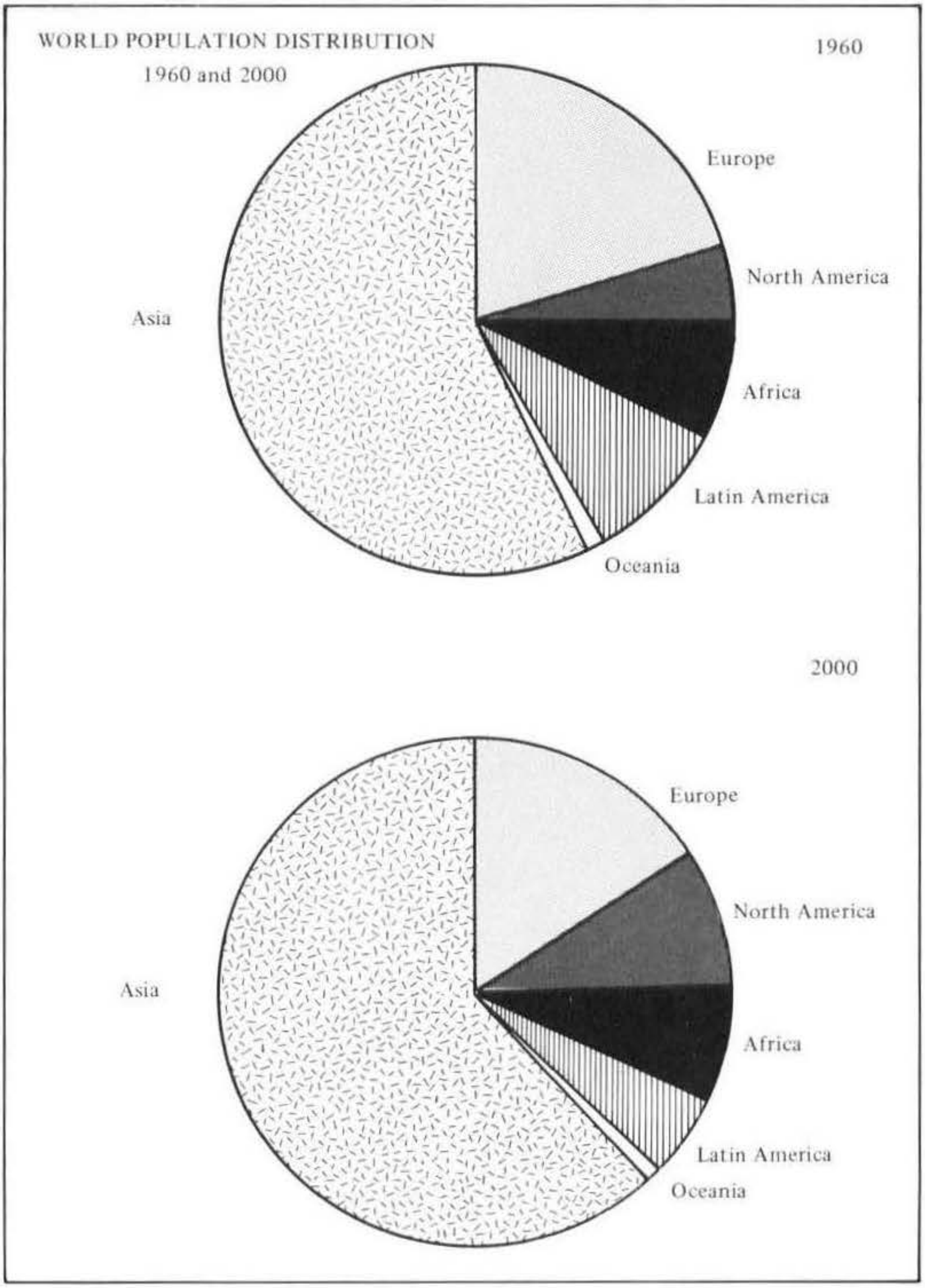


FIG. 1. A comparison of the distribution of world population in 1960 with the projected population in the year 2000.

TABLE 4. Percentage distribution of gross domestic product by economic class and region.

Region	1960	1970	1980
World	100.00	100.00	100.00
Economic Class 1	70.09	69.08	67.24
North America	38.73	35.46	31.61
Western Europe	25.51	24.72	23.13
Oceania	1.42	1.45	1.49
Other developed market economies	4.42	7.44	11.00
Economic Class 2	12.89	12.90	14.45
Africa	1.51	1.32	1.37
Latin America	5.13	5.15	5.90
Near East	1.62	1.92	2.25
Asia and Far East	4.58	4.45	4.87
Other developing market economies	0.04	0.04	0.04
Economic Class 3	17.00	18.00	18.30
Asian central plural economies	3.56	2.86	2.64
USSR and Eastern Europe	13.43	15.14	15.65

projected changes are that Asian and Latin American shares of world population will increase to 71% (their 1960 share was 64%); Europe's (inclusive of USSR) share will decrease to 15% (21% in 1960); and other regions will maintain approximately fixed shares in world population. Given the importance of population in determining the demand for food, indications are that Latin America and Asia will experience the greatest increases in food demand. The pressures in these two areas will be accentuated by income changes and initial food situations.

Income Differences in per capita Gross Domestic Product (GDP) growth rates between LDCS and developed countries which existed in the past are expected to continue (Table 3), but LDCS are expected to increase their share of world GDP (Table 4). The large increases expected in LDC per capita GDP growth rate (Economic Class 2 growth rate increases from 2.5%, 1965–70, to 4.0%, 1970–80), will exert two forces on the demand for food in these countries. First, rapid GDP growth rate means that the income demand elasticity effect[7] will be greatest in LDCS. Second, this rapid increase in income could alter consumer preferences. Although estimates of cross-elasticities of some food items are available, it is argued here that confidence in projected changes in diet must be low since projected values are outside the original range of observations. It is possible that income demand elasticities for food will decline sharply as soon as diets are subjectively adequate (from the consumer's point of view), and that income demand elasticities for other goods and services will increase. This being the case, the change in diets will not be as great as indicated by either existing income elasticities or consumption patterns in developed countries, which LDCS are assumed to emulate. In fact, income disparities between developed and less developed countries are such that emulation is impossible, and the tendency to copy the food habits of developed countries is relatively low in the aspiration hierarchies of LDCS. A further inhibitor to radical changes in diets is the unavailability of a wide range of foods.

Production Two of the main factors upon which production depends are land and fertilizer.

While LDCS, in terms of population, have a relatively small proportion of world agricultural land (Table 5), this condition owes primarily to the high population densities in Asia. Africa and Latin America, in fact, appear to have per capita land resources comparable to North America and substantially greater than Europe. Thus, where Far East Asian countries are concerned, land is a clearly identifiable constraint to rapid increases in agricultural production. With respect to Africa and Latin America, however, low per unit productivity, relating to extensive farming practices (in particular, negligible application of fertilizer;[8] Table 6) is a main obstacle to increased production.

As a consequence of low productivity and unfavourable man–land ratios, LDCS in 1970

[7]Income demand elasticity is defined as the percentage change of consumption which results from a percentage change in per capita income. Income demand elasticity effect is, therefore, the amount by which per capita consumption increases for a given growth rate of per capita GDP. Since LDCS in general have higher income elasticities (Table 1) and higher income growth rates, they will have a proportionally higher growth rate in the demand for food than developed countries.

TABLE 5. Land utilization and distribution by economic class and region 1970 (millions of hectares) (source: FAO, Production Yearbook, 1971).

	Arable land + land under tree crops	Permanent meadows + pasture	All other land	World share of agric. land	Land:man ratio[a]
World	1 432	3 059	8 900	13 391	1.21
(%)	(10.69)	(22.84)	(66.46)	(100.00)	
Economic Class 1	383	913	2 019	3 315	1.78
(%)	(11.55)	(27.54)	(60.90)	(28.85)	
North America	220	280	1 468	1 968	2.20
(%)	(11.17)	(14.22)	(74.59)	(11.13)	
Western Europe	100	78	213	391	0.50
(%)	(25.57)	(19.94)	(54.47)	(3.96)	
Oceania	45	463	287	795	33.87
(%)	(5.66)	(58.23)	(36.10)	(11.31)	
Other developed market economies	18	92	51	161	0.85
(%)	(11.18)	(57.14)	(31.67)	(2.04)	
Economic Class 2	655	1 435	4 495	6 585	1.19
(%)	(9.94)	(21.79)	(68.26)	(46.53)	
Africa	181	729	1 472	2 382	3.23
(%)	(7.59)	(30.60)	(61.79)	(20.26)	
Latin America	119	505	1 432	2 056	2.20
(%)	(5.78)	(24.56)	(69.64)	(13.89)	
Near East	84	169	951	1 204	1.51
(%)	(6.97)	(14.03)	(78.98)	(5.63)	
Asia and Far East	269	31	597	897	0.29
(%)	(29.98)	(3.45)	(66.55)	(6.68)	
Other developing market economies	2	1	43	46	0.75
(%)	(4.34)	(2.17)	(93.47)	(0.06)	
Economic Class 3	394	711	2 386	3 491	0.90
(%)	(11.28)	(20.36)	(68.34)	(24.60)	
Asian central plural economies	114	322	713	1 149	0.49
(%)	(9.92)	(28.02)	(62.05)	(9.70)	
USSR and Eastern Europe	280	389	1 673	2 342	1.92
(%)	(11.95)	(16.60)	(71.43)	(14.89)	

[a]Land:man ratios (*hectares per caput*) are expressed in terms of agricultural land per individual (arable land and land under permanent crops, plus permanent meadows and pastures).

accounted for only 30% of world agricultural production (Tables 7 and 8). While it is predicted that LDCs will increase their share of world production, it is obvious that their levels of production will not only be substantially below that of developed countries but also below self-sufficiency. Given accelerated applications of fertilizer, LDCs may be expected to account for a larger share of world production. Nevertheless, it must be anticipated that they will remain deficit regions in terms of both production and nutrients, as will be shown later.

[8]The low level of fertilizer application in all LDCs is perhaps a reflection of poor agricultural practices; it can also be accounted for by limited supplies and high prices of fertilizers, which are often driven up not by market forces but by the pricing policies of firms that wish to cover investments quickly, or import policies.

TABLE 6. Fertilizer consumption, 1970–71 (*'000 metric tons*) (source: FAO, Production Yearbook, 1971).

Region	Commercial nitrogenous fertilizer	Commercial phosphate fertilizer	Commercial potash fertilizer	Total fertilizer consumption	Distribution of fertilizer consumption in regions (%)	Fertilizer consumption/arable and tree crop acre (*kg/ha*)
World	31 608	19 823	16 538	67 969	100.00	47
Western Europe	9 675	7 824	7 485	24 983	36.75	250
North America	7 477	4 628	3 993	16 098	23.68	73
Latin America	1 407	948	691	3 046	4.48	26
Near East	800	323	37	1 160	1.70	14
Far East	4 019	1 728	1 238	6 985	10.27	26
Africa	475	521	234	1 230	1.81	7
Oceania	163	1 067	195	1 425	2.09	32
USSR	4 605	2 210	2 585	9 400	13.82	20
China (Mainland)	2 987	574	80	3 641	5.35	33

Requirements and Demand for Food The world food requirements may be viewed from the nutrition or the consumer point of view. Consumer demand for food, while determined in part by protein and caloric requirements, is greatly influenced by cultural practices and beliefs, prices, and income. On the other hand, nutritionists often equate demand for food with requirements for food, requirements being determined on the basis of regional temperatures, body weight of individuals, age, and sex distribution of the population.

Such calculations result in daily caloric standards ranging from 2223 calories per capita in the Far East to 2560 calories per capita in North America,[9] and daily protein standards ranging

[9]Prior to April 1971 the daily adult reference calorie requirements were 3200 calories for men and 2300 for women; the revised standards, resulting from a 1971 FAO/WHO meeting, were 3000 for men, and 2200 for women. Protein requirements were reduced from 0.71 to 0.57 g/kg for men and 0.51 g/kg for women (FAO 1971, p. 45).

TABLE 7. Index of past and projected gross agricultural production (source: FAO, Agricultural Commodity Projections 1970–80, Rome, 1971).

	1980 index numbers (1970 = 100)		Annual compound rates of growth			
			Total production		Per caput production	
	Total	Per caput	1959–69 Actual	1970–80 Projected	1959–69 Actual	1970–80 Projected
World	128	104	2.7	2.5	0.5	0.4
High income countries	123	111	2.5	2.1	1.3	1.1
Developed market economies	123	111	2.3	2.1	1.2	1.0
USSR and Eastern Europe	124	112	3.1	2.1	2.0	1.2
Developing countries	139	106	2.9	3.3	0.3	0.6
Latin America	138	104	3.3	3.3	0.4	0.4
Africa	139	106	2.4	3.4	0.1	0.6
Near East	141	106	2.9	3.5	0.2	0.6
Asia and Far East	139	107	2.9	3.3	0.3	0.6
Asian central plural economies	129	104	—	2.5	—	0.5

TABLE 8. Regional shares of world agricultural production (*in* %) (source: FAO, Agricultural Commodity Projections 1970–80, Rome, 1971).

	Total agricultural production			Food and feed		
	1960	1970	1980	1960	1970	1980
High income countries	70.9	70.1	67.5	72.3	71.5	69.0
North America	24.2	21.7	20.8	24.5	22.3	21.5
Western Europe	19.2	19.1	17.9	20.3	20.0	18.7
Oceania	3.0	3.1	3.2	2.1	2.3	2.4
Other developed market economies	3.6	4.3	4.4	3.8	4.5	4.6
USSR and Eastern Europe	20.9	21.9	21.2	21.6	22.4	21.8
Developing countries	29.1	29.9	32.5	27.7	28.5	31.0
Latin America	7.8	8.2	8.9	6.9	7.6	8.3
Africa	4.2	4.1	4.5	4.1	3.9	4.3
Near East	3.9	4.0	4.4	3.7	3.7	4.1
Asia and Far East	13.2	13.6	14.7	13.0	13.2	14.3

from 36.6 g/capita in the Far East to 45.5 g/capita in the Near East. With daily world averages of 2400 calories and 38.7 g protein, world food consumption in 1970 at the aggregate level represented 101% of calorie and 173% of protein requirements (FAO 1971). However, for LDCs food consumption provided only 96% of calorie requirements and 147% of protein requirements. Only in Latin America was food consumption sufficient to meet calorie requirements (106%). As might be expected, aggregation conceals national differences. For example, in South America only Argentina, Brazil, Chile, Paraguay, Uruguay, and Venezuela consume within 100 calories per day of requirements (Fig. 2).

It is projected that the apparent caloric shortage in LDCs will be overcome on average by 1980 (Table 9), but Africa and the Far East are expected to continue to consume below requirements. The increased per capita caloric consumption in LDCs implies a 3.6%/year increased demand for food—the rate in developed countries is 1.7%.

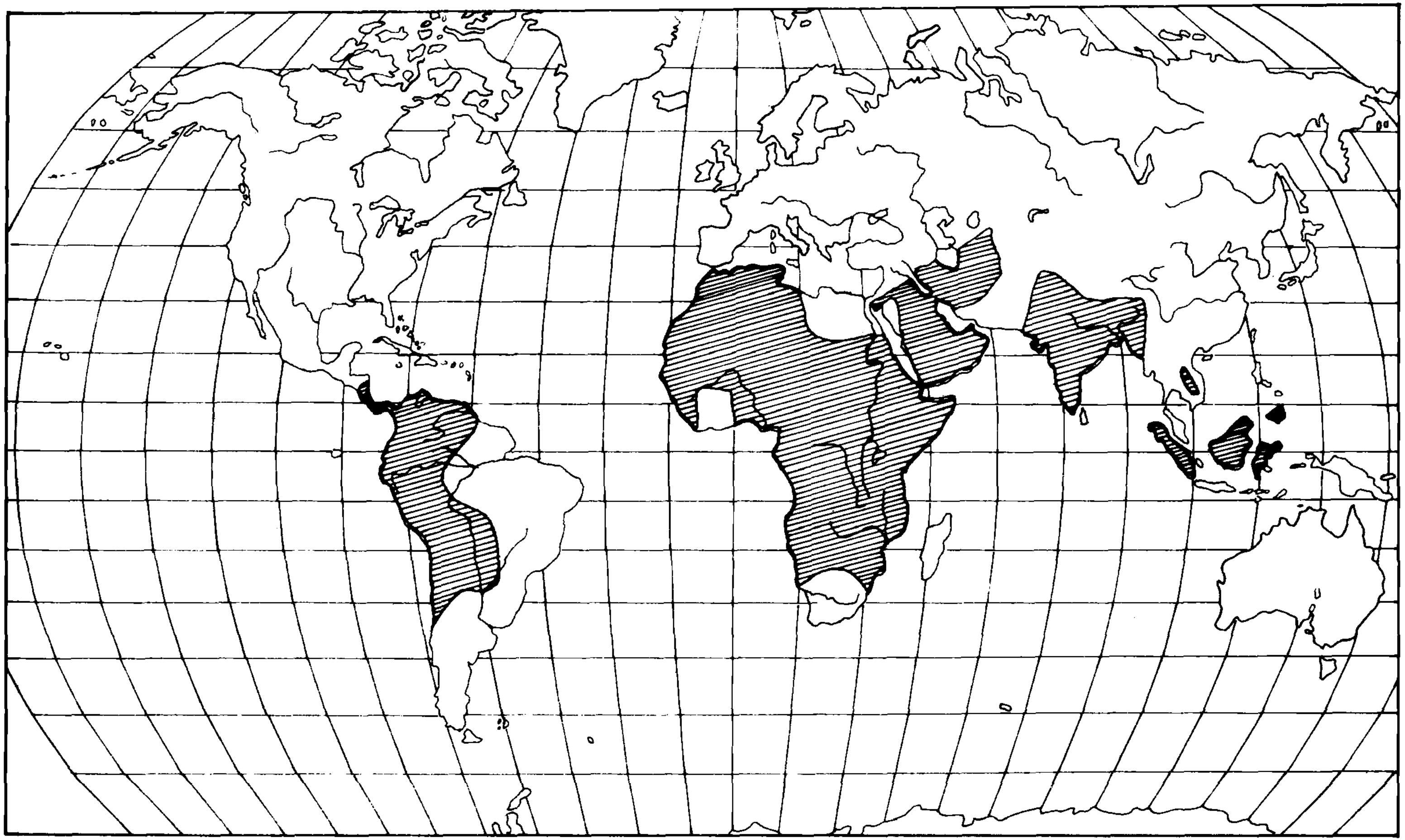
In summary, both the nutrition and the consumer points of view lead to the prediction that the demand for food in 1980 will increase more rapidly in LDCs than in developed countries. One implication of this greater increase is that agricultural production must grow more rapidly in LDCs if this food demand is to be met. Unfortunately, projections based on past trends indicate that the growth of agricultural production in LDCs will not match demand. However, movement to increased application of fertilizer, and to higher percentage of land devoted to arable crops could improve the production growth rate. In any event, it appears that in the coming years LDCs will have the substantial task of trying to meet consumption demands and nutrition requirements. A crucial element in this supply and demand balance is the ability of LDCs to produce sufficient calories. The single most important tropical root crop in terms of caloric production is cassava. The following sections examine the role which cassava may be expected to play in the future diet of populations in the Cassava Belt.

Cassava in the Human Diet

The importance of cassava in LDCs is evident in Fig. 3 which shows the countries deriving 60% or more of roots and tuber production from cassava, potatoes, or yams. Clearly, in the tropical regions cassava is a ubiquitous crop.

The form in which cassava is consumed varies by country and region. In Africa cassava is universally consumed as a vegetable for baking or boiling, or in the form of pastes or mushes made from cassava flour. Other regional preferences encompass consumption of leaves, and pastes made from fermented roots (East Africa). Tapioca, fufu (made from pounded, boiled roots), and gari (dried, grated, fermented cassava) are basic dietary elements in West Africa (Jones 1959).

In South America cassava is eaten as a vegetable or in soups after being soaked overnight or



Regions with more than 100 calories deficit per day

FIG. 2. Areas of the world with more than a 100-calorie/day deficit.

TABLE 9. Projected calorie and protein supply in 1980 (source: FAO, Agricultural Commodity Projections, 1970–80, Vol. 2, Rome, 1971).

Region	Total calories	Calorie intake as % of requirements	Calories from cereals and starchy staples (%)	Total protein (g)	Protein intake as % of requirements	Protein from animal source (%)
World	2499	105	67.5	69.0	178	33.6
Economic Class 1	3111	122	45.6	92.8	237	62.0
North America	3301	125	38.4	99.0	249	73.3
Western Europe	3128	122	45.1	92.3	231	59.0
Oceania	3302	124	41.9	101.4	261	69.8
Other developed market economies	2718	115	62.5	82.4	227	46.2
Economic Class 2	2307	101	74.6	59.5	155	21.8
Africa	2280	98	78.9	61.9	149	17.5
Latin America	2616	110	62.9	67.5	179	39.5
Near East	2472	101	71.1	69.4	153	22.4
Asia and Far East	2200	99	78.0	54.8	150	16.9
Economic Class 3	2466	102	72.2	71.0	183	28.6
Asian central plural economies	2195	93	78.9	62.4	163	17.3
USSR and Eastern Europe	3227	126	59.4	95.1	238	49.4

cooked. In Brazil it is processed into a flour (farinha de mandioca) which is served as a complement to main courses, or boiled to produce a mush (farofa). In Colombia cassava flour is mixed with cheese and other flours to produce the popular pan de bono. It is also cooked in sugar syrup and served as a dessert, or fermented to make beer. In Indonesia cassava is used to make a flat bread with dried fish as an added component.

Cassava constitutes an insignificant proportion of carbohydrate intake in North America and Europe, where it is consumed as a dessert (tapioca pudding); used as a thickening agent in gravies of frozen pre-packaged foods, especially frozen dinners; as a gelling agent in a number of "convenience foods" and quick-setting puddings; or as a binder in sweets and candies.

In the tropics it has been estimated that cassava is the staple food of approximately 200 million people (Coursey and Haynes 1970). As an estimate of the number of people who derive their basic source of carbohydrates from cassava, this appears accurate if Food Balance Sheets are a good approximation of consumption. FAO Food Balance Sheets for 1964–66 on cassava consumption, and cassava production data (FAO Production Yearbook) suggest that cassava provides 38.6% of the calorie requirement in Africa, 11.7% in Latin America, and 6.7% in the Far East. These percentages represent a theoretical maximum of the percentage of people who completely derive their calories from cassava—in 1970 this represented approximately 210 million people.[10]

If cassava maintains its relative position in the increasing demand for food, there will be a growing demand for it in the future. However, it is future populations and incomes which will largely determine the eventual demand for cassava[11] as

[10]The calculation entails summing the product of regional population (Table 2) and percentage of cassava in the diet. If a major staple is defined as providing 50% of caloric requirement then cassava could be a major staple for 420 million people.

[11]Price and relative prices will also affect the future demand for cassava, but there is little information upon which to estimate future prices. Thus the analysis is carried out on the basis that present price relativities are indicative of future conditions, or at least that cassava prices will not increase relative to other prices.

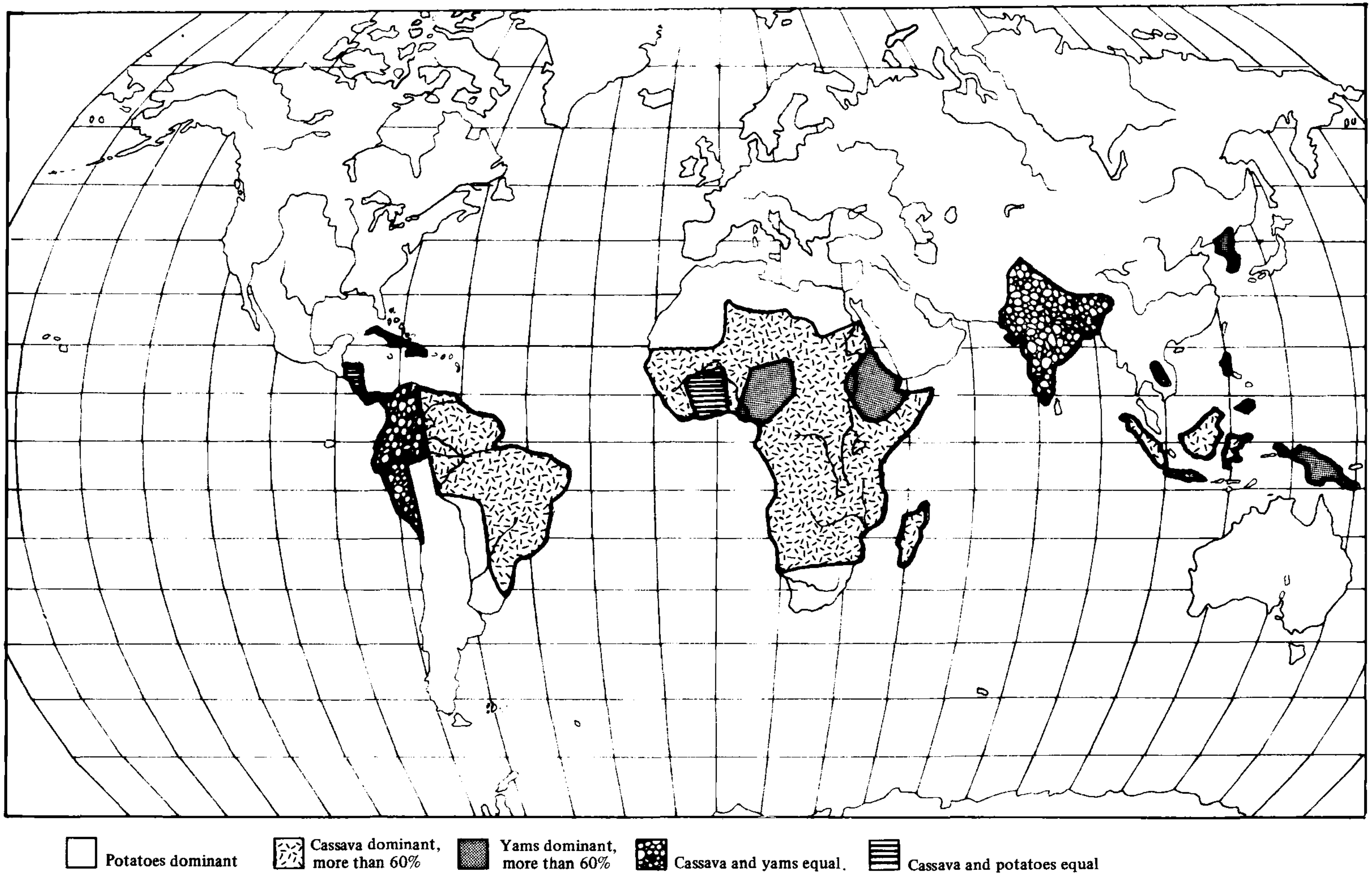


FIG. 3. Map of the world showing areas of importance for specific root crops.

well as for all other foods, and thus the relative importance of cassava may change.

Future demand estimates for cassava derived from equation 1 are presented in Table 10.

$$D_{cjt} = [d_{cjo} + \eta_j(\Delta Y_j/Y_{jo})]P_{jt} \qquad \ldots (1)$$

where D_{cjt} = demand for cassava at time t; d_{cjo} = per caput demand at time 0; η_j = income demand elasticity for cassava (Table 11); ΔY_j = change of income; Y_{jo} = income at initial period; P_{jt} = population at time t; and j = jth country.

It should be noted from Table 11 that 57% of income demand elasticities, which range from −0.40 to 0.70, are greater than zero, indicating that cassava is not in general an inferior food. Admittedly, the magnitudes of the income demand

TABLE 10. Projected human demand for cassava given high and low growth assumptions (*'000 metric tons*) (source: Commodities and Trade Division, FAO, Rome).

Country	1970	1975T[a]	1975H[a]	1980T	1980H
World Total	55 087	62 736	62 657	71 500	70 460
Economic Class 1	7	8	8	8	8
Western Europe	7	8	8	8	8
Other Western Europe	7	8	8	8	8
Portugal	7	8	8	8	8
Economic Class 2	54 346	61 883	61 788	70 521	69 446
Africa	27 328	31 121	31 124	35 444	34 727
Western Africa	10 606	12 081	12 019	13 888	13 596
Dahomey	401	459	459	530	525
Gambia	6	6	6	7	7
Ghana	1 240	1 445	1 445	1 693	1 689
Guinea	356	398	395	450	437
Ivory Coast	340	345	326	347	316
Liberia	234	260	228	282	217
Mali	57	64	65	73	75
Niger	93	108	110	128	130
Nigeria	7 088	8 109	8 102	9 374	9 204
Senegal	164	183	183	203	203
Sierra Leone	67	75	76	85	87
Togo	457	519	516	596	589
Upper Volta	27	31	31	35	36
Central Africa	10 953	12 532	12 613	14 198	13 889
Angola	1 224	1 314	1 308	1 399	1 368
Cameroon	598	663	661	742	783
Central African Republic	533	600	597	680	671
Chad	47	49	50	54	57
Congo (Brazzaville)	437	473	473	515	512
Gabon	181	185	178	191	179
Eastern Africa	5 769	6 507	6 492	7 358	7 241
Burundi	42	47	47	52	53
Kenya	458	522	508	585	533
Madagascar	510	580	580	663	665
Malawi	128	151	154	181	185
Mozambique	2 335	2 581	2 581	2 857	2 849
Rwanda	58	68	68	80	81
Somalia	19	22	22	26	26
Tanzania	1 168	1 338	1 337	1 541	1 525
Uganda	848	965	962	1 103	1060
Zaire	7 824	9 125	9 221	10 480	10 231
Zambia	151	174	172	203	197
Latin America	8 492	9 593	9 524	10 838	10 651
Central America	87	103	103	123	123
Costa Rica	11	13	13	15	15
El Salvador	10	13	13	15	15
Guatemala	6	7	7	8	8
Honduras	29	34	34	41	41
Nicaragua	15	18	18	21	21
Panama	16	19	19	23	23
Caribbean Islands	464	527	529	598	595
Cuba	182	202	202	221	212
Dominican Republic	121	146	146	175	177
Haiti	113	127	128	145	149
Jamaica	7	8	8	8	8
Puerto Rico	5	6	6	6	6
South America	7 941	8 963	8 892	10 117	9 933
Argentina	109	114	113	118	116
Bolivia	124	142	142	163	164
Brazil[b]	5 966	6 658	6 591	7 436	7 267
Colombia	548	642	642	748	748
Ecuador	89	105	105	124	124

(continued next page)

TABLE 10. (*concluded*)

Country	1970	1975T[a]	1975H[a]	1980T	1980H
Guyana	10	12	12	14	14
Paraguay	416	477	472	552	534
Peru	396	476	477	561	561
Surinam	2	2	3	3	3
Venezuela	279	333	334	395	399
Near East	1 978	2 330	2 330	2 760	2 754
Near East and Africa	1 978	2 330	2 330	2 760	2 754
Sudan	1 978	2 330	2 330	2 760	2 754
Asia and Far East	16 422	18 696	18 667	21 318	21 154
South Asia	3 529	3 935	3 876	4 325	4 183
Ceylon	333	365	364	396	393
India	3 191	3 563	3 505	3 922	3 783
East Southeast Asia	12 893	14 762	14 791	16 993	16 971
Burma	7	7	7	8	8
Khmer Republic	22	25	25	29	29
(China) Taiwan	12	11	11	10	9
Indonesia	11 158	12 771	12 815	14 708	14 717
Laos	9	11	11	12	12
Malaysia	91	103	103	117	114
West Malaysia	81	91	90	102	100
Sabah	4	5	5	6	6
Sarawak	6	7	7	9	9
Philippines	581	690	690	824	824
Singapore	3	3	3	3	3
Thailand	686	776	763	872	842
Vietnam Republic	243	276	276	315	316
Economic Class 3	734	846	862	971	1 007
Asian central plural economies	734	846	862	971	1 007
Vietnam N.	734	846	862	971	1 007

[a]T represents a projection of past trends, and H represents "high" alternatives based on targets established by the UN and its Regional Commissions for the Second UN Development Decade.

[b]See Chapter 5 for an adjustment of these figures.

elasticities are small, but there is a quantitative difference between positive and negative income demand elasticities. As a result of the combined effect of population growth and income growth (in those countries with positive income demand elasticities) the 1980 demand for cassava as a food in the tropics is expected to be 33% greater than the 1970 demand for cassava (Table 10). Converted into calorie equivalents the 1980 demand for cassava is equivalent to 37% of the projected demand for calories in Africa, 11% in Latin America, and 7% in the Far East (Table 12). Thus, the FAO projections indicate that cassava will continue to be a popular source of carbohydrates.

Demand projections, especially aggregate projections, cease to be meaningful if supply is not available. This is particularly true for cassava, since in the tropics trade in the form of food has been virtually nonexistent. The following section, therefore, examines the projected demand for, and supply of, cassava on a country-by-country basis.

Comparison of Projected Supply and Demand Table 13 presents a comparison of the demand for and supply of cassava by major producing countries. The demand projections are the 1980T projections (Table 10). Supply projections for cassava were estimated from time trend functions which regressed production of cassava on time (equation 2), since desired economic production data were not available.

$$S_{ct} = \alpha + \beta t \qquad \ldots (2)$$

where S_{ct} = production of cassava at time t, expressed in linear and logarithmic terms, and t = time (data from 1955 to 1971 inclusive were used).

As a check on production projections, acreage and yield were also projected,[12] their product

[12]The acreage and yield equations were similar to equation 2:

$$A_t = \delta' + \beta' t$$
$$Y_t = \delta' + \beta' t$$

when A_t = acreage at time t; Y_t = yield at time t (both A and Y are expressed in linear and logarithmic terms); and t = time.

TABLE 11. Cassava income demand elasticities and equational form used in estimation[a] (source: Commodities and Trade Division, FAO, Rome).

Country	Elasticity	Equation number	Country	Elasticity	Equation number
World Total	0.023	4	Zambia	−0.10	2
			Latin America	−0.18	2
Economic Class 1	−0.02		*Central America*	−0.04	2
EEC	−0.05		Costa Rica	−0.20	2
Other Western Europe	0.06		El Salvador	0.20	2
			Caribbean Islands	0.23	2
			Cuba	0.20	4
Economic Class 2	0.00	4	Dominican Republic	0.20	2
Africa	0.62	4	Haiti	0.30	4
West Africa	−0.26	2	*South America*	−0.16	2
Dahomey	0.20	4	Argentina	−0.02	2
Gambia	−0.30	2	Bolivia	−0.02	2
Ghana	−0.10	2	Brazil	−0.02	2
Guinea	−0.10	2	Paraguay	−0.04	2
Ivory Coast	−0.04	2	Surinam	0.30	4
Liberia	0.20	4	Venezuela	0.10	2
Gabon	−0.30	2	Near East	0.01	2
Mali	0.40	2	N.E. Africa	0.13	4
Niger	0.20	2	Sudan	0.20	4
Nigeria	−0.20	2	Asia and Far East	−0.03	2
Senegal	−0.20	2	South Asia	−0.27	2
Sierra Leone	0.30	2	Ceylon	−0.20	2
Togo	−0.10	2	India	−0.30	2
Upper Volta	0.20	2	East and S.E. Asia	−0.01	2
Central Africa	0.51	2	Khmer Republic	0.20	2
Angola	0.20	4	China (Taiwan)	−0.50	2
Cameroon	−0.10	2	Indonesia	0.20	2
Central African Republic	−0.20	2	Laos	0.20	2
Chad	0.30	2	Malaysia	0.22	2
Zaire	0.70	4	Sabah	−0.20	2
East Africa	0.07	4	Sarawak	−0.20	2
Burundi	0.20	2	Philippines	−0.20	2
Ethiopia	0.20	2	Singapore	−0.20	2
Kenya	0.30	4	Thailand	−0.20	2
Madagascar	0.20	4	Vietnam Rep.	0.21	2
Malawi	0.40	2			
Mozambique	0.20	4			
Rwanda	0.30	2	*Economic Class* 3	0.23	2
Somalia	0.20	2	Asian central plural economies	0.60	2
Tanzania	0.20	4	China (Mainland)	0.07	2
Uganda	0.10	4	Vietnam N.	0.20	2

[a]The empirically derived elasticity estimates were based on the following mathematical relationships:

Eqn. 1. $\ln Y = a + b \ln x$ $\quad \varepsilon = b$

Eqn. 2. $Y = a + b \ln x$ $\quad \varepsilon = b/Y$

Eqn. 4. $\ln Y = a - b/x - c \ln x$ $\quad \varepsilon = (b/x) - c$

where Y = per caput demand

x = per caput GNP or private consumer expenditure.

TABLE 12. Projected (caloric) demand for cassava compared with total calorie requirements, 1980.

Country	Demand for cassava (*millions of calories*)	Requirement of calories (*millions of calories*)	Demand for cassava as % of requirement
Argentina	398 840	24 194 218	1
Bolivia	550 940	5 513 632	9
Brazil	25 133 680	108 343 406	23
Colombia	2 528 240	25 042 267	10
Ecuador	419 120	7 397 608	5
Paraguay	1 865 760	2 872 933	64
Peru	1 896 180	16 044 239	11
Venezuela	1 335 100	13 287 858	10
Ceylon	1 338 480	12 696 708	10
Taiwan	33 800	14 741 423	–
India	13 256 360	574 692 416	2
Indonesia	49 713 040	127 476 644	38
Thailand	2 947 360	39 244 742	7
Vietnam N.	3 281 980	21 805 429	15
W. Malaysia	344 760	9 799 217	3
Philippines	2 785 120	44 199 120	6
Vietnam Republic	1 064 700	18 953 377	5
Angola	4 728 620	5 414 505	87
Burundi	175 760	3 752 565	4
Cameroon	2 507 960	6 261 666	40
Central African Republic	2 298 400	1 630 404	140
Chad	182 520	3 673 305	4
Congo (Brazzaville)	1 740 700	926 425	187
Dahomey	1 791 400	3 046 885	58
Equatorial Guinea	–	4 351 716	–
Gabon	645 580	481 537	134
Ghana	5 722 340	10 358 550	55
Guinea	1 521 000	4 351 716	34
Ivory Coast	1 172 860	5 825 301	20
Kenya	1 977 300	12 772 193	15
Liberia	953 160	1 231 539	77
Madagascar	2 240 940	7 548 602	29
Mali	246 740	5 332 687	4
Niger	432 640	4 697 740	9
Nigeria	31 684 120	78 495 382	40
Senegal	686 140	4 088 361	16
Sierra Leone	287 300	2 627 566	10
Sudan	9 328 800	18 533 572	50
Rwanda	270 400	4 177 852	6
Tanzania	5 208 580	14 892 653	34
Togo	2 014 480	2 096 597	96
Uganda	3 728 140	9 601 730	38
Zaire	35 422 400	19 203 460	184
Zambia	686 140	5 099 163	13
Latin America	36 632 400	327 251 671	11
Africa	199 800 720	316 637 208	37
Far East	72 054 840	1 079 404 448	6
World	241 670 000	3 982 811 183	6

being compared with the production projections. If large discrepancies existed between projected production and the product of acreage and yield, data and/or projections were altered to more closely reflect what appeared to be the realities of the situation. (Appendix Tables A.1 and A.2 contain summaries of the projection equations and projections, respectively.) A comparison of supply and demand projections reveals that if present patterns continue, several tropical countries are expected to have cassava deficits, particularly Colombia, Indonesia, Philippines, Vietnam Republic, Congo Brazzaville, Gabon, Nigeria, Sierra Leone, Sudan, Zaire, and Zambia. Such deficits indicate that food (calorie) shortage may be critical in these countries. On the other hand, several countries are expected to have large surpluses, notably Brazil, Paraguay, Taiwan, India, Thailand, Angola, Burundi, Madagascar, Togo, Uganda, and China.

A cassava deficit would be expected to increase the cassava selling price, and as such may result in increases in supply which could erase the deficit. In fact, the deficits appear to be inadequacies of supply rather than an excessively large increase in demand. Another alternative is that forseeable food shortages will be avoided by government policies which will affect the forces limiting the supply of food.

Countries with projected surpluses of cassava can consider the possibility of exporting cassava as an industrial starch or animal feed; or utilizing cassava domestically in food processing, industry and mining, and livestock rearing. Surpluses of

TABLE 13. Comparison of projections of production and demand for cassava (deficit areas marked by an asterisk).

Country	1980 Projection of production (*linear function*)	1980 T Projection of demand	Country	1980 Projection of production (*linear function*)	1980 T Projection of demand
Argentina	304	118	Dahomey	854	530
Bolivia	312	163	Equatorial Guinea	47	–
Brazil	40 733	7 436	Gabon	146	191*
Colombia	715	748*	Ghana	2 395	1 693
Ecuador	559	124	Guinea	545	450
Paraguay	2 409	552	Ivory Coast	393	347
Peru	668	561	Kenya	650	585
Venezuela	417	395	Liberia	351	282
Ceylon	538	396	Madagascar	1 338	663
Taiwan	449	10	Mali	197	73
India	7 058	3 922	Niger	300	128
Indonesia	11 413	14 708*	Nigeria	6 945	9 374*
Thailand	3 317	872	Senegal	249	203
Vietnam N.	567	315	Sierra Leone	78	85*
West Malaysia	430	102	Sudan	163	2 760*
Philippines	605	824*	Rwanda	566	80
Vietnam Republic	283	315*	Tanzania	1 737	1 541
Angola	2 007	1 399	Togo	1 801	596
Burundi	2 087	52	Uganda	3 530	1 103
Cameroon	1 308	742	Zaire	8 145	10 480*
Central African Republic	1 084	680	Zambia	153	203*
Chad	58	54	Latin America	48 042	10 838
Comoro Island	179	–	Africa	37 107	35 444
Congo (Brazzaville)	92	515*	Far East	26 357	21 318
			World	110 581	71 500

cassava may be maintained only if the alternative markets for cassava are viable and realizable. The exploitation of such markets will in many instances require a concerted effort on the part of producers, processors, and governments. It is therefore not surprising that a number of countries with actual or projected surpluses have requested assistance from the United Nations Development Program and/or World Bank in carrying out feasibility studies on the potential of exporting cassava. My findings on these matters are discussed in subsequent chapters.

Recapitulation Further analysis of the world food situation and the role of cassava in human diets leads to the following observations and conclusions:

- the demand for food will increase more rapidly in LDCs than in developed countries;
- LDCs, particularly Africa and the Far East, could be faced with a carbohydrate shortage;
- Africa and Latin America appear to have a sufficient agricultural land base to meet future demands if productivity is increased;
- the Far East is faced with an agricultural land constraint if a high degree of self-sufficiency is desired;
- cassava is not an inferior food in 57% of the countries for which estimates are available;
- LDCs will consume more cassava in the future;
- cassava will maintain its importance in the human diet (e.g. in Africa, Latin America, and the Far East, 37, 11, and 7% of calories, respectively, are expected to derive from cassava by 1980). At these rates cassava could supply 500 million people with half of their required calories;

Research is being carried out on large-scale production of cassava using chemicals.

- Africa as a continent may by 1980 have a supply of cassava only 5% greater than human demand;
- Latin America and the Far East will have surpluses of cassava with the greatest amounts occurring in Brazil and Thailand.

These findings need to be viewed in terms of new developments, the effects of which, while difficult to quantify, may alter the present findings.

Human Demand: Other Factors

Four factors which may influence future utilization of and demand for cassava are: (1) concern over its hydrocyanic acid (HCN) content; (2) changes in production practices; (3) its low protein content; and (4) development and commercialization of new food products utilizing cassava.

Hydrocyanic Acid HCN content, once thought to be a distinguishing characteristic of "bitter" vs "sweet" cassava varieties, is now known to be primarily a function of production practices. Bitter varieties (high in HCN) convert to sweet merely by planting in new environments and under different production practices (Ayres 1972). On the other hand, it is not an uncommon practice for small farmers to encircle cassava fields with bitter varieties to ward off pests such as pigs and monkeys. These varieties, though planted in the same soil and under similar practices as the sweet crop they are meant to protect, apparently remain bitter—thus, in such instances region and production practices do not explain the bitter–sweet difference.

de Bruijn (1973) tested the numerous theories related to the production of HCN and has concluded that soil nutrients affect the development of HCN in the roots: nitrogen increases HCN, but potassium and farmyard manure decrease HCN, while phosphate, calcium and magnesium have little influence on HCN. Prolonged drought can increase glucoside content, as does the presence of organic matter. de Bruijn also found, contrary to earlier studies, that age of plant has no effect on HCN content. de Bruijn's experiments revealed that root toxicity decreases with stem ringing, leaf elimination, and stem cutting, because "... glucoside or products that cause its formation (amino acids) are synthesized in the leaves and transported, at least partially, to the tuberous roots."

Production Practices Production practices are defined as planting, growing, harvesting, and storing activities. At present, cassava production is labour-intensive. Attempts to "modernize" (in the sense of increased use of fertilizers, herbicides, pesticides, and labour-saving capital) production practices have failed, in part, because of the small size of most plots, uneconomic costs (viz high price of fertilizer), and finally because of the unavailability of appropriate techniques and equipment. (For example, in Thailand the recommended use of 100 kg of 8–8–4 fertilizer per *rai* (2.5 rai = 1 acre; 6.25 rai = 1 ha), besides being costly, is, according to some studies, too low to induce an economic supply response.) In short, the general lack of strong and coordinated cassava research programs has resulted in the unhappy situation where practices deriving from empirical observations of small farmers are often more accurate than the recommendations of researchers. The work at CIAT, coupled with the emerging interest elsewhere in cassava, should overcome this problem.

Thus it may be expected that new, applicable production practices could dramatically increase the availability of cassava and/or reduce the amount of land required for its production. This would be advantageous for countries having a cassava deficit, or for countries wishing to increase production for purposes other than human consumption. Such practices would also release land for diversification and cultivation of other commercial crops (labour permitting).

Of the several yield-improving developments related to cassava production, the following is a list of some of the more obvious techniques:

- improved field preparation, involving the use of "walking tractors" or two-wheeled tractors;
- indentification of optimum planting density for different planting times and different soil conditions. (Research of this nature is under way in several locations. Appendix B contains a directory of cassava research programs known to me.);
- improved cassava yields (volume, starch and protein) per unit of land and time;
- discovery of the fertilizer requirements of cassava;
- increased understanding of required growing practices (use of green manures, rotation patterns, etc.);
- development of herbicides and pesticides for cassava;

- breeding of easier-harvesting varieties (by hand or machine);
- development of planting and harvesting machines;
- development of non-space-consuming storage methods.

A number of the above techniques are presently being studied, and once applied could substantially intensify production. Of course, not all techniques mentioned are applicable to all cassava planters, but it can be argued that these techniques will make improved production possible at all levels—from backyard plot to estate. Insight into the magnitude of possible improvement can be gained from a comparison of average world yields with CIAT experimental yields: 8 metric tons/ha, with production normally taking more than 12 months, vs 75 metric tons/ha in 9 months, respectively! Thus, appropriate application of existing knowledge could overcome expected cassava deficits. The potential of a 10-fold increase in cassava production raises the question of whether or not a similar increase can be expected for cassava demand. The following sections discuss new products which could influence demand for cassava as a human food.

Protein Content Cassava is primarily a carbohydrate and therefore should not necessarily be viewed as a protein source. It is blamed for the occurrence of "kwashiorkor" in regions of high per capita cassava consumption. This criticism seems unjustified because kwashiorkor is primarily a protein deficiency and not a calorie excess.

Given projected demand for cassava (Table 10) it can be calculated that cassava at 1% protein content would provide 2.2% of required protein for Economic Class 2 countries. Thus by extrapolation, development of a 5% protein cassava would imply that more than 10% of LDC protein requirements could be provided by cassava. However, the quality of cassava protein in terms of essential amino acids or even digestibility is not thought to be high. Furthermore, it appears that cassava protein can more easily be increased by microbiological means rather than by breeding improvements (see following section). In any event, the predicted calorie deficits insure that cassava will continue to be consumed, because it is a carbohydrate. Any developments which increase cassava protein content, without adversely affecting taste, will only serve to enhance the demand for cassava. Chapter 8 by Angus Hone contains a report on yield improvements in India that have adversely affected taste and hence human demand.

New Products Apart from the use of cassava in beer and alcohol production in parts of the tropics, and as a gel and thickener in convenience foods in North America and Europe, cassava destined for human consumption undergoes minimal processing. Research now underway shows that a number of new products can be made from cassava. Major advances are being made with the development of composite flours and baby foods, both utilizing cassava, as well as the use of cassava as a substrate for growing protein.

Efforts with respect to the development of cassava flour have been greater than for other food aspects of the plant. In Brazil and Madagascar bread is manufactured from a mixed flour containing cassava. In Brazil a law passed in 1953 attempting to reduce wheat imports required that all bread contain 10–13% cassava flour. With increased wheat production the cassava content of bread decreased to a 1972 level of 1–3%, and it is likely that even these low limits are not enforced.

The prospects for fortifying cassava either by an admixture of protein or by microbiological action are promising. The difficult part of the exercise is distributing the fortified product to needy consumers. The prime reason for fortification is to improve the diet of disadvantaged sectors of the economy; unfortunately it is this sector which is least likely to consume new products. Thus, the alternative of improving the protein content of cassava bears consideration.

The introduction of a higher protein variety of cassava into a region would certainly improve diets (assuming that the improved cassava can be and is used in the same manner as original varieties). However, to develop an improved cassava capable of being produced by traditional cultivation practices may take too much time. Thus, there could be greater returns to research on fortification, marketing, and production practices than to research on genetic improvement of cassava. Additionally, educational programs regarding nutritional requirements of the family could improve diets within the constraints of limited budgets.

Summary

World food projection results suggest in general that LDCs will continue to find it difficult to achieve or maintain self-sufficiency in agricultural commodities. It is expected that demand for agricultural goods will increase more rapidly than supply. Furthermore, by 1980 most LDCs will be faced with a calorie shortage. It is in this context that the importance of cassava in the human diet stands out in bold relief.

Cassava in 1970 provided 38% of calories in Africa, 12% in Latin America, and 7% in the Far East. By 1980, it is predicted that cassava will continue to provide 37% of calories consumed in Africa, 11% in Latin America, and 6% in the Far East. Some of these forecast consumption rates may not be achieved, however, because of insufficient cassava supplies. Colombia, Indonesia, Philippines, Vietnam Republic, Congo Brazzaville, Gabon, Nigeria, Sierra Leone, Sudan, Zaïre, and Zambia are identified as areas of potential cassava shortages.

If a cassava shortage is to be avoided, production in the above regions should be stimulated. If, however, alternative sources of carbohydrates become available, the dietary reason for promoting cassava may no longer be valid.

Starch production is labour intensive and depends on natural sun-drying.

Chapter 3. Starch Market

Evaluation of the competitive position of starch, not only in the present markets, but, more significantly, in future markets requires an understanding of certain basic information. This information includes: (a) the history of starch in the development of the food and chemical industry; (b) the factors governing the constant availability of starch at low price; (c) the possibility that one starch, for example corn starch, will dominate the market; (d) the possibilities for agronomic development of new, special starches; (e) the evaluation of competitive hydrocolloids, their persistence in future markets, and the changing costs which affect their selling price; (f) the ability of the chemist to gain a far better understanding of the relation between molecular structures and physical behaviour; and (g) the ability of the chemist to devise new low-cost reactions by which molecules can be tailored to fit specific end uses in either the food or chemical fields.

ROY L. WHISTLER

Starch ($(C_6H_{10}O_5)_n$, where n is normally greater than 1000) is a widely employed commodity whose use dates from 4000 BC in Egypt (Whistler 1965). Starches are derived from numerous plant sources, the most important commercial starches today being maize, cassava, potato, sago, waxy-maize, wheat, sorghum, rice, and arrowroot. Starches, in most instances, are substitutable and have numerous applications in the manufacture of foodstuffs, adhesives, textiles, paper, gelling and thickening agents, fillers, munitions, and drilling "mud." Not surprisingly, the relative importance of different types of starches varies between countries, with maize starch being most important in the United States and Canada; potato starch in Europe; sweet potato and rice in Japan and the Far East; and domestically produced starches of various types in LDCs. The major markets for cassava starch are Japan, United States, and Canada, but even in these markets cassava accounts for less than 10% of total starch utilization. Before dealing with these three markets, the attributes of the main categories of starch derivatives are briefly defined.

Starches and Derivatives

The physical properties of individual starches are primarily determined by the structure, size, and shape of grains. In general, the grains of starch, when heated in water, swell and burst at approximately 70°C to form a paste. Starches have a narrow density range of 1.50–1.53 and are insoluble in water. Starches may be divided into four categories (Pearson 1970) as indicated below. Derived and modified starches are also described.

Round Starches

Wheat Starch mostly round grains with both small and large diameter, 35–45 μ; the larger grains are oval or lenticular when rolled. With polarized light a cross is visible.

Barley Starch similar to but smaller than wheat starch (maximum size 35 μ).

Rye Starch similar to but larger than wheat starch with sizes as great as 60 μ.

Angular Starches

Rice Starch closely packed angular grains without hilum (the nucleus of the starch grain), uniform in size measuring 6–9 μ. Compound grains, while common, are easily broken under pressure. A cross is visible under polarized light.

Oat Starch similar to but larger than rice starch, 10–11 μ. Compound grains are not easily fractured by pressure, and oat starch does not exhibit a cross under polarized light.

Maize Starch grains are uniformly polygonal, usually with five to six sides, and measure approximately 15 μ. There is a distinct hilum on most grains, and a well-defined cross when examined under polarized light.

Oval Starches

Potato Starch composed of large oval or conchoidal grains with oyster-shell markings of less than 100 μ, and smaller rounded or flattened grains approximately 15 μ in size. A visible hilum is located near the end of the grain. The cross seen under polarized light is centred at the hilum.

Arrowroot Starches constitute both the largest (135 μ) and smallest (7–12 μ) starches, and are similar to potato starch.

Miscellaneous Starches

Cassava Starch the unswollen grains are roughly circular with concentric rings and usually a hilum. The size is approximately 15–25 μ in diameter. Gelatinized cassava starch, commercially traded, is three times larger than unswollen starch, and has saucer-like shapes with no regular markings. The centre is usually dark.

Sago Starch similar to cassava starch ranging from 20 to 60 μ.

Pea, Bean, and Lentil Starches are similar, having an irregular bean-shape or elliptical form, and most grains have concentric markings. Bean starch grains are as large as 57 μ, pea starch grains 15–47 μ, and lentil starch grains 20–40 μ.

Starch Derivatives or Modified Starches

Acid Modified Starch formed by allowing starch to stand in contact with an aqueous acid solution. Superficially the starch granules do not change; however the acid-modified starch differs from the parent starch by having (a) less hot paste viscosity, (b) higher alkali number, and (c) higher ratio of cold:hot paste viscosity.

Hypochlorite-Oxidized Starches formed by treating a suspension of starch granules with an alkaline hypochlorite solution which is neutralized and freed of salts after the reaction. The distinctive properties are: (a) whiteness; (b) granules lose birefringence at temperatures several degrees lower than unmodified starches; (c) pasting occurs more rapidly and at lower temperatures; (d) granules may completely disintegrate during cooking, producing an extremely clear solution; and (e) aging with relatively little deterioration.

Dextrin is the generic name of degraded starch. Most dextrin involves an enzyme or acid modification of a parent starch followed by heat treatment.[13] The important properties are: (a) viscosity is reduced; (b) cold water solubility improves; and (c) sugar content decreases.

Starch Derivatives defined as "chemically modified starch in which the chemical structure of some of the glucose units has been altered . . . (this) excludes acid modified starches but includes all oxidized starches" (Roberts 1967). Hypochlorite-oxidized starches are commonly excluded from this category, because their commercial use preceded the development of other starch derivatives. Starch derivatives are produced to form products having physical or chemical properties which are required for specific applications. The more common starch derivatives are: starch phosphate, starch acetate, cationic starch, hydroxyethyl starch, dialdehyde starch, and cross-bonded starch.

The preceding discussion suggests approximately half the complexity of the starch industry because it relates only to the supply side. Because starches, modified starches, and starch derivatives (to a lesser extent) are highly interchangeable, it is extremely difficult to unravel the complex factors which determine the demand for starch. It proved impossible within the confines of this study to attempt a detailed examination of starch-using industries. However, the results of analyses of available data pertinent to international trade of starch, especially cassava starch, are presented in subsequent sections.

World Trade

In aggregate the world trade of starch has increased but not without some setbacks (Table 14). Unfortunately, the Standard International Trade

[13]It is claimed that dextrin was accidentally discovered following the 1821 fire of a Dublin textile mill. An observant workman noticed that unused starch which was burnt dissolved easily in water to produce a thick adhesive paste (Whistler 1965).

TABLE 14. Quantity (SITC 599.5) and value of starch traded internationally since 1965 (source: Trade by Commodities, Statistics of Foreign Trade, OECD series C).

	1965		1966		1967		1968		1969		1970	
	Quantity (*metric tons*)	Value ('000 *US$*)	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	–	–	–	10 249	–	10 855	–	9 902	–	11 372	–	12 382
USA	97 665	40 790	95 577	45 496	80 591	40 630	91 203	42 075	90 237	42 276	104 969	50 710
Japan	56 256	12 106	65 416	18 812	121 425	26 122	115 965	24 448	109 731	22 528	108 552	25 704
OECD (Europe)	570 627	–	608 247	150 786	591 999	144 843	660 148	155 049	790 737	181 521	829 495	199 255
EEC	219 527	–	259 547	78 335	258 677	73 542	277 631	77 670	347 872	92 746	377 473	102 722
EFTA	312 010	–	309 404	61 963	298 640	61 538	348 142	67 232	406 185	77 718	418 878	84 946
Total:	1 256 085	52 896	1 252 171	365 641	1 651 332	357 530	1 493 089	376 376	174 462	428 161	1 839 367	475 719

TABLE 15. 1970 quantity and value of starch imported by source (source: Trade by Commodities, OECD).

	Canada		USA		Japan		OECD (Europe)		EEC		EFTA	
From/To	Quantity (*metric tons*)	Value ('000 *US$*)	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	n.a.	–	6 794	4 088	5	5	1 150	1 067	43	390	619	386
USA	n.a.	7 982	–	–	239	558	14 106	10 585	2 496	3 193	8 014	6 128
Japan	n.a.	4	64	5	–	–	444	427	55	69	147	187
OECD (Europe)	n.a.	2 258	32 169	14 392	2 502	2 538	624 115	130 203	301 352	70 550	297 124	52 225
EEC	n.a.	756	28 459	11 797	602	874	570 380	112 132	295 006	66 244	257 357	40 684
EFTA	n.a.	1 502	3 682	2 576	1 890	1 336	41 186	15 991	6 258	4 173	29 940	9 816
OECD (total)	n.a.	10 244	39 027	18 495	2 746	3 101	639 815	142 282	303 946	74 202	305 904	58 926
Other	n.a.	2 138	65 942	32 215	105 806	22 603	189 680	56 973	73 527	28 520	112 974	26 038

Classification (SITC) 599.5, upon which Table 14 is based, does not necessarily include all types of starch,[14] and basically omits cassava flour (starch). Therefore, Table 14 may understate the extent of starch trade, particularly with respect to North American and Japanese imports.

Sixty-five percent of OECD Europe starch imports is internally generated, with exports from the Netherlands (potato) accounting for 46.8% of OECD European trade (Table 15). OECD Europe imports a further 58% of its requirements from the United States and Canada (maize), and 28.6% from LDCs. American starch imports by origin are: OECD Europe 28.4%; Canada 8.1%; Australia, New Zealand, and South Africa 27.7%; and LDCs 36.0%. Japan derives 9.9% of its starch imports from OECD Europe, 2.2% from the United States and Canada, and 87.9% from LDCs. Thus, in terms of SITC 599.5, only Japan provides a sizeable market for LDC starch products.

The failure of LDCs to realize a larger proportion of the international starch market may be partially accounted for by: (a) the inability of LDCs to provide a steady supply of starch of a desired quality; (b) a tendency in developed countries to trade with neighbouring countries;[15] and (c) non-competitiveness of LDC prices.

Of these factors, only the first and perhaps third can be directly influenced by LDCs. Even so, while the inability to consistently supply quality starch may result in loss of buyers, the mere ability to do so does not necessarily assure a place in the market—viz any improvement in LDC starch supplies (and one might anticipate some improvement to have occurred over the 6 years covered in Table 14) was not accompanied by greater LDC market shares. Moreover, the ability of LDCs to be price competitive is limited. Although labour costs are lower, LDC starch production normally does not realize the economies of production scale of developed countries. In brief, while the combined effects of labour cost and scale of production are insufficient to insure that either developed or less developed countries can manufacture starch more cheaply, it does appear that the latter cannot necessarily produce starch at substantially lower costs than the former and thus, cannot expect substantial price-induced growth in the demand for their product. Furthermore, the advent of starch derivatives in the past two decades could mean that these specifically designed starches could replace the normally unmodified LDC starches. Hypochlorite-oxidized starch was the only starch derivative commercially available, in fact, as early as 1896 (Scallet and Sowell 1965, p. 238).

The extent to which the demand for cassava starch in the United States, Canada and Japan is likely to be influenced by the aforementioned is examined in the following section.

United States Demand for Cassava Starch

The United States is virtually self-sufficient in starch. Currently, 92% of American starch output derives from maize, with wheat and potato accounting for small amounts. Imports are equivalent to approximately 8% of American starch production (Table 16). Maize starch production appears to utilize approximately 5% of maize production.[16]

Maize starch has not always ruled supreme in America. Wheat and potato starch plants were established in the 19th century, more than 20 years before the first maize starch plants (about 1842). However, by the late 1800s maize starch had come to the fore, annual corn starch production in 1895 equalling 200 million lb, potato starch production 24 million lb, and wheat starch production 8.3 million lb (Scallet and Sowell 1965). By 1970, maize starch production equalled 310 million lb.

Data on the current demand for maize starch are not readily available, but 1958 data indicate the following breakdown of utilization: 44% for paper products; 24.5% for grocers, brewers, and

[14]SITC 599.5 includes: starches and insulin; gluten and gluten flour; casein, caseinates and other casein derivatives; casein glues; albumins, albuminates and other albumin derivatives; gelatin and gelatin derivatives; peptones and other protein substances and their derivatives; dextrins, soluble or roasted starches and starch glues; prepared glues (SITC 1961). Cassava starch (flour) is included under SITC 055.45.

[15]Transportation costs can be an important element in price since starch is often shipped in small quantities (100 kg).

[16]Maize production in 1970 was 4110 million bushels. Maize sales from the farm were 2178 million bushels, and maize starch manufacturing utilized 230 million bushels. Expressed in percentages, maize starch production utilized 5.6% of maize production and 10.6% of maize sales according to Agricultural Statistics issued by the U.S. Department of Agriculture.

TABLE 16. United States maize starch production and starch imports (sources: US Foreign Trade Statistics FT141, Dept. of Commerce, and Agricultural Statistics, US Dept. of Agriculture).

	Cassava		Arrowroot		Potato		Non-specified		Dextrin		Maize starch production
Year	*'000 lb*	*$/lb*	*'000 lb*	*$/lb*	*'000 lb*	*$/lb*	*'000 lb*	*$/lb*	*'000 lb*	*$/lb*	*('000 lb)*
1957	163 464	0.048	6514	0.083	6 561	0.053	12 378	0.053	19 613	0.093	2 043 777
1958	178 654	0.045	8106	0.082	5 987	0.056	7 257	0.059	19 363	0.094	2 063 134
1959	226 146	0.037	7321	0.091	3 504	0.057	27 851	0.048	24 817	0.091	2 190 491
1960	279 980	0.036	6160	0.102	7 018	0.060	41 865	0.047	24 246	0.091	2 127 759
1961	306 640	0.035	4661	0.106	5 519	0.065	28 760	0.049	25 439	0.094	2 158 929
1962	163 248	0.037	5924	0.110	2 446	0.065	37 267	0.040	22 846	0.100	2 341 375
1963	244 438	0.037	5841	0.118	27 258	0.041	34 752	0.040	24 585	0.095	2 355 473
1964	294 420	0.032	4260	0.111	7 652	0.043	17 774	0.046	2 362	0.092	2 495 063
1965	358 028	0.034	4913	0.105	28 510	0.041	29 191	0.041	25 463	0.097	2 636 884
1966	340 604	0.034	3025	0.093	1 539	0.056	21 958	0.053	33 557	0.099	2 755 902
1967	304 078	0.035	3515	0.108	1 461	0.071	6 876	0.063	25 230	0.100	2 707 500
1968	193 799	0.036	3433	0.099	1 092	0.063	4 659	0.095	27 058	0.093	2 680 714
1969	195 069	0.035	2978	0.089	795	0.125	2 912	0.123	24 855	0.094	2 850 000
1970	206 764	0.034	3499	0.115	3 003	0.086	3 886	0.086	27 542	0.097	2 930 000
1971	182 022	0.039	3231	0.100	5 092	0.076	2 626	0.117	25 027	0.108	3 010 000

bakers; 15.3% for textiles; 9.9% for building materials and laundries; and 5.9% for export (data presented in Starch, U.S. Tariff Commission Report 1960, and Farris 1965, p. 27).

The demand for starch derives from the demand for specific manufactured goods, and these, in turn depend on per capita income and population. Farris has attempted to quantify the effect of some of these factors on the demand for maize used in starch production (Farris 1965). Using ordinary least squares (OLS) methods, he estimated a demand equation (equation 3):

$$Y = 61.62 - \underset{4.084\,\text{SE}}{8.496X_1} + \underset{0.044\,\text{SE}}{0.334X_2} - \underset{0.570\,\text{SE}}{1.174t} \ldots (3)$$

$$R^2 = 0.98$$

where Y = million bushels of maize used in wet milling (the process by which starch is extracted);

X_1 = price of No. 3 corn at Chicago in 1957–59 dollars;

X_2 = GNP in billion dollars in 1963 dollars; and

t = time ($t = 70$ for 1970, etc.).

This model suggests that demand for maize used for starch is proportionally influenced by GNP changes and inversely influenced by price and time changes. The negative time factor may imply that starch extraction rate has improved over time, hence requires less maize to produce a given amount of starch. Farris' model appears to be still applicable, since prediction of maize used in wet milling in 1969 is within 10% of the actual figure (considered sufficiently accurate for this study) 226 million bushels. Equation 3 may be used to project the future demand for maize used in wet milling for given assumptions regarding future GNP and price of maize. Estimates of 1980 demand, given two estimates for GNP and corn price,[17] suggest that demand could be within the range of 436 to 461 million lb, an increase of 188% to 195% over the 1970 levels. These projections must be evaluated in the context of possible changes in (a) the importance of different industrial sectors; (b) starch uses; and (c) competition of alternative starch products.

With respect to the first and second points, the forecast is for expansion. Newsprint production, a prime user of starch, is growing at a rate at

[17]GNP = $1089 billion (FAO); or GNP = $1144 billion (OECD), and corn price in constant dollars = $1.00 or $0.85, the high and low price of the past 5 years (1957–59 = 100).

least equivalent to GNP,[18] thus suggesting that the demand for starch will increase more rapidly than GNP growth rate. Furthermore, new developments in prepackaged foods are providing greater markets for starch as a thickener and gelling agent. The last point is more difficult to assess, but it is assumed that competition among starch products will be an extremely important factor in determining future starch demand.

The greatest competition for maize starch may come from cassava starch. American imports of cassava starch peaked during the interbellum years at 390 million lb. (It is reported that corn starch was first modified to replace Indonesian cassava starch which ceased to be available during World War II.) Although this level has not been duplicated since World War II, cassava starch imports have exceeded all others (Table 16). Two things should be borne in mind. First, the volume of cassava starch imported makes up only a small fraction of total starch used, and second, even though cassava imports may increase, its share of the total market may not improve.

Multiple factors undoubtedly account for the continuing demand for cassava, the most important being price of cassava starch, price of other starches, production levels of starch-using industries, maize starch production, and GNP. The specification of equation 4 tests the influences of these factors on the demand for cassava starch.

$$D_{sct} = \alpha + \sum_{i=1}^{6} \beta_i' P_{sit} + \beta_1 Y_t + \beta_2 MS_t + \sum_{j=1}^{2} \beta_j'' X_{jt} + u_t \quad \ldots (4)$$

where

D_{sct} = demand for cassava starch;
P_{sit} = price of the ith starch ($i = 1, 2 \ldots 6$);
Y_t = GNP;
MS_t = maize starch production;
X_{jt} = production of the jth starch-consuming industry ($j = 1, 2$);
u_t = error term with the expected properties $E(u) = 0$;
$E(u^2) = \sigma^2$ and $E(u_i u_j) = 0$; subscript t signifies time.

After fitting numerous modifications of equation 4, the following was found to be the best in terms of a priori expectations and statistical significance (values in parentheses are t-values):

$$D_{sct} = \underset{}{767\,233\,566} - \underset{(4.9)}{2.98 \times 10^8} \left(\frac{P_{s1t}}{P_{s4t}}\right) - \underset{(2.7)}{4.29 \times 10^8} \left(\frac{P_{s1t}}{P_{s6t}}\right) + \underset{(12.7)}{1.28\, D_{st}} - \underset{(11.8)}{1.41\, MS_t}$$

$$R^2 = .998 \qquad DW = 2.8 \qquad \ldots (5)$$

where

P_{s1t} = price, cassava starch;
P_{s4t} = price, nonspecified starches;
P_{s6t} = price, maize starch;
D_{st} = demand for all starches; and
MS_t = production of maize starch.

Newsprint and cotton yarn production were excluded from the model because the coefficients were not significantly different from zero. However, the indications were that cotton yarn production was more influential than newsprint production in determining demand for cassava starch. The GNP variable was also excluded because its coefficient was not significantly different from zero (but greater than zero as expected), and because it reduced the degrees of freedom.[19]

The implications of equation 5 are: (1) an increase of cassava starch prices relative to nonspecified or maize starch prices will reduce the demand for cassava starch, as will increased maize starch production; (2) increased consumption of all starches will increase the demand for cassava starch—other things being equal, a 1% increase in the demand for starch resulted in a 1.3% increase[20] in the demand for cassava starch. Since 1963, cassava price relative to nonspecified and maize starch has *decreased*. Thus, the demand for cassava starch has positively benefited from decreasing price and generally increased demand for starch, while suffering from the effect of increased maize starch production.

[18] Although complete data are not available, the production of newsprint and cotton yarn (taken as proxy measures of paper product and textile production) have grown at 4.5 and 0%/annum. GNP has grown at 3.75%/annum.

[19] That is, newsprint and cotton yarn production and GNP were not explicitly included in equation 3, but because D_{st} may be assumed to be a function of these factors they are implicitly included in equation 5.

[20] The elasticity, η_{ms}, is defined from equation 5 as $\eta_{ms} = 1.41 \frac{MS_t}{D_{sct}}$ which for 1971 is evaluated as 1.3. $\left(\eta = 1.41 \frac{3\,010\,000\,000}{3\,227\,997\,658}\right)$.

Equations 3 and 5 provide the basic ingredients for projections of future demand for cassava starch, if past patterns are assumed to continue. For projection purposes three assumptions are made: (1) price relativities between cassava starch and nonspecified or maize starch will remain constant; (2) maize starch production will increase, as indicated in equation 3; and (3) consumption of starch will be 3863–4241 million lb by 1980.[21]

Substituting the resulting values into equation 5 produces the estimates of 1980 demand for cassava starch of 90–750 million pounds. The implications of these assumptions are that cassava starch may share in the expected demand increase with maize starch, and, more specifically, that the demand for cassava starch could decrease by as much as 55% or increase by as much as 375% in comparison with the 1965–70 average.[22] This range is perhaps indicative of the volatility of the American starch market.

These estimates must be viewed in the context of the assumptions of the projection models, namely, (a) that cassava price will maintain its present relativity to nonspecified and maize starch; (b) that cassava starch will conform to quality standards;[23] and (c) that new starches, modified starches, or starch derivatives[24] do not replace cassava starch. These are factors which cassava starch exporters to the United States should consider when assessing their long-term export prospects.

[21]Projections are based upon the equations

$$D_{st} = 215.98 \times 10^7 + \underset{(10.99)}{7.10 \times 10^7 t} \qquad R^2 = .90$$

and

$$D_{st} = -120\,384\,835 + \underset{(1.73)}{1.33 \times 10^7 Y_t} + \underset{(0.44)}{1.37 \times 10^5 X_{1t}} + \underset{(1.59)}{6.22 \times 10^5 X_{2t}} \qquad R^2 = .93$$

where D_{st} = total demand for starch; Y_t = GNP; X_{1t} = newsprint production; X_{2t} = cotton yarn production. (Terms in parentheses are t-values.)

[22]Employing averages of projected demand for starch and production of maize starch provides an estimate in 1980 for demand for cassava starch of 180 million lb, a 10% decrease on the 1965–70 average.

[23]Appendix C summarizes standards of some of the major American starch users and the attributes which make cassava starch desirable.

[24]Farris (1965, p. 33) notes that starches may have to compete with resin glue, latex, resin finishes, and synthetic polymers, all of which have properties that make them more desirable for specific uses.

Canadian Demand for Cassava Starch

The Canadian starch market resembles that of the United States to the degree that maize starch predominates and similar levels of technology exist in both countries. While domestic starch production constitutes a major share of starch, Canada does, because of lower maize production, import a substantial quantity of maize starch (Table 17), primarily from the United States.

An estimate of Canadian starch production was not available because only two companies in Canada manufacture starch (by law precluding publication of data). However, data are available on the quantity of starch imports, exports, and use in particular industries.[25] Starch production, therefore, was estimated to be the sum of starch utilization plus exports minus imports. It was, of course, not possible to validate this calculation by published data; however the estimates appear to be the right order of magnitude (i.e. 1970 estimation is 108 987 000 lb (Table 4) while 1972 production is approximately 125 million lb (estimates from the National Starch and Chemical Co. (Canada) Ltd.). Under these circumstances, it did not seem advisable to attempt to quantitatively derive a maize starch demand function.

Attempts to quantitatively estimate a cassava demand function similar to equation 4 met with only limited success. The most satisfactory function occurred when cassava starch imports were regressed on GNP, price of cassava relative to rice, and potato starch price (equation 6):

$$D'_{sct} = -8\,240\,040 - \underset{(1.50)}{1.26 \times 10^7} \left(\frac{P'_{s1t}}{P'_{s6t}}\right) - \underset{(1.35)}{9.82 \times 10^6} \left(\frac{P'_{s1t}}{P'_{s7t}}\right) + \underset{(5.14)}{2.87 \times 10^5\, Y'_t}$$

$$R^2 = .93 \qquad DW = 2.11 \qquad \ldots (6)$$

where

D'_{sct} = Canadian demand for cassava starch;
P'_{s1t} = price of cassava starch;
P'_{s6t} = price of rice starch;
P'_{s7t} = price of potato starch;
Y'_t = GNP; subscript t signifies time.

This model suggests that the demand for cassava starch will increase when GNP increases,

[25]Industries for which starch utilization data are available are: paper mills, consuming 75% of starch; cotton yarn, 13%; other chemical production, 6%; and miscellaneous, 6%.

TABLE 17. Canadian starch imports and estimated maize starch production (source: Annual Statistics, Information Canada, Ottawa).

	Maize		Rice		Potato		Cassava		Tapioca[a]		Dextrin		Maize starch[b] production
Year	'000 lb	$/lb	'000 lb	$/lb	'000 lb	$/lb	'000 lb	$/lb	'000 lb	$/lb	'000 lb	$/lb	(million lb)
1960	15 680	0.12	1766	0.09	6 484	0.07	4 350	0.05	1450	0.13	1023	0.13	–
1961	16 800	0.12	1717	0.09	2 822	0.09	3 970	0.05	1739	0.13	540	0.22	–
1962	17 920	0.12	2232	0.10	3 458	0.09	3 419	0.06	1475	0.14	366	0.27	–
1963	15 333	0.12	1926	0.10	4 616	0.10	3 425	0.07	2595	0.12	301	0.29	–
1964	21 919	0.12	1712	0.09	8 343	0.08	6 575	0.07	1671	0.15	3528	0.20	–
1965	19 955	0.13	951	0.11	14 769	0.06	9 685	0.06	1465	0.14	3236	0.23	–
1966	21 673	0.13	1062	0.10	9 545	0.08	12 705	0.05	1276	0.14	3012	0.21	72
1967	20 562	0.13	798	0.13	6 851	0.09	20 114	0.05	1626	0.14	2864	0.26	73
1968	22 356	0.11	1094	0.12	7 727	0.09	15 812	0.06	2309	0.12	3100	0.22	78
1969	24 398	0.11	1097	0.12	13 670	0.06	14 587	0.06	1923	0.08	2249	0.30	93
1970	10 314	0.12	921	0.13	19 818	0.06	20 133	0.05	1374	0.13	3097	0.26	109
1971	5 610	0.14	1088	0.12	2 883	0.10	9 241	0.07	1436	0.13	2828	0.31	–

[a]The distinction between cassava and tapioca starch may be the state of processing.
[b]Maize starch production is estimated as the sum of starch exported and starch consumed minus starch imports.

and will decrease if cassava price increases relative to either rice or potato starch prices. Thus, the model behaves according to expectations. Equation 6 is used to derive projections of the future demand for cassava starch. The assumptions made are: (a) that GNP will be within the levels indicated by FAO and OECD projections; (b) that cassava price relative to rice and potato starch prices will remain constant; and (c) that past patterns will persist in the future. Using these assumptions, it is estimated that the 1980 demand for cassava starch could range from 44 to 46 million lb, 293–307% of the 1965–70 average.[26]

As with the previous starch projections (see preceding section), the above must be tempered by the possibilities that new, competitive products may enter in the future, that cassava starch may not be available in sufficient quantity or quality, and that maize starch producers may be able to capture the entire market. The cassava starch exporter wishing to assess the Canadian market potential at different points in time must therefore continually monitor those developments which may alter the cassava demand model or the projection assumptions.

[26]Increase between early and late 1960s was approximately 442%, thus the growth in demand for cassava starch is predicted to be decreased in the 1970s.

Japanese Demand for Cassava Starch

The Japanese market differs substantially from the North American market because Japan is not a major starch producer and imports a high proportion of starch from LDCs in the Far East. Political considerations,[27] in the form of specific agricultural support policies, have enabled potato and sweet potato starch rather than rice starch to predominate in Japan. Moreover, although the prices of both cassava and maize starch are competitive with potato starch ($90, $120, and $230/metric ton, respectively, in 1972–73), Japanese restrictive policies on the former[28] encourage use of the latter. The Japanese 1972–73 quota on cassava starch is fixed at 50 000 tons, thereby precluding greater use of this cheaper starch, and quotas and licensing policies on maize starch are such that use of domestic potato starch is promoted—I was informed that maize starch

[27]Many of the contentions of this section are derived from interviews with individuals in the Japanese Ministry of Agriculture, and Mitsubishi and Kanematsu-Gosho companies.

[28]The International Trade Centre report (1969) does not mention licensing of imports, but the author was told in January 1973 that licensing of maize starch now exists. The full extent of the licensing could not be determined.

import licenses are generally linked to use of potato starch on approximately a one-to-one basis. Thus, the manufacturer requiring maize starch or larger quantities of starch than are domestically available must utilize potato starch in order to obtain an import license.

The substantial political component in starch policy suggests that future developments of Japanese demand for starch are very hard to predict, but it is probable that the potential for cassava starch imports is limited. However, the high degree to which Japanese trade policy in general is determined by bilateral trade arrangements could well entail increased Japanese purchase of cassava starch from Far East producers in return for access to particular markets. The only sound conclusion to be drawn with respect to Japan, therefore, is that Japan, with its impressive industrial growth, will increase starch consumption. It is impossible at this point to suggest the future relative importance of various starches.

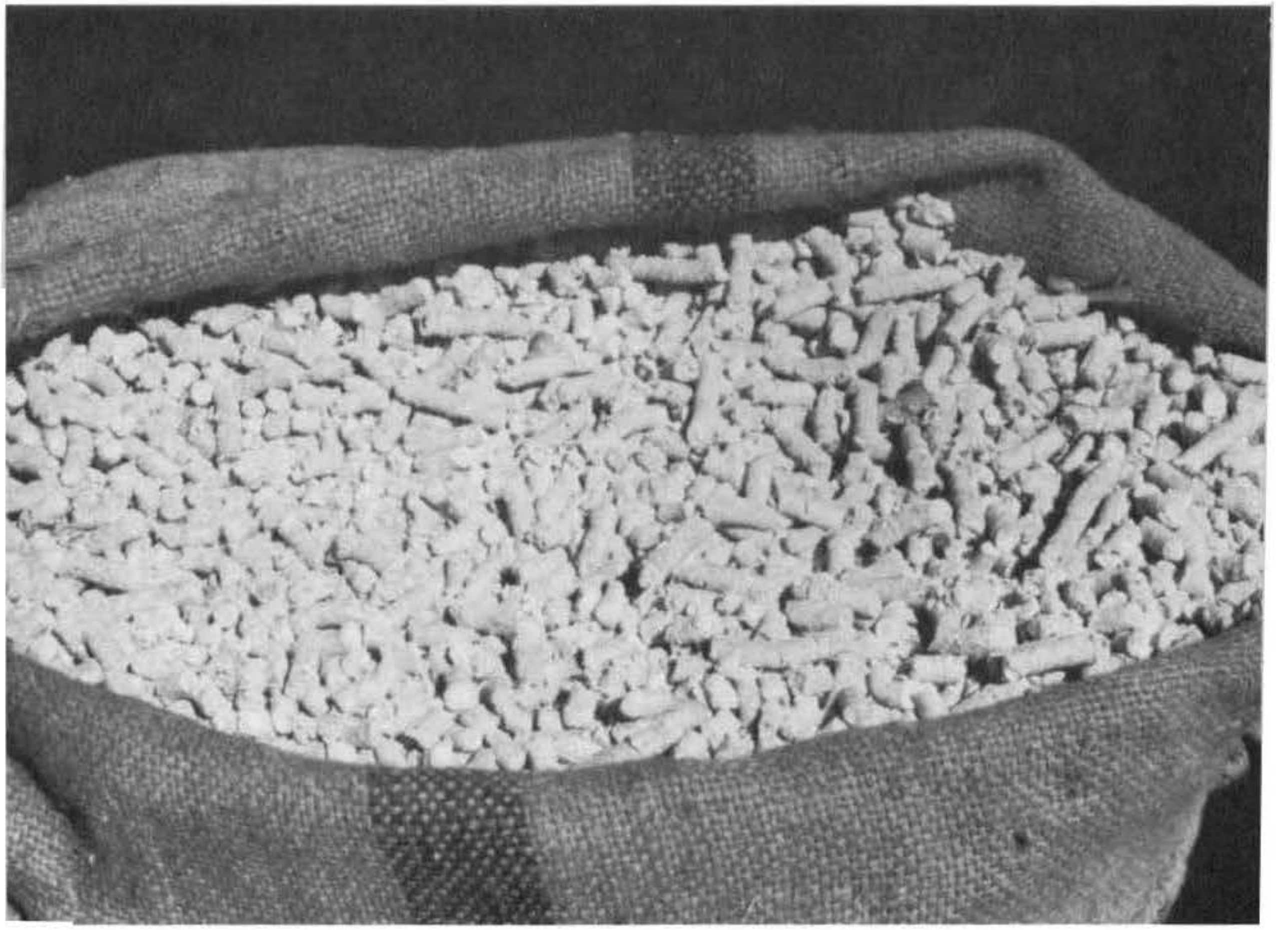
Summary

Similarities between starches, as well as the ability of chemists to tailor starches, means that the market for a given starch can be drastically altered in a matter of years. The future of cassava starch in this context is less definite than that of domestically produced starches in the United States, Canada, and Japan. The latter starches are partially protected from competition by the oligopolistic nature of domestic starch industries, and in the case of Japan, agricultural price support policies. Additionally, the proximity of starch supply and demand in North America results in suppliers of starch being aware of emerging markets for starch before most exporters. It is possible that North American starch manufacturers can coordinate the development and marketing of new starch products with emerging demand, thereby virtually excluding other supplies from the market.

There are several applications for which cassava starch is preferred, newsprint and cardboard production, glues for stamps and envelopes, and food preparation, but even in these areas alternative starch products are appearing. Thus the uncertainty of the starch market should be kept in mind when examining the projected 1980 demand for cassava. The high and low projections are (in metric tons):

	Low	High
United States	41 000	340 000
Canada	20 000	21 000
Japan	50 000	50 000
Total	111 000	411 000

The total projected 1980 demand for cassava starch is 20–447% greater than 1970 levels. These figures suggest that the collective demand for cassava starch in the 1970s will grow at a compound annual rate of 2–16%. Furthermore, the range of the projections indicate the uncertainty of the future of international starch markets.



Cassava producers have been responsive to European demands. From 1962–1973 EEC cassava imports rose from 413 000 to 1 900 000 metric tons; the percentage imported in pellet form increased from 0 to 90%.

Chapter 4. The Animal Feed Market

It is likely that concessions suggested by Europe may be directed in favour of developing countries rather than the US *or Canada. Nevertheless, changes in the* CAP *can and will occur. The most constructive approach of outside suppliers may be one of mutuality of interest in solving common problems rather than direct confrontation and conflict. Europe too has a stake in a satisfactory outcome of the trade talks.*

TIM JOSLING

The growth in demand for cassava as an ingredient in animal feed coincides with the development of the EEC's Common Agricultural Policy (CAP). World market price relativities between energy, protein, and cereals were altered by CAP, making it attractive for European compounders to use large quantities of relatively cheap protein and energy sources (viz, soybean meal and cassava, respectively) rather than cereals in the production of compound feeds. In short, a product of superior quality to cereal is fabricated from an appropriate mix of soybeans and cassava. The development of the European market for cassava must be preceded by an understanding of the effects of CAP and the developments that have transpired in the EEC compound feed industry itself. To this end, the analysis of the future European demand for cassava is prefaced by a brief discussion of the history of the EEC animal feed market.

