United States
Department of
Agriculture

Economic
Research
Service

**International
Economics
Division**

Crop Output Growth

Changes in Component Contributions for Six Developing Countries

Daniel Feinstein

CROP OUTPUT GROWTH: CHANGES IN COMPONENT CONTRIBUTIONS FOR SIX DEVELOPING COUNTRIES. Daniel Feinstein. International Economics Division, Economic Research Service, U.S. Department of Agriculture. Washington, D.C. June 1984, ERS Staff Report No. AGES 840419.

ABSTRACT

Using a components-of-growth approach, this study analyzes factors affecting declining long-term rates of agricultural growth in selected countries of Latin America and Asia. In both regions, the contribution of expanding agricultural land area to crop output growth has significantly declined and the contribution of yield increase has been marginal. However, the relative importance of changes in the cropping pattern has increased moderately over the long term. Prospects for production growth will depend upon the development and adoption of yield-enhancing innovations in Latin America, and a shift to higher value cereals in Asia.

Keywords: Agricultural growth components, rate of crop output growth, interactions, Latin America, Asia.

CONTENTS

GLOSSARY OF TERMS

Crop output: Value of crop production in nominal dollar terms.

Initial and end periods: A period is 1 or more years. Yearly crop area, yield, and output data are averaged for multiyear periods. Growth rates and component contributions (see below) are calculated between initial and end periods.

Time interval: Span of time between initial and end periods. An interval may be any number of years.

Growth rate of crop output: The average annual compound rate of growth over an interval.

Gross area component (A): A gross area component is the gain or loss in crop output attributable solely to a change in gross area. Gross area is the area of all crops harvested in a country during a period with land harvested more than once counted more than once. A change in gross area over a time interval will, *ceteris paribus*, produce a change in the level of crop output.

Net area component: This component is the gain or loss in crop output attributable solely to a change in net area. Net area is the area of crops harvested in a country during a period with land harvested more than once counted only once. The ratio of gross area to net area is the cropping intensity.

Yield component (Y): A net change in production per hectare over an interval (with production translated into value by virtue of constant price weights) will, ceteris paribus, produce a change in crop output attributable strictly to change in crop yields.

Cropping pattern component (C): Change in the proportion of land harvested in crops will produce a change in the value of crop output over an interval even if gross area and yields remain constant because producer price weights differ from crop to crop. The cropping pattern component is the gain or loss in output owing strictly to shifts in cropping pattern.

Primary component: A primary component is the gross area (A), the yield (Y), or the cropping pattern (Cl) component of growth. In contrast to primary components, secondary components are interaction components.

Interaction components: Because area, yield, and cropping pattern change simultaneously, a part of the change in crop output over an interval is due to the joint action of components. That part of output growth which cannot be attributed to the action of one component acting alone is assigned to one of four interaction components. The gross area-yield interaction (AY) is the growth that would be sustained by joint action of area and yield changes, with cropping patterns held constant. Similar definitions hold for the gross area-cropping pattern interaction (AC) and yield-cropping pattern interaction (YC). A final term (AYC) captures that small part of output change owing to the joint action of all three components.

Component contribution: A measure of the magnitude of a component is the annual compound rate of growth sustained by the component. For example, if the growth rate is 3 percent and the primary yield effect accounts for 40 percent of growth in output, the yield contribution is 1.2 percent.

Aggregate component: An aggregate component is an area, yield, or cropping pattern component to which a part of the sum of all interaction components has been allocated.

Composite interaction statistic (Cl): This statistic is the sum of the AY, YC, and AYC interaction components.

Multiple cropping: It is possible to calculate growth components using first gross area and then net area. By distributing the interaction terms among the primary components, we can calculate aggregate gross area and an aggregate net area component. The difference between the two is a measure of the multiple cropping effect. It captures that part of the change in output over an interval attributable to a shift in cropping intensity.

Crop Output Growth:

Changes in Component Contributions for Six Developing Countries

Daniel Feinstein

INTRODUCTION

This report describes long-term changes in the growth rates of agricultural production in selected countries of Asia and Latin America in terms of area, yield, and cropping pattern components. Increases in cropland area have accounted for a significant proportion of the increases in global crop output. However, since land area suitable for agricultural production is limited, the question has always been how long area expansion would be a significant contributor to agricultural output growth.

A number of studies, Brown (2), CEQ (3), Dregne (4), Eckholm (5), FAO (6), and Smith (13) 1/ have addressed the issue of the deterioration of the agricultureal resource base and its effects on affect global agricultural output. Underlying this issue is the more general question of whether the rate of agricultural growth is declining in the long term. This study examines how the expansion of area devoted to agricultural production, increases in crop yields, and changes in the composition of crops produced have affected the rate of crop output growth in the long term. Also, it examines whether over the long term the continuous expansion in land area devoted to agricultural production has led to reduced yields or changes in cropping patterns that have altered the rate of crop output growth. This latter interaction effect becomes especially relevant when the expansion of area involves increased use of less productive agricultural land. If the increased use of less productive land is not offset by an increase in the use of nonland inputs, or a higher level of technology, this interaction effect will be negative and tend to reduce the rate of crop output growth.

The approach used revives the components-of-growth methodology used in Economic Research Service (ERS) studies of the sixties (15, 16, 17) that compared sources of crop output growth in developing countries. There are two reasons for estimating a new set of component statistics. First, mathematical methods employed in the older studies have been improved. Second, with the extension of time series data since 1960, it is possible to incorporate dynamic elements into the analysis and to quantify long-term changes in growth components.

The analysis is based on a sample of six developing countries; three in Latin America (Brazil, Peru, and Mexico) and three in Asia (Thailand, India, and the Philippines). In Latin America, Brazil possesses abundant cropland relative

1/ Underscored numbers in parentheses cite sources in References Cited section.

to its population size; Peru is a small, land-scarce country; and Mexico is intermediate in its population and land endowments. In Asia, Thailand is a land-abundant country, India a land-scarce country, and the Philippines a country occupying an intermediate position.

The sample of countries selected makes it possible to examine two developing regions characterized by diverse population sizes and person-land ratios. 2/ In both noncommunist Asia and Latin America, the selected countries account for approximately 55 percent of the agricultural land area (table 1). The selected sample of countries account for 37 percent of the agricultural land area of all developing countries and 20 percent of the world's agricultural land area.

Main objective of this study is to determine how the components of crop output growth have affected the long-term growth rate of crop output in developing countries. Both groups of countries analyzed in this report have experienced a decline in their rate of crop output growth. While these rates are still positive, long-term trends indicate that they will continue to decline. This paper seeks to determine what has influenced this decline over the long term.

While the purpose of the analysis is to assess the importance of the components of growth over the long term, a significant methodological statement can also be made. Therefore, additional objectives of the study include:

1. To identify the most appropriate methodology for quantifying components of crop output growth;

2. To apply the chosen methodology to a selected sample of countries over 30 years;

3. To describe the changes in the components of growth for the selected sample of countries;

4. To assess the potential of the growth component approach for identifying and analyzing long-term trends in crop output growth; and

5. To draw appropriate policy conclusions.

2/ African countries were not considered because of inadequate data for the earlier part of the long-term time span considered.

Table 1--Cropland area of selected countries, 1980

Region/ country	Cropland area	Distribution of total cropland: Region/ country as a percentage of world	Sample countries as a percentage of entire selected sample	Selected sample as percentage of developing countries	Sample Asian countries as a percentage of Asia region	Sample Lat. Am. countries as a percentage of Lat. Am. region
	1,000 hectares	Percent				
World	1,452.2	100.0	---	---	---	---
Developing countries	780.6	53.8	---	---	---	---
Developed countries	671.6	46.2	---	---	---	---
Africa	150.2	10.3	---	---	---	---
Asia 1/	355.8	24.5	---	---	100.0	---
Latin America	162.1	11.1	---	---	---	100.0
Brazil	62.0	4.3	21.7	7.9	---	38.2
India	169.1	11.6	59.2	21.7	47.5	---
Mexico	23.3	1.6	8.2	3.0	---	14.4
Peru	3.4	.2	1.2	.4	---	2.1
Philippines	9.9	.7	3.5	1.3	2.8	---
Thailand	18.0	1.2	6.3	2.3	5.1	---
Selected sample	285.7	19.7	100.0	36.6	---	---

--- = Does not apply.

1/ Excludes China.

Source: (7).

METHODOLOGY

From an accounting standpoint, there are seven components of change in the gross crop output of an agricultural sector over time. These are:

(1) A change in gross area harvested;
(2) A change in crop yields;
(3) A change in the cropping pattern of the crop sector; and
(4) Four interaction components:

(a) gross area--yield
(b) gross area--cropping pattern
(c) yield--cropping pattern
(d) gross area--yield--cropping pattern.

Algebraic Definition of the Problem

The first step in quantifying the three primary components of crop output growth is to select a unit to describe gross output. 3/

Crop area, production, and producer price information is available for the last 20-30 years for major crops in most developed and many developing countries. These data can be used to compute the change in crop output between an initial and end period 4/ according to the equation:

$$V_t - V_o = \sum_{i=1}^{n} (A_{it} Y_{it} w_i) - \sum_{i=1}^{n} (A_{io} Y_{io} w_i) \qquad [1]$$

where subscripts o and t define the initial and end periods, respectively, and

V = crop output in value units
i = the i^{th} crop in a crop sector of n crops
A = area harvested in hectares
Y = crop yield in metric tons per hectare
w = crop price weight

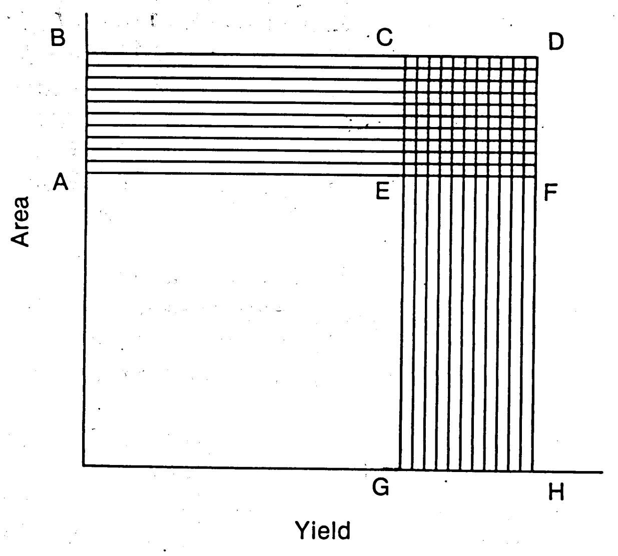
Manipulation of equation [1] enables us to partition the change in crop output growth among three primary components and their associated four interaction components. The interaction components arise because some of the change in output cannot be attributed solely to changes in area, yield, or cropping pattern, but rather are the result of the joint action of the primary components. This concept is most easily grasped via a geometrical representation of the one-crop case where it is a question only of a change in the level of production.

3/ It is possible to choose a physical unit and express gross output as the sum of calories contributed by grains, oilseeds, roots, and tubers (1). It is also possible to choose a monetary unit and express gross output as the sum of the dollar values of each crop. While use of a physical unit is attractive because the calorie count per metric ton of crop is more stable over time than the relative price of the crop, it has the disadvantage of being limited to food crops. Consequently, in order to investigate the entire crop sector, and to take account of substitutions between food and nonfood crops, gross output is described in terms of value, i.e. production in metric tons times price in U.S. dollars in a selected year.

4/ For definition of initial and end periods and of interaction components, see Glossary of Terms.

That is:

ABCE = area component,
EFHG = yield component, and
CDFE = an interaction component.



In the multiple crop case, it is not possible to represent the interaction components geometrically. Nevertheless, addition of another dimension in the form of a cropping pattern component gives rise to seven components. The three primary components are gross area (A), yield (Y), and cropping pattern (C). The three two-way interaction components are the gross area-yield (AY), the gross area-cropping pattern (AC), and the yield-cropping pattern (YC) components. The three-way interaction term (AYC) captures the joint effects of all three primary components. 5/

Calculation of Growth Components

A number of studies have used alternative algebraic procedures for partitioning components of change in crop output over a time interval. They differ primarily in their treatment of interaction components.

A 1968 ERS publication (16) estimated components of growth by aggregating all interaction components into the yield component. A 1970 ERS publication (17) limited the components of growth to area and "output per hectare." The second component is a combination of the yield and cropping pattern components. In the 1970 study, there is no indication of how the residual components of growth were distributed among the two primary components. Another ERS study in 1965 (15) revealed neither the method for computing nor distributing the interaction effects.

Minhas and Vaidyanathan (14), in a 1967 report of India's Directorate of Economics and Statistics, used two methods to estimate components of crop output growth. The first aggregated the four secondary components into one interaction component between yield and cropping pattern changes. This method distorts the primary yield and cropping pattern components by a factor equal to the ratio of gross area in the end period to gross area in the initial period. The second method estimated components by using a logorithmic

5/ Equation [1] holds prices constant for the initial and end periods. In reality prices may change over the time interval. Equation [1] could incorporate price changes in the calculation of (V_t-V_o). A primary price component would then capture the change in output owing strictly to change in prices with changes in gross area, yields, and cropping pattern ignored. It would be accompanied by four additional interaction terms. In this study it is assumed that the ratio of prices between any two crops is stable over time. Hence, a price component and its corresponding interaction terms are not considered.

equation. It has the disadvantage of aggregating the four interaction components into one residual component.

The formula used in this study is the one used by Minhas in 1966 (9). He rewrites equation [1] in its equivalent form:

$$V_t - V_o = A_t \sum_{i=1}^{n} (w_i Y_{it} C_{it}) - A_o \sum_{i=1}^{n} (w_i Y_{io} C_{io}) \qquad [2]$$

where A is the gross area harvested and C_i is the ratio of the area in crop i to the gross area in a period. The seven components, which are in nominal monetary units, can be factored out. 6/ That is:

$$A = (A_t - A_o) \sum_{i=1}^{n} w_i Y_{io} C_{io} \qquad [3]$$

$$Y = A_o \sum_{i=1}^{n} w_i (Y_{it} - Y_{io}) C_{io} \qquad [4]$$

$$C = A_o \sum_{i=1}^{n} w_i (C_{it} - C_{io}) Y_{io} \qquad [5]$$

$$AY = (A_t - A_o) \sum_{i=1}^{n} w_i (Y_{it} - Y_{io}) C_{io} \qquad [6]$$

$$AC = (A_t - A_o) \sum_{i=1}^{n} w_i (C_{it} - C_{io}) Y_{io} \qquad [7]$$

$$YC = A_o \sum_{i=1}^{n} w_i (Y_{it} - Y_{io}) (C_{it} - C_{io}) \qquad [8]$$

$$AYC = (A_t - A_o) \sum_{i=1}^{n} w_i (Y_{it} - Y_{io}) (C_{it} - C_{io}) \qquad [9]$$

This method has the advantage of defining seven components that sum to the total change in crop output over a time interval. It can accommodate time periods of any duration.

Component Contributions

If the seven terms defined by equations [3] through [9] are divided by $(V_t - V_o)$ and multipled by 100, the new set of quantities equals the percentage of the change in output derived from each component. Multiplying these figures by the compounded annual growth rate gives the growth rate sustained by each primary and interaction component, that is, the component contribution. 7/

6/ Since the monetary units cancel out in the calculation of the component contributions, they do not influence the estimated statistics.

7/ The compounded annual growth rate equals $r = 1 - V_t^{\frac{1}{n}}/V_o$.

Aggregation of Components

For some purposes, it is useful to allocate the interaction components among the primary area, yield, and cropping pattern components. These aggregate components summarize total output growth into three major components of growth. While various aggregating procedures can be used, this study distributes the interaction components in proportion to the weight of the primary effects, according to the absolute values of the gross area, yield, and cropping pattern components. That is:

$$A_T = A_1 + AY \cdot [|A_1| + (|A_1| + |Y_1|)] + AC \cdot [|A_1| + (|A_1| + |C_1|)] + AYC \cdot [|A_1| + (|A_1| + |Y_1| + |C_1|)] \quad [10]$$

$$Y_T = Y_1 + AY \cdot [|Y_1| + (|A_1| + |Y_1|)] + YC \cdot [|Y_1| + (|Y_1| + |C_1|)] + AYC \cdot [|Y_1| + (|A_1| + |Y_1| + |C_1|)] \quad [11]$$

$$C_T = (V_T = V_o) - (A_T + Y_T) \quad [12]$$

where A_T, Y_T, and C_T define aggregate components of growth.