History of the EEC Animal Feed Market

The Common Agricultural Policy (CAP), centred on cereals, has greatly influenced EEC agriculture. As a consequence of CAP the EEC cereal market is highly organized and regulated. In essence, CAP attempts to insure that EEC agriculture is viable; that barriers to intra-EEC trade are removed; and that EEC agriculture is protected from external competition. The latter two goals have clearly been achieved. The first goal has not. CAP policies have raised farm prices, but they have not promoted the structural change required to make all agriculture viable. In fact, higher prices have probably enabled small, inefficient farmers to remain in farming. Therefore, effort is now being directed toward the formulation of policies which are specifically concerned with structural change.

Development of CAP has been coincidental with substantial production changes (Table 18). Cereal production other than oats has increased, and maize production has virtually doubled between the early 1960s and 1970. Livestock production has also rapidly expanded, owing to both increased number and productivity. Milk production has increased by 18%, while cow numbers have remained nearly constant.

It is the EEC grain policy that has to a large degree been responsible for the importation of "new" ingredients, such as cassava, for the production of compound animal feeds.[29] In essence, the grain policy is based on three prices specified by the EEC council. These prices (which may also be defined as target, minimum import, and support) are:

Indicative price—the expected wholesale price of different grains at Duisburg, Germany; Duisburg is regarded as the area with greatest cereal deficiency.

Threshold price—the import price which ensures that imported cereals do not enter the market below indicative price at Duisburg. The threshold price is the indicative price less transportation costs between Rotterdam, the main port of entry, and Duisburg. Variable levies

[29]Compound animal feeds is loosely defined for the purposes of this study as those feeds which are commercially mixed by cooperative and private firms. When possible farm mixed feeds are excluded from the analysis, as those feeds will not normally contain cassava.

TABLE 18. Production of selected agricultural commodities (source: FAO Production Yearbook, various volumes).

Cereals (in '000 metric tons)

	Wheat			Barley			Maize			Oats		
Year	EEC	United Kingdom	Denmark	EEC	United Kingdom	Denmark	EEC	United Kingdom	Denmark	EEC	United Kingdom	Denmark
1960	24 051	3040	320	9 763	4309	2801	6 649	–	–	7239	2091	681
1961	23 055	2614	434	9 145	5054	2808	6 432	–	–	6991	1851	684
1962	29 493	3974	644	10 873	5865	3299	5 173	–	–	7791	1775	609
1963	24 436	3046	495	12 010	6705	3399	7 618	–	–	7757	1460	671
1964	29 133	3793	541	11 752	7522	3900	6 122	–	–	7103	1346	821
1965	30 347	4171	564	11 841	8191	4125	6 832	–	–	6790	1232	780
1966	26 385	3475	400	12 360	8723	4159	7 976	–	–	7133	1120	864
1967	31 158	3902	421	15 877	9214	4382	8 192	–	–	8031	1386	904
1968	32 018	3571	461	15 155	8406	5059	9 444	–	–	7738	1231	861
1969	31 547	3364	428	15 876	8664	5255	10 651	–	–	6328	1308	765
1970	29 605	4172	452	14 003	7494	5000	12 771	–	–	5463	1233	637

Livestock (in '000 livestock units except where noted)

	Milk (*'000 metric tons*)			Cows			Poultry			Pigs		
Year	EEC	United Kingdom	Denmark	EEC	United Kingdom	Denmark	EEC	United Kingdom	Denmark	EEC	United Kingdom	Denmark
1960	64 340	12 086	5399	21 367	4013	1438	318 586	127 500	25 340	33 340	5724	6147
1961	66 050	12 554	5524	22 010	4154	1493	340 247	139 100	32 240	36 082	6043	7095
1962	66 872	12 910	5355	22 257	4268	1463	349 350	134 300	30 270	35 764	6722	7181
1963	67 357	12 599	5086	21 809	4260	1408	361 410	137 300	26 110	35 317	6859	7334
1964	67 518	12 381	5233	21 488	4126	1370	371 620	143 300	26 120	37 969	7379	8011
1965	70 251	12 857	5367	21 691	4204	1350	378 290	143 000	21 510	38 116	7979	8591
1966	72 430	12 658	5306	21 720	4268	1350	386 350	144 000	22 030	39 117	7333	8120
1967	74 168	13 065	5193	22 036	4355	1329	388 500	151 000	19 900	42 004	7107	8486
1968	75 970	13 348	5127	22 062	4377	1295	388 720	153 000	19 950	44 077	7387	8003
1969	75 759	12 764	4877	22 227	5309	1232	415 950	126 514	19 610	48 368	7783	8022
1970	76 211	13 000	4600	21 910	5409	1232	421 092	143 420	19 730	51 340	8088	8378

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are applied to imports to insure that threshold prices are met.

Intervention price—the price at which "intervention agencies" will guarantee to buy cereal of the specified quality. The intervention price is 8% lower than the indicative price.

Intervention prices are determined for different points[30] or centres in each country. These centres are meant to be buyers of last resort, but farmers in some countries sell directly into intervention to avoid storage, handling, and other costs. Variable levies are defined as the difference between the current month's threshold price and the lowest cif price of the preceding day.

Full variable levies are not normally applied to cassava,[31] vegetable protein (soybean cakes, rapeseed extract, etc.), and many non-cereal energy sources. This means that within the EEC, conventional vegetable energy sources are relatively more expensive than protein sources in comparison to prevailing world patterns.

Given EEC price relativities, feed compounders in the Common Market have been forced to seek new, cheaper ingredients which would enable them to avoid sharp price increases while maintaining nutritional standards. The nature of ingredient changes is briefly examined in the following discussion.

Feed Compounding in Western Europe Commercial feed mixing or compounding in the original EEC has experienced substantial growth since 1963 (Table 19), greater than that of agriculture, industry, and GNP (Table 20). In contrast, the production of compound feeds in the United Kingdom, Denmark, and Ireland has been relatively fixed.[32]

The growth of consumption of compound feeds in the 1960s (Table 21) appears to have been inversely related to 1960 per animal consumption rate. Those countries with relatively high feeding rates in the early 1960s, United Kingdom, Denmark and Netherlands, had the least dynamic increases in consumption of compound feed. Conversely the country with the lowest general compound feed utilization rate (Italy) experienced the greatest increase in compound feed production, 279%. It seems likely, therefore, that the growth rates which prevailed during the 1960s will not continue. Nevertheless, the ex-post analysis does provide information which may enable prediction of the general nature of future developments.

During the 1960s the growth in demand for compound feeds was accompanied by a changing dependency by the major categories of livestock (Table 22). In Germany, France, Netherlands, and Belgium the percentage of compound feed consumed by pigs increased, while in Germany, France, Belgium, and the United Kingdom the percentage of total compound feed consumed by cattle and calves decreased. In all countries the percentage of compound feed consumed by poultry generally decreased.[33]

Changing market shares of specific compound feeds are partially explained by compound feeding rates in different countries (Table 21). Clearly, the Netherlands, United Kingdom, Belgium-Luxembourg, and Denmark generally employ compound feeds at much higher rates than their fellow members. This, of course, suggests that the latter countries (Germany, France, and Italy) will in the future experience higher growth rates in the consumption of compound feeds than the former because of the relatively low levels of feed technology presently existing in these countries.

Additionally, demand for compound feeds is affected by changes in livestock numbers. Data of the 1960s reveal that the Netherlands, Italy, Germany, and the United Kingdom experienced greater increases in livestock numbers than the

[30]There are 11 intervention agencies in Germany; 11 in France; 1 in Holland; 10 in Italy; 2 in Belgium; and 1 in Luxembourg.

[31]Cassava is subject only to a flexible levy of 18% of the barley flexible levy. However, by GATT regulations, this levy may not exceed 6% ad valorem for imports under Brussels Tariff Nomenclature 07.06 (cassava chips, roots, and pellets), or 11% ad valorem for imports under BTN 11.06. On 1 January 1973 the tariff limit on BTN 07.06 was reduced to 3% ad valorem for an indeterminate period (International Trade Centre 1972).

[32]Ireland and Luxembourg are not specifically accounted for in the analyses of this chapter because of the small size of these countries in terms of consumption of compound feeds.

[33]This is not surprising because high initial levels of consumption in poultry production in all countries meant that growth in demand was determined almost entirely by increase in poultry numbers. Other livestock categories experienced increased compound feed consumption through higher feeding rates per animal and/or increased animal units, hence the relative decline of poultry ration consumption.

TABLE 19. Production of compound feeds in EEC, United Kingdom and Denmark, 1960–70 (*'000 metric tons*).

Year	W. Germany	France	Italy	Nether-lands	Belgium-Luxem-bourg	EEC of six	United Kingdom	Denmark
1960	3593	2218	800	4300	1554	12 466	8 979	n.a.
1961	3853	2552	900	4600	1849	13 754	9 489	n.a.
1962	5086	3131	1050	5050	2217	16 534	9 464	n.a.
1963	4917	3421	1300	4900	2030	16 568	9 283	n.a.
1964	5576	4011	1500	5370	2209	18 666	9 667	2630
1965	6597	4544	2000	5625	2527	21 292	9 850	2712
1966	7532	4951	2300	6128	2901	23 812	9 475	2739
1967	7723	5582	2500	6386	3119	25 309	10 114	2575
1968	7545	5516	3098	6629	3240	26 029	10 394	n.a.
1969	8191	6244	3300	7117	3636	28 488	10 680	2405
1970	9727	7441	3633	7891	4210	32 902	9 700	2574

Sources: The Markets for Manioc as a Raw material for Compound Animal Feedingstuffs, International Trade Centre, UNCTAD/GATT, Geneva, 1968.
Markets for Cassava, FAO (unpublished), Rome, 1972.
Study on the Factor(s) Influencing the Use of Cereals in Animal Feeding, OECD, Paris, 1971.
The Major Import Markets for Oilcake, International Trade Centre, UNCTAD/GATT, Geneva, 1972.

other countries under investigation. This suggests that growth in livestock numbers may in the future be greater in the latter countries since it may be assumed that some maximum exists for livestock numbers.

The future demand for compound feeds in the EEC of six[34] will be a function of (a) consumption of livestock products; (b) changing composition of reared livestock; (c) changing dependency on compound feeds; and (d) increasing livestock numbers. It is suggested that:

- demand in italy will increase the most rapidly:
- demand in France will increase only slightly less rapidly than in Italy;
- demand in the Netherlands will not increase greatly;
- demand in Belgium-Luxembourg will increase only slightly more quickly than in the Netherlands;
- demand in Germany will change at about the average rate.

The United Kingdom and Denmark, following the implementation of CAP, are expected to

[34]The United Kingdom and Denmark are not included in this summary because changes resulting from the introduction of CAP will invalidate most trends based solely on ex-post observations.

TABLE 20. Index of per capita GNP, industry, agriculture and compound feed production, 1970. (1963 = 100)

Country	Compound feed produc-tion	Agri-culture	Industry	Per capita GNP[a]
Belgium	213	120	139	127
Denmark	98[b]	100	157	132
France	189	121	149	132
Germany	198	111	153	127
Ireland	–	113	152	128
Italy	279	124	150	135
Luxembourg	–[c]	–[c]	128	126
Netherlands	160	127	175	141
United Kingdom	104	118	124	115

[a]1969 figures.
[b]1964 = 100.
[c]Included in Belgium figures.

Sources: Statistical Yearbook, United Nations, 1971.
W. Esselmann, Development of Future Mixed-Feed Consumption in the Common Market, a paper presented at the Eighth European Mixed-Feed Congress, Rotterdam, 19 May, 1972.
Study on the Factor(s) Influencing the Use of Cereals in Animal Feeding, OECD, Paris, 1971.

TABLE 21. Compound consumption rate by class of animal, 1960–70 (*kg/head*) (source: Production Yearbook, FAO, Rome).

Date	Germany			France			Netherlands			Belgium-Luxembourg		
	Cattle	Pigs	Poultry	Cattle	Pigs	Poultry	Cattle	Pigs	Poultry	Cattle	Pigs	Poultry
1960	170.97	68.03	23.48	50.82	69.71	9.96	609.76	579.41	44.55	395.92	356.17	19.84
1961	161.76	64.47	24.99	54.25	79.60	10.68	606.80	550.67	45.42	479.34	367.46	17.65
1962	213.10	97.06	29.93	59.56	114.81	12.40	726.74	589.35	47.17	575.40	432.05	18.70
1963	210.98	82.20	28.76	67.10	106.59	15.09	745.49	582.40	43.55	559.93	435.51	19.91
1964	250.13	83.97	30.70	91.11	129.57	16.02	828.33	595.74	45.00	587.63	443.17	21.31
1965	300.29	105.14	33.17	100.14	151.83	17.23	957.01	551.79	41.32	683.05	484.93	22.67
1966	344.35	120.01	34.93	110.48	165.67	17.98	1038.94	617.80	39.77	735.52	512.41	24.69
1967	335.98	118.32	36.09	119.97	186.10	19.25	1045.84	583.15	40.63	717.81	560.69	23.75
1968	325.20	118.63	35.06	121.18	175.94	19.29	1046.61	587.94	40.47	703.28	566.65	24.87
1969	378.85	135.61	32.21	143.16	203.50	21.04	1052.58	565.88	33.61	748.28	450.59	25.49
1970	438.33	160.03	36.38	148.00	203.40	21.27	1267.53	536.99	34.46	791.84	546.12	25.98

Date	EEC			United Kingdom			Italy			Denmark		
	Cattle	Pigs	Poultry	Cattle	Pigs	Poultry	Cattle	Pigs	Poultry	Cattle	Pigs	Poultry
1960	141.83	124.09	15.68	776.97	308.18	28.32	50.16	46.14	4.44	1188.46	514.72	30.19
1961	145.77	126.16	16.56	734.23	306.14	27.99	60.05	50.25	4.84	1123.91	468.36	25.78
1962	179.93	159.60	18.22	753.28	319.40	28.99	74.37	56.58	5.00	1187.97	472.64	24.78
1963	185.57	145.40	18.87	729.58	297.42	28.35	76.97	65.62	5.90	1257.10	476.41	27.77
1964	217.28	157.72	19.97	747.46	276.87	28.08	99.82	69.33	6.55	1411.68	477.84	26.76
1965	254.40	181.86	21.48	790.68	277.85	28.19	129.91	96.60	8.73	1500.00	473.75	30.45
1966	286.25	203.54	22.65	772.02	263.74	27.35	158.80	103.93	9.55	1525.93	490.27	29.78
1967	293.15	211.47	23.31	807.35	283.52	27.22	191.10	113.21	9.68	1400.30	478.79	31.96
1968	297.64	206.91	23.27	822.94	289.83	26.31	317.96	76.54	13.15	–	–	–
1969	337.24	209.17	23.85	735.92	307.59	31.45	283.45	55.64	13.43	–	–	–
1970	391.09	229.67	25.24	743.02	315.03	28.18	378.31	72.78	13.71	–	–	–

Table 22. Percentage of total concentrate feeds used by different classes of animal.

	Germany	France	Italy	Netherlands	Belgium	Luxembourg	EEC Total	United[a] Kingdom	Denmark[a]
1960									
Total production ('000 tons)	3592.5	2217.5	800.0	4300.0	1550.0	3.6	12 463.6	8979.0	n.a.
(EEC)	(28.8)	(17.8)	(6.5)	(34.5)	(12.4)	(0.0)	(100.0)		
Cattle and calves	27.0	22.5	20.0	22.7	27.5	–	24.3	40.0	29.9
Pigs	29.9	27.0	25.0	39.5	36.3	–	33.2	24.3	55.6
Poultry	41.6	46.3	50.0	35.5	35.5	–	40.1	30.0	13.4
Other livestock	1.5	4.2	5.0	2.3	0.7	–	2.4	5.7	1.1
1965									
Total production ('000 tons)	6596.8	4543.5	2000.0	5625.0	2478.5	48.5	21 292.3	9850.0	2712.0
(EEC)	(31.0)	(21.3)	(9.4)	(26.4)	(11.7)	(0.2)	(100.0)		
Cattle and calves	26.5	21.4	22.0	28.9	29.0	33.0	25.9	39.1	29.9
Pigs	28.2	30.9	25.0	39.1	38.1	43.3	32.5	28.7	60.0
Poultry	42.7	41.0	48.0	30.7	30.3	23.7	38.2	28.9	9.7
Other livestock	2.6	6.7	5.0	1.3	2.6	–	3.4	3.3	–
1970									
Total production ('000 tons)	9727.0	6474.5	3632.5	7850.6	4282.3	–	31 966.9	10 680.0	2405.0
(EEC)	(30.4)	(20.3)	(11.4)	(24.5)	(13.4)	–	(100.0)		
Cattle and calves	25.9	21.9	37.0	30.7	20.2	–	26.8	38.5	28.8
Pigs	34.5	35.3	18.0	42.1	51.2	–	36.9	25.9	47.1
Poultry	37.7	35.5	41.5	25.9	26.2	–	33.2	32.2	22.0
Other livestock	1.9	7.3	3.5	1.3	2.4	–	3.1	3.4	2.8

[a]1960–61, 1965–66 and 1969–70 figures.

Sources: W. Esselmann, Development of Future Mixed-Feed Consumption in the Common Market.

John Ferris et al., The impact on US Agricultural Trade of the Accession of the United Kingdom, Ireland, Denmark and Norway to the European Economic Community, Research Report No. 11, Institute of International Agriculture, Michigan State University, 1971.

experience pressures to increase livestock production, resulting from increased livestock prices. These pressures will be countered by increasing feed prices.

Numerous studies have been undertaken to quantitatively estimate the future demand for livestock products, animal feeds, and compound feeds in EEC countries.[35] To varying degrees, these studies assume that compound feed demand derives from livestock product demand and thus project the former on the basis of estimates of the latter.

Table 23 summarizes the livestock projections of four of the above-mentioned studies (Esselmann 1972, Ferris 1971, FAO 1971, and OECD 1968). The projections all result in like values—not surprisingly, since similar data and techniques were employed. These projections, combined with projected compound feeding rates, produce the estimates of 1980 demand for compound feeds shown in Table 24.

The basic finding of the summarized studies is that the demand for compound feeds will increase substantially in both original and new EEC countries. Thus, the task remains to determine what proportion of this growing market can be met by cassava imports.

History of Cassava in the EEC

The economic potential of the EEC as a market for cassava has been developed largely through German effort (in particular, German establishment over the past 15 years of several processing plants in cassava-producing countries).[36] German processing plants encouraged production of cassava by providing both demand and supply, in the form of: (1) a ready market for the crop as an ingredient in compound feeds; and (2) relatively constant shipments to Europe. German investments have proven timely in view of the growth of demand for cassava which has occurred since the early 1960s (Table 25). In 1962, demand for cassava was 413 704 tons; by 1971 the market had expanded to 1.5 million tons, an increase of 363%. In 1973 demand for cassava is estimated to have been approximately 1.9 million tons. The average annual growth rate in European cassava consumption over the past decade has been 13%, exceeding the growth rate of consumption of compound feeds (10%), and thereby implying increased utilization of cassava in compound feeds.

In most instances,[37] the composition of compound feeds is determined by least-cost linear programming techniques. The use of specific ingredients is determined by an analysis of:

- relative prices;
- nutritional composition of feed;
- nutritional requirements of ration;
- quality requirements of ration (e.g. layer rations may be required to have a minimum amount of maize).

Of all the factors listed above, cassava's low price and high energy content relative to cereals have been primarily responsible for making it an economically attractive compound feed ingredient. With the application of CAP, compound feed manufacturers have found that cassava mixed with appropriate amounts of high protein feeds (such as 40% protein soybean meal and extract) produces a cheaper feed than could be produced if large quantities of cereal are used.

Two additional factors, physical quality and availability, also influence the demand for specific feeds. Physical quality of a feed ingredient is becoming more important because modern feed handling techniques are not as flexible as earlier systems. For example, cassava chips exceeding 15 cm are not easily handled by pneumatic or small bore auger equipment—hence the popularity of pellets. Availability has been somewhat of a problem with respect to cassava, since supply may be inconsistent or even unavailable. (In economic terms, a short-run inelastic supply schedule is implied.) Consistent supply of an ingredient becomes crucial, because large feed compounders find it too expensive to stockpile feeds, especially bulky feeds, or to change feed ingredients continually (viz, leading United Kingdom compounders estimate that the short-

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[35]See Esselmann 1972; Ferris et al. 1971; Sturgess and Reeves 1972; USDA 1970, 1972; Weightman 1967; OECD 1968; and FAO 1971.

[36]Early ventures in northeastern Brazil met with failure. Ventures in Thailand, however, have proved to be quite successful. See Chapter 7 on the development of the Thai cassava industry.

[37]Even on-farm compounding often utilizes computer-formulated rations. In several EEC countries grain merchants, farm management consultant firms, and cooperatives will develop least-cost feed rations for farmers.

term cost of changing a feed ration is between £1.25 to £2.00/long ton of feed added).

Since the formation of the EEC, the composition of compound feeds has altered substantially. It should be noted, however, that the United Kingdom and Denmark have not up to now participated in these changes (Table 26). The overriding pattern for the EEC of six has been a decline in the percentage of cereals used coupled with a relative increase in the percentage of cereal by-products and oilseed cakes. The most dramatic change has occurred in the Netherlands where cereal content dropped from 63 to 34%; oilseed and cake content increased from 16 to 26%; and animal meal decreased to 2%. At the other end of the spectrum, France, with its relatively cheap cereals, continued

TABLE 23. Livestock projections (*'000 metric tons*).

	Esselman	Ferris	FAO[a]	OECD[b]	
	1980	1980	1980	1975	1985
W. Germany					
Cows	–	–	1458	1315	1448
Pigs	3100	–	2754	2645	3057
Poultry	400	–	731	285	427
France					
Cows	–	–	2045	1978	2307
Pigs	1750	–	1816	1751	2104
Poultry	950	–	926	733	912
Italy					
Cows	–	–	730	525	590
Pigs	650	–	574	510	660
Poultry	950	–	646	565	760
Netherlands					
Cows	–	–	350	312	323
Pigs	950	–	441	621	749
Poultry	430	–	117	194	269
Belgium-Luxembourg					
Cows	–	–	247	244	256
Pigs	550	–	313	328	404
Poultry	140	–	111	130	160
EEC					
Cows	–	–	4830	4374	4924
Pigs	7000	–	5899	5855	6974
Poultry	2870	–	2531	1907	2528
United Kingdom					
Cows	–	1219	1132	883	1016
Pigs	–	1194	1640	1051	1269
Poultry	–	732	820	615	775
Denmark					
Cows	–	260	173	210	201
Pigs	–	947	156	849	919
Poultry	–	68	27	85	94

[a]Source: Agricultural Commodity Projections, 1970–80, FAO Rome, 1971.
[b]Source: Agricultural Projections for 1975 and 1985, Europe, North America, Japan, Oceania, OECD, Paris, 1968.

TABLE 24. Projected EEC demand for compound feeds in 1980 (*'000 metric tons*).

Types of livestock	W. Germany[a]	France[a]	Italy[a]	Netherlands[a]	Belgium–Luxembourg[a]	United Kingdom[bc]	Denmark[bc]	EEC
Cattle and calves	3 550	4 250	2200	2550	1100	6 689	2283	17 667
Hogs	6 200	5 250	1300	4560	2475	5 571	5070	30 644
Poultry	4 180	4 195	4530	2180	1305	5 937	554	18 481
Total:	13 930	13 695	8030	9290	4880	18 197	7907	66 792

[a]Source: W. Esselmann, Development of Future Mixed-Feed Consumption in the Common Market, a paper given at the Eighth European Mixed-Feed Congress in Rotterdam on 19 May, 1972.

[b]Source: John Ferris et al., The Impact on US Agricultural Trade of the Accession of the United Kingdom, Ireland, Denmark and Norway to the European Economic Community, Research Report No. 11, Institute of International Agriculture, Michigan State University, 1971 (Table 2.9, p 87, and Table 4.8, p 176).

[c]These figures, relating to all mixed feed, are adjusted in later sections to reflect the amount of compound feed commercially produced.

to include high percentages of cereals in compound feeds in the 1960s. Denmark and the United Kingdom, with relatively constant prices (relative to price changes wrought by CAP), also maintained cereal at a high level.

As already noted, consumption of cassava has grown at a rate exceeding consumption of compound feeds. Thus, a third trend of particular interest to this study has been the increased percentage of cassava in compound feeds (cassava content of Dutch feeds, for example, has increased from 0.0 to 5.4%). EEC prices, when fully applicable,[38] will undoubtedly induce Danish and British compounders also to decrease cereal content and increase cassava, cereal by-product, dried grass, citrus pulp, and protein oil cake content in compound feeds.

[38]Technically EEC policies now apply to Denmark and the United Kingdom; however these countries have been granted a transition period in which to bring their prices in line with those of the original EEC.

Subsequent sections examine these expectations, and quantify possible changes to the year 1980.

Future Demand for Cassava in the EEC

Most feed compounders in the EEC determine feed formulas by linear programming. In essence, this technique minimizes the cost of feed ration while satisfying specified nutrient (e.g. protein, energy, lycine, etc.) and quality requirements. The general cost function is shown in equation 7, while the constraint set is illustrated by equation 8.

TABLE 25. Imports of cassava products into the European Economic Community, 1962–70 (*'000 metric tons*).

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
W. Germany	366	387	462	520	702	533	481	548	591	479	387	420
France	23	20	18	17	16	n.a.	n.a.	n.a.	35	79	n.a.	n.a.
Italy	0	0	0	1	0	n.a.	n.a.	n.a.	14	n.a.	n.a.	n.a.
Netherlands	1	5	17	76	96	159	237	444	502	599	650	700
Belgium	23	72	105	100	70	113	127	212	268	278	n.a.	n.a.
Total:	413	484	602	714	884	805	845	1204	1410	1750	8150	1900

Sources: 1962–66, The Markets for Manioc as a Raw material for Compound Animal Feedingstuffs, International Trade Centre, UNCTAD/GATT, Geneva, 1968.

1967–70, The EEC Tapioca Market–Possibilities and Limits. FAO 1972 (unpublished manuscript).

1971–73, Unpublished country and EEC estimates.

$$\text{Minimize:} \quad Z = CX \qquad \ldots (7)$$
$$AX \geqslant B \qquad \ldots (8)$$
$$X \geqslant O$$

where Z = cost of feed ration; C = a $1 \times n$ vector of the cost of each ingredient; X = an $n \times 1$ vector of all possible ingredients; A = an $m \times n$ matrix specifying the attributes of each ingredient; and B = an $m \times 1$ vector of the constraint set associated with each ration.

Because this technique is widely used in Europe, the future demand for a particular ingredient such as cassava may be estimated through the development and evaluation of least-cost feed matrices for different rations and countries. For this study, 61 different formulas were estimated.

Two distinct matrices were developed, based on Dutch and United Kingdom constraints. The differences between these matrices rest mainly with differences of ration type rather than with nutrient requirements for similar feeds.[39] The United Kingdom constraint matrix was used in the evaluation of British and Danish least-cost rations. The Dutch constraints were used in all other instances.

The analysis did not attempt to estimate the future costs of ingredients. Instead, secondary price projections or existing price relativities were assumed to be applicable for projection purposes. The United Kingdom analysis employed prices projected by Ellis (1972), which detailed expected changes for the transition period, 1973–1978. For the remaining EEC countries it was assumed that current price relativities will prevail in the future. This assumption is crucial to the analysis; to the extent that CAP maintains a single policy for feed grains, and that inflation rates apply equally to all feed grains, the price assumption is tenable. To the degree that price relativities change, the following analysis will be subject to biases, although several sensitivity analyses have been attempted to determine the possible extent and direction of such biases.

[39]Rations estimated with the United Kingdom matrix were: dairy, 3.5 gal/day/cow; dairy, 4.0 gal/day/cow; beef fattening; grazing cake; layer medium ration; poultry grower; broiler raiser; broiler finisher; pig grower; pig fattening. Dutch rations were: cow standard; beef and calf; layer medium energy; poultry grower; broiler raiser; broiler finisher; pig starter; pigs 0–30 kg; pigs 30–100 kg; sows. Technical coefficients were derived from *Hulptabel* (ACV 1970), instead of Morrison (1959) which is commonly used in North America. The former was thought to be more appropriate for European conditions.

TABLE 26. Major ingredients in compound feeds of some European countries, 1960–70 (%).

Ingredient	1960	1965	1970	1960	1965	1970
	Netherlands			Germany		
Cereal	63.2	50.2	33.7	43.9	37.1	n.a.
Oilseed and cake	15.9	21.2	25.5	20.8	23.9	37.7
Animal meal	4.4	3.4	1.9	3.7	4.3	6.4
Cassava	n.a.	1.1	5.6	2.8	6.4	5.6
	France			Belgium		
Cereal	50.8	43.8	51.9	n.a.	40.0	43.3
Oilseed and cake	20.0	22.3	23.1	n.a.	15.9	18.9
Animal meal	5.4	4.6	3.3	n.a.	4.3	2.9
Cassava	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Sources: Study on the Factor(s) Influencing the Use of Cereals in Animal Feeding, OECD, Paris, 1971.
The Markets for Manioc as a Raw Material for Compound Animal Feedingstuffs, ITC, UNCTAD/GATT, Geneva, 1968.
The Major Import Markets for Oilcake, ITC, UNCTAD/GATT, Geneva, 1972.

The following is a discussion of the 1980 projections of the demand for cassava in the EEC countries.

Netherlands

Since 1962, demand for cassava has increased more rapidly in Holland than in any other EEC country. Today the Netherlands is the most important European market for cassava. This growth is the consequence of:

- a high animal:land ratio which invokes heavy dependence on purchased feeds;
- an efficient and relatively inexpensive water transportation system which enables imported feeds to be easily shipped to any part of the country;
- development of a large compound feed industry which utilizes computer formulation in feed rations;
- overall increased demand for compound feeds.

Feed compounding in Holland is undertaken by both private firms and cooperatives, with the latter being slightly more important and of larger average capacity. In 1970–71, cooperatives accounted for 51% of production and averaged 24 846 metric tons per plant, against a private firm average of 6104 metric tons per plant (Mengvoede-Enquete 1971, p. 22–23). Feed compounding accounts for virtually all swine and poultry feed and 90% of high protein feeds.[40]

High swine dependency on compound feeds and the rapid growth of pig numbers (the national pig herd nearly doubled during the 1960s) have been primarily responsible for increasing Dutch demand for compound feeds. In fact, it appears that compound pig feed consumption is expanding at an exponential rate with no indication of leveling off in the near future (Fig. 4). However, it is difficult to project this rate in the Dutch context, particularly since expansion of pig numbers may eventually be inhibited by pollution regulations (International Trade Centre, 1972). Certainly, Esselmann's projections do not extrapolate this trend (Table 23). He assumes that market shares will alter slightly between 1970 and 1980, that demand for pig meat will increase by 20% by 1980, and that Dutch pig production will increase by 29% by that same date.

Esselmann's projections, however, are probably low. The 1971 consumption of pig feed was 15% above his projected 1970 level, and 1972 consumption is estimated to have already exceeded the 1980 forecast. Furthermore, his projection of total demand for compound feeds for 1980 may have been exceeded in 1972.[41] Faced with the choice of accepting or altering Esselmann's projections, it was decided to err on the side of conservatism and to utilize his estimations of the future magnitude of Dutch demand for compound feeds.

What percentage of the projected compound feed market may cassava be expected to claim? The initial results of equations 7 and 8 are presented in Tables 27 and 28. They indicate that, given present price relativities:

1 Cassava percentages, if permitted, will exceed their present allowable maximum in layer, broiler rearing, broiler finishing, and all pig rations;
2 Cereal percentages will decrease, with no cereal being found in cow, beef, pig starter, and sow rations;
3 Oil cake and meal percentages will increase.

The largest increase in cassava utilization is predicted to occur in pig feeds. If constraints on cassava are dropped,[42] cassava utilization will increase at the expense of cereals and "other" ingredients. In general, the removal of constraints and increased use of cassava could reduce the cost of compound feeds by as much as $5.18/metric ton, or by as little as $0.63/metric ton.[43]

As already noted, fixed prices or price relativities have been assumed. However, it is interesting to evaluate the possible effects of price changes. Linear programming techniques permit the quantification of short- and long-run price change effects.

Calculated short-run demand elasticities[44] (Table 29) for cassava by feed category indicate

[40]Data on the importance of compound feeds in cattle rearing are not available, but it is assumed that perhaps 90% of cattle feed is manufactured by compounders. Certainly, most grains used in cattle rearing are used as an ingredient in compound feed, since 96% of all cereals fed are used in mixed feeds (Meeker, USDA memo).

[41]Esselmann's projection of 1980 total compound feed consumption is equivalent to an increase of approximately 144 000 tons/year. This increase is probably modest. One large Dutch feed compounder informed me that the long-run projected increase for his plant alone was 100 000 tons/year.

[42]One of Europe's largest feed compounders successfully trial-fed cassava at the 60% level; thus no technical constraint hinders its increased use.

[43]Of course, cow, beef, and poultry starter rations, which experience no increase in cassava utilization, will not experience cost changes if cassava constraints are removed.

[44]Short-run demand elasticity is defined as the percentage change in the quantity demanded divided by the percentage change in price, given that other prices remain constant and that no ingredients are added or removed from the feed ration. The long-run effect is defined as the change in feed ration resulting from price changes, while allowing ingredients used in the ration to be altered. Those familiar with IBM's MPSX or MPS linear programming packages will recognize that the short-run effects are evaluated by use of the range option while the long-run effects are evaluated by use of the parametric option.

For purposes of exposition, elasticities for specific categories are averaged, e.g. demand elasticity for cow feed = (2.49 + 0.59)/2 = 1.54.

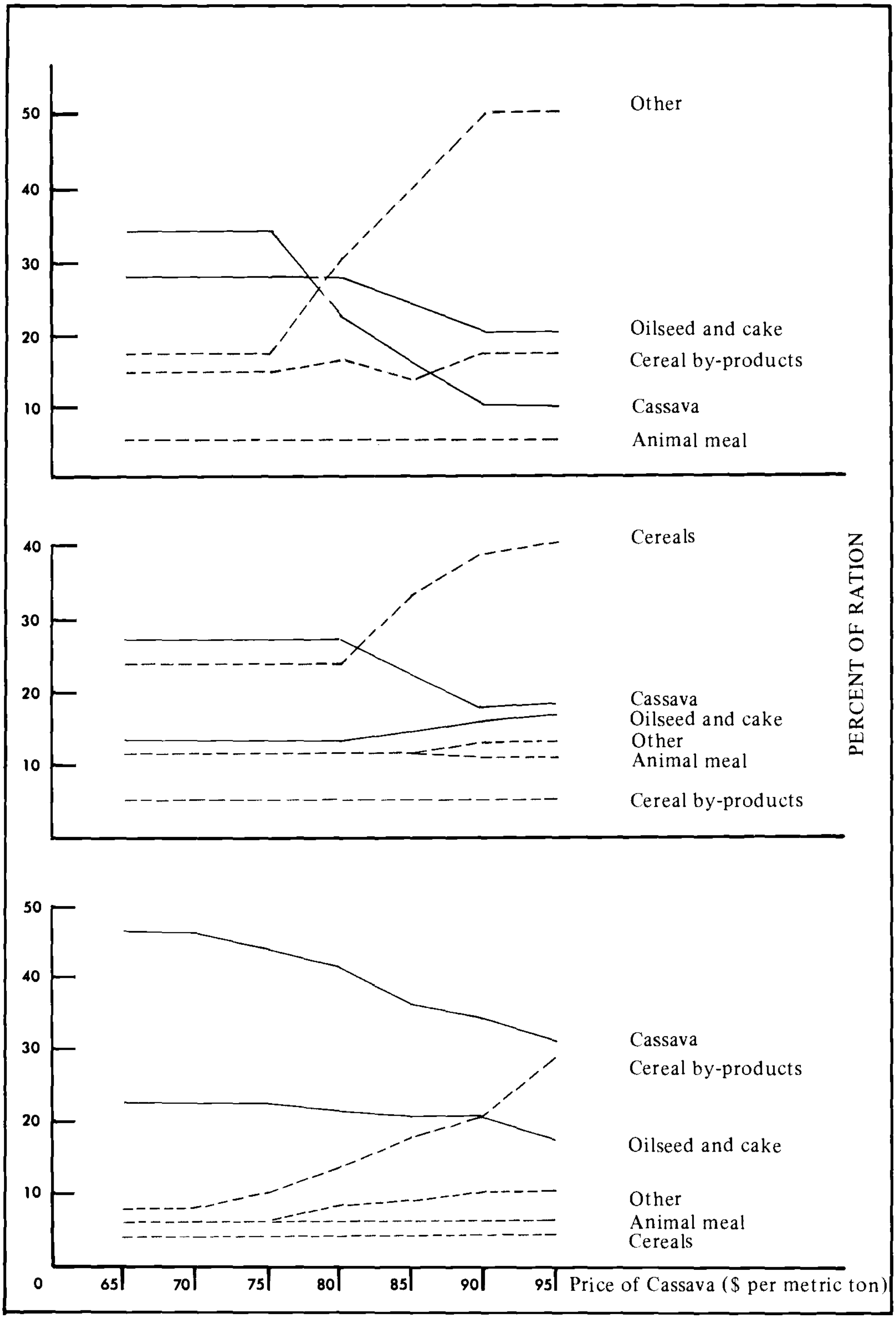

FIG. 4. Composition of compound cattle (*top*), poultry (*centre*), and pig (*bottom*) feed in the Netherlands.

TABLE 27. Projected composition of animal feed in the Netherlands (constraint on cassava[a]) (%).

Type of feed	Cow standard	Beef and calf	Layer medium	Poultry grower	Broiler	Broiler Finisher	Pig Starter	Pig 0–30 kg	Pig 30–100 kg	Sow
Cost[b]	(74.97)	(78.63)	(100.67)	(134.26)	(112.44)	(101.97)	(97.40)	(93.72)	(88.66)	(90.25)
Cereals	–	–	49.0	59.8	50.0	46.5	23.5	27.8	17.8	11.0
Cereal by-products	19.6	15.0	8.0	8.0	3.0	3.0	28.6	17.3	19.0	45.0
Oil cake and meal	18.9	35.4	11.0	12.8	21.0	22.6	16.4	16.1	16.0	–
Animal meal	4.2	5.0	9.0	16.0	8.9	5.4	7.4	6.4	5.5	8.2
Cassava	11.0	9.2	10.0	0.0	5.0	10.0	5.0	10.0	15.0	7.0
Other	46.3	45.4	13.0	3.4	12.1	12.5	19.1	22.4	26.7	28.2

[a]Cassava maximums are cow standard 20%; beef and calf 20%; layer medium 10%; poultry grower 0%; broiler 5%; broiler finisher 10%; pig starter 5%; pig 0–30 kg, 15%; pig 30–100 kg, 15%; and sows 7%.

[b]Unit of account (u.a.)/metric ton. Exchange rate used 1 u.a. = $1.00.

that cassava utilization in broiler finishing feeds is most sensitive to price increases, while cassava utilization in beef and calf feeds is least sensitive.

The analysis suggests, therefore, that on average a 1% increase of cassava price would, in the short-term, reduce the demand for cassava in cow feeds by 1.5%; in pig feeds by 0.0%; and in poultry feeds by 0.9%. Conversely a 1% decrease in the price of cassava would increase the demand for cassava in cow feeds by 0.07%; in pig feeds by 0.78%; and in poultry feeds by 0.88%.

Long-run price changes (Fig. 4) vary in effect depending upon feed type.[45] Where cow feeds are concerned (Fig. 4, top), cassava is competitive with other energy sources and, to a lesser extent, cereal by-products (a cassava price increase results in decreased utilization of cassava and increased utilization of cereal by-products and "other" feed ingredients). The complementarity between cassava and protein sources should also be noted, viz, utilization of cassava, and oilseed and cake decrease together. This complementarity is not commonly appreciated, and consequently the degree to which cassava utilization can be adversely affected by policies or events that limit the supply of vegetable protein sources in the EEC, is not widely realized. In short, if high protein sources were not available, cassava would cease to be utilized in compound feeds.

This somewhat unexpected complementarity between cassava, and oilseed and cake is to a large

[45]Appendix Table E.1 summarizes the effects of cassava price changes for each ration.

TABLE 28. Projected composition of animal feed in the Netherlands (unconstrained cassava limit) (%).

Type of feed	Cow standard	Beef and calf	Layer medium	Poultry grower	Broiler	Broiler finisher	Pig starter	Pig 0–30 kg	Pig 30–100 kg	Sow
Cost[a]	(74.79)	(78.63)	(100.04)	(134.26)	(111.27)	(100.42)	(92.22)	(91.10)	(87.04)	(87.98)
Cereals	–	–	38.7	59.8	32.6	20.0	–	10.0	10.0	–
Cereal by-products	19.6	15.0	8.5	8.0	3.0	8.0	45.0	17.0	17.0	35.0
Oil cake and meal	18.9	35.4	13.3	12.8	23.7	19.8	15.8	24.0	21.6	8.2
Animal meal	4.2	5.0	11.0	16.0	9.2	6.2	8.5	7.6	7.2	9.0
Cassava	11.0	9.2	16.9	0.0	18.7	31.5	26.3	33.4	29.8	30.6
Other	46.3	45.4	13.9	3.4	12.5	14.3	4.1	7.7	14.2	16.9

[a]u.a./metric ton.

TABLE 29. Short-run price demand elasticities for cassava in the Netherlands.

	η_c for price increase[a]	η_c for price decrease
Cow standard	2.49	0.06
Cow and calves	.59	0.08
Layer medium	1.06	1.52
Poultry[b]	–	–
Broiler rearing	1.20	0.40
Broiler finisher	0.54	0.71
Pig starter	0.00[b]	2.04
Pig 0–30 kg	0.00[c]	0.16
Pig 30–100 kg	0.00[c]	0.76
Sow	0.00[c]	0.16

[a]$\eta_c = -\frac{\Delta Q/Q}{\Delta P/P}$, average cassava price $65/metric ton,
where Q = quantity of cassava in ration;
and P = price of cassava.
ΔQ and ΔP are the maximum changes which can occur in the ration without changing ingredients in the ration.
[b]Cassava is not allowed in poultry ration.
[c]Short-run demand schedules are inelastic for price increases of 1–8% (i.e. the quantity demanded does not change for a 1–8% increase in price).

extent the product of least-cost feed ration techniques. Least-cost linear programming techniques do not compare one specific ingredient with another (thus, the popular assumption that cassava competes with barley is not wholly accurate). Rather, the technique selects the least-cost combination of ingredient attributes (thus, cassava competes with barley or other cereal *energy*, while soybean cake replaces barley or other cereal *protein*).

With respect to the other feed types, the demand for cassava in poultry rations (Fig. 4, centre) is constant up to $80/metric ton, and then drops to 20% of ration at $95/metric ton. Unlike cattle feeds cassava in poultry rations competes primarily with cereals, not "other" feeds. The demand for cassava in pig feeds is also fairly insensitive to price change (Fig. 4, bottom) (cassava percentage dropping from 45 to 35% as price increases from $65 to $95/ton). Cassava competes mainly with cereal by-products and "other" feeds. There is also a slight decrease in the use of oilseed and cake, once again suggesting a complementarity between cassava, and oilseed and cake.

Projections of the Dutch demand for cassava in 1980 may be derived from the cassava demand functions (Fig. 4) and the projected demand for compound feed (Table 24). The procedure is to multiply the appropriate demand projection[46] by the percentage of cassava in the diet for specific conditions. Two points from each cassava demand function are used in the estimation of future demand for cassava. The first point is taken at average price and existing maximum cassava limits; the second point is taken at average price and economic maximum of cassava.

Thus, the low projection of demand for cassava in pig feeds is derived by multiplying projected consumption of pig feed (4 560 000 metric tons) by 12%, the average maximum limit of cassava now allowed in the ration; and the high projection is derived by multiplying projected consumption of pig feed by the economic maximum percentage of cassava in the ration, 38%. The resulting projections of the demand are 547 200 metric tons and 1 732 800 metric tons. Projections of the 1980 demand for cassava in cattle and poultry rations (Table 30) were similarly calculated. The combined effect of these projections is that the 1980 demand for cassava will be 1 to 2.4 million metric tons—at least a doubling of the 1970 demand.

TABLE 30. Projected demand for cassava[a] in the Netherlands 1980 (*'000 metric tons*).

	Low	High
Cattle	255	255
Poultry	218	392
Pig	547	1733
Total:	1020	2380
Increase over 1970	203%	474%

[a]Cassava price assumed to be $90/metric ton.

The method used for calculating 1980 projections of cassava demand in the Netherlands has

[46]Because consumption projections (Table 25) relate only to categories of feed and not specific rations, it is possible to estimate only the demand for cassava by feed categories. When projections of specific feeds become available, they can be used with the compound feed demand functions (presented in Appendix E) to estimate the demand for cassava for each feed. This latter approach would be expected to improve the accuracy of the projected demand for cassava.

been applied to the markets of Germany, Belgium-Luxembourg, France, Italy, the United Kingdom and Denmark. In many cases similarities with the Dutch situation are exhibited. To avoid redundancies, the discussion will deal primarily with characteristics peculiar to each market.

Federal Republic of Germany

Germany, formerly the major importer of cassava products, lost its position to the Netherlands in 1971. Although it will likely remain a large market for cassava, it is expected that Holland will dominate. However, German consumption of compound feeds is predicted to predominate in the EEC, with France forecast as a near second (Table 24). A substantial proportion of this projection results from anticipated enlargement of the national pig herd and greater use of compound feeds.

The feed rations evaluated for Germany have the same basic linear programming matrix as the Dutch rations (information collected from German compounders indicates that only minor differences exist between German and Dutch compounded feeds), but prices of ingredients are altered to reflect differences resulting from CAP and transportation costs (Appendix Table E.3). The procedure in the case of wheat, barley, oats, and maize was to weight Dutch end-user prices by the relativity of German-Dutch producer prices, assuming the ratio of producer prices: user prices to be equal. For sorghum, wheat middlings, wheat bean, brewer's grain, and rice bran, average price relativities of intervention prices between the Netherlands and other countries were used to weight Dutch end-user prices. Remaining ingredient prices were held constant for all countries.

The estimated German feed rations with unconstrained cassava content (Table 31) resemble the Dutch results at low cassava prices. The major differences are that greater percentages of cassava are used in German broiler starter rations than in Dutch rations; and that in this ration the Germans use no cereal while the Dutch use 10% cereal. Varying the price relativities of cassava to other ingredients (Fig. 5) again produces results similar to those of the Netherlands, although German demand for cassava decreases more rapidly to increasing price changes than in the Netherlands. In Germany, cassava is not used in cattle or poultry rations if its price is equal to or greater than $95/metric ton. Again, cassava's competition with cereal by-products and complementarity with oilseed and cake, are indicated in cattle and pig rations (Fig. 5, top and bottom). In poultry rations, cassava competes with cereals.

As in the Dutch projections, feed rations are combined with projected compound feed demand to estimate the 1980 demand for cassava. In the past few years feed compounders in southern Germany have not included cassava in feed rations, but used instead denatured wheat, the denaturing of which is subsidized under CAP. The wheat price reduction resulting from this subsidy premium and the additional transportation cost for cassava to reach southern Germany are sufficient to make denatured wheat economically more attractive than cassava. Thus, for projection purposes, it is assumed that only 60% of German compound feeds will contain cassava; this percentage repre-

TABLE 31. Composition of animal feed in Germany (%).

Type of feed	Cow standard	Beef and calf	Layer medium	Poultry grower	Broiler	Broiler finisher	Pig starter	Pig 0–30 kg	Pig 30–100 kg	Sow
Cost[a]	(67.48)	(72.03)	(88.00)	(111.17)	(91.36)	(82.59)	(75.76)	(75.54)	(73.98)	(71.53)
Cereals	–	–	26.4	45.7	–	–	–	10.0	10.0	–
Cereal by-products	13.4	17.3	8.0	8.0	3.0	6.1	20.0	10.0	10.0	10.0
Oil cake and seed	24.7	36.6	11.2	3.1	17.0	15.1	25.3	23.3	21.8	13.8
Animal meal	4.5	5.0	12.0	20.0	16.5	12.4	6.3	7.6	5.8	10.4
Cassava	43.2	24.1	31.6	20.0	56.2	60.1	47.3	40.8	44.5	49.6
Other	14.0	16.8	10.6	3.0	6.9	6.1	0.9	8.0	7.6	16.0

[a]u.a./metric ton.

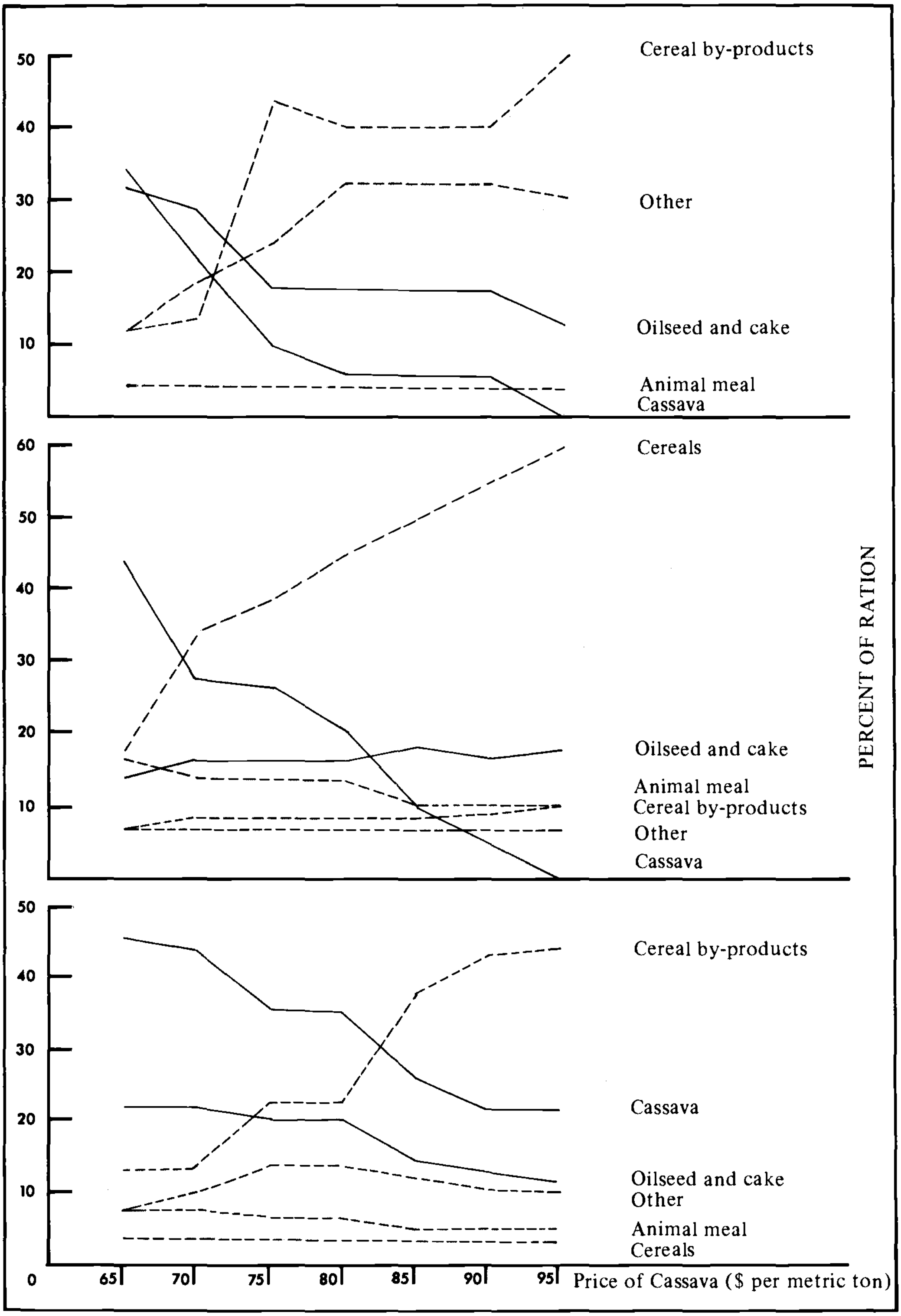

FIG. 5. Composition of compound cattle (*top*), poultry (*centre*), and pig (*bottom*) feed in Germany.

TABLE 32. Projected demand for cassava[a] in Germany, 1980 (*'000 metric tons*).

	Low	High
Cattle	106	106
Poultry	125	125
Pigs	446	930
Total:	677	1161
Increase over 1970	115%	196%

[a]Cassava price to user assumed to be $90/metric ton.

sents approximately the proportion of production which occurs north of Bonn, the demarcation line for cassava utilization.[47]

The assumptions used in projecting 1980 German demand for cassava are:

- that existing price relativities will persist in the future;
- that cassava utilization will be constrained by persent maximums;
- that cassava utilization will not be constrained; and
- that only 60% of 1980 compound feed will contain cassava.

The projections (Table 32) indicate that demand for cassava may not grow as rapidly as the demand for compound feeds. These projections depend primarily upon the growth in demand for compound feeds and the price competitiveness of cassava. Thus, adverse movement of either could limit cassava demand.

[47]A more accurate estimate could be derived if percentages of specific feeds produced North and South of Bonn were known. However, this data was not available.

Belgium-Luxembourg

Cassava used in Belgium (Luxembourg is assumed to behave similarly to Belgium) has generally been of a higher quality than in other EEC countries, owing to stricter quality regulations (International Trade Centre 1968, p. 38). It is reported that compounders check the quality of cassava received in Belgium (International Trade Centre 1968, p. 40), because quality certificates issued by exporters have been found in some instances to be unreliable. The exporter of cassava, therefore, is obliged to conform faithfully to Belgium standards if sales are to be cleared, and increased cassava utilization is possible only if standards are met.

Esselmann's projections of 1980 compound feed for cattle and pigs represent a continuation of trends of the 1960s; the projection of poultry feed, however, represents a sharp decline caused by a reduction in the growth rate of poultry production and the limited scope in Belgium for increasing compound feed consumption rate. Nevertheless, in aggregate, the prediction is that compound feed demand for Belgium-Luxembourg will increase by 17%.

The estimated feed rations for Belgium (Table 33) are similar to those of the Netherlands and Germany, although Belgian cereal consumption in poultry feed, and cassava consumption in cattle feed, are greater than in either of the other two countries. The effects of long-term increases in cassava price (Fig. 6) indicate the competition

TABLE 33. Composition of animal feed in Belgium-Luxembourg (%).

Type of feed	Cow standard	Beef and calf	Layer medium	Poultry grower	Broiler	Broiler finisher	Pig starter	Pig 0–30 kg	Pig 30–100 kg	Sow
Cost[a]	(67.04)	(71.46)	(86.04)	(108.64)	(91.04)	(82.26)	(75.46)	(74.94)	(73.38)	(71.23)
Cereals	–	–	35.2	51.5	28.8	13.3	–	10.0	10.0	–
Cereal by-products	15.0	19.7	8.0	8.0	3.0	8.0	20.0	10.0	10.0	10.0
Oil cake and seed	24.0	35.8	13.9	4.9	16.8	15.4	25.3	23.3	21.8	13.8
Animal meal	4.3	5.0	9.0	18.2	14.2	10.7	6.3	7.6	5.8	10.4
Cassava	43.1	22.7	22.8	14.3	33.1	47.5	47.3	40.8	44.5	49.6
Other	13.4	16.6	10.9	3.0	3.9	4.9	0.9	8.0	7.6	16.0

[a]u.a./metric ton.

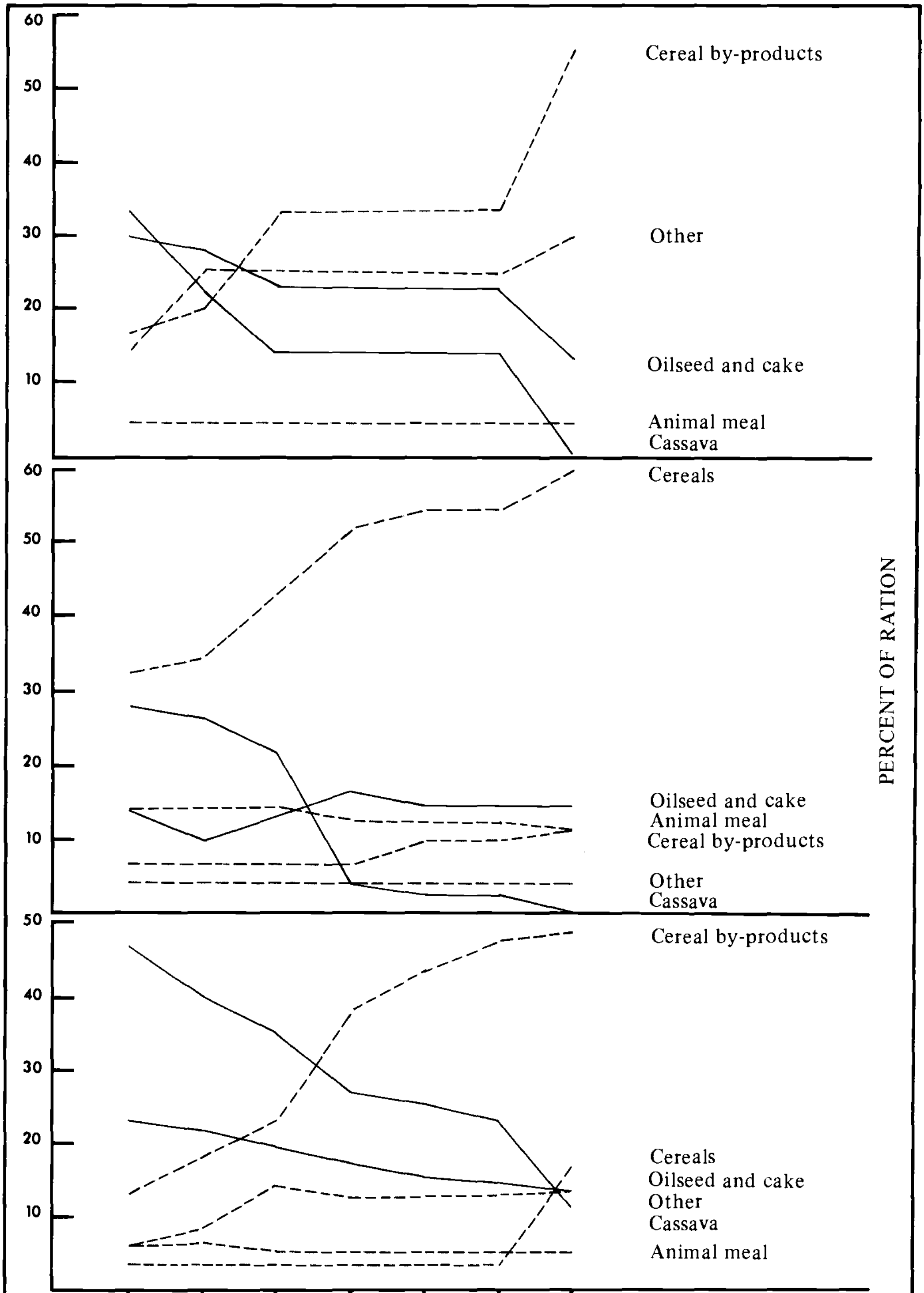

FIG. 6. Composition of compound cattle (*top*), poultry (*centre*), and pig (*bottom*) feed in Belgium-Luxembourg.

TABLE 34. Projected demand for cassava[a] in Belgium-Luxembourg, 1980 (*'000 metric tons*).

	Low	High
Cattle	110	165
Poultry	65	65
Pigs	297	495
Total:	472	725
Increase over 1970	176%	271%

[a]Cassava price assumed to be $90/metric ton.

between cassava and cereal by-products in cattle and pig feeds, and between cassava and cereal in poultry rations; and the complementarity of cassava, and oilseed and cake in cattle and pig rations.

The assumptions that existing price relativities persist, that cassava price remains constant and that cassava percentages in feed rations will be between present constraints and economic maximum, result in a projected increase in Belgium-Luxembourg demand for cassava of 176 to 271% by 1980 (Table 34).

France

Prior to 1972, very little cassava[48] was used in compound feed in France, owing to the availability and relatively low price of cereals, and to the high cost of transporting cassava to internal regions. In 1972, however, compounders in Brittany found it economical to include 15% cassava in pig feed rations for the 6 months of the year immediately prior to cereal harvest. Breton compounders characterize the substitution effect as being:

19% wheat + 1% bran = 15% cassava + 5% soybean meal; and
15% maize + 4% bran = 15% cassava + 4% soybean meal (Meeker, USDA memo).

French animal feed compounding is expected to grow, including an increased demand for cassava, if cassava prices remain favourable. Esselmann has predicted substantial increases in all categories of mixed feed, based on enlarged animal numbers and increased feeding rates. Consumption of compound feed for cattle is expected to increase by a spectacular 348% in 1980 reflecting an 882% increase in feeding rate over 1970. This expansion is possible because the French feeding rate is much lower than for other EEC countries; even the projected 1980 feeding rate[49] is lower than present rates of other countries.

Estimated French pig and poultry rations contain greater amounts of cereals (reflecting France's cheaper cereal prices) and in consequence, less cassava (Table 35), compared with similar Dutch, German or Belgian feeds. On the other hand, cassava content in French cattle rations is higher and more stable than for all other EEC countries. The competitive-complementary relationships al-

[48]An interesting exception is rabbit feed, compounded in the Loire Valley, and based primarily on cassava, grass and alfalfa meal. This region produces a major proportion of total French production.

[49]The projected feeding rate of 750 kg/cow is substantially below the 1970 Dutch feeding rate of 1091 kg/cow.

TABLE 35. Composition of animal feed in France (%).

Type of feed	Cow standard	Beef and calf	Layer medium	Poultry grower	Broiler	Broiler finisher	Pig starter	Pig 0–30 kg	Pig 30–100 kg	Sow
Cost[a]	(66.34)	(70.55)	(75.74)	(99.45)	(84.52)	(77.93)	(75.06)	(73.68)	(72.28)	(70.41)
Cereals	–	–	58.7	64.8	40.0	40.0	–	10.0	10.0	–
Cereal by-products	17.3	24.8	8.0	8.0	3.0	15.0	20.0	17.0	10.0	30.0
Oil cake and seed	23.6	34.2	10.2	7.8	19.6	16.6	25.3	20.8	21.8	7.5
Animal meal	4.0	5.0	9.0	16.3	12.0	6.6	6.3	7.8	5.8	10.0
Cassava	42.3	21.7	3.0	–	20.8	14.7	47.3	36.4	44.5	37.2
Other	12.7	14.1	11.0	3.0	4.2	6.9	0.9	7.8	7.6	15.1

[a]u.a./metric ton.

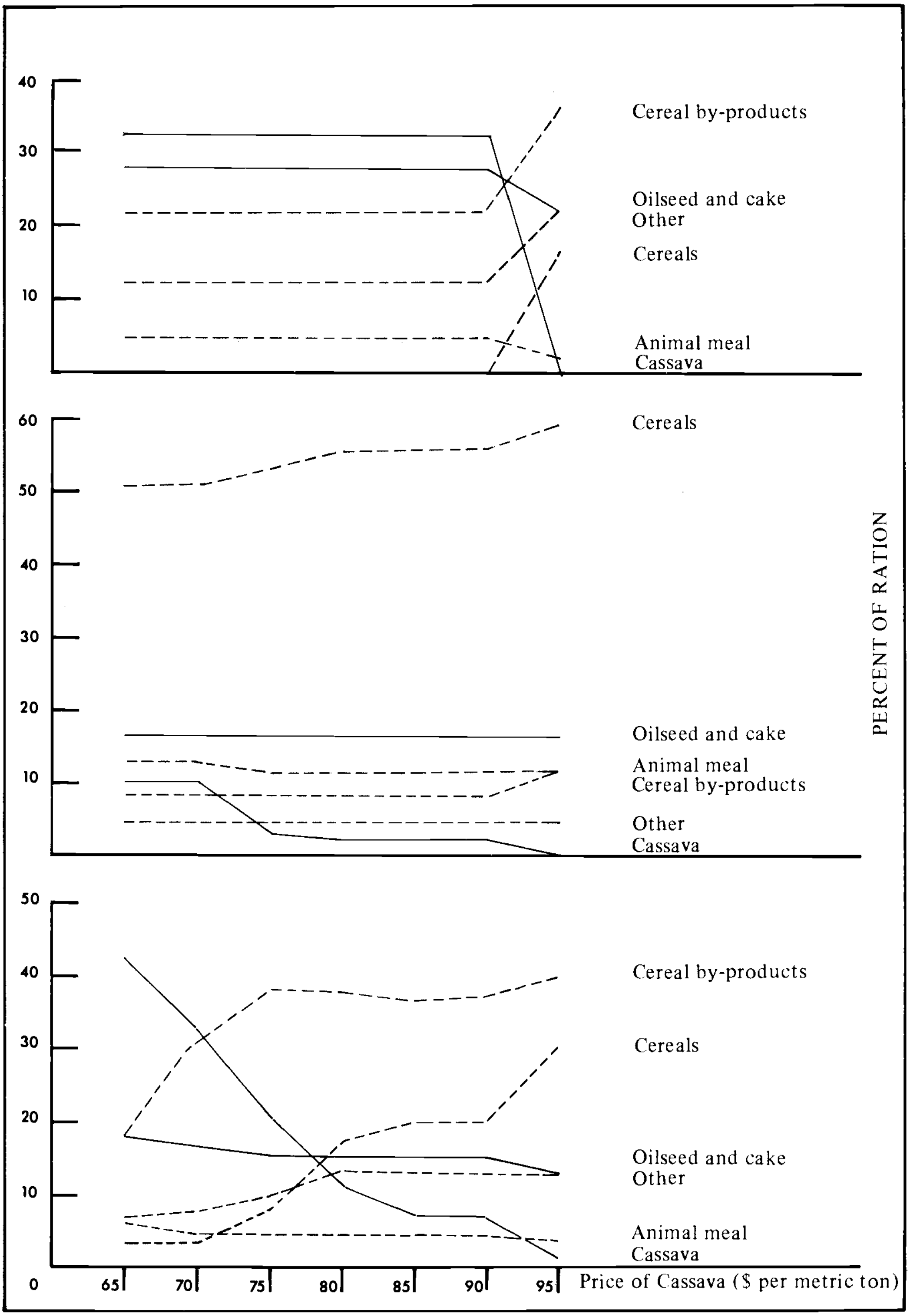

FIG. 7. Composition of compound cattle (*top*), poultry (*centre*), and pig (*bottom*) feed in France.

TABLE 36. Projected demand for cassava in France, 1980 (*'000 metric tons*).

	Low		High[b]
	L_1[a]	L[b]	
Cow	0	425	1275
Poultry	0	126	126
Pigs	157	557	557
Total:	157	1108	1958

[a]Cassava price assumed to be $95/metric ton.
[b]Cassava price assumed to be $90/metric ton.

TABLE 38. Projected demand for cassava in Italy, 1980 (*'000 metric tons*).

	Low		High[b]
	L_1[a]	L[b]	
Cow	0	220	220
Poultry	0	227	227
Pig	117	130	130
Total:	117	577	577

[a]Cassava price assumed to be $95/metric ton.
[b]Cassava price assumed to be $90/metric ton.

ready noted between cassava, cereal by-products, cereal, and oilseed and cake are again discernible for France (Fig. 7).

Employing the assumptions of fixed price relativities, and constrained and unconstrained cassava content, the 1980 demand for cassava is projected to be 1 108 000 to 1 958 000 metric tons. If cassava price is assumed to be $95 rather than $90/metric ton, the projected demand decreases to 157 000 metric tons. This estimate in the final analysis will be used as the low projection of demand (Table 36).

Italy

Italy has not employed large quantities of cassava in the past because of her limited use of compound feeds and low maize prices (resulting from a preferential CAP policy). Esselmann projects a 129% increase in Italian compound feed consumption by 1980 (approximately equal to the French rate), with growth mainly resulting from a major expansion of poultry production.

Estimated Italian least-cost feed rations resemble those of France (Table 37), although cassava content in poultry rations is higher in Italy. For all feed, as cassava price rises, its content decreases (Fig. 8), with cassava not being utilized when its price reaches the $95/metric ton level.

The projections contained in Table 24 combined with values derived from Fig. 8, given the assumptions of fixed price relativities, and constrained and unconstrained cassava content, result in a 1980 demand (Table 38) of between 117 000 metric tons (cassava price, $95/metric ton) and 577 000 metric tons (cassava price, $90/metric ton).

United Kingdom

United Kingdom entry into the EEC will undoubtedly induce many changes in British agriculture. Numerous predictions for British agriculture exist but in almost all instances there is no precedent upon which to base projections of future events. The evaluation of compound feed

TABLE 37. Composition of animal feed in Italy (%).

Type of feed	Cow standard	Beef and calf	Layer medium	Poultry grower	Broiler	Broiler finisher	Pig starter	Pig 0–30 kg	Pig 30–100 kg	Sow
Cost[a]	(67.38)	(71.93)	(80.84)	(104.68)	(87.85)	(80.86)	(75.66)	(75.24)	(73.68)	(71.43)
Cereals	–	–	55.0	45.7	32.8	15.5	–	10.0	10.0	–
Cereal by-products	13.4	17.3	8.0	8.0	3.0	8.0	20.0	10.0	10.0	10.0
Oil cake and seed	24.7	36.6	10.8	3.1	17.3	15.4	25.3	23.3	21.8	13.8
Animal meal	4.5	5.0	9.0	20.0	13.7	10.4	6.3	7.6	5.8	10.4
Cassava	43.2	24.1	9.0	20.0	29.1	44.5	47.3	40.8	44.5	49.6
Other	14.0	16.8	8.0	3.0	3.6	5.8	0.9	8.0	7.6	16.0

[a]u.a./metric ton.

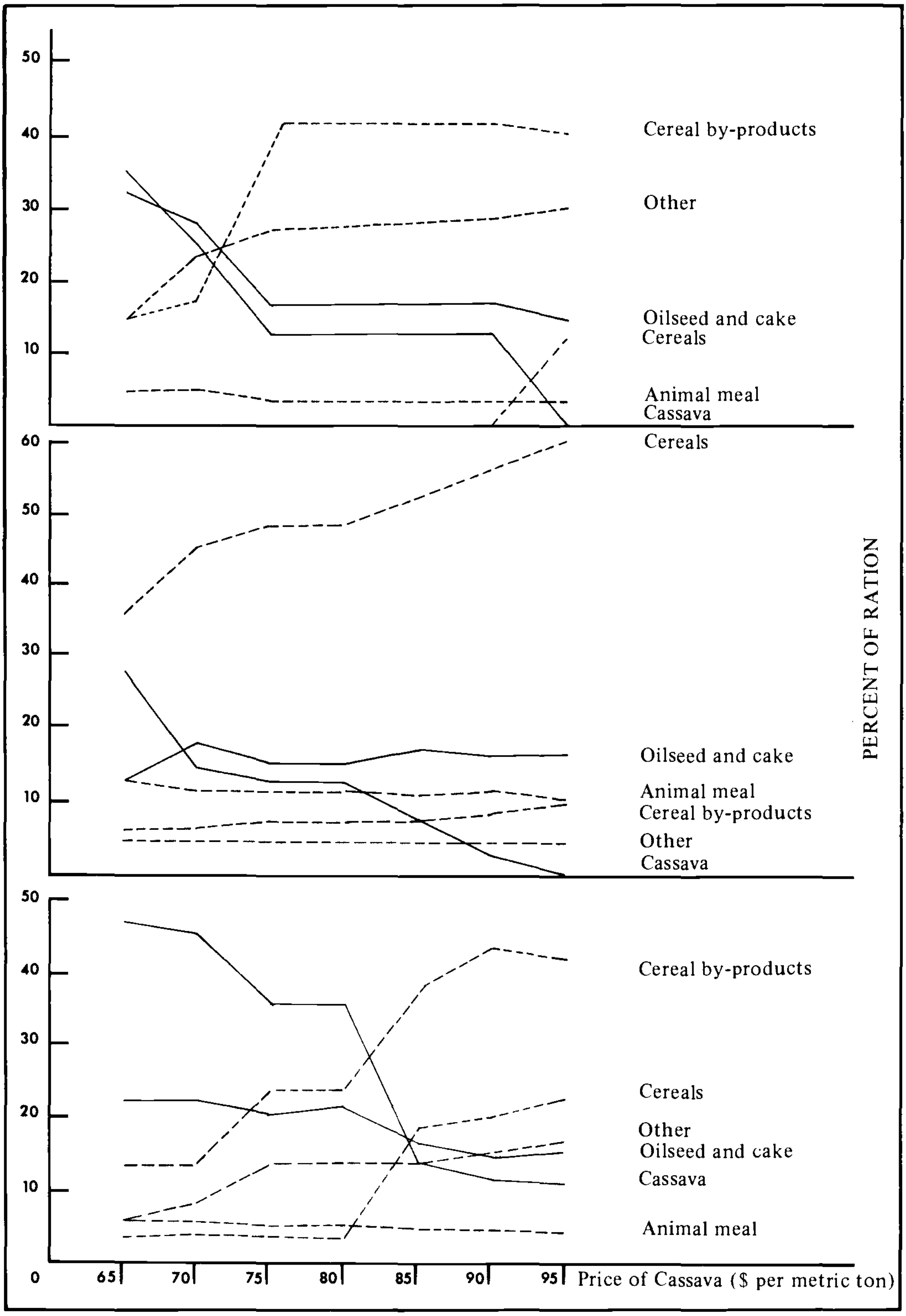

FIG. 8. Composition of compound cattle (*top*), poultry (*centre*), and pig (*bottom*) feed in Italy.

rations avoids much of this problem because it is based on the clearly defined concept of minimizing costs of mixed feeds. The estimation of future demand for livestock products and compound feeds is more difficult, since expected price changes are outside past observations. Thus the conclusions of this section must be qualified by the possibility that the future may differ substantially from what best available information now suggests.

A priori, one would expect that compound feed consumption per livestock unit will not increase greatly in the 1970s, owing to already existing high rates of consumption. Estimates show that mixed feed consumption (Sturgess and Reeves 1972, Chap. 8) is more important in the United Kingdom than in the EEC as a whole, and that consumption of compound dairy rations is greater than in any EEC country. However, it is expected that a proportion of compound dairy feeds consumed will be replaced by bulk feeds once CAP becomes effective in the United Kingdom. Nevertheless, growth in demand for compound feeds will be primarily determined by expansion of livestock numbers. Hence, the greatest increase in consumption of compound feeds is expected to occur for pig feed, while consumption of compound dairy rations is expected to decrease. Two sets of projections of compound feed utilization are available (Ferris et al. 1971, Sturgess and Reeves 1972). Ferris et al. project that by 1980 cattle utilization of compound feeds will decrease by 7%; pig utilization will increase by 119 to 124%; and poultry utilization by 108%.[50] Extrapolation of Sturgess' and Reeves' 1977–78 projections of concentrate consumption of 1980–81[51] suggests that cattle utilization will decrease by 10%; pig utilization will increase by 134%; and poultry utilization will increase by 109%, over the 1969–70 feeding rates.

Both sets of projections are based on farm-mixed and commercially-mixed compound feeds, with the latter accounting for approximately 55%. Sturgess and Reeves assume that compounder: farmer mixer rations will not change, and argue that "farm mixers who grow their own cereals will generally not use energy sources other than cereals" (1972, p. 9.2). Thus, for the purposes of this study, it is assumed that only feeds compounded commercially will use cassava. This assumption probably understates the potential market for cassava, because much farm-mixed poultry feed is done on a sufficiently large scale to warrant the use of cheaper, unconventional feed ingredients. Nevertheless, since the use of cassava is untried in the United Kingdom it seems best to rely on conservative estimates of future demand.

TABLE 39. Projected use of commercially compounded feeds in the United Kingdom, 1980 (*'000 metric tons*).

Type of feed	1969–70	1980–81	Index (1969–70 = 100)
Dairy	3383	2 533	75
Beef	500	500	100
Pig	2360	3 171	134
Layer	2635	2 712	103
Poultry	1010	1 253	124
Total:	9888	10 169	103

Source: I. M. Sturgess and R. Reeves, The Potential Market for British Cereals, Agricultural Adjustment Unit, University of Newcastle, Newcastle upon Tyne, 1972.

Ferris' et al., and Sturgess' and Reeves' projections were therefore deflated to provide estimates of commercially-compounded feeds. The deflators used were for dairy feed (68%), beef feed (23%), pig feed (49%), poultry feed (61%), and layer feed (61%). By this procedure it was estimated that the demand for commercial compound feeds will increase by approximately 103% by 1980 (Table 39).

Evaluation of least-cost feed rations necessitated estimating feed ingredient prices once CAP is fully effective. Price predictions made by Sturgess and Reeves (1972) and Campbell (1972) were combined and used in the objective function of the least-cost matrix. Ration constraints were based on information provided in the two studies.[52]

The rations considered for the United Kingdom differ slightly from those used in the analysis of

[50]The calculations are based on Ferris' Case 3, that the United Kingdom joins the EEC in 1972 and has a 5-year transition period; and Case 4, as Case 2 plus annual growth rate of 3.4% and annual inflation rate of 5%. (1971, p. 35)

[51]Projected 1972–73 to 1977–78 changes were converted to compound rates which were then used to project 1980–81 values.

[52]Ian Sturgess kindly provided me with additional information and details regarding the United Kingdom compound animal feed market.

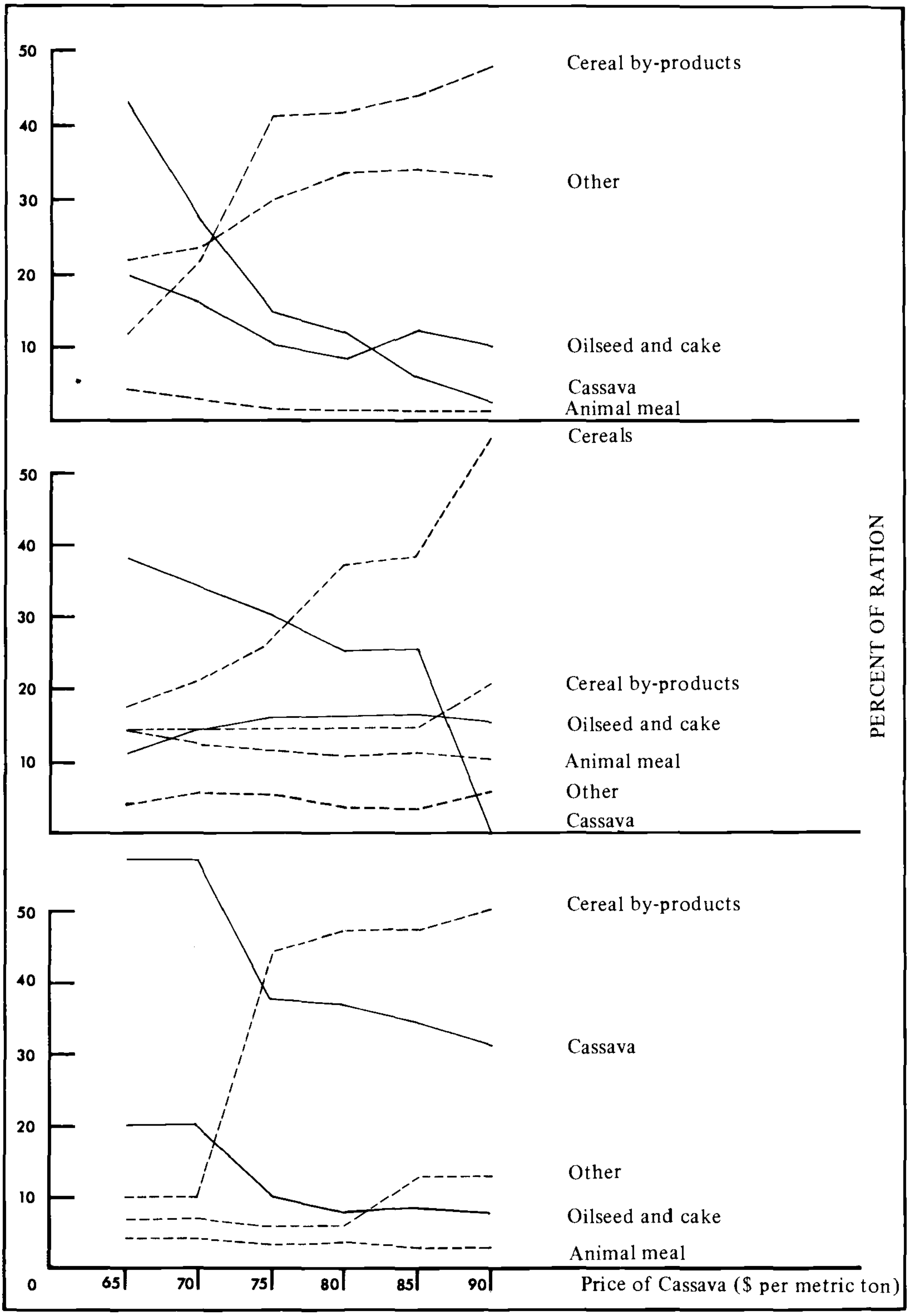

FIG. 9. Composition of compound cattle (*top*), poultry (*centre*), and pig (*bottom*) feed in the United Kingdom.

TABLE 40. Projected composition of animal feed in the United Kingdom (%).

Type of feed	Dairy 3.5 gallons	Dairy 4.0 gallons	Beef fattening	Grazing cake	Layer medium	Poultry grower	Broiler rearing	Broiler Finishing	Pig growing	Pig fattening
Cost[a]	(77.84)	(71.83)	(69.90)	(67.91)	(82.95)	(79.15)	(107.86)	(104.91)	(74.07)	(71.16)
Cereals	–	–	–	–	–	–	40.3	35.6	–	–
Cereal by-products	15.0	10.0	12.7	10.5	15.0	15.0	12.5	12.5	10.0	10.0
Oil cake and meal	30.3	23.6	12.5	13.5	10.5	12.5	14.6	10.3	24.0	16.7
Animal meal	5.0	5.0	5.0	5.0	13.0	12.2	16.3	16.5	6.0	5.5
Cassava	40.0	47.5	42.2	40.6	54.1	59.7	12.4	21.3	53.9	57.7
Other	10.0	13.9	27.6	20.4	7.4	0.6	3.9	3.8	6.1	10.1

[a]u.a./metric ton.

the original six and reflect conditions peculiar to the United Kingdom. The greatest difference is that dairy rations are more varied than those previously evaluated, expressing a higher dependency on dairy rations in the United Kingdom than in the rest of the EEC. Pig and poultry rations resemble those of the EEC.

The evaluation of the least-cost rations suggests, not surprisingly, that cereal content in compound feeds, given EEC prices, will be low and that cassava content will be high (Table 40). The results indicate that no cereals will be consumed in cattle feeds, and that cassava will constitute more than 40% of this ration. Broiler feeds, on the other hand, will contain more than 35% cereals, while pig rations indicate cassava content above 50%.

Long run cassava price changes induce the same general effects (Fig. 9) as in the original six. The previously indicated complementarity between cassava, and oilseed and cake in cattle rations is not clearly demonstrated. The results indicate that cassava will not be used in cattle or dairy rations if cassava price is greater than $90/metric ton, while cassava content in pig feeds is predicted to be greater than 25% at this price.

TABLE 41. Projected demand for cassava[a] in the United Kingdom, 1980 (*'000 metric tons*).

	Low	High
Cows	91	91
Poultry	0	0
Pigs	381	856
Total:	472	947

[a]Cassava price assumed to be $90/metric ton.

Least-cost feed rations are again combined with projected consumption of commercially-produced compound feeds (Table 39) to derive estimates of the demand for cassava in 1980 (Table 41). It is assumed that predicted 1980 prices or price relativities prevail; that cassava is utilized within the constrained and unconstrained levels (with a technical maximum of 50%); and that port and country compounders use equal amounts of cassava.[53] This latter assumption is not held to be accurate by all British compounders. Nevertheless, Campbell (1972) found that cassava will be used to its constraint level by both country and port compounders.

The projected demand for cassava indicates that the United Kingdom could, by 1980, rank as high as third in terms of cassava utilization. Utilization, however, is expected to be near the smaller estimate since it will require time for compounders to become confident in the applicability of cassava.

United Kingdom transition period and the demand for cassava: It is obvious that projected demand for cassava will develop differently for the United Kingdom than for the original six, because price

[53]Differences in consumption patterns between country and port compounders could be important since it is anticipated that < 50% of compounding will occur in future at country locations. This inland shift of compounding was mentioned by commercial feed manufacturers, and Simon Harris of the Economics Division of the United Kingdom Ministry of Agriculture, Fisheries and Food, 1972. Sturgess and Reeves (1972, p. 3–15) show that port compounding dropped to 52.6% of total by 1969–70.

changes in the United Kingdom will be greater than those in the other countries. Thus, feed rations were evaluated for a set of transition prices for the years 1973, 1974, 1975, 1976, 1977 and 1978. The prices (Appendix Table E.4) were derived from a study conducted by Ellis (1972). The estimated rations[54] (Table 42) suggest not only that cassava could be used as early as 1974 in cow and pig feeds, but at levels in excess of current maximums in pig feeds. It is predicted that cassava utilization in poultry rations will begin in 1975.

The results presented in Table 42 clearly show the expected pattern of change in United Kingdom compound feeds: cereal content of compound feeds will decrease, perhaps to disappear in cattle feeds after 1975; cassava, and oilseed and cake content will increase; other ingredients will generally increase; and the cost of compound feeds will increase by 113 to 124% by 1978.

[54]Note that the average rations presented in Table 42 and Fig. 9 differ slightly owing to the fact that Ellis' transition prices had slightly different relativities than those used in the original linear programming matrix.

Denmark

The consumption of compound feeds in Denmark is less than that of the United Kingdom, Netherlands, Germany, Belgium, France and perhaps Italy. Danish compound feeding rates are relatively high, however, with dependency in pig meat production being greater than in any of the previously analyzed countries. As a result of these relatively high consumption rates, future demand for compound feeds will depend primarily on future livestock numbers, except in dairy feeds where a substantial increase in use of compound feeds is predicted (Ferris et al. 1971, p. 15). It is assumed that between 1967 and 1980 consumption of compound feed for cows will increase by 53%; for pigs by 56%; and for poultry by 4%. It is calculated therefore, that total 1980 consumption of compound feeds will be 7 907 000

TABLE 42. Average composition of animal feed rations during United Kingdom transition period, 1973–78.