Multiple Cropping

Multiple cropping is the practice of harvesting the same piece of land more than once during a year. A measure for the incidence of multiple cropping for a crop sector is the cropping intensity index, defined as the ratio of gross area to net area harvested. The greater the incidence of multiple cropping, the higher the ratio.

With the Minhas formula, area can be handled either as gross or net area harvested. In the first case, the growth in output over an interval due to increased multiple cropping is automatically assigned to the area component; in the second case, it is added to the yield component. The cropping pattern component is unaffected by the choice.

An argument can be made for the use of either measure of area. The repeated use of land during a year uses the land base and therefore draws on crop area as a source of growth. However, increased cropping intensity may occur in conjunction with the use of improved crop technology and/or more intensive use of inputs that produce higher yields. Where data permits, an approximation of the multiple cropping effect is derived in this study by estimating the aggregate area component using first one and then the other measure of area and defining the difference between the results as a new source of growth: the multiple cropping effect (MC) of crop output growth. That is, the multiple cropping (MC) effect is calculated as follows:

$$MC = A_{T\text{-}gross} - A_{T\text{-}net} \quad [13]$$

Where $A_{T\text{-}gross}$ = the aggregate gross area component, and

$A_{T\text{-}net}$ = the aggregate net area component.

The new yield component becomes:

$$Y'_T = Y_T + MC \qquad [14]$$

Where: Y_T = the aggregate yield component.

Equation [14] means that if the MC effect were not subtracted out of the total effect, it would automatically be added to the aggregate yield component. The yield term Y'_T is an approximation in that the use of gross area and net area in the computation ignores the slightly different magnitudes in interaction terms.

Composite Interaction Statistic

An important concern associated with global agricultural output is how the continuous expansion in cropland affects yields and the overall rate of crop output growth in the long term. The component statistics derived in this study cannot be used to unravel economic cause and effect. It is not possible to assign a cause-and-effect relationship between a factor of production (be it land, labor, management, a land-augmenting input, or a labor-augmenting input) and a component of growth (8). Any one of a number of factors can influence more than one component of growth. Conversely, the magnitude of a component contribution is probably a function of several factors of production as well as weather conditions. Further, the incentive or disincentive impact of changing producer prices is invisible to the component approach.

While growth components have no necessary relation to factors of production or to one another, they can be very useful in formulating hypotheses about cause-and-effect relations and the relative importance of individual factors. Moreover, they can be used to formulate hypotheses on how the continuous cropland expansion affects crop yields and the overall rate of crop output growth in the long term. Several interaction components are involved.

First, there is the direct relationship between expanding area and yields that is measured by the area-yield interaction component; a negative component indicating that yields tend to decline as area expands and vice versa. Second, if this effect is significant, farmers might substitute high-value crops for low-value crops to compensate for the loss in yields. The magnitude of this effect is measured by the yield-cropping pattern interaction; a positive component indicating that farmers substitute high-value crops for low value crops as area expands and vice versa. Thus, any hypothesis on how the continuous expansion in agricultural area affects the overall rate of crop output growth must consider both of these interaction components. For instance, it must consider the joint interaction of the three primary components or the area-yield-cropping pattern interaction component. To facilitate an assessment of the reasonableness of hypotheses concerning these interactions, a composite interaction (CI) statistic is defined as the sum of the three interaction components. That is,

$$CI = AY + YC + AYC \qquad [15]$$

Equation [15] reduces to:

$$CI = \sum_{i=1}^{n} w_i (A_{it} - A_{io}) (Y_{it} - Y_{io}) \qquad [16]$$

The CI statistic allows us to assess how the confluence of changes in area, yield, and cropping pattern affects the rate of crop output growth. A positive CI value means that on balance the higher priced crops that have shown increased area harvested over an interval also tend to show increased yields. That is, the price-weighted contribution to output of the area harvested in the crop and the level of yields experience simultaneous increases or decreases. A negative CI term means that on balance an increase in the area harvested tends to be associated with falling yields, whereas decreasing crop area is associated with rising yields. In the general case, some crops would likely show increased area and some reduced area over an interval. A positive CI statistic means that the crops are experiencing either simultaneous increases or decreases in their area and yields. That is, the magnitude of the CI statistic increases with the tendency of crop areas and crop yields to move in the same direction. Similarly, if the CI statistic is negative, the conclusion is that they move in opposite directions.

Interpretation of the CI statistic may depend on an understanding of changes in the cropping sector of a country. For example, suppose a new high-yielding seed variety of a staple crop is introduced over an interval. If farmers merely substitute it for traditional varieties, the interaction effect will be null despite the increase in yields because the area in the crop is constant. The high-yielding variety will contribute to a positive interaction component only if it increases output per unit of gross area and/or if it replaces other crops. In the second case, the positive effect will be reinforced to the extent that the high-yielding crop is planted on the most productive land that was previously devoted to other crops, so that the yields of the crops with reduced area fall.

DATA REQUIREMENTS AND LIMITATIONS

Data were assembled for a sample of six countries: Brazil, India, Mexico, Peru, the Philippines, and Thailand. While the sample is limited to developing countries, it includes countries with diverse population densities, resource endowments, and reserves of cultivable land. The six exhibit the wide range of crop types typical of tropical agriculture. Area and production information for all crops grown in each country would ideally be incorporated into the analysis in order to provide for substitution of one crop for another over time and avoid falsely recording change in crop area of excluded crops as the introduction or disappearance of cropland. Practically, it is sufficient to include only the major food and nonfood crops (table 2).

Requirements

The data needed to estimate the components of growth are area, production, and prices for each crop over the time period 1948 to 1978. Yields are derived from the production and area data.

FAO Production Yearbooks (7) provide annual data for harvested area and production for all of the countries included in this study and for most of the crops included in table 2. USDA publishes a comparable but independent production series. A USDA harvested area series is available for grains only. We have used USDA data for grain (19) and FAO data (7) for the remaining crops.

Price data are more difficult to assemble than production and area data. Ratios between crop prices normally change very slowly over time. Hence, it

Table 2--Crop list for sample countries

Country	Grains	Roots & tubers	Pulses	Oilseeds	Fruits & vegetables	Other
Brazil	Wheat Paddy Barley Maize Rye Oats Sorghum	Potatoes Sweet pot. Cassava	Dry beans	Soybeans Groundnuts Castor beans	Tomatoes Dry onions	Sugar cane Coffee Cocoa Tobacco Jute Sisal Cotton
India	Wheat Paddy Barley Maize Millet Sorghum	Potatoes Sweet pot. Cassava	Dry beans Dry peas Chick peas Lentils	Soybeans Groundnuts Castor beans Rapeseed Sesame seed Linseed		Sugar cane Coffee Tea Tobacco Jute Cotton
Mexico	Wheat Paddy Barley Maize Oats Sorghum	Potatoes Sweet pot.	Dry beans Chick pea	Soybeans Groundnuts Sesame seed Sunflower seed	Tomatoes Bananas	Sugar cane Coffee Cocoa Tobacco Sisal Cotton
Peru	Wheat Paddy Barley Maize Millet Sorghum	Potatoes Sweet pot. Cassava	Dry beans Bread beans Dry peas			Sugar cane Coffee Cotton
Philippines	Paddy Maize	Potatoes Sweet pot. Cassava	Dry beans	Groundnuts Coconuts	Tomatoes Bananas	Sugar cane Coffee Tobacco Sisal
Thailand	Paddy Maize Sorghum	Sweet pot. Cassava	Dry beans	Soybeans Groundnuts Castor beans Sesame seed Coconut	Dry onions	Sugar cane Tobacco Jute Cotton Rubber

is assumed that price weights at 5- or 10-year intervals are adequate, particularly since the calculation of a price effect is explicitly excluded in this study.

USDA production indices (20) include dollar weights by crop and country averaged for the 1957-59, 1961-65, and 1969-71 periods. FAO has collected annual production prices in local currencies for an extensive set of countries (7). They are averaged together for the 1961-65 period and subsequently compiled on a year-to-year basis from 1966 through 1974. The currency unit is irrelevant because only relative crop prices are used in the analysis. Therefore, the USDA and FAO price data can be combined to establish price sets for the four periods used in the analysis: 1957-59, 1961-65, 1969-71, and 1972-74.