Type of ration	1973	1974	1975	1976	1977	1978
Cattle						
Cost[a]	67.15	70.97	72.71	73.73	74.83	76.28
Cereal	55.9	29.7	–	–	–	–
Cereal by-products	16.7	32.3	30.0	30.0	19.3	7.5
Oilseed and cake	7.3	9.3	16.3	15.7	20.0	22.4
Animal meal	3.2	2.4	2.9	2.6	2.9	4.5
Cassava	–	5.7	26.9	26.2	35.9	43.3
Other	16.9	20.5	23.9	25.5	21.9	22.3
Poultry						
Cost[a]	82.80	86.53	90.34	94.65	96.94	102.71
Cereal	68.9	64.5	49.6	43.9	37.5	18.0
Cereal by-products	5.2	8.7	8.7	8.7	11.3	11.2
Oilseed and cake	13.9	13.7	15.8	21.3	22.7	23.5
Animal meal	9.5	9.1	9.7	7.8	7.5	9.7
Cassava	–	–	13.4	14.0	16.3	32.6
Other	2.5	3.9	2.8	4.3	4.7	5.0
Pig						
Cost[a]	68.16	72.62	75.15	77.55	79.73	82.48
Cereal	69.7	42.7	18.2	16.3	13.1	4.6
Cereal by-products	15.4	21.9	30.0	30.0	22.5	30.3
Oilseed and cake	7.1	8.0	12.4	12.1	15.0	15.7
Animal meal	5.1	5.3	4.7	4.6	4.3	5.2
Cassava	–	20.6	30.9	30.9	36.3	37.4
Other	2.5	1.5	3.8	6.1	8.8	6.8

[a]u.a./metric ton.

metric tons, of which 33% of cattle feed, 88% of pig feed, and 79% of poultry feed are assumed to be commercially mixed.[55]

As in the previous case, only commercially-compounded feed is assumed to use cassava. Thus the amount of feed which will utilize cassava is estimated to be (in '000 metric tons):

Cattle feed	753
Poultry feed	437
Pig feed	4461
Total	5651

Because similar levels of technology prevail in Denmark and the United Kingdom, the least-cost rations derived for the latter country are applied to the Danish situation. Combining the feed rations derived from Fig. 9 with the above estimates of Danish compound feeds which could utilize cassava, produces the predictions of Danish demand for cassava in 1980 (Table 43).

TABLE 43. Projected demand for cassava[a] in Denmark, 1980 (*'000 metric tons*).

	Low	High
Cows	23	23
Poultry	0	0
Pigs	535	1204
Total:	558	1227

[a]Cassava price assumed to be $90/metric ton.

Summary of Projected Demand for Cassava in the EEC

The analyses of compound feed utilization in the EEC reveal that the 1980 demand for cassava may be from 246 to 634% greater than the 1970 demand. In order of importance the maximum consumption levels are (in '000 metric tons):

	Low	*High*
Netherlands	1020	2380
France	157	1950
Denmark	558	1227
Germany	677	1161
United Kingdom	472	947
Belgium	472	725
Italy	117	577
Total	3473	8967

[55]These are 1971 percentages (International Trade Centre 1972, p. 79) which, lacking information to the contrary, are assumed to apply in the future.

The accuracy of these projections depends on the reliability of:

- projected 1980 consumption of compound feeds;[56]
- percentage of compound feeds utilizing cassava;
- price relativities among ingredients;
- least-cost feed rations as a reflection of the types of feed formulas which will be consumed.

Of these assumptions the price relativity assumption is the most crucial. Two points must be considered in this regard. First, regional prices will undoubtedly differ from national averages. Whether these differences will be sufficient to alter formulation dramatically is difficult to predict. It was illustrated in Fig. 4–9 that in many instances cassava content would exceed existing maximums for a wide range of prices, thereby suggesting that, for minimum projections at least, regional price differences will not result in marked changes in feed formulas.

Second, the EEC could alter agricultural policies in such a way as to adversely affect cassava imports. Three specific policies which could produce such an effect are: (1) decrease of cereal prices; (2) introduction of variable levies on cassava; and (3) introduction of variable levies on oilseed and cake.

The first option, often discredited by North Americans, has been shown to be possible (Josling 1973). The second option, while possible, seems unlikely because: (a) the EEC has committed itself to assisting LDCs, and the importation of cassava is an obvious means of fulfilling this commitment; and (b) imported cassava enables commercial compounders to keep feed prices low, thereby holding down livestock production costs[57] (in the extreme, the removal of cassava from feed rations would increase Dutch feed costs by more than

[56]These projections depend in turn upon 1980 projections of demand for livestock products, production of livestock, and feeding rates of compound feeds.

[57]On the other hand, if cheap manufactured single cell protein becomes available, a levy on vegetable protein would have no effect on cost of compound feeds. It has been suggested that single cell protein will not be economically attractive before 1980 (International Trade Centre 1972). There are, however, two single cell protein plants now in operation in Italy, with a capacity in excess of 100 000 tons, and BP in France has a history of working with petro-protein.

Projections indicate that the EEC demand for cassava in 1980 may be 246–634% higher than the 1970 demand.

$10/metric ton in broiler finisher feeds). Finally, the third option, introduction of a variable levy on oilseed and cake, although again possible, is not desirable because it would increase the cost of compound feeds. Furthermore, the major exporter of oil cake and meal, the United States, would certainly contest any policy which adversely affects the market for oil cake and meal. However, the events of 1972 and 1973 illustrate that the price of protein feeds can increase dramatically without the introduction of new policies. The effects which such changes may have upon the demand for cassava are examined in the section *Other Aspects* in this chapter.

Such changes, should they occur, are not expected to be announced before the end of the forthcoming trade liberalization talks in Geneva in 1975. In any case, full implementation of policy changes would require several years, thereby affecting demand for cassava only in the latter years of the 1970s.

Thus, the tentative conclusion is that demand for cassava will be relatively secure until 1980. The post-1980 demand for cassava is less definite. Quite possibly the CAP of the 1980s will differ substantially from the present CAP. Furthermore, new sources of protein, and perhaps energy, could affect the ingredients used in compound feeds.

Exporters can look forward to a growing demand for cassava if it can be supplied in sufficient quantity, required quality, and correct price. One expects that quality requirements will become stricter and more rigidly enforced. The important standards will be:

moisture: < 13 or 14%
starch content: > 70 or 75%
fibre content: < 5%
foreign material (vegetable and mineral): < 3%.

The cif price of cassava over the past few years has varied from approximately $65/metric ton to $78/metric ton. For the purposes of this study, end-user prices of $90 to $95/metric ton have been assumed. This is the price range which the exporter must meet. Thus, the implication for exporting countries is that production and processing cost must be in the range of $16 to $22/metric ton of fresh roots (Table 44) (on the basis of a 2.5–3:1 conversion ratio of roots to ton of chips or pellets).

TABLE 44. Estimates of cost targets for cassava exports.

Cost item	Low	High
Pellets to end-user	90.00	95.00
Pellets cif Rotterdam[a]	70.00	75.00
Transportation cost[b]	20.00	20.00
Technical coefficient roots to pellets[c]	3:1	2.5:1
Cost for processing and roots	16.67	22.00

[a]Shipping costs from Rotterdam assumed to be in the order of $20/ton.
[b]An average of Thai charter and conference shipping rates.
[c]The first technical coefficient is an estimate of the Brazilian average; the second is an estimate of the Thai average.

In the future, a major proportion of cassava trade will be in the form of pellets because of ease of handling[58] and lower transportation costs. Quality of pellets will be subject to constant testing for two specific reasons:

1 To insure that pellets do not contain cassava waste (if so, pellets must then be imported under Brussels Tariff Nomenclature 11.06, which is subject to an 11% duty); and
2 To insure that foreign material content is not above 3%.

The exporter and potential exporter must bear these multiple factors in mind when evaluating the potential of the market with reference to his particular operation. If the exporter anticipates that quantity, quality, and price requirements can be met, he may ship to Europe with some assurance that the market of the 1970s will require the product, since demand is expected to experience accelerated growth after 1975 when the United Kingdom and Denmark become consumers of

[58]Compounders will undoubtedly require better physical quality of pellets. Empirical observation indicates that the breakdown of some pellet shipments is undesirably high, such that the delivered shipment constitutes a high proportion of flour and dust and a low proportion of pellets. It was suggested that some German compounders continue to use chips because they are not so dusty. Many Dutch compounders, however, do not have this option because their equipment is not suited to handling chips.

cassava. However, the exporter who cannot supply Europe before the late 1970s or early 1980s would, at that point in time, be entering a very uncertain market.

Other Aspects

The preceding analyses have not attempted to assess the demand effects of changing high protein feed prices or changing the quality of cassava. A brief examination of these effects follows. First, the prices of all high protein ingredients (those feeds with more than 22% protein) are increased by 10% increments, with a new feed ration being evaluated for each increment. Second, the consequences of altering cassava quality are examined—specifically, the effects of altering protein, starch, and metabolizable energy content. Again the procedure is analogous to that of changing price, namely a particular quality attribute is altered by a finite amount and the least-cost formula is re-estimated. The procedure is iterated until the desired number of alternatives have been accounted for. Because of the similarities of the country-by-country results, both analyses are conducted only for Dutch rations. It is assumed that the findings are generally applicable to all EEC countries.

Changing Protein Price The sudden shortage of Peruvian fish meal in 1972 and subsequent increases of soybean product prices suggest the possibility of the price of protein feeds being consistently higher than in the past. Because cassava and protein feeds have been shown to be complementary, an increase in the price of protein feeds is expected to decrease the demand for cassava. This hypothesis is confirmed by the analysis. The calculation involves the estimation of least-cost feed rations with high protein feed[59] prices simultaneously increased by as much as 60% and with cassava prices at $65/metric ton, and $90/metric ton.

The results (Fig. 10–11) with both levels of cassava price again illustrate the complementary relationship which exists between cassava and protein feeds. Furthermore, the results indicate that higher-priced cassava is more sensitive to changing protein prices than lower-priced cassava. In fact, for cow feeds cassava disappears from the ration if all protein prices increase by more than 20%; for poultry rations the quantity of cassava used is approximately 1% when protein prices are increased by 60%. However, in pig feeds the content of cassava is relatively stable and always greater than 22.5% of the ration.

If, however, cassava is available at $65/metric ton then the content of cassava in feed rations may remain fairly high, even with all protein prices increased by 60%. These new results are used to derive estimates of Dutch demand for cassava given a 60% increase in protein prices (in '000 metric tons):

	Low ($90/metric ton)	*High* ($65/metric ton)
Cows	0	459
Poultry	21	556
Pigs	1026	1322
Total	1047	2337

Both the high and low projection exceed the minimum projection presented in Table 30 indicating that the arbitrary limits to cassava utilization are the most severe constraints. A comparison of the above figures with the projections contained in Table 30 suggest that a combination of high cassava and protein prices could markedly reduce the demand for cassava (cassava demand is expressed in '000 metric tons):

	Protein feed prices increased by	
	0%	60%
$65/metric ton	3480	2337
$90/metric ton	2380	1047

With cassava at $90/metric ton and original protein feed prices, projected demand for cassava is as great as 2 380 000 metric tons, but with protein prices increased by 60% the projection reduces to 1 047 000 metric tons. Conversely, with protein prices raised by 60% and cassava prices dropped by 28% to $65/metric ton the projected demand is 2 337 000 metric tons. Thus cassava exporters, even faced with substantial increases in protein feed prices, can greatly influence the demand for their product if they can reduce or at least maintain the cost of their product.

Changing Cassava Quality The market for cassava may also be bolstered by improving the

[59]The ingredients considered to have a high protein content are linseed, soybeans, maize gluten, cottonseed meal, linseed expellor, groundnut, fish meal, meat and bone meal, rapeseed meal, soybean meal (44%), and sunflower meal (>42%).

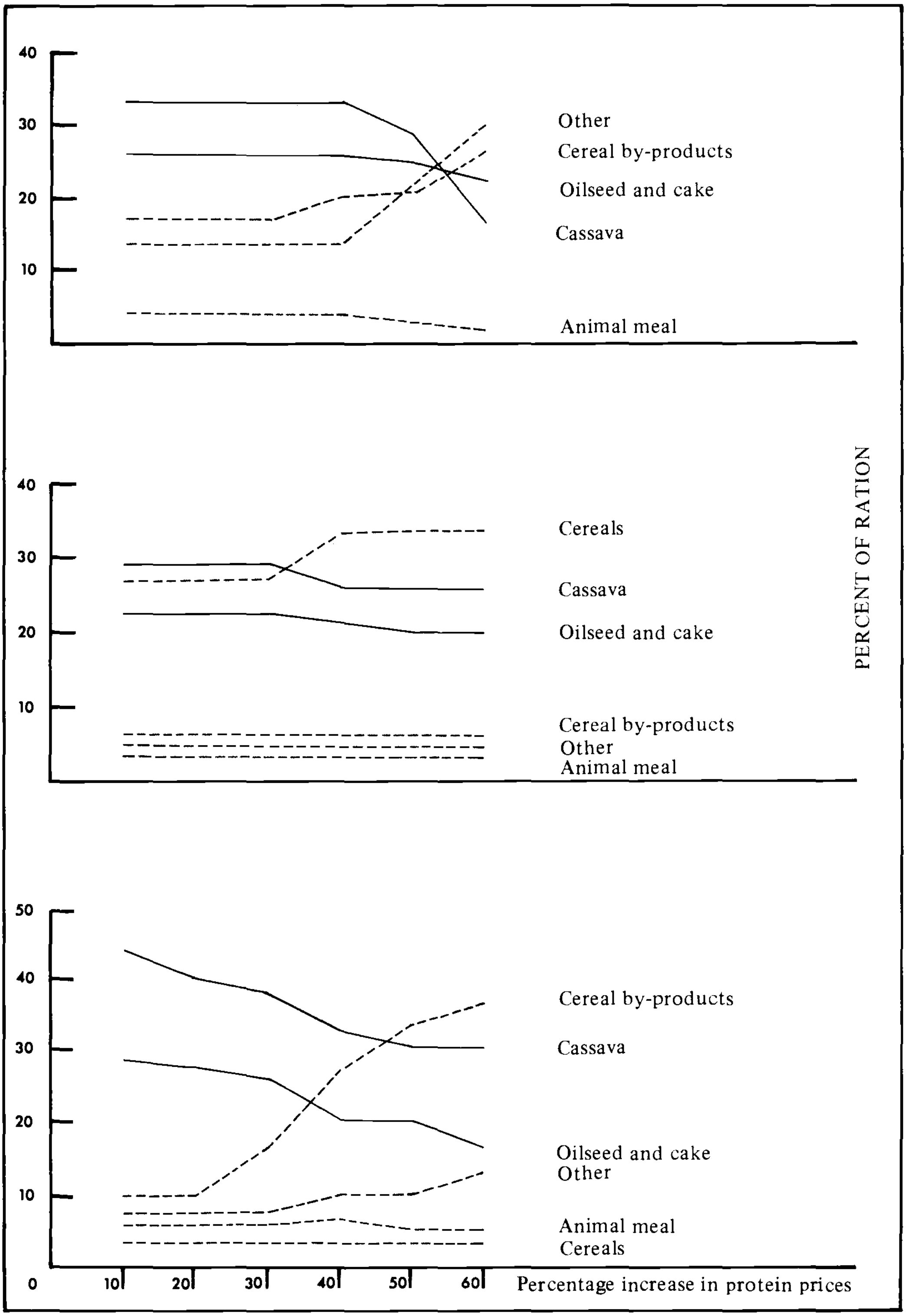

FIG. 10. Composition of cattle (*top*), poultry (*centre*), and pig (*bottom*) feed in the Netherlands given differing high protein feed prices (cassava price = $65/metric ton).

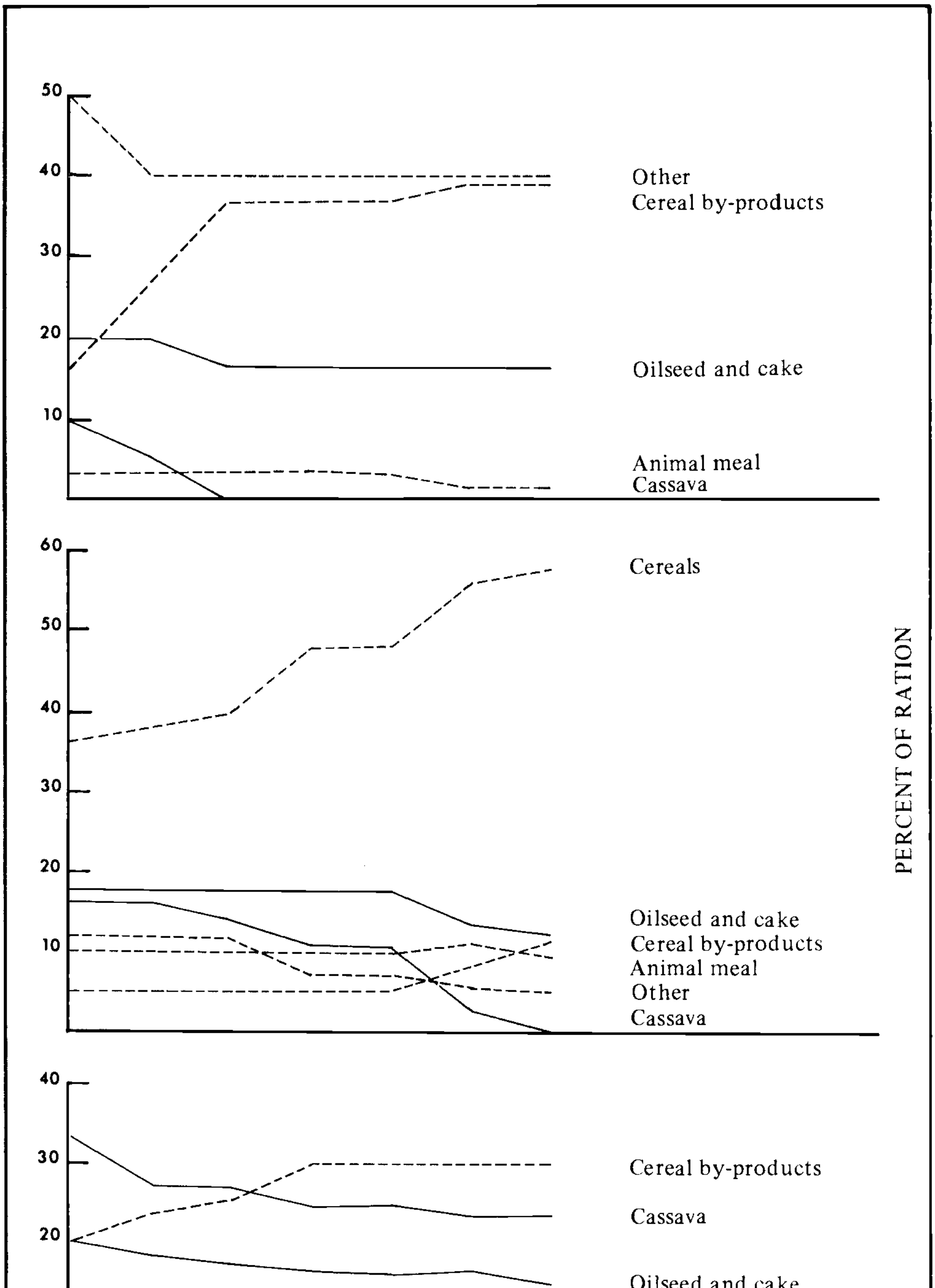

FIG. 11. Composition of cattle (*top*), poultry (*centre*), and pig (*bottom*) feed in the Netherlands given differing high protein feed prices (cassava price = $90/metric ton).

quality of cassava exported. A first step in this direction is the adoption of more rigorous quality control procedures. A second and more difficult step would be the improvement of the genetic quality such as protein, starch, and metabolizable energy content. The effects of such changes are briefly discussed in the following paragraphs.

The first quality factor to be altered was cassava crude protein content, which was changed from 2.2 to 6.2%. Changes within this range were found to have little impact on the composition of feed rations in general, or on the content of cassava specifically. However, one interesting result was that all pig feeds, except sow feeds, increased in cost. The reason for this result is that pig feeds have a maximum protein limit which is invoked as cassava's protein content is increased. Theoretically, this is a more constrained, cost-minimizing problem, and as such, produces a more costly feed than the less-constrained original problem. Practically, the active upper limit on protein causes cassava protein, and oilseed and cake protein to compete rather than capitalizing on the complementarity between oilseed and cake protein, and cassava energy. This additional competition is expensive, as indicated by the increased cost of the pig feed rations. The greatest increase in cost is $1.61/metric ton for 0–30 kg pig feeds. Accompanying this cost change is an increase of cereal by-product content by 17 to 28%, a decrease of oilseed and cake from 24 to 19% and a decrease of cassava from 33 to 27%.

For cow and poultry feeds, for which no maximum protein limit is invoked, there is little change in feed formulas. Therefore, with the exception of pig feeds, it appears that changing the amount of crude protein in cassava has little effect and that what results do occur are not necessarily desirable from the point of view of exporters, who could lose earnings.

Altering energy content of cassava has more marked effects than protein changes. In the case of increased starch, total digestible nutrients (TDN), or metabolizable energy content, the utilization of cassava increases and the cost of compound animal feeds decreases. As metabolizable energy increased from 2910 calories/kg to 3310 calories/kg, cassava content increased from 17.9 to 28.2%,[60] cereal content decreased from 37.4 to 25.0%, and compound feed costs decreased by $3.88/metric ton. While increasing TDN increases the cassava content in pig rations it does so only marginally. This is because the original TDN constraint is easily met. Similar results are found for increases in starch equivalent and the demand for cassava in cow feeds.

It may be concluded that, in general, the improvement of cassava energy attributes could expand the demand for cassava. Furthermore, a cassava product with higher energy content will be more impervious to price changes. In fact, price of cassava could be raised if energy content were higher, without adversely affecting demand for cassava.

Although it is possible that the suggested quality alterations may be wrought by improvements of processing, it is likely that such alterations will depend largely on varietal selection. The possibility of genetically improving starch, metabolizable energy, and total digestible nutrient content should be evaluated by CIAT. Additionally, attention must be paid to emerging LDC compound feed industries, which, unlike their EEC counterparts, may desire higher protein content cassava. For domestic purposes, it may be more economical to fortify cassava than to improve its protein content genetically.

In summary, the indications are that growth in demand for cassava can be affected by changes of its price and/or quality or by changes of protein feed prices. The astute cassava exporting nation may influence favourably the demand for its product by controlling price and quality. Conversely, a country may lose its market if quality or price are unattractive.

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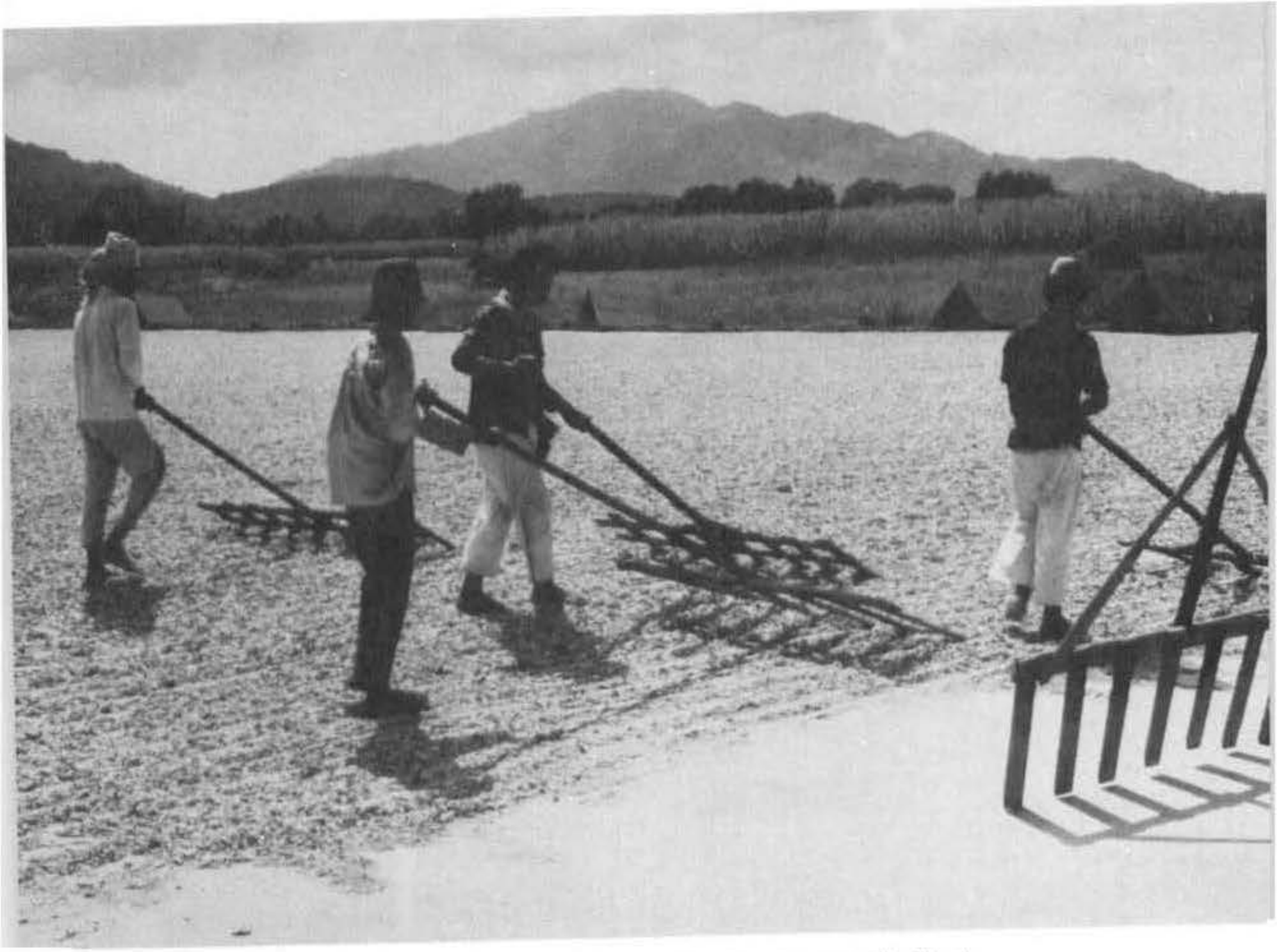
[60]The increase of cassava energy content strengthens the complementary relationship between cassava, and oilseed and cake.



The business of preparing cassava for export has grown rapidly. Simple one-man drying operations have given way to multi-person operations using concrete drying floors.

Chapter 5. Reconciliation

I would willingly say that forecasting would be an absurd enterprise were it not inevitable. We have to make wagers about the future; we have no choice in the matter.

BERTRAND DE JOUVENEL

The three preceding chapters have presented the results of the analyses of potential 1980 demand for and supply of cassava. The projections of supply and demand are now compared in order to derive indicators of possible imbalances which might be expected if production trends continue. Because demand data are more accurate and readily available than production data, it is presumed that demand projections are more reliable than supply projections, and focus is therefore on the former. The approach of reconciliation is to derive from 1980 demand estimates a measure of required supply. The latter is then compared with extrapolated supply trends to determine if supply will match apparent demand.

The markets for cassava, ranked in terms of their ability to capture supply, are: human food market (the obvious exception being the export market for Thailand); other domestic markets; and export markets. Given this ranking, it is assumed that if supply of cassava is insufficient to meet domestic demand, export markets will be the first to suffer. Bearing this in mind, the projections of total demand for and supply of cassava are considered.

1980 Demand for Cassava

The demand projections for cassava as a human food (Chapter 2) must be altered for reconciliation purposes, owing to the inconsistency of FAO and Brazilian figures. FAO estimates of 1980 Brazilian human demand are less than the 1970 consumption level, despite the fact that there is little indication that total consumption of cassava in Brazil will decrease during the 1970s. The problem may be one of data and/or definition. FAO projections of 1980 Brazilian cassava demand may relate to the demand for processed cassava, primarily farinha de mandioca, while Brazilian statistics relate to demand for cassava in fresh root units. Or, it is possible that FAO projections may relate only to mandioca mansa. Because the extent to which either of these possibilities adequately explains the difference between the two sets of data could not be determined, it was considered necessary to estimate cassava consumption functions using the Brazilian data. Statistically, the best fitting function (equation 9) indicates that the demand elasticity (including both income and population effects) for cassava is 2.65 (at evaluated mean values).

$$D_{Bc} = -74.9 + \underset{(2.14)}{1785/Y_B} + \underset{(2.15)}{14\,Y_B} \quad R^2 = .87 \qquad \ldots (9)$$

where D_{Bc} = Brazilian demand for cassava;
Y_B = Brazilian income; terms in parentheses are t-values.

The projection of 1980 Brazilian demand, based on equation 9, is 13 990 000 metric tons. The FAO projection is 7 436 000 metric tons. Using the former estimate to assess Latin American and world human demand for cassava alters the original FAO projections to 17 393 000 and 78 054 000 metric tons, respectively.

Brazil is also reported to use substantial amounts of cassava in livestock feeding. Thus, an accurate assessment of domestic demand for cassava requires a prediction of 1980 cassava demand for animal feeding. FAO Food Balance Sheets for 1964–66 data (published in Rome 1971) indicate that 47% of Brazilian cassava production is so used. However, as is noted in Chapter 6, this figure could be an overstatement. For purposes of the study, therefore, it was decided that only 22% of production (the share of cassava production in Santa Catarina and Rio Grande do Sul utilizing cassava as an animal feed) would be used for animal feeds.[61] The resulting estimates of cassava utilization in animal feeding in Brazil are thus 8961 000 and 11 143 000 metric tons, depending upon which production projection is used (Appendix A). These figures, combined with the 1980 human demand estimates of Chapter 2, provide the following projections of 1980 cassava demand in producing countries (in '000 metric tons):

	Low	*High*
Latin America	26 353	29 036
Africa	34 727	35 444
Far East	21 154	21 318
World Total	82 234	85 798

Projected demands for industrial cassava starch, presented in Chapter 2, are given in final product terms. For the purpose of reconciliation, however, it is necessary to convert the projections to fresh root terms. The starch conversion coefficient is taken to be 1 ton of starch = 4.49 tons of roots.[62] The 1980 demand for industrial cassava starch in fresh root terms is thus (in '000 metric tons):

	Low	*High*
United States	184	1527
Canada	90	94
Japan	225	225
Total	499	1846

The projected demand for cassava as an animal feed (Chapter 3), converted to fresh root terms at a ratio of 1 ton of pellets to 2.5 tons of roots (the approximate conversion rate in Thailand), is (in '000 metric tons):

	Low	*High*
Netherlands	2550	5950
France	393	4875
Denmark	1395	3067
Germany	1692	2902
United Kingdom	1180	2367
Belgium-Luxembourg	1180	1813
Italy	292	1443
EEC Total	8682	22417

The total world demand for cassava in 1980 is projected to be between 91 415 000 and 110 060 000 metric tons, a 145–174% increase in demand for cassava.

The following section considers the question: if past trends persist, will supply of cassava in 1980 be sufficient to meet projected demand?

Reconciliation of Cassava Supply and Demand Projections

The 1980 regional supply of cassava, extrapolated from past trends, is predicted to be (in '000 metric tons):

	Low	*High*
Latin America	48 052	60 491
Africa	37 107	37 207
Far East	26 357	29 592
Total[63]	111 516	127 290

Comparison of 1980 supply and demand projections (Table 45) reveals:

- that the EEC market can account for as much as 20% of world demand for cassava;
- that human demand can account for 78–90% of world demand;
- that industrial starch demand will account for less than 1% of world demand for cassava;
- that supply of and human demand for cassava in Africa are nearly equal, with supply exceeding demand by less than 7%.
- that supply of cassava in Latin America and the Far East substantially exceeds human demand;
- that given high demand projections and low supply forecasts, the world markets for cassava would appear to be near equilibrium, supply exceeding demand by only 1%.

Reliability and Implications of Reconciliation

While the analyses of this study have attempted to estimate lower and upper limits for cassava demand and supply by 1980, the reasonableness of these limits must still be assessed.

[61]This measure must be taken as a proxy measure for future Brazilian animal feed demand for cassava because it will probably be demand rather than supply considerations which will determine 1980 animal consumption levels of cassava. According to the Food Balance Sheets most other tropical countries are not reported to use cassava as an animal feed. However, those countries which do, use small quantities relative to Brazil. Therefore, only adjustments to the estimate of domestic demand in Brazil are made.

[62]This is reported to be the root:starch conversion ratio during the hot season in Thailand. The average conversion ratio is 5.29, while the technologically feasible ratio is approximately 3.5 tons of roots to 1 ton of starch.

[63]Using aggregated world data, 1980 world supplies of cassava are estimated to be between 110 581 000 and 119 163 000 metric tons.

The 1980 projections of human demand for cassava imply an annual growth in world demand of 2–3%. Because this rate closely approximates population growth rate (the prime factor in determining the human demand for cassava), it is deduced that the rate of change conforms to a priori expectations. However, this does not imply that the magnitudes of the projections are necessarily correct. It was assumed that projected demand for cassava was in fresh root terms. If some projections relate to processed cassava, however, then the 1980 demand estimates are incorrect. For example, if in actual fact 10% of projected human demand relates to processed cassava, the 1980 figure will understate demand by approximately 15% (21 million metric tons). Such an error is great enough to alter the minimum difference reconciliation (Table 45) from a position of near equilibrium to one of insufficient supply.

The industrial starch demand projections imply an increase which is less than that experienced during the 1960s. It could be argued that the 1980 estimates are conservative. However, noneconomic factors, such as quality, new requirements, or political policies, could adversely affect the demand for cassava industrial starch. Countering this argument are the facts that cassava starch constitutes a relatively small proportion of starch consumed, providing little incentive to interfere with the market, and that Japanese demand for starch could grow very rapidly if internal price support policies were altered. Even so, it would appear that foreseeable changes in the demand for cassava starch will be small relative to total demand.

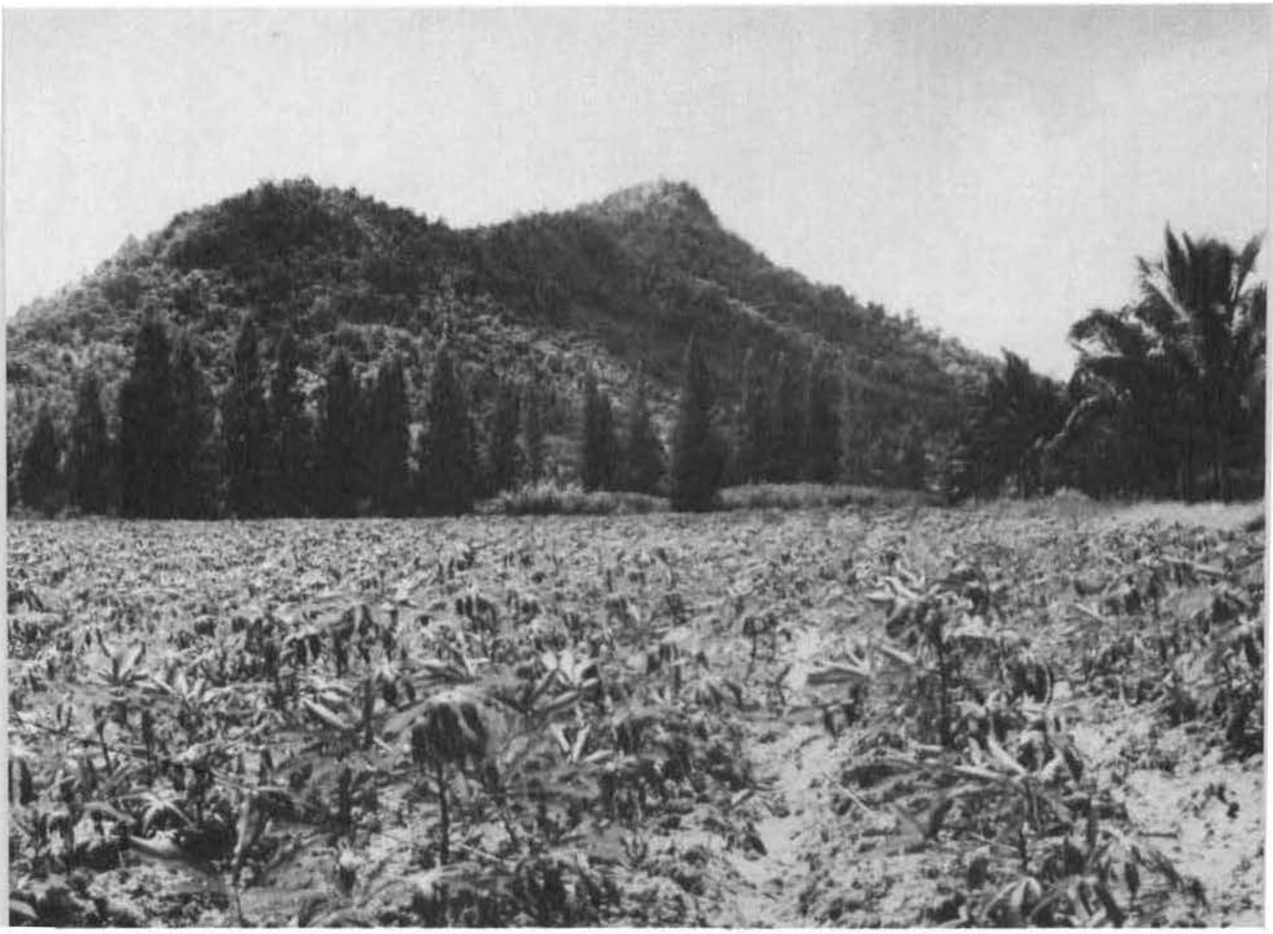
The 1980 projections of the European demand for cassava cover a wide range. The uncertainties associated with estimates of future prices, cassava limits in feeds, and spread of cassava utilization in the United Kingdom and Denmark, require that the projections of 1980 demand be diverse. The upper prediction is unlikely to be surpassed unless total demand for compound feeds increases more rapidly than this study assumes, but the lower prediction should be exceeded, barring drastic changes in CAP[64] and/or cost of cassava. It is therefore assumed that the deviations in the demand for cassava as an animal feed will occur within the range defined by the upper and lower estimates.

The supply estimates, which are again extrapolations of past trends, indicate future changes in the absence of new forces. If, however, changes of

[64]If policies are introduced which interfere with cassava imports, then the lower estimate may become zero very quickly.

TABLE 45. Reconciliation of total cassava supply and demand projections for 1980 (*'000 metric tons of fresh roots*).

	Demand	Supply	Difference between demand and supply
Minimum differences			
Latin America (human)	29 036	48 052	19 016
Africa (human)	35 444	37 107	1 663
Far East (human)	21 318	26 357	5 039
Europe (animal)	22 417	–	–22 417
North America (starch)	1 621	–	–1 621
Japan (starch)	225	–	–225
Total:	110 061	111 516	1 455
Maximum differences			
Latin America (human)	26 353	60 491	34 138
Africa (human)	34 727	37 207	2 480
Far East (human)	21 154	29 592	8 438
Europe (animal)	8 682	–	–8 682
North America (starch)	274	–	–274
Japan (starch)	225	–	–225
Total:	90 415	127 290	35 845



Large surpluses of cassava put Thailand in a good export position.

price, cost, policy, etc. occur, the trend projections will be incorrect. A 1% decrease in 1980 supply would result in the minimum difference reconciliation (Table 45) estimate being negative (demand for cassava would exceed supply).

In summary, both the predictions of human demand for, and supply of, cassava are crucial in the determination of whether supply and demand will be in equilibrium or if one will exceed the other. Because human demand for cassava may be underestimated, it is possible that there could be insufficient supply to meet the export demand for cassava. On the other hand, it is not expected that the maximum difference reconciliation of 36 million tons will occur, because it is unlikely that production would be allowed to exceed demand by so much.

It should be realized that the positive differences between supply and demand are a reflection of large cassava surpluses in Brazil, Paraguay, India, Thailand, and Uganda (Table 13), and it is these countries that will be in the best supply position to export cassava. The total surpluses of these countries (approximately 29 million metric tons) are sufficient to exceed the predicted minimum size of the market. If this predicted surplus is converted to animal feed, and if EEC demand for cassava does not approach the maximum limits, there may be little scope for other countries to export cassava to Europe. That some of these surplus countries[65] will export cassava has been indicated by individuals involved with the trade. Thus, only the traditional domestic markets can be considered to be assured for most producing countries.

Conclusions

There are many intangibles associated with the future demand for cassava. By definition, these are unquantifiable. Nevertheless, these factors can be interpreted as indicating certain potentialities. The overriding impression is that cassava and cassava products will be used in larger quantities in the future. Domestic demands are almost certainly expected to emerge for cassava in the 1970s. General livestock and industrial production trends suggest that there could be an increasing need for cassava products. As countries in the Cassava Belt further increase industrial and livestock production, they will create demands which can be satisfied by utilization of cassava. These countries may choose to rely on this domestic input, or they may prefer to import products such as maize and maize starch. The choice, however, should be made with the full knowledge of the possible uses of cassava products.

The security of the European market for cassava in the 1980s is questionable. First, cassava-exporting countries must be wary of the fact that inflation in their country could exceed that of importing countries, thereby making cassava (if its price inflates) relatively more expensive than competing goods. Second, changes in CAP, which will certainly occur by the 1980s could affect the demand for cassava. However, exporters of cassava as a compound animal feed ingredient may be hopeful that Japan will become a major consumer of cassava.

If barriers to cassava imports to Japan are removed, and cassava is attractively priced, the Japanese could import in excess of 1 million tons of pellets, thus indicating that at the minimum difference reconciliation (Table 45) level, there would be insufficient supplies to meet projected Japanese demand. Even if enough cassava is available, the opening of a Japanese market for cassava could disrupt current trade patterns. The possible rationalization of cassava exporting (Pacific countries exporting to Japan and Atlantic countries exporting to Europe) could actually result in a loss of markets if rationalization is not orderly, e.g. if Thailand suddenly diverted all exports to Japan and no new supplies were forthcoming for Europe, European compounders would be forced to change to other energy sources, resulting in a perhaps irreversible loss of this market to cassava-producing countries. Thus, it is imperative that the exporter or potential exporter understand the markets involved and the types of changes which could occur. Failure to do so could result in loss of actual or potential trade.

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[65]Thailand, Brazil, and India are considering increasing or beginning shipments of cassava to Europe. Combined export targets of Thailand and Brazil in fresh roots exceed 6 million tons.

Brazil, the world's largest producer of cassava, depends primarily on human labour for planting and harvesting.

Chapter 6. Cassava (Mandioca) in Brazil

A mandioca è uma planta de cultura multisecular que se adapta a quase todas as regiões do Brasil. Sua cultura pouco exigente oferece grandes facilidades. Não obstente, sua evolucão agricola e industrial tem estado praticamente estacionária. Planta das mais rústicas produzindo atè nos solos pobres e resistindo satisfatoriamente às oscilacões climáticas, è cultura das mais recomendá veis para uma exploracão ampla e racional estando, inclusive, destinada a ocupar lugar de destaque entre as mais promissoras a solucão de grave problema alimentar nos trópicos.

ALINO MATTA SANTANA

This chapter[66] considers primarily the supply of, and demand for, cassava after the 1960s, and perforce begs the question of sectorial balance between industry and agriculture. Furthermore, no attempt is made to exhaustively examine the merits of different agricultural sectors. Instead, an attempt is made to derive from a positive analysis of the evolution of the supply of, and demand for, cassava the possible future role of the crop in Brazil. Indicated developments are evaluated in terms of emerging research programs which may affect future cassava supply and demand.[67] The analysis is mainly descriptive, with quantitative estimations being drawn primarily from secondary sources.

The Context

Brazil (Fig. 12), the fifth largest country in the world in areal terms, has a population of 93 565 000 (1970) (FAO 1972) and a Gross Domestic Product of US$32 482 000 000 (Conjuntura Economica 1972). Excluding centrally planned countries, Brazil ranks tenth in total Gross National Product but much lower in terms of per capita GDP. This ranking is an improvement over its 1958 position, which was fourteenth.

Not surprisingly, with its large land base, Brazilian agriculture contributes 19.8% of GDP (Conjuntura Economica 1972) and accounts for 72% of export earnings (FAO 1972). The history of agriculture as an export earner has been checkered. Schuh (1970, p. 102) states: "With one crop after another (Brazil) has had a leading position, only to lose it when other countries improved their competitive position while Brazil stayed at the same level. This was the case in its early history with sugar, with rubber, and with cocoa; and it appears that the same thing is happening with coffee."

On the other hand, Brazil has moved from a position of relative obscurity to become the fifth largest exporter of maize, second largest exporter of soybean cake and meal, and is slowly approaching self-sufficiency in wheat production (discounting the 1972–73 wheat failure, which is expected to be 1.5 million tons below projected production) after importing a high of 2.6 million tons in 1968 (FAO 1972). Brazil is also the sixth largest producer of sweet potatoes and yams; the third largest producer of soybeans; the second largest producer of maize, sugar cane, oranges, and pineapples; and the largest producer of bananas, coffee, dry beans, and cassava (Table 46) (FAO 1972, and Conjuntura Economica 1972). Although Brazil ranks high in the production of some temperate (developed country) crops, its agriculture is similar to that of many developing countries (viz, a large number of small holdings,

[66]Rafael Orlando Diaz, CIAT Economist who travelled to Brazil with me, deserves credit for compiling a major portion of the data in this chapter.

[67]Current attributes and research programs must be taken to mean those which are known to me.

FIG. 12. Map of Brazil showing major state and territory divisions of the country.

TABLE 46. Ranking of countries by production of selected crops, 1971 levels (source: FAO, Production Yearbook).

Crop	1st	2nd	3rd
Soybeans	USA (31 823)[a]	China (Mainland) (11 500)	Brazil (2 218)
Maize	USA (140 733)	Brazil (14 360)	USSR (11 500)
Sugar cane	India (128 769)	Brazil (79 753)	Pakistan (31 977)
Oranges	USA (7 841)	Brazil (3 400)	Japan (3 000)
Pineapples[b]	USA (831)	Brazil (424)	Malaysia (353)
Bananas[b]	Brazil (6 396)	India (3 300)	Equador (3 000)
Coffee	Brazil (16 655)	Colombia (5 200)	Ivory Coast (2 400)
Dry beans	Brazil (2 430)	India (2 090)	China (Mainland) (1 400)
Cassava	Brazil (30 258)	Zaire (10 500)	Indonesia (10 042)

[a]Units 1000 metric tons.
[b]1970 levels.

and a small proportion of GNP (19.8%; Conjuntura Economica 1972) generated in relation to agricultural labour force (44%; FAO 1972). Apart from coffee, Brazilian agricultural production has displayed steady growth (Table 47), but this growth is primarily the result of increased agricultural acreage (Table 48) rather than increased yield. Apparently, Brazilian agriculture has not benefited from the adoption of new technology or the "Green Revolution". This conclusion, however, is curiously contradicted by data on fertilizer application per hectare which has expanded rapidly since 1963 (Table 49). This contradiction is not easily interpreted. Perhaps the use of principal crop rather than total agricultural acreage biases the figures upward, but it does seem logical that fertilizer would be applied first to principal crops. Or perhaps initial data on fertilizer consumption may have been low, but this in itself cannot account for apparent annual increases in fertilizer application. Finally, it is possible that new lands brought into production (or areas not dropped from production) are of poorer quality and therefore require higher levels of fertilizer application. Although this does not provide a complete explanation of the rather slow growth rate of crop yields, it does suggest that once the factors inhibiting increases of crop yields are identified and overcome, Brazilian crop production could explode.

The following sections analyze the post-1960 role of cassava in Brazil, and suggest possible future roles.

Cassava Production

Cassava is produced in all regions of Brazil,[68] with the North and Northeast accounting for 33% of production and the South for 35% (Table 50). The states producing more than 1 million tons of roots in 1970 were: Bahia, Rio Grande do Sul, Santa Catarina, Paraná, Maranhão, Minas Gerais, Ceará, São Paulo, Pernambuco and Goiás.

Generally production is increasing in all states with the exception of Amapá. Fitting of the simple supply function, equation 10 (production regressed on cassava prices), reveals that the influence of cassava selling price varies between regions.

$$Q_{ci} = \alpha_i + \beta_i P_{ci} + u_i \qquad \ldots(10)$$

where Q_c = quantity of cassava produced; P_c = selling price of cassava and i = ith state.

The resulting regressions (Table 51) generally conform to a priori expectations that price increases will be accompanied by supply increases (e.g., a positive β). Only three states, Paraiba, Alagoas, and Amapá, indicate perverse relationships. Apart from Paraná, the supply functions of the seven largest cassava-producing states are statistically significant. However, the general results are disappointing to the degree that the supply functions of other large producing states (more than 1 million tons), Paraná, São Paulo, Pernambuco and Goiás, are statistically insignificant. Nevertheless, the 27 supply models indicate that Brazilian cassava producers respond positively to price changes. In economic terms the supply schedules are inelastic, as indicated by the .17 supply elasticity calculated from the

[68]There are five regions: *North* (Acre, Amazonas, Pará); *Northeast* (Maranhão, Piaui, Ceará, Rio Grande do Norte, Paraiba, Pernambuco, Alagoas); *East* (Sergipe, Bahia, Minas Gerais, Espirito Santo, Rio de Janeiro); *Central West* (Mato Grosso, Goiás); and *South* (São Paulo, Paraná, Santa Catarina, Rio Grande do Sul).

TABLE 47. Principal crops—quantity produced (*'000 tons*).

Year	Cotton	Brazil nuts	Rice	Bananas[a]	Potatoes	Cashews	Coffee, cocoa	Sugar cane	Beans	Soybeans	Leaf tobacco	Oranges	Cassava	Sorghum	Wheat
1947	1051	53	2596	127	575	119	1895	28 990	1046	–	111	5 310	11 845	5 503	359
1948	968	139	2554	136	585	97	2075	30 893	1133	–	118	6 129	12 455	5 607	405
1949	1200	136	2720	148	748	133	2137	30 929	1257	–	115	5 975	12 616	5 449	438
1950	1191	118	3218	163	707	153	2143	32 671	1248	–	108	6 015	12 532	6 024	532
1951	996	151	3182	170	722	121	2160	33 653	1238	–	118	6 182	11 918	6 218	424
1952	1504	145	2931	185	735	114	2251	36 041	1152	78	106	6 116	12 809	5 907	690
1953	1111	146	3072	185	815	137	2221	38 337	1387	88	132	6 177	13 441	5 984	772
1954	1166	168	3367	198	815	163	2074	40 302	1544	117	147	6 384	14 493	6 789	871
1955	1281	186	3737	204	898	158	2740	40 946	1475	107	148	6 502	14 863	6 690	1101
1956	1194	181	3489	224	1003	161	1959	43 976	1379	115	144	6 870	15 316	6 999	855
1957	1177	192	4072	233	999	165	2819	47 703	1582	122	140	7 244	15 443	7 763	781
1958	1145	308	3829	230	1017	164	3392	50 020	1454	131	144	7 458	15 354	7 370	584
1959	1399	357	4101	244	1025	178	4397	53 512	1550	152	151	7 993	16 575	7 787	611
1960	1609	408	4795	256	1113	163	4170	56 927	1731	206	161	8 360	17 613	8 672	713
1961	1828	584	5392	271	1080	156	4906	59 377	1745	271	168	8 809	18 058	9 036	545
1962	1902	648	5557	301	1134	140	3638	62 535	1709	345	187	9 255	19 843	9 587	706
1963	1957	604	5740	313	1168	143	2980	63 723	1943	323	207	10 532	22 249	10 418	392
1964	1770	470	6345	338	1264	154	1186	66 399	1951	305	210	10 275	24 356	9 408	643
1965	1986	743	7580	349	1246	161	4588	75 853	2290	523	248	11 428	24 993	12 112	585
1966	1865	895	5802	356	1329	170	2406	75 788	2148	595	228	11 767	24 710	11 371	615
1967	1692	751	6792	403	1467	195	3015	77 087	2548	716	243	12 523	27 268	12 825	629
1968	1999	754	6652	422	1606	149	2115	76 611	2420	654	258	13 587	29 203	12 814	856
1969	2111	754	6394	463	1507	211	2567	75 247	2200	1057	250	14 434	30 074	12 693	1374
1970	1955	928	7553	493	1583	197	1510	79 753	2211	1509	244	15 497	29 464	14 216	1844
1971	2153	894	7111	524	1434	212	3591	79 595	2500	1977	–	16 694	30 258	14 307	2132

[a]1000 bunches.

TABLE 48. Principal crops–area of cultivation (*'000 hectares*).

Year	Cotton	Brazil nuts	Rice	Bananas	Potatoes	Cashews	Coffee, cocoa	Sugar cane	Beans	Leaf tobacco	Soybeans	Oranges	Cassava	Sorghum	Wheat
1947	2470	52	1651	91	117	258	2415	773	1584	134	–	78	911	4 323	392
1948	2308	142	1662	96	128	260	2464	819	1650	144	–	76	913	4 347	536
1949	2497	136	1758	100	155	258	2538	797	1791	145	–	81	941	4 517	630
1950	2689	127	1964	110	148	276	2663	828	1808	142	–	77	957	4 682	652
1951	2487	141	1967	116	150	291	2738	874	1787	160	–	77	964	4 750	725
1952	3035	141	1873	128	152	284	2823	920	1838	154	60	76	1015	4 864	810
1953	2587	137	2072	136	163	340	2919	991	1995	168	63	77	1062	5 120	910
1954	2487	139	2425	141	165	353	3005	1027	2199	184	68	76	1102	5 528	1081
1955	2617	166	2512	156	179	368	3266	1073	2229	196	74	78	1149	5 623	1196
1956	2663	163	2555	162	185	376	3412	1124	2257	180	81	85	1178	5 998	886
1957	2771	169	2490	164	190	387	3672	1172	2323	179	97	88	1193	6 095	1154
1958	2706	228	2514	166	192	461	4078	1208	2124	181	107	98	1226	5 790	1446
1959	2746	255	2683	175	188	466	4297	1291	2379	191	114	106	1239	6 189	1186
1960	2930	291	2966	185	199	471	4420	1340	2560	213	171	112	1342	6 681	1141
1961	3234	436	3174	194	191	474	4692	1367	2581	228	241	119	1381	6 886	1022
1962	3457	476	3350	209	196	465	4420	1467	2716	232	314	126	1476	7 348	743
1963	3554	423	3722	231	200	470	4082	1509	2982	250	340	139	1618	7 958	793
1964	3765	430	4182	228	209	487	3846	1519	3131	251	360	144	1716	8 106	734
1965	4004	541	4619	239	202	482	3511	1705	3273	274	432	150	1750	8 771	767
1966	3898	644	4005	250	199	456	3057	1636	3325	265	491	165	1780	8 703	717
1967	3720	694	4291	256	217	473	2792	1681	3651	261	612	167	1914	9 274	831
1968	3902	606	4459	268	227	433	2623	1687	3663	276	722	173	1998	9 584	970
1969	4195	613	4621	273	221	438	2571	1672	3633	258	906	183	2029	9 654	1407
1970	4299	670	4979	278	214	444	2403	1725	3485	245	1319	202	2025	9 858	1895
1971	4460	672	5042	280	207	442	2584	1692	3743	–	1589	216	2041	10 709	2261

TABLE 49. Fertilizer consumption, 1961–62 to 1970–71 (*per hectare*) (source: FAO, Production Yearbook).

	1961–62 to 1965–66	1966-67	1967–68	1968–69	1969–70	1970–71
Nitrogen[a]	578	711	1 064	1 443	1 644	2 759
Phosphate	860	916	1 660	2 141	2 366	3 753
Potash	800	933	1 369	1 843	2 003	3 067
Principal crop acreage[b]	30 720	26 971	31 592	32 674	34 040	36 181
Nitrogen/acre[c]	1.9	2.6	3.4	4.4	4.8	7.6
Phosphate/acre	2.8	3.4	5.3	6.6	6.9	10.4
Potash/acre	2.6	3.5	4.3	5.6	5.9	8.5

[a]Units 100 metric tons.
[b]1000 hectares.
[c]kg/ha.

TABLE 50. Cassava production by states (*'000 metric tons*) (source: Anuario Estadistico do Brasil, 1962–71, IBGE).

States	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Bahia	2356	2082	2319	2668	2820	2962	3374	3899	4057	4014
Rio Grande do Sul	2228	2523	2658	2887	2767	3200	3352	3426	3622	3608
Santa Catarina	1638	1866	2017	2203	2227	2438	2553	2832	2936	3017
Paraná	447	551	845	2051	2108	1664	2005	1953	1851	2119
Maranhão	892	1084	1291	1224	1381	1589	1776	1744	2113	2075
Minas Gerais	1636	1705	1690	1807	1864	1918	2045	2087	2023	2004
Ceará	910	940	1059	1075	1077	1120	1369	1908	2164	1867
São Paulo	1310	1478	2104	2146	2445	2027	1884	2032	2020	1827
Pernambuco	1193	1692	1623	1607	1445	1196	1530	1598	1756	1644
Goiás	801	865	1004	1105	1264	1315	1312	1289	1220	1155
Espírito Santo	428	436	538	528	493	534	572	606	693	878
Pará	546	668	966	1063	965	634	750	880	949	832
Sergipe	676	693	855	781	872	785	813	820	763	783
Mato Grosso	466	583	562	448	478	492	505	607	677	711
Paraíba	562	633	625	617	597	578	695	623	535	545
Piauí	439	540	702	664	674	591	715	738	720	542
Rio de Janeiro	423	426	423	447	440	460	460	447	476	536
Amazonas	99	227	170	210	224	265	372	497	434	424
Alagoas	463	491	523	485	457	467	475	506	502	380
Rio Grande do N.	217	235	216	198	237	326	556	556	399	348
Acre	75	86	80	82	80	79	83	85	91	98
Amapá	39	34	31	25	22	19	17	16	16	15
Guanabara	4	16	15	15	16	16	16	16	15	15
Rondônia	8	9	9	9	12	12	11	11	13	13
Roraima	–	–	12	13	16	10	11	11	11	12
Distrito Federal	0.3	0.4	0.9	6	14	13	18	18	18	2
Brasil	1806	1984	2224	2435	2500	2471	2726	2920	3007	2946

TABLE 51. Cassava price response functions by state (source: Anuario Estadistico do Brasil, 1962-71, IBGE).

State	α	β[a]	R^2	State	α	β[a]	R^2
Bahia	2 193 063	52 536 677 (9.01)	.91	Mato Grosso	463 247	2 959 902 (3.46)	.60
Rio Grande do Sul	2 469 067	22 583 939 (8.32)	.90	Paraíba	622 557	−677 073 (−1.05)	.12
Santa Catarina	1 857 657	39 274 918 (11.27)	.94	Piauí	607 806	1 608 967 (0.69)	.05
Paranà	1 113 271	22 512 060 (2.22)	.38	Rio de Janeiro	421 950	1 284 613 (3.55)	.61
Maranhão	1 069 337	35 738 779 (8.35)	.90	Amazonas	118 583	18 097 616 7.39	.87
Minas Gerais	1 700 678	8 900 560 (5.93)	.81	Alagoas	500 485	−954 375 (−2.14)	.36
Cearà	804 614	36 201 308 (8.12)	.89	Rio Grande do N.	167 174	5 689 821 (4.07)	.67
São Paulo	1 850 556	4 379 370 (0.51)	.03	Acre	78 074	134 874 (4.79)	.73
Pernambuco	1 455 290	2 773 273 (0.91)	.09	Amapá	36 985	−333 544 (−0.01)	.95
Goiàs	1 061 246	3 426 680 (1.34)	.18	Guanabara	11 943	32 605 (1.52)	.22
Espirito Santo	415 446	10 263 223 (5.12)	.78	Rondonia	9 430	61 986 (3.71)	.63
Parà	794 690	2 441 333 (0.46)	.03	Roraima	6 069	50 841 (1.72)	.27
Sergipe	761 583	887 870 (0.79)	.07	Distrito Fed.	−2 042	314 927 (3.02)	.53
				Brasil	2 080 149	2 302 051 (5.20)	.77

[a]Values in brackets are t values.

Brazilian function.[69] In other words, nearly a 6% price change is required to induce a 1% change in production. Thus the encouragement of cassava production through price policies would, if these supply models are representative, appear to be expensive, relative to the gains in production.

The above supply models quite clearly cannot account explicitly for regionally different production practices, wage rates (opportunity costs), and resources. While the development of such models would be useful in assessing the future for cassava, appropriate data were not available at the time of this study.

However, regional studies of cassava production and marketing are available, and these provide a useful basis for furthering one's understanding of the factors influencing cassava supply functions.

Data collected by the Superintendencia de Desenvolvimento do Nordeste (Superintendency for Development of the Northeast: SUDENE) and the Banco do Nordeste do Brasil[70] (Table 52) indicate that labour input varies from a low of 50 man-days/ha for rainfall zone 3 to 165.4 man-

[69]The general supply elasticity for equation 1 is $\eta s = \beta_i \frac{P_{ci}}{Q_{ci}}$. For evaluation of the Brazilian supply elasticity ηs is evaluated assuming average values of P_{ci} and Q_{ci} (viz $\eta s = (2\,302\,051)\,(.18)/(2\,459\,164)$).

[70]Convenio SUDENE/Estado de Sergipe, CONDESE, 1969; Convenio SUDENE/Estado Alagoas, Secretaris da Agricultura, Industria e Comercio, 1968/69; Informacoes Basicas para Elaboracao de Orcamentos Agriculas no Nordeste, Banco do Nordeste do Brasil, Fortaleza, Ceara, Junho, 1969; Dept. of Secretary of Agricultural Economics, Agricultural Dept. of Maranhao, 1969.

TABLE 52. Labour input in cassava production in the Northeast (*man days/hectare*).

	Alagoas (10.7tons)	Maranhão (10tons)	Sergipe (13.9tons)	Average (11.5tons)
Land preparation	39.0	22.0	25.6	28.9
Planting	10.0	15.0	24.3	16.3
Cultivation	34.0	20.0	100.0	51.3
Harvest	13.0	12.0	15.5	13.5
Total:	96.0	69.0	165.4	110.0

Zone:	1		2		3	
Rainfall (*mm*):	>750		500–750		<500	
	Mean	Range	Mean	Range	Mean	Range
Land preparation	17	9–25	20	12–28	13	7–19
Planting	33	20–47	31	17–45	13	7–20
Cultivation	27	17–37	18	11–25	10	5–15
Harvest	16	10–22	21	10–32	14	9–19
Total:	93		90		50	
Yield per hectare (*in tons*)	9.6	5.1–14.1	10.8	7.6–14.1	10.2	7.3–13.2

Source: Hendershott et al., Feasibility of Manioc Production in Northeast Brazil. University of Georgia. 1971. pp. 44, 45.

days/ha in Sergipe. This latter figure results from relatively large labour cultivation input.

A University of Georgia research team, using average labour requirements and wages, and adding estimates of rent and interest charges, calculated per hectare cost of cassava production to be Cr$488.70[71] (Table 53). Clearly, labour costs constitute the major share of production costs (79%).

As previously noted, the use of average wage rates to cost labour is not appropriate if opportunity costs of labour are low. Thus, the above estimate of production cost may be overstated, but the amount of overestimation is not determined. The values presented in Table 53 are used in the calculation of net returns.

Assuming average yield of 11.5 tons/ha and a price of Cr$0.10/kg (Hendershott et al. 1971, p. 52), the cassava producer can expect to make Cr$662.00/ha over variable costs. In the Northeast this return is greater than the net returns on corn or beans.

[71]At Cr$6 to $1 this cost is translated to $81.45/ha.

Expansion of the discussion of cassava production practices requires, at the minimum, data on cassava response to fertilizer and production costs and returns of other crops normally grown in conjunction with cassava. Such data were not available. Suffice it to say that the simple supply function analysis reveals that cassava production is responsive to price changes and that the returns to cassava production are competitive with other crops. The conclusion to be drawn at this point, therefore, is that cassava production is economically attractive, and that any policy which increases cassava prices will result in increased supplies.

Human Utilization of Cassava

Cassava as a human food is extremely important in the Brazilian diet, on average accounting for 11% of total caloric intake and 13% of vegetable calories (FAO 1971). As expected, substantial deviation from this rate exists among regions and income levels (Fundacao Getulio Vargas

TABLE 53. Production costs per hectare of cassava, N.E. Brazil, 1971.

	Man days (*average Northeast*)	Cost (*Cr$*)
Land preparation	28.9	101.1
Planting	16.3	57.1
Cultivation	51.3	179.6
Harvest	13.5	47.3
Land rent or equivalent/ha	–	45.0
Interest charges[a]	–	58.6
Total charges:	–	488.7
Cost per ton (11.5 tons/ha) (*Cr$*)		42.5
Cost per kilogram (*centavos*)		4.25

[a]Land preparation and planting charged for 18 months at 13%, cultivation cost computed for 12 months, land rent computed for an average of 9 months.

Source: Hendershott et al., Feasibility of Manioc Production in Northeast Brazil. University of Georgia, 1971, pp. 46.

1970) (Table 54). The highest dependency on cassava (38% of calories) is associated with families living in the rural areas of the Northeast and in the income range of Cr$150–249, whereas lowest dependency (1% of calories) is associated with families living in urban centres of the South with incomes over Cr$2500. Table 54 includes findings which, if correct, contradict expectations —namely, that the relative consumption of fresh cassava is greatest in the rural areas of the South, not the Northeast, while highest relative consumption of cassava flour is in the Northeast (both urban and rural areas). However, the expectation that rural areas consume more cassava than urban areas is confirmed.

Attempts to measure the income demand elasticity[72] for various income categories and regions met with partial success. Aggregate urban income demand functions for fresh cassava and cassava flour were statistically significant, as shown below (t values in parentheses):

$$D_{cy1} = 1.74 + .00095\,Y_y \quad \ldots (11)$$
$$(3.39) \qquad R^2 = .62$$

$$D_{cy2} = 12.02 - .00166\,Y_y \quad \ldots (12)$$
$$(-4.49) \qquad R^2 = .74$$

The elasticities are 1.36 and −.06, respectively. The rather surprising implication is that there is a positive income demand elasticity for fresh cassava, but not for cassava flour in urban areas. Indications for rural areas are the opposite (Appendix Table F.2), but the equations are not statistically

[72]The data presented in Appendix Table F.1, was used to derive the income demand function.

$$D_{cyk} = \alpha + \beta Y_y \qquad k = 1,2$$

where D_{cyk} = per capita demand for cassava at income level y; Y_y = average income of income level y; and $k = 1$ for fresh cassava or $k = 2$ for cassava flour. D_{cyk} and Y_y are in log or linear terms. In order to fit these functions it was assumed that the income of each income range was at its mean level with highest income arbitrarily assumed to be Cr$2750.

TABLE 54. Percent of calories consumed derived from fresh cassava and cassava flour (*ranges of annual family income in New Cruzeiros*).

	Brazil		East		Northeast		South	
	Fresh cassava	Cassava flour	Fresh cassava	Cassava flour	Fresh cassava	Cassava flour	Fresh cassava	Cassava flour
Urban								
<100	0.2	7.4	0.4	6.9	0.1	17.6	0.1	2.9
100–149	0.3	7.4	0.6	7.1	0.1	16.1	0.2	3.1
150–249	0.4	6.1	0.5	5.7	0.1	12.8	0.4	2.5
250–349	0.4	5.3	0.6	5.6	0.1	10.4	0.5	1.8
350–499	0.4	4.7	0.6	5.3	0.1	8.7	0.5	1.8
500–799	0.4	3.7	0.6	4.5	0.2	7.0	0.4	1.0
800–1199	0.4	3.0	0.7	4.0	0.0	4.9	0.5	0.9
1200–2499	0.5	2.6	0.8	2.9	0.1	4.5	0.5	0.9
>2500	0.4	2.1	0.7	2.7	0.0	3.1	0.3	0.7
Rural								
<100	4.8	17.5	4.5	15.4	1.2	34.4	7.5	6.6
100–149	3.2	18.0	3.3	15.0	1.2	36.5	4.6	6.9
150–249	3.7	17.5	2.4	14.2	2.5	35.5	6.2	3.4
250–349	4.5	13.8	2.4	9.9	2.0	33.6	8.6	4.3
350–499	3.0	13.3	1.7	13.6	1.1	25.8	6.0	2.5
500–799	3.9	12.4	3.6	8.4	3.0	26.0	4.9	3.3
800–1199	3.2	13.5	4.7	9.7	0.8	26.1	4.9	5.5
1200–2499	2.7	9.0	1.5	7.4	1.1	18.0	4.9	3.1
>2500	1.5	10.5	1.2	3.7	0.0	29.4	3.1	4.4

Source: Food Consumption in Brazil: Family Budget Surveys in the Early 1960's, Fundacao Getulio Vargas, Rio de Janeiro, 1970.

significant. Regional disaggregation supports these findings.

If the implications of these equations, as indicated by the signs of the elasticities (Table 55), are considered valid and applicable to the contemporary situation, it suggests that as income increases:

1 Demand for fresh cassava will increase in urban areas;
2 Demand for fresh cassava will decrease in rural areas;
3 Demand for cassava flour will decrease in urban areas; and
4 Demand for cassava flour will increase in rural areas.

The net effect of these changes on total demand for cassava cannot be precisely estimated, but an attempt will be made to suggest the direction of the net effect. The factors which determine future demand for cassava will be original consumption levels, income and population growth, changes in the urban–rural population proportions, and income demand elasticities. Products with positive income demand elasticities will experience demand increases greater than population growth, but if the income demand elasticity is negative the demand will not increase as rapidly as population (given sufficiently large income increases or negative elasticities, the total demand could decrease). Thus in urban areas total consumption of fresh cassava will increase by more than population growth, while consumption of cassava flour will not grow as quickly or may remain relatively constant. In rural areas total consumption of fresh cassava may remain relatively constant, while consumption of flour will increase by more than the growth of population. Rural–urban migration will (if migrants adopt urban habits) accentuate the growing demand for fresh roots in urban centres, further decreasing rural demand; retard the decreasing demand for cassava flour in urban areas; and lessen demand for cassava flour in rural areas.

TABLE 55. Signs of income demand elasticities for fresh cassava and cassava flour for different regions of Brazil (source: regression results, Appendix F).

	Fresh cassava	Cassava flour
Urban Regions		
Brazil	+	–
Northeast	–	–
East	+	–
South	+	–
Rural Regions		
Brazil	–	+
Northeast	–	+
East	–	–
South	–	+

The net effect of the hypothesized set of conditions are that total consumption of cassava will increase; that consumption of fresh roots will decrease when migration is considered; and that consumption of farinha de mandioca may remain constant or may even increase.

Consideration must be given, however, to factors which were not operative in the foregoing analysis. One such factor is the development of protein-fortified farinha de mandioca. The National Food Commission (CNA), Institute of Food Technology, Centre of Agricultural Technology and Food (CTAA), Granfino Ltd, Bank of Brazil and the United States Agency for International Development (USAID) are presently collaborating on research related to fortified farinha de mandioca. Cassava flour was selected for fortification because:

- it is a widely accepted product at all income levels;
- it is a basic food in rural areas and has high per capita consumption in many urban areas;
- it is relatively simple to fortify;
- it is more readily available throughout the year than are rice, corn and bean products (Costa et al. 1972).

The first phase of the fortification program involved the evaluation of the acceptability of three possible protein sources: (1) soy protein isolate (SPI) plus methionine or calcium caseinate; (2) calcium caseinate; and (3) fish protein concentrate. The second phase entails testing the market-acceptability of the fortified cassava flour in the greater Rio de Janeiro area. A study of fortifying agents has concluded that the first fortification method is the most attractive, because of its cost, and because soy protein isolate is produced domestically.

In accordance with the above recommendation, the largest distributor and reprocessor of cassava flour in the greater Rio de Janeiro area agreed to fortify a proportion of its sales. It was possible to fortify only "roasted" farinha de mandioca, because SPI discolours the standard, unroasted product. Unfortunately, roasted farinha de mandioca is more expensive than plain farinha de mandioca and presumably is not consumed as much by lower income groups who are in greatest need of protein. Nevertheless, a fortified roasted farinha de mandioca could improve the protein intake of a substantial proportion of the population.

Evaluation of the market acceptability of the fortified product is not complete. However, a limited survey (information supplied by USAID, Rio de Janeiro, December 1972) of low and middle income consumers of the new 7% protein product found that:

- 27% of the families used it for purão (mush) and 75% for farofa;
- 86% said they would buy it;
- 45% of the families noticed a difference.

Of the last group:

- 60% thought it was better overall;
- 10% thought the odour was better;
- 50% thought the colour was worse;
- 20% thought it tasted better;
- 20% thought it tasted worse.

The survey was not designed for extrapolation purposes, but USAID consider the initial findings encouraging for the future of fortified farinha de mandioca.

The USAID fortification program has expanded as a result of: (1) a contract signed with the Federal Government regarding cooperation in the fortification of cassava flour, and (2) cooperation of selected Recife farinha de mandioca firms who will test-market fortified cassava flour. The program has also benefited from the introduction of a new protein source, soy grits, which are preferable to SPI because the former is thermally treated to destroy anti-tretic fractions, and can be granulated to any size to make it undistinguishable from farinha de mandioca.

Thus, information on this new product should be available within the next few years. Such information may make it possible to alter presently projected trends in per capita consumption of cassava. In any event, the development of an available and acceptable fortified cassava product should reduce the protein deficiency existing in parts of the country. In short, the development of the fortification program should prove extremely interesting and should be closely observed.

Other Domestic Uses of Cassava

Although cassava starch could be used by numerous industries in Brazil it apparently is not. In Brazil, a major producer of maize, an estimated 60% of industrial starch used derives from maize. However, increased production and use of cassava starch, thereby releasing maize for potentially more productive uses, could possibly prove economically advantageous. The expansion of cassava starch production could be inhibited by two factors: (1) cassava starch manufacturers are small and are only concerned with local markets; and (2) Brazil's largest maize starch producer resists any attempt to expand starch production at the expense of maize starch. Data on the relative economic merits of cassava and maize starch were not available, but it is known that the average price for cassava in 1970 was Cr$2.85/50 kg, while that for maize was Cr$11.06/60 kg for 1970–71 (Sr. Méirelles, personal communication). Superficially, it seems that the possibility of producing more cassava starch warrants further exploration.

Another domestic market for cassava is the animal feed market which, as shown in Table 56, utilizes a substantial proportion of total cassava production. The figures in Table 56 indicate that during the 1964–68 period 63% of cassava produc-

TABLE 56. Brazil's utilization of cassava for animal feed, 1964–68 (*'000 metric tons*).

Commodities	Years	Animal	Residue	Transformation	Total
Sweet mandioca	1964	3951	988	–	4 939
	1965	4237	1059	–	5 927
	1966	4238	1060	–	5 298
	1967	4523	1131	–	5 654
	1968	4725	1181	–	5 906
Mandioca brava	1964	–	1475	9 571	11 018
	1965	–	1440	9 465	10 905
	1966	–	1411	9 336	10 747
	1967	–	1596	10 715	12 311
	1968	–	1739	11 262	13 001

Source: Mandioca, Productos Esenciais. Brasil, Ministerio da Agricultura. 1972. Vol. II.

TABLE 57. Beef and veal, mutton and lamb, and pork production (*'000 metric tons*) (source: FAO, Production Yearbook, 1971).

	Beef + veal	Mutton + lamb	Pork	Total
1948–52	1092	32	351	1475
1961–65	1404	48	574	2026
1967	1506	52	668	2226
1968	1694	57	718	2469
1969	1826	56	719	2601
1970	1900	56	735	2691
1971	1900	57	740	2697

tion was used for animal feed, and that the proportion is increasing. This percentage is greater than FAO estimates (47% of production used for animal feed; FAO 1971). Both figures appear to be inconsistent with the general assessment that virtually all cassava fed to animals is in Rio Grande do Sul and Santa Catarina (22% of Brazilian production). The consensus is that most cassava fed to animals is fed fresh and that virtually none of the cassava is used as an energy source in compound animal feeds. At present there is very little production of compound animal feed, no doubt because of the extensive nature of livestock production. But livestock production is rapidly expanding (Table 57), and it appears that production is becoming more intensive. Thus, it might be expected that use of compound feeds will increase. In this event, there could be a growing market for cassava in this area. The future size of this market has not been projected, owing to a lack of data. However, cassava utilization is not expected to decrease in the future, and in fact the demand for cassava will increase at least at the same rate as livestock.

TABLE 59. Value of Brazilian exports of cassava products, 1960–71 (*thousands of US$*) (source: discussions with Banco do Brasil).

Year	Flour	Meal	Starch	Tapioca	Chips	Total
1960	1184	140	2675	129	-	4128
1961	504	299	1338	199	-	2340
1962	66	94	781	196	-	1137
1963	58	256	295	171	-	780
1964	1387	380	1149	204	-	3243
1965	982	974	2122	189	1877	6144
1966	1159	1029	1393	217	1318	5116
1967	9	839	558	212	41	1618
1968	79	510	648	216	-	1453
1969	2015	476	863	191	1630	3545
1970	1729	521	1049	212	1254	2999
1971	536	152	773	223	477	1453

Export Markets for Brazilian Cassava

Brazil has exported cassava as flour, meal, starch, tapioca, and chips, but over the years the most important exports in quantity and value have been cassava flour and chips (Tables 58 and 59). The high point (119 870 tons valued at

TABLE 58. Brazilian exports of cassava products, 1960–71 (*metric tons*) (source: discussions with Banco do Brasil).

Year	Flour[a]	Meal	Starch	Tapioca	Chips	Total
1960	28 333	2 508	35 258	846	-	66 945
1961	11 429	5 381	16 555	1217	-	34 582
1962	527	1 692	8 507	1197	-	11 923
1963	524	6 825	2 814	914	-	11 077
1964	36 030	9 487	17 522	1200	3 203	64 239
1965	23 514	21 561	31 911	1083	41 801	119 870
1966	24 270	19 583	16 088	1084	27 052	88 077
1967	81	13 932	5 558	1025	711	20 637
1968	754	7 887	7 172	1013	-	16 826
1969	46 598	9 611	10 354	837	38 135	105 535
1970	34 236	8 690	12 835	990	24 672	72 733
1971	12 980	2 167	7 557	1014	9 069	23 063

[a]Headings from left to right; farinha de mandioca, farinha de raspa de mandioca, fecula de mandioca, tapioca, raspa de mandioca.

TABLE 60. Brazilian exports of cassava products (metric tons) by country of destination, 1964–71 (rounded to the nearest thousands of dollars).

	1964		1965		1966		1967		1968		1969		1970		1971	
	t[a]	$[b]	t	$	t	$	t	$	t	$	t	$	t	$	t	$
Chips																
Germany	3 203	125	36 670	1646			267	15	–	–	33 213	1417	17 631	918	5 873	305
Hungary	–	–	944	46			–	–	–	–	–	–	–	–	–	–
Netherlands	–	–	2 036	84	not	not	287	16	–	–	3 612	154	5 516	258	515	25
Switzerland	–	–	2 150	101	available	available	–	–	–	–	–	–	–	–	–	–
USA	–	–	–	–			167	10	–	–	1 000	46	–	–	–	–
Belgium-Luxembourg	–	–	–	–			–	–	–	–	100	4	1 525	79	2 681	146
France	–	–	–	–			–	–	–	–	100	3	–	–	–	–
Paraguay	–	–	–	–			–	–	–	–	100	4	–	–	–	–
Total	3 203	125	41 800	1877	27 052	1318	721	41	–	–	38 125	1628	24 672	1255	9 069	476
Flour																
Germany	35 036	1305	23 088	953			–	–	–	–	9 530	397	–	–	–	–
USA	18	2	40	4			22	3	43	5	46	5	59	6	1 021	88
Portugal	74	6	25	2	not	not	29	3	48	3	29	3	35	2	30	3
Uruguay	902	74	359	23	available	available	28	3	668	70	474	40	531	48	72	7
Italy	–	–	1	–			–	–	–	–	–	–	–	–	–	–
Bolivia	–	–	–	–			–	–	–	–	–	–	–	–	–	–
Belgium-Luxembourg	–	–	–	–			–	–	–	–	36 518	1570	24 922	1154	9 189	481
France	–	–	–	–			–	–	–	–	–	–	–	–	1	–
Netherlands	–	–	–	–			–	–	–	–	–	–	–	–	500	25
Total	36 030	1387	23 513	982	24 270	1159	79	9	759	78	46 597	2015	25 547	1210	10 813	604
Meal																
Germany	7 605	2298	1 954	86			–	–	–	–	549	23	1 467	87	–	–
Belgium-Luxembourg	150	6	–	–			100	6	–	–	1 000	50	–	–	464	25
Canada	54	1	1 941	89	not	not	1 090	66	2612	165	1 919	94	2 675	160	485	34
USA	1 678	74	15 667	705	available	available	12 531	753	5275	344	6 043	304	4 547	272	1 218	91
Switzerland	–	–	2 000	94			–	–	–	–	–	–	–	–	–	–
France	–	–	–	–			5	–	–	–	–	–	–	–	–	–
Netherlands	–	–	–	–			200	12	–	–	100	4	–	–	–	–
United Kingdom	–	–	–	–			5	–	–	–	–	–	–	–	–	–
Total	9 487	379	21 562	974	19 583	1029	13 931	837	7887	509	9 611	475	8 689	519	2 167	150

(continued next page)

TABLE 60 *(continued)*

	1964		1965		1966		1967		1968		1969		1970		1971	
	t[a]	$[b]	t	$	t	$	t	$	t	$	t	$/t	t	$/t	t	$/t
Starch																
Germany	700	43	8 300	332			200	20	200	19	–	–	99	8	–	–
Canada	496	32	432	30			160	16	800	68	2 809	243	835	70	1 115	112
USA	15 971	1043	22 287	1706			5 108	513	5818	523	6 792	562	11 183	920	6 033	613
France	40	3	–	–	not	not	–	–	–	–	–	–	–	–	–	–
Guatemala	20	1	–	–	available	available	–	–	–	–	–	–	–	–	–	–
Italy	6	1	–	–			–	–	–	–	–	–	–	–	–	–
Netherlands	179	12	142	11			90	9	131	12	128	10	218	18	396	45
United Kingdom	110	8	–	–			–	–	213	24	–	–	–	–	–	–
Denmark	–	–	250	14			–	–	–	–	–	–	–	–	–	–
Peru	–	–	500	29			–	–	–	–	–	–	–	–	–	–
Portugal	–	–	–	–			–	–	10	1	–	–	–	–	–	–
Argentina	–	–	–	–			–	–	–	–	625	47	–	–	–	–
Belgium-Luxembourg	–	–	–	–			–	–	–	–	–	–	500	33	–	–
Spain	–	–	–	–			–	–	–	–	–	–	–	–	6	2
South Africa	–	–	–	–			–	–	–	–	–	–	–	–	4	1
Total	17 522	1143	31 911	2122	16 088	1393	5 558	558	7172	647	10 354	862	12 835	1049	7 554	773
Tapioca																
Belgium-Luxembourg	15	2	36	6			–	–	–	–	–	–	–	–	–	–
Canada	102	19	65	12			107	22	178	34	194	36	131	27	137	30
Spain	135	23	129	22			74	13	5	1	–	–	9	1	–	–
USA	918	153	805	139			823	172	859	178	717	148	839	182	829	184
Mexico	–	–	22	4	not	not	11	3	–	–	24	4	–	–	8	1
Portugal	5	1	7	1	available	available	–	–	8	2	–	–	5	1	5	1
Switzerland	20	4	20	4			10	8	5	1	5	1	6	1	35	7
Uruguay	6	1	–	–			–	–	–	–	–	–	–	–	–	–
Netherlands	–	–	–	–			–	–	–	–	–	–	–	–	–	–
South Africa	–	–	–	–			–	–	–	–	–	–	–	–	–	–
Total	1 201	203	1 084	188	1 158	217	1 025	218	1055	216	940	189	990	212	1 014	223

[a]t = metric tons.
[b]1000's of dollars.

TABLE 61. Cassava exports by port of embarkation (source: Banco do Brasil).

		Chips		Starch		Tapioca	
	Port of embarkation	Quantity (*metric tons*)	Value *US $*	Quantity	Value	Quantity	Value
1960	Santos (SP)	2 508	140 000	4 537	318 140	–	–
	Rio de Janeiro (GB)	–	–	1	81	–	–
	Itajaí (SC)	–	–	28 792	2 220 180	840	128 067
	Laguna (SC)	–	–	1 927	137 048	–	–
	Pôrto Alegre (RS)	–	–	–	–	6	1 047
1961	Santos (SP)	5 052	281 000	2 664	205 636	–	–
	São Paulo (SP)	329	18 000	–	–	–	–
	Itajaí (SC)	–	–	13 456	1 095 393	1211	198 216
	Laguna (SC)	–	–	436	36 565	–	–
	Pôrto Alegre (RS)	–	–	–	–	6	1 089
1962	Santos (SP)	754	41 909	1 334	106 331	113	19 927
	Itajaí (SC)	938	52 178	7 173	675 146	1083	176 098
1963	Santos (SP)	6 134	216 349	323	33 388	19	3 627
	Itajaí (SC)	691	39 559	2 485	260 814	815	152 432
	Livramento (RS)	–	–	5	590	–	–
	Paranaguá (PR)	–	–	–	–	79	14 974
1964	Salvador (BA)	1 000	39 200	–	–	–	–
	Santos (SP)	7 276	289 354	–	–	11	2 337
	Itajaí (SC)	1 210	51 256	16 509	1 082 057	–	–
	Outros	–	–	1 014	66 489	1150	195 340
	Paranaguá (PR)	–	–	–	–	39	6 550
1965	Salvador (BA)	120	6 000	–	–	–	–
	Santos (SP)	20 941	942 890	2 064	144 700	–	–
	Itajaí (SC)	500	25 553	21 377	1 632 661	879	152 418
	Laguna (SC)	–	–	8 300	332 000	–	–
	Outros	–	–	170	12 445	204	36 743
1966	Santos (SP)	18 738	985 575	260	22 852	–	–
	Itajaí (SC)	308	15 573	15 828	1 369 768	898	171 406
	Laguna (SC)	538	27 810	–	–	–	
	Outros	–	–	–	–	260	45 912
1967	Santos (SP)	12 415	747 309	20	2 646	–	–
	Itajaí (SC)	1 517	91 456	5 483	550 188	946	195 248
	Paranaguá (PR)			55	5 604	67	13 592
	Pôrto Alegre (RS)			–	–	11	2 818
1968	Santos (SP)	7 887	509 825	283	28 342	7	1 621
	Itajaí (SC)	–	–	6 610	589 321	929	192 567
	Parnaiba (PI)	–	–	213	23 587	–	–
	Paranaguá (PR)		–	65	6 549	78	15 815

US$6 144 000) reached in 1965 has not been duplicated—in fact, it appears that exports have generally declined since that date. The important export markets, while varying through time, have been Germany, United States, and Belgium-Luxembourg (Table 60). This table reveals that the demand for specific cassava products differs from one country to another. The United States and Canada are the main markets for Brazilian cassava starch and tapioca, while Germany and Belgium-Luxembourg are the main markets for cassava chips and flour. The erratic nature of exports is perhaps indicative of Brazil's inability to respond to the export potential for cassava.