Average 3-year periods were used to smooth out the variability in crop output due to weather fluctuations. The average periods are centered 4 years apart on 1950, 1954, 1958, 1962, 1966, 1970, 1974, and 1978. For example, the 1978 period averages reported values for 1977, 1978, and 1979. Thus, there are a total of seven 4-year intervals used in the study: 1950-54, 1954-58, 1958-62, 1962-66, 1966-70, 1907-74, and 1974-78.

Because producer price data are available for certain periods only, the initial and end periods used in the study may or may not correspond to the price data intervals. In most cases, however, one price list is closer to the initial period, whereas in the other cases it is closer to the end period. Since the methodology calls for constant prices over the intervals, and there is no reason on a priori grounds to prefer the initial or the end period price data, all calculations use the price data closest to the beginning of each time period used in the analysis.

Data Limitations

Quality

The least reliable data are the area figures for perennial tree crops that are not confined to plantations but are planted randomly across the countryside. Since the midsixties, FAO has omitted area figures for bananas, coconuts, rubber, and hard fiber because estimation is so hazardous. Still, these crops can represent a large proportion of crop output; for example, rubber in Thailand and coconuts in Thailand and the Philippines. When FAO does not carry an area figure for a tree crop, other estimates of area and production have been used despite, sometimes, the questionable value of the information (7, 10, 11, 12, 18).

Planted Area

Both the FAO and the USDA define area as area harvested. It is likely, however, that for some crops the figures reported are estimates of planted area. The two area series will differ most dramatically in countries subject to severe droughts or widespread flooding during which time much more area is planted than harvested. It follows that in these periods the use of planted area data will result in lower calculated yields than will the use of harvested area data. Therefore, a lower yield contribution to growth will be the result of these periods. The averaging of area information over 3 years lessens this effect; but, wherever the planted area series has been used in place of the harvested area series, there is a potential source of error.

The Appearance (or Disappearance) of a Crop Between 1948 and 1978

Because the yield component is calculated by comparing the ratios of crop production to crop area in an end and initial period, area and production figures must be entered for both periods. If the initial area and production data are zero, because the crop was not yet in production (or because the level of production was so low records were not kept), the yield in the end period will be treated as a net gain from zero. Likewise, in a case of the disappearance of a crop in the end period, the yield will be treated as a net decrease to zero. The problem has been handled by inserting very small area and production quantities in place of zero values. For example, if a crop first appears in an end period, minimum production and area figures generating the same yield as in the end period are entered for the initial period. This approach assumes that there is no basis for assuming a positive or negative yield effect, and ensures, first, that no net yield effect is registered, and second, that the area and cropping pattern contributions are not distorted.

USDA grain data do not include sorghum for a number of countries during the early years considered in this study. The initial production data recorded are small in every case. Therefore, very small values were used for Brazil for the years 1950-66, in Mexico for 1950-60, and for Thailand for 1950-62. In a number of other cases, small FAO production quantities appeared for the first time after 1950. Thus, for Mexico in 1950-60, soybeans and safflower seeds are represented by very small values. In India, soybeans first appeared in 1970. In each case, small nominal values were inserted into the data series.

EMPIRICAL RESULTS

Long-term Trends in Crop Output Growth Rates

Rates of crop output growth and their component contributions have been estimated for six countries for seven time periods over the entire period of analysis, 1948-78 (table 3).8/ These growth rates vary substantially both over time and among the component contributions. To facilitate an analysis of how they have changed in the long term, we show the three primary components and the sum of the interaction components in graphs 1-5. As a further aid to the analysis of long-term trends, a linear regression line has been estimated for the seven data points associated with each statistical series. The statistics relevant to each regression equation are given on the graph itself and in accompanying tables 4, 5, 6, 7, and 8.

In four of the six countries studied, there was a downward long-term trend in the rate of crop output growth over the 1948-78 period (graph 1). The decline was most pronounced for Mexico where the rate of growth declined by 7.1 percentage points (table 4). Part of the decline was due to the exceptionally high rate of growth at the beginning of the period. Even if the rate of growth at the beginning of the period had been much lower, there still would have been a significant decline in the rate of crop output growth in Mexico over this long-term period. There was also a significant decline in the rate of growth in crop output for Peru. At the beginning of the period, crop output was growing at a rate of 4.8 percent; by the end of the period, it

8/ A computer program written by Ellen Reynolds of ERS was used to make the calculations.

Table 3--Growth rate of crop output attributable to gross area, yield, cropping pattern, and interaction components

Country and interval	Crop output growth 1/	Components 2/							
		Primary			Interaction				
		A	Y	C	Total inter.	AY	AC	YC	AYC
		Percent							
Brazil:									
1950-54	2.87	3.77	-0.94	0.32	-0.28	-0.15	0.05	-0.16	-0.03
1955-58	6.24	4.65	1.27	.30	-0.10	.25	-.06	-.24	-.05
1959-62	4.82	4.08	.83	0	-.09	.14	0	-.20	-.03
1963-66	2.28	1.79	1.45	-.04	-.56	.11	-.03	-.60	-.04
1967-70	1.84	4.17	-1.20	-.09	-.24	-.20	-.15	.10	.02
1971-74	4.54	2.47	2.14	-.30	.29	.22	-.03	.09	.01
1975-78	3.06	3.40	.02	-.20	-.16	—	-.03	-.12	-.02
India:									
1950-54	4.44	2.17	2.78	-.06	.09	.25	-.06	-.10	0
1955-58	2.58	1.70	.70	.12	.06	.05	.01	0	0
1959-62	3.84	1.44	1.84	.41	.15	.11	.02	.01	.01
1963-66	.58	0	.41	.17	0	0	0	0	0
1967-70	4.96	.94	3.07	.55	.42	.13	.02	.27	.01
1971-74	1.31	.22	.86	.30	-.07	.01	0	-.08	0
1975-78	3.40	.71	2.01	.51	.16	.06	.01	.09	0
Mexico:									
1950-54	7.51	4.13	2.59	.16	.64	.48	.03	.11	.02
1955-58	6.52	3.96	2.29	.03	.24	.40	.01	-.14	-.03
1959-62	5.23	1.96	3.73	-.48	.03	.31	-.04	-.22	-.02
1963-66	6.58	4.38	3.87	-1.38	-.29	.75	-.27	-.65	-.13
1967-70	1.08	-1.04	1.71	.62	-.21	-.07	-.03	-.12	0
1971-74	2.22	1.65	.86	-.21	-.09	.06	-.01	-.13	-.01
1975-78	0.73	-.21	1.30	-.26	-.09	-.01	0	-.08	0
Peru:									
1950-54	4.52	1.52	.83	2.21	-.05	.05	.14	-.23	-.01
1955-58	1.51	.73	-.98	2.04	-.27	-.03	.06	-.29	-.01
1959-62	6.70	4.56	1.62	.03	.21	.33	.06	-.15	-.03
1963-66	.90	.25	.82	-.22	.06	.01	0	.05	0
1967-70	1.41	.98	.70	-.17	-.10	-.03	-.01	-.12	0
1971-74	-.67	-.88	.32	-.05	-.08	-.01	0	-.07	0
1975-78	-1.42	-1.75	.18	.25	-.10	-.01	-.02	-.07	0

See footnotes at end of table.

-- continued

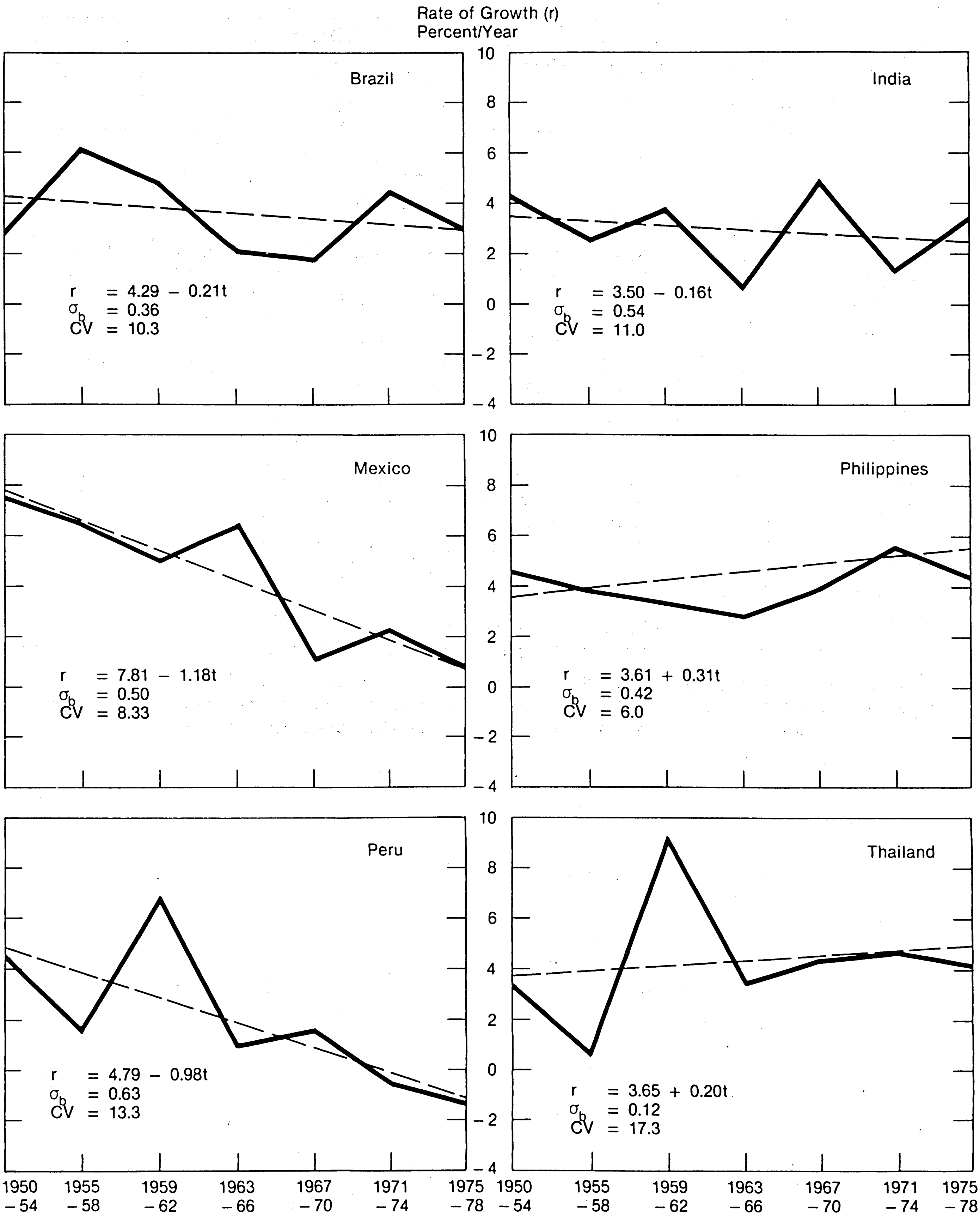
Table 3--Growth rate of crop output attributable to gross area, yield, cropping pattern, and interaction components--continued

Country and interval	Crop output growth 1/	Components 2/							
		Primary			Interaction				
		A	Y	C	Total inter.	AY	AC	YC	AYC
		Percent							
Philippines:									
1950-54	4.54	3.50	0.81	0.28	-0.05	0.12	0.04	-0.18	-0.03
1955-58	3.72	4.06	-.33	.18	-.19	-.06	.03	-.14	-.03
1959-62	3.22	1.15	2.75	-.55	-.13	.13	-.03	-.22	-.01
1963-66	2.76	2.11	.91	-.11	-.14	.08	-.01	-.20	-.02
1967-70	3.89	1.61	2.16	.26	-.15	.15	.02	-.29	-.02
1971-74	5.50	3.73	1.71	-.15	.21	.28	-.02	-.04	-.01
1975-78	4.31	2.77	1.87	-.22	-.11	.22	-.03	-.27	-.03
Thailand:									
1950-54	3.30	.60	1.48	.99	.23	.04	.03	.16	0
1955-58	.67	-.50	-.19	1.22	.13	0	-.03	.16	0
1959-62	9.18	6.49	1.89	.43	.37	.56	.13	-.25	-.07
1963-66	3.46	2.59	-.12	1.20	-.18	-.01	.13	-.27	-.03
1967-70	4.36	4.13	.09	-.04	.18	.02	-.01	.15	.03
1971-74	4.62	5.43	-1.70	1.11	-.22	-.39	.26	-.06	-.01
1975-78	4.11	5.30	-1.84	1.26	-.60	-.41	.28	-.39	-.09

1/ The average annual compound rate of growth over an interval.
2/ Sum of primary and total interaction components equals the crop output growth rate. The sum of the interaction components equals total interaction.

Graph 1

Crop Output Growth, Selected Countries*



*Notes to Graph 1:

1. The data used to construct each country graph are given in table 3.

2. The individual datum points in each graph are connected by a solid line; the linear regression line through the datum points is shown as a broken line.

3. In the equation for the rate of growth (r) t = o for the first interval and t = 6 for the last interval.

4. σ_b = standard deviaton of the regression coefficient.

5. CV = coefficient of variation of the regression line.

Table 4--Trendline crop output growth rates for the first and last intervals over the 1948-78 span

Country	Crop output growth rates 1/		Change in growth rate in 1950-78 period
	First interval	Last interval	
	Percent		Percentage points
Brazil	4.3	3.0	-1.3
India	3.5	2.5	-1.0
Mexico	7.8	.7	-7.1
Peru	4.8	-1.1	-5.9
Philippines	3.6	5.6	2.0
Thailand	3.7	4.9	1.2
Asia 2/5/	3.5	2.6	-.9
Latin America 3/5/	5.2	2.2	-3.0
Entire sample 4/5/	4.1	2.8	-1.3

1/ The growth rates were derived from the equations in graph 1; for the first interval t=0 and for the second interval t=6.
2/ Weighted average of Asian countries in the sample.
3/ Weighted average of Latin American countries in the sample.
4/ Weighted average of all countries in the selected sample.
5/ The weights used are agricultural land use in 1980. On a scale of 100, the weights are: Brazil, 22; India, 59; Mexico, 8; Peru, 1; Philippines, 4; and Thailand, 6.

had fallen to -1.1 percent. There were also significant declines in the rate of crop output growth in both Brazil and India. Only two countries, Thailand and the Philippines, experienced an increase in the rate of crop output growth over the 30-year period. In Thailand, it increased from 3.7 to 4.9, and in the Philippines from 3.6 to 5.5.

If the initial and final period growth rates are weighted by the amount of agricultural land in each country, the weighted sample average growth rate for crop output shows a decline from 4.1 at the beginning of the period to 2.7 at the end of the period. The reduction in the rate of crop output growth was much greater in the Latin American sample--from 5.2 to 2.2--than in the Asian sample--from 3.5 to 2.6. While the sample of countries was not chosen to represent global agricultural performance, it does cover 55 percent of the agricultural land used in Asia and Latin America (table 1). This suggests that these results can be generalized to Latin America and Asia as regions. Whether they can be generalized to developing countries as a group is debatable, especially considering that the selected sample does not include any African countries. Nevertheless, the sample includes 37 percent of the agricultural land of the developing countries, suggesting that the rate of crop output growth in this group of countries may be experiencing a long-term decline. Further, these results indicate that the relative importance of these nations in supplying agricultural products for international markets will be different than the present, and that these changes may have a significant influence on trade flows of agricultural commodities.