TABLE 62. Average price of cassava exports (*US$/metric ton: fob*).

	1966	1967	1968	1969	1970	1971
Meal	52.54	60.22	64.66	49.52	59.95	70.09
Flour	47.75	112.50[a]	104.77[a]	43.24	47.47	54.19
Chips	48.72	57.11	–	42.75	51.66	52.64
Starch	86.58	100.40	90.35	83.34	81.90	102.30
Tapioca	187.40	207.00	207.10	209.08	215.95	221.05

[a]Includes edible farinha de mandioca.

Reinforcing this contention is the fact that both the North American starch market (Chapter 3) and the EEC flour and chip market (Chapter 4) have been growing while Brazilian exports have exhibited no clear trend. In part, this failure reflects the facts that:

1 Exports come primarily from the south of Brazil (Table 61), and thus draw on only a proportion of Brazilian production capacity;
2 Export prices, except for tapioca and starch, are lower than domestic prices (Table 62) (viz farinha de mandioca costs approximately $115/metric ton while fob export price may be half this value). The extra quality control required for the tapioca and starch markets no doubt means that returns from these two export markets are not much higher than the less-demanding domestic markets;
3 Cassava exports have not consistently met minimum quality standards.

The third point may be overcome by the implementation of export standards approved by the National Council of External Trade in 1971 (Table 63). Adherence to these standards should stimulate export demand for Brazilian cassava.

Summary

The evidence presented in this chapter suggests that the role of cassava in Brazil is similar to the pattern common in many LDCs, namely, that cassava production is required to meet home food requirements before other domestic demands (in this instance, primarily animal feed demands). The residual is then exported.

The aggregate analysis of Brazil (see Chapter 2) indicates that the human demand for, and supply of, cassava will continue to increase during the 1970s. The more disaggregated approach supports these findings in principle, although the present analysis indicates that growth in demand will be primarily for cassava flour rather than for fresh cassava, if migrational patterns are accounted for. It appears that by 1980 Brazil will have plentiful supplies to meet additional domestic demands or to export.

The 1980 domestic demand for cassava is expected to be 13 990 000 metric tons for food and an average of 10 052 000 metric tons for animal feed.[73] The 1980 supply of cassava is expected to range from 40 733 000 metric tons to 50 653 000 metric tons. These projections suggest that by 1980 Brazil could have from 16 691 000 to 26 611 000 metric tons available for domestic or export purposes. If this quantity were all exported as pellets, Brazil could theoretically export from 6 676 000 to 10 644 000 metric tons,[74] with an approximate fob value of $367 180 000 to $585 420 000. From the demand point of view, it would appear that Brazil could capture (if not glut) a substantial proportion of EEC demand for cassava. From the supply standpoint, Brazil must evaluate her export potential in terms of competition between cassava export earnings and opportunity costs of cassava production as opposed to production of other crops. Moreover, exportation implies not only availability of supplies but the necessary transportation and port infrastructure, which is notably lacking in cassava-growing regions of the North and Northeast. On this point, the Brazilian case differs substantially from the Thai situation—the Brazilian decision to export requires state and/or federal support for infrastructure development.

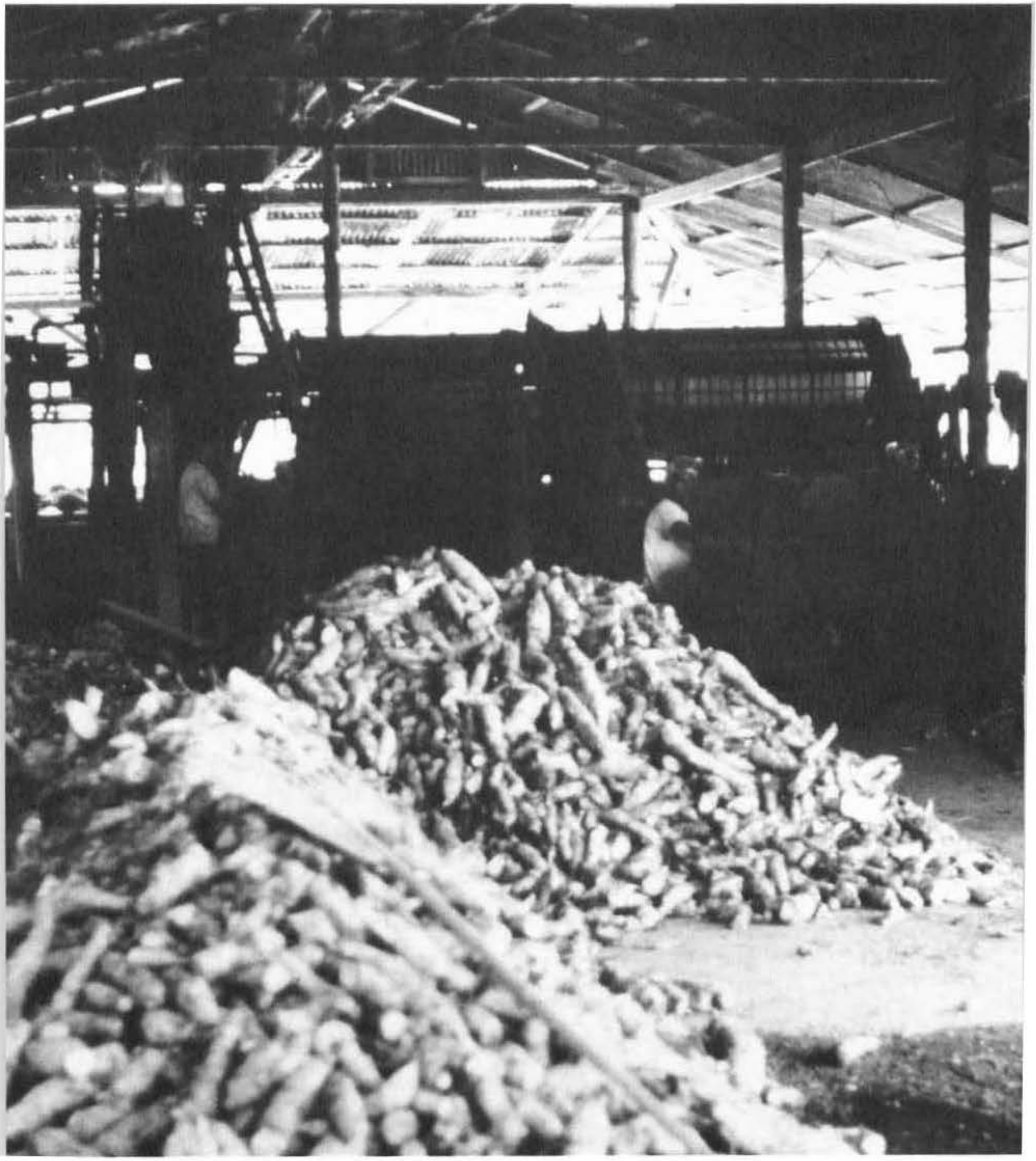
[73]Animal feed estimate is an average of the projections presented in Chapter 5.

[74]Based on a conversion rate of 2.5 tons of roots equals 1 ton of pellets.

TABLE 63. Cassava export standards (source: Farinha de Mandioca e Productors Amilaceos, CACEX, 1972).

Characteristics and limits	Starch 1			Tapioca 2				Chips 3		Meal 4	
Classes				granules		artificial sago					
Types	1 or A	2 or B	3 or C	1	2	1	2	1	2	1	2
Starch (*minimum %*)	84.0	82.0	80.0					75.0	70.0	71.0	70.0
Mesh size (*mm*)	0.105	0.105	0.105							0.160	0.160
(%)	99.0	99.0	99.0							99.0	99.0
Moisture (*maximum %*)	14.0	14.0	14.0	15.0	15.0	15.0	15.0	13.0	14.0	13.0	14.0
Breaking point (°*C*)	58–83	58–83	58–83								
Colouration[a]	9A1 10A1 11A1	9A1 10A1 11A1 12A1 13A1	9A1 10A1 11A1 12A1 12B1 13A1	white to creamy gray	white to light gray	white to ash	ashy to cream to yellowish, and yellow			10A1 10A2 10B1 10B2 11A1 11A2 11A3 11B1 11B2 11B3 11C1 11C2 11C3	10A1 10A2 10B1 10B2 11A1 11A2 11A3 11B1 11B2 11B3 11C1 11C2 11C3 13A1 13A2 13B1 13B2
Viscosity	good	regular	poor								
Acid factor content	4.5	4.5	6.0								
pH	4.5–6.5	4.5–6.5	4.0–6.5								
Acidity (*ml % in solution of NaOH N/1*)								2.0	2.5	2.0	2.5
Ash/powder (*maximum %*)	0.12	0.5	1.0	0.2	0.5	0.2	0.5	2.0	3.0	2.0	2.0
Pulp (*ml*)	0.5	2.5	3.5							40.0	45.0
Odor				Distinctive		Distinctive		Distinctive			
Foreign material or impurities (*maximum %*)				0.0	0.0	0.0	0.0	1.0	2.0	0.5	1.0
Length (*cm*)								5.0	5.0		

[a]Colouration relates to the standards in Maerz and Paul (1950).



Thailand's export success rests in part with its efficient chipping plants which dot the landscape.

Chapter 7. Cassava (Tapioca) in Thailand

There's no doubt about it. Thailand is at the top of the Tapioca tree. And it's gonna take a lot to shake her out of it.

BILL MANSON

Agriculture in Thailand has undergone two major changes in the latter half of this century. First, agriculture, historically the preeminent industry in the Thai economy (Table 64), has declined in terms of GDP. Today it accounts for only 30% of GDP (but employs 76% of the labour force (Table 65), reflecting the persistence of low-wage, labour-intensive conditions). Second, since the mid 1950s, efforts to diversify have transformed the former rice monoculture into a nearly self-sufficient agricultural economy (Thailand's main imports are now cotton, tobacco, wheat, and wheat flour).

Cassava Production and Export

In the wake of the diversification drive, the crops to experience the greatest increases in production have been cassava, maize, and kenaf, with cassava exhibiting the greatest increase of all (Tables 66 and 67). Growth in cassava production clearly reflects both the rapid development of the EEC export market (note the sudden and substantial increase after 1959; Table 68), and high returns to cassava cultivation (Table 69). Of 15 major crops, cassava, in terms of returns per unit area, ranks after kapok, tobacco, and coconut. Moreover, because the cost of cassava production is relatively low, the crop, in returns over cost per unit land, may rank even higher.

The Thai cassava processing industry has also responded rapidly to changing market conditions (Table 68); probably the most spectacular adjustment was the virtual replacement in 2 years of cassava chips and waste by pellets. Growth in cassava exports has elevated its export earnings to fifth position (Table 70). The extent of exports would most probably have been impossible if cassava constituted an important part of the Thai diet. The Thai farmer plants cassava solely as a cash crop—in all other countries cassava is generally cultivated as a local food crop.

Prior to the mid 1950s, cassava exports consisted primarily of starch to the United States. Three people and one event are credited with the initiation of cassava exports to Europe. In 1956, Messrs Erich Funke, R. Schaller, and Overseas Barter (*sic*) introduced Thai cassava products to the European animal feed market. This introduction combined fortuitously with a freight war between Thai and French shipping lines, which had the effect of reducing shipping costs to Europe by roughly a third of the normal price (140 shillings/long ton) (Rakbamrung 1970). Initial shipments of cassava feeds were in the form of cassava waste (meal) from starch manufacturing. In 1958, with the invention of the cassava chipper and the importation of a German hammer mill, cassava meal came to be produced directly from roots. By 1963, export of cassava chips exceeded those of meal, and in 1965, cassava exports to Europe earned more than total starch exports. In 1967, starch earnings rose above earnings from Europe, but the introduction of cassava pellets in 1969 swung the balance (perhaps permanently) back in favour of the European animal feed market.

Production of pellets in 1967–68 was initiated primarily by German interests who invested a reported 20 million baht[75] into the first pelleting plant. Pellets were immediately accepted by the European market because of their superior nutrient and physical properties (pellets are less dusty than meal, their greater density makes them cheaper to ship, and they are more readily worked by bulk handling facilities).

It did not take long for processors to appreciate that the future of cassava lay in the form of the pellet. There are now a reported 300 pelletizing

[75]The current rate of exchange is 20 Bht = $1.00 US.

TABLE 64. Gross domestic products by industrial origin (*million baht*) (source: National Accounts Division, National Economic Development Board of Thailand).

	1966		1967		1968		1969		1970	
	Value	%	Value	%	Value	%	Value	%	Value	%
Agriculture	37 320	36.8	34 890	32.4	36 760	31.4	41 680	31.9	40 050	29.6
Mining and quarrying	1 950	1.9	2 060	1.9	2 110	1.8	2 470	1.9	2 960	2.2
Manufacturing	13 910	13.7	16 040	14.9	17 550	15.0	19 190	14.7	20 210	14.9
Construction	6 180	6.1	7 400	6.9	8 190	7.0	8 620	6.6	9 420	7.0
Electricity and water supply	890	0.9	1 080	1.0	1 300	1.1	1 560	1.2	1 850	1.4
Transportation and communication	6 330	6.2	6 810	6.3	7 320	6.2	7 960	6.1	8 490	6.3
Trade	16 740	16.5	18 710	17.4	20 290	17.3	22 890	17.5	23 260	17.2
Banking, insurance and real estate	2 820	2.8	3 440	3.2	4 060	3.5	4 820	3.7	5 600	4.1
Ownership of dwellings	2 230	2.2	2 340	2.2	2 470	2.1	2 560	2.0	2 710	2.0
Public administration and defence	3 810	3.8	4 290	4.0	4 990	4.3	5 570	4.3	6 310	4.7
Other services	9 240	9.1	10 660	9.9	12 090	10.3	13 310	10.2	14 470	10.7
GDP	101 430	100.0	107 720	100.0	117 140	100.0	130 610	100.0	135 320	100.0

TABLE 65. Employment trend in Thailand[a] by sectors.

Sector	1954 Number	%	1960 Number	%	1966 Number	%	1971 Number	%
Agriculture, forestry, hunting and fishing	8 971 600	88	10 341 857	82	11 618 752	80	12 675 498	76
Mining and quarrying	19 200	–	28 443	–	41 486	–	51 322	–
Manufacturing	212 520	2	454 807	4	689 134	5	982 143	6
Construction	28 440	–	68 260	1	110 687	1	164 247	1
Electricity, gas, water and sanitary services	4 680	–	15 454	–	33 249	–	57 548	–
Commerce	463 240	5	744 424	6	1 027 574	7	1 368 792	8
Transport, storage and communications	84 520	1	164 142	1	228 949	2	324 818	2
Services	393 080	4	643 595	5	804 304	6	1 139 818	7
Others	23 400	–	220 275	2	–	–	–	–
Total number of persons employed:	10 200 680	100	12 681 257	100	14 554 135	100	16 764 198	100

[a]Relates to persons aged 15 years and over.
Sources: 1954 Demographic and Economic Survey.
1960 Population Census.
Estimate of Manpower Planning Division, NEDB.

TABLE 66. Production of principal crops by groups, 1953–70 (*'000 metric tons*) (source: Agricultural statistics of Thailand).

Year	Upland food crops	Oilseed	Fiber crops	Rubber	Tobacco (Virginia)	All crops except rice	Rice[a]	All crops
1953	1 944	965	40	98	12	3 058	8 239	11 297
1954	2 574	1278	31	120	10	4 013	5 709	9 722
1955	2 844	1377	35	133	6	4 395	7 334	11 729
1956	4 137	1475	49	137	7	5 805	8 297	14 102
1957	4 489	1506	182	142	7	6 325	5 570	11 895
1958	4 728	1338	175	150	9	6 400	7 053	13 453
1959	6 434	1102	208	161	8	7 913	6 770	14 683
1960	7 208	1279	355	172	9	9 023	7 834	16 857
1961	6 349	1231	351	186	9	8 126	8 177	16 303
1962	5 950	1300	235	195	9	7 689	9 279	16 968
1963	7 818	1362	350	198	9	9 737	10 029	19 766
1964	7 676	1300	450	211	9	9 645	9 558	19 203
1965	7 101	1370	687	217	8	9 382	9 198	18 580
1966	6 975	1389	853	218	8	9 443	11 975	21 418
1967	8 026	1387	606	219	8	10 246	9 595	19 841
1968	10 182	988	539	258	8	11 975	10 771	22 746
1969	10 840	949	514	282	9	12 594	13 410	26 004
1970	12 150	982	511	287	10	13 940	13 270	27 210

[a]From area planted in specified year.

TABLE 67. Index of production of selected crops (source: Agricultural statistics of Thailand, 1970).

	Maize	Cassava	Kenaf	All crops except rice	All crops
1950–53	100	100	100	100	100
1954	150	107	63	165	101
1955	165	98	76	181	121
1956	279	352	131	239	146
1957	332	373	137	260	123
1958	451	434	229	263	139
1959	768	2461	386	325	152
1960	1319	2777	1400	371	174
1961	1450	3923	1848	334	169
1962	1612	4720	1038	316	175
1963	2080	4798	1635	400	204
1964	2267	3539	2341	397	199
1965	2475	3352	4086	386	192
1966	2720	4300	5115	388	222
1967	3188	4686	3257	421	205
1968	3656	5934	2440	492	235
1969	4121	6998	2883	518	269
1970	4727	7798	2941	573	281

machines (Manson 1972, p. 37) in 90 plants (Mathot 1972, p. 9) in Thailand.

Pellets are defined as "native" and "branded." To a large extent this distinction also reflects a difference in quality. Branded pellets, constituting 30–40% of exports and primarily produced by large, commercial[76] firms, are generally considered to be of better quality. However, this should not be taken to imply that all native pellets are of low quality. I visited one native plant whose product is rated as being one of the top two in quality.

Poor product quality has been a common complaint on the part of Thailand's European customers. The main criticisms are that:

- minimum starch content is not met;
- maximum sand and foreign matter content is exceeded;
- maximum moisture content is exceeded;
- bacteria and mold content is too high; and
- pellets are of poor, friable consistency.

Failure to provide a better product rests first with the fact that, despite poor quality, the market for cassava has not decreased. German and Dutch importers have combined complaints with increased demand and steady price for the products. Only Belgium has cancelled Thai imports, preferring, since 1969, to use the more sporadic but higher quality products of Indonesia, Africa, and the People's Republic of China (Manson 1972, p. 40).

TABLE 69. Value of output (*baht*) per rai[a] of selected crops (source: The Agricultural Economy of Thailand, Omero Sabatoni, US Dept. of Agriculture, 1972).

Product	1958–60	1965–67
Maize	269	325
Mung beans	370	414
Cassava	713	611
Rice	169	291
Sugar cane	596	606
Castor beans	523	321
Groundnuts	437	507
Sesame	618	533
Soybeans	350	363
Coconuts	1249	757
Cotton	486	501
Kapok	1663	1452
Kenaf	1531	569
Rubber	637	377
Tobacco	976	917

[a]2.5 rai = 1 acre; 6.25 rai = 1 ha.

Second, and perhaps more important, the low market margins on chips in Thailand make it economical to chip cassava only if the final product weight is supplemented with sand and other foreign matter. Moreover, export standards[77] have not been rigorously enforced by licensed inspectors or employees of the Office of Commodity Standards; acquisition of a quality certificate depends in many cases more on sub rosa payments than on quality of product. However, in 1973, in an effort to enforce export standards, the Thai

[76]Formerly, "commercial" was synonymous with foreign-owned plants. Today, however, the largest single production unit is Thai-owned. The producers of branded pellets are Peter Cremer (2 plants), Khrone (2 plants), Thai Wah (2 plants), Trakulkam (1 plant), and Tradex (1 plant).

[77]The export standards are: minimum starch 60%; maximum fibre 5%; maximum sand 3%; maximum moisture 14% (14.3% for period 1 June–30 September).

TABLE 68. Export of cassava products, 1953–70.

Year	Cassava root (*tons*)	Cassava root (*'000 baht*)	Cassava flour (*tons*)	Cassava flour (*'000 baht*)	Cassava pellets (*tons*)	Cassava pellets (*'000 baht*)	Cassava waste (*tons*)	Cassava waste (*'000 baht*)	Saga flour and pearl (*tons*)	Saga flour and pearl (*'000 baht*)	Total (*tons*)	Total (*'000 baht*)
1953	985	727	21 939	36 312	–	–	17 362	8 771	3747	5672	44 033	51 482
1954	1 054	767	29 733	58 524	–	–	22 249	11 288	1683	2701	54 719	73 280
1955	909	750	29 359	52 864	–	–	23 854	15 551	1595	2736	55 717	71 900
1956	673	545	56 482	94 603	–	–	28 276	17 005	1547	2619	86 973	114 772
1957	286	217	76 990	127 237	–	–	21 053	9 224	446	884	98 775	137 562
1958	2 063	1 870	124 708	177 383	–	–	24 475	12 012	380	799	151 626	192 064
1959	208	34	149 248	193 646	3 735	3 190	44 574	29 511	619	1225	227 895	227 606
1960	2 957	2 611	241 424	270 447	–	–	24 988	14 006	363	733	269 732	287 797
1961	8 405	6 921	416 022	427 930	–	–	18 568	10 805	372	714	443 367	446 370
1962	12 670	10 143	378 240	403 690	–	–	9 586	8 501	292	626	400 788	422 960
1963	93 422	76 324	311 304	346 711	–	–	22 391	15 146	326	664	427 443	438 845
1964	339 418	252 420	353 760	370 082	–	–	45 520	29 745	162	269	738 698	652 100
1965	400 526	315 241	220 923	283 293	–	–	97 811	77 212	182	342	719 260	675 600
1966	359 817	277 222	220 765	283 272	–	–	107 858	83 206	163	347	688 439	643 700
1967	337 307	236 414	373 515	445 228	–	–	70 238	43 280	297	613	781 059	724 900
1968	323 209	223 558	532 416	529 876	–	–	33 082	19 493	147	297	888 707	772 900
1969	56 394	42 839	148 939	204 310	752 751	616 863	16 905	12 011	152	302	974 940	876 000
1970	8 111	7 317	148 681	211 200	1 163 985	999 393	5 906	4 870	182	446	1 326 683	1 222 800
1971	2 500	2 500	151 352	253 400	963 895	976 100	4 151	4 200	n.a.	n.a.	1 121 898	1 237 700
1972	5 365	7 000	130 144	229 000	1 144 139	1 325 000	n.a.	n.a.	n.a.	n.a.	1 279 648	1 560 000
1973 (Jan.–10 Mar.)	648	n.a.	n.a.	n.a.	263 606	n.a.	n.a.	n.a.	n.a.	n.a.	264 254	n.a.
1973 (extrapolated)	3 428	n.a.	n.a.	n.a.	1 394 437	n.a.	n.a.	n.a.	n.a.	n.a.	1 397 865	n.a.

TABLE 70. Quantity (*metric tons*) and value (*million baht*) of major exports (source: Dept. of Customs).

	Rice		Maize		Rubber		Tin[a]		Cassava		Kenaf and Jute		Teak and Wood	
Period	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume (*cu m*)	Value
1961	1 575 998	3598	567 236	597	184 598	2130	18 104	617	443 376	446	143 477	626	135 279	321
1962	1 271 023	3240	472 405	502	194 180	2111	19 841	685	400 788	423	237 898	579	104 617	232
1963	1 417 673	3424	744 046	828	186 887	1903	22 003	741	427 443	439	125 753	358	118 161	216
1964	1 896 258	4389	1 115 041	1346	216 993	2060	22 339	962	738 859	653	162 095	495	130 367	269
1965	1 895 223	4334	804 380	969	210 854	1999	20 503	1166	719 442	676	316 986	1102	117 380	279
1966	1 507 550	4001	1 218 537	1520	202 535	1861	18 898	1316	688 603	644	473 269	1614	98 514	295
1967	1 482 272	4653	1 090 762	1355	211 118	1574	27 107	1822	781 357	726	317 112	866	66 319	244
1968	1 068 185	3775	1 480 841	1556	252 220	1816	24 017	1510	888 854	772	289 478	674	64 735	218
1969	1 023 064	2945	1 476 106	1674	276 381	2664	23 431	1631	975 091	876	255 978	780	62 133	216
1970	1 063 616	2516	1 371 474	1857	275 610	2232	22 246	1618	1 326 865	1223	257 663	719	61 830	206
1971	1 661 840	2901	1 829 878	2251	307 873	1901	21 703	1561	1 112 466	1229	270 977	933	85 457	269
1972[b]	2 084 982	4434	1 719 194	1939	324 832	1894	21 350	1643	1 279 648	1560	252 243	1074	94 858	330
Jan.	179 417	330	242 391	243	23 859	136	1 524	113	117 628	129	50 759	219	5 188	19
Feb.	131 785	236	188 600	204	27 975	161	1 880	141	125 849	142	28 469	122	8 640	25
Mar.	198 388	369	269 711	285	33 570	194	2 743	213	128 395	137	36 974	162	6 161	24
Jan.–Mar.	509 590	935	700 702	732	85 404	491	6 147	467	371 872	408	116 202	503	19 989	68
Apr.	151 532	283	174 677	184	17 209	101	2 083	165	80 435	96	27 061	126	7 256	30
May	192 310	355	130 218	138	30 214	175	1 433	112	174 446	198	4 813	25	7 601	29
June	108 191	310	50 745	60	21 886	123	1 178	91	90 661	131	3 705	18	7 839	27
Apr.–June	452 033	948	355 640	382	69 309	399	4 694	368	345 542	425	35 579	169	22 746	86
July	209 108	395	33 937	42	34 891	196	1 778	135	84 825	102	417	2	8 746	26
Aug.	209 954	407	51 634	60	24 080	136	1 168	90	109 634	133	1 833	6	9 106	34
Sept.	217 459	484	32 221	40	22 597	127	2 051	160	68 164	90	4 292	18	8 054	25
July–Sept.	636 521	1286	117 802	142	81 568	459	4 997	385	262 623	325	6 542	26	25 906	85
Oct.	149 848	351	170 874	205	31 078	178	2 311	179	102 352	134	22 910	97	7 851	29
Nov.	151 132	406	196 931	252	33 855	211	1 626	124	95 373	126	27 159	102	9 773	36
Dec.	185 858	508	177 245	226	23 618	156	1 575	120	101 886	142	43 851	177	8 593	26
Oct.–Dec.	486 838	1265	545 050	683	88 551	545	5 512	423	299 611	402	93 920	376	26 217	91

[a]1960–64 tin concentrates only; 1965–67 tin concentrate and tin metal combined; from 1968 tin metal only.
[b]Preliminary figures.

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Minister of Commerce announced that importers of Thai cassava products could appoint their own surveyors to insure that shipments from Thailand met established standards. It is anticipated that this change will improve the quality of Thai exports and may eventually lead to higher prices for Thai cassava products.[78]

Assuming that Thai cassava exports achieve the desired quality level, what is the export potential for cassava? In recent years, root production has expanded by more than 10%/annum, owing primarily to increased acreage diverted to cultivation. If this growth rate is projected through the 1970s, production in 1980 will be 8 886 000 metric tons,[79] or 2.59 times greater than the 1970 level. However, processors and exporters believe that by 1980 their root supply will only be sufficient to allow them to export 2 million tons of processed cassava, principally in pellet form. In fresh root units, this represents a production of only 5 million tons. Therefore, those most closely connected with the trade suggest that the growth rate of cassava production will not be maintained at the 10% level but will decrease in the 1970s.

In any event, because of present production practices, an increase in cassava production is inevitably associated with a proportionate increase in land devoted to cassava. However, the current Five Year Agricultural Plan encourages expanding cassava production through higher yields without expansion of acreage. If this goal is to be realized, there clearly must be a break with prevailing production practices. The consensus of individuals with whom I spoke is that, on the one hand, production practices will not change readily, and on the other, government cannot easily restrict expanding cassava acreage.

Such a break will certainly require not only applied research on cultivation practices but effective dissemination of research findings. Perhaps the most obvious and important area of need is fertilizer application. Field trials, conducted by the Division of Agricultural Chemistry since 1954, indicated an optimum fertilizer application level for cassava of 8–8–4 (N, P_2O_5, K_2O) at 100 kg/rai (625 kg/ha). A more recent study, conducted in 1970 by FAO/UNDP, found fertilizer application to be economic for Thai cassava cultivation over a wide range of applications, with maximum profit occurring at levels of N 75.6 kg/ha, P_2O_5 15.7 kg/ha, and K_2O 30.3 kg/ha on sattahip soils (*sic*) (FAO 1970, p. 74). The results of these reports have remained largely academic, however, and have not found expression in application by cassava growers.

[78]Mathot (1972) claims that Thai cassava products receive from 1 to 4 Dutch guilders/100 kg less than their nutritional value because of lack of proper quality control.

[79]This projection is about equal to that derived from the log–log time trend model (production regressed on time), and more than that derived from the linear time trend model (Appendix Table A.2), 8 987 000 tons and 3 317 000 tons, respectively.

TABLE 71. Composition of survey of cassava producers, processors, and traders.

		Factory				Wholesale			
Province	Farmers	Starch	Chip	Pellet	Sago	Root chips	Starch and pearls	Retailers	Export
Cholburi	84	38	12	17	4	8	12	21	–
Rayong	25	8	55	7	–	5	6	10	–
Chantburi	14	–	2	–	–	–	3	7	–
Nakornrajsima	22	2	5	–	–	–	3	15	–
Prachinburi	29	–	2	–	–	5	2	13	–
Chachoengsao	58	1	7	2	–	–	1	10	–
Ratburi	46	–	2	–	–	–	2	9	–
Petburi	10	1	2	–	–	–	2	10	–
Prachuabkirikan	23	–	3	–	–	–	1	6	–
Bangkok	–	–	–	–	–	–	10	8	10
Total:	311	50	90	28	4	18	42	109	10

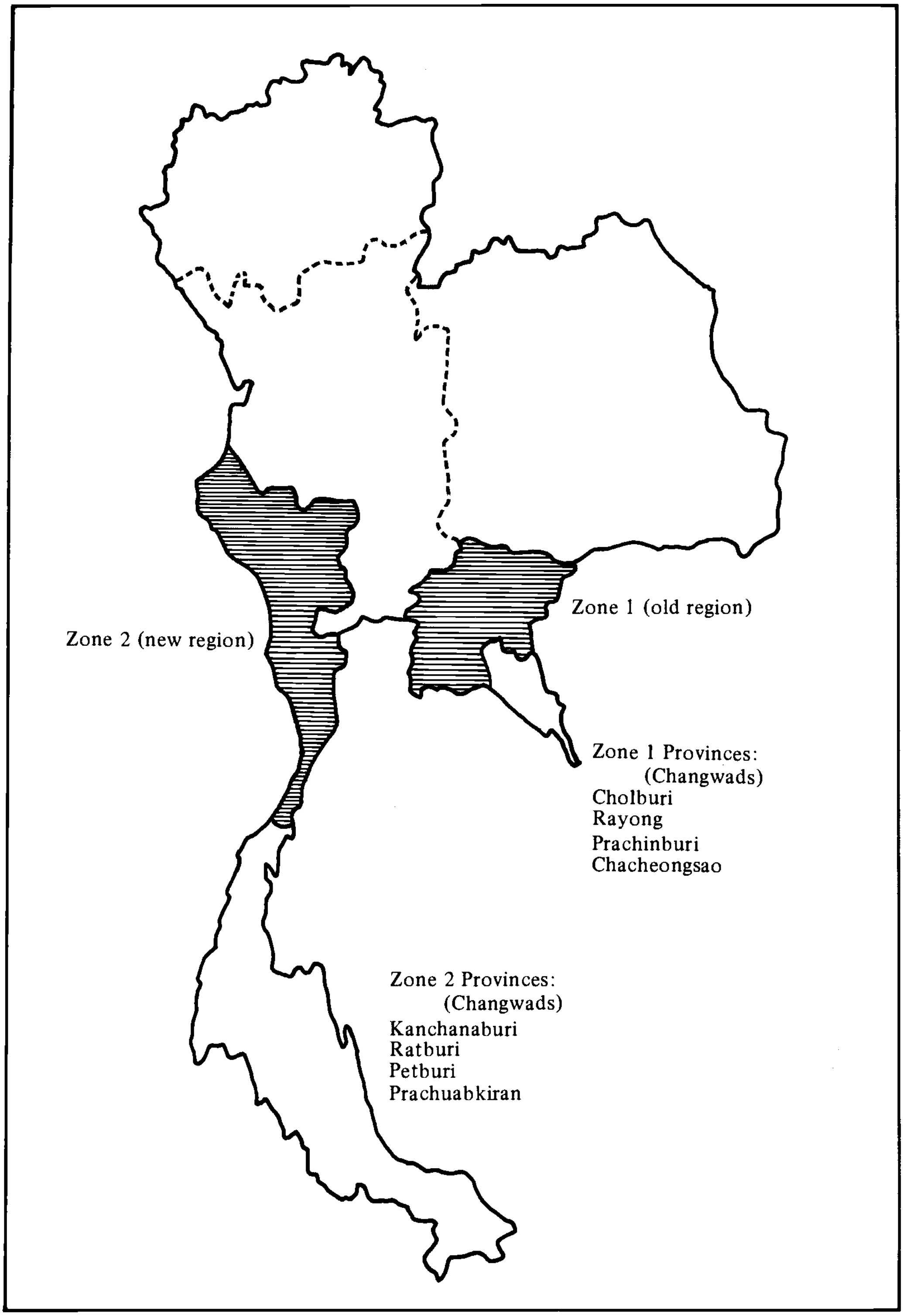

FIG. 13. Outline map of Thailand showing the cassava agro-economic zones.

Non-adoption may be accounted for by several factors. First, use of fertilizer requires a radical change of attitude on the part of Thai farmers. Second, government efforts to disseminate results and stimulate adoption appear to have been inadequate. Third, despite its technical appropriateness, fertilizer utilization may involve a liquidity problem—the farmer may not be able to afford fertilizer when needed. And finally, marginal returns to fertilizer applications are visibly greater for such crops as chilies, tomatoes, and other vegetables.

Limited research has also been conducted on spacing, intercropping, chemical weed control, and other aspects of production, but little that can be applied has emerged from these studies. The request of the Thai Tapioca Trade Association to the Department of Agriculture to conduct research on varietal selection, production methods, and fertilizer response has also failed to produce tangible results (Tulalamba 1970). The Association's observation that research efforts have been primarily concerned with theoretical and not applied research does seem appropriate.

Economics of Cassava Production and Processing

Information on the economics of Thai production and processing is of great interest because of Thailand's preeminence in the world trade of cassava. Such information may not only be useful in establishing a world standard but may also indicate areas where Thailand can further improve efficiency. For these reasons, this section draws heavily upon data reported in a survey conducted in 1972 by the Thai Department of Agriculture on all aspects of cassava production, processing, and trade (Table 71).

TABLE 72. Cost of production for different acreages of cassava (*baht*).

	Cost/rai	Cost/kg	Kg/rai
<6.0 rai	462.84	0.22	2068.29
6.0–10.9	445.19	0.24	1831.01
11.0–15.9	403.43	0.21	1965.76
16.0–20.9	395.10	0.22	1739.53
21.0–25.9	386.05	0.21	1806.03
26.0–30.9	373.43	0.18	2062.84
31.0–35.9	381.90	0.19	1964.83
36.0–40.9	397.82	0.19	2048.62
41.0–45.9	386.44	0.19	1984.67
46.0–50.9	422.24	0.22	1926.36
>51.0	392.93	0.20	1892.51
Avg:	407.99	0.21	1929.98

TABLE 73. Provincial cost of production (*baht*).

Province	Cost/rai	Cost/kg	Kg/rai
Cholburi	457.58	0.31	1456.51
Rayong	437.55	0.18	2489.97
Chantburi	430.02	0.16	2705.12
Nakornrajsima	447.86	0.26	1722.22
Prachinburi	351.76	0.18	1855.65
Chachoengsao	375.19	0.22	1718.46
Ratburi	286.70	0.12	2384.14
Petburi	382.49	0.17	2236.36
Prachuabkirikan	317.53	0.14	2249.92
Avg:	407.99	0.21	1929.98

The survey[80] is a massive work, comprising data gathered from a 25% random sample of handlers and exporters, a 50% sample of processors, and a 10% sample of producer families on a two village per district basis. In all, 35% of the districts in Thailand's nine cassava-growing provinces were surveyed. (These provinces lie primarily in the cassava agro-economic zones (Sriplung and Manowalailao 1972), indicated by cross-hatching in Fig. 13. The eastern zone is the traditional region of cassava production, with Cholburi recognized as the oldest cassava-growing region in the country. The western zone is a relatively new area of cassava production).[81]

Producer farms average 53.7 rai, with 47% of land in cassava, 17% in rice, 13% in upland crops, 5% in vegetables, 2% in buildings, and 16% devoted to other uses. The farmers interviewed were highly market-oriented; 91.5% of cassava production was sold, 4.7% went to labour perquisites, and 3.8% was held in credit.

The average capacity (potential/realized) of the processing plants were: chip plants, 16 tons per

[80]The survey was directed by Mr. Thawee, Economist, Department of Agriculture, who kindly gave his time to discuss details of the survey with me. This section draws largely from our conversation.

[81]The survey also covers Chantburi, and Nakornrajsima, not shown in Fig. 13, and excludes Kanchanaburi.

day/9 tons per day; pellet plants, 21 tons per day/14 tons per day; sago plants, 4 tons per day/3 tons per day; and starch plants, 32 tons per day/21 tons per day.

The market structure for cassava involves a movement of 91% of crop sold from farmer to handler/transporter, to factory, to wholesaler, and finally to retailer or exporter. Partnership arrangements are involved in 5.1% of sales while 2.3% involve companies. Only 16.8% of handlers deal exclusively in cassava; the remainder deal in numerous crops.

Production costs vary according to acreage devoted to cassava (Table 72), and region (Table 73). Of these two parameters, region appears to be the most important, with late-comers to production exhibiting relatively lower production costs and higher yields. Ratburi and Prachabkirikan, the provinces with the lowest production costs (287 Bht/rai and 318 Bht/rai, respectively), are both new producer areas. Production costs for Petburi, also a new cassava-growing province, are 25 Bht/rai below the average (408 Bht/rai)[82] for all farms surveyed. All three provinces rank among the highest in terms of yield. On the other hand, the province with the longest history of cassava production, Cholburi, has the highest production costs and lowest yields. Obviously, production cost is highly associated with yield, and yield, in turn, is largely a function of soil condition. In old regions, cassava has succeeded rice or other crops on already-depleted soil. Higher yields in new provinces clearly reflect better soil conditions. It should be stated, however, that cassava yields of 4 to 5 tons/rai on newly cleared land are reported to diminish to 2.5 to 3 tons/rai within 3 years.[83] Thus, lower costs in new regions may also be a consequence of better production practices and higher levels of technology compared with old established provinces.

From Table 72 it would appear that cassava is profitable at all levels of production (viz, maximum cost/kg is 24 Bht while minimum price is 26 Bht), a fact that is fully appreciated by farmers and no doubt explains the steady increase of production. Rather surprisingly, however, production costs on very large plantations are nearly as great as on very small plantations, with critical size occurring at the 26 to 31 rai level. Costs generally decrease up to this point and increase beyond it. Labour is clearly the crucial input. As indicated in Table 73 labour costs/rai are lowest for the 26 to 31 rai category, and it is suggested here that this is because that size may be the optimum scale of enterprise for the family labour unit. Beyond this level, hired labour is required. Finally, if the calculated gross returns are valid, net returns (184 Bht/rai) for this size plantation are greater than for any other category (Table 74).

The following discussion of the price structure of the cassava marketing chain draws on survey data to indicate how the margin between farmer selling price for fresh roots and the final fob Bangkok price is shared among the various participants in the chain. The reader is referred throughout to Table 75 and reminded that all prices shown apply to 1972, the year of the survey.

Surveyed farmer selling prices for poor to good quality (low to high starch content) roots range from .26 to .30 Bht/kg. Average production cost in kilograms of roots is calculated as .21 Bht, giving the Thai cassava grower a net return of .06 Bht/kg (or $35/ha). Surveyed handler/transporter selling price to chipping plants ranges from .28 to .34 Bht/kg, and the average chipping plant selling price to higher level processors is approximately .75 Bht/kg, or .31 Bht/kg in fresh root terms.[84] Thus, it appears that only if lower quality roots are purchased and/or if the chipper assumes the handling/transport function can he realize a profit. For the chipper who buys from a middleman, clearly the extremely slim margin between purchase and resale price is a great incentive for him to dilute his product with other exotic ingredients (corn cobs, rice husks, sand, etc.).

The flour (starch) manufacturer also operates within a fairly small margin, and it is probable that returns on cassava waste are largely responsible for making his operation economic. Wholesalers, retailers, and exporters of starch, however, appear to make a more substantial profit on their activities.

[82]At the current exchange, this average is equivalent to a production cost of $127.50/ha.

[83]The question of cassava as a soil depleter has been discussed in Chapter 1. It is iterated that production practice, not the crop per se, is largely responsible for soil depletion.

[84]This selling price would appear to be high, because in early 1973 commercial pelleters were paying .48 to .50 Bht/ton. It is possible that these prices differ because of some form of transportation cost.

TABLE 74. Input costs for different sized plantations (*baht/rai*).

	Size of plantation (*rai*)											
	<6.0	6.0–10.9	11.0–15.9	16.0–20.9	21.0–25.9	26.0–30.9	31.0–35.9	36.0–40.9	41.0–45.9	46.0–50.9	>51.0	Average
Labour cost	216.09	255.76	235.64	220.88	222.45	204.97	228.76	241.97	244.33	251.74	242.27	228.73
(%)	(46.70)	(57.45)	(58.40)	(55.90)	(57.62)	(54.88)	(59.90)	(60.82)	(63.26)	(59.62)	(61.66)	(56.06)
Land preparation	52.03	65.23	67.53	67.80	52.75	67.09	80.84	92.14	93.88	80.15	72.33	70.40
(%)	(11.24)	(14.65)	(16.74)	(17.16)	(13.66)	(17.96)	(21.16)	(23.16)	(24.29)	(18.98)	(18.41)	(17.26)
Planting	28.82	32.16	30.67	25.75	30.93	21.37	22.90	19.54	25.95	25.50	39.52	26.19
(%)	(6.23)	(7.22)	(7.60)	(6.25)	(8.01)	(5.72)	(6.00)	(4.91)	(6.71)	(6.03)	(00.06)	(6.42)
Cultivating	69.26	100.35	89.01	81.21	93.49	64.69	66.76	63.10	71.19	85.49	71.88	77.24
(%)	(14.95)	(22.54)	(22.06)	(20.55)	(24.21)	(17.32)	(17.48)	(15.80)	(18.42)	(20.24)	(18.29)	(18.93)
Harvesting	66.18	58.02	48.43	46.12	45.28	51.82	58.25	67.19	53.87	60.60	58.54	54.90
(%)	(14.27)	(13.03)	(12.00)	(11.67)	(11.72)	(13.87)	(15.32)	(16.88)	(13.94)	(14.35)	(14.90)	(13.46)
	17.31	13.76	12.29	9.06	9.66	11.16	5.07	9.53	5.88	8.40	6.24	8.77
(%)	(3.74)	(3.09)	(3.04)	(2.29)	(2.50)	(2.98)	(1.32)	(2.39)	(1.52)	(1.98)	(1.59)	(2.15)
Pesticide cost	13.20	–	–	–	–	–	–	–	–	–	7.56	8.50
(%)	(2.85)	–	–	–	–	–	–	–	–	–	(1.92)	(2.08)
Fertilizer cost	65.12	46.67	40.05	26.25	37.15	31.67	28.06	15.75	19.52	22.79	25.61	39.80
(%)	(14.07)	(10.48)	(9.92)	(6.64)	(9.62)	(8.48)	(7.34)	(3.95)	(5.05)	(5.39)	(6.52)	(9.76)
Transportation cost	52.88	42.75	41.50	62.36	43.27	55.00	52.19	58.46	54.67	63.63	39.83	47.28
(%)	(11.43)	(9.60)	(10.28)	(15.78)	(11.20)	(14.72)	(13.67)	(14.69)	(14.15)	(15.06)	(10.13)	(11.59)
Constant cost	98.14	86.25	73.95	76.55	73.52	70.62	67.82	72.11	62.04	75.68	71.42	74.91
(%)	(21.20)	(19.37)	(18.38)	(19.37)	(19.04)	(18.91)	(17.76)	(18.21)	(16.05)	(17.92)	(18.17)	(18.36)
Total input cost:	462.74	445.19	403.43	395.10	386.05	373.43	381.90	397.82	386.44	422.24	392.93	407.99
(%)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
Estimated gross returns[b]	558	494	530	469	487	557	530	553	536	520	511	521
Estimated net returns[b]	95	49	127	74	101	184	149	155	150	98	119	113

[a]Heading missing.

[b]Returns estimated as average yield times .27 baht/kg (average price for good quality roots). Net returns = gross returns minus total input costs. Calculations made by author.

TABLE 75. Selling price of cassava and cassava products (actual prices and prices in fresh root units (*baht/kg*).

Seller (product)	Rural dealers Lower	Upper	Average	Actual	Urban dealers Lower	Upper	Average	Actual
Farmer (roots)	.26	.30	.27	.27	–	–	–	–
Merchant (transportation)	.28	.33	.28	.28	.31	.34	.32	.32
Chippers (chips)[a]	.31	.31	.31	.71	.31	.34	.31	.71
Flour (starch)	.29	.30	–	1.58	.29	.31	–	1.64
(waste)	–	–	.10	.53	–	–	.10	.53
Flour wholesaler (transportation)	.37	.39	–	2.01	–	–	–	2.38
Flour retailer	–	–	–	–	.45	.52	–	2.49
Exporter (flour)	.39	.40	–	2.06	–	–	–	–
Pelleters (pellets)	.30	.33	.31	.78	.31	.34	.32	.81
Exporter (pellets)	.56	.64	.57	1.44	–	–	–	–
Tapioca—sago	.12	.13	.12	1.06	.13	.14	.13	1.15
Sago wholesalers (transportation)	.23	.26	.24	2.12	–	–	–	–
Sago retailer	–	–	–	–	.29	.31	.29	2.56

[a]Technical coefficients: 2.26 tons roots = 1 ton chips
2.53 tons roots = 1 ton pellets
5.29 tons roots = 1 ton flour
8.83 tons roots = 1 ton sago.

Tapioca-sago production and sale do not appear to be viable operations. The figures may be misleading, however, because tapioca production is in many instances performed in conjunction with starch production and may be complementary to it. It is possible, therefore, that the astute starch-tapioca producer may schedule production to optimize returns for given price relativities in the various markets.

Small-scale, native pellet manufacturers do not clear much above their purchase cost of chips. Actual pellet selling price (.77 to .86 Bht/kg) expressed in terms of root units ranges from .30 to .34 Bht/kg. Obviously, the profitability of this operation depends greatly on chip price—the lower the price of chips, the greater the profits to pellets. It does appear however, that production costs[85] are low (chips .05 Bht/kg; flour .08 Bht/kg; pellets .06 Bht/kg; and sago .06 Bht/kg), and therefore profits may be obtainable on what appear to be very small margins.

The greatest marginal share clearly belongs to the pellet exporter, whose selling price in root units ranges from .56 to .64 Bht/kg, giving an average fob Bangkok price of 1440 Bht/metric ton (or $72/metric ton).[86]

The participant (excluding retailers, wholesalers, and exporters of starch) with the next most profitable operation appears to be the cassava producer. In between, extremely low profit margins produce conditions which can be best described as a fragile ecological balance between entrepreneurs. The response of these entrepreneurs has been to favour the use of lower quality chips and the practice of product adulteration.

At first glance pellet manufacturing appears to be potentially the most profitable operation, starch and tapioca the most vulnerable, and chipping the economic bottleneck. A change in price relativities up the line, resulting in reduced share for the exporter or large processor-exporter could insure profitability at all levels of processing. Barring this, however, it seems likely that production of starch and tapioca will decrease relative to production of pellets.

With respect to pellet manufacturing, however, the following qualification should be made. Some

[85]These cost estimates are taken to be variable costs.

[86]This figure also appears to be high, because commercial pelleters-exporters claim that fob price is approximately $60/metric ton.

representatives of commercial processing plants believe that the purchase price of chips will increase in future. The chipper, despite his rather precarious position in the domestic cassava marketing chain, provides a service to both small and large pelleters which neither wishes nor is easily able to assume.[87] Commercial firms, whose greater volume enables them to undertake wholesale and export activities[88] profitably, can, and apparently will, tolerate higher chip prices in return for better quality. Smaller pelleters, however, will have greater difficulty in meeting increased chip prices because they may not necessarily be able to command higher purchase prices from exporters for their product. Thus, it appears that the small pelleter will prove less viable than the chipper, and that, in future, a greater proportion of pellets may be expected to be produced in larger, commercial plants.

Further Considerations

A brief glance at the price structures of other would-be suppliers to the European animal feed market indicates that Thai pellets are not in fact appreciably cheaper in terms of fob prices.[89] The real competitiveness of the Thai product rests on two main attributes:

1 Volume and consistency of supply—Thailand's ability to fulfill large European consignments regularly is possibly the most significant factor in the development not only of Thai production capacities but of the international market for cassava itself. The sheer volume, moreover, of Thai exports enables exporters to charter ships which result in substantial reduction in costs (e.g., September 1971 conference rates for pellets in bulk were $19/ton while charter rate was $14/ton; FAO 1972, p. 20).[90]
2 Entrepreneurship—Thailand's pelleting industry benefited in the first instance from foreign investment and stimulation. That events should have so combined when they did in Thailand and not somewhere else is perhaps an historical accident. The development of the industry over the past few years, however, owes little to chance and much to the capabilities of Thailand's large and small entrepreneurs. In aggregate, the Thai cassava industry has exhibited great market sensitivity, and commendable pragmatism with respect to optimization of available capabilities[91] and responsiveness in terms of price and quantity. Particularly to be commended are Thailand's small and medium operators whose flexibility and astuteness have permitted them to function under conditions of small margins and high risk that operators in many other parts of the world would consider unacceptable.

[87]Operators of large native and commercial pelleting plants specified that they did not want to get involved with drying roots. It was suggested that the small scale chippers were more efficient than any alternative the pelleting plants could provide.

[88]It is my observation that pellet production should be of the order of 40 000 tons per year in order to insure the profitability of the final wholesale activities.

[89]As indicated by the Ministry of Agriculture survey, fob price can be as high as $72/metric ton (large pelleter-exporters claim fob price of approximately $60/ton), which is still more than the Brazilian costs of $47.17/ton fob for chips (Hendershott et al. 1971), or the pellet price of $56 to $60/ton included in the budgets of several investment proposals for establishing pelleting plants.

[90]The advantage of volume exporting is reflected in the fact that shipping costs from Indonesia were approximately $10/ton more than shipping costs from Thailand.

[91]For example, in regard to chip drying, Thai processors, large and small, seem to be willing to rely on two natural endowments: sunshine, and plentiful labour. By contrast, other would-be exporters (also well-provisioned in those two inputs) favour installation of relatively expensive mechanical drying devices.

The bulk of such large tubers suggests the need for mechanical assistance in harvesting.

Chapter 8. Tapioca: A Case Study of India with Particular Reference to Kerala*

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Introduction

Tapioca (cassava) in India grows easily and produces large yields even on the poor laterite soils of South Kerala. It also grows on hill patches and slopes where the yield from other crops would be extremely low even if cultivation were possible (Government of Kerala 1964).

Tapioca in Kerala is only affected by two important diseases: "cassava mosaic" and "cercospora" leaf spot; of these, mosaic is a far more serious threat as it has principally affected important eating varieties which are preferred for domestic use. It is widely presumed that tapioca is a soil-depleting crop, but the evidence of its root systems and many experiments, as well as regular high yields from small plots over a series of years, suggest that these views are inaccurate (FAO 1971).

The greatest advantages of tapioca are: (1) high yield of calories/acre; (2) adaptability to poor soil conditions; (3) relative resistance to disease; and (4) flexibility of harvesting time.

Yield The yields of calories/ha of various crops were estimated by Ruthenberg (1971) as follows: "These (yields) amount, in kilocalories per hectare, to 2060 (millet), 4270 (maize), 7750 (sweet potatoes) and 33 800 (manioc). If we estimate the growing period of maize, millet and sweet potatoes to be 4 months and that of manioc to be 18 months, the monthly returns in kilocalories per hectare are 515 (millet), 1070 (maize), 1930 (sweet potatoes) and with manioc, which occupies the field for an especially long period, 1880." In Kerala it is extremely difficult because of rainfall characteristics (2000–4000 mm for the most important areas of the state; Government of Kerala 1964) to cultivate three continuous crops of sweet potatoes, which are best grown in rotation with rice. Tapioca is almost always harvested 9–12 months after planting. Therefore the actual yields in calories per acre or hectare are substantially above those of any other crop.

Adaptability to Soil Tapioca grows best in light sandy loams that are moist and deep, but also grows well in soils of low fertility, such as the hill terraces and slopes of red laterite which are characteristic of the Trivandrum and Quilon districts in Kerala State. The soil texture in Kerala is not friable enough to allow full development of the root systems, but planting on ridges or hillocks and substantial deep digging of the soils do produce improved yields. Certainly no other cereal or tuber crop could provide such a large supply of food from such poor soils.

Resistance to Disease The tapioca crop in Kerala is seriously affected by the mosaic disease and a major part of the work of the Central Tuber Crops Research Institute, Trivandrum, has been concentrated on the development of new "mosaic resistant" varieties. The actual effect on overall yields can run as high as 30–40% for badly affected varieties in a poor crop year, but if plant-

*This study was carried out with the aid of a grant from the International Development Research Centre, Ottawa, Canada. The views expressed are those of the author and do not necessarily represent the views of the Centre.

ing is carried out with only healthy stem cuttings, and if the diseased plants are uprooted and burned, it is possible to control the losses.

Harvesting Tapioca can be left in the garden patch or on the hill slope after reaching maturity and can be harvested for the next 6–8 months when it is required to supplement the family food supply (Ruthenberg 1971): "Manioc can stay in the soil and can be dug out when required or when time is available. Manioc is often grown in excess of need and what is not used stays in the soil as a safeguard against hunger, being harvested only when another crop unexpectedly fails." It is a very valuable supplement in Kerala to a rice ration which is heavily dependent on central government procurement policies and on the overall crop level of the rice harvest in other parts of India (Kerala produces only 60% of its annual rice requirements).

The major disadvantage of tapioca as a constituent of the human diet is its low protein and vitamin content. It is not a balanced food, as it consists almost entirely of starch (carbohydrate). Dried tapioca chips (Gaplek) or tapioca flour contains about 80% carbohydrate while peeled fresh cassava tubers contain 30–35%. The green leaves and leaf shoots are extremely rich in protein and can be eaten as a cooked vegetable, although this practice is not followed in Kerala because many local varieties drop their leaves 1 or 2 months before maturity. Tapioca also contains small amounts of vitamins B and C. The low protein and vitamin content is not a major problem in Kerala as most people are able to supplement their diets with fish, fruits, coconut products, and certain additional amounts of rice.

Some excellent work has recently been undertaken by Panikar (1972) at the Centre for Development Studies, Trivandrum. (See also "Food Balance Sheet of Kerala" Working Paper No. 6.) Panikar (1972) shows that the Indian Council of Medical Research diet surveys did not adequately take into account the importance of tapioca in providing an adequate number of calories in the basic diet and that the Planning Commission underestimated the role that fish, tapioca, and bananas could play in providing a minimum diet: "It is seen that a balanced diet can be obtained at a cost of 62.4 paise per day for an adult male ... it indicates that a diet which provides sufficient levels of essential nutrients and reasonable palatability is within the reach of most people, even in Kerala which has been identified as the state with the highest proportion of undernourished people." Panikar, in a further paper (The Level of Nutrition in Kerala), shows that the major problem is distribution of food between economic groups and the overdependence of the poor on cereals such as milled rice, and tubers such as tapioca and potatoes. This is confirmed by Jose (1973) in his study of agricultural wages: "This disparity in per capita consumption (of cereals) can be attributed to the relative predominance of tapioca in the diet pattern of the low-income households in the state." Without tapioca the poor in Kerala would starve.

Other problems of the tapioca economy in Java were described by Geertz (1963) and are paraphrased by Ruthenberg (1971). It is difficult to avoid the conclusion that the four southern districts of Kerala closely approximate the conditions described in the tapioca-growing areas of East Java: "The final stage of this type of involution consists of very small holdings, without room for cash cropping, which grow root crops almost exclusively. The families living by this type of farming are particularly poorly nourished, diseases are more widespread than elsewhere, and the extent of underemployment is particularly great" (Geertz 1963).

Nutrition in Kerala is supplemented by fish and fruit, but the level of unemployment and underemployment is worsened by the interaction of tapioca cultivation with coconut plantations and groves which have even lower labour requirements. As well, there has been a gradual decline of the labour-intensive coir industry, which once provided substantial wage employment in southern Kerala.

Tapioca Production, Cultivation, and Usage

Background and Production As background material for this section, I referred to "The Report of the Sub-Committee of the Tapioca Market Expansion Board" published in Trivandrum in 1972 and a shorter booklet "Tapioca in Kerala" by P. R. Krishna Pillai also published in 1972. These materials were supplemented by a number of State Planning Board publications, the Annual Reports of the Central Tuber Crops Research Institute, and an extensive series of interviews in Trivandrum, Quilon, Ernakulam,

TABLE 76. Indian acreage and production of tapioca tubers (raw tuber weight) (source: Report of the Sub-Committee of the Tapioca Market Expansion Board 1972, appendix 12).

	Area (*ha*)	Production (*tons*)
Kerala	295 585	4 665 764
Tamilnadu	29 135	500 000
Andhra Pradesh	2 379	9 333
Mysore	667	1 615
Assam	900	10 234
Tripura	16	56
Orissa	4	29
Maharastra	61	427
Total:	328 747	5 187 458

and Trichur districts with government officials, researchers, and processors.

First, it is essential to emphasize how important Kerala is as the production centre of tapioca in India. Although suitable soil and rainfall conditions exist in coastal Mysore, Maharastra, Andhra Pradesh, Orissa, and West Bengal, the crop has spread very little, and even today within Kerala it is largely concentrated within the boundaries of the old princely states of Travancore where the early rulers encouraged its cultivation (Table 76).

The district distribution of acreage under tapioca in Kerala is shown in Table 77 for the 1969–70 crop season. These figures reveal a rather slow growth of total acreage—a little over 20% in 9 years. The four southern districts of the state continue to account for over 75% of total production area, but the really dramatic increases have taken place in the Quilon district with a 70% rise in acreage. The 500% rise in acreage in the Palghat district is even more striking.

The production figures reveal a similar trend, although the yield per hectare has risen sharply throughout the state (Table 78) over the same 9 years. A major reason has been improved cultivation and increased plantings of M-4 and other "mosaic-resistant" varieties.

The overall output rose much more rapidly than acreage between 1960–61 and 1969–70. The yield per hectare on an overall state average rose from 7 tons/ha to over 15 tons/ha and the total output rose by 180%. Tapioca prices rose sharply from a state weighted average of 7.85 rupees/quintal in 1960–61 to a 1969–70 figure of 18.48 rupees at the farm level, while retail prices rose from 10 paise/kilo in Trivandrum/Quilon in 1960–1961 to 25 paise/kilo in 1969–70 in the same districts (Statistics for Planning, No. 5, "Prices," The State Planning Board 1972, Tables 1A and B, and 3).

Tapioca in Kerala is grown in poor soils with very limited attention paid to fertilization and cultivation. The average yields of 15 tons/ha on the 1969–70 acreage are impressive in the circumstances, although there is little doubt that proper cultivation practices, if widely adopted, would improve yields. However, at present levels of per capita consumption in rural areas, a major increase in yield without some outlet in industrial processing would lead to a sharp fall in prices. Kerala will

TABLE 77. Area (*hectares*) under tapioca by district, 1960–61 and 1969–70 (source: Statistics for Planning, No. 1, Agriculture, the State Planning Board, Table 1:11; all figures rounded).

	1960–61	1969–70
Trivandrum	56 918	62 937
Quilon	58 050	101 813
Alleppey	28 217	24 003
Kottayam	44 231	37 107
Ernakulam	17 732	15 552
Trichur	7 632	7 439
Palghat	3 351	20 628
Kozhikode	18 994	17 342
Cannanore	7 081	8 759
Total:	242 000	295 580

TABLE 78. Production of tapioca (*thousands of tons*) by district, 1960–61 and 1969–70 (source: Statistics for Planning No. 1, Agriculture, the State Planning Board, Table 1:11; all figures rounded).

	1960–61	1969–70
Trivandrum	395	823
Quilon	402	1652
Alleppey	196	574
Kottayam	307	689
Ernakulam	123	197
Trichur	530	869
Palghat	23	252
Kozhikode	131	279
Cannanore	49	109
Total:	1683	4665

TABLE 79. Population of Kerala districts (*thousands*) in 1971, and per capita consumption of raw tapioca (*kilos per individual per day*) (source: Population: "Economic Review of Kerala" 1971, State Planning Board; consumption data: Table 12 of the Sub-Committee of the Tapioca Market Expansion Board 1972).

		Consumption	
	Population	Rural	Urban
Trivandrum	2 200	0.23	0.17
Quilon	2 400	0.33	0.26
Alleppey	2 100	0.30	0.21
Kottayam	2 100	0.07	0.07
Ernakulam	2 400	0.09	0.10
Trichur	2 100	0.10	0.04
Palghat	1 700	0.03	–
Malappuram	1 900	0.11	nil
Kozhikode	2 100	0.15	0.14
Cannanore	2 400	0.15	0.04
Total:	21 300		

have to work out an integrated policy linking a package of improved practices, new varieties, and distribution of essential inputs with a guaranteed support price, and the development of major processing units for the export of tapioca products. The high level of human consumption in the southern districts of Kerala can be seen from Table 79. These levels of human consumption in the major producing districts are unlikely to grow significantly, and the bulk of the planned Fifth Plan expansion (1974–79) of 2–2.5 million tons of raw tuber will glut the market and depress prices sharply if a series of industrial processing activities are not planned in the near future.

A major increase in tapioca usage as a food is still possible if an increase in per capita consumption in the central and northern districts was promoted by the state government. However, dietary habits in India are deeply ingrained and difficult to change. Per capita consumption has risen in the course of the 1960s and is likely to continue to grow slowly, but increased production in terms of rising yields per acre should be based on a planned expansion of processing facilities and a guaranteed producers' floor price, and not on the possibility of a rapid increase in domestic usage.

Government Policies in the Past The importance of tapioca as a basic foodstuff has always rendered its trade susceptible to differing degrees of government regulation. The government relies on the Kerala Tapioca (Manufacture and Export Control) Order 1966 to control exports from the state. Any legal export (and the extent of illegal exports is unfortunately unavailable) requires a permit issued by District Collectors or District Supply Officers. There is also a levy of 75 paise/quintal of raw tuber and 1.25 rupees/quintal of tapioca chips. The authorized exports of raw tuber in 1971, mainly to the processing centre of Salem in Tamilnadu, were slightly over 400 000 tons, although it is clear that significant smuggling also takes place. (A provisional usage pattern for Kerala tapioca production will be worked out later.) The agricultural department has made desultory efforts to expand tapioca production, but it must be emphasized that the major effort of Kerala's extension services from 1960–61 to the present has been geared to the expansion of rice production, which has not been an overwhelming success. Table 80 shows the expansion of rice production in Kerala.

These results compared with the rapid growth in output and yield per acre of tapioca are poor. Tapioca, the neglected crop, grew fast (Tables 77 and 78). The failures in the rice expansion program are analyzed in greater detail by three economists working in Kerala (Raj et al. 1972), who conclude that water control failures and a failure to switch to summer-planted varieties have blunted the Green Revolution in Kerala.

The contrasting problems of rice and tapioca production are vividly illustrated by the performance of four Kerala districts. Two districts (Palghat and Alleppey) were chosen to benefit from the Intensive Agricultural District Program in Kerala, while two other districts (Trichur and Quilon) were chosen as control districts. The results are striking (Table 81).

TABLE 80. Rice output in Kerala (*thousands of tons*) and area (*thousands of hectares*) (source: Statistics for Planning No. 1, Agriculture, Table 1:11).

	Output	Area
1955–56	884	759
1960–61	1067	779
1964–65	1121	801
1969–70	1226	874
1970–71	1296	875

TABLE 81. Percentage of production in 1969–70 based on 1961–62 production (source: report on IAD program in Kerala Evaluation Series No. 9, State Planning Board, Trivandrum 1971).

	Rice	Tapioca
Palghat	127	1096
Alleppey	115	295
Trichur	141	165
Quilon	100	426

It is possible that farmers substituted the new inputs which were largely used on the rice crop (the pumpsets, fertilizers, herbicides, and pesticides) for labour inputs, and that this substitution of new inputs for labour produced the extremely poor improvements in rice yields in the state. There is little doubt, however, that the production growth of tapioca is extremely impressive given the minimal share of inputs, weak credit position, and limited extension services allocated to it.

The major problem of any extension programs directed toward tapioca in the Fifth and Sixth Plan periods will be the poverty of the average cultivator, the small size of the average holding, and the limited credit risk such a cultivator represents for even the most dynamic rural lending institution. These constraints make it very difficult for cultivators to adopt any improved package of practices, particularly where fertilizers and crop protection practices are involved. It is also difficult for the extension services to reach these small farmers.

TABLE 82. Cultivated area under tapioca by urban and rural households in Kerala (*percent*) (source: Report of the Sub-Committee of the Tapioca Market Expansion Board 1972, Tables 3 and 4).

	Rural	Urban
Not reporting	62.39	89.69
$<\frac{1}{10}$ acre	2.00	1.92
$\frac{1}{10}$–$\frac{1}{4}$ acre	8.09	3.34
$\frac{1}{4}$–$\frac{1}{2}$ acre	8.53	2.02
$\frac{1}{2}$–1 acre	10.07	1.85
1–2 acres	6.27	0.73
2–5 acres	2.45	0.25
5–10 acres	0.16	0.20
10–15 acres	0.04	-
Total:	100.00	100.00

Most farmers in Kerala grow some tapioca and the majority grow it in garden patches or plots on the hillsides, in holdings of 1 acre or less. There are very few large growers. Table 82 shows the pattern of tapioca acreage.

In the four major districts of southern Kerala, 75–80% of the growers cultivate 1 acre or less, but in Trichur and Palghat districts there are a number of large growers who specialize in supplying the processing units in Salem. Most tapioca is eaten within the household as a food, although the district pattern shows that Palghat, Trichur, and Trivandrum have the greatest quantities available for sale either for industrial processing or urban consumption. This pattern tends to confirm earlier suggestions about the district origin of shipments to Tamilnadu and the importance of growing for non-food usage in Palghat and Trichur (Table 83).

Tapioca is not only grown by the poor on extremely small landholdings; it is the major food of the poorest sections of the community. Those responsible for planning Kerala's agricultural production now recognize that the resources allocated to tapioca cultivation over the last decade are totally inadequate for the task of expanding rural real incomes. An improvement in tapioca yields with a guaranteed floor price would raise per capita food consumption and stabilize real incomes of the poorest sections of the community far more successfully than any other government policy instrument available.

Price Trends and Production Costs The data on production costs of tapioca and full details on

TABLE 83. Quantity of tapioca available for sale (percentage to total production) (source: Report of the Sub-Committee of the Tapioca Market Expansion Board 1972, Table 5).

District	Quantity available
Trivandrum	46.75
Quilon	32.21
Alleppey	33.89
Kottayam	28.51
Ernakulam	16.93
Trichur	53.35
Palghat	77.58
Malappuram	42.56
Kozhikode	38.20
Cannanore	23.02
State	39.30

TABLE 84. Average cost of production of tapioca (*per acre*) (source: Report of the Sub-Committee of the Tapioca Market Expansion Board 1972, Table 13).

Production	Rupees
Preparatory cultivation (digging)	102.14
Cost of organic manure	141.52
Cost of fertilizers	102.25
Application of manures	26.54
Cost of planting materials	26.55
Cost of planting	24.03
Weeding	39.28
After cultivation	40.65
Plant protection	3.90
Irrigation	18.23
Harvesting	45.89
Other charges	7.50
Total costs:	578.47
Average yield (*tons/acre*)	5.52
Cost of production (*rupees/kilo*)	0.11

price levels at various points in the marketing chain still await detailed research. The production costs in 1971 are shown for the south and major producing region in Table 84.

The figure for harvesting is probably too low, but these figures at least reveal the nature of the problem. The yield per acre is far too low to sustain a viable processing industry at world prices compared with Thailand or Indonesia. A farmer with 1 acre and production costs of 110 rupees or $15/ton could only produce tapioca chips at $40/ton and pellets would emerge from the processing mill at $45–50/ton. Although this is in line with the current world price of $90–95 cif Antwerp, Bremen, or Rotterdam for 2000-ton lots of good quality Thai pellets, it is unlikely to remain competitive with Thai or Brazilian producers, who can produce pellets at $35–40/ton fob or $50–60/ton cif North European ports. Shipping costs on a chartered vessel basis will add $15-20 to each ton. However, the profitability is highly sensitive to yield, as a calculation of the improved cultivation methods (see Addendum, *Package of Practices for Tapioca*) shows the cost per acre is 690 rupees and the yield is calculated on the basis of 14 tons/acre. This yield would produce a production cost of 50 rupees/ton and would move Indian tapioca chips and pellets into the world markets without payment of a subsidy after allowing normal profits to the farmers and processors.

The present level of retail prices at 25 rupees/quintal (100 kilos) or farm prices in the range 20–22 rupees/quintal are not representative of the actual selling price received by the farmers, who would be willing to sell for lower prices if they could be sure of a guaranteed floor price (Dr K. J. S. Nair, G. S. Pathak, Tapioca Products, Chalakudy, and K. Krishnamurthi, Laxmi Starch Factory, Kundara, personal communication). In 1972 the buying price for the local processing units was 150–160 rupees/ton, but this rose in 1973 to 220–250 rupees. These fluctuations hinder the development of the large-scale industry and make tapioca at present a very uncertain raw material source for starch and glucose. The prospects for an export industry based on tapioca are extremely poor at present and would have to be based on a substantial subsidy. Among the reasons for high prices are: (1) lack of adequate state government effort to expand tapioca production; (2) no legally binding contractual system, which would oblige farmers to sell to processors at a predetermined price; (3) no proper extension program to convince farmers that the new hybrids can raise yield and incomes; (4) shortage of high-grade planting material, lack of finance for the propagation program for new varieties developed at the Central Tuber Crops Research Institute, and insufficient liaison between the Central Tuber Crops Research Institute and the state extension service; and (5) the problem of credit to finance improved practices. Clearly no processing program will succeed unless there is a systematic attempt to lower raw tuber prices to processors.

Present Processing Industries At present there are two major units in Kerala: Laxmi Starch at Kundara in Quilon district and Tapioca Products at Chalakudy in Trichur district. Both produce starch, glucose, and certain other derivatives. The two plants together buy about 300 000–400 000 tons of raw tuber in an average year. There is also a sago factory at Machallur, which is working very far below its capacity, and a tapioca flour mill with a capacity of 1 ton/day based on an input of tapioca chips. There are about 50 small cottage industry starch units scattered through the state, but these units find it very difficult to produce a high-quality starch. A proposal in the period 1958–60 to establish a Tapioca Macaroni factory based on a tapioca enriched with groundnut flour and wheat semolina proved unsuccessful (Tapioca Market Expansion Board 1972). The bulk of processing activity now takes place at Salem in Tamilnadu where 175 000–250 000 tons of sago are produced in 750 units. Local production of tuber is only 500 000 tons so that at least 50% of the raw tuber requirement (500 000–600 000 tons) must be imported from Kerala, and the figure could be much higher if a proportion of Tamilnadu's 500 000-ton production is eaten as food. This figure corresponds with the licensed exports from Kerala of 400 000 tons.

The processing methods in Salem are simple. The roots are peeled. The peeled roots are then washed in two tanks and ground on perforated sheet scrapers. The shredded, finely ground material is fed to shaking sieves and the starch is sent to settling tanks and washed thoroughly to ensure production of a good-coloured sago (Tapioca Market Expansion Board 1972, p. 107–111).

In the period 1955–65 small quantities of tapioca chips from Kerala were exported to West Germany, Holland, and Belgium for conversion into animal feedstuffs, but higher local prices and rising freight costs have meant India has not been able to quote competitive cif prices in recent years.

Cultivation, Consumption, and Trading Practices
It is clear that rice in Kerala will be grown in the valley bottoms and on lower hill slopes with access to sufficient quantities of water, while tapioca will continue to be grown on the hill slopes, in the sandy soil of the coastal coconut belt, close to houses, and on patches of forest land in the process of being cleared. Tapioca is usually grown on land not considered suitable for other crops and only very rarely is tapioca competitive with rice for marginal land. It is often suggested, however, that the prices of rice and tapioca are linked. A study of the interaction of farm, wholesale, and retail prices of rice and tapioca in the period since 1959 produced no close correlation or price interaction (Tables 85 and 86), and it is probable that while there is a tenuous link there is only a limited amount of substitution possible at the consumer level. Tapioca eaters are extremely unlikely to be able to switch to the more expensive rice at times of high tapioca prices, although there may well be limited purchases by urban and middle-class rice-eaters in times of very high rice prices. There is some relationship between rice and tapioca prices but it is a tenuous one and subject to irregular fluctuation.

TABLE 85. Price ratio between average farm prices (state weighted average; 1 para of paddy to 1 quintal of tapioca).

Year	Ratio
1959–60	170
1964–65	280
1970–71	210
Avg 1954–55 to 1970–71	200

The cultivation of tapioca is relatively simple and easy. About 60–65% of the crop is planted in April–May before the monsoon, while the remaining 35–40% of the acreage is planted in September–October. The bulk of the crop is harvested from December through February and the subsidiary crop is harvested from June to August. The prices fluctuate seasonally, although November–March prices tend to be lower than those for the rest of the year. (The detailed monthly prices from 1954–55 to 1970–71 on an individual district and state level are available in Statistics for Planning No. 5, "Prices," State Planning Board 1972, Tables 1A and 1B.)

Plantings of tapioca are made directly from cuttings taken from the healthy stems of the previous year's crop. Cuttings are taken in 15–20-cm lengths from stems, which should be 2.5–3.5 cm thick. These stems in Kerala are cut at harvest and left in a hut or outhouse, which is used to store seeds, agricultural implements, etc. Often this storeroom is simply one part of the small landowner's house. The cuttings are usually

TABLE 86. Price ratio 1 kilo of rice to 1 kilo of tapioca at average retail prices (Trivandrum/Quilon) (sources: Statistics for Planning, "Prices," State Planning Board 1972).

Year	Ratio
1960	5.6
1962	3.5
1966	6.6
1970	6.0
Avg	6.3

planted vertically and there is little common practice in Kerala of ridge, flat, or mound planting. Mounds are often used on laterite soil as it makes the task of digging out the mature tubers at harvest time much easier; there is also a substantial amount of flat planting in the northern districts of the state. The cuttings are usually planted 5–8 cm below the surface. The width between the rows and the plants varies between 75 and 100 cm, although there is a tendency in small garden plots for the plants to be placed too close together for proper development of the tubers. The regular rainfall characteristics of Kerala make it possible to plant throughout the year, although in terms of starch content the April–May plantings produce the best results. It is important not to leave the tubers in the ground beyond 8–9 months for the white varieties and 10–12 months for the black varieties; after peaking, the starch content begins to fall. Water is essential in the first months of growth and this is particularly true in Kerala where the laterite soil makes it difficult for the root systems to develop if the soil in the mound or pit has not been properly cultivated. Dr N. Rajendran, the soil chemist at the Central Tuber Crops Research Institute, believes that the pit manuring system may assist the tapioca root and tuber system to develop in laterite soil and that the nutrient effect of manure (farmyard manure) may be much less important than the pit's role in tuber development in an otherwise heavy and compacted soil.

The amount of fertilizer and manure used at present is very small, suffering from the limited availability of farmyard manure as a result of the small livestock population in Kerala; the 1966 census of livestock showed only 2.8 million cattle and an additional 280 000 buffalo (Statistics for Planning, No. 1, "Agriculture," The State Planning Board 1972, Tables 1, 32, and 33). Artificial fertilizer has been used, mainly on rice and commercial cash crops, but it is difficult for small farmers growing tapioca to raise the necessary money for purchases of fertilizers or to get bagged fertilizers in the appropriate N:P:K ratios for tapioca cultivation. Certainly there is little chance for most farmers to follow the excellent package of practices recommended by the Central Tuber Crops Research Institute (see Addendum, *Package of Practices for Tapioca*).

The weeds are removed and the soil around the plant is often loosened two or three times during the first 3 months of growth, although the amount of weeding done on most garden plots is limited—usually almost no irrigation is carried out as the problem of getting water to hillslope gardens is formidable and rainfall is considered sufficient by most farmers. A certain proportion of tapioca in Kerala is still planted in the partial shade of coconut palms and there is little doubt that this shade-grown tapioca is responsible for the substantially lower yields of some plots; full development of tapioca demands a lot of sunlight and for this reason intercultivation in coconut plantations is not widely practised. After the first 3 months no further hoeing or weeding is required as the plant growth inhibits any development of weed cover. The tapioca can be harvested 9–10 months after planting. The mature tubers can usually be predicted as the leaves drop or become yellow. The tubers are harvested by removing the earth from the base of the plant, particularly if it was planted on a mound; the base of the stem is then pulled out along with the tubers. In practice, in the red laterite soil of Kerala which is baked hard by harvest time, it is usually necessary to dig out a portion of the tubers.

The tapioca tubers in Kerala are eaten boiled or roasted throughout the year as a substitute for or a supplement to rice. The typical meal of the poor in the four southern districts of Kerala is tapioca and fish, supplemented by bananas, some coconut, and in rare cases some pulses. A secondary usage is for the tapioca to be sun-dried into chips, which can be moistened and cooked, or ground into tapioca flour. Finally it is possible to parboil tapioca, which is then dried and becomes less liable to insect infestation than the untreated tapioca chips. The raw tubers can be processed into sago for consumption in West Bengal, but sago is eaten only rarely in Kerala.

Most of the tapioca crop is eaten by small farmers (Table 87) on their own farms or garden plots. However, the high figures for urban consumption in southern Kerala, and the trade with Salem, make it essential to discuss the trade and marketing channels as they affect the economic viability of industrial processing and export processing. The most common practice is for growers to dispose of the standing crop to an agent or broker for a lump sum payment. A number of these agents are particularly important in Palghat and Trichur districts where they export the purchased crop to Salem, but in Trivandrum

TABLE 87. Estimated breakdown of tapioca raw tuber usage in Kerala[a] (*tons*)

Production	4 600 000
Human consumption	3 200 000
Industrial usage within the state	500 000–600 000
Export to Salem	700 000–800 000

[a]It is very difficult to find any reliable figures, and I question Shri G. S. Pathak's estimate that only 2 000 000 tons are consumed as food (see Report of the Sub-Committee of the Tapioca Market Expansion Board 1972, appendix 19). There is no way to account for the major expansion in the four southern districts shown in Table 3 other than through increased human consumption. The limited availability of rice in the state and rising retail tapioca prices over this period would support this conclusion. The growth in Malabar district in the north was almost certainly in response to local processing opportunities, increased exports to Salem as the sago industry expanded, and increased consumption as a foodstuff, which certainly expanded in the northern districts during the 1960s.

and Quilon districts there are a number of travelling merchants, who buy, harvest, and transport the crop to the urban centre in Trivandrum. Many growers themselves harvest the crop gradually and sell to consumers or to an assembling market. This custom is common in the high consumption districts of Trivandrum, Quilon, and Alleppey. The actual sellers, who are usually women, carry headloads of tapioca to retail markets in these districts. The tapioca processing units buy direct from the field or through agents, who purchase from the growers or at the assembling market, and arrange transport to the major factories. In North Kerala dried chips are prepared and bought for shipment to two factories in Chalakudy or Kundara. In these cases agents or brokers are almost always involved.

Raw tubers can only be stored in the open for 2 days in tropical climates without deterioration and so harvesting is geared to market demand. The chips are prepared by sun-drying and can be stored in old sacks. The quality of the chips in Kerala leaves a great deal to be desired. The outside skin is dirty, the peeling is poorly done, and there are considerable inclusions of earth, woody root, and stem. The impurities and waste average between 8 and 12%, sometimes rising to 15% in seasons when prices are high. The result will not affect the quality of animal feed pellets, but it does affect the cost of starch production and leads to the manufacture of a less than fully white starch.

Research and Extension Activities of the State and Centre In 1969–70 Kerala produced 4 665 000 tons of tapioca in the raw tuber form with a farm price value based on state weighted average price of 18.5 rupees/quintal or 185 rupees/ton. The total farm price value of the tapioca crop is therefore around 90 crores of rupees (or US$130–140 million). The amount of assistance received from the state and centre governments, and the amount of time and energy devoted by the state extension service to the improvement of cultivation practices has been minimal. Most centre/state energy and inputs were poured into the somewhat less than successful rice programs ("Report on I.A.D. Programme in Kerala," Evaluation Series No. 9, 1971).

Raj et al. (1972) discussed the importance of the role of tapioca in the agricultural and dietary patterns of Kerala, and emphasized that: "The main reason for according high priority to irrigation has been the chronic rice deficit in the State and the consequent emphasis on increasing the internal output of rice."

The state government through Dr K. N. S. Nair of the State Planning Board now fully recognizes the vital role of tapioca, and the long discussion of problems at the state-level seminar held at the Agricultural College at Vellanyi, and the interest in tapioca at the research stations operated by the Department of Agriculture are all hopeful signs. At the same time, close links are gradually being forged between the state's agricultural services and the Central Tuber Crops Research Institute, which is a unit directly under the Indian Council for Agricultural Research. However, agricultural extension staff and credit institutions in Kerala need to be strengthened to improve the promotion of new practices and new varieties. The Central Tuber Crops Research Institute (CTCRI) could also become much more active in the improvement of extension and credit facilities.

The CTCRI was established in Trivandrum in July 1963 with a small budget. An area of 21 ha (50 acres) of highly suitable hillslope land was acquired by the government of Kerala at Sreekaryam, 11 km from the city of Trivandrum where the Institute has its offices, laboratories, and library, and given without cost to CTCRI. The objectives of CTCRI are: (1) The breeding of high-yielding, better-quality, disease- and pest-resistant

One of the objectives of the Central Tuber Crops Research Institute is control of the major diseases and pests that affect cassava.

varieties of tuber crops concentrating on tapioca and sweet potato; (2) Determination of the best practices for cultivation, manuring, and storage with particular reference to the soils of Kerala; (3) Survey and analysis of control possibilities of the major diseases and pests; (4) The production, multiplication, and distribution of disease-free planting materials based on improved varieties; and (5) The mounting of fundamental research on the breeding and genetic patterns of tuber crops and their agronomic, chemical, technological, and nutritional features.

The Institute has seven sections: Genetics, Crops and Soils, Crop Physiology, Plant Pathology, Entomology, Extension, and Technology, but it must be emphasized that the Institute's budget of 3–4 lakhs of rupees until 1970 ($40 000–60 000) and even its 1973–74 planned budget of 8–10 lakhs of rupees ($130 000) is certainly not sufficient for the multiple roles and tasks it is required to perform.

Among the Institute's early tasks was the building up of a germ plasm bank of different varieties of tuber crops from inside and outside India. These materials were used either directly or for research purposes. The Institute has had certain difficulties with foreign exchange and government procedures in the importing of new tapioca varieties and their planting materials, but they have developed and improved cultivation practices to produce yields of 15–20 tons/acre with hybrids such as H-165, H-226, and H-97. There has been extensive work on the development of "mosaic"-resistant varieties, which are being examined for their yield characteristics in field trials at the Central Research Farm. CTCRI has also pioneered a series of links with research institutes throughout India, which will make field trials possible in different climates and soils. The new hybrids with yields of 23–84 tons/ha will be tested outside the state on different soils, and H-97, which has been found to have a starch content of up to 30% compared with an average of 23–25% in the standard local varieties, can be developed for production in other states. CTCRI has also developed similar programs for the improvement of sweet potato yields and two new varieties H-41(2) and H-42(1) have yielded 26 tons/ha in field trials compared with the 10–11-ton yields from local varieties.