Long-term Trends in the Contribution of Growth Components to Crop Output Growth

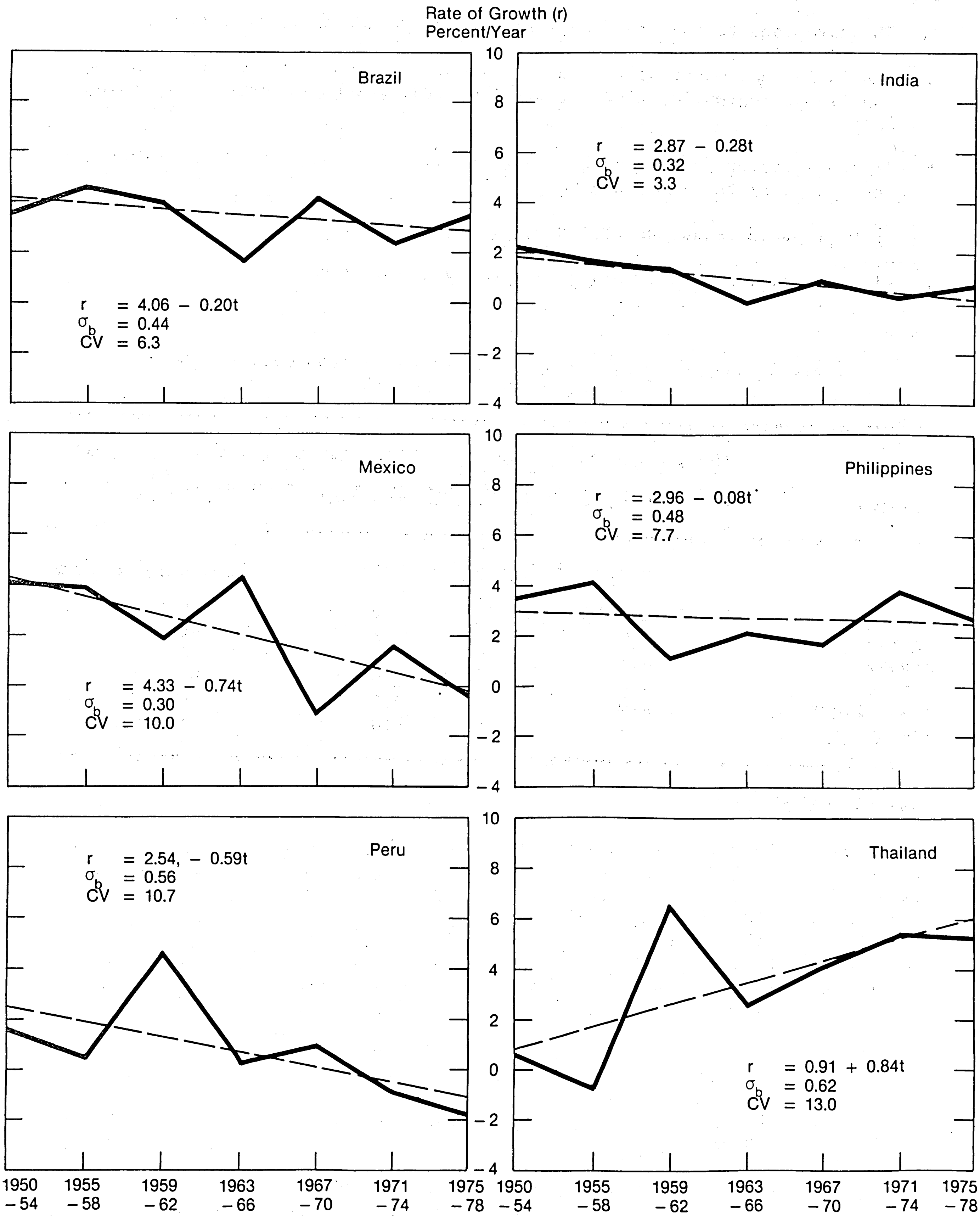
The long-term trend in the contribution of the area component to crop output growth is negative for five of the six countries studied (graph 2). The declining effect of area expansion on crop output growth is most evident for Mexico and Peru where the rate of crop output attributable to land expansion declined 4.4 and 3.5 percentage points, respectively (table 5). However, the declining effect of land expansion is also significant in Brazil and India. In Brazil, it declined from 4.1 to 2.9, and in India from 1.9 to 0.2. Only Thailand shows a positive long-term trend in the contribution of expanding area to crop output growth. The area component in Thailand increased over the 30-year period from 0.9 to 6 percentage points.

There was a decline in the effect of yield increases on crop output growth for three of the countries studied, a zero effect for one country, and a positive effect for two countries (graph 3). The relative magnitude of the effect of changes in yields was less than the effect of changes in area expansion. Nevertheless, the effect of yield changes could still be be considered significant for three of the countries analyzed. In Thailand, the effect of declining rates of growth in yields was especially evident, with a percentage point decline of -3.2 (table 6). Also, in Mexico the rate of growth in yields declined by 1.9 percentage points over the 30-year period. In only one country, the Philippines, was there a significant increase in the rate of growth of yields from 0.7 to 2.1 percent per year.

With the exception of India, the effect of changes in cropping patterns had a negative or zero effect on long-term rates of crop output growth (graph 4 and table 8). The negative effect of changes in cropping pattern on the rate of crop output growth was especially marked in Peru, which registered a percentage point decline of -2.25 (table 7). In the other countries, however,

Graph 2

Area Contribution to Crop Output Growth, Selected Countries*



*Notes to Graph 2:

1. The data used to construct each country graph are given in table 3.

2. The individual datum points in each graph are connected by a solid line; the linear regression line through the datum points is shown as a broken line.

3. In the equation for the rate of growth (r), t = 0 for the first interval and t = 6 for the last interval.

4. σ_b = standard deviation of the regression coefficient.

5. CV = coefficient of variation of the regression line.

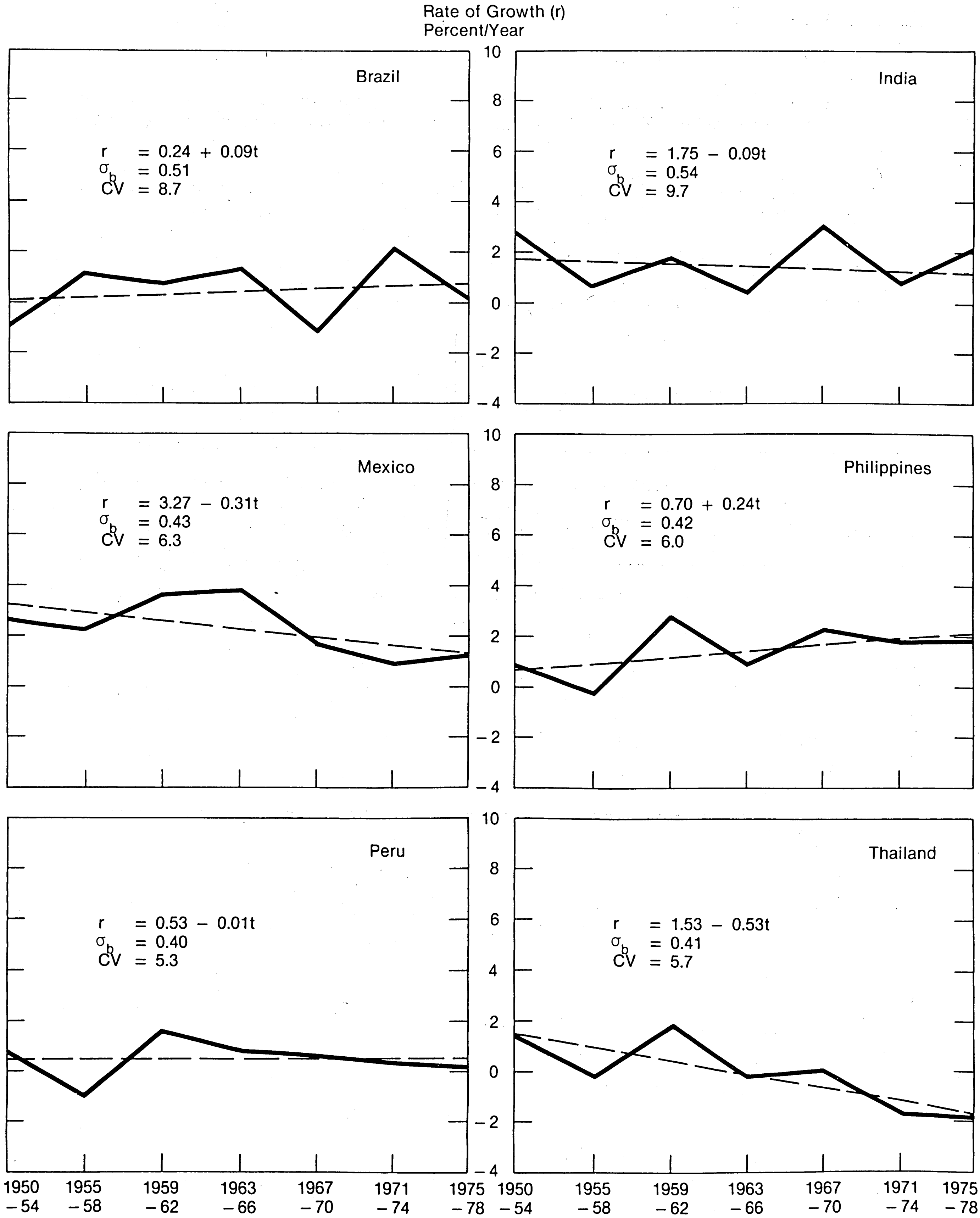
Table 5--Trend line of area contribution to crop output growth in six countries, 1950-78

Country	Area contribution to crop output growth: First interval	Area contribution to crop output growth: Last interval	Change in growth rate 1950-78
	Percent	Percent	Percentage points
Brazil	4.1	2.9	-1.2
India	1.9	.2	-1.7
Mexico	4.3	-.1	-4.4
Peru	2.5	-1.0	-3.5
Philippines	3.0	2.5	-.5
Thailand	.9	6.0	5.1

Source: Graph 2

Graph 3

Yield Contribution to Crop Output Growth, Selected Countries*



*Notes to Graph 3:

1. The data used to construct each country graph are given in table 3.

2. The individual datum points in each graph are connected by a solid line; the linear regression line through the datum points is shown as a broken line.

3. In the equation for the rate of growth (r), t = 0 for the first interval and t = 6 for the last interval.

4. σ_b = standard deviation of the regression coefficient.

5. CV = coefficient of variation of the regression line.

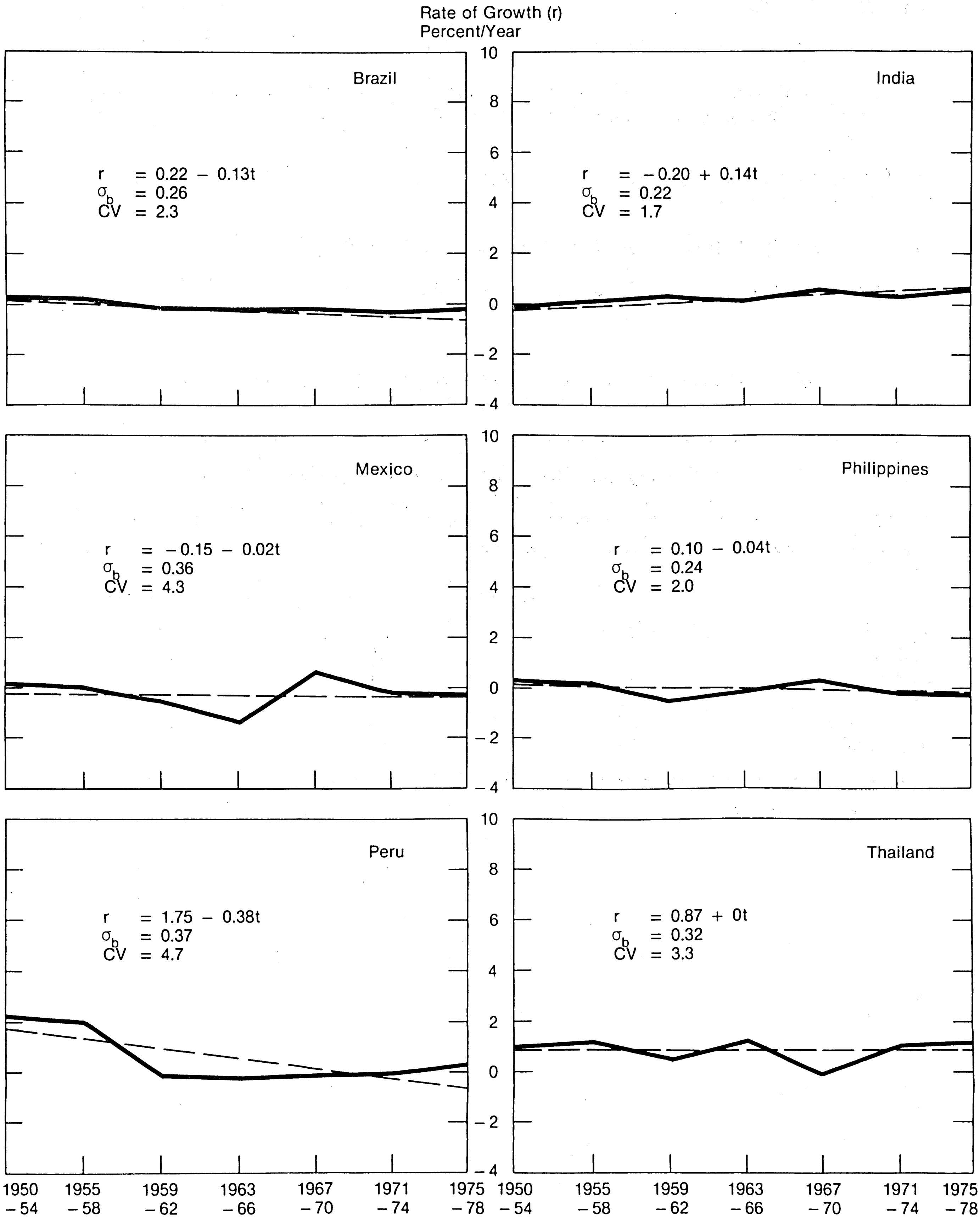
Table 6--Trend line of area contribution to crop output growth in six countries, 1950-78

Country	Yield contribution to crop output growth		Change in growth rate 1950-78
	First interval	Last interval	
	-------- Percent --------		Percentage points
Brazil	0.2	0.8	0.6
India	1.8	1.2	-.6
Mexico	3.3	1.4	-1.9
Peru	.5	.5	0
Philippines	.7	2.1	1.4
Thailand	1.5	-1.7	-3.2

Source: Graph 3

Graph 4

Contribution of Cropping Pattern to Crop Output Growth, Selected Countries*



*Notes to Graph 4:

1. The data used to construct each country graph are given in table 3.

2. The individual datum points in each graph are connected by a solid line; the linear regression line through the datum points is shown as a broken line.

3. In the equation for the rate of growth (r), t = 0 for the first interval and t = 6 for the last interval.

4. σ_b = standard deviation of the regression coefficient.

5. CV = coefficient of variation of the regression line.

Table 7--Trend line of area contribution to crop output growth in six countries, 1950-78

Country	Cropping pattern contribution to output growth		Change in growth rate
	First interval	Last interval	1950-78
	Percent		Percentage points
Brazil	0.22	-0.56	-0.78
India	-.20	.64	.84
Mexico	-.15	-.27	-.12
Peru	1.75	-.50	-2.25
Philippines	.10	-.14	-.24
Thailand	.87	.87	0

Source: Graph 4

it was relatively small. The positive effect seen in India reflects a shift into high-yielding wheat varieties and will be discussed in more detail later. Likewise, the zero effect of changes in cropping patterns on long-term crop output growth rates for Thailand is significant and will be discussed in more detail later.

The effect of the aggregate interaction components on long-term rates of crop output growth was negative or zero for three of the six countries studied and positive for the other three (graph 5 and table 8). In all cases, these effects were small in relative terms. A more useful measure of how the confluence of area, yield, and cropping pattern interactions affect the rate of crop output growth is given by the composite interaction (CI) statistic (table 9). Compared to the primary component, these statistics are small for all of the countries studied and for the sample of countries as a whole. Moreover, there are no discernable trends for the sample as a whole over the 30-year period studied. This suggests that the interaction among area expansion, yield changes, and changes in crop mix has had little effect on the rate of crop output growth in the long term.

Relative Contribution of Growth Components to Crop Output Growth

An analysis of the relative importance of the components of crop output growth taken over the entire span shows the area component dominating the effects of the other components for three of the six countries. On a percentage scale ranging from 0 to 100, the relative importance of land is 83, 78, and 64 for Brazil, Thailand, and the Philippines, respectively (table 10). While the area component for the other three countries did not dominate the other components (was not over 50 percent), it was important. In relative terms, it accounted for 45, 40, and 36 percent of the effects on crop output growth for Mexico, Peru, and India, respectively.

The yield component for India and Mexico dominated the other components, but to a lesser extent than the land component dominated the other components in Brazil, Thailand, and the Philippines. The relative importance of yield increases in India and Mexico was 52 and 50 percent, respectively.