The Institute trials indicate that April–May plantings (the standard time for the main crop) produce the largest yields and that spacing of 75 x 75 cm can be used with any non-branching varieties of tapioca. (Additional details on cultivation can be found in Addendum, *Package of Practices for Tapioca*). The Institute has also established that hybrid varieties should be harvested early in the eighth or ninth month if they are to be used as food, but they must be left until the tenth month if the maximum starch content is required for industrial use. The extension wing of the CTCRI has only recently begun to expand because of a past shortage of funds, but in 1971 and 1972 a number of plots based on new varieties, and cultivation techniques and practices have been laid out in farmers' fields. The Institute plans to build up its extension service and increase the number of these demonstration plots in the Fifth Plan period from 1973–74 onwards, and will also expand its research into tapioca and tuber crop usage as (1) food, (2) animal feed, and (3) raw material for processing into pellets for export or as a base for starch, glucose, and other industrial raw materials.

The staff of the Institute in 1973 consists of over 30 scientific and technical personnel of extremely high quality, over 50 field staff and over 30 administrative staff. (This foregoing account of the work of the Central Tuber Crops Research Institute is based on discussions with Drs R. C. Mandal, C. I. Chacko, N. Rajendran, and R. Krishnan in Trivandrum and at the Research Farm, and annual reports for 1968, 1969, and 1970, and a short account of the Institute's work published in 1972 on the 25th anniversary of independence.)

Future Policy Options for Kerala and India

Usage of Tapioca as a Foodstuff It was emphasized above that the four southern districts of Kerala are unlikely to be able to absorb the amounts of tapioca which a successful extension of the new hybrid varieties could produce over the next 5 years. The result of a major increase in production from 4.6 million tons/annum to 6–7 million tons/annum would be a sharp fall in price which would reduce cash incomes for a large number of small farmers, who supplement their limited earnings from wage labour by the sale of tapioca in towns and villages.

Usage Locally as Animal Feed The government of Kerala plans a major expansion of milk production and dairy development in the state, which will require substantial quantities of fodder and supplemental feeds. At present very little tapioca is fed to cows because it is thought to fatten the animals without improving milk yields. The shortage of suitable pasture lands for hay and silage production or grazing, and the high moisture content of many local grasses, will mean that whatever grass is available will have to be supplemented with oil cakes and perhaps a 20–25% ration of tapioca pellets. In addition, pig feeds of up to 30% tapioca, and poultry feeds of up to 25% can be developed in conjunction with the livestock research unit of the State Agricultural University. The lack of appreciation of the value of tapioca meal and pellets as an animal feed is a major deficiency in Kerala's livestock development program, and CTCRI and the State Department of Agriculture should immediately begin to coordinate research studies (K. N. S. Nair and the Dairy Development Officer, personal communication). The difficulties of growing sufficient grass in Kerala would be a major factor inducing a considerable investment in these research efforts.

Industrial Usage The present level of industrial usage of tapioca in Kerala is rather low. The exact balance of industrial and human consumption is difficult to estimate, although an accurate survey should certainly precede any major investment in State-owned processing facilities. Table 87 is an estimate based on 1972–73 evidence. A possible error in Table 87 would certainly have occurred if the border districts of Tamilnadu started to eat tapioca smuggled from Kerala as a foodstuff, but there is very little available evidence on this subject.

The problems of any processing industry are considerable. The price fluctuates, supply is irregular, but above all the price level is too high at 200–250 rupees/ton to be used locally as a fodder replacement animal feed or as a raw material for pellet production for export to the EEC, whose high price policy for feed grains has opened up an enormous medium-term market for tapioca as an animal feed (International Trade Centre 1968; de Viana et al. 1972).

A policy is required which would encourage the production throughout the state of the new hybrid, high-yielding varieties to provide a basis for low-cost industrial processing. Any program would have to be carefully planned by the state and CTCRI to ensure that there was sufficient cultivation of, and research on, M-4 and the other highly prized local varieties, which have superior taste to the hybrids. Any production expansion program will run into difficulties if it is forgotten that the major usage of tapioca at present is as a major daily foodstuff; taste is more important than CTCRI realized in the past. The extension program would have to be backed by a guaranteed purchase price of 130–150 rupees/ton for raw tuber or 400–450 rupees/ton for tapioca chips (on the conservative assumption of a 3:1 ratio between tubers and dried chips). This support price system would prevent heavy losses to cultivators, who are at present dealing with a small number of brokers, who buy at prices well below the recorded farm prices and resell to processing units at much higher levels. In addition, it cannot be expected that the average cultivator will be able to use the amounts of fertilizer (farmyard manure or artificial) shown in the section on *Package of Practices for Tapioca*, but a more realistic calculation still shows that it could be grown profitably by small farmers even if jointly with a proportion of low-yielding eating varieties for household use (Table 88).

TABLE 88. Cost of cultivation and returns from hybrid varieties assuming average cultivation practices (*per acre*).

	Rupees
Cost of cultivation	600
Yield of 11 tons at Rs 150 (support price)	1650
Net income per acre	1050

This price level would produce the possibility of a viable industry processing large quantities of sun-dried chips into pellets for shipment to Europe (Table 89).

The delivered cost of 1 ton of Indian pellets shipped by a 12000-ton charter from Chochin to Antwerp or Bremen would be around $85. This price is currently below that being paid for top quality Thai pellets ($90–105), but the present price level is a result of a short crop in Thailand, limited expansion of Indonesian and Brazilian export capacity, and the worldwide shortage and price rise in feed grains in 1972 and 1973 as a result of widespread crop failures in Asia. The long-term

TABLE 89. Estimate of viability of a pelletizing unit in Kerala (cost of 1 ton); all figures rounded.

	Rupees
Raw material (1.1 tons of sun-dried chips at Rs 450)	495
Cost of processing, depreciation, and profit	50
Transport to Cochin	15
fob price	560
(less 5% cash subsidy)	28
	532
Charter cost/ton ($15)	105
cif European ports	637

level for tapioca pellets delivered to European ports is likely to be in the range of $60–70/ton (see Addendum, *A Note on Future Price Projections of Tapioca Pellets for Shipment*).

The cost of production in Kerala is unlikely to fall sharply, even if an extension program is successful, and so a state government pelletizing and processing unit would have three alternatives: (1) Reduction of the support price of dried chips from 450 rupees to 360 rupees (producing an equivalent raw tuber price of 120 rupees/ton); (2) Manufacture of local pellets for sale at a high price as well as starch and glucose. The profits from these domestic sales could be used to subsidize exports of pellets when world prices fall; and (3) Application to the Ministry of Foreign Trade's Export Development Fund, which makes payment of cash subsidies, for an increase in the cash subsidy from 5–15% of the fob value. (A general reluctance to subsidize potentially fast-growing minor commodity exports adequately has been an unfortunate feature of India's export policies since the 1966 devaluation.)

Any cut in the support price to farmers should almost certainly be delayed until 1975 or 1976 when a processing complex has been established and has built up a reputation with the European importers in Antwerp, Hamburg, and Bremen, and the extension program has had a chance to distribute the new hybrids and increase the statewide marketable surplus. The combination of 5% subsidy of 50 rupees/ton of pellets through a higher sale price for local sales from the processing unit, and an increase in the cash subsidy from 5 to 15% would enable the fob price to be cut by another 70–80 rupees and would bring Indian delivered prices for pellets more into line with the expected European price levels for 1974 and beyond (Table 90).

This price of $70/ton is still too high, but only a further increase of the cash subsidy to around 25% is likely to bring local prices into line with the offer prices of other competing producers. It must be emphasized that even this level of subsidy as a proportion of domestic value added is often exceeded substantially in the case of exports of non-traditional manufactured goods.

Steps Taken by the Kerala Government in the Field of Industrial Processing The government of Kerala has recently shown great interest in the feasibility of building a processing unit. The Tapioca Market Expansion Board (1972) was clear in its recommendation to the government: "On the assumption that the existing production will be doubled after three years, there will be a surplus of tapioca for industrial use. So the committee recommends to explore the possibility of setting up public sector factories (large scale) to produce sophisticated items like industrial alcohol, protein-enriched foods etc. in the northern region and small scale starch units in major production centres."

The actual recommendations did not include a processing plant for animal feedstuffs and pellets for local use, and its location in northern Kerala may be disputed, but the Industries and Commerce Department commissioned a study from the FACT Engineering and Design Organization which was finished at the end of 1972 (Tapioca Processing: A Feasibility Study, FEDO, Alwaye 1972). This

TABLE 90. Revised export prices of pellets from Kerala (these figures are based on a 3/1 raw tuber/chips ratio, which is very conservative; 2.5/1–2.7/1 is more likely).

	Rupees
Raw material	495
Cost of processing	50
Transport costs	15
fob price (imported)	560
(less 15% subsidy)	84
(less internal subsidy)	50
Actual fob price	426
Charter cost	105
cif price	531

study was based on the assumption that the new unit would be located in the Malappuram district, would have a capacity of 90 000–100 000 tons of raw tuber (300 tons/day) and would be capable of producing 60 tons of starch, 20 tons of dextrose and 10 tons of liquid glucose per day. It was planned to have a small cattle feed plant to use the fibrous pulp residue.

The factory cost of raw tuber was assumed to be 190 rupees/ton, and even at this high level the plant would be able to earn 8–10%, implying a breakeven purchase point of 205–210 rupees/ton (K. N. Kesava Pillai, FEDO Alwaye, personal communication).

Subsequent to receipt of this report, the government of Kerala approached the United Nations Development Program in New Delhi with a request that the United Nations Industrial Development Organization carry out a comprehensive study of the prospects for tapioca in Kerala; an agronomist would work on a policy for improvement of yields per acre, a marketing specialist would examine the markets in Kerala, India, and the rest of the world for tapioca products, and an industrial engineer would advise on the best processing techniques for a full range of end products. There are some delays in carrying out this feasibility study now, but it must be stressed that an examination of the viability of an expansion of tapioca output, the prospects for processed products inside and outside India, and the cultivation, marketing, support price, and subsidy policies required, must precede any major investment in the expansion of output through distribution of the new varieties and extension of processing units.

Conclusions A great deal of care should be taken and a substantial amount of basic research is needed before a clear set of policies can be evolved to guide the medium- and long-term development of the Kerala tapioca industry. However, some of the priorities are discussed below.

Future Policies for Tapioca Development in Kerala

Introduction Any set of policies will have to integrate the following: an improvement in yield per acre resulting from better cultivation practices and increased fertilizer use; a pricing and marketing policy providing a support price to farmers; an extension and credit program to reach the smallest farmers; and a carefully planned research program geared to the farming practices of the tapioca growers, with an industrial processing policy ensuring the highest returns possible from manufacture of starch, glucose, and other derivatives for sale in the Indian domestic market, and as animal feedstuffs for local consumption and exports. The basis of all such planned development should be a thorough feasibility study of the production of the hybrid tapioca, the viability of a support price scheme, and the correct scale and locations of the industrial processing units.

Cultivation Practices It should be accepted that all packages of practices suggested by CTCRI or the state extension service must be based on the practical possibilities of their being implemented by poor farmers on extremely small holdings. Any scheme will have to accept that these farmers need to grow a certain proportion of low-yielding "eating" varieties for household consumption, or domestic sale within a few miles of the holding. It will also have to take into account the problems of a limited supply of farmyard manure and the present lack of packaged fertilizer in the appropriate (30:30:40, N:P:K) ratio. These cultivation practices will be best demonstrated through a joint CTCRI and state extension service development of typical farmers' plots throughout the state, which use the improved methods of cultivation.

Pricing and Marketing Structure It must be emphasized that the farmer at present sells his crop at far lower prices than those shown in the statistics of "farm prices." He is extremely anxious to secure a certain amount of cash as soon as his tubers are mature and is seldom in a position to hold his new season's crop until the best market; nor is he able to arrange transport to a processing unit. It is also essential to recognize that a rise in yield per acre and overall production by 2 million tons (from 4.6 to 6–7 million tons) would almost certainly lead to a sharp fall in prices as the expansion of tapioca consumption as a major food outside the four southern districts of the state is likely to develop slowly. A processing outlet is vital for the orderly development of the industry, but a processing activity must achieve a regular and moderately priced supply of raw material if it is to operate on the scale and efficiency required to compete in world markets.

The Tapioca Marketing Board should be reconstituted and authorized to buy and store tapioca at approximately 150 rupees/ton or tapioca chips at 375–450 rupees. This arrangement would provide a fallback price for all cultivators and would guarantee a substantial and regular supply of raw material to any processing units later established.

Extension and Credit It is certain that agricultural development in Kerala will be limited and hampered unless there is a major overhaul of these vital support activities.

The extension service of CTCRI should be built up on a priority basis and should then begin a training program at the Central Research Farm for a new group of extension officers recruited exclusively for work on tuber crops. This extension program, which should also involve the State Agricultural College at Vellanyi, could be jointly funded by CTCRI from its grant for extension and the Tapioca Marketing Board of the state government.

The problem of credit stretches far deeper into the fabric of the economic structure of rural Kerala. The conventional lending institutions find it very difficult to lend to extremely small farmers, who, on less than 1 ha, grow more than 90% of total tapioca tonnage. The solution could possibly be found through extension services and a series of buying contracts for the crop worked out by the Tapioca Marketing Board. The planting material and packaged fertilizer could be distributed to farmers agreeing to grow the hybrid varieties, who would pledge their crop against these advances. The crop would be bought by the Tapioca Marketing Board after harvesting and the farmers would receive the support price per ton, less the costs of planting materials and fertilizers distributed to them before planting.

Research Programs The CTCRI should be the central coordinating agency for all work on tuber crops. In Kerala they should work closely with the State Agricultural College and the various agricultural and livestock agencies working for development throughout the state. On an all-India basis the major links would be with the Central Food Technology Research Institute, Mysore, and the Central Fodder Crops Research Institute, Jhansi, although some major links with livestock programs elsewhere within the Indian Council for Agricultural Research network should be developed to ensure the most efficient program of introducing tapioca as animal feed throughout south India. A major allocation should be made immediately to expand the extension services of CTCRI and to build an adequate economic evaluation and survey unit at the Institute. The research programs, which CTCRI is planning outside the state, should be linked to the "normal" agricultural practices of the regions and not to unattainable "best" practice standards.

Industrial Processing and its Feasibility The prospects of expanding production of tapioca tuber in Kerala through the programs described above will remain poor until a processing policy is evolved to utilize the extra 2 million tons or more of tapioca, which is the minimum expected production of the Fifth Plan.

First, any major program should include a series of plants in south or central Kerala capable of producing 5–6 million tons of pellets a year. These plants could be based in Quilon district, the major producing area at present, and close to the railways for direct shipment to silos and to a modern bulk-loading terminal located in Cochin port (which is deep enough to handle most modern bulk carriers). The complex would consume 500 000–650 000 tons of fully dried tapioca chips at 400–450 rupees/ton (or 1.5–2 million tons of raw tuber). The complex would be able to supply more than 100 000–200 000 tons of pellets to the Kerala, Mysore, and Tamilnadu livestock development programs and would be able to export the residual 300 000–400 000 tons from 1975–76 on a world market, which is expected to require 2.5–3 million tons of pellets at that time. The complex would be able to earn substantial sums (*export sales*, 400 000 tons × \$60 (450 rupees) = \$24 000 000; *domestic sales*, 200 000 tons × 600 rupees = 12 crores) by the end of 1976 operating at full capacity. The Kerala government should immediately undertake with UNDP assistance or independently, a study of a large-scale complex and should also examine the locational and economic possibilities of concentrating on three or four smaller complexes capable of producing 100 000–150 000 tons of pellets in Quilon, Trichur, Ernakulam, and Palghat districts.

A group of small units would, however, still be forced to ship to Europe through the port of Cochin. The economic viability of the tapioca pellet complexes would not affect the economics of the starch, glucose, and dextrose unit, which has been examined in the FEDO report for location in Malappuram district. A unit using only 100 000 tons/annum of raw tapioca is unlikely to make a great difference to the supply position in 1975 or 1976 if a properly integrated program of expanded production is implemented in the meantime.

Conclusions The future development of Kerala's second crop with a value at farm prices in 1970–71 of over 90 crores of rupees ($130–140 million) will depend on a carefully integrated agricultural program linking cultivation, a floor price and marketing scheme, adequate provision of extension and credit, and a practical research program using the expertise available in an expanded Central Tuber Crops Research Institute, with a major industrial processing unit or units. The goal for Kerala can be stable incomes for the poorest farmers in the state, considerable feed-stuff for its livestock program, and a substantial sum in the form of export earnings. The State Planning Board should immediately establish an interdepartmental working group to study the feasibility of these proposals and to ensure fully coordinated programs for crop development. Tapioca was neglected in the 1960s and expanded rapidly. In the 1970s a fully planned program could go far in helping the state authorities achieve their goal of substantially raising the level of per capita incomes in rural Kerala.

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S. L. Katyal of the Indian Council of Agricultural Research, New Delhi, arranged for introductions to the Central Tuber Crops Research Institute, Trivandrum, and I was able to attend a State symposium on the Package of Practices at the Agricultural College and Research Institute, Vellayani. Dr R. C. Mandal of the Crops and Soil Section and Dr R. C. Chacko of the Plant Pathology Section were extremely helpful in answering my many questions. Robert de Viana of the International Trade Centre talked to me frequently about the compound animal feedstuffs market in the EEC and any knowledge I possess in this area is due to our discussions.

This study was revised after a 2-day workshop held at the International Development Research Centre in Ottawa in June 1973.

Annotated Bibliography

Bibliographical Sources (valuable for India)

The best bibliography available on tapioca (cassava/manioc) is found in "*Cassava Processing*", *Agricultural Services Bulletin No. 8*, FAO Rome, 1971, p. 104–111.

Included are references to an Indian report on tapioca dating back to 1956 which I was unable to trace in Delhi or Trivandrum. There are also references to the work of V. Subrahmanyan, P. B. Mather, S. K. Majumder, and S. Kuppuswamy concerning spoilage of raw tubers, dehydration, tapioca flour as a feeding supplement, and starch recovery. Most of this work was carried out at the Central Food Technology Research Institute in Mysore during 1956–62. It was during this period that the Institute produced its Tapioca Macaroni which was demonstrated without success in 1958–60.

The limited work cited on the food uses of tapioca and the lack of work on the value of tapioca as an animal feed or its processing into pellets for export suggests an urgent need for the Indian Council of Agricultural Research to initiate a research program linking the Central Tuber Crops Research Institute with the Central Food Technology Research Institute, Mysore, and the Central Fodder Crops Research Institute at Jhansi in Bihar.

Further research at these three institutes combined with the agricultural universities should become a major source of information on future developments.

Government Publications

Central

The *Annual Reports of the Central Tuber Crops Research Institute* (1968, 1969, 1970). These reports contain much valuable information on the research projects being undertaken, but they are written for use by other agricultural scientists. It would be useful if a shorter, more general report could be issued for extension workers, government officials, and farmers. This report should be available in Malayalam and would record work of practical value carried out during the year and its possible use by farmers.

Package of Practices for Tapioca, CTCRI, Trivandrum, 1972 (see Addendum).

State

Report of the Sub-Committee of the Tapioca Market Expansion Board 1972, Trivandrum, 1972. This report is the most comprehensive and valuable document written on tapioca in India. It was prepared over 2 years and the members of the committee were growers, government officials, processors, and representatives of CTCRI and other organizations. A large quantity of material can be found in the multiple appendices to the report, but some vitally important economic questions are left unanswered. However, without the report my own work would have been very difficult to complete.

Kerala in Maps, Bureau of Economics and Statistics, Government of Kerala, Trivandrum, 1964. This publication gives excellent information on rainfall and soil conditions in the state, although the production data on tapioca are out of date.

Report on Intensive Agricultural District Programme in Kerala, Evaluation series No. 9, State Planning Board, Trivandrum, 1971. This is an excellent account of the failures of IADP in Kerala, which faithfully records the poor performance in rice production and the massive output and per acre yield increases in tapioca.

Tapioca in Kerala by P. R. Krishna Pillai, Bureau of Economics and Statistics, Trivandrum, 1972. This is a short and somewhat derivative study which is valuable for its plea for comprehensive planning and export promotion of tapioca products.

Statistics for Planning, No. 1 Agriculture, No. 5 Prices, State Planning Board, Trivandrum, 1972. These are excellent documents, which bring together state and district statistical series from the early 1950s.

International Publications

Cassava Processing, Agricultural Services Bulletin No. 8, FAO Rome, 1971. This superb publication gives comprehensive background data on the growth, consumption, and processing of tapioca throughout the world, although unfortunately it contains very little information on the techniques and costs of producing tapioca pellets for animal feedstuffs.

The Markets for Manioc as a Raw Material for the Manufacture of Compound Animal Feeding-Stuffs in West Germany, the Netherlands and Belgium, International Trade Centre, Geneva, 1968. This is the first detailed report on the enormous growth potential for tapioca (manioc) as a low-cost animal-feed ingredient, which can enter the European Economic Community as a result of a 6% tariff compound with the immensely high variable levies imposed on imports of feedgrains such as maize, wheat, and barley.

Books and Articles

Farming Systems in the Tropics, by Hans Ruthenberg, Oxford, 1971. This is an excellent source book for economists or agricultural economists with limited knowledge of tropical crops and soils.

I also used the conclusions of a number of working papers prepared at the Centre for Development Studies, Trivandrum, by K. N. Rai, P. G. K. Panikar, T. N. Krishnan, and A. V. Jose. All these papers are based on Professor Raj's belief that a concentration on planning at the state and district levels will produce extremely interesting results. The early *Working Papers No. 1–8* on state-level planning, nutrition, and agricultural wages are all useful and stimulating.

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ADDENDUM

Package of Practices for Tapioca

Tapioca is one of the subsidiary starchy (25–30%) food crops grown mostly in Kerala, parts of Tamilnadu, and Assam. Recently, the Central Tuber Crops Research Institute, Trivandrum, has evolved some hybrids (H-97, H-165, H-226 and others) which can produce two to three times more yield than the local varieties. On the basis of results of research and experience gained, the following package of practices is recommended for increasing the production per unit area.

Soil and Climatic Condition

Tapioca is essentially a tropical crop which grows well in well-drained laterite, gravelly, sandy loam, or red loam soils. The crop is susceptible to frost and severe winter. It requires a well-distributed annual rainfall of 1500–2000 mm.

Site Selection and Preparation of Land

Tapioca can be cultivated profitably on hill slopes, waste lands, and areas where normal cultivation is difficult. The land should be ploughed two or three times or dug to a depth of 25–30 cm (9–12 inches).

Planting Material

Tapioca is propagated from cuttings obtained from mature, healthy stems. Discarding the immature top portion, 6–8 cuttings of about 15–20 cm (6–8 inches) can be obtained from a mature stem. Planting is done in a square alignment at a spacing of 90 × 90 cm (3 × 3 ft) and thus 4840 sets/acre or 12 100 sets/ha are required for planting.

Time and Method of Planting

Tapioca is generally planted in April–May with the onset of the "southwest" monsoon. Planting can also be done in September taking advantage of the "northeast" monsoon. Under irrigated conditions, planting can be done throughout the year provided there is sufficient moisture in the soil.

Cuttings are planted vertically, after smoothing the lower portion, 4–6 cm (2–2.5 inches), in the soil. Flat, ridge, or mound method of planting can be adopted considering the soil type, topography, and water table of the land. The "pit followed by mound" method and localized placement of manures and fertilizers in the pit are best.

Manuring

Cattle manure or compost may be applied at 12.5 tons/ha (5 tons/acre) during the preparation of the land. (Application of organic manures at 0.75–1 kg/pit is better than spreading the manure in the whole area.) Tapioca responds well to 75 kg nitrogen, 75 kg phosphorus, and 100 kg potash per hectare (30:30:40 kg N:P:K/acre approximately) applied as fertilizers in two split doses as shown in the schedule below (doses in kg/ha (kg/acre)):

Fertilizer	Application: Time of planting	Two months after planting
Calcium ammonium nitrate	190(80)	190(80)
or		
Urea	85(35)	85(35)
Super phosphate	235(95)	235(95)
Muriate of potash	85(35)	85(35)

Instead of straight fertilizers, fertilizer mixture (8:8:16) can also be applied, 620 kg mixture, 156 kg super phosphate, and 35 kg urea/ha in two equal split doses (250 kg mixture + 22 kg urea + 62 kg super phosphate/acre). In acid-laterite soil, application of 1 ton/ha of lime (0.4 ton/acre) will be beneficial.

Intercultivation

Removing the weeds and loosening the soil by light digging or hoeing may be done two to three times, up to 3 months, followed by light earthing up. Excess shoots should be removed after retaining two per plant (about 6 weeks after planting).

Irrigation

Irrigation is not necessary for tapioca when the rainfall is well distributed. Irrigation may be done at the time of planting if there is a long dry period. Depending on the soil moisture, three to five irrigations may be provided to overcome the drought period. It has been observed that irrigated crops yield about double that of the rainfed crop.

Rotation and Mixed Cropping

Tapioca can be rotated with maize, banana, yams, etc., with proper fertilization once in 2 years.

Intercropping with short duration leguminous crops like groundnut or cowpea is advantageous and economical.

Plant Protection

The two important diseases of tapioca are "cassava mosaic" and "cercospora" leaf spot. The mosaic disease is apparently transmitted by the insect vector, *Bemisia* sp. (white fly). As a rule, only stem cuttings from healthy plants should be used for planting to minimize the spread. The diseased plants should be uprooted and destroyed when the symptoms are visible. Spraying 0.03% dimethoate (Rogor) three to four times at monthly intervals in the first 4 months of the crop controls the "vector" and thereby controls the spread of the disease. The leaf-spot disease can be controlled by spraying "Bordeaux" mixture (5:5:50) three to four times.

The insect pests like red mites and scales which attack tapioca plants can be controlled by spraying with "Rogor" 0.03%, Metasystox 0.05%, or folidol 0.05%.

Harvesting

Tapioca becomes ready for harvest 9–10 months after planting. Harvesting is done by removing the soil from the base of the plants and pulling out the tubers by holding the basal portion of the stem.

Yield

The hybrids like H-165, H-226, H-97, and others, along with improved agronomic practices recorded on an average 40–50 tons of tuber/ha (15–20 tons/acre), while the local varieties including M-4 produce 12–14 tons of tuber/ha (5–6 tons/acre).

Cost of Cultivation and Net Income

The cost of cultivation varies from place to place, and under Trivandrum conditions, the cost of improved methods of tapioca cultivation comes to 1700 rupees/ha (690 rupees/acre). Presuming the average yield of 14 tons/acre and prevailing market rate of tuber at 160 rupees/ton, the gross income comes to 5500 rupees/ha (2230 rupees/acre) and thus the net income is expected to be 3800 rupees/ha (1540 rupees/acre).

A Note on Future Price Projections of Tapioca Pellets for Shipment to EEC Markets

The world shortage of feed grains (maize, wheat, and barley) and high EEC prices as a result of the variable levy which inflated prices so sharply in 1972–73, is likely to continue into 1974. The demand for tapioca will expand as the United Kingdom, Eire, and Denmark gradually switch from open import policies to high feedgrain prices. At present there is no sign that a radical shift in the Common Agricultural Policy is likely to take place as far as feed is concerned. My discussions in March and April in Hamburg and Rotterdam with leading importers and compounders revealed that pellet prices had risen as follows (in US$ fob Bangkok): December 1970, 35–40; December 1972, 60–65; and March–April 1973, 75–80. This price for top-quality Thai pellets produces, after charter shipment is arranged to European ports, at around $90/ton.

It is clear that with normal crops of tapioca in Thailand and an expansion in feedgrain production these price levels will not be sustained. Furthermore high prices will stimulate increased plantings and further processing investments in Latin America (Brazil), Indonesia, Malaysia, and India. Future prices might stabilize as follows (pellet prices fob, developing countries): 1973, $75–80; 1974, $70; 1975 and 1980, $60–70. This price level would partially reflect the devaluation of the US dollar since 1970 as well as a steady rise in charter rates from 1971. Certainly a target price of $60/ton is possible given Europe's rapidly rising demand for animal feedstuffs and the potential for increased usage of tapioca-using compounds.

Indian Currency and Weights: A Key

100 paise = 1 rupee
7.50 rupees = 1 US dollar (approx.) (1/5/73)
1 lakh = 100 000 rupees
100 lakhs = 1 crore
1 crore = 10 000 000 rupees
1 quintal = 100 kilos
10 quintals = 1 metric ton
1 para (of paddy) = $16\frac{2}{3}$ lb

In its few years of existence, CIAT has amply illustrated that the potential of cassava has been scarcely topped.

Chapter 9. Research Recommendations

The raison d'être of this study, as conceived by IDRC and CIAT, is to derive economically based priorities for research in cassava. From the beginning it was apparent that any comprehensive statement on research priorities should be preceded by a quantitative and qualitative survey of on-going or completed work, not only to provide building blocks for future research activities, but to point up areas of research needs. Ideally, such a directory would classify research by type and region to facilitate flows of information between individuals, organizations, institutions, and countries[92], as well as to avoid duplication of work.[93] Unfortunately, such a directory does not appear to exist, and its compilation is clearly beyond the scope of this study. Therefore, the first recommendation forwarded by this report is that a comprehensive survey of past and present cassava research, classified by type and region, be undertaken.

A general bibliography, presently being compiled at CIAT, should go a long way, when completed, toward realizing this recommendation, but even this bibliography may fail to include a sizeable body of information which is unpublished or of limited circulation. In these cases, the individual cassava researcher must be the main instrument for channelling obscure data to a wider audience. Possibly, systematic collection of this hidden wealth of information can be undertaken in cooperation with CIAT in an effort to encourage, centralize, and facilitate the collection and use of cassava research data.

The following other recommendations are forwarded:

Breeding

The study reveals that the demand for cassava, present and future, is a demand for carbohydrate. Therefore, selection and breeding which improves starch yield per tuber, per unit land, and per unit time is highly desirable.

- It should be recognized that the three cassava markets require different types of starch. The human market may require high amylopectin and low amylose starch, while the relative content of amylose and amylopectin is not so important for animals. Amylose content of cassava may be more important in starch manufacturing. It is recommended, therefore, that selection and breeding work screen varieties according to the properties demanded by the different markets.
- The properties of different cassava varieties at different stages of maturity should be explored. Tuber properties which should be specifically examined are: protein and starch content, composition, and digestibility; vitamin availability and suitability for digestion; viscosity, gelling, and other starch properties; pest, virus, and bacteria resistence; drought and flood tolerance; adaptability to different soils; HCN content; and yield. Research should be directed at determining both physical and economic optima.
- It is recommended that breeding for a high protein cassava be given low priority. Protein content of cassava is unimportant in starch and animal feed manufacture. In some circumstances, high protein content is a disadvantage—protein is considered a waste product in starch manufacture, and in

[92]For example, results of pre-World War II Dutch selection trials conducted in Indonesia are generally thought to have been destroyed. Yet Dr M. M. Flach has informed me that almost all of the reports of this research activity are available in the University of Wageningen archives.

[93]Such a directory will help to avoid intra-regional redundancies as well. For example, in Malaysia, both NISIR (National Institute of Scientific and Industrial Research) and the Ministry of Agriculture's Crop Promotion Division are working on the development of small-scale cassava chipping and pelleting machinery. The disadvantages of duplication in this case are not readily apparent, since the resulting machinery is quite different. However, it is possible that joint effort could have produced a machine that is perhaps even superior to the first two.

European animal feed rations with maximum protein constraints, a high protein cassava (say, 6–10%) could actually inhibit use of cassava in the formula. However, if cassava is used in LDC feed compounding, price relativities might be such to make a high protein cassava desirable. This possibility requires further investigation. Where the human market is concerned, high cassava consumption coupled with regional protein deficiency and poor protein distribution within the family unit suggests that a higher protein cassava could be beneficial. However, in terms of essential amino acids, cassava protein is not of high quality, and there seems to be little evidence to show that an increase in crude protein results in an improvement of cassava protein quality. On the other hand, cassava may be efficient as a protein carrier or growth medium when fortified or used as a substrate. These latter aspects should receive continued attention.

Cultivation

- The great part of cassava cultivation is presently and presumably will continue to be small scale. In this context three areas of research are recommended: (a) selection of improved varieties which will grow under small-scale, traditional production conditions; (b) development of appropriate cultivation methods designed to support the use of improved but perhaps less hardy varieties; and (c) identification of production practices which are economically applicable to small-scale production.
- Labour-saving or production-increasing machinery that is compatible with small-scale production should be developed. All aspects of cassava production could benefit from improved tools. Such machinery should, in most instances, be labour-augmenting and not labour-replacing.
- On the other hand, estate cultivation will likely become more common in the future—many would-be exporters base their export potential on estate production, while in some places large-scale cultivation already occurs as an adjunct to intensive poultry systems. Thus, techniques and machinery suitable to large-scale production are also required. Harvesting machinery is one area of particular need.
- Development of space-economizing harvesting, storage, and handling methods will release valuable land to other uses. Cheap storage methods, by permitting more consistently available supply, could enable existing cassava processing plants to more fully realize production capacities (or, alternatively, existing production could be generated by smaller plants).
- Research is required on intercropping. For example, field work might show that a less leafy variety is best suited for intercropping (that is, tuber yield may decrease with thinly-leafed varieties, but yield of intercalated crops could increase, with a net effect of gain in production and income). Studies of cassava intercropping with rubber and oil palm are available, but information on intercropping with legumes or cereals does not appear to be available.
- The notion of cassava as a soil depleter should be examined, as must be the counterargument that soil depletion is a result of poor production methods and consequent leeching. If the latter contention proves to be correct, development of improved production practices is obviously necessary.
- The economics of cassava production must be understood in regional contexts. For example, while the advantages of fertilizer application may be amply demonstrable for cassava production in general, regional variability of availability and cost of fertilizer, and relative marginal returns to its application may preclude its use in some areas, or for certain sized farms.
- The results of varietal and cultivation research should not reduce the usefulness of cassava as a risk-aversion crop. Thus, higher yielding varieties which are more susceptible to complete failure should not be encouraged at small-scale or subsistence levels.

Processing

- Rapid transformation of roots to a less perishable state through drying, soaking, and/or fermenting is critical to the production of many cassava products. Further study is needed in the drying of sliced or chipped roots. Initial CIAT findings are that cassava's α solar absorption coefficient is low and that ambient temperature and air circulation are the most important factors in drying. This finding calls for confirmation in numerous environments. Furthermore, cassava's low α value (provided this can be preserved under treatment) suggests another possible use for cassava (e.g. as a solar-reflecting paint).
- Processing of chips and pellets requires research at the small-scale, farm-cooperative level and the large-scale, commercial level. The latter is fairly well researched, but methods for optimum pre-heating before pelleting, or post-pelleting cooling do not seem to be available—perhaps this information is kept at limited circulation for commercial reasons. Research on small-scale pelleting machines must be done with a view to costs and market requirements, viz, density and friability of pellets. Furthermore, research should be undertaken on the comparative advantages of different chip size and form. The cassava bar (measuring $1 \times 1 \times 5$ cm), presently under consideration at CIAT, for example, could replace the pellet if the former can be shown to have the physical properties required by the market and to be manufacturable at a competitive price.

- Technical and economic research relating to the use of cassava as an animal feed in LDCs through compounding or micro-biological processes seems justifiable and appropriate. Although it was not possible in the course of this study to assess quantitatively the scope for using mixed or complete feeds in LDC livestock production, it does appear that cassava could play an important part in the future livestock production of LDCs if the availability of appropriate products accompanies the emergence of that market.

- Research on the production of cassava starch and modified cassava starches is required. This work should be conducted in the context of the needs of external markets as well as existing and emerging domestic starch markets. As cassava-producing LDCs expand their industrial base and experience greater requirements for starch, development in this area may be important in obviating importation of foreign starches.

- Research into the development of cassava foods for human consumption (flours, breads, cakes, baby foods) should continue with a view to price and market acceptability, viz. if white bread is not normally consumed in a given region, it is not apparent that the development of a white cassava bread will be a successful innovation, as seems to have been the case in parts of West Africa.

Marketing

- Cassava products are not unique and can be replaced by other commodities when economic or political reasons demand. For exporters, therefore, a global marketing research service which monitors developments in the industrial starch and animal feed markets seems necessary. Such a service, in the form of periodical publications, could provide information on marketing trends which will enable LDCs to plan investments.

- Greater information is required in producer countries on the domestic markets for cassava. There is a need to bring producers, processors, and consumers together to promote flows of information and to coordinate development of potential markets. It should be pointed out in this context that the adoption of technologies from developed countries is often taken to be synonymous with use of developed country inputs. It is important for producers and processors to realize under what conditions an indigenously produced input, such as cassava, can do the job equally well.

Systems

- The results of research on breeding, cultivation, processing, economics, and marketing should be brought together into a more comprehensive study of the "cassava system". Analysis of this system will point up research bottlenecks and weaknesses. Moreover, the creation of such a system will enable the appropriateness of research results to be judged and will promote the smooth introduction of new findings into the system.

In summary, the major research need, as determined by this study, is that of applied research into cassava breeding, cultivation, processing, economics, and marketing. Existing and potential cassava markets[94] require an immediate supply of cassava and cassava products. In many instances the ability of producers to meet these demands depends upon the availability of better varieties, production and processing practices, and economic information which to date may not have been researched. A failure to realize some of these markets in the first instance may in fact mean a loss of the market and a financial hardship for certain producers. Thus it would appear that great returns could be achieved by research which is quickly available and easily adopted. A need for short-run research should not necessarily be seen as a diminuation of long-run studies; rather it is an indication that there are a number of problems requiring simple answers which, if researched, can be solved in a relatively short time. The point should also be made that because a problem appears difficult and requires long-run research, this is not sufficient justification for establishing research priorities. Cassava is a crop which is prized for its durability, ease of cultivation, flexibility, starch content, and price. Therefore, it would seem that research, long or short term, which enhances these attributes should be given highest priority.

The promoter of the export of cassava must temper his enthusiasm for cassava as an earner of foreign exchange by the realization that these markets, primarily the animal feed market, are less certain than the markets for traditional LDC agricultural exports. For this reason, it could be wrong to commit substantial resources to a long-run cassava export scheme. Nevertheless, the promotion of cassava for short-run foreign ex-

[94]For example the non-human domestic market and the Japanese animal feed market.

change earnings would appear to be profitable. The concurrent development of expertise in all phases of the "cassava system" will, moreover, have long-run pay-offs closer to home in terms of domestic application, particularly where home markets come to equal or exceed in importance foreign demand. In this sense, the present export market has given a new perspective to cassava and has focused attention on what it *is* and what it can *become*.

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Appendix A

Summary of Cassava Production Time Trend Models and Cassava Production Projections

TABLE A.1. Coefficients of production acreage and yield time trend regressions.

ARGENTINA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	242.40	2.464	0.42	5.49	0.009	0.41
ACREAGE	18.60	0.397	0.68	2.93	0.018	0.66
YIELD	128.90	-1.044	0.77	4.86	-0.009	0.77

BOLIVIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	44.46	10.690	0.90	4.09	0.086	0.87
ACREAGE	0.12	0.983	0.93	0.97	0.121	0.93
YIELD	215.80	-5.396	0.96	5.41	-0.034	0.95

BRAZIL

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	13383.00	1094.000	0.97	9.56	0.051	0.97
ACREAGE	1075.00	64.470	0.97	7.02	0.041	0.97
YIELD	127.30	1.307	0.93	4.85	0.010	0.93

COLOMBIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	1776.00	-42.430	0.30	7.47	-0.032	0.32
ACREAGE	273.60	-7.900	0.45	5.65	-0.041	0.50
YIELD	61.75	0.700	0.23	4.15	0.008	0.17

ECUADOR

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	111.70	17.900	0.90	5.01	0.062	0.90
ACREAGE	14.58	1.622	0.91	2.86	0.054	0.91
YIELD	83.04	0.974	0.51	4.42	0.011	0.50

PARAGUAY

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	561.50	73.900	0.78	6.39	0.070	0.55
ACREAGE	48.01	4.561	0.92	4.00	0.051	0.92
YIELD	146.00	-0.214	0.20	4.98	-0.001	0.20

PERU

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	287.30	15.230	0.85	5.67	0.040	0.85
ACREAGE	25.69	1.262	0.61	3.17	0.044	0.67
YIELD	123.60	-0.636	0.19	4.80	-0.004	0.15

VENEZUELA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	228.40	7.526	0.75	5.41	0.030	0.75
ACREAGE	33.50	0.028	0.02	3.48	0.002	0.04
YIELD	80.61	1.536	0.24	4.23	0.028	0.37

CEYLON

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	172.10	14.620	0.84	5.16	0.056	0.83
ACREAGE	46.56	0.943	0.35	3.81	0.019	0.40
YIELD	42.08	1.563	0.50	3.65	0.038	0.57

TAIWAN

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	123.90	12.990	0.94	4.89	0.061	0.94
ACREAGE	10.94	0.681	0.94	2.42	0.044	0.93
YIELD	116.50	2.169	0.75	4.76	0.016	0.76

INDIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	860.50	247.900	0.91	7.20	0.083	0.92
ACREAGE	218.00	7.258	0.80	5.41	0.025	0.80
YIELD	53.18	5.822	0.89	4.10	0.057	0.88

INDONESIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	10984.00	17.160	0.10	9.30	0.002	0.12
ACREAGE	1318.00	14.900	0.54	7.18	0.011	0.56
YIELD	83.42	-0.729	0.80	4.42	-0.009	0.80

W. MALAYSIA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	202.30	9.091	0.79	5.37	0.030	0.79
ACREAGE	13.20	0.436	0.57	2.59	0.026	0.59
YIELD	160.30	0.816	0.18	5.08	0.004	0.16

PHILIPPINES

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	419.90	7.407	0.35	5.99	0.020	0.42
ACREAGE	76.73	0.877	0.40	4.32	0.012	0.45
YIELD	53.29	0.447	0.32	3.97	0.008	0.35

THAILAND

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	491.90	113.000	0.85	6.08	0.121	0.85
ACREAGE	33.44	7.494	0.90	3.46	0.114	0.87
YIELD	145.90	0.278	0.05	4.93	0.007	0.17

VIET NAM N.

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	920.60	-14.130	0.64	6.83	-0.018	0.64
ACREAGE	109.80	-0.591	0.17	4.67	-0.004	0.11
YIELD	86.85	-1.127	0.68	4.47	-0.015	0.69

VIET NAM S.

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	242.60	1.631	0.12	5.43	0.011	0.20
ACREAGE	42.80	-0.432	0.25	3.74	-0.010	0.23
YIELD	53.66	1.374	0.72	3.99	0.021	0.71

ANGOLA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	1001.00	40.230	0.97	6.96	0.028	0.97
ACREAGE	99.77	1.409	0.96	4.61	0.012	0.96
YIELD	103.50	1.950	0.91	4.65	0.016	0.91

BURUNDI

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	133.40	78.160	0.81	6.12	0.068	0.83
ACREAGE	-31.35	10.970	0.70	3.41	0.091	0.68
YIELD	141.50	-2.148	0.32	5.01	-0.023	0.39

CAMEROON

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	504.20	32.150	0.83	6.27	0.041	0.83
ACREAGE	38.04	10.340	0.88	4.01	0.085	0.91
YIELD	93.28	-2.935	0.90	4.56	-0.043	0.91

CENTR.AF.REP

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	947.30	5.455	0.52	6.86	0.005	0.52
ACREAGE	194.70	0.545	0.52	5.27	0.003	0.52
YIELD	48.74	0.130	0.52	3.89	0.003	0.52

CHAD

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	41.53	0.654	0.15	3.60	0.022	0.24
ACREAGE	-1.34	1.336	0.87	0.97	0.138	0.81
YIELD	84.96	-3.933	0.73	4.53	-0.079	0.76

COMORO IS.

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	-19.86	7.955	0.88	2.53	0.142	0.87
ACREAGE	6.16	1.382	0.89	2.27	0.069	0.88
YIELD	7.53	2.038	0.85	2.54	0.075	0.85

CONGO BRAZZ

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	1119.00	-49.550	0.84	7.19	-0.081	0.82
ACREAGE	169.40	-4.636	0.72	5.16	-0.036	0.70
YIELD	71.23	-2.160	0.87	4.34	-0.045	0.86

CONGO REP

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	6857.00	51.510	0.22	8.83	0.006	0.18
ACREAGE	629.20	0.266	0.02	6.44	0.000	0.00
YIELD	109.30	0.712	0.28	4.70	0.005	0.26

DAHOMEY

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	1166.00	-12.490	0.30	7.07	-0.014	0.32
ACREAGE	234.60	-5.843	0.70	5.52	-0.036	0.70
YIELD	47.31	1.239	0.73	3.86	0.022	0.73

EQUAT GUINEA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	35.92	0.445	0.81	3.59	0.011	0.81
ACREAGE	11.32	0.227	0.41	2.44	0.016	0.40
YIELD	31.93	-0.188	0.22	3.46	-0.006	0.21

GABON

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	130.10	0.655	0.14	4.87	0.004	0.13
ACREAGE	33.55	1.913	0.89	3.56	0.039	0.88
YIELD	37.69	-1.095	0.63	3.61	-0.035	0.59

GHANA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	649.60	69.830	0.81	6.61	0.054	0.85
ACREAGE	52.25	9.603	0.87	4.11	0.080	0.86
YIELD	122.70	-2.701	0.63	4.80	-0.026	0.60

GUINEA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	369.20	7.031	0.80	5.91	0.017	0.79
ACREAGE	41.60	-0.898	0.44	3.65	-0.019	0.39
YIELD	106.50	3.378	0.54	4.56	0.036	0.55

IVORY COAST

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	851.70	-18.360	0.36	6.71	-0.025	0.35
ACREAGE	158.70	2.195	0.32	5.05	0.014	0.36
YIELD	52.49	-1.494	0.55	3.97	-0.038	0.52

KENYA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	575.20	3.000	0.85	6.36	0.005	0.85
ACREAGE	85.93	0.436	0.89	4.45	0.005	0.89
YIELD	67.58	-0.044	0.49	4.21	-0.001	0.49

LIBERIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	420.90	-2.784	0.59	6.04	-0.007	0.60
ACREAGE	62.24	-0.248	0.45	4.13	-0.004	0.46
YIELD	67.81	-0.209	0.81	4.22	-0.003	0.81

MADAGASCAR

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	608.90	29.160	0.78	6.48	0.031	0.79
ACREAGE	216.20	1.971	0.16	5.35	0.009	0.18
YIELD	28.65	1.155	0.40	3.43	0.022	0.32

MALI

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	170.80	1.033	0.16	5.14	0.004	0.13
ACREAGE	14.65	-0.263	0.49	2.67	-0.020	0.48
YIELD	120.60	3.197	0.76	4.79	0.023	0.73

NIGER

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	50.11	10.000	0.97	4.21	0.075	0.96
ACREAGE	8.40	1.219	0.94	2.37	0.062	0.96
YIELD	63.61	0.856	0.40	4.13	0.014	0.44

NIGERIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	7420.00	-19.000	0.16	8.90	-0.002	0.11
ACREAGE	749.40	29.810	0.71	6.57	0.036	0.74
YIELD	106.80	-3.459	0.74	4.63	-0.038	0.73

SENEGAL

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	139.60	4.359	0.44	4.97	0.022	0.44
ACREAGE	31.90	1.386	0.46	3.51	0.028	0.46
YIELD	43.20	-0.251	0.35	3.76	-0.006	0.36

SIERRA LEONE

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	49.02	1.145	0.96	3.90	0.020	0.96
ACREAGE	18.75	0.167	0.91	2.93	0.008	0.91
YIELD	26.67	0.305	0.93	3.28	0.011	0.93

SUDAN

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	99.66	2.518	0.98	4.63	0.020	0.99
ACREAGE	15.48	0.154	0.85	2.74	0.009	0.85
YIELD	65.86	0.763	0.86	4.19	0.010	0.85

RWANDA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	-97.98	26.560	0.91	3.50	0.149	0.81
ACREAGE	-9.64	2.552	0.94	1.12	0.152	0.85
YIELD	110.70	-0.406	0.10	4.70	-0.004	0.10

TANZANIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	803.80	37.190	0.83	6.77	0.029	0.85
ACREAGE	258.50	1.545	0.78	5.56	0.006	0.78
YIELD	32.52	1.065	0.80	3.53	0.023	0.81

TOGO

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	366.60	57.390	0.90	6.07	0.073	0.87
ACREAGE	59.48	6.773	0.91	4.19	0.062	0.89
YIELD	65.39	0.783	0.59	4.18	0.011	0.58

UGANDA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	287.40	129.700	0.94	6.52	0.081	0.92
ACREAGE	379.60	-8.318	0.40	5.94	-0.027	0.42
YIELD	-5.69	6.240	0.89	2.89	0.108	0.89

ZAMBIA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	152.40	0.036	0.02	5.03	0.000	0.00
ACREAGE	32.88	1.118	0.70	3.53	0.025	0.71
YIELD	44.38	-0.931	0.83	3.82	-0.027	0.83

LAT.AMERICA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	16327.00	1269.000	0.97	9.75	0.050	0.97
ACREAGE	1482.00	76.070	0.96	7.32	0.038	0.95
YIELD	113.90	1.446	0.93	4.74	0.012	0.93

FAR EAST

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	13472.00	515.400	0.95	9.51	0.031	0.94
ACREAGE	1717.00	48.720	0.89	7.45	0.025	0.89
YIELD	78.70	0.561	0.79	4.37	0.007	0.79

AFRICA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	28500.00	344.300	0.61	10.26	0.011	0.60
ACREAGE	3434.00	109.700	0.96	8.15	0.026	0.95
YIELD	81.21	-1.058	0.65	4.39	-0.014	0.64

WORLD

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	59806.00	2031.000	0.97	11.01	0.027	0.98
ACREAGE	6786.00	227.400	0.98	8.83	0.028	0.97
YIELD	88.55	-0.007	0.01	4.48	-0.000	0.01

TABLE A.2. Projections of production acreage and yield for 1970 to 1985.

ARGENTINA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	279.	25.	113.	278.	24.	113.
1971	282.	25.	112.	281.	25.	112.
1972	284.	25.	111.	283.	25.	111.
1973	287.	26.	110.	286.	26.	110.
1974	289.	26.	109.	288.	26.	109.
1975	292.	27.	108.	291.	27.	108.
1976	294.	27.	107.	294.	27.	107.
1977	297.	27.	106.	296.	28.	107.
1978	299.	28.	105.	299.	28.	106.
1979	302.	28.	104.	302.	29.	105.
1980	304.	29.	103.	304.	29.	104.
1981	306.	29.	102.	307.	30.	103.
1982	309.	29.	101.	310.	30.	102.
1983	311.	30.	100.	313.	31.	101.
1984	314.	30.	99.	316.	31.	100.
1985	316.	31.	98.	319.	32.	99.

BOLIVIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	205.	15.	135.	218.	16.	135.
1971	215.	16.	129.	238.	18.	131.
1972	226.	17.	124.	260.	21.	126.
1973	237.	18.	119.	283.	23.	122.
1974	248.	19.	113.	309.	26.	118.
1975	258.	20.	108.	337.	30.	114.
1976	269.	21.	102.	367.	33.	110.
1977	280.	22.	97.	400.	38.	107.
1978	290.	23.	92.	436.	43.	103.
1979	301.	24.	86.	476.	48.	100.
1980	312.	25.	81.	519.	54.	97.
1981	322.	26.	76.	565.	61.	93.
1982	333.	27.	70.	616.	69.	90.
1983	344.	28.	65.	672.	78.	87.
1984	354.	29.	59.	733.	88.	84.
1985	365.	30.	54.	799.	99.	82.

BRAZIL

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	29793.	2042.	147.	30505.	2077.	147.
1971	30887.	2107.	148.	32092.	2165.	148.
1972	31981.	2171.	150.	33761.	2256.	150.
1973	33075.	2235.	151.	35517.	2352.	151.
1974	34169.	2300.	152.	37365.	2451.	153.
1975	35263.	2364.	153.	39309.	2554.	154.
1976	36357.	2429.	155.	41353.	2662.	156.
1977	37451.	2493.	156.	43504.	2775.	157.
1978	38545.	2558.	157.	45767.	2892.	159.
1979	39639.	2622.	159.	48148.	3014.	160.
1980	40733.	2687.	160.	50653.	3142.	162.
1981	41827.	2751.	161.	53288.	3274.	163.
1982	42921.	2816.	163.	56059.	3413.	165.
1983	44015.	2880.	164.	58976.	3557.	166.
1984	45109.	2945.	165.	62043.	3707.	168.
1985	46203.	3009.	167.	65271.	3864.	170.

COLOMBIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1140.	155.	72.	1093.	153.	71.
1971	1097.	147.	73.	1058.	147.	71.
1972	1055.	139.	74.	1025.	141.	72.
1973	1012.	131.	74.	993.	135.	73.
1974	970.	123.	75.	962.	130.	73.
1975	927.	116.	76.	932.	124.	74.
1976	885.	108.	76.	902.	119.	74.
1977	843.	100.	77.	874.	114.	75.
1978	800.	92.	78.	846.	110.	75.
1979	758.	84.	79.	820.	105.	76.
1980	715.	76.	79.	794.	101.	77.
1981	673.	68.	80.	769.	97.	77.
1982	630.	60.	81.	745.	93.	78.
1983	588.	52.	81.	722.	89.	78.
1984	546.	44.	82.	699.	86.	79.
1985	503.	37.	83.	677.	82.	80.

ECUADOR

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	380.	39.	98.	380.	39.	98.
1971	398.	41.	99.	404.	41.	99.
1972	416.	42.	100.	430.	43.	100.
1973	434.	44.	101.	458.	46.	101.
1974	452.	45.	102.	487.	48.	102.
1975	470.	47.	103.	518.	51.	103.
1976	488.	49.	103.	551.	54.	104.
1977	505.	50.	104.	587.	57.	105.
1978	523.	52.	105.	624.	60.	106.
1979	541.	54.	106.	664.	63.	107.
1980	559.	55.	107.	707.	67.	108.
1981	577.	57.	108.	752.	70.	110.
1982	595.	58.	109.	800.	74.	111.
1983	613.	60.	110.	851.	78.	112.
1984	631.	62.	111.	906.	83.	113.
1985	649.	63.	112.	964.	87.	114.

PARAGUAY

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1670.	116.	143.	1698.	118.	143.
1971	1744.	121.	143.	1820.	124.	142.
1972	1818.	126.	142.	1952.	131.	142.
1973	1892.	130.	142.	2093.	137.	142.
1974	1966.	135.	142.	2244.	145.	142.
1975	2039.	139.	142.	2406.	152.	142.
1976	2113.	144.	142.	2579.	160.	141.
1977	2187.	148.	141.	2766.	169.	141.
1978	2261.	153.	141.	2965.	177.	141.
1979	2335.	157.	141.	3180.	187.	141.
1980	2409.	162.	141.	3409.	197.	141.
1981	2483.	167.	140.	3655.	207.	140.
1982	2557.	171.	140.	3919.	218.	140.
1983	2631.	176.	140.	4203.	229.	140.
1984	2705.	180.	140.	4506.	241.	140.
1985	2778.	185.	140.	4831.	254.	140.

PERU

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	516.	45.	114.	528.	46.	114.
1971	531.	46.	113.	549.	48.	113.
1972	546.	47.	113.	572.	51.	113.
1973	561.	48.	112.	595.	53.	112.
1974	577.	50.	112.	619.	55.	112.
1975	592.	51.	111.	644.	58.	111.
1976	607.	52.	110.	671.	60.	111.
1977	622.	53.	110.	698.	63.	110.
1978	638.	55.	109.	727.	66.	110.
1979	653.	56.	108.	756.	69.	109.
1980	668.	57.	108.	787.	72.	109.
1981	683.	59.	107.	819.	75.	108.
1982	699.	60.	106.	853.	79.	108.
1983	714.	61.	106.	888.	82.	107.
1984	729.	62.	105.	924.	86.	107.
1985	744.	64.	105.	962.	90.	106.

VENEZUELA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	341.	34.	104.	348.	33.	105.
1971	349.	34.	105.	358.	33.	108.
1972	356.	34.	107.	369.	33.	111.
1973	364.	34.	108.	380.	34.	114.
1974	371.	34.	110.	391.	34.	118.
1975	379.	34.	111.	403.	34.	121.
1976	386.	34.	113.	415.	34.	125.
1977	394.	34.	114.	428.	34.	128.
1978	401.	34.	116.	440.	34.	132.
1979	409.	34.	117.	454.	34.	135.
1980	417.	34.	119.	467.	34.	139.
1981	424.	34.	121.	481.	34.	143.
1982	432.	34.	122.	496.	34.	147.
1983	439.	34.	124.	510.	34.	152.
1984	447.	34.	125.	526.	34.	156.
1985	454.	34.	127.	541.	34.	160.

CEYLON

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	391.	61.	66.	406.	60.	68.
1971	406.	62.	67.	429.	61.	70.
1972	421.	63.	69.	454.	62.	73.
1973	435.	64.	70.	480.	64.	76.
1974	450.	64.	72.	508.	65.	79.
1975	464.	65.	73.	537.	66.	82.
1976	479.	66.	75.	568.	67.	85.
1977	494.	67.	76.	601.	69.	88.
1978	508.	68.	78.	635.	70.	91.
1979	523.	69.	80.	672.	71.	95.
1980	538.	70.	81.	711.	73.	98.
1981	552.	71.	83.	752.	74.	102.
1982	567.	72.	84.	795.	75.	106.
1983	581.	73.	86.	841.	77.	110.
1984	596.	74.	87.	890.	78.	114.
1985	611.	75.	89.	941.	80.	119.

TAIWAN

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	319.	21.	149.	332.	22.	149.
1971	332.	22.	151.	353.	23.	151.
1972	345.	23.	153.	376.	24.	154.
1973	358.	23.	156.	399.	25.	156.
1974	371.	24.	158.	425.	26.	159.
1975	384.	25.	160.	451.	27.	162.
1976	397.	25.	162.	480.	28.	164.
1977	410.	26.	164.	510.	29.	167.
1978	423.	27.	166.	542.	31.	170.
1979	436.	27.	169.	577.	32.	172.
1980	449.	28.	171.	613.	34.	175.
1981	462.	29.	173.	652.	35.	178.
1982	475.	29.	175.	693.	37.	181.
1983	488.	30.	177.	737.	38.	184.
1984	501.	31.	179.	783.	40.	187.
1985	514.	31.	182.	833.	42.	190.

INDONESIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	11241.	1541.	72.	11233.	1546.	73.
1971	11259.	1556.	72.	11254.	1563.	72.
1972	11276.	1571.	71.	11275.	1580.	71.
1973	11293.	1586.	70.	11295.	1598.	71.
1974	11310.	1601.	70.	11316.	1615.	70.
1975	11327.	1616.	69.	11337.	1633.	69.
1976	11344.	1631.	68.	11358.	1651.	69.
1977	11362.	1646.	67.	11379.	1670.	68.
1978	11379.	1661.	67.	11400.	1688.	67.
1979	11396.	1676.	66.	11421.	1707.	67.
1980	11413.	1690.	65.	11442.	1726.	66.
1981	11430.	1705.	64.	11463.	1745.	65.
1982	11447.	1720.	64.	11484.	1764.	65.
1983	11464.	1735.	63.	11505.	1784.	64.
1984	11482.	1750.	62.	11527.	1804.	64.
1985	11499.	1765.	62.	11548.	1824.	63.

INDIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	4579.	327.	141.	4618.	325.	142.
1971	4827.	334.	146.	5016.	333.	150.
1972	5075.	341.	152.	5448.	341.	159.
1973	5323.	349.	158.	5918.	349.	168.
1974	5571.	356.	164.	6428.	358.	178.
1975	5818.	363.	170.	6981.	367.	189.
1976	6066.	370.	175.	7583.	376.	200.
1977	6314.	378.	181.	8236.	386.	212.
1978	6562.	385.	187.	8946.	395.	224.
1979	6810.	392.	193.	9717.	405.	237.
1980	7058.	399.	199.	10554.	415.	251.
1981	7306.	407.	205.	11463.	426.	266.
1982	7554.	414.	210.	12451.	436.	281.
1983	7802.	421.	216.	13524.	447.	298.
1984	8050.	428.	222.	14689.	459.	316.
1985	8297.	436.	228.	15955.	470.	334.

W. MALAYSIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	339.	20.	173.	339.	20.	172.
1971	348.	20.	173.	349.	20.	172.
1972	357.	21.	174.	360.	21.	173.
1973	366.	21.	175.	371.	21.	174.
1974	375.	21.	176.	382.	22.	174.
1975	384.	22.	177.	394.	23.	175.
1976	393.	22.	177.	406.	23.	176.
1977	402.	23.	178.	419.	24.	176.
1978	411.	23.	179.	432.	24.	177.
1979	420.	24.	180.	445.	25.	178.
1980	430.	24.	181.	459.	26.	179.
1981	439.	25.	182.	473.	26.	179.
1982	448.	25.	182.	487.	27.	180.
1983	457.	25.	183.	502.	28.	181.
1984	466.	26.	184.	518.	29.	181.
1985	475.	26.	185.	534.	29.	182.

PHILIPPINES

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	531.	90.	60.	536.	91.	60.
1971	538.	91.	60.	547.	92.	60.
1972	546.	92.	61.	558.	93.	61.
1973	553.	93.	61.	569.	94.	61.
1974	561.	93.	62.	580.	95.	62.
1975	568.	94.	62.	591.	96.	62.
1976	575.	95.	63.	603.	98.	63.
1977	583.	96.	63.	615.	99.	64.
1978	590.	97.	64.	627.	100.	64.
1979	598.	98.	64.	640.	101.	65.
1980	605.	99.	64.	652.	103.	65.
1981	612.	100.	65.	665.	104.	66.
1982	620.	100.	65.	678.	105.	66.
1983	627.	101.	66.	692.	107.	67.
1984	635.	102.	66.	705.	108.	67.
1985	642.	103.	67.	719.	109.	68.

THAILAND

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	2187.	146.	150.	2682.	176.	152.
1971	2300.	153.	150.	3027.	197.	153.
1972	2413.	161.	151.	3416.	221.	154.
1973	2526.	168.	151.	3855.	248.	155.
1974	2639.	176.	151.	4351.	278.	156.
1975	2752.	183.	151.	4910.	312.	157.
1976	2865.	191.	152.	5541.	349.	158.
1977	2978.	198.	152.	6253.	392.	160.
1978	3091.	206.	152.	7056.	439.	161.
1979	3204.	213.	153.	7963.	492.	162.
1980	3317.	221.	153.	8987.	551.	163.
1981	3430.	228.	153.	10142.	618.	164.
1982	3543.	236.	153.	11445.	693.	165.
1983	3656.	243.	154.	12916.	777.	166.
1984	3769.	251.	154.	14576.	870.	167.
1985	3882.	258.	154.	16449.	976.	168.

VIET NAM N.

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	709.	101.	70.	709.	101.	70.
1971	695.	100.	69.	696.	101.	69.
1972	680.	100.	68.	684.	100.	68.
1973	666.	99.	67.	672.	100.	67.
1974	652.	99.	65.	660.	100.	66.
1975	638.	98.	64.	648.	99.	65.
1976	624.	97.	63.	636.	99.	64.
1977	610.	97.	62.	625.	99.	63.
1978	596.	96.	61.	614.	98.	62.
1979	581.	96.	60.	603.	98.	61.
1980	567.	95.	59.	592.	97.	61.
1981	553.	94.	58.	582.	97.	60.
1982	539.	94.	56.	571.	97.	59.
1983	525.	93.	55.	561.	96.	58.
1984	511.	93.	54.	551.	96.	57.
1985	497.	92.	53.	541.	96.	56.

VIET NAM S.

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	267.	36.	74.	268.	36.	74.
1971	269.	36.	76.	271.	36.	76.
1972	270.	35.	77.	274.	35.	78.
1973	272.	35.	78.	277.	35.	79.
1974	274.	35.	80.	280.	35.	81.
1975	275.	34.	81.	283.	34.	83.
1976	277.	34.	83.	286.	34.	84.
1977	278.	33.	84.	289.	34.	86.
1978	280.	33.	85.	292.	33.	88.
1979	282.	32.	87.	295.	33.	90.
1980	283.	32.	88.	298.	33.	92.
1981	285.	32.	89.	302.	32.	94.
1982	287.	31.	91.	305.	32.	96.
1983	288.	31.	92.	308.	32.	98.
1984	290.	30.	94.	311.	31.	100.
1985	292.	30.	95.	315.	31.	102.

ANGOLA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1604.	121.	133.	1608.	121.	133.
1971	1645.	122.	135.	1654.	122.	135.
1972	1685.	124.	137.	1702.	124.	137.
1973	1725.	125.	139.	1750.	125.	139.
1974	1765.	127.	141.	1800.	127.	142.
1975	1806.	128.	142.	1852.	129.	144.
1976	1846.	129.	144.	1905.	130.	146.
1977	1886.	131.	146.	1959.	132.	148.
1978	1926.	132.	148.	2015.	133.	151.
1979	1967.	134.	150.	2073.	135.	153.
1980	2007.	135.	152.	2132.	137.	156.
1981	2047.	136.	154.	2193.	138.	158.
1982	2087.	138.	156.	2256.	140.	161.
1983	2127.	139.	158.	2321.	142.	163.
1984	2168.	141.	160.	2387.	143.	166.
1985	2208.	142.	162.	2455.	145.	168.

BURUNDI

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1306.	133.	109.	1271.	120.	106.
1971	1384.	144.	107.	1361.	131.	104.
1972	1462.	155.	105.	1457.	144.	101.
1973	1540.	166.	103.	1560.	158.	99.
1974	1618.	177.	101.	1670.	173.	97.
1975	1697.	188.	99.	1788.	189.	95.
1976	1775.	199.	96.	1914.	207.	92.
1977	1853.	210.	94.	2049.	227.	90.
1978	1931.	221.	92.	2194.	249.	88.
1979	2009.	232.	90.	2349.	273.	86.
1980	2087.	243.	88.	2515.	299.	84.
1981	2166.	254.	86.	2693.	328.	82.
1982	2244.	265.	84.	2883.	359.	80.
1983	2322.	276.	81.	3086.	393.	79.
1984	2400.	287.	79.	3304.	431.	77.
1985	2478.	298.	77.	3538.	472.	75.

CAMEROON

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	986.	193.	49.	988.	197.	50.
1971	1019.	203.	46.	1030.	214.	48.
1972	1051.	214.	43.	1073.	233.	46.
1973	1083.	224.	40.	1119.	254.	44.
1974	1115.	234.	38.	1166.	276.	42.
1975	1147.	245.	35.	1216.	300.	40.
1976	1179.	255.	32.	1267.	327.	39.
1977	1211.	266.	29.	1321.	356.	37.
1978	1244.	276.	26.	1377.	387.	36.
1979	1276.	286.	23.	1435.	422.	34.
1980	1308.	297.	20.	1496.	459.	33.
1981	1340.	307.	17.	1559.	499.	31.
1982	1372.	317.	14.	1625.	543.	30.
1983	1404.	328.	11.	1694.	591.	29.
1984	1437.	338.	8.	1766.	644.	27.
1985	1469.	348.	5.	1841.	701.	26.

CENTR.AF.REP

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1029.	203.	51.	1029.	203.	51.
1971	1035.	203.	51.	1034.	203.	51.
1972	1040.	204.	51.	1039.	204.	51.
1973	1045.	205.	51.	1045.	205.	51.
1974	1051.	205.	51.	1050.	205.	51.
1975	1056.	206.	51.	1056.	206.	51.
1976	1062.	206.	51.	1061.	206.	51.
1977	1067.	207.	52.	1067.	207.	52.
1978	1073.	207.	52.	1072.	207.	52.
1979	1078.	208.	52.	1078.	208.	52.
1980	1084.	208.	52.	1084.	208.	52.
1981	1089.	209.	52.	1089.	209.	52.
1982	1095.	209.	52.	1095.	210.	52.
1983	1100.	210.	52.	1101.	210.	52.
1984	1105.	211.	53.	1106.	211.	52.
1985	1111.	211.	53.	1112.	211.	53.

CHAD

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	51.	19.	26.	51.	21.	29.
1971	52.	20.	22.	52.	24.	26.
1972	53.	21.	18.	53.	27.	24.
1973	53.	23.	14.	55.	31.	23.
1974	54.	24.	10.	56.	36.	21.
1975	55.	25.	6.	57.	41.	19.
1976	55.	27.	2.	58.	47.	18.
1977	56.	28.	-2.	60.	54.	17.
1978	57.	29.	-5.	61.	62.	15.
1979	57.	31.	-9.	62.	72.	14.
1980	58.	32.	-13.	64.	82.	13.
1981	59.	33.	-17.	65.	94.	12.
1982	59.	35.	-21.	66.	108.	11.
1983	60.	36.	-25.	68.	124.	10.
1984	61.	37.	-29.	69.	143.	10.
1985	61.	39.	-33.	71.	164.	9.

COMORO IS.

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	99.	27.	38.	106.	27.	39.
1971	107.	28.	40.	123.	29.	42.
1972	115.	30.	42.	141.	31.	45.
1973	123.	31.	44.	163.	34.	49.
1974	131.	32.	46.	188.	36.	53.
1975	139.	34.	48.	217.	39.	57.
1976	147.	35.	50.	250.	41.	61.
1977	155.	37.	52.	288.	44.	66.
1978	163.	38.	54.	332.	48.	71.
1979	171.	39.	56.	383.	51.	76.
1980	179.	41.	58.	442.	55.	82.
1981	187.	42.	61.	510.	59.	89.
1982	195.	43.	63.	588.	63.	96.
1983	203.	45.	65.	678.	67.	103.
1984	211.	46.	67.	782.	72.	111.
1985	219.	48.	69.	901.	77.	120.

CONGO BRAZZ

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	376.	100.	39.	396.	101.	39.
1971	326.	95.	37.	365.	97.	37.
1972	277.	91.	35.	337.	94.	36.
1973	227.	86.	32.	311.	91.	34.
1974	178.	81.	30.	287.	87.	33.
1975	128.	77.	28.	264.	84.	31.
1976	78.	72.	26.	244.	81.	30.
1977	29.	67.	24.	225.	78.	29.
1978	-21.	63.	22.	208.	76.	27.
1979	-70.	58.	19.	192.	73.	26.
1980	-120.	54.	17.	177.	70.	25.
1981	-169.	49.	15.	163.	68.	24.
1982	-219.	44.	13.	150.	65.	23.
1983	-268.	40.	11.	139.	63.	22.
1984	-318.	35.	9.	128.	61.	21.
1985	-367.	30.	6.	118.	59.	20.

CONGO REP

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	7630.	633.	120.	7470.	629.	119.
1971	7681.	633.	121.	7512.	629.	119.
1972	7733.	634.	121.	7554.	629.	120.
1973	7784.	634.	122.	7596.	629.	121.
1974	7836.	634.	123.	7639.	629.	121.
1975	7887.	635.	124.	7681.	629.	122.
1976	7939.	635.	124.	7724.	629.	123.
1977	7990.	635.	125.	7768.	629.	123.
1978	8042.	635.	126.	7811.	629.	124.
1979	8093.	636.	126.	7855.	629.	125.
1980	8145.	636.	127.	7899.	629.	125.
1981	8196.	636.	128.	7943.	629.	126.
1982	8248.	636.	129.	7987.	629.	127.
1983	8299.	637.	129.	8032.	629.	127.
1984	8351.	637.	130.	8077.	630.	128.
1985	8402.	637.	131.	8122.	630.	129.

DAHOMEY

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	979.	147.	66.	961.	144.	66.
1971	966.	141.	67.	948.	139.	68.
1972	954.	135.	68.	935.	134.	69.
1973	941.	129.	70.	922.	129.	71.
1974	929.	124.	71.	910.	125.	73.
1975	916.	118.	72.	898.	120.	74.
1976	904.	112.	73.	886.	116.	76.
1977	891.	106.	75.	874.	112.	78.
1978	879.	100.	76.	862.	108.	79.
1979	866.	94.	77.	850.	104.	81.
1980	854.	89.	78.	839.	100.	83.
1981	841.	83.	80.	828.	97.	85.
1982	829.	77.	81.	816.	93.	87.
1983	816.	71.	82.	805.	90.	89.
1984	804.	65.	83.	795.	87.	91.
1985	791.	59.	84.	784.	84.	93.

EQUAT GUINEA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	43.	15.	29.	43.	15.	29.
1971	43.	15.	29.	43.	15.	29.
1972	43.	15.	29.	43.	15.	29.
1973	44.	15.	29.	44.	15.	28.
1974	44.	16.	28.	44.	16.	28.
1975	45.	16.	28.	45.	16.	28.
1976	45.	16.	28.	45.	16.	28.
1977	46.	16.	28.	46.	16.	28.
1978	46.	17.	28.	46.	17.	28.
1979	47.	17.	27.	47.	17.	27.
1980	47.	17.	27.	47.	17.	27.
1981	48.	17.	27.	48.	17.	27.
1982	48.	17.	27.	48.	18.	27.
1983	48.	18.	27.	49.	18.	27.
1984	49.	18.	26.	49.	18.	27.
1985	49.	18.	26.	50.	19.	26.

GABON

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	140.	62.	21.	139.	63.	22.
1971	141.	64.	20.	139.	66.	21.
1972	141.	66.	19.	140.	68.	20.
1973	142.	68.	18.	140.	71.	20.
1974	143.	70.	17.	141.	74.	19.
1975	143.	72.	16.	141.	77.	18.
1976	144.	74.	15.	142.	80.	18.
1977	145.	76.	14.	143.	83.	17.
1978	145.	78.	13.	143.	86.	17.
1979	146.	79.	11.	144.	89.	16.
1980	146.	81.	10.	144.	93.	15.
1981	147.	83.	9.	145.	97.	15.
1982	148.	85.	8.	146.	100.	14.
1983	148.	87.	7.	146.	104.	14.
1984	149.	89.	6.	147.	108.	13.
1985	150.	91.	5.	147.	113.	13.

GHANA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1697.	196.	82.	1684.	204.	83.
1971	1767.	206.	79.	1778.	221.	80.
1972	1837.	216.	77.	1877.	240.	78.
1973	1907.	225.	74.	1982.	260.	76.
1974	1976.	235.	71.	2093.	282.	74.
1975	2046.	244.	69.	2211.	305.	73.
1976	2116.	254.	66.	2334.	331.	71.
1977	2186.	264.	63.	2465.	358.	69.
1978	2256.	273.	61.	2603.	388.	67.
1979	2326.	283.	58.	2748.	421.	66.
1980	2395.	292.	55.	2902.	456.	64.
1981	2465.	302.	52.	3065.	494.	62.
1982	2535.	312.	50.	3236.	536.	61.
1983	2605.	321.	47.	3417.	580.	59.
1984	2675.	331.	44.	3609.	629.	58.
1985	2744.	340.	42.	3810.	682.	56.

GUINEA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	475.	28.	157.	476.	29.	164.
1971	482.	27.	161.	485.	29.	169.
1972	489.	26.	164.	493.	28.	176.
1973	496.	25.	167.	501.	28.	182.
1974	503.	25.	171.	510.	27.	189.
1975	510.	24.	174.	518.	27.	195.
1976	517.	23.	177.	527.	26.	203.
1977	524.	22.	181.	536.	26.	210.
1978	531.	21.	184.	545.	25.	217.
1979	538.	20.	188.	554.	25.	225.
1980	545.	19.	191.	564.	24.	234.
1981	552.	18.	194.	573.	24.	242.
1982	559.	17.	198.	583.	23.	251.
1983	566.	16.	201.	593.	23.	260.
1984	573.	16.	204.	603.	22.	269.
1985	580.	15.	208.	613.	22.	279.

IVORY COAST

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	576.	192.	30.	565.	191.	30.
1971	558.	194.	29.	551.	194.	29.
1972	540.	196.	27.	537.	197.	28.
1973	521.	198.	26.	524.	199.	27.
1974	503.	200.	24.	511.	202.	26.
1975	485.	203.	23.	498.	205.	25.
1976	466.	205.	21.	486.	208.	24.
1977	448.	207.	20.	474.	210.	23.
1978	429.	209.	18.	462.	213.	22.
1979	411.	211.	17.	451.	216.	21.
1980	393.	214.	15.	440.	219.	20.
1981	374.	216.	14.	429.	222.	20.
1982	356.	218.	12.	418.	225.	19.
1983	338.	220.	11.	408.	228.	18.
1984	319.	222.	9.	398.	231.	17.
1985	301.	225.	8.	388.	235.	17.

KENYA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	620.	92.	67.	620.	92.	67.
1971	623.	93.	67.	623.	93.	67.
1972	626.	93.	67.	626.	93.	67.
1973	629.	94.	67.	629.	94.	67.
1974	632.	94.	67.	632.	94.	67.
1975	635.	95.	67.	635.	95.	67.
1976	638.	95.	67.	638.	95.	67.
1977	641.	96.	67.	642.	96.	67.
1978	644.	96.	67.	645.	96.	67.
1979	647.	96.	67.	648.	97.	66.
1980	650.	97.	66.	651.	97.	66.
1981	653.	97.	66.	654.	97.	66.
1982	656.	98.	66.	657.	98.	66.
1983	659.	98.	66.	661.	98.	66.
1984	662.	99.	66.	664.	99.	66.
1985	665.	99.	66.	667.	99.	66.

LIBERIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	379.	59.	65.	379.	58.	65.
1971	376.	58.	64.	376.	58.	64.
1972	374.	58.	64.	373.	58.	64.
1973	371.	58.	64.	371.	58.	64.
1974	368.	58.	64.	368.	57.	64.
1975	365.	57.	64.	365.	57.	64.
1976	362.	57.	63.	363.	57.	63.
1977	360.	57.	63.	360.	57.	63.
1978	357.	57.	63.	358.	57.	63.
1979	354.	56.	63.	355.	56.	63.
1980	351.	56.	63.	353.	56.	63.
1981	349.	56.	62.	350.	56.	62.
1982	346.	56.	62.	348.	56.	62.
1983	343.	55.	62.	345.	55.	62.
1984	340.	55.	62.	343.	55.	62.
1985	337.	55.	62.	340.	55.	62.

MADAGASCAR

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1046.	246.	46.	1038.	242.	43.
1971	1075.	248.	47.	1071.	244.	44.
1972	1105.	250.	48.	1104.	246.	45.
1973	1134.	252.	49.	1139.	249.	46.
1974	1163.	254.	51.	1175.	251.	47.
1975	1192.	256.	52.	1212.	253.	48.
1976	1221.	258.	53.	1251.	256.	49.
1977	1250.	260.	54.	1290.	258.	50.
1978	1280.	262.	55.	1331.	260.	51.
1979	1309.	264.	56.	1373.	263.	52.
1980	1338.	265.	58.	1417.	265.	54.
1981	1367.	267.	59.	1461.	268.	55.
1982	1396.	269.	60.	1508.	270.	56.
1983	1425.	271.	61.	1555.	272.	57.
1984	1455.	273.	62.	1604.	275.	58.
1985	1484.	275.	63.	1655.	278.	60.

MALI

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	186.	11.	169.	183.	11.	170.
1971	187.	10.	172.	184.	11.	174.
1972	188.	10.	175.	185.	10.	178.
1973	189.	10.	178.	186.	10.	183.
1974	190.	10.	181.	187.	10.	187.
1975	191.	9.	185.	187.	10.	191.
1976	192.	9.	188.	188.	10.	196.
1977	194.	9.	191.	189.	9.	200.
1978	195.	9.	194.	190.	9.	205.
1979	196.	8.	197.	191.	9.	210.
1980	197.	8.	201.	191.	9.	215.
1981	198.	8.	204.	192.	9.	220.
1982	199.	8.	207.	193.	9.	225.
1983	200.	7.	210.	194.	8.	230.
1984	201.	7.	213.	195.	8.	236.
1985	202.	7.	217.	196.	8.	241.

NIGER

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	200.	27.	76.	209.	27.	77.
1971	210.	28.	77.	226.	29.	78.
1972	220.	29.	78.	243.	31.	79.
1973	230.	30.	79.	262.	33.	80.
1974	240.	32.	80.	283.	35.	81.
1975	250.	33.	81.	305.	37.	83.
1976	260.	34.	82.	329.	39.	84.
1977	270.	35.	82.	355.	42.	85.
1978	280.	36.	83.	383.	44.	86.
1979	290.	38.	84.	413.	47.	87.
1980	300.	39.	85.	445.	50.	88.
1981	310.	40.	86.	480.	53.	90.
1982	320.	41.	87.	517.	57.	91.
1983	330.	43.	88.	558.	60.	92.
1984	340.	44.	88.	601.	64.	94.
1985	350.	45.	89.	649.	68.	95.

NIGERIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	7135.	1197.	55.	7146.	1231.	58.
1971	7116.	1226.	51.	7134.	1277.	56.
1972	7097.	1256.	48.	7121.	1323.	54.
1973	7078.	1286.	45.	7109.	1372.	52.
1974	7059.	1316.	41.	7096.	1422.	50.
1975	7040.	1346.	38.	7083.	1475.	48.
1976	7021.	1375.	34.	7071.	1529.	46.
1977	7002.	1405.	31.	7058.	1585.	44.
1978	6983.	1435.	27.	7046.	1643.	43.
1979	6964.	1465.	24.	7033.	1703.	41.
1980	6945.	1495.	20.	7021.	1766.	40.
1981	6926.	1524.	17.	7008.	1831.	38.
1982	6907.	1554.	13.	6996.	1898.	37.
1983	6888.	1584.	10.	6983.	1968.	35.
1984	6869.	1614.	6.	6971.	2040.	34.
1985	6850.	1644.	3.	6959.	2115.	33.

SENEGAL

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	205.	53.	39.	201.	51.	39.
1971	209.	54.	39.	205.	53.	39.
1972	214.	55.	39.	210.	54.	39.
1973	218.	57.	39.	214.	56.	39.
1974	222.	58.	38.	219.	57.	38.
1975	227.	60.	38.	224.	59.	38.
1976	231.	61.	38.	229.	61.	38.
1977	235.	62.	38.	234.	62.	38.
1978	240.	64.	37.	239.	64.	37.
1979	244.	65.	37.	245.	66.	37.
1980	249.	67.	37.	250.	68.	37.
1981	253.	68.	37.	256.	70.	37.
1982	257.	69.	36.	262.	72.	37.
1983	262.	71.	36.	268.	74.	36.
1984	266.	72.	36.	274.	76.	36.
1985	270.	73.	36.	280.	78.	36.

SIERRA LEONE

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	66.	21.	31.	67.	21.	31.
1971	67.	21.	32.	68.	21.	32.
1972	68.	22.	32.	69.	22.	32.
1973	70.	22.	32.	71.	22.	32.
1974	71.	22.	32.	72.	22.	33.
1975	72.	22.	33.	74.	22.	33.
1976	73.	22.	33.	75.	22.	33.
1977	74.	22.	33.	77.	23.	34.
1978	75.	23.	34.	78.	23.	34.
1979	76.	23.	34.	80.	23.	34.
1980	78.	23.	34.	81.	23.	35.
1981	79.	23.	35.	83.	23.	35.
1982	80.	23.	35.	85.	24.	35.
1983	81.	23.	35.	86.	24.	36.
1984	82.	24.	36.	88.	24.	36.
1985	83.	24.	36.	90.	24.	37.

SUDAN

YEAR	LINEAR FUNCTION PROD	AREA	YIELD	LOG FUNCTION PROD	AREA	YIELD
1970	137.	18.	77.	138.	18.	77.
1971	140.	18.	78.	140.	18.	78.
1972	142.	18.	79.	143.	18.	79.
1973	145.	18.	80.	146.	18.	80.
1974	148.	18.	80.	149.	18.	81.
1975	150.	19.	81.	152.	19.	81.
1976	153.	19.	82.	155.	19.	82.
1977	155.	19.	83.	158.	19.	83.
1978	158.	19.	83.	161.	19.	84.
1979	160.	19.	84.	164.	19.	85.
1980	163.	19.	85.	168.	19.	86.
1981	165.	19.	86.	171.	20.	87.
1982	168.	20.	86.	174.	20.	87.
1983	170.	20.	87.	178.	20.	88.
1984	173.	20.	88.	181.	20.	89.
1985	175.	20.	89.	185.	20.	90.

RWANDA

YEAR	LINEAR FUNCTION PROD	AREA	YIELD	LOG FUNCTION PROD	AREA	YIELD
1970	300.	29.	105.	313.	30.	104.
1971	327.	31.	104.	363.	35.	104.
1972	354.	34.	104.	422.	41.	103.
1973	380.	36.	103.	490.	48.	103.
1974	407.	39.	103.	569.	55.	102.
1975	433.	41.	103.	661.	65.	102.
1976	460.	44.	102.	767.	75.	102.
1977	486.	47.	102.	891.	87.	101.
1978	513.	49.	101.	1034.	102.	101.
1979	539.	52.	101.	1201.	119.	101.
1980	566.	54.	101.	1394.	138.	100.
1981	593.	57.	100.	1619.	161.	100.
1982	619.	59.	100.	1880.	187.	99.
1983	646.	62.	99.	2182.	218.	99.
1984	672.	64.	99.	2534.	254.	99.
1985	699.	67.	99.	2942.	296.	98.

TANZANIA

YEAR	LINEAR FUNCTION PROD	AREA	YIELD	LOG FUNCTION PROD	AREA	YIELD
1970	1362.	282.	48.	1355.	282.	48.
1971	1399.	283.	50.	1395.	283.	49.
1972	1436.	285.	51.	1437.	285.	51.
1973	1473.	286.	52.	1480.	286.	52.
1974	1510.	288.	53.	1523.	288.	53.
1975	1548.	289.	54.	1569.	290.	54.
1976	1585.	291.	55.	1615.	291.	56.
1977	1622.	292.	56.	1663.	293.	57.
1978	1659.	294.	57.	1713.	294.	58.
1979	1696.	296.	58.	1763.	296.	59.
1980	1734.	297.	59.	1816.	298.	61.
1981	1771.	299.	60.	1870.	299.	62.
1982	1808.	300.	61.	1925.	301.	64.
1983	1845.	302.	62.	1982.	303.	65.
1984	1882.	303.	63.	2041.	304.	67.
1985	1919.	305.	64.	2102.	306.	68.

TOGO

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1227.	161.	77.	1296.	168.	77.
1971	1285.	168.	78.	1395.	179.	78.
1972	1342.	175.	79.	1501.	190.	79.
1973	1400.	181.	79.	1615.	203.	80.
1974	1457.	188.	80.	1737.	216.	81.
1975	1514.	195.	81.	1869.	230.	82.
1976	1572.	202.	82.	2012.	244.	83.
1977	1629.	208.	83.	2164.	260.	84.
1978	1687.	215.	83.	2329.	277.	84.
1979	1744.	222.	84.	2506.	294.	85.
1980	1801.	229.	85.	2697.	313.	86.
1981	1859.	236.	86.	2902.	333.	87.
1982	1916.	242.	87.	3122.	355.	88.
1983	1974.	249.	87.	3360.	378.	89.
1984	2031.	256.	88.	3615.	402.	90.
1985	2088.	263.	89.	3890.	428.	91.

UGANDA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	2233.	255.	88.	2285.	253.	90.
1971	2363.	247.	94.	2478.	246.	101.
1972	2492.	238.	100.	2687.	240.	112.
1973	2622.	230.	107.	2914.	233.	125.
1974	2752.	222.	113.	3160.	227.	139.
1975	2881.	213.	119.	3427.	221.	155.
1976	3011.	205.	125.	3716.	215.	172.
1977	3141.	197.	132.	4030.	209.	192.
1978	3270.	188.	138.	4370.	204.	214.
1979	3400.	180.	144.	4739.	198.	238.
1980	3530.	172.	150.	5138.	193.	265.
1981	3660.	163.	157.	5572.	188.	295.
1982	3789.	155.	163.	6042.	183.	329.
1983	3919.	147.	169.	6552.	178.	366.
1984	4049.	138.	175.	7105.	173.	408.
1985	4178.	130.	182.	7705.	169.	454.

ZAMBIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	153.	50.	30.	153.	50.	30.
1971	153.	51.	29.	153.	51.	30.
1972	153.	52.	29.	153.	52.	29.
1973	153.	53.	28.	153.	54.	28.
1974	153.	54.	27.	153.	55.	27.
1975	153.	55.	26.	153.	56.	27.
1976	153.	56.	25.	153.	58.	26.
1977	153.	57.	24.	153.	59.	25.
1978	153.	59.	23.	153.	61.	25.
1979	153.	60.	22.	153.	62.	24.
1980	153.	61.	21.	153.	64.	23.
1981	153.	62.	20.	153.	66.	23.
1982	153.	63.	19.	153.	67.	22.
1983	153.	64.	18.	153.	69.	21.
1984	153.	65.	17.	153.	71.	21.
1985	153.	66.	16.	153.	73.	20.

LAT.AMERICA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	35362.	2623.	136.	36583.	2681.	136.
1971	36631.	2699.	137.	38470.	2785.	137.
1972	37900.	2775.	138.	40454.	2892.	139.
1973	39169.	2851.	140.	42541.	3004.	140.
1974	40438.	2927.	141.	44735.	3120.	142.
1975	41707.	3003.	143.	47042.	3241.	144.
1976	42976.	3079.	144.	49468.	3366.	145.
1977	44245.	3156.	146.	52020.	3496.	147.
1978	45514.	3232.	147.	54703.	3631.	149.
1979	46783.	3308.	149.	57524.	3772.	151.
1980	48052.	3384.	150.	60491.	3918.	152.
1981	49321.	3460.	151.	63611.	4069.	154.
1982	50590.	3536.	153.	66892.	4226.	156.
1983	51859.	3612.	154.	70342.	4390.	158.
1984	53128.	3688.	156.	73970.	4560.	159.
1985	54397.	3764.	157.	77785.	4736.	161.

FAR EAST

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	21203.	2448.	87.	21650.	2486.	87.
1971	21718.	2497.	88.	22337.	2548.	88.
1972	22234.	2545.	88.	23046.	2612.	88.
1973	22749.	2594.	89.	23778.	2677.	89.
1974	23265.	2643.	89.	24532.	2744.	89.
1975	23780.	2691.	90.	25311.	2813.	90.
1976	24295.	2740.	90.	26115.	2883.	91.
1977	24811.	2789.	91.	26944.	2955.	91.
1978	25326.	2838.	92.	27799.	3029.	92.
1979	25842.	2886.	92.	28681.	3105.	93.
1980	26357.	2935.	93.	29592.	3183.	93.
1981	26872.	2984.	93.	30531.	3262.	94.
1982	27388.	3032.	94.	31500.	3344.	94.
1983	27903.	3081.	94.	32500.	3428.	95.
1984	28419.	3130.	95.	33532.	3513.	96.
1985	28934.	3179.	96.	34596.	3601.	96.

AFRICA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	33664.	5079.	65.	33475.	5142.	66.
1971	34009.	5189.	64.	33831.	5279.	65.
1972	34353.	5299.	63.	34190.	5421.	64.
1973	34697.	5409.	62.	34553.	5566.	63.
1974	35042.	5518.	61.	34920.	5715.	62.
1975	35386.	5628.	60.	35292.	5868.	61.
1976	35730.	5738.	59.	35667.	6025.	60.
1977	36075.	5847.	58.	36046.	6186.	60.
1978	36419.	5957.	57.	36429.	6351.	59.
1979	36763.	6067.	56.	36816.	6521.	58.
1980	37107.	6176.	55.	37207.	6696.	57.
1981	37452.	6286.	54.	37602.	6875.	56.
1982	37796.	6396.	53.	38002.	7059.	56.
1983	38140.	6506.	52.	38406.	7248.	55.
1984	38485.	6615.	51.	38814.	7442.	54.
1985	38829.	6725.	49.	39226.	7641.	53.

WORLD

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	90271.	10197.	88.	90849.	10359.	88.
1971	92302.	10424.	88.	93347.	10650.	88.
1972	94333.	10652.	88.	95914.	10950.	88.
1973	96364.	10879.	88.	98552.	11257.	88.
1974	98395.	11107.	88.	101262.	11574.	88.
1975	100426.	11334.	88.	104047.	11899.	88.
1976	102457.	11561.	88.	106909.	12233.	88.
1977	104488.	11789.	88.	109849.	12577.	88.
1978	106519.	12016.	88.	112870.	12930.	88.
1979	108550.	12244.	88.	115974.	13294.	88.
1980	110581.	12471.	88.	119163.	13667.	88.
1981	112612.	12698.	88.	122440.	14051.	88.
1982	114643.	12926.	88.	125808.	14446.	88.
1983	116674.	13153.	88.	129268.	14852.	88.
1984	118705.	13381.	88.	132823.	15269.	88.
1985	120736.	13608.	88.	136475.	15698.	88.

Appendix B

Cassava Research Programs

The attempt to catalogue briefly cassava research projects known to me is fraught with many dangers. One may inadvertently overlook some of the research activities of a particular agency; one may over- or underestimate the emphasis or results of some agencies; or one may unintentionally suggest weaknesses of one research project relative to others. Conversely, the mere knowledge that someone somewhere else is working on a particular aspect of cassava may facilitate the transfer of knowledge and thereby raise the overall quality of research. It is in hopes of realizing this latter possibility that I have attempted to produce an annotated list of cassava research projects.

Production

CIAT is clearly the world centre for production research, with over 3000 germ plasm in its collection. Research is being carried out on propagation, breeding, yield, and fertilizer response, at diverse altitudes and in differing soils and pHs.

Brazil The Ministry of Agriculture, with its *National Commission on Cassava* (Comissão Nacional da Mandioca), is attempting to coordinate much of the varietal and fertilizer response trials carried out by various states and federal agencies. They are also experimenting with the use of cassava tops for the production of forage feed. *Brascan Nordeste*, Recife, is funding cassava production research (as well as other research) at the University of Bahia. *Instituto Agronomico de Campinas*, Campinas, has a long history of conducting cassava production research.

Thailand The *Ministry of Agriculture* research station in Rayone has conducted fertilizer response trials for years. The *Applied Scientific Research Corporation of Thailand* may become involved in field varietal studies.

Malaysia The *Crop Promotion Division* of the Ministry of Agriculture is conducting varietal and fertilizer response experiments. They are also examining the yields of top growth in order to determine if they are sufficient to suggest using cassava tops as an animal feed. *MARDI, Malaysian Agricultural Research Development Institute*, is reported to be conducting fertilizer and varietal trials.

India The *Central Tuber Crops Research Institute*, Trivandrum, is breeding for high-yielding, mosaic-resistant varieties of cassava.

Fortification

Brazil *USAID* is funding research into the feasibility of fortifying farinha de madioca with soy protein isolate or soyagrits, carried out by Brazilian commercial firms, banks, and research centres. The research was originally centred in Rio de Janeiro but another project is now under way in the Recife area. USAID is also supporting studies in Zaire and Nigeria which, in part, will examine the feasibility of fortifying cassava.

University of Guelph is studying a wet process which uses cassava as a substrate for growing protein with a view to producing a nutritionally complete animal feed.

University of Malaya is also using cassava as a growth medium for protein; however they are exploring a dry process.

The *Applied Scientific Corporation of Thailand* is researching the production and use of protein produced from the cassava starch waste milk.

Composite Flour

The *Institute for Cereals, Flour and Bread*, TNO, Wageningen, Netherlands, has much experience in the production of cassava composite flours. They also have compiled a useful list of institutions which are engaged in composite flour studies.

The *Instituto de Investigaciones Tecnologicas*, Bogota, Colombia, has also developed a number of cassava-based flour products.

The *Central Food Technological Research Institute*, Mysore, India, was one of the first institutions to produce composite flour products, most of which were designed to resemble traditional foods.

The *Food and Agriculture Organization*, Agricultural Service Division, Rome, Italy, has been involved in the production and promotion of composite flour products.

Processing and Storage

CIAT has developed machinery which will produce cassava "bars" (1 × 1 × 5 cm) directly from roots. If density, strength, and dryness meet the appropriate standards the bars may compete with pellets on the European market. In this connection work on the drying characteristics of cassava is also being conducted. Furthermore, CIAT is experimenting with ground clamp storage of cassava. This research is being done in collaboration with the Tropical Products Institute, London.

The *Tropical Products Institute*, London, England, is, as mentioned above, exploring the use of clamps to store cassava; they have also experimented with the treatment of roots with proprianic acid to improve shelf life. TPI is also engaged in studies related to the production of gari (similar to farinha de mandioca) and starch.

The *Applied Scientific Research Corporation of Thailand*, Bangkok, may become involved with research related to the processing of cassava pellets.

Malaysia The *Crop Promotion Division* of the Ministry of Agriculture, *MARDI*, and *NISIR* are all experimenting with small-scale processing units for pellets. *Bank Pertanian* is examining large-scale pellet processing plants.

Brazil The Ministry of Agriculture has researched different methods of producing farinha de mandioca.

The *Central Tuber Crops Research Institute*, Trivandrum, India, has developed a package of production practices which is felt to be suitable for traditional agriculture.

Economics

CIAT is investigating the cost of production and processing for different phases of production. They are planning a survey (over 300 farm families in Colombia) to determine production practices and costs. The economics of using cassava as a pig feed are also being researched.

Thailand The *Ministry of Agriculture* has completed a large survey of the economic operations of producers, processors, exporters and middle men. The *Trade Department* is now examining a number of aspects related to the export of cassava.

The *Comissão Nacional da Mandioca*, Brazil, has established as one of its research priorities the determination of production and processing costs in Brazil.

Malaysia The *Crop Promotion Division*, Ministry of Agriculture has studied the economics of cassava processing plants.

The *International Trade Centre*, GATT, Geneva, Switzerland, has studied the animal feed market for cassava, and may research the starch market for cassava.

The *Tropical Products Institute*, London, England, has conducted studies of the economics of processing and marketing cassava and cassava products.

The *Food and Agriculture Organization*, Rome, has carried out various economic studies related to numerous aspects of production, processing, and marketing.

Again the reader is reminded that the foregoing list is not exhaustive, and may in fact overlook some very important projects.[95] However, the list does indicate some of the current research in cassava and the locations where this research is being carried out.

[95] For example, the *University of Georgia* has compiled an annotated review of cassava literature, but because it is not clear that this is an ongoing project it was not included in the Appendix. Furthermore, it is known that *International Institute of Tropical Agriculture*, Ibadan, Nigeria, has a substantive cassava research program But I am not personally familiar with many of the details; thus this work was not included in the Appendix.

Appendix C

Some United States Industrial Starch Standards for Cassava Starch

	Paper manufacturing	Food manufacturing 1	Food manufacturing 2
Moisture content	12.5% avg 13.5% max	12.5% max	11–14%
Ash content	0.2% max	0.15% max	.30% max
Speck count (no./inch^2)	15 max	8 max	5 max
Viscosity peak (Brabender units)	300–900	600	350–450 (at 92.5°C: 280–400)
Pulp	.25cc/50g	0.1cc/50g	0.5cc/50g
pH	6.5–7.0 (6.7 desired)	5.5–7.5	5.0–6.5
Acid factor	–	2.6 max	1.75–2.5
Cleanliness	FDA approved	FDA approved	FDA approved

Appendix D

Linear Programming Matrix Used in Estimating EEC Least-Cost Feed Rations

TABLE D.1. Linear programming matrix used for least-cost feed rations, of Netherlands, Germany, France, Italy, Belgium-Luxembourg (format that of IBM MPSX).

```
NAME           EECOTH
ROWS
 G  S.E.
 G  M.E.
 G  TDN
 G  PROT.MIN
 L  PROT.MAX
 G  CR.FAT
 L  CR.FIB
 G  LYSINE
 G  METH
 G  METH+CYS
 G  CAL.MIN.
 L  CAL.MAX.
 G  PHOSOP
 L  BARLEY
 L  WHEAT
 L  MAIZE
 L  LINDSEED
 L  SOYBEAN
 L  M.GLUTTN
 L  COTTMEAL
 L  LINDMEAL
 L  GRNUTEXP
 L  WH.MIDD
 L  WH.BRAN
 L  BEETPULP
 L  BREWGRAN
 L  CITRPULP
 L  RICEBRAN
 L  FISHMEAL
 L  OYSTSHEL
 L  MEATBONE
 L  MOLASSES
 L  TALLOW
 L  RAPE
 L  CASSAVA
 E  M.TON
 G  MINMAIZ
 G  MINGRLUC
 G  MINFISH
 G  MINMAZGL
 G  MINBATLY
 N  P.GER
 N  P.FRA
 N  P.BEL
 N  P.ITA
 N  P.CASDEL
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COLUMNS
    SORGHUM    S.E.          75.5000   M.E.       3240.0000
    SORGHUM    TON            1.1700   PROT.MIN     10.2000
    SORGHUM    PROT.MAX      10.2000   CR.FAT        3.2000
    SORGHUM    CR.FIB         2.0000   LYSINE        0.2300
    SORGHUM    METH           0.1700   METH+CYS      0.3500
    SORGHUM    CAL.MIN.       0.0200   CAL.MAX.      0.0200
    SORGHUM    PHOSOP         0.2500   M.TON         1.0000
    SORGHUM    P.GER          0.0970   P.FRA         0.0870
    SORGHUM    P.BEL          0.0930   P.ITA         0.0960
    BARLEY     S.E.          70.6000   M.E.       2690.0000
    BARLEY     TON            1.0400   PROT.MIN     10.9000
    BARLEY     PROT.MAX      10.9000   CR.FAT        2.0000
    BARLEY     CR.FIB         5.1000   LYSINE        0.3900
    BARLEY     METH           0.1800   METH+CYS      0.4300
    BARLEY     CAL.MIN.       0.0700   CAL.MAX.      0.0700
    BARLEY     PHOSOP         0.3600   BARLEY        1.0000
    BARLEY     M.TON          1.0000   MINBATLY      1.0000
    BARLEY     P.GER          0.0990   P.FRA         0.0890
    BARLEY     P.BEL          0.0960   P.ITA         0.0970
    WHEAT      S.E.          76.2000   M.E.       3020.0000
    WHEAT      TON            1.1100   PROT.MIN     11.5000
    WHEAT      PROT.MAX      11.5000   CR.FAT        1.7000
    WHEAT      CR.FIB         2.1000   LYSINE        0.3300
    WHEAT      METH           0.1900   METH+CYS      0.4600
    WHEAT      CAL.MIN.       0.0500   CAL.MAX.      0.0500
    WHEAT      PHOSOP         0.3800   WHEAT         1.0000
    WHEAT      M.TON          1.0000   P.GER         0.1120
    WHEAT      P.FRA          0.1000   P.BEL         0.1090
    WHEAT      P.ITA          0.1180
    MAIZE      S.E.          30.6000   M.E.       3360.0000
    MAIZE      TON            1.1700   PROT.MIN      9.1000
    MAIZE      PROT.MAX       9.1000   CR.FAT        4.2000
    MAIZE      CR.FIB         2.4000   LYSINE        0.2700
    MAIZE      METH           0.2000   METH+CYS      0.4200
    MAIZE      CAL.MIN.       0.0200   CAL.MAX.      0.0200
    MAIZE      PHOSOP         0.3000   MAIZE         1.0000
    MAIZE      M.TON          1.0000   MINMAIZ       1.0000
    MAIZE      P.GER          0.1000   P.FRA         0.0760
    MAIZE      P.BEL          0.0950   P.ITA         0.0840
    LINSEED    S.E.         127.3000   TON           1.7200
    LINSEED    PROT.MIN      21.5000   PROT.MAX     21.5000
    LINSEED    CR.FAT        34.2000   CR.FIB        7.3000
    LINSEED    LYSINE         0.7900   METH          0.4300
    LINSEED    METH+CYS       0.8300   CAL.MIN.      0.2300
    LINSEED    CAL.MAX.       0.2300   PHOSOP        0.6600
    LINSEED    LINOSEED       1.0000   M.TON         1.0000
    LINSEED    P.GER          0.1310   P.FRA         0.1310
    LINSEED    P.BEL          0.1310   P.ITA         0.1310
    SOYBEAN    S.E.          97.9000   M.E.       2900.0000
    SOYBEAN    TON            1.3600   PROT.MIN     36.6000
    SOYBEAN    PROT.MAX      36.6000   CR.FAT       18.3000
    SOYBEAN    CR.FIB         6.0000   LYSINE        2.2600
    SOYBEAN    METH           0.5100   METH+CYS      1.0600
    SOYBEAN    CAL.MIN.       0.2900   CAL.MAX.      0.2900
    SOYBEAN    PHOSOP         0.6200   SOYBEAN       1.0000
    SOYBEAN    M.TON          1.0000   P.GER         0.1470
    SOYBEAN    P.FRA          0.1470   P.BEL         0.1470
    SOYBEAN    P.ITA          0.1470
    M.GLUTTN   S.E.          64.7900   M.E.       1900.0000
    M.GLUTTN   TON            0.9000   PROT.MIN     22.6000
    M.GLUTTN   PROT.MAX      22.6000   CR.FAT        3.9000
    M.GLUTTN   CR.FIB         8.2000   LYSINE        0.7200
    M.GLUTTN   METH           0.4300   METH+CYS      0.9500
    M.GLUTTN   CAL.MIN.       0.1400   CAL.MAX.      0.1400
```

M.GLUTTN	PHOSOP	0.5500	M.GLUTTN	1.0000
M.GLUTTN	M.TON	1.0000	MINMAZGL	1.0000
M.GLUTTN	P.GER	0.0790	P.FRA	0.0790
M.GLUTTN	P.BEL	0.0790	P.ITA	0.0790
COTTMEAL	S.E.	62.0000	M.E.	2030.0000
COTTMEAL	TDN	0.9600	PROT.MIN	41.3000
COTTMEAL	PROT.MAX	41.3000	CR.FAT	5.6000
COTTMEAL	CR.FIB.	11.5000	LYSINE	1.5600
COTTMEAL	METH	0.6600	METH+CYS	1.3600
COTTMEAL	CAL.MIN.	0.2000	CAL.MAX.	0.2000
COTTMEAL	PHOSOP	1.1500	COTTMEAL	1.0000
COTTMEAL	M.TON	1.0000	P.GER	0.1020
COTTMEAL	P.FRA	0.1020	P.BEL	0.1020
COTTMEAL	P.ITA	0.1020		
LINSEXP	S.E.	68.9000	M.E.	1600.0000
LINSEXP	TDN	1.0000	PROT.MIN	33.4000
LINSEXP	PROT.MAX	33.4000	CR.FAT	6.3000
LINSEXP	CR.FIB	9.0000	LYSINE	1.2300
LINSEXP	METH	0.6600	METH+CYS	1.3000
LINSEXP	CAL.MIN.	0.3300	CAL.MAX.	0.3300
LINSEXP	PHOSOP	0.8000	LINDMEAL	1.0000
LINSEXP	M.TON	1.0000	P.GER	0.0950
LINSEXP	P.FRA	0.0950	P.BEL	0.0950
LINSEXP	P.ITA	0.0950		
GRNUTEXP	S.E.	78.1000	M.E.	2630.0000
GRNUTEXP	TDN	1.1300	PROT.MIN	49.8000
GRNUTEXP	PROT.MAX	49.8000	CR.FAT	7.0000
GRNUTEXP	CR.FIB	5.3000	LYSINE	1.6400
GRNUTEXP	METH	0.5400	METH+CYS	1.1900
GRNUTEXP	CAL.MIN.	0.1400	CAL.MAX.	0.1400
GRNUTEXP	PHOSOP	0.6400	GRNUTEXP	1.0000
GRNUTEXP	M.TON	1.0000	P.GER	0.1310
GRNUTEXP	P.FRA	0.1310	P.BEL	0.1310
GRNUTEXP	P.ITA	0.1310		
WH.MIDDL	S.E.	64.6000	M.E.	2060.0000
WH.MIDDL	TDN	0.9400	PROT.MIN	16.3000
WH.MIDDL	PROT.MAX	16.3000	CR.FAT	4.3000
WH.MIDDL	CR.FIB	7.5000	LYSINE	0.6500
WH.MIDDL	METH	0.2600	METH+CYS	0.6200
WH.MIDDL	CAL.MIN.	0.1000	CAL.MAX.	0.1000
WH.MIDDL	PHOSOP	0.9000	WH.MIDD	1.0000
WH.MIDDL	M.TON	1.0000	P.GER	0.0760
WH.MIDDL	P.FRA	0.0690	P.BEL	0.0730
WH.MIDDL	P.ITA	0.0760		
WH.BRAN	S.E.	56.5000	M.E.	1800.0000
WH.BRAN	TDN	1.1000	PROT.MIN	15.8000
WH.BRAN	PROT.MAX	15.8000	CR.FAT	4.3000
WH.BRAN	CR.FIB	9.0000	LYSINE	0.6300
WH.BRAN	METH	0.2500	METH+CYS	0.6000
WH.BRAN	CAL.MIN.	0.1000	CAL.MAX.	0.1000
WH.BRAN	PHOSCP	1.2600	WH.BRAN	1.0000
WH.BRAN	M.TON	1.0000	P.GER	0.0840
WH.BRAN	P.FRA	0.0760	P.BEL	0.0810
WH.BRAN	P.ITA	0.0840		
BEETPULP	S.E.	67.1000	TDN	0.9400
BEETPULP	PROT.MIN	8.2000	PROT.MAX	8.2000
BEETPULP	CR.FIB	7.8000	LYSINE	0.4600
BEETPULP	METH	0.1300	METH+CYS	0.2400
BEETPULP	CAL.MIN.	0.6800	CAL.MAX.	0.6800
BEETPULP	PHOSOP	0.0700	BEETPULP	1.0000
BEETPULP	M.TON	1.0000	P.GER	0.0710
BEETPULP	P.FRA	0.0710	P.BEL	0.0710
BEETPULP	P.ITA	0.0710		
BR.GRAN	S.E.	70.0000	M.E.	2866.0000
BR.GRAN	TDN	0.9800	PROT.MIN	27.0000

BR.GRAN	PROT.MAX	27.0000	CR.FAT	9.0000
BR.GRAN	CR.FIB	5.0000	LYSINE	0.9000
BR.GRAN	METH	0.4000	METH+CYS	0.6200
BR.GRAN	CAL.MIN.	3.7500	CAL.MAX.	3.7500
BR.GRAN	PHOSOP	0.9800	BREWGRAN	1.0000
BR.GRAN	M.TON	1.0000	P.GER	0.0840
BR.GRAN	P.FRA	0.0760	P.BEL	0.0810
BR.GRAN	P.ITA	0.0840		
CITRPULP	S.E.	65.2000	TDN	0.9000
CITRPULP	PROT.MIN	6.2000	PROT.MAX	6.2000
CITRPULP	CR.FAT	3.3000	CR.FIB	12.9000
CITRPULP	LYSINE	0.2100	METH	0.0800
CITRPULP	METH+CYS	0.2000	CAL.MIN.	1.9000
CITRPULP	CAL.MAX.	1.9000	PHOSOP	0.1000
CITRPULP	CITRPULP	1.0000	M.TON	1.0000
CITRPULP	P.GER	0.0630	P.FRA	0.0630
CITRPULP	P.BEL	0.0630	P.ITA	0.0630
RICEBRAN	S.E.	89.9000	M.E.	3270.0000
RICEBRAN	TDN	1.3300	PROT.MIN	13.3000
RICEBRAN	PROT.MAX	13.3000	CR.FAT	14.8000
RICEBRAN	CR.FIB	5.7000	LYSINE	0.6200
RICEBRAN	METH	0.2600	METH+CYS	0.5300
RICEBRAN	CAL.MIN.	0.0400	CAL.MAX.	0.0400
RICEBRAN	PHOSOP	1.1000	RICEBRAN	1.0000
RICEBRAN	M.TON	1.0000	P.GER	0.0670
RICEBRAN	P.FRA	0.0600	P.BEL	0.0640
RICEBRAN	P.ITA	0.0660		
FISHMEAL	S.E.	70.9000	M.E.	2910.0000
FISHMEAL	TDN	0.9900	PROT.MIN	66.3000
FISHMEAL	PROT.MAX	66.3000	CR.FAT	8.1000
FISHMEAL	LYSINE	4.9100	METH	1.9200
FISHMEAL	METH+CYS	2.5800	CAL.MIN.	4.2000
FISHMEAL	CAL.MAX.	4.2000	PHOSOP	2.7500
FISHMEAL	FISHMEAL	1.0000	M.TON	1.0000
FISHMEAL	MINFISH	1.0000	P.GER	0.1910
FISHMEAL	P.FRA	0.1910	P.BEL	0.1910
FISHMEAL	P.ITA	0.1910		
OYSTSHEL	CR.FAT	0.5000	CAL.MIN.	38.0000
OYSTSHEL	CAL.MAX.	38.0000	OYSTSHEL	1.0000
OYSTSHEL	M.TON	1.0000	P.GER	0.0270
OYSTSHEL	P.FRA	0.0270	P.BEL	0.0270
OYSTSHEL	P.ITA	0.0270		
MEATBONE	S.E.	63.0000	M.E.	2425.0000
MEATBONE	TDN	0.7600	PROT.MIN	50.0000
MEATBONE	PROT.MAX	50.0000	CR.FAT	10.0000
MEATBONE	LYSINE	2.8000	METH	0.6500
MEATBONE	METH+CYS	1.2000	CAL.MIN.	10.0000
MEATBONE	CAL.MAX.	10.0000	PHOSOP	4.8000
MEATBONE	MEATBONE	1.0000	M.TON	1.0000
MEATBONE	P.GER	0.1030	P.FRA	0.1030
MEATBONE	P.BEL	0.1030	P.ITA	0.1030
MOLASSES	S.E.	42.7000	M.E.	2140.0000
MOLASSES	TDN	0.7600	PROT.MIN	3.4000
MOLASSES	PROT.MAX	3.4000	CR.FIB	0.2000
MOLASSES	CAL.MIN.	0.3400	CAL.MAX.	0.3400
MOLASSES	PHOSOP	0.0500	MOLASSES	1.0000
MOLASSES	M.TON	1.0000	P.GER	0.0480
MOLASSES	P.FRA	0.0480	P.BEL	0.0480
MOLASSES	P.ITA	0.0480		
TALLOW	S.E.	283.5999	M.E.	6850.0000
TALLOW	TDN	4.0100	CR.FAT	99.5000
TALLOW	TALLOW	1.0000	M.TON	1.0000
TALLOW	P.GER	0.1990	P.FRA	0.1990
TALLOW	P.BEL	0.1990	P.ITA	0.1990

RAPEEXT	S.E.	52.8000	M.E.	1690.0000
RAPEEXT	TDN	0.7900	PROT.MIN	35.3000
RAPEEXT	PROT.MAX	35.3000	CR.FAT	1.8000
RAPEEXT	CR.FIB	12.7000	LYSINE	2.0500
RAPEEXT	METH	0.7400	METH+CYS	1.3000
RAPEEXT	CAL.MIN.	0.6000	CAL.MAX.	0.6000
RAPEEXT	PHOSOP	1.1000	RAPE	1.0000
RAPEEXT	M.TON	1.0000	P.GER	0.0660
RAPEEXT	P.FRA	0.0660	P.BEL	0.0660
RAPEEXT	P.ITA	0.0660		
CASSAVA	S.E.	74.0000	M.E.	2910.0000
CASSAVA	TDN	1.1100	PROT.MIN	2.2000
CASSAVA	PROT.MAX	2.2000	CR.FAT	0.5000
CASSAVA	CR.FIB	3.0000	LYSINE	0.1100
CASSAVA	METH	0.0400	METH+CYS	0.0700
CASSAVA	CAL.MIN.	0.1100	CAL.MAX.	0.1100
CASSAVA	PHOSCP	0.0900	CASSAVA	1.0000
CASSAVA	M.TON	1.0000	P.GER	0.0620
CASSAVA	P.FRA	0.0620	P.BEL	0.0620
CASSAVA	P.ITA	0.0620	P.CASDEL	0.0050
GRASMEAL	S.E.	49.8000	M.E.	940.0000
GRASMEAL	TDN	0.7000	PROT.MIN	16.1000
GRASMEAL	PROT.MAX	16.1000	CR.FAT	3.5000
GRASMEAL	CR.FIB	22.4000	LYSINE	0.7600
GRASMEAL	METH	0.2400	METH+CYS	0.4200
GRASMEAL	CAL.MIN.	0.5800	CAL.MAX.	0.5800
GRASMEAL	PHOSOP	0.3400	M.TON	1.0000
GRASMEAL	MINGRLUC	1.0000	P.GER	0.0730
GRASMEAL	P.FRA	0.0730	P.BEL	0.0730
GRASMEAL	P.ITA	0.0730		
ALFAMEAL	S.E.	33.8000	M.E.	890.0000
ALFAMEAL	TDN	0.5000	PROT.MIN	17.0000
ALFAMEAL	PROT.MAX	17.0000	CR.FAT	2.3000
ALFAMEAL	CR.FIB	27.6000	LYSINE	0.8000
ALFAMEAL	METH	0.2600	METH+CYS	0.4500
ALFAMEAL	CAL.MIN.	1.7000	CAL.MAX.	1.7000
ALFAMEAL	PHOSOP	0.2500	M.TON	1.0000
ALFAMEAL	MINGRLUC	1.0000	P.GER	0.0650
ALFAMEAL	P.FRA	0.0650	P.BEL	0.0650
ALFAMEAL	P.ITA	0.0650		
SOYBMEAL	S.E.	70.0000	M.E.	1980.0000
SOYBMEAL	TDN	0.9600	PROT.MIN	42.3000
SOYBMEAL	PROT.MAX	42.3000	CR.FAT	2.0000
SOYBMEAL	CR.FIB	8.1000	LYSINE	2.6200
SOYBMEAL	METH	0.5900	METH+CYS	1.2300
SOYBMEAL	CAL.MIN.	0.3000	CAL.MAX.	0.3000
SOYBMEAL	PHOSOP	0.7000	M.TON	1.0000
SOYBMEAL	P.GER	0.1030	P.FRA	0.1030
SOYBMEAL	P.BEL	0.1030	P.ITA	0.1030
SUNFMEAL	S.E.	54.7000	M.E.	1790.0000
SUNFMEAL	TDN	0.9300	PROT.MIN	44.3000
SUNFMEAL	PROT.MAX	44.3000	CR.FAT	1.3000
SUNFMEAL	CR.FIB	14.4000	LYSINE	1.5000
SUNFMEAL	METH	0.9700	METH+CYS	1.7200
SUNFMEAL	CAL.MIN.	0.4000	CAL.MAX.	0.4000
SUNFMEAL	PHOSCP	0.9000	M.TON	1.0000
SUNFMEAL	P.GER	0.0870	P.FRA	0.0870
SUNFMEAL	P.BEL	0.0870	P.ITA	0.0870
OATS	S.E.	64.8000	M.E.	2580.0000
OATS	TDN	0.9200	PROT.MIN	10.4000
OATS	PROT.MAX	10.4000	CR.FAT	4.9000
OATS	CR.FIB	10.4000	LYSINE	0.3700
OATS	METH	0.1500	METH+CYS	0.4100
OATS	CAL.MIN.	0.1000	CAL.MAX.	0.1000
OATS	PHOSOP	0.3500	M.TON	1.0000
OATS	P.GER	0.0950	P.FRA	0.0890
OATS	P.BEL	0.1030	P.ITA	0.1040

RHS

COW.STAN	S.E.	66000.0000	M.E.	0.0
COW.STAN	TDN	0.0	PROT.MIN	16000.0000
COW.STAN	PROT.MAX	30000.0000	CR.FAT	3000.0000
COW.STAN	CR.FIB	7000.0000	LYSINE	0.0
COW.STAN	METH	0.0	METH+CYS	0.0
COW.STAN	CAL.MIN.	800.0000	CAL.MAX.	1100.0000
COW.STAN	PHOSOP	650.0000	BARLEY	100.0000
COW.STAN	WHEAT	200.0000	MAIZE	200.0000
COW.STAN	LINDSEED	200.0000	SOYBEAN	200.0000
COW.STAN	M.GLUTTN	250.0000	COTTMEAL	150.0000
COW.STAN	LINDMEAL	200.0000	GRNUTEXP	80.0000
COW.STAN	WH.MIDD	200.0000	WH.BRAN	200.0000
COW.STAN	BEETPULP	200.0000	BREWGRAN	50.0000
COW.STAN	CITRPULP	200.0000	RICEBRAN	100.0000
COW.STAN	FISHMEAL	50.0000	OYSTSHEL	0.0
COW.STAN	MEATBONE	50.0000	MOLASSES	150.0000
COW.STAN	TALLOW	20.0000	RAPE	100.0000
COW.STAN	CASSAVA	200.0000	M.TON	1000.0000
COW.STAN	MINMAIZ	0.0	MINGRLUC	0.0
COW.STAN	MINFISH	0.0	MINMAZGL	0.0
COW.STAN	MINBATLY	0.0	P.GER	0.0
COW.STAN	P.FRA	0.0	P.BEL	0.0
COW.STAN	P.ITA	0.0		
COW.CALF	S.E.	64000.0000	M.E.	0.0
COW.CALF	TDN	0.0	PROT.MIN	22000.0000
COW.CALF	PROT.MAX	40000.0000	CR.FAT	4000.0000
COW.CALF	CR.FIB	7000.0000	LYSINE	0.0
COW.CALF	METH	0.0	METH+CYS	0.0
COW.CALF	CAL.MIN.	850.0000	CAL.MAX.	1200.0000
COW.CALF	PHOSOP	800.0000	BARLEY	100.0000
COW.CALF	WHEAT	200.0000	MAIZE	200.0000
COW.CALF	LINDSEED	200.0000	SOYBEAN	200.0000
COW.CALF	M.GLUTTN	250.0000	COTTMEAL	150.0000
COW.CALF	LINDMEAL	200.0000	GRNUTEXP	80.0000
COW.CALF	WH.MIDD	200.0000	WH.BRAN	200.0000
COW.CALF	BEETPULP	200.0000	BREWGRAN	50.0000
COW.CALF	CITRPULP	200.0000	RICEBRAN	100.0000
COW.CALF	FISHMEAL	50.0000	OYSTSHEL	0.0
COW.CALF	MEATBONE	50.0000	MOLASSES	150.0000
COW.CALF	TALLOW	20.0000	RAPE	100.0000
COW.CALF	CASSAVA	200.0000	M.TON	1000.0000
COW.CALF	MINMAIZ	0.0	MINGRLUC	0.0
COW.CALF	MINFISH	0.0	MINMAZGL	0.0
COW.CALF	MINBATLY	0.0	P.GER	0.0
COW.CALF	P.FRA	0.0	P.BEL	0.0
COW.CALF	P.ITA	0.0		
LAY.MED	S.E.	0.0	M.E.	2800000.0000
LAY.MED	TDN	0.0	PROT.MIN	15000.0000
LAY.MED	PROT.MAX	25000.0000	CR.FAT	2000.0000
LAY.MED	CR.FIB	6000.0000	LYSINE	650.0000
LAY.MED	METH	320.0000	METH+CYS	600.0000
LAY.MED	CAL.MIN.	3000.0000	CAL.MAX.	3200.0000
LAY.MED	PHOSOP	450.0000	BARLEY	1000.0000
LAY.MED	WHEAT	100.0000	MAIZE	1000.0000
LAY.MED	LINDSEED	1000.0000	SOYBEAN	1000.0000
LAY.MED	M.GLUTTN	70.0000	COTTMEAL	0.0
LAY.MED	LINDMEAL	1000.0000	GRNUTEXP	50.0000
LAY.MED	WH.MIDD	100.0000	WH.BRAN	150.0000
LAY.MED	BEETPULP	50.0000	BREWGRAN	50.0000
LAY.MED	CITRPULP	0.0	RICEBRAN	30.0000
LAY.MED	FISHMEAL	50.0000	OYSTSHEL	50.0000
LAY.MED	MEATBONE	70.0000	MOLASSES	30.0000
LAY.MED	TALLOW	30.0000	RAPE	50.0000
LAY.MED	CASSAVA	100.0000	M.TON	1000.0000
LAY.MED	MINMAIZ	250.0000	MINGRLUC	30.0000

LAY.MED	MINFISH	20.0000	MINMAZGL	0.0
LAY.MED	MINBATLY	0.0	P.GER	0.0
LAY.MED	P.FRA	0.0	P.BEL	0.0
LAY.MED	P.ITA	0.0		
PROULGRW	S.E.	0.0	M.E.	3200000.0000
PROULGRW	TDN	0.0	PROT.MIN	20000.0000
PROULGRW	PROT.MAX	24000.0000	CR.FAT	2500.0000
PROULGRW	CR.FIB	5500.0000	LYSINE	1150.0000
PROULGRW	METH	430.0000	METH+CYS	820.0000
PROULGRW	CAL.MIN.	1000.0000	CAL.MAX.	1150.0000
PROULGRW	PHOSOP	500.0000	BARLEY	450.0000
PROULGRW	WHEAT	300.0000	MAIZE	400.0000
PROULGRW	LINDSEED	1000.0000	SOYBEAN	1000.0000
PROULGRW	M.GLUTTN	100.0000	COTTMEAL	0.0
PROULGRW	LINDMEAL	1000.0000	GRNUTEXP	70.0000
PROULGRW	WH.MIDD	250.0000	WH.BRAN	250.0000
PROULGRW	BEETPULP	0.0	BREWGRAN	50.0000
PROULGRW	CITRPULP	0.0	RICEBRAN	30.0000
PROULGRW	FISHMEAL	200.0000	OYSTSHEL	50.0000
PROULGRW	MEATBONE	70.0000	MOLASSES	20.0000
PROULGRW	TALLOW	30.0000	RAPE	50.0000
PROULGRW	CASSAVA	0.0	M.TON	1000.0000
PROULGRW	MINMAIZ	0.0	MINGRLUC	0.0
PROULGRW	MINFISH	20.0000	MINMAZGL	0.0
PROULGRW	MINBATLY	0.0	P.GER	0.0
PROULGRW	P.FRA	0.0	P.BEL	0.0
PROULGRW	P.ITA	0.0		
BROILRER	S.E.	0.0	M.E.	2800000.0000
BROILRER	TDN	0.0	PROT.MIN	0.0
BROILRER	PROT.MAX	23000.0000	CR.FAT	4000.0000
BROILRER	CR.FIB	5000.0000	LYSINE	1050.0000
BROILRER	METH	400.0000	METH+CYS	750.0000
BROILRER	CAL.MIN.	950.0000	CAL.MAX.	1150.0000
BROILRER	PHOSOP	450.0000	BARLEY	250.0000
BROILRER	WHEAT	200.0000	MAIZE	400.0000
BROILRER	LINDSEED	1000.0000	SOYBEAN	100.0000
BROILRER	M.GLUTTN	50.0000	COTTMEAL	0.0
BROILRER	LINDMEAL	1000.0000	GRNUTEXP	50.0000
BROILRER	WH.MIDD	100.0000	WH.BRAN	100.0000
BROILRER	BEETPULP	0.0	BREWGRAN	30.0000
BROILRER	CITRPULP	0.0	RICEBRAN	0.0
BROILRER	FISHMEAL	200.0000	OYSTSHEL	0.0
BROILRER	MEATBONE	50.0000	MOLASSES	20.0000
BROILRER	TALLOW	40.0000	RAPE	50.0000
BROILRER	CASSAVA	50.0000	M.TON	1000.0000
BROILRER	MINMAIZ	0.0	MINGRLUC	30.0000
BROILRER	MINFISH	20.0000	MINMAZGL	0.0
BROILRER	MINBATLY	0.0	P.GER	0.0
BROILRER	P.FRA	0.0	P.BEL	0.0
BROILRER	P.ITA	0.0		
BROILFIN	S.E.	0.0	M.E.	2800000.0000
BROILFIN	TDN	0.0	PROT.MIN	0.0
BROILFIN	PROT.MAX	19500.0000	CR.FAT	5000.0000
BROILFIN	CR.FIB	5000.0000	LYSINE	840.0000
BROILFIN	METH	320.0000	METH+CYS	600.0000
BROILFIN	CAL.MIN.	800.0000	CAL.MAX.	1000.0000
BROILFIN	PHOSOP	420.0000	BARLEY	250.0000
BROILFIN	WHEAT	200.0000	MAIZE	400.0000
BROILFIN	LINDSEED	1000.0000	SOYBEAN	70.0000
BROILFIN	M.GLUTTN	100.0000	COTTMEAL	0.0
BROILFIN	LINDMEAL	1000.0000	GRNUTEXP	50.0000
BROILFIN	WH.MIDD	100.0000	WH.BRAN	150.0000
BROILFIN	BEETPULP	0.0	BREWGRAN	30.0000
BROILFIN	CITRPULP	0.0	RICEBRAN	50.0000
BROILFIN	FISHMEAL	200.0000	OYSTSHEL	0.0
BROILFIN	MEATBONE	50.0000	MOLASSES	30.0000

BROILFIN	TALLOW	40.0000	RAPE	50.0000
BROILFIN	CASSAVA	100.0000	M.TON	1000.0000
BROILFIN	MINMAIZ	0.0	MINGRLUC	30.0000
BROILFIN	MINFISH	0.0	MINMAZGL	0.0
BROILFIN	MINBATLY	0.0	P.GER	0.0
BROILFIN	P.FRA	0.0	P.BEL	0.0
BROILFIN	P.ITA	0.0		
PIGSTART	S.E.	0.0	M.E.	0.0
PIGSTART	TDN	1070.0000	PROT.MIN	0.0
PIGSTART	PROT.MAX	19500.0000	CR.FAT	2500.0000
PIGSTART	CR.FIB	6000.0000	LYSINE	940.0000
PIGSTART	METH	0.0	METH+CYS	600.0000
PIGSTART	CAL.MIN.	800.0000	CAL.MAX.	1000.0000
PIGSTART	PHOSOP	650.0000	BARLEY	100.0000
PIGSTART	WHEAT	300.0000	MAIZE	300.0000
PIGSTART	LINDSEED	1000.0000	SOYBEAN	1000.0000
PIGSTART	M.GLUTTN	200.0000	COTTMEAL	0.0
PIGSTART	LINDMEAL	1000.0000	GRNUTEXP	50.0000
PIGSTART	WH.MIDD	250.0000	WH.BRAN	250.0000
PIGSTART	BEETPULP	0.0	BREWGRAN	50.0000
PIGSTART	CITRPULP	50.0000	RICEBRAN	100.0000
PIGSTART	FISHMEAL	70.0000	OYSTSHEL	0.0
PIGSTART	MEATBONE	200.0000	MOLASSES	30.0000
PIGSTART	TALLOW	30.0000	RAPE	50.0000
PIGSTART	CASSAVA	50.0000	M.TON	1000.0000
PIGSTART	MINMAIZ	0.0	MINGRLUC	0.0
PIGSTART	MINFISH	0.0	MINMAZGL	100.0000
PIGSTART	MINBATLY	0.0	P.GER	0.0
PIGSTART	P.FRA	0.0	P.BEL	0.0
PIGSTART	P.ITA	0.0		
PIG-30KG	S.E.	0.0	M.E.	0.0
PIG-30KG	TDN	1000.0000	PROT.MIN	0.0
PIG-30KG	PROT.MAX	18500.0000	CR.FAT	2500.0000
PIG-30KG	CR.FIB	6000.0000	LYSINE	900.0000
PIG-30KG	METH	0.0	METH+CYS	560.0000
PIG-30KG	CAL.MIN.	800.0000	CAL.MAX.	1000.0000
PIG-30KG	PHOSOP	650.0000	BARLEY	600.0000
PIG-30KG	WHEAT	350.0000	MAIZE	150.0000
PIG-30KG	LINDSEED	1000.0000	SOYBEAN	1000.0000
PIG-30KG	M.GLUTTN	70.0000	COTTMEAL	0.0
PIG-30KG	LINDMEAL	1000.0000	GRNUTEXP	50.0000
PIG-30KG	WH.MIDD	70.0000	WH.BRAN	70.0000
PIG-30KG	BEETPULP	0.0	BREWGRAN	50.0000
PIG-30KG	CITRPULP	50.0000	RICEBRAN	100.0000
PIG-30KG	FISHMEAL	70.0000	OYSTSHEL	0.0
PIG-30KG	MEATBONE	200.0000	MOLASSES	40.0000
PIG-30KG	TALLOW	30.0000	RAPE	50.0000
PIG-30KG	CASSAVA	100.0000	M.TON	1000.0000
PIG-30KG	MINMAIZ	0.0	MINGRLUC	0.0
PIG-30KG	MINFISH	0.0	MINMAZGL	0.0
PIG-30KG	MINBATLY	100.0000	P.GER	0.0
PIG-30KG	P.FRA	0.0	P.BEL	0.0
PIG-30KG	P.ITA	0.0		
PG30-100	S.E.	0.0	M.E.	0.0
PG30-100	TDN	1030.0000	PROT.MIN	0.0
PG30-100	PROT.MAX	18000.0000	CR.FAT	2000.0000
PG30-100	CR.FIB	7000.0000	LYSINE	800.0000
PG30-100	METH	0.0	METH+CYS	520.0000
PG30-100	CAL.MIN.	800.0000	CAL.MAX.	1000.0000
PG30-100	PHOSOP	650.0000	BARLEY	600.0000
PG30-100	WHEAT	350.0000	MAIZE	100.0000
PG30-100	LINDSEED	1000.0000	SOYBEAN	1000.0000
PG30-100	M.GLUTTN	100.0000	COTTMEAL	0.0
PG30-100	LINDMEAL	1000.0000	GRNUTEXP	50.0000
PG30-100	WH.MIDD	70.0000	WH.BRAN	70.0000

PG30-100	BEETPULP	0.0	BREWGRAN	50.0000
PG30-100	CITRPULP	50.0000	RICEBRAN	100.0000
PG30-100	FISHMEAL	300.0000	OYSTSHEL	0.0
PG30-100	MEATBONE	200.0000	MOLASSES	50.0000
PG30-100	TALLOW	30.0000	RAPE	50.0000
PG30-100	CASSAVA	150.0000	M.TON	1000.0000
PG30-100	MINMAIZ	0.0	MINGRLUC	30.0000
PG30-100	MINFISH	0.0	MINMAZGL	0.0
PG30-100	MINBATLY	100.0000	P.GER	0.0
PG30-100	P.FRA	0.0	P.BEL	0.0
PG30-100	P.ITA	0.0		
SOWS	S.E.	0.0	M.E.	0.0
SOWS	TDN	970.0000	PROT.MIN	0.0
SOWS	PROT.MAX	18000.0000	CR.FAT	2000.0000
SOWS	CR.FIB	7000.0000	LYSINE	800.0000
SOWS	METH	0.0	METH+CYS	520.0000
SOWS	CAL.MIN.	800.0000	CAL.MAX.	1200.0000
SOWS	PHOSOP	650.0000	BARLEY	600.0000
SOWS	WHEAT	350.0000	MAIZE	100.0000
SOWS	LINDSEED	1000.0000	SOYBEAN	1000.0000
SOWS	M.GLUTTN	100.0000	COTTMEAL	0.0
SOWS	LINDMEAL	1000.0000	GRNUTEXP	50.0000
SOWS	WH.MIDD	200.0000	WH.BRAN	200.0000
SOWS	BEETPULP	0.0	BREWGRAN	50.0000
SOWS	CITRPULP	50.0000	RICEBRAN	100.0000
SOWS	FISHMEAL	300.0000	OYSTSHEL	0.0
SOWS	MEATBONE	200.0000	MOLASSES	50.0000
SOWS	TALLOW	30.0000	RAPE	50.0000
SOWS	CASSAVA	70.0000	M.TON	1000.0000
SOWS	MINMAIZ	0.0	MINGRLUC	70.0000
SOWS	MINFISH	30.0000	MINMAZGL	0.0
SOWS	MINBATLY	0.0	P.GER	0.0
SOWS	P.FRA	0.0	P.BEL	0.0
SOWS	P.ITA	0.0		
CASSE	S.E.	2.0000	M.E.	0.0
CASSE	TDN	0.0	PROT.MIN	0.0
CASSE	PROT.MAX	0.0	CR.FAT	0.0
CASSE	CR.FIB	0.0	LYSINE	0.0
CASSE	METH	0.0	METH+CYS	0.0
CASSE	CAL.MIN.	0.0	CAL.MAX.	0.0
CASSE	PHOSOP	0.0	BARLEY	0.0
CASSE	WHEAT	0.0	MAIZE	0.0
CASSE	LINDSEED	0.0	SOYBEAN	0.0
CASSE	M.GLUTTN	0.0	COTTMEAL	0.0
CASSE	LINDMEAL	0.0	GRNUTEXP	0.0
CASSE	WH.MIDD	0.0	WH.BRAN	0.0
CASSE	BEETPULP	0.0	BREWGRAN	0.0
CASSE	CITRPULP	0.0	RICEBRAN	0.0
CASSE	FISHMEAL	0.0	OYSTSHEL	0.0
CASSE	MEATBONE	0.0	MOLASSES	0.0
CASSE	TALLOW	0.0	RAPE	0.0
CASSE	CASSAVA	0.0	M.TON	0.0
CASSE	MINMAIZ	0.0	MINGRLUC	0.0
CASSE	MINFISH	0.0	MINMAZGL	0.0
CASSE	MINBATLY	0.0	P.GER	0.0
CASSE	P.FRA	0.0	P.BEL	0.0
CASSE	P.ITA	0.0		
CASME	S.E.	0.0	M.E.	50.0000
CASME	TDN	0.0	PROT.MIN	0.0
CASME	PROT.MAX	0.0	CR.FAT	0.0
CASME	CR.FIB	0.0	LYSINE	0.0
CASME	METH	0.0	METH+CYS	0.0
CASME	CAL.MIN.	0.0	CAL.MAX.	0.0
CASME	PHOSOP	0.0	BARLEY	0.0
CASME	WHEAT	0.0	MAIZE	0.0

CASME	LINDSEED	0.0	SOYBEAN	0.0
CASME	M.GLUTTN	0.0	COTTMEAL	0.0
CASME	LINDMEAL	0.0	GRNUTEXP	0.0
CASME	WH.MIDD	0.0	WH.BRAN	0.0
CASME	BEETPULP	0.0	BREWGRAN	0.0
CASME	CITRPULP	0.0	RICEBRAN	0.0
CASME	FISHMEAL	0.0	OYSTSHEL	0.0
CASME	MEATBONE	0.0	MOLASSES	0.0
CASME	TALLOW	0.0	RAPE	0.0
CASME	CASSAVA	0.0	M.TON	0.0
CASME	MINMAIZ	0.0	MINGRLUC	0.0
CASME	MINFISH	0.0	MINMAZGL	0.0
CASME	MINBATLY	0.0	P.GER	0.0
CASME	P.FRA	0.0	P.BEL	0.0
CASME	P.ITA	0.0		
CASPROT	S.E.	0.0	M.E.	0.0
CASPROT	TDN	0.0	PROT.MIN	0.5000
CASPROT	PROT.MAX	0.5000	CR.FAT	0.0
CASPROT	CR.FIB	0.0	LYSINE	0.0
CASPROT	METH	0.0	METH+CYS	0.0
CASPROT	CAL.MIN.	0.0	CAL.MAX.	0.0
CASPROT	PHOSOP	0.0	BARLEY	0.0
CASPROT	WHEAT	0.0	MAIZE	0.0
CASPROT	LINDSEED	0.0	SOYBEAN	0.0
CASPROT	M.GLUTTN	0.0	COTTMEAL	0.0
CASPROT	LINDMEAL	0.0	GRNUTEXP	0.0
CASPROT	WH.MIDD	0.0	WH.BRAN	0.0
CASPROT	BEETPULP	0.0	BREWGRAN	0.0
CASPROT	CITRPULP	0.0	RICEBRAN	0.0
CASPROT	FISHMEAL	0.0	OYSTSHEL	0.0
CASPROT	MEATBONE	0.0	MOLASSES	0.0
CASPROT	TALLOW	0.0	RAPE	0.0
CASPROT	CASSAVA	0.0	M.TON	0.0
CASPROT	MINMAIZ	0.0	MINGRLUC	0.0
CASPROT	MINFISH	0.0	MINMAZGL	0.0
CASPROT	MINBATLY	0.0	P.GER	0.0
CASPROT	P.FRA	0.0	P.BEL	0.0
CASPROT	P.ITA	0.0		
CASPLUS	S.E.	2.0000	M.E.	50.0000
CASPLUS	TDN	0.0200	PROT.MIN	0.5000
CASPLUS	PROT.MAX	0.5000	CR.FAT	0.0
CASPLUS	CR.FIB	0.0	LYSINE	0.0
CASPLUS	METH	0.0	METH+CYS	0.0
CASPLUS	CAL.MIN.	0.0	CAL.MAX.	0.0
CASPLUS	PHOSOP	0.0	BARLEY	0.0
CASPLUS	WHEAT	0.0	MAIZE	0.0
CASPLUS	LINDSEED	0.0	SOYBEAN	0.0
CASPLUS	M.GLUTTN	0.0	COTTMEAL	0.0
CASPLUS	LINDMEAL	0.0	GRNUTEXP	0.0
CASPLUS	WH.MIDD	0.0	WH.BRAN	0.0
CASPLUS	BEETPULP	0.0	BREWGRAN	0.0
CASPLUS	CITRPULP	0.0	RICEBRAN	0.0
CASPLUS	FISHMEAL	0.0	OYSTSHEL	0.0
CASPLUS	MEATBONE	0.0	MOLASSES	0.0
CASPLUS	TALLOW	0.0	RAPE	0.0
CASPLUS	CASSAVA	0.0	M.TON	0.0
CASPLUS	MINMAIZ	0.0	MINGRLUC	0.0
CASPLUS	MINFISH	0.0	MINMAZGL	0.0
CASPLUS	MINBATLY	0.0	P.GER	0.0
CASPLUS	P.FRA	0.0	P.BEL	0.0
CASPLUS	P.ITA	0.0		
CASTDN	S.E.	0.0	M.E.	0.0
CASTDN	TDN	0.0200	PROT.MIN	0.5000
CASTDN	PROT.MAX	0.5000	CR.FAT	0.0
CASTDN	CR.FIB	0.0	LYSINE	0.0

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    CASTDN      METH           0.0      METH+CYS      0.0
    CASTDN      CAL.MIN.       0.0      CAL.MAX.      0.0
    CASTDN      PHOSOP         0.0      BARLEY        0.0
    CASTDN      WHEAT          0.0      MAIZE         0.0
    CASTDN      LINDSEED       0.0      SOYBEAN       0.0
    CASTDN      M.GLUTTN       0.0      COTTMEAL      0.0
    CASTDN      LINDMEAL       0.0      GRNUTEXP      0.0
    CASTDN      WH.MIDD        0.0      WH.BRAN       0.0
    CASTDN      BEETPULP       0.0      BREWGRAN      0.0
    CASTDN      CITRPULP       0.0      RICEBRAN      0.0
    CASTDN      FISHMEAL       0.0      OYSTSHEL      0.0
    CASTDN      MEATBONE       0.0      MOLASSES      0.0
    CASTDN      TALLOW         0.0      RAPE          0.0
    CASTDN      CASSAVA        0.0      M.TON         0.0
    CASTDN      MINMAIZ        0.0      MINGRLUC      0.0
    CASTDN      MINFISH        0.0      MINMAZGL      0.0
    CASTDN      MINBATLY       0.0      P.GER         0.0
    CASTDN      P.FRA          0.0      P.BEL         0.0
    CASTDN      P.ITA          0.0
ENDATA
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Appendix E

Least-Cost Feed Rations for Varying Cassava Prices, and Price Data

TABLE E.1. Feed rations with variable cassava prices.

Price increment[a]	+1	+2	+3	+4	+5	+6	+1	+2	+3	+4	+5	+6
			Cow standard						*Beef and calf*			
Netherlands												
Cost	*69.53*	*71.62*	*73.29*	*73.99*	*74.55*	*75.08*	*74.23*	*75.45*	*76.65*	*77.72*	*78.26*	*78.71*
Cereal	–	–	–	–	–	–	–	–	–	–	–	–
Cereal byproducts	15.0	15.0	15.8	14.7	19.6	19.6	16.3	16.3	16.6	15.0	15.0	15.0
Oilseed and cake	21.9	21.9	19.6	20.1	18.9	18.9	36.9	36.9	36.6	29.3	18.4	18.4
Animal meal	5.0	5.0	5.0	5.0	4.1	4.1	5.0	5.0	5.0	5.0	5.0	5.0
Cassava	43.0	43.0	18.2	13.1	10.9	10.9	25.4	24.8	23.3	19.0	9.2	9.2
Other	15.0	15.0	41.1	46.8	46.1	46.1	16.2	16.7	18.2	31.5	52.2	52.2
Germany												
Cost	*69.41*	*70.47*	*70.88*	*70.88*	*70.88*	*70.88*	*73.16*	*74.13*	*74.13*	*74.13*	*74.13*	*74.37*
Cereal	–	–	–	–	–	–	–	–	–	–	–	–
Cereal byproducts	12.0	41.8	38.0	38.0	38.0	38.3	20.8	40.0	40.0	40.0	40.0	59.5
Oilseed and cake	23.4	10.0	10.0	10.0	10.0	10.0	34.8	25.1	25.1	25.1	25.1	18.7
Animal meal	5.0	3.9	4.1	4.1	4.1	4.1	5.0	5.0	5.0	5.0	5.0	5.0
Cassava	28.3	9.5	0.2	0.2	0.2	–	22.3	11.9	11.9	11.9	11.9	–
Other	31.1	34.5	47.3	47.3	47.3	47.3	16.8	17.8	17.8	17.8	17.8	16.5
France												
Cost	*66.34*	*66.34*	*66.34*	*66.34*	*66.34*	*67.47*	*70.55*	*70.55*	*70.55*	*70.55*	*70.55*	*71.18*
Cereal	–	–	–	–	–	18.9	–	–	–	–	–	16.4
Cereal byproducts	17.3	17.3	17.3	17.3	17.3	35.0	24.8	24.8	24.8	24.8	24.8	35.0
Oilseed and cake	23.6	23.6	23.6	23.6	23.6	15.9	34.2	34.2	34.2	34.2	34.2	28.8
Animal meal	4.0	4.0	4.0	4.0	4.0	1.5	5.0	5.0	5.0	5.0	5.0	4.1
Cassava	42.3	42.3	42.3	42.3	42.3	–	21.7	21.7	21.7	21.7	21.7	–
Other	12.7	12.7	12.7	12.7	12.7	28.6	14.1	14.1	14.1	14.1	14.1	15.3
Belgium-Luxembourg												
Cost	*68.98*	*69.70*	*69.70*	*69.70*	*69.70*	*69.91*	*72.60*	*72.60*	*72.60*	*72.60*	*72.60*	*73.33*
Cereal	–	–	–	–	–	–	–	–	–	–	–	–
Cereal byproducts	20.4	46.9	46.9	46.9	46.9	43.9	19.7	19.7	19.7	19.7	19.7	59.5
Oilseed and cake	21.0	10.0	10.0	10.0	10.0	10.0	35.8	35.8	35.8	35.8	35.8	18.8
Animal meal	3.9	4.2	4.2	4.2	4.2	4.3	5.0	5.0	5.0	5.0	5.0	5.0
Cassava	21.1	5.2	5.2	5.2	5.2	–	22.7	22.7	22.7	22.7	22.7	–
Other	33.3	33.4	33.4	33.4	33.4	41.6	16.6	16.6	16.6	16.6	16.6	16.6
Italy												
Cost	*69.31*	*70.37*	*70.37*	*70.37*	*70.37*	*70.65*	*73.06*	*74.03*	*74.03*	*74.03*	*74.03*	*74.25*
Cereal	–	–	–	–	–	10.2	–	–	–	–	–	11.4
Cereal byproducts	12.0	41.8	41.8	41.8	41.8	38.5	20.8	40.0	40.0	40.0	40.0	40.0
Oilseed and cake	23.4	10.0	10.0	10.0	10.0	10.0	34.8	25.1	25.1	25.1	25.1	22.9
Animal meal	5.0	3.9	3.9	3.9	3.9	3.7	5.0	5.0	5.0	5.0	5.0	5.0
Cassava	28.3	9.5	9.5	9.5	9.5	–	22.3	11.9	11.9	11.9	11.9	–
Other	31.1	34.5	34.5	34.5	34.5	37.3	16.8	17.8	17.8	17.8	17.8	20.4

TABLE E.1. (*continued*)

Price increment	+1	+2	+3	+4	+5	+6	+1	+2	+3	+4	+5	+6
	Layer medium						*Poultry grower*					
Netherlands												
Cost	*95.03*	*96.13*	*97.24*	*98.35*	*99.22*	*100.04*	*134.26*	*134.26*	*134.26*	*134.26*	*134.26*	*134.26*
Cereal	35.2	35.2	35.2	35.2	38.7	38.7	59.8	59.8	59.8	59.8	59.8	59.8
Cereal byproducts	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	13.9	13.9	13.9	13.9	13.3	13.3	5.7	5.7	5.7	5.7	5.7	5.7
Animal meal	11.0	11.0	11.0	11.0	11.0	11.0	16.2	16.2	16.2	16.2	16.2	16.2
Cassava	22.8	22.8	22.8	22.8	16.9	16.9	–	–	–	–	–	–
Other	10.9	10.9	10.9	10.9	13.9	13.9	10.0	10.0	10.0	10.0	10.0	10.0
Germany												
Cost	*89.17*	*90.15*	*90.90*	*90.90*	*90.90*	*91.20*	*112.02*	*112.02*	*112.02*	*112.02*	*112.02*	*112.15*
Cereal	37.9	37.9	58.6	58.6	58.6	60.7	55.8	55.8	55.8	55.8	55.8	64.8
Cereal byproducts	8.0	8.0	8.0	8.0	8.0	9.7	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	14.6	14.6	10.2	10.2	10.2	9.1	5.9	5.9	5.9	5.9	5.9	7.8
Animal meal	9.0	9.0	9.0	9.0	9.0	9.0	17.3	17.3	17.3	17.3	17.3	16.3
Cassava	19.4	19.4	3.0	3.0	3.0	–	9.8	9.8	9.8	9.8	9.8	–
Other	10.9	10.9	11.0	11.0	11.0	11.3	3.0	3.0	3.0	3.0	3.0	3.0
France												
Cost	*75.89*	*75.89*	*75.89*	*75.89*	*75.89*	*75.89*	*99.45*	*99.45*	*99.45*	*99.45*	*99.45*	*99.45*
Cereal	60.7	60.7	60.7	60.7	60.7	60.7	64.8	64.8	64.8	64.8	64.8	64.8
Cereal byproducts	9.7	9.7	9.7	9.7	9.7	9.7	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	9.1	9.1	9.1	9.1	9.1	9.1	7.8	7.8	7.8	7.8	7.8	7.8
Animal meal	9.0	9.0	9.0	9.0	9.0	9.0	16.3	16.3	16.3	16.3	16.3	16.3
Cassava	–	–	–	–	–	–	–	–	–	–	–	–
Other	11.3	11.3	11.3	11.3	11.3	11.3	3.0	3.0	3.0	3.0	3.0	3.0
Belgium-Luxembourg												
Cost	*87.04*	*87.58*	*87.73*	*87.73*	*87.73*	*87.88*	*108.91*	*108.91*	*108.91*	*108.91*	*108.91*	*108.91*
Cereal	37.9	58.7	58.7	58.7	58.7	60.7	64.8	64.8	64.8	64.8	64.8	64.8
Cereal byproducts	8.0	8.0	8.0	8.0	8.0	9.7	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	14.6	10.2	10.2	10.2	10.2	9.1	7.8	7.8	7.8	7.8	7.8	7.8
Animal meal	9.0	9.0	9.0	9.0	9.0	9.0	16.3	16.3	16.3	16.3	16.3	16.3
Cassava	19.4	3.0	3.0	3.0	3.0	–	–	–	–	–	–	–
Other	10.9	11.0	11.0	11.0	11.0	11.3	3.0	3.0	3.0	3.0	3.0	3.0
Italy												
Cost	*81.17*	*81.33*	*81.33*	*81.33*	*81.33*	*81.43*	*105.43*	*105.43*	*105.43*	*105.43*	*105.43*	*105.47*
Cereal	58.7	58.7	58.7	58.7	58.7	61.5	55.8	55.8	55.8	55.8	55.8	64.8
Cereal byproducts	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	10.2	10.2	10.2	10.2	10.2	9.4	5.9	5.9	5.9	5.9	5.9	7.8
Animal meal	9.0	9.0	9.0	9.0	9.0	8.8	17.3	17.3	17.3	17.3	17.3	16.3
Cassava	3.0	3.0	3.0	3.0	3.0	–	9.8	9.8	9.8	9.8	9.8	–
Other	11.0	11.0	11.0	11.0	11.0	12.0	3.0	3.0	3.0	3.0	3.0	3.0

(continued next page)

TABLE E.1. *(continued)*

Price increment	+1	+2	+3	+4	+5	+6	+1	+2	+3	+4	+5	+6
			Broiler						*Broiler finisher*			
Netherlands												
Cost	*103.34*	*105.37*	*107.40*	*109.07*	*110.36*	*111.27*	*89.86*	*92.38*	*94.90*	*97.17*	*98.81*	*100.42*
Cereal	10.1	10.1	10.1	24.3	32.6	32.6	–	–	–	10.4	18.1	20.0
Cereal byproducts	3.0	3.0	3.0	3.0	3.0	3.0	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	16.8	16.8	16.8	20.6	23.7	23.7	14.2	14.2	14.2	15.9	19.4	19.8
Animal meal	14.1	14.1	14.1	11.1	9.2	9.2	10.3	10.3	10.3	8.7	6.5	6.2
Cassava	41.7	41.7	41.7	26.7	18.7	18.7	51.9	51.9	51.9	41.8	33.4	31.5
Other	14.0	14.0	14.0	14.0	12.5	12.5	14.8	14.8	14.8	15.0	14.3	14.3
Germany												
Cost	*94.12*	*95.87*	*97.42*	*98.09*	*98.09*	*98.27*	*85.55*	*87.85*	*89.92*	*91.40*	*91.98*	*92.00*
Cereal	23.8	25.2	31.0	53.6	53.6	58.2	13.1	15.5	20.1	33.5	50.7	53.0
Cereal byproducts	3.0	3.0	3.0	3.0	3.0	5.5	8.0	8.0	8.0	8.6	18.0	18.0
Oilseed and cake	18.2	18.0	18.3	23.9	23.9	21.8	15.5	15.4	15.7	20.7	16.4	16.2
Animal meal	14.3	14.2	13.6	9.0	9.0	9.2	10.7	10.4	9.9	6.1	5.8	5.7
Cassava	35.6	34.7	27.4	4.8	4.8	–	47.6	44.5	38.4	23.5	2.3	–
Other	4.9	4.6	6.4	5.4	5.4	5.0	4.9	5.8	7.7	7.3	6.5	6.8
France												
Cost	*85.56*	*86.35*	*86.35*	*86.35*	*86.35*	*86.43*	*78.67*	*79.41*	*79.78*	*79.78*	*79.78*	*79.81*
Cereal	40.0	55.1	55.1	55.1	55.1	58.2	40.0	40.0	50.7	50.7	50.7	53.0
Cereal byproducts	3.0	3.0	3.0	3.0	3.0	5.5	15.0	15.0	18.0	18.0	18.0	18.0
Oilseed and cake	19.6	23.5	23.5	23.5	23.5	21.8	16.6	16.6	16.4	16.4	16.4	16.2
Animal meal	12.0	9.0	9.0	9.0	9.0	9.2	6.6	6.6	5.8	5.8	5.8	5.7
Cassava	20.8	3.8	3.8	3.8	3.8	–	14.7	14.7	2.3	2.3	2.3	–
Other	4.2	5.2	5.2	5.2	5.2	5.0	6.9	6.9	6.5	6.5	6.5	6.8
Belgium-Luxembourg												
Cost	*92.70*	*94.29*	*95.21*	*95.21*	*95.21*	*95.37*	*84.60*	*86.75*	*88.29*	*88.89*	*88.89*	*88.94*
Cereal	28.8	32.8	55.1	55.1	55.1	58.2	14.8	20.1	33.5	50.7	50.7	53.0
Cereal byproducts	3.0	3.0	3.0	3.0	3.0	5.5	8.0	8.0	8.6	18.0	18.0	18.0
Oilseed and cake	16.8	17.5	23.5	23.5	23.5	21.8	15.6	15.7	20.7	16.4	16.4	16.2
Animal meal	14.2	13.7	9.0	9.0	9.0	9.2	10.4	9.9	6.1	5.8	5.8	5.7
Cassava	33.1	29.1	3.8	3.8	3.8	–	45.7	38.4	23.5	2.3	2.3	–
Other	3.9	3.6	5.2	5.2	5.2	5.0	5.3	7.7	7.3	6.5	6.5	6.8
Italy												
Cost	*89.00*	*90.05*	*91.06*	*91.55*	*91.55*	*91.69*	*82.44*	*83.58*	*84.35*	*85.11*	*85.42*	*85.42*
Cereal	40.0	40.0	40.0	55.1	55.1	58.2	33.7	40.0	40.0	40.0	51.8	53.0
Cereal byproducts	3.0	3.0	3.0	3.0	3.0	5.5	8.0	12.7	12.7	12.7	18.0	18.0
Oilseed and cake	19.6	19.6	20.2	23.5	23.5	21.8	20.7	18.8	18.8	18.8	16.2	16.2
Animal meal	12.0	12.0	11.7	9.0	9.0	9.2	6.1	5.9	5.9	5.9	5.7	5.7
Cassava	20.8	20.8	18.9	3.8	3.8	–	23.8	15.2	15.2	15.2	1.2	–
Other	4.2	4.2	5.8	5.2	5.2	5.0	7.4	6.9	6.9	6.9	6.6	6.8

TABLE E.1. *(continued)*

Price increment	+1	+2	+3	+4	+5	+6	+1	+2	+3	+4	+5	+6
	Pig starter						*Pig (0–30 kg)*					
Netherlands												
Cost	*83.42*	*85.43*	*87.44*	*89.24*	*90.79*	*92.22*	*81.74*	*83.74*	*85.69*	*87.63*	*89.47*	*91.10*
Cereal	–	–	–	–	–	–	10.0	10.0	10.0	10.0	10.0	10.0
Cereal byproducts	20.0	20.0	20.0	34.5	34.5	45.0	5.4	10.0	10.0	10.0	17.0	17.0
Oilseed and cake	25.7	25.7	25.7	20.8	20.8	15.8	26.8	25.5	25.5	25.5	24.0	24.0
Animal meal	8.2	8.2	8.2	8.3	8.3	8.5	7.7	7.8	7.8	7.8	7.6	7.6
Cassava	41.4	41.4	41.4	31.8	31.8	26.3	43.3	40.0	40.0	40.0	33.4	33.4
Other	4.4	4.4	4.4	4.3	4.3	4.1	6.5	6.4	6.4	6.4	7.7	7.7
Germany												
Cost	*78.10*	*80.17*	*82.08*	*83.28*	*84.26*	*85.18*	*77.58*	*79.35*	*80.84*	*82.27*	*83.53*	*84.64*
Cereal	–	–	–	–	–	–	10.0	10.0	10.0	10.0	10.0	10.0
Cereal byproducts	20.0	20.0	20.0	45.0	50.0	53.2	10.0	24.0	24.0	29.0	36.0	36.0
Oilseed and cake	25.5	26.8	26.8	16.1	16.2	15.3	23.3	17.9	17.9	18.3	16.9	17.0
Animal meal	6.2	5.3	5.3	7.7	6.2	6.4	7.6	7.2	7.2	5.5	5.7	5.7
Cassava	43.7	38.1	38.1	20.9	18.9	17.9	40.8	29.6	29.6	26.6	22.1	22.1
Other	4.2	9.5	9.5	10.0	8.5	6.9	8.0	11.0	11.0	10.4	9.0	9.0
France												
Cost	*77.33*	*78.36*	*78.70*	*78.86*	*78.95*	*79.04*	*75.47*	*76.97*	*77.70*	*78.23*	*78.75*	*79.26*
Cereal	–	8.8	19.2	30.0	30.0	30.0	10.0	10.0	25.0	25.0	25.0	29.1
Cereal byproducts	40.2	52.9	43.0	34.3	34.3	34.3	22.0	31.4	31.5	31.5	31.5	29.0
Oilseed and cake	20.2	15.2	17.3	18.4	18.4	18.4	20.7	18.0	16.8	16.8	16.8	17.1
Animal meal	4.5	6.6	5.7	5.8	5.8	5.8	6.0	5.6	5.7	5.7	5.7	5.6
Cassava	30.7	11.1	4.4	1.8	1.8	1.8	33.6	25.0	10.4	10.4	10.4	8.0
Other	4.1	5.1	10.1	9.4	9.4	9.4	7.5	9.7	10.3	10.3	10.3	11.0
Belgium-Luxembourg												
Cost	*77.80*	*79.87*	*81.15*	*82.09*	*82.98*	*83.81*	*76.88*	*78.54*	*79.98*	*81.25*	*82.36*	*83.43*
Cereal	–	–	–	–	–	2.5	10.0	10.0	10.0	10.0	10.0	13.6
Cereal byproducts	20.0	20.0	50.0	53.2	55.6	55.5	17.0	24.0	29.0	36.0	36.0	36.0
Oilseed and cake	25.5	26.8	18.2	15.3	13.9	13.0	20.8	17.9	18.3	16.9	16.9	16.7
Animal meal	6.2	5.3	4.4	6.4	7.5	8.6	7.8	7.2	5.5	5.7	5.7	5.7
Cassava	43.7	38.1	20.6	17.9	17.2	14.8	36.4	29.6	26.6	22.1	22.1	18.5
Other	4.2	9.5	6.5	6.9	5.4	5.4	7.8	11.0	10.4	9.0	9.0	9.2
Italy												
Cost	*78.00*	*80.07*	*81.98*	*82.67*	*82.89*	*83.00*	*77.28*	*79.05*	*80.54*	*81.94*	*82.59*	*83.16*
Cereal	–	–	–	19.2	19.2	30.0	10.0	10.0	10.0	22.3	25.0	25.0
Cereal byproducts	20.0	20.0	20.0	43.0	43.0	33.4	10.0	24.0	24.0	29.0	27.7	31.4
Oilseed and cake	25.5	26.8	26.8	17.3	17.3	18.5	23.3	17.9	17.9	17.3	17.0	15.3
Animal meal	6.2	5.3	5.3	5.7	5.7	5.5	7.6	7.2	7.2	5.5	5.9	7.4
Cassava	43.7	38.1	38.1	4.4	4.4	1.0	40.8	29.6	29.6	14.7	12.9	10.4
Other	4.2	9.5	9.5	10.1	10.1	11.4	8.0	11.0	11.0	10.9	11.2	10.3

(continued next page)

TABLE E.1. (*concluded*)

Price increment	+1	+2	+3	+4	+5	+6	+1	+2	+3	+4	+5	+6
			Pig (30–100 kg)							*Sow*		
Netherlands												
Cost	*78.41*	*80.35*	*82.30*	*84.14*	*85.59*	*87.04*	*76.78*	*79.45*	*81.91*	*84.17*	*86.26*	*87.98*
Cereal	10.0	10.0	10.0	10.0	10.0	10.0	–	–	–	–	–	–
Cereal byproducts	10.0	10.0	10.0	17.0	17.0	17.0	1.6	1.6	10.0	13.5	15.0	35.0
Oilseed and cake	23.6	23.6	23.6	21.8	21.6	21.6	17.6	17.6	14.1	16.9	16.9	8.2
Animal meal	8.0	8.0	8.0	7.2	7.2	7.2	10.4	10.4	10.4	8.8	8.3	9.0
Cassava	40.0	40.0	40.0	30.4	29.8	29.8	55.1	55.1	49.5	43.7	42.6	30.6
Other	8.1	8.1	8.1	13.3	14.2	14.2	15.0	15.0	15.7	17.0	16.9	16.9
Germany												
Cost	*76.20*	*78.28*	*80.02*	*81.40*	*82.37*	*83.23*	*74.00*	*76.02*	*77.70*	*79.12*	*80.03*	*81.47*
Cereal	10.0	10.0	10.0	10.0	10.0	10.0	–	–	–	–	–	–
Cereal byproducts	10.0	10.0	10.0	29.0	39.0	39.0	10.0	30.9	30.9	45.0	46.4	46.4
Oilseed and cake	21.9	26.5	26.8	20.5	16.1	16.1	13.8	7.0	7.0	5.8	5.0	5.0
Animal meal	5.8	4.7	4.9	3.4	3.5	3.5	10.4	10.2	10.2	7.9	8.0	8.0
Cassava	44.1	35.1	34.7	23.4	17.2	17.2	49.6	33.4	33.4	24.2	23.5	23.5
Other	8.0	13.4	13.2	13.4	14.0	14.0	16.0	18.2	18.2	16.9	16.9	16.9
France												
Cost	*74.44*	*75.80*	*76.53*	*77.26*	*77.26*	*77.38*	*72.19*	*73.74*	*74.75*	*75.58*	*75.58*	*75.91*
Cereal	10.0	20.0	20.0	20.0	20.0	29.8	–	–	10.0	10.0	10.0	21.3
Cereal byproducts	18.9	29.0	29.0	29.0	29.0	37.8	35.0	39.2	42.9	42.9	42.9	50.0
Oilseed and cake	20.3	19.6	19.6	19.6	19.6	12.9	6.6	6.1	5.0	5.0	5.0	5.0
Animal meal	4.0	3.2	3.2	3.2	3.2	3.1	8.9	8.5	8.3	8.3	8.3	6.6
Cassava	38.5	14.6	14.6	14.6	14.6	–	34.1	28.5	16.6	16.6	16.6	–
Other	8.0	13.4	13.4	13.4	13.4	16.1	15.0	17.4	17.0	17.0	17.0	17.0
Belgium-Luxembourg												
Cost	*75.60*	*77.68*	*79.06*	*80.23*	*81.20*	*81.97*	*73.43*	*75.12*	*76.71*	*78.03*	*79.20*	*80.11*
Cereal	10.0	10.0	10.0	10.0	10.0	24.1	–	–	–	–	–	16.0
Cereal byproducts	10.0	10.0	29.0	29.0	39.0	39.0	30.0	30.9	36.8	46.4	46.4	51.1
Oilseed and cake	21.9	26.5	20.5	20.5	16.1	12.3	7.3	7.0	6.4	5.0	5.0	5.0
Animal meal	5.8	4.7	3.4	3.4	3.5	3.6	10.3	10.2	8.4	8.0	8.0	6.4
Cassava	44.1	35.1	23.4	23.4	17.2	3.4	34.8	33.4	30.1	23.5	23.5	4.3
Other	8.0	13.4	13.4	13.4	14.0	17.3	17.3	18.2	17.9	16.9	16.9	17.0
Italy												
Cost	*75.90*	*77.98*	*79.72*	*80.91*	*81.49*	*81.89*	*73.91*	*75.92*	*77.60*	*78.89*	*79.67*	*80.44*
Cereal	10.0	10.0	10.0	20.0	20.0	20.0	–	–	–	8.2	10.0	10.0
Cereal byproducts	10.0	10.0	10.0	29.0	39.0	39.0	10.0	30.9	30.9	43.8	45.0	45.0
Oilseed and cake	21.9	26.5	26.8	19.6	14.6	12.8	13.8	7.0	7.0	5.0	5.0	5.0
Animal meal	5.8	4.7	4.9	3.2	3.2	3.6	10.4	10.2	10.2	8.0	7.6	7.6
Cassava	44.1	35.1	34.7	14.6	8.5	7.7	49.6	33.4	33.4	17.8	15.3	15.3
Other	8.0	13.4	13.2	13.4	14.4	15.6	16.0	18.2	18.2	17.0	16.9	16.9

[a] +i = i × \$5 + \$65 = cassava price. Therefore +1 = cassava price of \$70/metric ton.

TABLE E.2. Feed rations with variable cassava prices: United Kingdom.

Price increment	0	1	2	3	4	5
Dairy (3.5 gal)						
Cost	*74.33*	*76.65*	*78.48*	*79.48*	*80.22*	*80.32*
Cereal	–	–	–	–	–	11.7
Cereal byproducts	15.0	15.0	45.0	47.9	43.5	47.7
Oilseed and cake	30.3	30.3	15.6	14.6	19.3	14.4
Animal meal	5.0	5.0	5.0	5.0	5.0	5.0
Cassava	39.9	39.9	22.7	20.5	14.3	–
Other	9.6	9.6	11.5	11.7	17.6	21.0
Dairy (4.0 gal)						
Cost	*68.60*	*70.85*	*72.00*	*72.45*	*72.79*	*73.12*
Cereal	–	–	–	–	–	–
Cereal byproducts	10.0	23.4	57.9	54.3	54.3	54.3
Oilseed and cake	23.6	22.1	7.5	7.5	7.5	7.5
Animal meal	5.0	2.1	2.5	2.6	2.6	2.6
Cassava	47.5	33.3	13.0	6.8	6.8	6.8
Other	13.6	18.8	18.9	28.5	28.5	28.5
Beef fattening						
Cost	*66.76*	*68.10*	*68.63*	*68.69*	–	*68.72*
Cereal	–	–	–	–	–	–
Cereal byproducts	12.6	35.0	36.4	36.4	36.4	38.4
Oilseed and cake	13.4	10.2	7.5	7.5	7.5	7.5
Animal meal	5.0	1.9	2.2	2.2	2.2	1.8
Cassava	42.2	13.7	1.4	1.4	1.4	–
Other	26.6	39.0	52.3	52.3	52.3	52.1
Grazing cake						
Cost	*64.85*	*67.03*	*68.36*	*69.27*	*69.83*	*70.00*
Cereal	–	–	–	–	–	–
Oilseed and cake	13.5	10.2	7.5	7.5	7.5	7.5
Animal meal	1.5	–	–	–	–	–
Cassava	40.6	33.9	18.9	18.9	8.6	–
Other	33.8	33.6	46.0	46.0	43.7	44.0
Layer medium						
Cost	*79.21*	*81.89*	*84.06*	*85.86*	*87.49*	*87.92*
Cereal	–	7.2	11.3	24.7	24.7	55.2
Cereal byproducts	15.0	15.0	15.0	15.0	15.0	15.0
Oilseed and cake	9.5	12.0	13.4	10.0	10.0	7.5
Animal meal	12.9	12.0	10.9	11.4	11.4	9.2
Cassava	54.1	46.2	41.7	33.6	33.6	–
Other	8.3	7.3	7.5	5.0	5.0	12.8

Price increment	0	1	2	3	4	5
Poultry grower						
Cost	*75.59*	*78.71*	*81.19*	*82.91*	*84.54*	*85.06*
Cereal	–	–	15.2	25.6	25.6	47.1
Cereal byproducts	15.0	15.0	15.0	15.0	15.0	35.5
Oilseed and cake	12.5	19.7	22.0	20.2	20.2	12.6
Animal meal	12.2	6.9	3.3	3.7	3.7	2.3
Cassava	59.7	54.5	40.6	33.5	33.5	–
Other	0.4	3.7	3.6	1.8	1.8	2.3
Broiler						
Cost	*103.00*	*103.73*	*104.33*	*104.83*	–	*104.93*
Cereal	40.3	40.3	40.3	47.8	47.8	54.1
Cereal byproducts	12.5	12.5	12.5	12.5	12.5	12.5
Oilseed and cake	14.6	14.6	14.6	17.0	17.0	15.0
Animal meal	16.3	16.3	16.3	15.1	15.1	15.1
Cassava	12.3	12.3	12.3	3.7	3.7	–
Other	3.7	3.7	3.7	3.7	3.7	2.6
Broiler finishing						
Cost	*100.18*	*101.24*	*102.22*	*103.07*	–	*103.08*
Cereal	35.6	36.4	37.0	44.6	44.6	54.4
Cereal byproducts	12.5	12.5	12.5	12.5	12.5	12.5
Oilseed and cake	10.3	10.7	10.7	13.0	13.0	16.8
Animal meal	16.4	16.1	16.2	15.0	15.0	12.4
Cassava	21.2	20.5	19.7	11.0	11.0	–
Other	3.7	3.7	3.7	3.7	3.7	3.7
Pig grower						
Cost	*70.73*	*73.78*	*75.75*	*77.29*	*78.69*	*80.03*
Cereal	–	–	–	–	–	–
Cereal byproducts	10.0	10.0	40.0	47.7	50.0	50.0
Oilseed and cake	24.0	24.0	14.6	10.9	10.1	9.7
Animal meal	6.0	6.0	4.6	4.7	4.4	4.6
Cassava	53.9	53.9	35.5	31.5	27.7	27.3
Other	5.8	5.8	5.1	5.0	7.6	8.2
Pig fattening						
Cost	*67.97*	*71.12*	*73.29*	*75.07*	*76.83*	*78.31*
Cereal	–	–	–	–	–	–
Cereal byproducts	10.0	10.0	45.6	45.6	44.5	50.0
Oilseed and cake	16.7	16.7	5.0	5.0	5.0	5.0
Animal meal	5.5	5.5	4.3	4.3	3.5	3.6
Cassava	57.7	57.7	36.7	36.7	32.6	28.1
Other	9.9	9.9	8.2	8.2	14.1	13.1

TABLE E.3. Prices of feed ingredients in EEC member countries, 1971 (*$/metric ton*).

	France	Germany	Italy	Belgium-Luxembourg	Netherlands
Sorghum	87.50	97.01	96.06	93.21	95.11
Barley	89.42	99.45	97.17	96.19	98.42
Wheat	100.44	112.20	118.68	109.87	110.78
Maize	76.08	100.89	84.76	95.47	97.29
Linseed	131.55	131.55	131.55	131.55	131.55
Soybean	147.48	147.48	147.48	147.48	147.48
Maize gluten	79.65	79.65	79.65	79.65	79.65
Cotton meal	102.74	102.74	102.74	102.74	102.74
Linseed expeller	95.44	95.44	95.44	95.44	95.44
Groundnut	131.08	131.08	131.08	131.08	131.08
Wheat middlings	69.26	76.79	76.03	73.77	75.28
Wheat bran	76.64	84.97	84.13	81.63	83.30
Beet pulp	71.44	71.44	71.44	71.44	71.44
Brewer's grain	76.54	84.86	84.03	81.54	83.20
Citrus pulp	63.88	63.88	63.88	63.88	63.88
Rice bran	60.94	67.56	66.90	64.92	66.24
Fish meal	191.47	191.47	191.47	191.47	191.47
Oyster shell	27.28	27.28	27.28	27.28	27.28
Meat and bone	103.92	103.92	103.92	103.92	103.92
Molasses	48.00	48.00	48.00	48.00	48.00
Tallow	199.15	199.15	199.15	199.15	199.15
Rape extract	66.98	66.98	66.98	66.98	66.98
Cassava	65.00	65.00	65.00	65.00	65.00
Grassmeal	73.33	73.33	73.33	73.33	73.33
Alfalfa meal	65.08	65.08	65.08	65.08	65.08
Soybean meal	103.65	103.65	103.65	103.65	103.65
Sunflower	87.16	87.16	87.16	87.16	87.16
Oats	89.35	95.66	104.76	103.46	92.71

Note:

1 Wheat, barley, oats, and maize:
  - (a) market price in 1971 was obtained from the publication, *Background to the EEC Cereal Market*, Home Grown Cereals Authority, Haymarket, March 1972;
  - (b) the price to the end user was available for Netherlands;
  - (c) from this, the price to the end user in other EEC member countries was obtained on a pro rata basis, on the assumption that the price relativities would be maintained.

2 Sorghum, wheat middlings, wheat bran, brewer's grain, and rice bran:
  - (a) an average of the price relativity of each of the member countries with respect to Netherlands was calculated;
  - (b) this was used to estimate the prices in the member countries from the prices given in Netherlands.

3 For the rest of the feed ingredients, the prices in other member countries were assumed to be the same as those prevailing in Netherlands.

TABLE E.4. Estimated United Kingdom prices of raw materials during transition to EEC prices 1973–1978 (*£/long ton*).

	1973 (Feb)		1974 (Feb)		1975 (Feb)		1976 (Feb)		1977 (Feb)		1978 (Feb)	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Wheat	31.0	31.0	34.0	34.5	36.5	37.5	39.0	41.0	42.0	44.5	48.5	53.0
Denatured wheat	25.0	25.0	28.0	28.5	30.5	31.5	33.0	35.0	35.5	38.0	41.5	46.5
Barley	26.0	26.0	28.5	29.5	31.0	32.0	34.0	35.5	36.5	39.0	42.5	47.0
Maize	28.5	28.5	31.0	31.0	33.5	34.0	36.0	37.0	38.5	40.5	44.5	48.5
Rye	24.0	24.0	27.5	27.5	31.0	32.0	35.0	36.0	38.5	41.0	47.0	51.0
Oats	27.0	27.0	29.5	29.5	32.0	32.5	34.5	35.5	37.0	39.0	42.5	46.5
Sorghum	27.5	27.5	30.0	30.5	33.0	33.5	35.5	36.5	38.0	40.0	43.5	48.0
Millet/buckwheat	27.0	27.0	29.5	29.6	32.0	32.5	35.0	36.0	37.5	39.0	43.0	47.0
European Maize	24.5	–	27.0	–	30.0	–	32.0	–	35.0	–	40.0	–
Soyabean extract	53.5	54.5	51.5	53.5	50.5	53.5	49.5	53.5	48.5	53.5	48.5	54.5
Rapeseed extract	34.0	35.0	33.0	34.0	32.0	34.0	31.5	34.0	31.0	34.0	31.0	35.0
Sunflower extract	42.5	43.5	43.0	42.5	42.0	42.5	41.0	42.5	40.0	42.5	40.0	43.5
Groundnut expeller	52.5	53.5	50.5	52.5	50.0	52.5	47.0	50.5	46.0	50.5	46.0	51.5
Groundnut extract	50.5	51.5	48.5	50.5	48.0	50.5	45.0	48.5	44.0	48.5	44.0	49.5
Cotton expeller	48.0	48.5	46.5	48.0	45.5	48.0	44.5	48.0	43.5	48.0	43.5	48.5
Cotton extract	40.0	41.0	39.0	40.0	38.5	40.0	37.5	40.0	36.5	40.0	36.5	41.0
Linseed expeller	48.5	49.5	47.0	48.5	46.0	48.5	45.0	48.5	44.0	48.5	44.0	49.5
Coconut expeller	40.0	40.5	38.5	40.0	38.0	40.0	37.0	40.0	36.0	40.0	36.0	40.5
Fish meal 65%	94.0	96.0	90.0	94.0	89.5	94.0	88.5	94.0	87.0	94.0	87.0	96.0
Meat meal	56.0	57.0	54.0	56.0	53.5	56.0	52.0	56.0	51.0	56.0	51.0	57.0
Wheat bran	31.0	31.0	32.0	32.5	33.0	33.5	34.0	35.0	35.0	36.5	37.0	39.0
Wheat middlings	28.0	29.0	29.5	30.0	30.5	30.5	31.0	32.0	32.0	33.5	34.0	36.0
Maize meal	35.5	35.5	36.5	37.0	37.5	38.0	38.5	39.5	39.5	41.0	41.5	43.5
Pollard pellets	29.0	29.0	30.0	30.5	31.0	31.5	32.0	32.0	33.0	34.5	35.0	37.0
Brewer's grain	33.0	33.0	34.0	34.5	35.0	35.5	36.0	36.0	37.0	38.5	39.0	41.0
Rolled barley	30.0	30.0	32.5	33.5	35.0	36.0	38.0	39.5	40.5	43.0	44.5	51.0
Flaked maize	35.5	35.5	38.0	38.0	40.5	41.0	43.0	44.0	45.5	47.5	51.5	55.5
Rice bran	36.0	36.0	37.0	37.5	38.0	39.0	39.0	40.5	40.0	42.0	42.0	44.5
Rice bran extract	26.5	27.0	26.5	27.5	26.5	28.0	26.5	28.5	26.5	29.0	26.5	29.5
Beet pulp	31.0	31.5	31.0	32.0	31.0	33.0	31.0	33.5	31.0	34.0	31.0	35.0
Maize gluten feed	36.0	36.5	36.0	37.0	36.0	38.0	36.0	38.5	36.0	39.0	36.0	40.0
Lucerne meal	30.5	31.0	30.5	31.5	30.5	32.5	30.5	33.0	30.5	33.5	30.5	34.5
Grass meal	29.0	29.5	29.0	30.0	29.0	31.0	29.0	31.5	29.0	32.0	29.0	33.0
Dried peas	42.0	42.5	42.0	43.5	42.0	44.0	42.0	45.0	42.0	45.5	42.0	46.5
Citrus pulp	27.0	27.5	27.0	28.0	27.0	28.5	27.0	29.5	27.0	30.0	27.0	31.0
Sliced potatoes	24.0	24.5	24.0	25.0	24.0	25.5	24.0	26.0	24.0	26.5	24.0	27.0
Manioc	27.0	27.5	27.0	28.0	27.0	28.5	27.0	29.5	27.0	30.0	27.0	31.0

Appendix F

Cross-Sectional Analysis of Consumption of Cassava in Brazil

TABLE F.1. Brazilian consumption models, cross-sectional data.

	Linear relationship				Logarithmic relationship			
	α	β (t-value)	r^2	F-value	α	β (t-value)	r^2	F-value
				Fresh cassava				
Urban areas								
Brazil	1.73604	.00099 (3.48)	63.39	12.12	−1.955	−0.45195 (6.27)	84.9	39.36
Northeast	0.61535	−0.00013 (0.69)	6.31	0.47	3.68238	−0.8532 (1.43)	22.62	2.05
East	2.31984	.00199 (7.39)	88.64	54.61	−1.4113	0.43611 (13.82)	96.46	190.9
South	1.84703	.00069 (1.64)	27.70	2.68	−2.8355	0.57049 (3.39)	62.21	11.52
Rural areas								
Brazil	24.25976	−0.00152 (0.83)	8.9	0.68	3.13703	−0.00317 (0.05)	0.03	0.
Northeast	10.25895	−0.00256 (1.25)	18.32	1.57	9.01852	−1.2934 (1.59)	26.55	2.53
East	19.36012	−0.00124 (0.36)	1.85	0.13	2.88302	−0.00778 (0.06)	0.06	0.
South	45.36469	−0.00062 (0.17)	0.4	0.03	3.70102	0.01409 (0.24)	0.81	0.06
				Cassava flour				
Urban areas								
Brazil	12.00853	−0.00149 (4.31)	72.62	18.57	2.9635	−0.0974 (3.2)	59.44	10.26
Northeast	25.07498	−0.00411 (4.77)	76.46	22.74	3.95875	−0.1473 (3.96)	69.17	15.71
East	11.53424	−0.00026 (0.48)	3.21	0.23	2.29849	0.01988 (0.52)	3.71	0.27
South	4.63895	−0.00102 (3.16)	58.79	9.98	2.76045	−0.2409 (5.02)	78.24	25.17
Rural areas								
Brazil	38.55973	0.00115 (0.46)	2.88	0.21	3.50996	0.02546 (0.54)	4.	0.29
Northeast	66.36729	0.00576 (1.05)	13.63	1.1	3.88345	0.05938 (1.04)	13.37	1.08
East	32.57811	−0.00516 (2.56)	48.3	6.54	3.96002	−0.10536 (1.47)	23.47	2.15
South	13.09487	0.00249 (1.16)	16.15	1.35	2.31686	0.05451 (0.45)	2.79	0.2

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IDRC-013e The first 100 projects, 29 p., July 1973.

IDRC-013f Les 100 premiers projets, 30 p., juillet 1973.

IDRC-014e Research policy: eleven issues: outline statement to the Board of Governors of the International Development Research Centre at their meeting in Bogota, Colombia, March 19, 1973, W. David Hopper, 16 p., 1973.

IDRC-014f La recherche pour le développement: onze principes fondamentaux: récapitulation des principes fondamentaux gouvernant les activités du Centre. Discours prononcé, le 19 mars 1973, devant le Conseil des Gouverneurs réuni en Assemblée à Bogota (Colombie), W. David Hopper, 21 p., 1973.

IDRC-015e Aquaculture in Southeast Asia: report on a seminar at the Freshwater Fishery Research Station, Malacca, West Malaysia, 17–25 April 1973, 22 p., 1973.

IDRC-016e Consumer food utilization in the semi-arid tropics of Africa: report of an interdisciplinary workshop, Zaria, Nigeria, 30 April–4 May 1973, 16 p., 1973.

IDRC-018f Éducation sexuelle en Afrique tropicale, 124 p., 1973.

IDRC-019s Administración Universitaria: Aspectos Fundamentales sobre la Administración Académica Universitaria, Henrique Tono T., 25 p., 1973.

IDRC-021e Nutritive value of triticale protein, Joseph H. Hulse and Evangeline M. Laing, 183 p., 1974.

Cost of Cultivation and Net Income

The cost of cultivation varies from place to place, and under Trivandrum conditions, the cost of improved methods of tapioca cultivation comes to 1700 rupees/ha (690 rupees/acre). Presuming the average yield of 14 tons/acre and prevailing market rate of tuber at 160 rupees/ton, the gross income comes to 5500 rupees/ha (2230 rupees/acre) and thus the net income is expected to be 3800 rupees/ha (1540 rupees/acre).

A Note on Future Price Projections of Tapioca Pellets for Shipment to EEC Markets

The world shortage of feed grains (maize, wheat, and barley) and high EEC prices as a result of the variable levy which inflated prices so sharply in 1972–73, is likely to continue into 1974. The demand for tapioca will expand as the United Kingdom, Eire, and Denmark gradually switch from open import policies to high feedgrain prices. At present there is no sign that a radical shift in the Common Agricultural Policy is likely to take place as far as feed is concerned. My discussions in March and April in Hamburg and Rotterdam with leading importers and compounders revealed that pellet prices had risen as follows (in US$ fob Bangkok): December 1970, 35–40; December 1972, 60–65; and March–April 1973, 75–80. This price for top-quality Thai pellets produces, after charter shipment is arranged to European ports, at around $90/ton.

It is clear that with normal crops of tapioca in Thailand and an expansion in feedgrain production these price levels will not be sustained. Furthermore high prices will stimulate increased plantings and further processing investments in Latin America (Brazil), Indonesia, Malaysia, and India. Future prices might stabilize as follows (pellet prices fob, developing countries): 1973, $75–80; 1974, $70; 1975 and 1980, $60–70. This price level would partially reflect the devaluation of the US dollar since 1970 as well as a steady rise in charter rates from 1971. Certainly a target price of $60/ton is possible given Europe's rapidly rising demand for animal feedstuffs and the potential for increased usage of tapioca-using compounds.

Indian Currency and Weights: A Key

100 paise = 1 rupee
7.50 rupees = 1 US dollar (approx.) (1/5/73)
1 lakh = 100000 rupees
100 lakhs = 1 crore
1 crore = 10000000 rupees
1 quintal = 100 kilos
10 quintals = 1 metric ton
1 para (of paddy) = 16$\frac{2}{3}$ lb

In its few years of existence, CIAT has amply illustrated that the potential of cassava has been scarcely topped.

Chapter 9. Research Recommendations

The raison d'être of this study, as conceived by IDRC and CIAT, is to derive economically based priorities for research in cassava. From the beginning it was apparent that any comprehensive statement on research priorities should be preceded by a quantitative and qualitative survey of on-going or completed work, not only to provide building blocks for future research activities, but to point up areas of research needs. Ideally, such a directory would classify research by type and region to facilitate flows of information between individuals, organizations, institutions, and countries[92], as well as to avoid duplication of work.[93] Unfortunately, such a directory does not appear to exist, and its compilation is clearly beyond the scope of this study. Therefore, the first recommendation forwarded by this report is that a comprehensive survey of past and present cassava research, classified by type and region, be undertaken.

A general bibliography, presently being compiled at CIAT, should go a long way, when completed, toward realizing this recommendation, but even this bibliography may fail to include a sizeable body of information which is unpublished or of limited circulation. In these cases, the individual cassava researcher must be the main instrument for channelling obscure data to a wider audience. Possibly, systematic collection of this hidden wealth of information can be undertaken in cooperation with CIAT in an effort to encourage, centralize, and facilitate the collection and use of cassava research data.

The following other recommendations are forwarded:

Breeding

The study reveals that the demand for cassava, present and future, is a demand for carbohydrate. Therefore, selection and breeding which improves starch yield per tuber, per unit land, and per unit time is highly desirable.

- It should be recognized that the three cassava markets require different types of starch. The human market may require high amylopectin and low amylose starch, while the relative content of amylose and amylopectin is not so important for animals. Amylose content of cassava may be more important in starch manufacturing. It is recommended, therefore, that selection and breeding work screen varieties according to the properties demanded by the different markets.
- The properties of different cassava varieties at different stages of maturity should be explored. Tuber properties which should be specifically examined are: protein and starch content, composition, and digestibility; vitamin availability and suitability for digestion; viscosity, gelling, and other starch properties; pest, virus, and bacteria resistence; drought and flood tolerance; adaptability to different soils; HCN content; and yield. Research should be directed at determining both physical and economic optima.
- It is recommended that breeding for a high protein cassava be given low priority. Protein content of cassava is unimportant in starch and animal feed manufacture. In some circumstances, high protein content is a disadvantage—protein is considered a waste product in starch manufacture, and in

[92]For example, results of pre-World War II Dutch selection trials conducted in Indonesia are generally thought to have been destroyed. Yet Dr M. M. Flach has informed me that almost all of the reports of this research activity are available in the University of Wageningen archives.

[93]Such a directory will help to avoid intra-regional redundancies as well. For example, in Malaysia, both NISIR (National Institute of Scientific and Industrial Research) and the Ministry of Agriculture's Crop Promotion Division are working on the development of small-scale cassava chipping and pelleting machinery. The disadvantages of duplication in this case are not readily apparent, since the resulting machinery is quite different. However, it is possible that joint effort could have produced a machine that is perhaps even superior to the first two.

European animal feed rations with maximum protein constraints, a high protein cassava (say, 6–10%) could actually inhibit use of cassava in the formula. However, if cassava is used in LDC feed compounding, price relativities might be such to make a high protein cassava desirable. This possibility requires further investigation. Where the human market is concerned, high cassava consumption coupled with regional protein deficiency and poor protein distribution within the family unit suggests that a higher protein cassava could be beneficial. However, in terms of essential amino acids, cassava protein is not of high quality, and there seems to be little evidence to show that an increase in crude protein results in an improvement of cassava protein quality. On the other hand, cassava may be efficient as a protein carrier or growth medium when fortified or used as a substrate. These latter aspects should receive continued attention.

Cultivation

- The great part of cassava cultivation is presently and presumably will continue to be small scale. In this context three areas of research are recommended: (a) selection of improved varieties which will grow under small-scale, traditional production conditions; (b) development of appropriate cultivation methods designed to support the use of improved but perhaps less hardy varieties; and (c) identification of production practices which are economically applicable to small-scale production.
- Labour-saving or production-increasing machinery that is compatible with small-scale production should be developed. All aspects of cassava production could benefit from improved tools. Such machinery should, in most instances, be labour-augmenting and not labour-replacing.
- On the other hand, estate cultivation will likely become more common in the future—many would-be exporters base their export potential on estate production, while in some places large-scale cultivation already occurs as an adjunct to intensive poultry systems. Thus, techniques and machinery suitable to large-scale production are also required. Harvesting machinery is one area of particular need.
- Development of space-economizing harvesting, storage, and handling methods will release valuable land to other uses. Cheap storage methods, by permitting more consistently available supply, could enable existing cassava processing plants to more fully realize production capacities (or, alternatively, existing production could be generated by smaller plants).
- Research is required on intercropping. For example, field work might show that a less leafy variety is best suited for intercropping (that is, tuber yield may decrease with thinly-leafed varieties, but yield of intercalated crops could increase, with a net effect of gain in production and income). Studies of cassava intercropping with rubber and oil palm are available, but information on intercropping with legumes or cereals does not appear to be available.
- The notion of cassava as a soil depleter should be examined, as must be the counterargument that soil depletion is a result of poor production methods and consequent leeching. If the latter contention proves to be correct, development of improved production practices is obviously necessary.
- The economics of cassava production must be understood in regional contexts. For example, while the advantages of fertilizer application may be amply demonstrable for cassava production in general, regional variability of availability and cost of fertilizer, and relative marginal returns to its application may preclude its use in some areas, or for certain sized farms.
- The results of varietal and cultivation research should not reduce the usefulness of cassava as a risk-aversion crop. Thus, higher yielding varieties which are more susceptible to complete failure should not be encouraged at small-scale or subsistence levels.

Processing

- Rapid transformation of roots to a less perishable state through drying, soaking, and/or fermenting is critical to the production of many cassava products. Further study is needed in the drying of sliced or chipped roots. Initial CIAT findings are that cassava's α solar absorption coefficient is low and that ambient temperature and air circulation are the most important factors in drying. This finding calls for confirmation in numerous environments. Furthermore, cassava's low α value (provided this can be preserved under treatment) suggests another possible use for cassava (e.g. as a solar-reflecting paint).
- Processing of chips and pellets requires research at the small-scale, farm-cooperative level and the large-scale, commercial level. The latter is fairly well researched, but methods for optimum pre-heating before pelleting, or post-pelleting cooling do not seem to be available—perhaps this information is kept at limited circulation for commercial reasons. Research on small-scale pelleting machines must be done with a view to costs and market requirements, viz, density and friability of pellets. Furthermore, research should be undertaken on the comparative advantages of different chip size and form. The cassava bar (measuring $1 \times 1 \times 5$ cm), presently under consideration at CIAT, for example, could replace the pellet if the former can be shown to have the physical properties required by the market and to be manufacturable at a competitive price.

- Technical and economic research relating to the use of cassava as an animal feed in LDCs through compounding or micro-biological processes seems justifiable and appropriate. Although it was not possible in the course of this study to assess quantitatively the scope for using mixed or complete feeds in LDC livestock production, it does appear that cassava could play an important part in the future livestock production of LDCs if the availability of appropriate products accompanies the emergence of that market.

- Research on the production of cassava starch and modified cassava starches is required. This work should be conducted in the context of the needs of external markets as well as existing and emerging domestic starch markets. As cassava-producing LDCs expand their industrial base and experience greater requirements for starch, development in this area may be important in obviating importation of foreign starches.

- Research into the development of cassava foods for human consumption (flours, breads, cakes, baby foods) should continue with a view to price and market acceptability, viz. if white bread is not normally consumed in a given region, it is not apparent that the development of a white cassava bread will be a successful innovation, as seems to have been the case in parts of West Africa.

Marketing

- Cassava products are not unique and can be replaced by other commodities when economic or political reasons demand. For exporters, therefore, a global marketing research service which monitors developments in the industrial starch and animal feed markets seems necessary. Such a service, in the form of periodical publications, could provide information on marketing trends which will enable LDCs to plan investments.

- Greater information is required in producer countries on the domestic markets for cassava. There is a need to bring producers, processors, and consumers together to promote flows of information and to coordinate development of potential markets. It should be pointed out in this context that the adoption of technologies from developed countries is often taken to be synonymous with use of developed country inputs. It is important for producers and processors to realize under what conditions an indigenously produced input, such as cassava, can do the job equally well.

Systems

- The results of research on breeding, cultivation, processing, economics, and marketing should be brought together into a more comprehensive study of the "cassava system". Analysis of this system will point up research bottlenecks and weaknesses. Moreover, the creation of such a system will enable the appropriateness of research results to be judged and will promote the smooth introduction of new findings into the system.

In summary, the major research need, as determined by this study, is that of applied research into cassava breeding, cultivation, processing, economics, and marketing. Existing and potential cassava markets[94] require an immediate supply of cassava and cassava products. In many instances the ability of producers to meet these demands depends upon the availability of better varieties, production and processing practices, and economic information which to date may not have been researched. A failure to realize some of these markets in the first instance may in fact mean a loss of the market and a financial hardship for certain producers. Thus it would appear that great returns could be achieved by research which is quickly available and easily adopted. A need for short-run research should not necessarily be seen as a diminuation of long-run studies; rather it is an indication that there are a number of problems requiring simple answers which, if researched, can be solved in a relatively short time. The point should also be made that because a problem appears difficult and requires long-run research, this is not sufficient justification for establishing research priorities. Cassava is a crop which is prized for its durability, ease of cultivation, flexibility, starch content, and price. Therefore, it would seem that research, long or short term, which enhances these attributes should be given highest priority.

The promoter of the export of cassava must temper his enthusiasm for cassava as an earner of foreign exchange by the realization that these markets, primarily the animal feed market, are less certain than the markets for traditional LDC agricultural exports. For this reason, it could be wrong to commit substantial resources to a long-run cassava export scheme. Nevertheless, the promotion of cassava for short-run foreign ex-

[94]For example the non-human domestic market and the Japanese animal feed market.

change earnings would appear to be profitable. The concurrent development of expertise in all phases of the "cassava system" will, moreover, have long-run pay-offs closer to home in terms of domestic application, particularly where home markets come to equal or exceed in importance foreign demand. In this sense, the present export market has given a new perspective to cassava and has focused attention on what it *is* and what it can *become*.

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Appendix A

Summary of Cassava Production Time Trend Models and Cassava Production Projections

TABLE A.1. Coefficients of production acreage and yield time trend regressions.

ARGENTINA

	LINEAR EQUATIONS CONSTANT	LINEAR EQUATIONS TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	LOGARITHMIC EQUATIONS TIME COEFF.	R2
PRODUCTION	242.40	2.464	0.42	5.49	0.009	0.41
ACREAGE	18.60	0.397	0.68	2.93	0.018	0.66
YIELD	128.90	-1.044	0.77	4.86	-0.009	0.77

BOLIVIA

	LINEAR EQUATIONS CONSTANT	LINEAR EQUATIONS TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	LOGARITHMIC EQUATIONS TIME COEFF.	R2
PRODUCTION	44.46	10.690	0.90	4.09	0.086	0.87
ACREAGE	0.12	0.983	0.93	0.97	0.121	0.93
YIELD	215.80	-5.396	0.96	5.41	-0.034	0.95

BRAZIL

	LINEAR EQUATIONS CONSTANT	LINEAR EQUATIONS TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	LOGARITHMIC EQUATIONS TIME COEFF.	R2
PRODUCTION	13383.00	1094.000	0.97	9.56	0.051	0.97
ACREAGE	1075.00	64.470	0.97	7.02	0.041	0.97
YIELD	127.30	1.307	0.93	4.85	0.010	0.93

COLOMBIA

	LINEAR EQUATIONS CONSTANT	LINEAR EQUATIONS TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	LOGARITHMIC EQUATIONS TIME COEFF.	R2
PRODUCTION	1776.00	-42.430	0.30	7.47	-0.032	0.32
ACREAGE	273.60	-7.900	0.45	5.65	-0.041	0.50
YIELD	61.75	0.700	0.23	4.15	0.008	0.17

ECUADOR

	LINEAR EQUATIONS CONSTANT	LINEAR EQUATIONS TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	LOGARITHMIC EQUATIONS TIME COEFF.	R2
PRODUCTION	111.70	17.900	0.90	5.01	0.062	0.90
ACREAGE	14.58	1.622	0.91	2.86	0.054	0.91
YIELD	83.04	0.974	0.51	4.42	0.011	0.50

PARAGUAY

	LINEAR EQUATIONS CONSTANT	LINEAR EQUATIONS TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	LOGARITHMIC EQUATIONS TIME COEFF.	R2
PRODUCTION	561.50	73.900	0.78	6.39	0.070	0.55
ACREAGE	48.01	4.561	0.92	4.00	0.051	0.92
YIELD	146.00	-0.214	0.20	4.98	-0.001	0.20

PERU

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	287.30	15.230	0.85	5.67	0.040	0.85
ACREAGE	25.69	1.262	0.61	3.17	0.044	0.67
YIELD	123.60	-0.636	0.19	4.80	-0.004	0.15

VENEZUELA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	228.40	7.526	0.75	5.41	0.030	0.75
ACREAGE	33.50	0.028	0.02	3.48	0.002	0.04
YIELD	80.61	1.536	0.24	4.23	0.028	0.37

CEYLON

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	172.10	14.620	0.84	5.16	0.056	0.83
ACREAGE	46.56	0.943	0.35	3.81	0.019	0.40
YIELD	42.08	1.563	0.50	3.65	0.038	0.57

TAIWAN

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	123.90	12.990	0.94	4.89	0.061	0.94
ACREAGE	10.94	0.681	0.94	2.42	0.044	0.93
YIELD	116.50	2.169	0.75	4.76	0.016	0.76

INDIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	860.50	247.900	0.91	7.20	0.083	0.92
ACREAGE	218.00	7.258	0.80	5.41	0.025	0.80
YIELD	53.18	5.822	0.89	4.10	0.057	0.88

INDONESIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	10984.00	17.160	0.10	9.30	0.002	0.12
ACREAGE	1318.00	14.900	0.54	7.18	0.011	0.56
YIELD	83.42	-0.729	0.80	4.42	-0.009	0.80

W. MALAYSIA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	202.30	9.091	0.79	5.37	0.030	0.79
ACREAGE	13.20	0.436	0.57	2.59	0.026	0.59
YIELD	160.30	0.816	0.18	5.08	0.004	0.16

PHILIPPINES

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	419.90	7.407	0.35	5.99	0.020	0.42
ACREAGE	76.73	0.877	0.40	4.32	0.012	0.45
YIELD	53.29	0.447	0.32	3.97	0.008	0.35

THAILAND

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	491.90	113.000	0.85	6.08	0.121	0.85
ACREAGE	33.44	7.494	0.90	3.46	0.114	0.87
YIELD	145.90	0.278	0.05	4.93	0.007	0.17

VIET NAM N.

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	920.60	-14.130	0.64	6.83	-0.018	0.64
ACREAGE	109.80	-0.591	0.17	4.67	-0.004	0.11
YIELD	86.85	-1.127	0.68	4.47	-0.015	0.69

VIET NAM S.

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	242.60	1.631	0.12	5.43	0.011	0.20
ACREAGE	42.80	-0.432	0.25	3.74	-0.010	0.23
YIELD	53.66	1.374	0.72	3.99	0.021	0.71

ANGOLA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	1001.00	40.230	0.97	6.96	0.028	0.97
ACREAGE	99.77	1.409	0.96	4.61	0.012	0.96
YIELD	103.50	1.950	0.91	4.65	0.016	0.91

BURUNDI

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	133.40	78.160	0.81	6.12	0.068	0.83
ACREAGE	-31.35	10.970	0.70	3.41	0.091	0.68
YIELD	141.50	-2.148	0.32	5.01	-0.023	0.39

CAMEROON

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	504.20	32.150	0.83	6.27	0.041	0.83
ACREAGE	38.04	10.340	0.88	4.01	0.085	0.91
YIELD	93.28	-2.935	0.90	4.56	-0.043	0.91

CENTR.AF.REP

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	947.30	5.455	0.52	6.86	0.005	0.52
ACREAGE	194.70	0.545	0.52	5.27	0.003	0.52
YIELD	48.74	0.130	0.52	3.89	0.003	0.52

CHAD

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	41.53	0.654	0.15	3.60	0.022	0.24
ACREAGE	-1.34	1.336	0.87	0.97	0.138	0.81
YIELD	84.96	-3.933	0.73	4.53	-0.079	0.76

COMORO IS.

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	-19.86	7.955	0.88	2.53	0.142	0.87
ACREAGE	6.16	1.382	0.89	2.27	0.069	0.88
YIELD	7.53	2.038	0.85	2.54	0.075	0.85

CONGO BRAZZ

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	1119.00	-49.550	0.84	7.19	-0.081	0.82
ACREAGE	169.40	-4.636	0.72	5.16	-0.036	0.70
YIELD	71.23	-2.160	0.87	4.34	-0.045	0.86

CONGO REP

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	6857.00	51.510	0.22	8.83	0.006	0.18
ACREAGE	629.20	0.266	0.02	6.44	0.000	0.00
YIELD	109.30	0.712	0.28	4.70	0.005	0.26

DAHOMEY

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	1166.00	-12.490	0.30	7.07	-0.014	0.32
ACREAGE	234.60	-5.843	0.70	5.52	-0.036	0.70
YIELD	47.31	1.239	0.73	3.86	0.022	0.73

EQUAT GUINEA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	35.92	0.445	0.81	3.59	0.011	0.81
ACREAGE	11.32	0.227	0.41	2.44	0.016	0.40
YIELD	31.93	-0.188	0.22	3.46	-0.006	0.21

GABON

	LINEAR EQUATIONS CONSTANT	TIME COEFF	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	130.10	0.655	0.14	4.87	0.004	0.13
ACREAGE	33.55	1.913	0.89	3.56	0.039	0.88
YIELD	37.69	-1.095	0.63	3.61	-0.035	0.59

GHANA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	649.60	69.830	0.81	6.61	0.054	0.85
ACREAGE	52.25	9.603	0.87	4.11	0.080	0.86
YIELD	122.70	-2.701	0.63	4.80	-0.026	0.60

GUINEA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	369.20	7.031	0.80	5.91	0.017	0.79
ACREAGE	41.60	-0.898	0.44	3.65	-0.019	0.39
YIELD	106.50	3.378	0.54	4.56	0.036	0.55

IVORY COAST

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	851.70	-18.360	0.36	6.71	-0.025	0.35
ACREAGE	158.70	2.195	0.32	5.05	0.014	0.36
YIELD	52.49	-1.494	0.55	3.97	-0.038	0.52

KENYA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	575.20	3.000	0.85	6.36	0.005	0.85
ACREAGE	85.93	0.436	0.89	4.45	0.005	0.89
YIELD	67.58	-0.044	0.49	4.21	-0.001	0.49

LIBERIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	420.90	-2.784	0.59	6.04	-0.007	0.60
ACREAGE	62.24	-0.248	0.45	4.13	-0.004	0.46
YIELD	67.81	-0.209	0.81	4.22	-0.003	0.81

MADAGASCAR

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	608.90	29.160	0.78	6.48	0.031	0.79
ACREAGE	216.20	1.971	0.16	5.35	0.009	0.18
YIELD	28.65	1.155	0.40	3.43	0.022	0.32

MALI

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	170.80	1.033	0.16	5.14	0.004	0.13
ACREAGE	14.65	-0.263	0.49	2.67	-0.020	0.48
YIELD	120.60	3.197	0.76	4.79	0.023	0.73

NIGER

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	50.11	10.000	0.97	4.21	0.075	0.96
ACREAGE	8.40	1.219	0.94	2.37	0.062	0.96
YIELD	63.61	0.856	0.40	4.13	0.014	0.44

NIGERIA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	7420.00	-19.000	0.16	8.90	-0.002	0.11
ACREAGE	749.40	29.810	0.71	6.57	0.036	0.74
YIELD	106.80	-3.459	0.74	4.63	-0.038	0.73

SENEGAL

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	139.60	4.359	0.44	4.97	0.022	0.44
ACREAGE	31.90	1.386	0.46	3.51	0.028	0.46
YIELD	43.20	-0.251	0.35	3.76	-0.006	0.36

SIERRA LEONE

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	49.02	1.145	0.96	3.90	0.020	0.96
ACREAGE	18.75	0.167	0.91	2.93	0.008	0.91
YIELD	26.67	0.305	0.93	3.28	0.011	0.93

SUDAN

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	99.66	2.518	0.98	4.63	0.020	0.99
ACREAGE	15.48	0.154	0.85	2.74	0.009	0.85
YIELD	65.86	0.763	0.86	4.19	0.010	0.85

RWANDA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	-97.98	26.560	0.91	3.50	0.149	0.81
ACREAGE	-9.64	2.552	0.94	1.12	0.152	0.85
YIELD	110.70	-0.406	0.10	4.70	-0.004	0.10

TANZANIA

	LINEAR EQUATIONS			LOGARITHMIC EQUATIONS		
	CONSTANT	TIME COEFF.	R2	CONSTANT	TIME COEFF.	R2
PRODUCTION	803.80	37.190	0.83	6.77	0.029	0.85
ACREAGE	258.50	1.545	0.78	5.56	0.006	0.78
YIELD	32.52	1.065	0.80	3.53	0.023	0.81

TOGO

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	366.60	57.390	0.90	6.07	0.073	0.87
ACREAGE	59.48	6.773	0.91	4.19	0.062	0.89
YIELD	65.39	0.783	0.59	4.18	0.011	0.58

UGANDA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	287.40	129.700	0.94	6.52	0.081	0.92
ACREAGE	379.60	-8.318	0.40	5.94	-0.027	0.42
YIELD	-5.69	6.240	0.89	2.89	0.108	0.89

ZAMBIA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	152.40	0.036	0.02	5.03	0.000	0.00
ACREAGE	32.88	1.118	0.70	3.53	0.025	0.71
YIELD	44.38	-0.931	0.83	3.82	-0.027	0.83

LAT.AMERICA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	16327.00	1269.000	0.97	9.75	0.050	0.97
ACREAGE	1482.00	76.070	0.96	7.32	0.038	0.95
YIELD	113.90	1.446	0.93	4.74	0.012	0.93

FAR EAST

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	13472.00	515.400	0.95	9.51	0.031	0.94
ACREAGE	1717.00	48.720	0.89	7.45	0.025	0.89
YIELD	78.70	0.561	0.79	4.37	0.007	0.79

AFRICA

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	28500.00	344.300	0.61	10.26	0.011	0.60
ACREAGE	3434.00	109.700	0.96	8.15	0.026	0.95
YIELD	81.21	-1.058	0.65	4.39	-0.014	0.64

WORLD

	LINEAR EQUATIONS CONSTANT	TIME COEFF.	R2	LOGARITHMIC EQUATIONS CONSTANT	TIME COEFF.	R2
PRODUCTION	59806.00	2031.000	0.97	11.01	0.027	0.98
ACREAGE	6786.00	227.400	0.98	8.83	0.028	0.97
YIELD	88.55	-0.007	0.01	4.48	-0.000	0.01

TABLE A.2. Projections of production acreage and yield for 1970 to 1985.

ARGENTINA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	279.	25.	113.	278.	24.	113.
1971	282.	25.	112.	281.	25.	112.
1972	284.	25.	111.	283.	25.	111.
1973	287.	26.	110.	286.	26.	110.
1974	289.	26.	109.	288.	26.	109.
1975	292.	27.	108.	291.	27.	108.
1976	294.	27.	107.	294.	27.	107.
1977	297.	27.	106.	296.	28.	107.
1978	299.	28.	105.	299.	28.	106.
1979	302.	28.	104.	302.	29.	105.
1980	304.	29.	103.	304.	29.	104.
1981	306.	29.	102.	307.	30.	103.
1982	309.	29.	101.	310.	30.	102.
1983	311.	30.	100.	313.	31.	101.
1984	314.	30.	99.	316.	31.	100.
1985	316.	31.	98.	319.	32.	99.

BOLIVIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	205.	15.	135.	218.	16.	135.
1971	215.	16.	129.	238.	18.	131.
1972	226.	17.	124.	260.	21.	126.
1973	237.	18.	119.	283.	23.	122.
1974	248.	19.	113.	309.	26.	118.
1975	258.	20.	108.	337.	30.	114.
1976	269.	21.	102.	367.	33.	110.
1977	280.	22.	97.	400.	38.	107.
1978	290.	23.	92.	436.	43.	103.
1979	301.	24.	86.	476.	48.	100.
1980	312.	25.	81.	519.	54.	97.
1981	322.	26.	76.	565.	61.	93.
1982	333.	27.	70.	616.	69.	90.
1983	344.	28.	65.	672.	76.	87.
1984	354.	29.	59.	733.	88.	84.
1985	365.	30.	54.	799.	99.	82.

BRAZIL

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	29793.	2042.	147.	30505.	2077.	147.
1971	30887.	2107.	148.	32092.	2165.	148.
1972	31981.	2171.	150.	33761.	2256.	150.
1973	33075.	2235.	151.	35517.	2352.	151.
1974	34169.	2300.	152.	37365.	2451.	153.
1975	35263.	2364.	153.	39309.	2554.	154.
1976	36357.	2429.	155.	41353.	2662.	156.
1977	37451.	2493.	156.	43504.	2775.	157.
1978	38545.	2558.	157.	45767.	2892.	159.
1979	39639.	2622.	159.	48148.	3014.	160.
1980	40733.	2687.	160.	50653.	3142.	162.
1981	41827.	2751.	161.	53288.	3274.	163.
1982	42921.	2816.	163.	56059.	3413.	165.
1983	44015.	2880.	164.	58976.	3557.	166.
1984	45109.	2945.	165.	62043.	3707.	168.
1985	46203.	3009.	167.	65271.	3864.	170.

COLOMBIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1140.	155.	72.	1093.	153.	71.
1971	1097.	147.	73.	1058.	147.	71.
1972	1055.	139.	74.	1025.	141.	72.
1973	1012.	131.	74.	993.	135.	73.
1974	970.	123.	75.	962.	130.	73.
1975	927.	116.	76.	932.	124.	74.
1976	885.	108.	76.	902.	119.	74.
1977	843.	100.	77.	874.	114.	75.
1978	800.	92.	78.	846.	110.	75.
1979	758.	84.	79.	820.	105.	76.
1980	715.	76.	79.	794.	101.	77.
1981	673.	68.	80.	769.	97.	77.
1982	630.	60.	81.	745.	93.	78.
1983	588.	52.	81.	722.	89.	78.
1984	546.	44.	82.	699.	86.	79.
1985	503.	37.	83.	677.	82.	80.

ECUADOR

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	380.	39.	98.	380.	39.	98.
1971	398.	41.	99.	404.	41.	99.
1972	416.	42.	100.	430.	43.	100.
1973	434.	44.	101.	458.	46.	101.
1974	452.	45.	102.	487.	48.	102.
1975	470.	47.	103.	518.	51.	103.
1976	488.	49.	103.	551.	54.	104.
1977	505.	50.	104.	587.	57.	105.
1978	523.	52.	105.	624.	60.	106.
1979	541.	54.	106.	664.	63.	107.
1980	559.	55.	107.	707.	67.	108.
1981	577.	57.	108.	752.	70.	110.
1982	595.	58.	109.	800.	74.	111.
1983	613.	60.	110.	851.	78.	112.
1984	631.	62.	111.	906.	83.	113.
1985	649.	63.	112.	964.	87.	114.

PARAGUAY

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1670.	116.	143.	1698.	118.	143.
1971	1744.	121.	143.	1820.	124.	142.
1972	1818.	126.	142.	1952.	131.	142.
1973	1892.	130.	142.	2093.	137.	142.
1974	1966.	135.	142.	2244.	145.	142.
1975	2039.	139.	142.	2406.	152.	142.
1976	2113.	144.	142.	2579.	160.	141.
1977	2187.	148.	141.	2766.	169.	141.
1978	2261.	153.	141.	2965.	177.	141.
1979	2335.	157.	141.	3180.	187.	141.
1980	2409.	162.	141.	3409.	197.	141.
1981	2483.	167.	140.	3655.	207.	140.
1982	2557.	171.	140.	3919.	218.	140.
1983	2631.	176.	140.	4203.	229.	140.
1984	2705.	180.	140.	4506.	241.	140.
1985	2778.	185.	140.	4831.	254.	140.

PERU

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	516.	45.	114.	528.	46.	114.
1971	531.	46.	113.	549.	48.	113.
1972	546.	47.	113.	572.	51.	113.
1973	561.	48.	112.	595.	53.	112.
1974	577.	50.	112.	619.	55.	112.
1975	592.	51.	111.	644.	58.	111.
1976	607.	52.	110.	671.	60.	111.
1977	622.	53.	110.	698.	63.	110.
1978	638.	55.	109.	727.	66.	110.
1979	653.	56.	108.	756.	69.	109.
1980	668.	57.	108.	787.	72.	109.
1981	683.	59.	107.	819.	75.	108.
1982	699.	60.	106.	853.	79.	108.
1983	714.	61.	106.	888.	82.	107.
1984	729.	62.	105.	924.	86.	107.
1985	744.	64.	105.	962.	90.	106.

VENEZUELA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	341.	34.	104.	348.	33.	105.
1971	349.	34.	105.	358.	33.	108.
1972	356.	34.	107.	369.	33.	111.
1973	364.	34.	108.	380.	34.	114.
1974	371.	34.	110.	391.	34.	118.
1975	379.	34.	111.	403.	34.	121.
1976	386.	34.	113.	415.	34.	125.
1977	394.	34.	114.	428.	34.	128.
1978	401.	34.	116.	440.	34.	132.
1979	409.	34.	117.	454.	34.	135.
1980	417.	34.	119.	467.	34.	139.
1981	424.	34.	121.	481.	34.	143.
1982	432.	34.	122.	496.	34.	147.
1983	439.	34.	124.	510.	34.	152.
1984	447.	34.	125.	526.	34.	156.
1985	454.	34.	127.	541.	34.	160.

CEYLON

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	391.	61.	66.	406.	60.	68.
1971	406.	62.	67.	429.	61.	70.
1972	421.	63.	69.	454.	62.	73.
1973	435.	64.	70.	480.	64.	76.
1974	450.	64.	72.	508.	65.	79.
1975	464.	65.	73.	537.	66.	82.
1976	479.	66.	75.	568.	67.	85.
1977	494.	67.	76.	601.	69.	88.
1978	508.	68.	78.	635.	70.	91.
1979	523.	69.	80.	672.	71.	95.
1980	538.	70.	81.	711.	73.	98.
1981	552.	71.	83.	752.	74.	102.
1982	567.	72.	84.	795.	75.	106.
1983	581.	73.	86.	841.	77.	110.
1984	596.	74.	87.	890.	78.	114.
1985	611.	75.	89.	941.	80.	119.

TAIWAN

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	319.	21.	149.	332.	22.	149.
1971	332.	22.	151.	353.	23.	151.
1972	345.	23.	153.	376.	24.	154.
1973	358.	23.	156.	399.	25.	156.
1974	371.	24.	158.	425.	26.	159.
1975	384.	25.	160.	451.	27.	162.
1976	397.	25.	162.	480.	28.	164.
1977	410.	26.	164.	510.	29.	167.
1978	423.	27.	166.	542.	31.	170.
1979	436.	27.	169.	577.	32.	172.
1980	449.	28.	171.	613.	34.	175.
1981	462.	29.	173.	652.	35.	178.
1982	475.	29.	175.	693.	37.	181.
1983	488.	30.	177.	737.	38.	184.
1984	501.	31.	179.	783.	40.	187.
1985	514.	31.	182.	833.	42.	190.

INDONESIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	11241.	1541.	72.	11233.	1546.	73.
1971	11259.	1556.	72.	11254.	1563.	72.
1972	11276.	1571.	71.	11275.	1580.	71.
1973	11293.	1586.	70.	11295.	1598.	71.
1974	11310.	1601.	70.	11316.	1615.	70.
1975	11327.	1616.	69.	11337.	1633.	69.
1976	11344.	1631.	68.	11358.	1651.	69.
1977	11362.	1646.	67.	11379.	1670.	68.
1978	11379.	1661.	67.	11400.	1688.	67.
1979	11396.	1676.	66.	11421.	1707.	67.
1980	11413.	1690.	65.	11442.	1726.	66.
1981	11430.	1705.	64.	11463.	1745.	65.
1982	11447.	1720.	64.	11484.	1764.	65.
1983	11464.	1735.	63.	11505.	1784.	64.
1984	11482.	1750.	62.	11527.	1804.	64.
1985	11499.	1765.	62.	11548.	1824.	63.

INDIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	4579.	327.	141.	4618.	325.	142.
1971	4827.	334.	146.	5016.	333.	150.
1972	5075.	341.	152.	5448.	341.	159.
1973	5323.	349.	158.	5918.	349.	168.
1974	5571.	356.	164.	6428.	358.	178.
1975	5818.	363.	170.	6981.	367.	189.
1976	6066.	370.	175.	7583.	376.	200.
1977	6314.	378.	181.	8236.	386.	212.
1978	6562.	385.	187.	8946.	395.	224.
1979	6810.	392.	193.	9717.	405.	237.
1980	7058.	399.	199.	10554.	415.	251.
1981	7306.	407.	205.	11463.	426.	266.
1982	7554.	414.	210.	12451.	436.	281.
1983	7802.	421.	216.	13524.	447.	298.
1984	8050.	428.	222.	14689.	459.	316.
1985	8297.	436.	228.	15955.	470.	334.

W.MALAYSIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	339.	20.	173.	339.	20.	172.
1971	348.	20.	173.	349.	20.	172.
1972	357.	21.	174.	360.	21.	173.
1973	366.	21.	175.	371.	21.	174.
1974	375.	21.	176.	382.	22.	174.
1975	384.	22.	177.	394.	23.	175.
1976	393.	22.	177.	406.	23.	176.
1977	402.	23.	178.	419.	24.	176.
1978	411.	23.	179.	432.	24.	177.
1979	420.	24.	180.	445.	25.	178.
1980	430.	24.	181.	459.	26.	179.
1981	439.	25.	182.	473.	26.	179.
1982	448.	25.	182.	487.	27.	180.
1983	457.	25.	183.	502.	28.	181.
1984	466.	26.	184.	516.	29.	181.
1985	475.	26.	185.	534.	29.	182.

PHILIPPINES

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	531.	90.	60.	536.	91.	60.
1971	538.	91.	60.	547.	92.	60.
1972	546.	92.	61.	558.	93.	61.
1973	553.	93.	61.	569.	94.	61.
1974	561.	93.	62.	580.	95.	62.
1975	568.	94.	62.	591.	96.	62.
1976	575.	95.	63.	603.	98.	63.
1977	583.	96.	63.	615.	99.	64.
1978	590.	97.	64.	627.	100.	64.
1979	598.	98.	64.	640.	101.	65.
1980	605.	99.	64.	652.	103.	65.
1981	612.	100.	65.	665.	104.	66.
1982	620.	100.	65.	678.	105.	66.
1983	627.	101.	66.	692.	107.	67.
1984	635.	102.	66.	705.	108.	67.
1985	642.	103.	67.	719.	109.	68.

THAILAND

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	2187.	146.	150.	2682.	176.	152.
1971	2300.	153.	150.	3027.	197.	153.
1972	2413.	161.	151.	3416.	221.	154.
1973	2526.	168.	151.	3855.	248.	155.
1974	2639.	176.	151.	4351.	278.	156.
1975	2752.	183.	151.	4910.	312.	157.
1976	2865.	191.	152.	5541.	349.	158.
1977	2978.	198.	152.	6253.	392.	160.
1978	3091.	206.	152.	7056.	439.	161.
1979	3204.	213.	153.	7963.	492.	162.
1980	3317.	221.	153.	8987.	551.	163.
1981	3430.	228.	153.	10142.	618.	164.
1982	3543.	236.	153.	11445.	693.	165.
1983	3656.	243.	154.	12916.	777.	166.
1984	3769.	251.	154.	14576.	870.	167.
1985	3882.	258.	154.	16449.	976.	168.

VIET NAM N.

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	709.	101.	70.	709.	101.	70.
1971	695.	100.	69.	696.	101.	69.
1972	680.	100.	68.	684.	100.	68.
1973	666.	99.	67.	672.	100.	67.
1974	652.	99.	65.	660.	100.	66.
1975	638.	98.	64.	648.	99.	65.
1976	624.	97.	63.	636.	99.	64.
1977	610.	97.	62.	625.	99.	63.
1978	596.	96.	61.	614.	98.	62.
1979	581.	96.	60.	603.	98.	61.
1980	567.	95.	59.	592.	97.	61.
1981	553.	94.	58.	582.	97.	60.
1982	539.	94.	56.	571.	97.	59.
1983	525.	93.	55.	561.	96.	58.
1984	511.	93.	54.	551.	96.	57.
1985	497.	92.	53.	541.	96.	56.

VIET NAM S.

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	267.	36.	74.	268.	36.	74.
1971	269.	36.	76.	271.	36.	76.
1972	270.	35.	77.	274.	35.	78.
1973	272.	35.	78.	277.	35.	79.
1974	274.	35.	80.	280.	35.	81.
1975	275.	34.	81.	283.	34.	83.
1976	277.	34.	83.	286.	34.	84.
1977	278.	33.	84.	289.	34.	86.
1978	280.	33.	85.	292.	33.	88.
1979	282.	32.	87.	295.	33.	90.
1980	283.	32.	88.	298.	33.	92.
1981	285.	32.	89.	302.	32.	94.
1982	287.	31.	91.	305.	32.	96.
1983	288.	31.	92.	308.	32.	98.
1984	290.	30.	94.	311.	31.	100.
1985	292.	30.	95.	315.	31.	102.

ANGOLA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1604.	121.	133.	1608.	121.	133.
1971	1645.	122.	135.	1654.	122.	135.
1972	1685.	124.	137.	1702.	124.	137.
1973	1725.	125.	139.	1750.	125.	139.
1974	1765.	127.	141.	1800.	127.	142.
1975	1806.	128.	142.	1852.	129.	144.
1976	1846.	129.	144.	1905.	130.	146.
1977	1886.	131.	146.	1959.	132.	148.
1978	1926.	132.	148.	2015.	133.	151.
1979	1967.	134.	150.	2073.	135.	153.
1980	2007.	135.	152.	2132.	137.	156.
1981	2047.	136.	154.	2193.	138.	158.
1982	2087.	138.	156.	2256.	140.	161.
1983	2127.	139.	158.	2321.	142.	163.
1984	2168.	141.	160.	2387.	143.	166.
1985	2208.	142.	162.	2455.	145.	168.

BURUNDI

YEAR	LINEAR FUNCTION PROD	LINEAR FUNCTION AREA	LINEAR FUNCTION YIELD	LOG FUNCTION PROD	LOG FUNCTION AREA	LOG FUNCTION YIELD
1970	1306.	133.	109.	1271.	120.	106.
1971	1384.	144.	107.	1361.	131.	104.
1972	1462.	155.	105.	1457.	144.	101.
1973	1540.	166.	103.	1560.	158.	99.
1974	1618.	177.	101.	1670.	173.	97.
1975	1697.	188.	99.	1788.	189.	95.
1976	1775.	199.	96.	1914.	207.	92.
1977	1853.	210.	94.	2049.	227.	90.
1978	1931.	221.	92.	2194.	249.	88.
1979	2009.	232.	90.	2349.	273.	86.
1980	2087.	243.	88.	2515.	299.	84.
1981	2166.	254.	86.	2693.	328.	82.
1982	2244.	265.	84.	2883.	359.	80.
1983	2322.	276.	81.	3086.	393.	79.
1984	2400.	287.	79.	3304.	431.	77.
1985	2478.	298.	77.	3538.	472.	75.

CAMEROON

YEAR	LINEAR FUNCTION PROD	LINEAR FUNCTION AREA	LINEAR FUNCTION YIELD	LOG FUNCTION PROD	LOG FUNCTION AREA	LOG FUNCTION YIELD
1970	986.	193.	49.	988.	197.	50.
1971	1019.	203.	46.	1030.	214.	48.
1972	1051.	214.	43.	1073.	233.	46.
1973	1083.	224.	40.	1119.	254.	44.
1974	1115.	234.	38.	1166.	276.	42.
1975	1147.	245.	35.	1216.	300.	40.
1976	1179.	255.	32.	1267.	327.	39.
1977	1211.	266.	29.	1321.	356.	37.
1978	1244.	276.	26.	1377.	387.	36.
1979	1276.	286.	23.	1435.	422.	34.
1980	1308.	297.	20.	1496.	459.	33.
1981	1340.	307.	17.	1559.	499.	31.
1982	1372.	317.	14.	1625.	543.	30.
1983	1404.	328.	11.	1694.	591.	29.
1984	1437.	338.	8.	1766.	644.	27.
1985	1469.	348.	5.	1841.	701.	26.

CENTR.AF.REP

YEAR	LINEAR FUNCTION PROD	LINEAR FUNCTION AREA	LINEAR FUNCTION YIELD	LOG FUNCTION PROD	LOG FUNCTION AREA	LOG FUNCTION YIELD
1970	1029.	203.	51.	1029.	203.	51.
1971	1035.	203.	51.	1034.	203.	51.
1972	1040.	204.	51.	1039.	204.	51.
1973	1045.	205.	51.	1045.	205.	51.
1974	1051.	205.	51.	1050.	205.	51.
1975	1056.	206.	51.	1056.	206.	51.
1976	1062.	206.	51.	1061.	206.	51.
1977	1067.	207.	52.	1067.	207.	52.
1978	1073.	207.	52.	1072.	207.	52.
1979	1078.	208.	52.	1078.	208.	52.
1980	1084.	208.	52.	1084.	208.	52.
1981	1089.	209.	52.	1089.	209.	52.
1982	1095.	209.	52.	1095.	210.	52.
1983	1100.	210.	52.	1101.	210.	52.
1984	1105.	211.	53.	1106.	211.	52.
1985	1111.	211.	53.	1112.	211.	53.

CHAD

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	51.	19.	26.	51.	21.	29.
1971	52.	20.	22.	52.	24.	26.
1972	53.	21.	18.	53.	27.	24.
1973	53.	23.	14.	55.	31.	23.
1974	54.	24.	10.	56.	36.	21.
1975	55.	25.	6.	57.	41.	19.
1976	55.	27.	2.	58.	47.	18.
1977	56.	28.	-2.	60.	54.	17.
1978	57.	29.	-5.	61.	62.	15.
1979	57.	31.	-9.	62.	72.	14.
1980	58.	32.	-13.	64.	82.	13.
1981	59.	33.	-17.	65.	94.	12.
1982	59.	35.	-21.	66.	108.	11.
1983	60.	36.	-25.	68.	124.	10.
1984	61.	37.	-29.	69.	143.	10.
1985	61.	39.	-33.	71.	164.	9.

COMORO IS.

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	99.	27.	38.	106.	27.	39.
1971	107.	28.	40.	123.	29.	42.
1972	115.	30.	42.	141.	31.	45.
1973	123.	31.	44.	163.	34.	49.
1974	131.	32.	46.	188.	36.	53.
1975	139.	34.	48.	217.	39.	57.
1976	147.	35.	50.	250.	41.	61.
1977	155.	37.	52.	288.	44.	66.
1978	163.	38.	54.	332.	48.	71.
1979	171.	39.	56.	383.	51.	76.
1980	179.	41.	58.	442.	55.	82.
1981	187.	42.	61.	510.	59.	89.
1982	195.	43.	63.	588.	63.	96.
1983	203.	45.	65.	678.	67.	103.
1984	211.	46.	67.	782.	72.	111.
1985	219.	48.	69.	901.	77.	120.

CONGO BRAZZ

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	376.	100.	39.	396.	101.	39.
1971	326.	95.	37.	365.	97.	37.
1972	277.	91.	35.	337.	94.	36.
1973	227.	86.	32.	311.	91.	34.
1974	178.	81.	30.	287.	87.	33.
1975	128.	77.	28.	264.	84.	31.
1976	78.	72.	26.	244.	81.	30.
1977	29.	67.	24.	225.	78.	29.
1978	-21.	63.	22.	208.	76.	27.
1979	-70.	58.	19.	192.	73.	26.
1980	-120.	54.	17.	177.	70.	25.
1981	-169.	49.	15.	163.	68.	24.
1982	-219.	44.	13.	150.	65.	23.
1983	-268.	40.	11.	139.	63.	22.
1984	-318.	35.	9.	128.	61.	21.
1985	-367.	30.	6.	118.	59.	20.

CONGO REP

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	7630.	633.	120.	7470.	629.	119.
1971	7681.	633.	121.	7512.	629.	119.
1972	7733.	634.	121.	7554.	629.	120.
1973	7784.	634.	122.	7596.	629.	121.
1974	7836.	634.	123.	7639.	629.	121.
1975	7887.	635.	124.	7681.	629.	122.
1976	7939.	635.	124.	7724.	629.	123.
1977	7990.	635.	125.	7768.	629.	123.
1978	8042.	635.	126.	7811.	629.	124.
1979	8093.	636.	126.	7855.	629.	125.
1980	8145.	636.	127.	7899.	629.	125.
1981	8196.	636.	128.	7943.	629.	126.
1982	8248.	636.	129.	7987.	629.	127.
1983	8299.	637.	129.	8032.	629.	127.
1984	8351.	637.	130.	8077.	630.	128.
1985	8402.	637.	131.	8122.	630.	129.

DAHOMEY

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	979.	147.	66.	961.	144.	66.
1971	966.	141.	67.	948.	139.	68.
1972	954.	135.	68.	935.	134.	69.
1973	941.	129.	70.	922.	129.	71.
1974	929.	124.	71.	910.	125.	73.
1975	916.	118.	72.	898.	120.	74.
1976	904.	112.	73.	886.	116.	76.
1977	891.	106.	75.	874.	112.	78.
1978	879.	100.	76.	862.	108.	79.
1979	866.	94.	77.	850.	104.	81.
1980	854.	89.	78.	839.	100.	83.
1981	841.	83.	80.	828.	97.	85.
1982	829.	77.	81.	816.	93.	87.
1983	816.	71.	82.	805.	90.	89.
1984	804.	65.	83.	795.	87.	91.
1985	791.	59.	84.	784.	84.	93.

EQUAT GUINEA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	43.	15.	29.	43.	15.	29.
1971	43.	15.	29.	43.	15.	29.
1972	43.	15.	29.	43.	15.	29.
1973	44.	15.	29.	44.	15.	28.
1974	44.	16.	28.	44.	16.	28.
1975	45.	16.	28.	45.	16.	28.
1976	45.	16.	28.	45.	16.	28.
1977	46.	16.	28.	46.	16.	28.
1978	46.	17.	28.	46.	17.	28.
1979	47.	17.	27.	47.	17.	27.
1980	47.	17.	27.	47.	17.	27.
1981	48.	17.	27.	48.	17.	27.
1982	48.	17.	27.	48.	18.	27.
1983	48.	18.	27.	49.	18.	27.
1984	49.	18.	26.	49.	18.	27.
1985	49.	18.	26.	50.	19.	26.

GABON

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	140.	62.	21.	139.	63.	22.
1971	141.	64.	20.	139.	66.	21.
1972	141.	66.	19.	140.	68.	20.
1973	142.	68.	18.	140.	71.	20.
1974	143.	70.	17.	141.	74.	19.
1975	143.	72.	16.	141.	77.	18.
1976	144.	74.	15.	142.	80.	18.
1977	145.	76.	14.	143.	83.	17.
1978	145.	78.	13.	143.	86.	17.
1979	146.	79.	11.	144.	89.	16.
1980	146.	81.	10.	144.	93.	15.
1981	147.	83.	9.	145.	97.	15.
1982	148.	85.	8.	146.	100.	14.
1983	148.	87.	7.	146.	104.	14.
1984	149.	89.	6.	147.	108.	13.
1985	150.	91.	5.	147.	113.	13.

GHANA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1697.	196.	82.	1684.	204.	83.
1971	1767.	206.	79.	1778.	221.	80.
1972	1837.	216.	77.	1877.	240.	78.
1973	1907.	225.	74.	1982.	260.	76.
1974	1976.	235.	71.	2093.	282.	74.
1975	2046.	244.	69.	2211.	305.	73.
1976	2116.	254.	66.	2334.	331.	71.
1977	2186.	264.	63.	2465.	358.	69.
1978	2256.	273.	61.	2603.	388.	67.
1979	2326.	283.	58.	2748.	421.	66.
1980	2395.	292.	55.	2902.	456.	64.
1981	2465.	302.	52.	3065.	494.	62.
1982	2535.	312.	50.	3236.	536.	61.
1983	2605.	321.	47.	3417.	580.	59.
1984	2675.	331.	44.	3609.	629.	58.
1985	2744.	340.	42.	3810.	682.	56.

GUINEA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	475.	28.	157.	476.	29.	164.
1971	482.	27.	161.	485.	29.	169.
1972	489.	26.	164.	493.	28.	176.
1973	496.	25.	167.	501.	28.	182.
1974	503.	25.	171.	510.	27.	189.
1975	510.	24.	174.	518.	27.	195.
1976	517.	23.	177.	527.	26.	203.
1977	524.	22.	181.	536.	26.	210.
1978	531.	21.	184.	545.	25.	217.
1979	538.	20.	188.	554.	25.	225.
1980	545.	19.	191.	564.	24.	234.
1981	552.	18.	194.	573.	24.	242.
1982	559.	17.	198.	583.	23.	251.
1983	566.	16.	201.	593.	23.	260.
1984	573.	16.	204.	603.	22.	269.
1985	580.	15.	208.	613.	22.	279.

IVORY COAST

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	576.	192.	30.	565.	191.	30.
1971	558.	194.	29.	551.	194.	29.
1972	540.	196.	27.	537.	197.	28.
1973	521.	198.	26.	524.	199.	27.
1974	503.	200.	24.	511.	202.	26.
1975	485.	203.	23.	498.	205.	25.
1976	466.	205.	21.	486.	208.	24.
1977	448.	207.	20.	474.	210.	23.
1978	429.	209.	18.	462.	213.	22.
1979	411.	211.	17.	451.	216.	21.
1980	393.	214.	15.	440.	219.	20.
1981	374.	216.	14.	429.	222.	20.
1982	356.	218.	12.	418.	225.	19.
1983	338.	220.	11.	408.	228.	18.
1984	319.	222.	9.	398.	231.	17.
1985	301.	225.	8.	388.	235.	17.

KENYA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	620.	92.	67.	620.	92.	67.
1971	623.	93.	67.	623.	93.	67.
1972	626.	93.	67.	626.	93.	67.
1973	629.	94.	67.	629.	94.	67.
1974	632.	94.	67.	632.	94.	67.
1975	635.	95.	67.	635.	95.	67.
1976	638.	95.	67.	638.	95.	67.
1977	641.	96.	67.	642.	96.	67.
1978	644.	96.	67.	645.	96.	67.
1979	647.	96.	67.	648.	97.	66.
1980	650.	97.	66.	651.	97.	66.
1981	653.	97.	66.	654.	97.	66.
1982	656.	98.	66.	657.	98.	66.
1983	659.	98.	66.	661.	98.	66.
1984	662.	99.	66.	664.	99.	66.
1985	665.	99.	66.	667.	99.	66.

LIBERIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	379.	59.	65.	379.	58.	65.
1971	376.	58.	64.	376.	58.	64.
1972	374.	58.	64.	373.	58.	64.
1973	371.	58.	64.	371.	58.	64.
1974	368.	58.	64.	368.	57.	64.
1975	365.	57.	64.	365.	57.	64.
1976	362.	57.	63.	363.	57.	63.
1977	360.	57.	63.	360.	57.	63.
1978	357.	57.	63.	358.	57.	63.
1979	354.	56.	63.	355.	56.	63.
1980	351.	56.	63.	353.	56.	63.
1981	349.	56.	62.	350.	56.	62.
1982	346.	56.	62.	348.	56.	62.
1983	343.	55.	62.	345.	55.	62.
1984	340.	55.	62.	343.	55.	62.
1985	337.	55.	62.	340.	55.	62.

MADAGASCAR

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1046.	246.	46.	1038.	242.	43.
1971	1075.	248.	47.	1071.	244.	44.
1972	1105.	250.	48.	1104.	246.	45.
1973	1134.	252.	49.	1139.	249.	46.
1974	1163.	254.	51.	1175.	251.	47.
1975	1192.	256.	52.	1212.	253.	48.
1976	1221.	258.	53.	1251.	256.	49.
1977	1250.	260.	54.	1290.	258.	50.
1978	1280.	262.	55.	1331.	260.	51.
1979	1309.	264.	56.	1373.	263.	52.
1980	1338.	265.	58.	1417.	265.	54.
1981	1367.	267.	59.	1461.	268.	55.
1982	1396.	269.	60.	1508.	270.	56.
1983	1425.	271.	61.	1555.	272.	57.
1984	1455.	273.	62.	1604.	275.	58.
1985	1484.	275.	63.	1655.	278.	60.

MALI

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	186.	11.	169.	183.	11.	170.
1971	187.	10.	172.	184.	11.	174.
1972	188.	10.	175.	185.	10.	178.
1973	189.	10.	178.	186.	10.	183.
1974	190.	10.	181.	187.	10.	187.
1975	191.	9.	185.	187.	10.	191.
1976	192.	9.	188.	188.	10.	196.
1977	194.	9.	191.	189.	9.	200.
1978	195.	9.	194.	190.	9.	205.
1979	196.	8.	197.	191.	9.	210.
1980	197.	8.	201.	191.	9.	215.
1981	198.	8.	204.	192.	9.	220.
1982	199.	8.	207.	193.	9.	225.
1983	200.	7.	210.	194.	8.	230.
1984	201.	7.	213.	195.	8.	236.
1985	202.	7.	217.	196.	8.	241.

NIGER

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	200.	27.	76.	209.	27.	77.
1971	210.	28.	77.	226.	29.	78.
1972	220.	29.	78.	243.	31.	79.
1973	230.	30.	79.	262.	33.	80.
1974	240.	32.	80.	283.	35.	81.
1975	250.	33.	81.	305.	37.	83.
1976	260.	34.	82.	329.	39.	84.
1977	270.	35.	82.	355.	42.	85.
1978	280.	36.	83.	383.	44.	86.
1979	290.	38.	84.	413.	47.	87.
1980	300.	39.	85.	445.	50.	88.
1981	310.	40.	86.	480.	53.	90.
1982	320.	41.	87.	517.	57.	91.
1983	330.	43.	88.	558.	60.	92.
1984	340.	44.	88.	601.	64.	94.
1985	350.	45.	89.	649.	68.	95.

NIGERIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	7135.	1197.	55.	7146.	1231.	58.
1971	7116.	1226.	51.	7134.	1277.	56.
1972	7097.	1256.	48.	7121.	1323.	54.
1973	7078.	1286.	45.	7109.	1372.	52.
1974	7059.	1316.	41.	7096.	1422.	50.
1975	7040.	1346.	38.	7083.	1475.	48.
1976	7021.	1375.	34.	7071.	1529.	46.
1977	7002.	1405.	31.	7058.	1585.	44.
1978	6983.	1435.	27.	7046.	1643.	43.
1979	6964.	1465.	24.	7033.	1703.	41.
1980	6945.	1495.	20.	7021.	1766.	40.
1981	6926.	1524.	17.	7008.	1831.	38.
1982	6907.	1554.	13.	6996.	1898.	37.
1983	6888.	1584.	10.	6983.	1968.	35.
1984	6869.	1614.	6.	6971.	2040.	34.
1985	6850.	1644.	3.	6959.	2115.	33.

SENEGAL

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	205.	53.	39.	201.	51.	39.
1971	209.	54.	39.	205.	53.	39.
1972	214.	55.	39.	210.	54.	39.
1973	218.	57.	39.	214.	56.	39.
1974	222.	58.	38.	219.	57.	38.
1975	227.	60.	38.	224.	59.	38.
1976	231.	61.	38.	229.	61.	38.
1977	235.	62.	38.	234.	62.	38.
1978	240.	64.	37.	239.	64.	37.
1979	244.	65.	37.	245.	66.	37.
1980	249.	67.	37.	250.	68.	37.
1981	253.	68.	37.	256.	70.	37.
1982	257.	69.	36.	262.	72.	37.
1983	262.	71.	36.	268.	74.	36.
1984	266.	72.	36.	274.	76.	36.
1985	270.	73.	36.	280.	78.	36.

SIERRA LEONE

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	66.	21.	31.	67.	21.	31.
1971	67.	21.	32.	68.	21.	32.
1972	68.	22.	32.	69.	22.	32.
1973	70.	22.	32.	71.	22.	32.
1974	71.	22.	32.	72.	22.	33.
1975	72.	22.	33.	74.	22.	33.
1976	73.	22.	33.	75.	22.	33.
1977	74.	22.	33.	77.	23.	34.
1978	75.	23.	34.	78.	23.	34.
1979	76.	23.	34.	80.	23.	34.
1980	78.	23.	34.	81.	23.	35.
1981	79.	23.	35.	83.	23.	35.
1982	80.	23.	35.	85.	24.	35.
1983	81.	23.	35.	86.	24.	36.
1984	82.	24.	36.	88.	24.	36.
1985	83.	24.	36.	90.	24.	37.

SUDAN

YEAR	LINEAR FUNCTION PROD	LINEAR FUNCTION AREA	LINEAR FUNCTION YIELD	LOG FUNCTION PROD	LOG FUNCTION AREA	LOG FUNCTION YIELD
1970	137.	18.	77.	138.	18.	77.
1971	140.	18.	78.	140.	18.	78.
1972	142.	18.	79.	143.	18.	79.
1973	145.	18.	80.	146.	18.	80.
1974	148.	18.	80.	149.	18.	81.
1975	150.	19.	81.	152.	19.	81.
1976	153.	19.	82.	155.	19.	82.
1977	155.	19.	83.	158.	19.	83.
1978	158.	19.	83.	161.	19.	84.
1979	160.	19.	84.	164.	19.	85.
1980	163.	19.	85.	168.	19.	86.
1981	165.	19.	86.	171.	20.	87.
1982	168.	20.	86.	174.	20.	87.
1983	170.	20.	87.	178.	20.	88.
1984	173.	20.	88.	181.	20.	89.
1985	175.	20.	89.	185.	20.	90.

RWANDA

YEAR	LINEAR FUNCTION PROD	LINEAR FUNCTION AREA	LINEAR FUNCTION YIELD	LOG FUNCTION PROD	LOG FUNCTION AREA	LOG FUNCTION YIELD
1970	300.	29.	105.	313.	30.	104.
1971	327.	31.	104.	363.	35.	104.
1972	354.	34.	104.	422.	41.	103.
1973	380.	36.	103.	490.	48.	103.
1974	407.	39.	103.	569.	55.	102.
1975	433.	41.	103.	661.	65.	102.
1976	460.	44.	102.	767.	75.	102.
1977	486.	47.	102.	891.	87.	101.
1978	513.	49.	101.	1034.	102.	101.
1979	539.	52.	101.	1201.	119.	101.
1980	566.	54.	101.	1394.	138.	100.
1981	593.	57.	100.	1619.	161.	100.
1982	619.	59.	100.	1880.	187.	99.
1983	646.	62.	99.	2182.	218.	99.
1984	672.	64.	99.	2534.	254.	99.
1985	699.	67.	99.	2942.	296.	98.

TANZANIA

YEAR	LINEAR FUNCTION PROD	LINEAR FUNCTION AREA	LINEAR FUNCTION YIELD	LOG FUNCTION PROD	LOG FUNCTION AREA	LOG FUNCTION YIELD
1970	1362.	282.	48.	1355.	282.	48.
1971	1399.	283.	50.	1395.	283.	49.
1972	1436.	285.	51.	1437.	285.	51.
1973	1473.	286.	52.	1480.	286.	52.
1974	1510.	288.	53.	1523.	288.	53.
1975	1548.	289.	54.	1569.	290.	54.
1976	1585.	291.	55.	1615.	291.	56.
1977	1622.	292.	56.	1663.	293.	57.
1978	1659.	294.	57.	1713.	294.	58.
1979	1696.	296.	58.	1763.	296.	59.
1980	1734.	297.	59.	1816.	298.	61.
1981	1771.	299.	60.	1870.	299.	62.
1982	1808.	300.	61.	1925.	301.	64.
1983	1845.	302.	62.	1982.	303.	65.
1984	1882.	303.	63.	2041.	304.	67.
1985	1919.	305.	64.	2102.	306.	68.

TOGO

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	1227.	161.	77.	1296.	168.	77.
1971	1285.	168.	78.	1395.	179.	78.
1972	1342.	175.	79.	1501.	190.	79.
1973	1400.	181.	79.	1615.	203.	80.
1974	1457.	188.	80.	1737.	216.	81.
1975	1514.	195.	81.	1869.	230.	82.
1976	1572.	202.	82.	2012.	244.	83.
1977	1629.	208.	83.	2164.	260.	84.
1978	1687.	215.	83.	2329.	277.	84.
1979	1744.	222.	84.	2506.	294.	85.
1980	1801.	229.	85.	2697.	313.	86.
1981	1859.	236.	86.	2902.	333.	87.
1982	1916.	242.	87.	3122.	355.	88.
1983	1974.	249.	87.	3360.	378.	89.
1984	2031.	256.	88.	3615.	402.	90.
1985	2088.	263.	89.	3890.	428.	91.

UGANDA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	2233.	255.	88.	2285.	253.	90.
1971	2363.	247.	94.	2478.	246.	101.
1972	2492.	238.	100.	2687.	240.	112.
1973	2622.	230.	107.	2914.	233.	125.
1974	2752.	222.	113.	3160.	227.	139.
1975	2881.	213.	119.	3427.	221.	155.
1976	3011.	205.	125.	3716.	215.	172.
1977	3141.	197.	132.	4030.	209.	192.
1978	3270.	188.	138.	4370.	204.	214.
1979	3400.	180.	144.	4739.	198.	238.
1980	3530.	172.	150.	5138.	193.	265.
1981	3660.	163.	157.	5572.	188.	295.
1982	3789.	155.	163.	6042.	183.	329.
1983	3919.	147.	169.	6552.	178.	366.
1984	4049.	138.	175.	7105.	173.	408.
1985	4178.	130.	182.	7705.	169.	454.

ZAMBIA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	153.	50.	30.	153.	50.	30.
1971	153.	51.	29.	153.	51.	30.
1972	153.	52.	29.	153.	52.	29.
1973	153.	53.	28.	153.	54.	28.
1974	153.	54.	27.	153.	55.	27.
1975	153.	55.	26.	153.	56.	27.
1976	153.	56.	25.	153.	58.	26.
1977	153.	57.	24.	153.	59.	25.
1978	153.	59.	23.	153.	61.	25.
1979	153.	60.	22.	153.	62.	24.
1980	153.	61.	21.	153.	64.	23.
1981	153.	62.	20.	153.	66.	23.
1982	153.	63.	19.	153.	67.	22.
1983	153.	64.	18.	153.	69.	21.
1984	153.	65.	17.	153.	71.	21.
1985	153.	66.	16.	153.	73.	20.

LAT.AMERICA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	35362.	2623.	136.	36583.	2681.	136.
1971	36631.	2699.	137.	38470.	2785.	137.
1972	37900.	2775.	138.	40454.	2892.	139.
1973	39169.	2851.	140.	42541.	3004.	140.
1974	40438.	2927.	141.	44735.	3120.	142.
1975	41707.	3003.	143.	47042.	3241.	144.
1976	42976.	3079.	144.	49468.	3366.	145.
1977	44245.	3156.	146.	52020.	3496.	147.
1978	45514.	3232.	147.	54703.	3631.	149.
1979	46783.	3308.	149.	57524.	3772.	151.
1980	48052.	3384.	150.	60491.	3918.	152.
1981	49321.	3460.	151.	63611.	4069.	154.
1982	50590.	3536.	153.	66892.	4226.	156.
1983	51859.	3612.	154.	70342.	4390.	158.
1984	53128.	3688.	156.	73970.	4560.	159.
1985	54397.	3764.	157.	77785.	4736.	161.

FAR EAST

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	21203.	2448.	87.	21650.	2486.	87.
1971	21718.	2497.	88.	22337.	2548.	88.
1972	22234.	2545.	88.	23046.	2612.	88.
1973	22749.	2594.	89.	23778.	2677.	89.
1974	23265.	2643.	89.	24532.	2744.	89.
1975	23780.	2691.	90.	25311.	2813.	90.
1976	24295.	2740.	90.	26115.	2883.	91.
1977	24811.	2789.	91.	26944.	2955.	91.
1978	25326.	2838.	92.	27799.	3029.	92.
1979	25842.	2886.	92.	28681.	3105.	93.
1980	26357.	2935.	93.	29592.	3183.	93.
1981	26872.	2984.	93.	30531.	3262.	94.
1982	27388.	3032.	94.	31500.	3344.	94.
1983	27903.	3081.	94.	32500.	3428.	95.
1984	28419.	3130.	95.	33532.	3513.	96.
1985	28934.	3179.	96.	34596.	3601.	96.

AFRICA

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	33664.	5079.	65.	33475.	5142.	66.
1971	34009.	5189.	64.	33831.	5279.	65.
1972	34353.	5299.	63.	34190.	5421.	64.
1973	34697.	5409.	62.	34553.	5566.	63.
1974	35042.	5518.	61.	34920.	5715.	62.
1975	35386.	5628.	60.	35292.	5868.	61.
1976	35730.	5738.	59.	35667.	6025.	60.
1977	36075.	5847.	58.	36046.	6186.	60.
1978	36419.	5957.	57.	36429.	6351.	59.
1979	36763.	6067.	56.	36816.	6521.	58.
1980	37107.	6176.	55.	37207.	6696.	57.
1981	37452.	6286.	54.	37602.	6875.	56.
1982	37796.	6396.	53.	38002.	7059.	56.
1983	38140.	6506.	52.	38406.	7248.	55.
1984	38485.	6615.	51.	38814.	7442.	54.
1985	38829.	6725.	49.	39226.	7641.	53.

WORLD

YEAR	LINEAR FUNCTION			LOG FUNCTION		
	PROD	AREA	YIELD	PROD	AREA	YIELD
1970	90271.	10197.	88.	90849.	10359.	88.
1971	92302.	10424.	88.	93347.	10650.	88.
1972	94333.	10652.	88.	95914.	10950.	88.
1973	96364.	10879.	88.	98552.	11257.	88.
1974	98395.	11107.	88.	101262.	11574.	88.
1975	100426.	11334.	88.	104047.	11899.	88.
1976	102457.	11561.	88.	106909.	12233.	88.
1977	104488.	11789.	88.	109849.	12577.	88.
1978	106519.	12016.	88.	112870.	12930.	88.
1979	108550.	12244.	88.	115974.	13294.	88.
1980	110581.	12471.	88.	119163.	13667.	88.
1981	112612.	12698.	88.	122440.	14051.	88.
1982	114643.	12926.	88.	125808.	14446.	88.
1983	116674.	13153.	88.	129268.	14852.	88.
1984	118705.	13381.	88.	132823.	15269.	88.
1985	120736.	13608.	88.	136475.	15698.	88.

Appendix B

Cassava Research Programs

The attempt to catalogue briefly cassava research projects known to me is fraught with many dangers. One may inadvertently overlook some of the research activities of a particular agency; one may over- or underestimate the emphasis or results of some agencies; or one may unintentionally suggest weaknesses of one research project relative to others. Conversely, the mere knowledge that someone somewhere else is working on a particular aspect of cassava may facilitate the transfer of knowledge and thereby raise the overall quality of research. It is in hopes of realizing this latter possibility that I have attempted to produce an annotated list of cassava research projects.

Production

CIAT is clearly the world centre for production research, with over 3000 germ plasm in its collection. Research is being carried out on propagation, breeding, yield, and fertilizer response, at diverse altitudes and in differing soils and pHs.

Brazil The Ministry of Agriculture, with its *National Commission on Cassava* (Comissão Nacional da Mandioca), is attempting to coordinate much of the varietal and fertilizer response trials carried out by various states and federal agencies. They are also experimenting with the use of cassava tops for the production of forage feed. *Brascan Nordeste*, Recife, is funding cassava production research (as well as other research) at the University of Bahia. *Instituto Agronomico de Campinas*, Campinas, has a long history of conducting cassava production research.

Thailand The *Ministry of Agriculture* research station in Rayone has conducted fertilizer response trials for years. The *Applied Scientific Research Corporation of Thailand* may become involved in field varietal studies.

Malaysia The *Crop Promotion Division* of the Ministry of Agriculture is conducting varietal and fertilizer response experiments. They are also examining the yields of top growth in order to determine if they are sufficient to suggest using cassava tops as an animal feed. *MARDI, Malaysian Agricultural Research Development Institute*, is reported to be conducting fertilizer and varietal trials.

India The *Central Tuber Crops Research Institute*, Trivandrum, is breeding for high-yielding, mosaic-resistant varieties of cassava.

Fortification

Brazil *USAID* is funding research into the feasibility of fortifying farinha de madioca with soy protein isolate or soyagrits, carried out by Brazilian commercial firms, banks, and research centres. The research was originally centred in Rio de Janeiro but another project is now under way in the Recife area. USAID is also supporting studies in Zaire and Nigeria which, in part, will examine the feasibility of fortifying cassava.

University of Guelph is studying a wet process which uses cassava as a substrate for growing protein with a view to producing a nutritionally complete animal feed.

University of Malaya is also using cassava as a growth medium for protein; however they are exploring a dry process.

The *Applied Scientific Corporation of Thailand* is researching the production and use of protein produced from the cassava starch waste milk.

Composite Flour

The *Institute for Cereals, Flour and Bread*, TNO, Wageningen, Netherlands, has much experience in the production of cassava composite flours. They also have compiled a useful list of institutions which are engaged in composite flour studies.

The *Instituto de Investigaciones Tecnologicas*, Bogota, Colombia, has also developed a number of cassava-based flour products.

The *Central Food Technological Research Institute*, Mysore, India, was one of the first institutions to produce composite flour products, most of which were designed to resemble traditional foods.

The *Food and Agriculture Organization*, Agricultural Service Division, Rome, Italy, has been involved in the production and promotion of composite flour products.

Processing and Storage

CIAT has developed machinery which will produce cassava "bars" (1 × 1 × 5 cm) directly from roots. If density, strength, and dryness meet the appropriate standards the bars may compete with pellets on the European market. In this connection work on the drying characteristics of cassava is also being conducted. Furthermore, CIAT is experimenting with ground clamp storage of cassava. This research is being done in collaboration with the Tropical Products Institute, London.

The *Tropical Products Institute*, London, England, is, as mentioned above, exploring the use of clamps to store cassava; they have also experimented with the treatment of roots with proprianic acid to improve shelf life. TPI is also engaged in studies related to the production of gari (similar to farinha de mandioca) and starch.

The *Applied Scientific Research Corporation of Thailand*, Bangkok, may become involved with research related to the processing of cassava pellets.

Malaysia The *Crop Promotion Division* of the Ministry of Agriculture, *MARDI*, and *NISIR* are all experimenting with small-scale processing units for pellets. *Bank Pertanian* is examining large-scale pellet processing plants.

Brazil The Ministry of Agriculture has researched different methods of producing farinha de mandioca.

The *Central Tuber Crops Research Institute*, Trivandrum, India, has developed a package of production practices which is felt to be suitable for traditional agriculture.

Economics

CIAT is investigating the cost of production and processing for different phases of production. They are planning a survey (over 300 farm families in Colombia) to determine production practices and costs. The economics of using cassava as a pig feed are also being researched.

Thailand The *Ministry of Agriculture* has completed a large survey of the economic operations of producers, processors, exporters and middle men. The *Trade Department* is now examining a number of aspects related to the export of cassava.

The *Comissão Nacional da Mandioca*, Brazil, has established as one of its research priorities the determination of production and processing costs in Brazil.

Malaysia The *Crop Promotion Division*, Ministry of Agriculture has studied the economics of cassava processing plants.

The *International Trade Centre*, GATT, Geneva, Switzerland, has studied the animal feed market for cassava, and may research the starch market for cassava.

The *Tropical Products Institute*, London, England, has conducted studies of the economics of processing and marketing cassava and cassava products.

The *Food and Agriculture Organization*, Rome, has carried out various economic studies related to numerous aspects of production, processing, and marketing.

Again the reader is reminded that the foregoing list is not exhaustive, and may in fact overlook some very important projects.[95] However, the list does indicate some of the current research in cassava and the locations where this research is being carried out.

[95]For example, the *University of Georgia* has compiled an annotated review of cassava literature, but because it is not clear that this is an ongoing project it was not included in the Appendix. Furthermore, it is known that *International Institute of Tropical Agriculture*, Ibadan, Nigeria, has a substantive cassava research program But I am not personally familiar with many of the details; thus this work was not included in the Appendix.

Appendix C

Some United States Industrial Starch Standards for Cassava Starch

	Paper manufacturing	Food manufacturing 1	Food manufacturing 2
Moisture content	12.5% avg 13.5% max	12.5% max	11–14%
Ash content	0.2% max	0.15% max	.30% max
Speck count (no./inch^2)	15 max	8 max	5 max
Viscosity peak (Brabender units)	300–900	600	350–450 (at 92.5°C: 280–400)
Pulp	.25cc/50g	0.1cc/50g	0.5cc/50g
pH	6.5–7.0 (6.7 desired)	5.5–7.5	5.0–6.5
Acid factor	–	2.6 max	1.75–2.5
Cleanliness	FDA approved	FDA approved	FDA approved

Appendix D

Linear Programming Matrix Used in Estimating EEC Least-Cost Feed Rations

TABLE D.1. Linear programming matrix used for least-cost feed rations, of Netherlands, Germany, France, Italy, Belgium-Luxembourg (format that of IBM MPSX).

```
NAME           EECOTH
ROWS
 G S.E.
 G M.E.
 G TDN
 G PROT.MIN
 L PROT.MAX
 G CR.FAT
 L CR.FIB
 G LYSINE
 G METH
 G METH+CYS
 G CAL.MIN.
 L CAL.MAX.
 G PHOSOP
 L BARLEY
 L WHEAT
 L MAIZE
 L LINDSEED
 L SOYBEAN
 L M.GLUTTN
 L COTTMEAL
 L LINDMEAL
 L GRNUTEXP
 L WH.MIDD
 L WH.BRAN
 L BEETPULP
 L BREWGRAN
 L CITRPULP
 L RICEBRAN
 L FISHMEAL
 L OYSTSHEL
 L MEATBONE
 L MOLASSES
 L TALLOW
 L RAPE
 L CASSAVA
 E M.TON
 G MINMAIZ
 G MINGRLUC
 G MINFISH
 G MINMAZGL
 G MINBATLY
 N P.GER
 N P.FRA
 N P.BEL
 N P.ITA
 N P.CASDEL
```

COLUMNS

SORGHUM	S.E.	75.5000	M.E.	3240.0000
SORGHUM	TON	1.1700	PROT.MIN	10.2000
SORGHUM	PROT.MAX	10.2000	CR.FAT	3.2000
SORGHUM	CR.FIB	2.0000	LYSINE	0.2300
SORGHUM	METH	0.1700	METH+CYS	0.3500
SORGHUM	CAL.MIN.	0.0200	CAL.MAX.	0.0200
SORGHUM	PHOSOP	0.2500	M.TON	1.0000
SORGHUM	P.GER	0.0970	P.FRA	0.0870
SORGHUM	P.BEL	0.0930	P.ITA	0.0960
BARLEY	S.E.	70.6000	M.E.	2690.0000
BARLEY	TON	1.0400	PROT.MIN	10.9000
BARLEY	PROT.MAX	10.9000	CR.FAT	2.0000
BARLEY	CR.FIB	5.1000	LYSINE	0.3900
BARLEY	METH	0.1800	METH+CYS	0.4300
BARLEY	CAL.MIN.	0.0700	CAL.MAX.	0.0700
BARLEY	PHOSOP	0.3600	BARLEY	1.0000
BARLEY	M.TON	1.0000	MINBATLY	1.0000
BARLEY	P.GER	0.0990	P.FRA	0.0890
BARLEY	P.BEL	0.0960	P.ITA	0.0970
WHEAT	S.E.	76.2000	M.E.	3020.0000
WHEAT	TON	1.1100	PROT.MIN	11.5000
WHEAT	PROT.MAX	11.5000	CR.FAT	1.7000
WHEAT	CR.FIB	2.1000	LYSINE	0.3300
WHEAT	METH	0.1900	METH+CYS	0.4600
WHEAT	CAL.MIN.	0.0500	CAL.MAX.	0.0500
WHEAT	PHOSOP	0.3800	WHEAT	1.0000
WHEAT	M.TON	1.0000	P.GER	0.1120
WHEAT	P.FRA	0.1000	P.BEL	0.1090
WHEAT	P.ITA	0.1180		
MAIZE	S.E.	30.6000	M.E.	3360.0000
MAIZE	TON	1.1700	PROT.MIN	9.1000
MAIZE	PROT.MAX	9.1000	CR.FAT	4.2000
MAIZE	CR.FIB	2.4000	LYSINE	0.2700
MAIZE	METH	0.2000	METH+CYS	0.4200
MAIZE	CAL.MIN.	0.0200	CAL.MAX.	0.0200
MAIZE	PHOSOP	0.3000	MAIZE	1.0000
MAIZE	M.TON	1.0000	MINMAIZ	1.0000
MAIZE	P.GER	0.1000	P.FRA	0.0760
MAIZE	P.BEL	0.0950	P.ITA	0.0840
LINSEED	S.E.	127.3000	TON	1.7200
LINSEED	PROT.MIN	21.5000	PROT.MAX	21.5000
LINSEED	CR.FAT	34.2000	CR.FIB	7.3000
LINSEED	LYSINE	0.7900	METH	0.4300
LINSEED	METH+CYS	0.8300	CAL.MIN.	0.2300
LINSEED	CAL.MAX.	0.2300	PHOSOP	0.6600
LINSEED	LINOSEED	1.0000	M.TON	1.0000
LINSEED	P.GER	0.1310	P.FRA	0.1310
LINSEED	P.BEL	0.1310	P.ITA	0.1310
SOYBEAN	S.E.	97.9000	M.E.	2900.0000
SOYBEAN	TON	1.3600	PROT.MIN	36.6000
SOYBEAN	PROT.MAX	36.6000	CR.FAT	18.3000
SOYBEAN	CR.FIB	6.0000	LYSINE	2.2600
SOYBEAN	METH	0.5100	METH+CYS	1.0600
SOYBEAN	CAL.MIN.	0.2900	CAL.MAX.	0.2900
SOYBEAN	PHOSOP	0.6200	SOYBEAN	1.0000
SOYBEAN	M.TON	1.0000	P.GER	0.1470
SOYBEAN	P.FRA	0.1470	P.BEL	0.1470
SOYBEAN	P.ITA	0.1470		
M.GLUTTN	S.E.	64.7900	M.E.	1900.0000
M.GLUTTN	TON	0.9000	PROT.MIN	22.6000
M.GLUTTN	PROT.MAX	22.6000	CR.FAT	3.9000
M.GLUTTN	CR.FIB	8.2000	LYSINE	0.7200
M.GLUTTN	METH	0.4300	METH+CYS	0.9500
M.GLUTTN	CAL.MIN.	0.1400	CAL.MAX.	0.1400

M.GLUTTN	PHOSOP	0.5500	M.GLUTTN	1.0000
M.GLUTTN	M.TON	1.0000	MINMAZGL	1.0000
M.GLUTTN	P.GER	0.0790	P.FRA	0.0790
M.GLUTTN	P.BEL	0.0790	P.ITA	0.0790
COTTMEAL	S.E.	62.0000	M.E.	2030.0000
COTTMEAL	TDN	0.9600	PROT.MIN	41.3000
COTTMEAL	PROT.MAX	41.3000	CR.FAT	5.6000
COTTMEAL	CR.FIB.	11.5000	LYSINE	1.5600
COTTMEAL	METH	0.6600	METH+CYS	1.3600
COTTMEAL	CAL.MIN.	0.2000	CAL.MAX.	0.2000
COTTMEAL	PHOSOP	1.1500	COTTMEAL	1.0000
COTTMEAL	M.TON	1.0000	P.GER	0.1020
COTTMEAL	P.FRA	0.1020	P.BEL	0.1020
COTTMEAL	P.ITA	0.1020		
LINSEXP	S.E.	68.9000	M.E.	1600.0000
LINSEXP	TDN	1.0000	PROT.MIN	33.4000
LINSEXP	PROT.MAX	33.4000	CR.FAT	6.3000
LINSEXP	CR.FIB	9.0000	LYSINE	1.2300
LINSEXP	METH	0.6600	METH+CYS	1.3000
LINSEXP	CAL.MIN.	0.3300	CAL.MAX.	0.3300
LINSEXP	PHOSOP	0.8000	LINDMEAL	1.0000
LINSEXP	M.TON	1.0000	P.GER	0.0950
LINSEXP	P.FRA	0.0950	P.BEL	0.0950
LINSEXP	P.ITA	0.0950		
GRNUTEXP	S.E.	78.1000	M.E.	2630.0000
GRNUTEXP	TDN	1.1300	PROT.MIN	49.8000
GRNUTEXP	PROT.MAX	49.8000	CR.FAT	7.0000
GRNUTEXP	CR.FIB	5.3000	LYSINE	1.6400
GRNUTEXP	METH	0.5400	METH+CYS	1.1900
GRNUTEXP	CAL.MIN.	0.1400	CAL.MAX.	0.1400
GRNUTEXP	PHOSOP	0.6400	GRNUTEXP	1.0000
GRNUTEXP	M.TON	1.0000	P.GER	0.1310
GRNUTEXP	P.FRA	0.1310	P.BEL	0.1310
GRNUTEXP	P.ITA	0.1310		
WH.MIDDL	S.E.	64.6000	M.E.	2060.0000
WH.MIDDL	TDN	0.9400	PROT.MIN	16.3000
WH.MIDDL	PROT.MAX	16.3000	CR.FAT	4.3000
WH.MIDDL	CR.FIB	7.5000	LYSINE	0.6500
WH.MIDDL	METH	0.2600	METH+CYS	0.6200
WH.MIDDL	CAL.MIN.	0.1000	CAL.MAX.	0.1000
WH.MIDDL	PHOSOP	0.9000	WH.MIDD	1.0000
WH.MIDDL	M.TON	1.0000	P.GER	0.0760
WH.MIDDL	P.FRA	0.0690	P.BEL	0.0730
WH.MIDDL	P.ITA	0.0760		
WH.BRAN	S.E.	56.5000	M.E.	1800.0000
WH.BRAN	TDN	1.1000	PROT.MIN	15.8000
WH.BRAN	PROT.MAX	15.8000	CR.FAT	4.3000
WH.BRAN	CR.FIB	9.0000	LYSINE	0.6300
WH.BRAN	METH	0.2500	METH+CYS	0.6000
WH.BRAN	CAL.MIN.	0.1000	CAL.MAX.	0.1000
WH.BRAN	PHOSOP	1.2600	WH.BRAN	1.0000
WH.BRAN	M.TON	1.0000	P.GER	0.0840
WH.BRAN	P.FRA	0.0760	P.BEL	0.0810
WH.BRAN	P.ITA	0.0840		
BEETPULP	S.E.	67.1000	TDN	0.9400
BEETPULP	PROT.MIN	8.2000	PROT.MAX	8.2000
BEETPULP	CR.FIB	7.8000	LYSINE	0.4600
BEETPULP	METH	0.1300	METH+CYS	0.2400
BEETPULP	CAL.MIN.	0.6800	CAL.MAX.	0.6800
BEETPULP	PHOSOP	0.0700	BEETPULP	1.0000
BEETPULP	M.TON	1.0000	P.GER	0.0710
BEETPULP	P.FRA	0.0710	P.BEL	0.0710
BEETPULP	P.ITA	0.0710		
BR.GRAN	S.E.	70.0000	M.E.	2866.0000
BR.GRAN	TDN	0.9800	PROT.MIN	27.0000

BR.GRAN	PROT.MAX	27.0000	CR.FAT	9.0000
BR.GRAN	CR.FIB	5.0000	LYSINE	0.9000
BR.GRAN	METH	0.4000	METH+CYS	0.6200
BR.GRAN	CAL.MIN.	3.7500	CAL.MAX.	3.7500
BR.GRAN	PHOSOP	0.9800	BREWGRAN	1.0000
BR.GRAN	M.TON	1.0000	P.GER	0.0840
BR.GRAN	P.FRA	0.0760	P.BEL	0.0810
BR.GRAN	P.ITA	0.0840		
CITRPULP	S.E.	65.2000	TDN	0.9000
CITRPULP	PROT.MIN	6.2000	PROT.MAX	6.2000
CITRPULP	CR.FAT	3.3000	CR.FIB	12.9000
CITRPULP	LYSINE	0.2100	METH	0.0800
CITRPULP	METH+CYS	0.2000	CAL.MIN.	1.9000
CITRPULP	CAL.MAX.	1.9000	PHOSOP	0.1000
CITRPULP	CITRPULP	1.0000	M.TON	1.0000
CITRPULP	P.GER	0.0630	P.FRA	0.0630
CITRPULP	P.BEL	0.0630	P.ITA	0.0630
RICEBRAN	S.E.	89.9000	M.E.	3270.0000
RICEBRAN	TDN	1.3300	PROT.MIN	13.3000
RICEBRAN	PROT.MAX	13.3000	CR.FAT	14.8000
RICEBRAN	CR.FIB	5.7000	LYSINE	0.6200
RICEBRAN	METH	0.2600	METH+CYS	0.5300
RICEBRAN	CAL.MIN.	0.0400	CAL.MAX.	0.0400
RICEBRAN	PHOSOP	1.1000	RICEBRAN	1.0000
RICEBRAN	M.TON	1.0000	P.GER	0.0670
RICEBRAN	P.FRA	0.0600	P.BEL	0.0640
RICEBRAN	P.ITA	0.0660		
FISHMEAL	S.E.	70.9000	M.E.	2910.0000
FISHMEAL	TDN	0.9900	PROT.MIN	66.3000
FISHMEAL	PROT.MAX	66.3000	CR.FAT	8.1000
FISHMEAL	LYSINE	4.9100	METH	1.9200
FISHMEAL	METH+CYS	2.5800	CAL.MIN.	4.2000
FISHMEAL	CAL.MAX.	4.2000	PHOSOP	2.7500
FISHMEAL	FISHMEAL	1.0000	M.TON	1.0000
FISHMEAL	MINFISH	1.0000	P.GER	0.1910
FISHMEAL	P.FRA	0.1910	P.BEL	0.1910
FISHMEAL	P.ITA	0.1910		
OYSTSHEL	CR.FAT	0.5000	CAL.MIN.	38.0000
OYSTSHEL	CAL.MAX.	38.0000	OYSTSHEL	1.0000
OYSTSHEL	M.TON	1.0000	P.GER	0.0270
OYSTSHEL	P.FRA	0.0270	P.BEL	0.0270
OYSTSHEL	P.ITA	0.0270		
MEATBONE	S.E.	63.0000	M.E.	2425.0000
MEATBONE	TDN	0.7600	PROT.MIN	50.0000
MEATBONE	PROT.MAX	50.0000	CR.FAT	10.0000
MEATBONE	LYSINE	2.8000	METH	0.6500
MEATBONE	METH+CYS	1.2000	CAL.MIN.	10.0000
MEATBONE	CAL.MAX.	10.0000	PHOSOP	4.8000
MEATBONE	MEATBONE	1.0000	M.TON	1.0000
MEATBONE	P.GER	0.1030	P.FRA	0.1030
MEATBONE	P.BEL	0.1030	P.ITA	0.1030
MOLASSES	S.E.	42.7000	M.E.	2140.0000
MOLASSES	TDN	0.7600	PROT.MIN	3.4000
MOLASSES	PROT.MAX	3.4000	CR.FIB	0.2000
MOLASSES	CAL.MIN.	0.3400	CAL.MAX.	0.3400
MOLASSES	PHOSOP	0.0500	MOLASSES	1.0000
MOLASSES	M.TON	1.0000	P.GER	0.0480
MOLASSES	P.FRA	0.0480	P.BEL	0.0480
MOLASSES	P.ITA	0.0480		
TALLOW	S.E.	283.5999	M.E.	6850.0000
TALLOW	TDN	4.0100	CR.FAT	99.5000
TALLOW	TALLOW	1.0000	M.TON	1.0000
TALLOW	P.GER	0.1990	P.FRA	0.1990
TALLOW	P.BEL	0.1990	P.ITA	0.1990

RAPEEXT	S.E.	52.8000	M.E.	1690.0000
RAPEEXT	TDN	0.7900	PROT.MIN	35.3000
RAPEEXT	PROT.MAX	35.3000	CR.FAT	1.8000
RAPEEXT	CR.FIB	12.7000	LYSINE	2.0500
RAPEEXT	METH	0.7400	METH+CYS	1.3000
RAPEEXT	CAL.MIN.	0.6000	CAL.MAX.	0.6000
RAPEEXT	PHOSOP	1.1000	RAPE	1.0000
RAPEEXT	M.TON	1.0000	P.GER	0.0660
RAPEEXT	P.FRA	0.0660	P.BEL	0.0660
RAPEEXT	P.ITA	0.0660		
CASSAVA	S.E.	74.0000	M.E.	2910.0000
CASSAVA	TDN	1.1100	PROT.MIN	2.2000
CASSAVA	PROT.MAX	2.2000	CR.FAT	0.5000
CASSAVA	CR.FIB	3.0000	LYSINE	0.1100
CASSAVA	METH	0.0400	METH+CYS	0.0700
CASSAVA	CAL.MIN.	0.1100	CAL.MAX.	0.1100
CASSAVA	PHOSCP	0.0900	CASSAVA	1.0000
CASSAVA	M.TON	1.0000	P.GER	0.0620
CASSAVA	P.FRA	0.0620	P.BEL	0.0620
CASSAVA	P.ITA	0.0620	P.CASDEL	0.0050
GRASMEAL	S.E.	49.8000	M.E.	940.0000
GRASMEAL	TDN	0.7000	PROT.MIN	16.1000
GRASMEAL	PROT.MAX	16.1000	CR.FAT	3.5000
GRASMEAL	CR.FIB	22.4000	LYSINE	0.7600
GRASMEAL	METH	0.2400	METH+CYS	0.4200
GRASMEAL	CAL.MIN.	0.5800	CAL.MAX.	0.5800
GRASMEAL	PHOSOP	0.3400	M.TON	1.0000
GRASMEAL	MINGRLUC	1.0000	P.GER	0.0730
GRASMEAL	P.FRA	0.0730	P.BEL	0.0730
GRASMEAL	P.ITA	0.0730		
ALFAMEAL	S.E.	33.8000	M.E.	890.0000
ALFAMEAL	TDN	0.5000	PROT.MIN	17.0000
ALFAMEAL	PROT.MAX	17.0000	CR.FAT	2.3000
ALFAMEAL	CR.FIB	27.6000	LYSINE	0.8000
ALFAMEAL	METH	0.2600	METH+CYS	0.4500
ALFAMEAL	CAL.MIN.	1.7000	CAL.MAX.	1.7000
ALFAMEAL	PHOSOP	0.2500	M.TON	1.0000
ALFAMEAL	MINGRLUC	1.0000	P.GER	0.0650
ALFAMEAL	P.FRA	0.0650	P.BEL	0.0650
ALFAMEAL	P.ITA	0.0650		
SOYBMEAL	S.E.	70.0000	M.E.	1980.0000
SOYBMEAL	TDN	0.9600	PROT.MIN	42.3000
SOYBMEAL	PROT.MAX	42.3000	CR.FAT	2.0000
SOYBMEAL	CR.FIB	8.1000	LYSINE	2.6200
SOYBMEAL	METH	0.5900	METH+CYS	1.2300
SOYBMEAL	CAL.MIN.	0.3000	CAL.MAX.	0.3000
SOYBMEAL	PHOSOP	0.7000	M.TON	1.0000
SOYBMEAL	P.GER	0.1030	P.FRA	0.1030
SOYBMEAL	P.BEL	0.1030	P.ITA	0.1030
SUNFMEAL	S.E.	54.7000	M.E.	1790.0000
SUNFMEAL	TDN	0.9800	PROT.MIN	44.3000
SUNFMEAL	PROT.MAX	44.3000	CR.FAT	1.3000
SUNFMEAL	CR.FIB	14.4000	LYSINE	1.5000
SUNFMEAL	METH	0.9700	METH+CYS	1.7200
SUNFMEAL	CAL.MIN.	0.4000	CAL.MAX.	0.4000
SUNFMEAL	PHOSCP	0.9000	M.TON	1.0000
SUNFMEAL	P.GER	0.0870	P.FRA	0.0870
SUNFMEAL	P.BEL	0.0870	P.ITA	0.0870
OATS	S.E.	64.8000	M.E.	2580.0000
OATS	TDN	0.9200	PROT.MIN	10.4000
OATS	PROT.MAX	10.4000	CR.FAT	4.9000
OATS	CR.FIB	10.4000	LYSINE	0.3700
OATS	METH	0.1500	METH+CYS	0.4100
OATS	CAL.MIN.	0.1000	CAL.MAX.	0.1000
OATS	PHOSOP	0.3500	M.TON	1.0000
OATS	P.GER	0.0950	P.FRA	0.0890
OATS	P.BEL	0.1030	P.ITA	0.1040

RHS

COW.STAN	S.E.	66000.0000	M.E.	0.0
COW.STAN	TDN	0.0	PROT.MIN	16000.0000
COW.STAN	PROT.MAX	30000.0000	CR.FAT	3000.0000
COW.STAN	CR.FIB	7000.0000	LYSINE	0.0
COW.STAN	METH	0.0	METH+CYS	0.0
COW.STAN	CAL.MIN.	800.0000	CAL.MAX.	1100.0000
COW.STAN	PHOSOP	650.0000	BARLEY	100.0000
COW.STAN	WHEAT	200.0000	MAIZE	200.0000
COW.STAN	LINDSEED	200.0000	SOYBEAN	200.0000
COW.STAN	M.GLUTTN	250.0000	COTTMEAL	150.0000
COW.STAN	LINDMEAL	200.0000	GRNUTEXP	80.0000
COW.STAN	WH.MIDD	200.0000	WH.BRAN	200.0000
COW.STAN	BEETPULP	200.0000	BREWGRAN	50.0000
COW.STAN	CITRPULP	200.0000	RICEBRAN	100.0000
COW.STAN	FISHMEAL	50.0000	OYSTSHEL	0.0
COW.STAN	MEATBONE	50.0000	MOLASSES	150.0000
COW.STAN	TALLOW	20.0000	RAPE	100.0000
COW.STAN	CASSAVA	200.0000	M.TON	1000.0000
COW.STAN	MINMAIZ	0.0	MINGRLUC	0.0
COW.STAN	MINFISH	0.0	MINMAZGL	0.0
COW.STAN	MINBATLY	0.0	P.GER	0.0
COW.STAN	P.FRA	0.0	P.BEL	0.0
COW.STAN	P.ITA	0.0		
COW.CALF	S.E.	64000.0000	M.E.	0.0
COW.CALF	TDN	0.0	PROT.MIN	22000.0000
COW.CALF	PROT.MAX	40000.0000	CR.FAT	4000.0000
COW.CALF	CR.FIB	7000.0000	LYSINE	0.0
COW.CALF	METH	0.0	METH+CYS	0.0
COW.CALF	CAL.MIN.	850.0000	CAL.MAX.	1200.0000
COW.CALF	PHOSOP	800.0000	BARLEY	100.0000
COW.CALF	WHEAT	200.0000	MAIZE	200.0000
COW.CALF	LINDSEED	200.0000	SOYBEAN	200.0000
COW.CALF	M.GLUTTN	250.0000	COTTMEAL	150.0000
COW.CALF	LINDMEAL	200.0000	GRNUTEXP	80.0000
COW.CALF	WH.MIDD	200.0000	WH.BRAN	200.0000
COW.CALF	BEETPULP	200.0000	BREWGRAN	50.0000
COW.CALF	CITRPULP	200.0000	RICEBRAN	100.0000
COW.CALF	FISHMEAL	50.0000	OYSTSHEL	0.0
COW.CALF	MEATBONE	50.0000	MOLASSES	150.0000
COW.CALF	TALLOW	20.0000	RAPE	100.0000
COW.CALF	CASSAVA	200.0000	M.TON	1000.0000
COW.CALF	MINMAIZ	0.0	MINGRLUC	0.0
COW.CALF	MINFISH	0.0	MINMAZGL	0.0
COW.CALF	MINBATLY	0.0	P.GER	0.0
COW.CALF	P.FRA	0.0	P.BEL	0.0
COW.CALF	P.ITA	0.0		
LAY.MED	S.E.	0.0	M.E.	2800000.0000
LAY.MED	TDN	0.0	PROT.MIN	15000.0000
LAY.MED	PROT.MAX	25000.0000	CR.FAT	2000.0000
LAY.MED	CR.FIB	6000.0000	LYSINE	650.0000
LAY.MED	METH	320.0000	METH+CYS	600.0000
LAY.MED	CAL.MIN.	3000.0000	CAL.MAX.	3200.0000
LAY.MED	PHOSOP	450.0000	BARLEY	1000.0000
LAY.MED	WHEAT	100.0000	MAIZE	1000.0000
LAY.MED	LINDSEED	1000.0000	SOYBEAN	1000.0000
LAY.MED	M.GLUTTN	70.0000	COTTMEAL	0.0
LAY.MED	LINDMEAL	1000.0000	GRNUTEXP	50.0000
LAY.MED	WH.MIDD	100.0000	WH.BRAN	150.0000
LAY.MED	BEETPULP	50.0000	BREWGRAN	50.0000
LAY.MED	CITRPULP	0.0	RICEBRAN	30.0000
LAY.MED	FISHMEAL	50.0000	OYSTSHEL	50.0000
LAY.MED	MEATBONE	70.0000	MOLASSES	30.0000
LAY.MED	TALLOW	30.0000	RAPE	50.0000
LAY.MED	CASSAVA	100.0000	M.TON	1000.0000
LAY.MED	MINMAIZ	250.0000	MINGRLUC	30.0000

LAY.MED	MINFISH	20.0000	MINMAZGL	0.0
LAY.MED	MINBATLY	0.0	P.GER	0.0
LAY.MED	P.FRA	0.0	P.BEL	0.0
LAY.MED	P.ITA	0.0		
PROULGRW	S.E.	0.0	M.E.	3200000.0000
PROULGRW	TDN	0.0	PROT.MIN	20000.0000
PROULGRW	PROT.MAX	24000.0000	CR.FAT	2500.0000
PROULGRW	CR.FIB	5500.0000	LYSINE	1150.0000
PROULGRW	METH	430.0000	METH+CYS	820.0000
PROULGRW	CAL.MIN.	1000.0000	CAL.MAX.	1150.0000
PROULGRW	PHOSOP	500.0000	BARLEY	450.0000
PROULGRW	WHEAT	300.0000	MAIZE	400.0000
PROULGRW	LINDSEED	1000.0000	SOYBEAN	1000.0000
PROULGRW	M.GLUTTN	100.0000	COTTMEAL	0.0
PROULGRW	LINDMEAL	1000.0000	GRNUTEXP	70.0000
PROULGRW	WH.MIDD	250.0000	WH.BRAN	250.0000
PROULGRW	BEETPULP	0.0	BREWGRAN	50.0000
PROULGRW	CITRPULP	0.0	RICEBRAN	30.0000
PROULGRW	FISHMEAL	200.0000	OYSTSHEL	50.0000
PROULGRW	MEATBONE	70.0000	MOLASSES	20.0000
PROULGRW	TALLOW	30.0000	RAPE	50.0000
PROULGRW	CASSAVA	0.0	M.TON	1000.0000
PROULGRW	MINMAIZ	0.0	MINGRLUC	0.0
PROULGRW	MINFISH	20.0000	MINMAZGL	0.0
PROULGRW	MINBATLY	0.0	P.GER	0.0
PROULGRW	P.FRA	0.0	P.BEL	0.0
PROULGRW	P.ITA	0.0		
BROILRER	S.E.	0.0	M.E.	2800000.0000
BROILRER	TDN	0.0	PROT.MIN	0.0
BROILRER	PROT.MAX	23000.0000	CR.FAT	4000.0000
BROILRER	CR.FIB	5000.0000	LYSINE	1050.0000
BROILRER	METH	400.0000	METH+CYS	750.0000
BROILRER	CAL.MIN.	950.0000	CAL.MAX.	1150.0000
BROILRER	PHOSOP	450.0000	BARLEY	250.0000
BROILRER	WHEAT	200.0000	MAIZE	400.0000
BROILRER	LINDSEED	1000.0000	SOYBEAN	100.0000
BROILRER	M.GLUTTN	50.0000	COTTMEAL	0.0
BROILRER	LINDMEAL	1000.0000	GRNUTEXP	50.0000
BROILRER	WH.MIDD	100.0000	WH.BRAN	100.0000
BROILRER	BEETPULP	0.0	BREWGRAN	30.0000
BROILRER	CITRPULP	0.0	RICEBRAN	0.0
BROILRER	FISHMEAL	200.0000	OYSTSHEL	0.0
BROILRER	MEATBONE	50.0000	MOLASSES	20.0000
BROILRER	TALLOW	40.0000	RAPE	50.0000
BROILRER	CASSAVA	50.0000	M.TON	1000.0000
BROILRER	MINMAIZ	0.0	MINGRLUC	30.0000
BROILRER	MINFISH	20.0000	MINMAZGL	0.0
BROILRER	MINBATLY	0.0	P.GER	0.0
BROILRER	P.FRA	0.0	P.BEL	0.0
BROILRER	P.ITA	0.0		
BROILFIN	S.E.	0.0	M.E.	2800000.0000
BROILFIN	TDN	0.0	PROT.MIN	0.0
BROILFIN	PROT.MAX	19500.0000	CR.FAT	5000.0000
BROILFIN	CR.FIB	5000.0000	LYSINE	840.0000
BROILFIN	METH	320.0000	METH+CYS	600.0000
BROILFIN	CAL.MIN.	800.0000	CAL.MAX.	1000.0000
BROILFIN	PHOSOP	420.0000	BARLEY	250.0000
BROILFIN	WHEAT	200.0000	MAIZE	400.0000
BROILFIN	LINDSEED	1000.0000	SOYBEAN	70.0000
BROILFIN	M.GLUTTN	100.0000	COTTMEAL	0.0
BROILFIN	LINDMEAL	1000.0000	GRNUTEXP	50.0000
BROILFIN	WH.MIDD	100.0000	WH.BRAN	150.0000
BROILFIN	BEETPULP	0.0	BREWGRAN	30.0000
BROILFIN	CITRPULP	0.0	RICEBRAN	50.0000
BROILFIN	FISHMEAL	200.0000	OYSTSHEL	0.0
BROILFIN	MEATBONE	50.0000	MOLASSES	30.0000

BROILFIN	TALLOW	40.0000	RAPE	50.0000
BROILFIN	CASSAVA	100.0000	M.TON	1000.0000
BROILFIN	MINMAIZ	0.0	MINGRLUC	30.0000
BROILFIN	MINFISH	0.0	MINMAZGL	0.0
BROILFIN	MINBATLY	0.0	P.GER	0.0
BROILFIN	P.FRA	0.0	P.BEL	0.0
BROILFIN	P.ITA	0.0		
PIGSTART	S.E.	0.0	M.E.	0.0
PIGSTART	TDN	1070.0000	PROT.MIN	0.0
PIGSTART	PROT.MAX	19500.0000	CR.FAT	2500.0000
PIGSTART	CR.FIB	6000.0000	LYSINE	940.0000
PIGSTART	METH	0.0	METH+CYS	600.0000
PIGSTART	CAL.MIN.	800.0000	CAL.MAX.	1000.0000
PIGSTART	PHOSOP	650.0000	BARLEY	100.0000
PIGSTART	WHEAT	300.0000	MAIZE	300.0000
PIGSTART	LINDSEED	1000.0000	SOYBEAN	1000.0000
PIGSTART	M.GLUTTN	200.0000	COTTMEAL	0.0
PIGSTART	LINDMEAL	1000.0000	GRNUTEXP	50.0000
PIGSTART	WH.MIDD	250.0000	WH.BRAN	250.0000
PIGSTART	BEETPULP	0.0	BREWGRAN	50.0000
PIGSTART	CITRPULP	50.0000	RICEBRAN	100.0000
PIGSTART	FISHMEAL	70.0000	OYSTSHEL	0.0
PIGSTART	MEATBONE	200.0000	MOLASSES	30.0000
PIGSTART	TALLOW	30.0000	RAPE	50.0000
PIGSTART	CASSAVA	50.0000	M.TON	1000.0000
PIGSTART	MINMAIZ	0.0	MINGRLUC	0.0
PIGSTART	MINFISH	0.0	MINMAZGL	100.0000
PIGSTART	MINBATLY	0.0	P.GER	0.0
PIGSTART	P.FRA	0.0	P.BEL	0.0
PIGSTART	P.ITA	0.0		
PIG-30KG	S.E.	0.0	M.E.	0.0
PIG-30KG	TDN	1000.0000	PROT.MIN	0.0
PIG-30KG	PROT.MAX	18500.0000	CR.FAT	2500.0000
PIG-30KG	CR.FIB	6000.0000	LYSINE	900.0000
PIG-30KG	METH	0.0	METH+CYS	560.0000
PIG-30KG	CAL.MIN.	800.0000	CAL.MAX.	1000.0000
PIG-30KG	PHOSOP	650.0000	BARLEY	600.0000
PIG-30KG	WHEAT	350.0000	MAIZE	150.0000
PIG-30KG	LINDSEED	1000.0000	SOYBEAN	1000.0000
PIG-30KG	M.GLUTTN	70.0000	COTTMEAL	0.0
PIG-30KG	LINDMEAL	1000.0000	GRNUTEXP	50.0000
PIG-30KG	WH.MIDD	70.0000	WH.BRAN	70.0000
PIG-30KG	BEETPULP	0.0	BREWGRAN	50.0000
PIG-30KG	CITRPULP	50.0000	RICEBRAN	100.0000
PIG-30KG	FISHMEAL	70.0000	OYSTSHEL	0.0
PIG-30KG	MEATBONE	200.0000	MOLASSES	40.0000
PIG-30KG	TALLOW	30.0000	RAPE	50.0000
PIG-30KG	CASSAVA	100.0000	M.TON	1000.0000
PIG-30KG	MINMAIZ	0.0	MINGRLUC	0.0
PIG-30KG	MINFISH	0.0	MINMAZGL	0.0
PIG-30KG	MINBATLY	100.0000	P.GER	0.0
PIG-30KG	P.FRA	0.0	P.BEL	0.0
PIG-30KG	P.ITA	0.0		
PG30-100	S.E.	0.0	M.E.	0.0
PG30-100	TDN	1030.0000	PROT.MIN	0.0
PG30-100	PROT.MAX	18000.0000	CR.FAT	2000.0000
PG30-100	CR.FIB	7000.0000	LYSINE	800.0000
PG30-100	METH	0.0	METH+CYS	520.0000
PG30-100	CAL.MIN.	800.0000	CAL.MAX.	1000.0000
PG30-100	PHOSOP	650.0000	BARLEY	600.0000
PG30-100	WHEAT	350.0000	MAIZE	100.0000
PG30-100	LINDSEED	1000.0000	SOYBEAN	1000.0000
PG30-100	M.GLUTTN	100.0000	COTTMEAL	0.0
PG30-100	LINDMEAL	1000.0000	GRNUTEXP	50.0000
PG30-100	WH.MIDD	70.0000	WH.BRAN	70.0000

PG30-100	BEETPULP	0.0	BREWGRAN	50.0000
PG30-100	CITRPULP	50.0000	RICEBRAN	100.0000
PG30-100	FISHMEAL	300.0000	OYSTSHEL	0.0
PG30-100	MEATBONE	200.0000	MOLASSES	50.0000
PG30-100	TALLOW	30.0000	RAPE	50.0000
PG30-100	CASSAVA	150.0000	M.TON	1000.0000
PG30-100	MINMAIZ	0.0	MINGRLUC	30.0000
PG30-100	MINFISH	0.0	MINMAZGL	0.0
PG30-100	MINBATLY	100.0000	P.GER	0.0
PG30-100	P.FRA	0.0	P.BEL	0.0
PG30-100	P.ITA	0.0		
SOWS	S.E.	0.0	M.E.	0.0
SOWS	TDN	970.0000	PROT.MIN	0.0
SOWS	PROT.MAX	18000.0000	CR.FAT	2000.0000
SOWS	CR.FIB	7000.0000	LYSINE	800.0000
SOWS	METH	0.0	METH+CYS	520.0000
SOWS	CAL.MIN.	800.0000	CAL.MAX.	1200.0000
SOWS	PHOSOP	650.0000	BARLEY	600.0000
SOWS	WHEAT	350.0000	MAIZE	100.0000
SOWS	LINDSEED	1000.0000	SOYBEAN	1000.0000
SOWS	M.GLUTTN	100.0000	COTTMEAL	0.0
SOWS	LINDMEAL	1000.0000	GRNUTEXP	50.0000
SOWS	WH.MIDD	200.0000	WH.BRAN	200.0000
SOWS	BEETPULP	0.0	BREWGRAN	50.0000
SOWS	CITRPULP	50.0000	RICEBRAN	100.0000
SOWS	FISHMEAL	300.0000	OYSTSHEL	0.0
SOWS	MEATBONE	200.0000	MOLASSES	50.0000
SOWS	TALLOW	30.0000	RAPE	50.0000
SOWS	CASSAVA	70.0000	M.TON	1000.0000
SOWS	MINMAIZ	0.0	MINGRLUC	70.0000
SOWS	MINFISH	30.0000	MINMAZGL	0.0
SOWS	MINBATLY	0.0	P.GER	0.0
SOWS	P.FRA	0.0	P.BEL	0.0
SOWS	P.ITA	0.0		
CASSE	S.E.	2.0000	M.E.	0.0
CASSE	TDN	0.0	PROT.MIN	0.0
CASSE	PROT.MAX	0.0	CR.FAT	0.0
CASSE	CR.FIB	0.0	LYSINE	0.0
CASSE	METH	0.0	METH+CYS	0.0
CASSE	CAL.MIN.	0.0	CAL.MAX.	0.0
CASSE	PHOSOP	0.0	BARLEY	0.0
CASSE	WHEAT	0.0	MAIZE	0.0
CASSE	LINDSEED	0.0	SOYBEAN	0.0
CASSE	M.GLUTTN	0.0	COTTMEAL	0.0
CASSE	LINDMEAL	0.0	GRNUTEXP	0.0
CASSE	WH.MIDD	0.0	WH.BRAN	0.0
CASSE	BEETPULP	0.0	BREWGRAN	0.0
CASSE	CITRPULP	0.0	RICEBRAN	0.0
CASSE	FISHMEAL	0.0	OYSTSHEL	0.0
CASSE	MEATBONE	0.0	MOLASSES	0.0
CASSE	TALLOW	0.0	RAPE	0.0
CASSE	CASSAVA	0.0	M.TON	0.0
CASSE	MINMAIZ	0.0	MINGRLUC	0.0
CASSE	MINFISH	0.0	MINMAZGL	0.0
CASSE	MINBATLY	0.0	P.GER	0.0
CASSE	P.FRA	0.0	P.BEL	0.0
CASSE	P.ITA	0.0		
CASME	S.E.	0.0	M.E.	50.0000
CASME	TDN	0.0	PROT.MIN	0.0
CASME	PROT.MAX	0.0	CR.FAT	0.0
CASME	CR.FIB	0.0	LYSINE	0.0
CASME	METH	0.0	METH+CYS	0.0
CASME	CAL.MIN.	0.0	CAL.MAX.	0.0
CASME	PHOSOP	0.0	BARLEY	0.0
CASME	WHEAT	0.0	MAIZE	0.0

CASME	LINDSEED	0.0	SOYBEAN	0.0
CASME	M.GLUTTN	0.0	COTTMEAL	0.0
CASME	LINDMEAL	0.0	GRNUTEXP	0.0
CASME	WH.MIDD	0.0	WH.BRAN	0.0
CASME	BEETPULP	0.0	BREWGRAN	0.0
CASME	CITRPULP	0.0	RICEBRAN	0.0
CASME	FISHMEAL	0.0	OYSTSHEL	0.0
CASME	MEATBONE	0.0	MOLASSES	0.0
CASME	TALLOW	0.0	RAPE	0.0
CASME	CASSAVA	0.0	M.TON	0.0
CASME	MINMAIZ	0.0	MINGRLUC	0.0
CASME	MINFISH	0.0	MINMAZGL	0.0
CASME	MINBATLY	0.0	P.GER	0.0
CASME	P.FRA	0.0	P.BEL	0.0
CASME	P.ITA	0.0		
CASPROT	S.E.	0.0	M.E.	0.0
CASPROT	TDN	0.0	PROT.MIN	0.5000
CASPROT	PROT.MAX	0.5000	CR.FAT	0.0
CASPROT	CR.FIB	0.0	LYSINE	0.0
CASPROT	METH	0.0	METH+CYS	0.0
CASPROT	CAL.MIN.	0.0	CAL.MAX.	0.0
CASPROT	PHOSOP	0.0	BARLEY	0.0
CASPROT	WHEAT	0.0	MAIZE	0.0
CASPROT	LINDSEED	0.0	SOYBEAN	0.0
CASPROT	M.GLUTTN	0.0	COTTMEAL	0.0
CASPROT	LINDMEAL	0.0	GRNUTEXP	0.0
CASPROT	WH.MIDD	0.0	WH.BRAN	0.0
CASPROT	BEETPULP	0.0	BREWGRAN	0.0
CASPROT	CITRPULP	0.0	RICEBRAN	0.0
CASPROT	FISHMEAL	0.0	OYSTSHEL	0.0
CASPROT	MEATBONE	0.0	MOLASSES	0.0
CASPROT	TALLOW	0.0	RAPE	0.0
CASPROT	CASSAVA	0.0	M.TON	0.0
CASPROT	MINMAIZ	0.0	MINGRLUC	0.0
CASPROT	MINFISH	0.0	MINMAZGL	0.0
CASPROT	MINBATLY	0.0	P.GER	0.0
CASPROT	P.FRA	0.0	P.BEL	0.0
CASPROT	P.ITA	0.0		
CASPLUS	S.E.	2.0000	M.E.	50.0000
CASPLUS	TDN	0.0200	PROT.MIN	0.5000
CASPLUS	PROT.MAX	0.5000	CR.FAT	0.0
CASPLUS	CR.FIB	0.0	LYSINE	0.0
CASPLUS	METH	0.0	METH+CYS	0.0
CASPLUS	CAL.MIN.	0.0	CAL.MAX.	0.0
CASPLUS	PHOSOP	0.0	BARLEY	0.0
CASPLUS	WHEAT	0.0	MAIZE	0.0
CASPLUS	LINDSEED	0.0	SOYBEAN	0.0
CASPLUS	M.GLUTTN	0.0	COTTMEAL	0.0
CASPLUS	LINDMEAL	0.0	GRNUTEXP	0.0
CASPLUS	WH.MIDD	0.0	WH.BRAN	0.0
CASPLUS	BEETPULP	0.0	BREWGRAN	0.0
CASPLUS	CITRPULP	0.0	RICEBRAN	0.0
CASPLUS	FISHMEAL	0.0	OYSTSHEL	0.0
CASPLUS	MEATBONE	0.0	MOLASSES	0.0
CASPLUS	TALLOW	0.0	RAPE	0.0
CASPLUS	CASSAVA	0.0	M.TON	0.0
CASPLUS	MINMAIZ	0.0	MINGRLUC	0.0
CASPLUS	MINFISH	0.0	MINMAZGL	0.0
CASPLUS	MINBATLY	0.0	P.GER	0.0
CASPLUS	P.FRA	0.0	P.BEL	0.0
CASPLUS	P.ITA	0.0		
CASTDN	S.E.	0.0	M.E.	0.0
CASTDN	TDN	0.0200	PROT.MIN	0.5000
CASTDN	PROT.MAX	0.5000	CR.FAT	0.0
CASTDN	CR.FIB	0.0	LYSINE	0.0

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    CASTDN     METH             0.0     METH+CYS        0.0
    CASTDN     CAL.MIN.         0.0     CAL.MAX.        0.0
    CASTDN     PHOSOP           0.0     BARLEY          0.0
    CASTDN     WHEAT            0.0     MAIZE           0.0
    CASTDN     LINDSEED         0.0     SOYBEAN         0.0
    CASTDN     M.GLUTTN         0.0     COTTMEAL        0.0
    CASTDN     LINDMEAL         0.0     GRNUTEXP        0.0
    CASTDN     WH.MIDD          0.0     WH.BRAN         0.0
    CASTDN     BEETPULP         0.0     BREWGRAN        0.0
    CASTDN     CITRPULP         0.0     RICEBRAN        0.0
    CASTDN     FISHMEAL         0.0     OYSTSHEL        0.0
    CASTDN     MEATBONE         0.0     MOLASSES        0.0
    CASTDN     TALLOW           0.0     RAPE            0.0
    CASTDN     CASSAVA          0.0     M.TON           0.0
    CASTDN     MINMAIZ          0.0     MINGRLUC        0.0
    CASTDN     MINFISH          0.0     MINMAZGL        0.0
    CASTDN     MINBATLY         0.0     P.GER           0.0
    CASTDN     P.FRA            0.0     P.BEL           0.0
    CASTDN     P.ITA            0.0
ENDATA
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Appendix E

Least-Cost Feed Rations for Varying Cassava Prices, and Price Data

TABLE E.1. Feed rations with variable cassava prices.

Price increment[a]	+1	+2	+3	+4	+5	+6	+1	+2	+3	+4	+5	+6
	Cow standard						*Beef and calf*					
Netherlands												
Cost	*69.53*	*71.62*	*73.29*	*73.99*	*74.55*	*75.08*	*74.23*	*75.45*	*76.65*	*77.72*	*78.26*	*78.71*
Cereal	–	–	–	–	–	–	–	–	–	–	–	–
Cereal byproducts	15.0	15.0	15.8	14.7	19.6	19.6	16.3	16.3	16.6	15.0	15.0	15.0
Oilseed and cake	21.9	21.9	19.6	20.1	18.9	18.9	36.9	36.9	36.6	29.3	18.4	18.4
Animal meal	5.0	5.0	5.0	5.0	4.1	4.1	5.0	5.0	5.0	5.0	5.0	5.0
Cassava	43.0	43.0	18.2	13.1	10.9	10.9	25.4	24.8	23.3	19.0	9.2	9.2
Other	15.0	15.0	41.1	46.8	46.1	46.1	16.2	16.7	18.2	31.5	52.2	52.2
Germany												
Cost	*69.41*	*70.47*	*70.88*	*70.88*	*70.88*	*70.88*	*73.16*	*74.13*	*74.13*	*74.13*	*74.13*	*74.37*
Cereal	–	–	–	–	–	–	–	–	–	–	–	–
Cereal byproducts	12.0	41.8	38.0	38.0	38.0	38.3	20.8	40.0	40.0	40.0	40.0	59.5
Oilseed and cake	23.4	10.0	10.0	10.0	10.0	10.0	34.8	25.1	25.1	25.1	25.1	18.7
Animal meal	5.0	3.9	4.1	4.1	4.1	4.1	5.0	5.0	5.0	5.0	5.0	5.0
Cassava	28.3	9.5	0.2	0.2	0.2	–	22.3	11.9	11.9	11.9	11.9	–
Other	31.1	34.5	47.3	47.3	47.3	47.3	16.8	17.8	17.8	17.8	17.8	16.5
France												
Cost	*66.34*	*66.34*	*66.34*	*66.34*	*66.34*	*67.47*	*70.55*	*70.55*	*70.55*	*70.55*	*70.55*	*71.18*
Cereal	–	–	–	–	–	18.9	–	–	–	–	–	16.4
Cereal byproducts	17.3	17.3	17.3	17.3	17.3	35.0	24.8	24.8	24.8	24.8	24.8	35.0
Oilseed and cake	23.6	23.6	23.6	23.6	23.6	15.9	34.2	34.2	34.2	34.2	34.2	28.8
Animal meal	4.0	4.0	4.0	4.0	4.0	1.5	5.0	5.0	5.0	5.0	5.0	4.1
Cassava	42.3	42.3	42.3	42.3	42.3	–	21.7	21.7	21.7	21.7	21.7	–
Other	12.7	12.7	12.7	12.7	12.7	28.6	14.1	14.1	14.1	14.1	14.1	15.3
Belgium-Luxembourg												
Cost	*68.98*	*69.70*	*69.70*	*69.70*	*69.70*	*69.91*	*72.60*	*72.60*	*72.60*	*72.60*	*72.60*	*73.33*
Cereal	–	–	–	–	–	–	–	–	–	–	–	–
Cereal byproducts	20.4	46.9	46.9	46.9	46.9	43.9	19.7	19.7	19.7	19.7	19.7	59.5
Oilseed and cake	21.0	10.0	10.0	10.0	10.0	10.0	35.8	35.8	35.8	35.8	35.8	18.8
Animal meal	3.9	4.2	4.2	4.2	4.2	4.3	5.0	5.0	5.0	5.0	5.0	5.0
Cassava	21.1	5.2	5.2	5.2	5.2	–	22.7	22.7	22.7	22.7	22.7	–
Other	33.3	33.4	33.4	33.4	33.4	41.6	16.6	16.6	16.6	16.6	16.6	16.6
Italy												
Cost	*69.31*	*70.37*	*70.37*	*70.37*	*70.37*	*70.65*	*73.06*	*74.03*	*74.03*	*74.03*	*74.03*	*74.25*
Cereal	–	–	–	–	–	10.2	–	–	–	–	–	11.4
Cereal byproducts	12.0	41.8	41.8	41.8	41.8	38.5	20.8	40.0	40.0	40.0	40.0	40.0
Oilseed and cake	23.4	10.0	10.0	10.0	10.0	10.0	34.8	25.1	25.1	25.1	25.1	22.9
Animal meal	5.0	3.9	3.9	3.9	3.9	3.7	5.0	5.0	5.0	5.0	5.0	5.0
Cassava	28.3	9.5	9.5	9.5	9.5	–	22.3	11.9	11.9	11.9	11.9	–
Other	31.1	34.5	34.5	34.5	34.5	37.3	16.8	17.8	17.8	17.8	17.8	20.4

TABLE E.1. *(continued)*

Price increment	+1	+2	+3	+4	+5	+6	+1	+2	+3	+4	+5	+6
	Layer medium						*Poultry grower*					
Netherlands												
Cost	*95.03*	*96.13*	*97.24*	*98.35*	*99.22*	*100.04*	*134.26*	*134.26*	*134.26*	*134.26*	*134.26*	*134.26*
Cereal	35.2	35.2	35.2	35.2	38.7	38.7	59.8	59.8	59.8	59.8	59.8	59.8
Cereal byproducts	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	13.9	13.9	13.9	13.9	13.3	13.3	5.7	5.7	5.7	5.7	5.7	5.7
Animal meal	11.0	11.0	11.0	11.0	11.0	11.0	16.2	16.2	16.2	16.2	16.2	16.2
Cassava	22.8	22.8	22.8	22.8	16.9	16.9	–	–	–	–	–	–
Other	10.9	10.9	10.9	10.9	13.9	13.9	10.0	10.0	10.0	10.0	10.0	10.0
Germany												
Cost	*89.17*	*90.15*	*90.90*	*90.90*	*90.90*	*91.20*	*112.02*	*112.02*	*112.02*	*112.02*	*112.02*	*112.15*
Cereal	37.9	37.9	58.6	58.6	58.6	60.7	55.8	55.8	55.8	55.8	55.8	64.8
Cereal byproducts	8.0	8.0	8.0	8.0	8.0	9.7	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	14.6	14.6	10.2	10.2	10.2	9.1	5.9	5.9	5.9	5.9	5.9	7.8
Animal meal	9.0	9.0	9.0	9.0	9.0	9.0	17.3	17.3	17.3	17.3	17.3	16.3
Cassava	19.4	19.4	3.0	3.0	3.0	–	9.8	9.8	9.8	9.8	9.8	–
Other	10.9	10.9	11.0	11.0	11.0	11.3	3.0	3.0	3.0	3.0	3.0	3.0
France												
Cost	*75.89*	*75.89*	*75.89*	*75.89*	*75.89*	*75.89*	*99.45*	*99.45*	*99.45*	*99.45*	*99.45*	*99.45*
Cereal	60.7	60.7	60.7	60.7	60.7	60.7	64.8	64.8	64.8	64.8	64.8	64.8
Cereal byproducts	9.7	9.7	9.7	9.7	9.7	9.7	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	9.1	9.1	9.1	9.1	9.1	9.1	7.8	7.8	7.8	7.8	7.8	7.8
Animal meal	9.0	9.0	9.0	9.0	9.0	9.0	16.3	16.3	16.3	16.3	16.3	16.3
Cassava	–	–	–	–	–	–	–	–	–	–	–	–
Other	11.3	11.3	11.3	11.3	11.3	11.3	3.0	3.0	3.0	3.0	3.0	3.0
Belgium-Luxembourg												
Cost	*87.04*	*87.58*	*87.73*	*87.73*	*87.73*	*87.88*	*108.91*	*108.91*	*108.91*	*108.91*	*108.91*	*108.91*
Cereal	37.9	58.7	58.7	58.7	58.7	60.7	64.8	64.8	64.8	64.8	64.8	64.8
Cereal byproducts	8.0	8.0	8.0	8.0	8.0	9.7	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	14.6	10.2	10.2	10.2	10.2	9.1	7.8	7.8	7.8	7.8	7.8	7.8
Animal meal	9.0	9.0	9.0	9.0	9.0	9.0	16.3	16.3	16.3	16.3	16.3	16.3
Cassava	19.4	3.0	3.0	3.0	3.0	–	–	–	–	–	–	–
Other	10.9	11.0	11.0	11.0	11.0	11.3	3.0	3.0	3.0	3.0	3.0	3.0
Italy												
Cost	*81.17*	*81.33*	*81.33*	*81.33*	*81.33*	*81.43*	*105.43*	*105.43*	*105.43*	*105.43*	*105.43*	*105.47*
Cereal	58.7	58.7	58.7	58.7	58.7	61.5	55.8	55.8	55.8	55.8	55.8	64.8
Cereal byproducts	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	10.2	10.2	10.2	10.2	10.2	9.4	5.9	5.9	5.9	5.9	5.9	7.8
Animal meal	9.0	9.0	9.0	9.0	9.0	8.8	17.3	17.3	17.3	17.3	17.3	16.3
Cassava	3.0	3.0	3.0	3.0	3.0	–	9.8	9.8	9.8	9.8	9.8	–
Other	11.0	11.0	11.0	11.0	11.0	12.0	3.0	3.0	3.0	3.0	3.0	3.0

(continued next page)

TABLE E.1. *(continued)*

Price increment	+1	+2	+3	+4	+5	+6	+1	+2	+3	+4	+5	+6
	Broiler						*Broiler finisher*					
Netherlands												
Cost	*103.34*	*105.37*	*107.40*	*109.07*	*110.36*	*111.27*	*89.86*	*92.38*	*94.90*	*97.17*	*98.81*	*100.42*
Cereal	10.1	10.1	10.1	24.3	32.6	32.6	–	–	–	10.4	18.1	20.0
Cereal byproducts	3.0	3.0	3.0	3.0	3.0	3.0	8.0	8.0	8.0	8.0	8.0	8.0
Oilseed and cake	16.8	16.8	16.8	20.6	23.7	23.7	14.2	14.2	14.2	15.9	19.4	19.8
Animal meal	14.1	14.1	14.1	11.1	9.2	9.2	10.3	10.3	10.3	8.7	6.5	6.2
Cassava	41.7	41.7	41.7	26.7	18.7	18.7	51.9	51.9	51.9	41.8	33.4	31.5
Other	14.0	14.0	14.0	14.0	12.5	12.5	14.8	14.8	14.8	15.0	14.3	14.3
Germany												
Cost	*94.12*	*95.87*	*97.42*	*98.09*	*98.09*	*98.27*	*85.55*	*87.85*	*89.92*	*91.40*	*91.98*	*92.00*
Cereal	23.8	25.2	31.0	53.6	53.6	58.2	13.1	15.5	20.1	33.5	50.7	53.0
Cereal byproducts	3.0	3.0	3.0	3.0	3.0	5.5	8.0	8.0	8.0	8.6	18.0	18.0
Oilseed and cake	18.2	18.0	18.3	23.9	23.9	21.8	15.5	15.4	15.7	20.7	16.4	16.2
Animal meal	14.3	14.2	13.6	9.0	9.0	9.2	10.7	10.4	9.9	6.1	5.8	5.7
Cassava	35.6	34.7	27.4	4.8	4.8	–	47.6	44.5	38.4	23.5	2.3	–
Other	4.9	4.6	6.4	5.4	5.4	5.0	4.9	5.8	7.7	7.3	6.5	6.8
France												
Cost	*85.56*	*86.35*	*86.35*	*86.35*	*86.35*	*86.43*	*78.67*	*79.41*	*79.78*	*79.78*	*79.78*	*79.81*
Cereal	40.0	55.1	55.1	55.1	55.1	58.2	40.0	40.0	50.7	50.7	50.7	53.0
Cereal byproducts	3.0	3.0	3.0	3.0	3.0	5.5	15.0	15.0	18.0	18.0	18.0	18.0
Oilseed and cake	19.6	23.5	23.5	23.5	23.5	21.8	16.6	16.6	16.4	16.4	16.4	16.2
Animal meal	12.0	9.0	9.0	9.0	9.0	9.2	6.6	6.6	5.8	5.8	5.8	5.7
Cassava	20.8	3.8	3.8	3.8	3.8	–	14.7	14.7	2.3	2.3	2.3	–
Other	4.2	5.2	5.2	5.2	5.2	5.0	6.9	6.9	6.5	6.5	6.5	6.8
Belgium-Luxembourg												
Cost	*92.70*	*94.29*	*95.21*	*95.21*	*95.21*	*95.37*	*84.60*	*86.75*	*88.29*	*88.89*	*88.89*	*88.94*
Cereal	28.8	32.8	55.1	55.1	55.1	58.2	14.8	20.1	33.5	50.7	50.7	53.0
Cereal byproducts	3.0	3.0	3.0	3.0	3.0	5.5	8.0	8.0	8.6	18.0	18.0	18.0
Oilseed and cake	16.8	17.5	23.5	23.5	23.5	21.8	15.6	15.7	20.7	16.4	16.4	16.2
Animal meal	14.2	13.7	9.0	9.0	9.0	9.2	10.4	9.9	6.1	5.8	5.8	5.7
Cassava	33.1	29.1	3.8	3.8	3.8	–	45.7	38.4	23.5	2.3	2.3	–
Other	3.9	3.6	5.2	5.2	5.2	5.0	5.3	7.7	7.3	6.5	6.5	6.8
Italy												
Cost	*89.00*	*90.05*	*91.06*	*91.55*	*91.55*	*91.69*	*82.44*	*83.58*	*84.35*	*85.11*	*85.42*	*85.42*
Cereal	40.0	40.0	40.0	55.1	55.1	58.2	33.7	40.0	40.0	40.0	51.8	53.0
Cereal byproducts	3.0	3.0	3.0	3.0	3.0	5.5	8.0	12.7	12.7	12.7	18.0	18.0
Oilseed and cake	19.6	19.6	20.2	23.5	23.5	21.8	20.7	18.8	18.8	18.8	16.2	16.2
Animal meal	12.0	12.0	11.7	9.0	9.0	9.2	6.1	5.9	5.9	5.9	5.7	5.7
Cassava	20.8	20.8	18.9	3.8	3.8	–	23.8	15.2	15.2	15.2	1.2	–
Other	4.2	4.2	5.8	5.2	5.2	5.0	7.4	6.9	6.9	6.9	6.6	6.8

TABLE E.1. *(continued)*

Price increment	+1	+2	+3	+4	+5	+6	+1	+2	+3	+4	+5	+6
	Pig starter						*Pig (0–30 kg)*					
Netherlands												
Cost	*83.42*	*85.43*	*87.44*	*89.24*	*90.79*	*92.22*	*81.74*	*83.74*	*85.69*	*87.63*	*89.47*	*91.10*
Cereal	–	–	–	–	–	–	10.0	10.0	10.0	10.0	10.0	10.0
Cereal byproducts	20.0	20.0	20.0	34.5	34.5	45.0	5.4	10.0	10.0	10.0	17.0	17.0
Oilseed and cake	25.7	25.7	25.7	20.8	20.8	15.8	26.8	25.5	25.5	25.5	24.0	24.0
Animal meal	8.2	8.2	8.2	8.3	8.3	8.5	7.7	7.8	7.8	7.8	7.6	7.6
Cassava	41.4	41.4	41.4	31.8	31.8	26.3	43.3	40.0	40.0	40.0	33.4	33.4
Other	4.4	4.4	4.4	4.3	4.3	4.1	6.5	6.4	6.4	6.4	7.7	7.7
Germany												
Cost	*78.10*	*80.17*	*82.08*	*83.28*	*84.26*	*85.18*	*77.58*	*79.35*	*80.84*	*82.27*	*83.53*	*84.64*
Cereal	–	–	–	–	–	–	10.0	10.0	10.0	10.0	10.0	10.0
Cereal byproducts	20.0	20.0	20.0	45.0	50.0	53.2	10.0	24.0	24.0	29.0	36.0	36.0
Oilseed and cake	25.5	26.8	26.8	16.1	16.2	15.3	23.3	17.9	17.9	18.3	16.9	17.0
Animal meal	6.2	5.3	5.3	7.7	6.2	6.4	7.6	7.2	7.2	5.5	5.7	5.7
Cassava	43.7	38.1	38.1	20.9	18.9	17.9	40.8	29.6	29.6	26.6	22.1	22.1
Other	4.2	9.5	9.5	10.0	8.5	6.9	8.0	11.0	11.0	10.4	9.0	9.0
France												
Cost	*77.33*	*78.36*	*78.70*	*78.86*	*78.95*	*79.04*	*75.47*	*76.97*	*77.70*	*78.23*	*78.75*	*79.26*
Cereal	–	8.8	19.2	30.0	30.0	30.0	10.0	10.0	25.0	25.0	25.0	29.1
Cereal byproducts	40.2	52.9	43.0	34.3	34.3	34.3	22.0	31.4	31.5	31.5	31.5	29.0
Oilseed and cake	20.2	15.2	17.3	18.4	18.4	18.4	20.7	18.0	16.8	16.8	16.8	17.1
Animal meal	4.5	6.6	5.7	5.8	5.8	5.8	6.0	5.6	5.7	5.7	5.7	5.6
Cassava	30.7	11.1	4.4	1.8	1.8	1.8	33.6	25.0	10.4	10.4	10.4	8.0
Other	4.1	5.1	10.1	9.4	9.4	9.4	7.5	9.7	10.3	10.3	10.3	11.0
Belgium-Luxembourg												
Cost	*77.80*	*79.87*	*81.15*	*82.09*	*82.98*	*83.81*	*76.88*	*78.54*	*79.98*	*81.25*	*82.36*	*83.43*
Cereal	–	–	–	–	–	2.5	10.0	10.0	10.0	10.0	10.0	13.6
Cereal byproducts	20.0	20.0	50.0	53.2	55.6	55.5	17.0	24.0	29.0	36.0	36.0	36.0
Oilseed and cake	25.5	26.8	18.2	15.3	13.9	13.0	20.8	17.9	18.3	16.9	16.9	16.7
Animal meal	6.2	5.3	4.4	6.4	7.5	8.6	7.8	7.2	5.5	5.7	5.7	5.7
Cassava	43.7	38.1	20.6	17.9	17.2	14.8	36.4	29.6	26.6	22.1	22.1	18.5
Other	4.2	9.5	6.5	6.9	5.4	5.4	7.8	11.0	10.4	9.0	9.0	9.2
Italy												
Cost	*78.00*	*80.07*	*81.98*	*82.67*	*82.89*	*83.00*	*77.28*	*79.05*	*80.54*	*81.94*	*82.59*	*83.16*
Cereal	–	–	–	19.2	19.2	30.0	10.0	10.0	10.0	22.3	25.0	25.0
Cereal byproducts	20.0	20.0	20.0	43.0	43.0	33.4	10.0	24.0	24.0	29.0	27.7	31.4
Oilseed and cake	25.5	26.8	26.8	17.3	17.3	18.5	23.3	17.9	17.9	17.3	17.0	15.3
Animal meal	6.2	5.3	5.3	5.7	5.7	5.5	7.6	7.2	7.2	5.5	5.9	7.4
Cassava	43.7	38.1	38.1	4.4	4.4	1.0	40.8	29.6	29.6	14.7	12.9	10.4
Other	4.2	9.5	9.5	10.1	10.1	11.4	8.0	11.0	11.0	10.9	11.2	10.3

(continued next page)

TABLE E.1. *(concluded)*

Price increment	+1	+2	+3	+4	+5	+6	+1	+2	+3	+4	+5	+6
			Pig (30–100 kg)							*Sow*		
Netherlands												
Cost	*78.41*	*80.35*	*82.30*	*84.14*	*85.59*	*87.04*	*76.78*	*79.45*	*81.91*	*84.17*	*86.26*	*87.98*
Cereal	10.0	10.0	10.0	10.0	10.0	10.0	–	–	–	–	–	–
Cereal byproducts	10.0	10.0	10.0	17.0	17.0	17.0	1.6	1.6	10.0	13.5	15.0	35.0
Oilseed and cake	23.6	23.6	23.6	21.8	21.6	21.6	17.6	17.6	14.1	16.9	16.9	8.2
Animal meal	8.0	8.0	8.0	7.2	7.2	7.2	10.4	10.4	10.4	8.8	8.3	9.0
Cassava	40.0	40.0	40.0	30.4	29.8	29.8	55.1	55.1	49.5	43.7	42.6	30.6
Other	8.1	8.1	8.1	13.3	14.2	14.2	15.0	15.0	15.7	17.0	16.9	16.9
Germany												
Cost	*76.20*	*78.28*	*80.02*	*81.40*	*82.37*	*83.23*	*74.00*	*76.02*	*77.70*	*79.12*	*80.03*	*81.47*
Cereal	10.0	10.0	10.0	10.0	10.0	10.0	–	–	–	–	–	–
Cereal byproducts	10.0	10.0	10.0	29.0	39.0	39.0	10.0	30.9	30.9	45.0	46.4	46.4
Oilseed and cake	21.9	26.5	26.8	20.5	16.1	16.1	13.8	7.0	7.0	5.8	5.0	5.0
Animal meal	5.8	4.7	4.9	3.4	3.5	3.5	10.4	10.2	10.2	7.9	8.0	8.0
Cassava	44.1	35.1	34.7	23.4	17.2	17.2	49.6	33.4	33.4	24.2	23.5	23.5
Other	8.0	13.4	13.2	13.4	14.0	14.0	16.0	18.2	18.2	16.9	16.9	16.9
France												
Cost	*74.44*	*75.80*	*76.53*	*77.26*	*77.26*	*77.38*	*72.19*	*73.74*	*74.75*	*75.58*	*75.58*	*75.91*
Cereal	10.0	20.0	20.0	20.0	20.0	29.8	–	–	10.0	10.0	10.0	21.3
Cereal byproducts	18.9	29.0	29.0	29.0	29.0	37.8	35.0	39.2	42.9	42.9	42.9	50.0
Oilseed and cake	20.3	19.6	19.6	19.6	19.6	12.9	6.6	6.1	5.0	5.0	5.0	5.0
Animal meal	4.0	3.2	3.2	3.2	3.2	3.1	8.9	8.5	8.3	8.3	8.3	6.6
Cassava	38.5	14.6	14.6	14.6	14.6	–	34.1	28.5	16.6	16.6	16.6	–
Other	8.0	13.4	13.4	13.4	13.4	16.1	15.0	17.4	17.0	17.0	17.0	17.0
Belgium-Luxembourg												
Cost	*75.60*	*77.68*	*79.06*	*80.23*	*81.20*	*81.97*	*73.43*	*75.12*	*76.71*	*78.03*	*79.20*	*80.11*
Cereal	10.0	10.0	10.0	10.0	10.0	24.1	–	–	–	–	–	16.0
Cereal byproducts	10.0	10.0	29.0	29.0	39.0	39.0	30.0	30.9	36.8	46.4	46.4	51.1
Oilseed and cake	21.9	26.5	20.5	20.5	16.1	12.3	7.3	7.0	6.4	5.0	5.0	5.0
Animal meal	5.8	4.7	3.4	3.4	3.5	3.6	10.3	10.2	8.4	8.0	8.0	6.4
Cassava	44.1	35.1	23.4	23.4	17.2	3.4	34.8	33.4	30.1	23.5	23.5	4.3
Other	8.0	13.4	13.4	13.4	14.0	17.3	17.3	18.2	17.9	16.9	16.9	17.0
Italy												
Cost	*75.90*	*77.98*	*79.72*	*80.91*	*81.49*	*81.89*	*73.91*	*75.92*	*77.60*	*78.89*	*79.67*	*80.44*
Cereal	10.0	10.0	10.0	20.0	20.0	20.0	–	–	–	8.2	10.0	10.0
Cereal byproducts	10.0	10.0	10.0	29.0	39.0	39.0	10.0	30.9	30.9	43.8	45.0	45.0
Oilseed and cake	21.9	26.5	26.8	19.6	14.6	12.8	13.8	7.0	7.0	5.0	5.0	5.0
Animal meal	5.8	4.7	4.9	3.2	3.2	3.6	10.4	10.2	10.2	8.0	7.6	7.6
Cassava	44.1	35.1	34.7	14.6	8.5	7.7	49.6	33.4	33.4	17.8	15.3	15.3
Other	8.0	13.4	13.2	13.4	14.4	15.6	16.0	18.2	18.2	17.0	16.9	16.9

[a] $+i = i \times \$5 + \$65$ = cassava price. Therefore +1 = cassava price of \$70/metric ton.

TABLE E.2. Feed rations with variable cassava prices: United Kingdom.

Price increment	0	1	2	3	4	5	Price increment	0	1	2	3	4	5
Dairy (3.5 gal)							*Poultry grower*						
Cost	*74.33*	*76.65*	*78.48*	*79.48*	*80.22*	*80.32*	Cost	*75.59*	*78.71*	*81.19*	*82.91*	*84.54*	*85.06*
Cereal	–	–	–	–	–	11.7	Cereal	–	–	15.2	25.6	25.6	47.1
Cereal byproducts	15.0	15.0	45.0	47.9	43.5	47.7	Cereal byproducts	15.0	15.0	15.0	15.0	15.0	35.5
Oilseed and cake	30.3	30.3	15.6	14.6	19.3	14.4	Oilseed and cake	12.5	19.7	22.0	20.2	20.2	12.6
Animal meal	5.0	5.0	5.0	5.0	5.0	5.0	Animal meal	12.2	6.9	3.3	3.7	3.7	2.3
Cassava	39.9	39.9	22.7	20.5	14.3	–	Cassava	59.7	54.5	40.6	33.5	33.5	–
Other	9.6	9.6	11.5	11.7	17.6	21.0	Other	0.4	3.7	3.6	1.8	1.8	2.3
Dairy (4.0 gal)							*Broiler*						
Cost	*68.60*	*70.85*	*72.00*	*72.45*	*72.79*	*73.12*	Cost	*103.00*	*103.73*	*104.33*	*104.83*	–	*104.93*
Cereal	–	–	–	–	–	–	Cereal	40.3	40.3	40.3	47.8	47.8	54.1
Cereal byproducts	10.0	23.4	57.9	54.3	54.3	54.3	Cereal byproducts	12.5	12.5	12.5	12.5	12.5	12.5
Oilseed and cake	23.6	22.1	7.5	7.5	7.5	7.5	Oilseed and cake	14.6	14.6	14.6	17.0	17.0	15.0
Animal meal	5.0	2.1	2.5	2.6	2.6	2.6	Animal meal	16.3	16.3	16.3	15.1	15.1	15.1
Cassava	47.5	33.3	13.0	6.8	6.8	6.8	Cassava	12.3	12.3	12.3	3.7	3.7	–
Other	13.6	18.8	18.9	28.5	28.5	28.5	Other	3.7	3.7	3.7	3.7	3.7	2.6
Beef fattening							*Broiler finishing*						
Cost	*66.76*	*68.10*	*68.63*	*68.69*	–	*68.72*	Cost	*100.18*	*101.24*	*102.22*	*103.07*	–	*103.08*
Cereal	–	–	–	–	–	–	Cereal	35.6	36.4	37.0	44.6	44.6	54.4
Cereal byproducts	12.6	35.0	36.4	36.4	36.4	38.4	Cereal byproducts	12.5	12.5	12.5	12.5	12.5	12.5
Oilseed and cake	13.4	10.2	7.5	7.5	7.5	7.5	Oilseed and cake	10.3	10.7	10.7	13.0	13.0	16.8
Animal meal	5.0	1.9	2.2	2.2	2.2	1.8	Animal meal	16.4	16.1	16.2	15.0	15.0	12.4
Cassava	42.2	13.7	1.4	1.4	1.4	–	Cassava	21.2	20.5	19.7	11.0	11.0	–
Other	26.6	39.0	52.3	52.3	52.3	52.1	Other	3.7	3.7	3.7	3.7	3.7	3.7
Grazing cake							*Pig grower*						
Cost	*64.85*	*67.03*	*68.36*	*69.27*	*69.83*	*70.00*	Cost	*70.73*	*73.78*	*75.75*	*77.29*	*78.69*	*80.03*
Cereal	–	–	–	–	–	–	Cereal	–	–	–	–	–	–
Oilseed and cake	13.5	10.2	7.5	7.5	7.5	7.5	Cereal byproducts	10.0	10.0	40.0	47.7	50.0	50.0
Animal meal	1.5	–	–	–	–	–	Oilseed and cake	24.0	24.0	14.6	10.9	10.1	9.7
Cassava	40.6	33.9	18.9	18.9	8.6	–	Animal meal	6.0	6.0	4.6	4.7	4.4	4.6
Other	33.8	33.6	46.0	46.0	43.7	44.0	Cassava	53.9	53.9	35.5	31.5	27.7	27.3
							Other	5.8	5.8	5.1	5.0	7.6	8.2
Layer medium							*Pig fattening*						
Cost	*79.21*	*81.89*	*84.06*	*85.86*	*87.49*	*87.92*	Cost	*67.97*	*71.12*	*73.29*	*75.07*	*76.83*	*78.31*
Cereal	–	7.2	11.3	24.7	24.7	55.2	Cereal	–	–	–	–	–	–
Cereal byproducts	15.0	15.0	15.0	15.0	15.0	15.0	Cereal byproducts	10.0	10.0	45.6	45.6	44.5	50.0
Oilseed and cake	9.5	12.0	13.4	10.0	10.0	7.5	Oilseed and cake	16.7	16.7	5.0	5.0	5.0	5.0
Animal meal	12.9	12.0	10.9	11.4	11.4	9.2	Animal meal	5.5	5.5	4.3	4.3	3.5	3.6
Cassava	54.1	46.2	41.7	33.6	33.6	–	Cassava	57.7	57.7	36.7	36.7	32.6	28.1
Other	8.3	7.3	7.5	5.0	5.0	12.8	Other	9.9	9.9	8.2	8.2	14.1	13.1

TABLE E.3. Prices of feed ingredients in EEC member countries, 1971 (*$/metric ton*).

	France	Germany	Italy	Belgium-Luxembourg	Netherlands
Sorghum	87.50	97.01	96.06	93.21	95.11
Barley	89.42	99.45	97.17	96.19	98.42
Wheat	100.44	112.20	118.68	109.87	110.78
Maize	76.08	100.89	84.76	95.47	97.29
Linseed	131.55	131.55	131.55	131.55	131.55
Soybean	147.48	147.48	147.48	147.48	147.48
Maize gluten	79.65	79.65	79.65	79.65	79.65
Cotton meal	102.74	102.74	102.74	102.74	102.74
Linseed expeller	95.44	95.44	95.44	95.44	95.44
Groundnut	131.08	131.08	131.08	131.08	131.08
Wheat middlings	69.26	76.79	76.03	73.77	75.28
Wheat bran	76.64	84.97	84.13	81.63	83.30
Beet pulp	71.44	71.44	71.44	71.44	71.44
Brewer's grain	76.54	84.86	84.03	81.54	83.20
Citrus pulp	63.88	63.88	63.88	63.88	63.88
Rice bran	60.94	67.56	66.90	64.92	66.24
Fish meal	191.47	191.47	191.47	191.47	191.47
Oyster shell	27.28	27.28	27.28	27.28	27.28
Meat and bone	103.92	103.92	103.92	103.92	103.92
Molasses	48.00	48.00	48.00	48.00	48.00
Tallow	199.15	199.15	199.15	199.15	199.15
Rape extract	66.98	66.98	66.98	66.98	66.98
Cassava	65.00	65.00	65.00	65.00	65.00
Grassmeal	73.33	73.33	73.33	73.33	73.33
Alfalfa meal	65.08	65.08	65.08	65.08	65.08
Soybean meal	103.65	103.65	103.65	103.65	103.65
Sunflower	87.16	87.16	87.16	87.16	87.16
Oats	89.35	95.66	104.76	103.46	92.71

Note:

1 Wheat, barley, oats, and maize:
  - (a) market price in 1971 was obtained from the publication, *Background to the* EEC *Cereal Market*, Home Grown Cereals Authority, Haymarket, March 1972;
  - (b) the price to the end user was available for Netherlands;
  - (c) from this, the price to the end user in other EEC member countries was obtained on a pro rata basis, on the assumption that the price relativities would be maintained.

2 Sorghum, wheat middlings, wheat bran, brewer's grain, and rice bran:
  - (a) an average of the price relativity of each of the member countries with respect to Netherlands was calculated;
  - (b) this was used to estimate the prices in the member countries from the prices given in Netherlands.

3 For the rest of the feed ingredients, the prices in other member countries were assumed to be the same as those prevailing in Netherlands.

TABLE E.4. Estimated United Kingdom prices of raw materials during transition to EEC prices 1973–1978 (*£/long ton*).

	1973 (Feb)		1974 (Feb)		1975 (Feb)		1976 (Feb)		1977 (Feb)		1978 (Feb)	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Wheat	31.0	31.0	34.0	34.5	36.5	37.5	39.0	41.0	42.0	44.5	48.5	53.0
Denatured wheat	25.0	25.0	28.0	28.5	30.5	31.5	33.0	35.0	35.5	38.0	41.5	46.5
Barley	26.0	26.0	28.5	29.5	31.0	32.0	34.0	35.5	36.5	39.0	42.5	47.0
Maize	28.5	28.5	31.0	31.0	33.5	34.0	36.0	37.0	38.5	40.5	44.5	48.5
Rye	24.0	24.0	27.5	27.5	31.0	32.0	35.0	36.0	38.5	41.0	47.0	51.0
Oats	27.0	27.0	29.5	29.5	32.0	32.5	34.5	35.5	37.0	39.0	42.5	46.5
Sorghum	27.5	27.5	30.0	30.5	33.0	33.5	35.5	36.5	38.0	40.0	43.5	48.0
Millet/buckwheat	27.0	27.0	29.5	29.6	32.0	32.5	35.0	36.0	37.5	39.0	43.0	47.0
European Maize	24.5	–	27.0	–	30.0	–	32.0	–	35.0	–	40.0	–
Soyabean extract	53.5	54.5	51.5	53.5	50.5	53.5	49.5	53.5	48.5	53.5	48.5	54.5
Rapeseed extract	34.0	35.0	33.0	34.0	32.0	34.0	31.5	34.0	31.0	34.0	31.0	35.0
Sunflower extract	42.5	43.5	43.0	42.5	42.0	42.5	41.0	42.5	40.0	42.5	40.0	43.5
Groundnut expeller	52.5	53.5	50.5	52.5	50.0	52.5	47.0	50.5	46.0	50.5	46.0	51.5
Groundnut extract	50.5	51.5	48.5	50.5	48.0	50.5	45.0	48.5	44.0	48.5	44.0	49.5
Cotton expeller	48.0	48.5	46.5	48.0	45.5	48.0	44.5	48.0	43.5	48.0	43.5	48.5
Cotton extract	40.0	41.0	39.0	40.0	38.5	40.0	37.5	40.0	36.5	40.0	36.5	41.0
Linseed expeller	48.5	49.5	47.0	48.5	46.0	48.5	45.0	48.5	44.0	48.5	44.0	49.5
Coconut expeller	40.0	40.5	38.5	40.0	38.0	40.0	37.0	40.0	36.0	40.0	36.0	40.5
Fish meal 65%	94.0	96.0	90.0	94.0	89.5	94.0	88.5	94.0	87.0	94.0	87.0	96.0
Meat meal	56.0	57.0	54.0	56.0	53.5	56.0	52.0	56.0	51.0	56.0	51.0	57.0
Wheat bran	31.0	31.0	32.0	32.5	33.0	33.5	34.0	35.0	35.0	36.5	37.0	39.0
Wheat middlings	28.0	29.0	29.5	30.0	30.5	30.5	31.0	32.0	32.0	33.5	34.0	36.0
Maize meal	35.5	35.5	36.5	37.0	37.5	38.0	38.5	39.5	39.5	41.0	41.5	43.5
Pollard pellets	29.0	29.0	30.0	30.5	31.0	31.5	32.0	32.0	33.0	34.5	35.0	37.0
Brewer's grain	33.0	33.0	34.0	34.5	35.0	35.5	36.0	36.0	37.0	38.5	39.0	41.0
Rolled barley	30.0	30.0	32.5	33.5	35.0	36.0	38.0	39.5	40.5	43.0	44.5	51.0
Flaked maize	35.5	35.5	38.0	38.0	40.5	41.0	43.0	44.0	45.5	47.5	51.5	55.5
Rice bran	36.0	36.0	37.0	37.5	38.0	39.0	39.0	40.5	40.0	42.0	42.0	44.5
Rice bran extract	26.5	27.0	26.5	27.5	26.5	28.0	26.5	28.5	26.5	29.0	26.5	29.5
Beet pulp	31.0	31.5	31.0	32.0	31.0	33.0	31.0	33.5	31.0	34.0	31.0	35.0
Maize gluten feed	36.0	36.5	36.0	37.0	36.0	38.0	36.0	38.5	36.0	39.0	36.0	40.0
Lucerne meal	30.5	31.0	30.5	31.5	30.5	32.5	30.5	33.0	30.5	33.5	30.5	34.5
Grass meal	29.0	29.5	29.0	30.0	29.0	31.0	29.0	31.5	29.0	32.0	29.0	33.0
Dried peas	42.0	42.5	42.0	43.5	42.0	44.0	42.0	45.0	42.0	45.5	42.0	46.5
Citrus pulp	27.0	27.5	27.0	28.0	27.0	28.5	27.0	29.5	27.0	30.0	27.0	31.0
Sliced potatoes	24.0	24.5	24.0	25.0	24.0	25.5	24.0	26.0	24.0	26.5	24.0	27.0
Manioc	27.0	27.5	27.0	28.0	27.0	28.5	27.0	29.5	27.0	30.0	27.0	31.0

Appendix F

Cross-Sectional Analysis of Consumption of Cassava in Brazil

TABLE F.1. Brazilian consumption models, cross-sectional data.

	Linear relationship				Logarithmic relationship			
	α	β (t-value)	r^2	F-value	α	β (t-value)	r^2	F-value
				Fresh cassava				
Urban areas								
Brazil	1.73604	.00099	63.39	12.12	−1.955	−0.45195	84.9	39.36
		(3.48)				(6.27)		
Northeast	0.61535	−0.00013	6.31	0.47	3.68238	−0.8532	22.62	2.05
		(0.69)				(1.43)		
East	2.31984	.00199	88.64	54.61	−1.4113	0.43611	96.46	190.9
		(7.39)				(13.82)		
South	1.84703	.00069	27.70	2.68	−2.8355	0.57049	62.21	11.52
		(1.64)				(3.39)		
Rural areas								
Brazil	24.25976	−0.00152	8.9	0.68	3.13703	−0.00317	0.03	0.
		(0.83)				(0.05)		
Northeast	10.25895	−0.00256	18.32	1.57	9.01852	−1.2934	26.55	2.53
		(1.25)				(1.59)		
East	19.36012	−0.00124	1.85	0.13	2.88302	−0.00778	0.06	0.
		(0.36)				(0.06)		
South	45.36469	−0.00062	0.4	0.03	3.70102	0.01409	0.81	0.06
		(0.17)				(0.24)		
				Cassava flour				
Urban areas								
Brazil	12.00853	−0.00149	72.62	18.57	2.9635	−0.0974	59.44	10.26
		(4.31)				(3.2)		
Northeast	25.07498	−0.00411	76.46	22.74	3.95875	−0.1473	69.17	15.71
		(4.77)				(3.96)		
East	11.53424	−0.00026	3.21	0.23	2.29849	0.01988	3.71	0.27
		(0.48)				(0.52)		
South	4.63895	−0.00102	58.79	9.98	2.76045	−0.2409	78.24	25.17
		(3.16)				(5.02)		
Rural areas								
Brazil	38.55973	0.00115	2.88	0.21	3.50996	0.02546	4.	0.29
		(0.46)				(0.54)		
Northeast	66.36729	0.00576	13.63	1.1	3.88345	0.05938	13.37	1.08
		(1.05)				(1.04)		
East	32.57811	−0.00516	48.3	6.54	3.96002	−0.10536	23.47	2.15
		(2.56)				(1.47)		
South	13.09487	0.00249	16.15	1.35	2.31686	0.05451	2.79	0.2
		(1.16)				(0.45)		

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