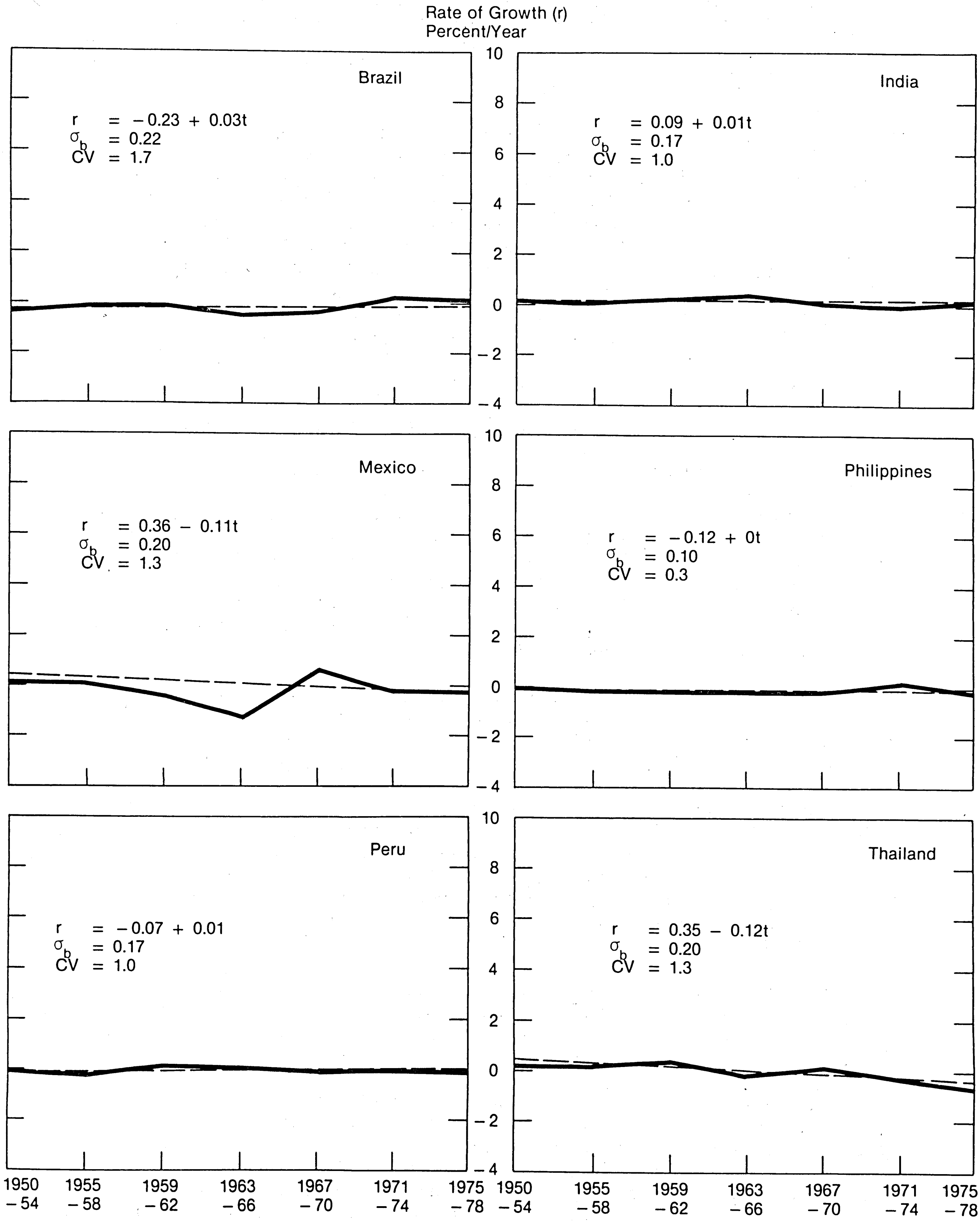
In one country, Peru, no single component was dominant (was over 50 percent in relative terms). However, in this case the cropping pattern component accounted for 33 percent of the relative importance of the growth components, indicating that changes in the cropping pattern in this country had a substantial effect on the rate of crop output growth. In only one other country, Thailand, was the cropping pattern component important as an effect on crop output growth.

The relative importance of the interaction components to crop output growth was negligible for all countries in the sample. This indicates that the three primary components--area, yield, and cropping pattern--do not interact in a way that affects the rate of crop output growth in the long term.

For the sample as a whole, the gross area and yield components together accounted for approximately 90 percent of the relative contributions of all components. However, the gross area component was much more important in Latin America, where its relative contribution was 72 percent, than in Asia where its relative contribution was 41 percent. Conversely, the yield component was much less important in Latin America, 25 percent, than in Asia

Graph 5

Contribution of Interaction Components (Summed) to Crop Output Growth, Selected Countries



*Notes to Graph 5:

1. The data used to construct each country graph are given in table 3.

2. The individual datum points in each graph are connected by a solid line; the linear regression line through the datum points is shown as a broken line.

3. In the equation for the rate of growth (r), t = 0 for the first interval and t = 6 for the last interval.

4. σ_b = standard deviation of the regression coefficient.

5. CV = coefficient of variation of the regression line.

Table 8—Trend line of area contribution to crop output growth in six countries 1950-78

Country	Interaction components contribution to output growth: First interval	Interaction components contribution to output growth: Last interval	Change in growth rate 1950-78
	Percent	Percent	Percentage points
Brazil	-0.23	-0.05	-0.18
India	.09	.15	.06
Mexico	.36	-.30	-.66
Peru	-.07	-.01	.06
Philippines	1.12	-.12	0
Thailand	.35	-.37	-.72

Source: Graph 5

Table 9--Composite interaction statistic by country and time interval 1/

Country	1950-54	1955-58	1959-62	1963-66	1967-70	1971-74	1975-78
	Time interval						
				Rate			
Brazil	-0.33	-0.04	-0.09	-0.53	-0.09	0.32	-0.13
India	.15	.05	.13	.01	.40	.08	.15
Mexico	.61	.23	.07	.02	.18	.08	-.09
Peru	.19	.33	.15	.06	.10	.07	-.08
Philippines	.09	.22	.10	.13	.16	.23	-.08
Thailand	.02	.15	.24	.31	.19	.47	-.89

1/ The composite interaction statistic is the sum of the area-yield, yield-cropping pattern, and the area-yield-cropping pattern interaction component.

Table 10--Relative contributions of growth components to crop output growth in the long term 1/

Country	Crop output growth	Components of growth: Gross Area	Yield	Cropping pattern	Interactions
			Percent		
Brazil	100	83	16	0	1
India	100	36	52	8	4
Mexico	100	45	50	0	5
Peru	100	40	27	33	0
Philippines	100	64	34	2	0
Thailand	100	78	0	21	1
Asia 2/3/	100	41	47	9	3
Latin America 3/4/	100	72	25	1	2
Entire sample 5/3/	100	51	40	6	3

1/ The data were derived by normalizing to a base of 100 percent the estimated rates of growth (r's) for the midpoints of the regression equations (regression equation values for 5 = 1963-66) shown in graphs 1-5.
2/ Weighted average of Asian countries in the sample.
3/ The weights used are explained in the footnotes to table 4.
4/ Weighted average of Latin American countries in the sample.
5/ Weighted average of all countries in the selected sample.

where it accounted for 47 percent of the relative contribution of all growth components.

Relative Importance of Long-term Changes in the Contributions of Growth Components to Crop Output Growth

The previous discussion indicated that for the selected sample of countries the combined effects of the area and yield components accounted for a substantial part of the relative contributions of all growth components. In the long term, the overall rate of crop output growth in these countries will be determined by the magnitude and direction of changes in these component contributions.

To facilitate an analysis of these long-term changes, the percentage point difference between the initial and end points of the regression equations in graphs 1-5 have been normalized to a base of 100 percent (table 11). These data show that the long-term changes in the contribution of the area component dominate the changes in the other growth components (are greater than 50 percent) for four of the six countries. Measured on a percentage scale ranging from 0 to 100, the importance of long-term changes in the area component were 62 percent for Mexico, 60 percent for Peru, 57 percent for Thailand, and 53 percent for Brazil. With the exception of Thailand, the long-term effect of changes in the rate of land expansion was negative; that is, it decreased the rate of crop output growth.9/ The long-term effect of changes in yields dominated the other components in only one country, the Philippines, with a relative effect of 66 percent. Moreover, the effect was positive; that is, it increased the rate of crop output growth. The effect of long-term changes in the yield component was positive in only one other country, Brazil. However, in this case, the relative effect was small, 22 percent. While the long-term effect of changes in cropping patterns did not dominate the changes in the other components in any of the countries, they were significant in three countries. In relative terms, they were 39 percent, 28 percent, and 26 percent for Peru, Brazil, and India, respectively. The long-term changes in the effect of the cropping pattern component were negative in Brazil and the Philippines but positive in India.10/

Variability in the Rate of Crop Output Growth

The countries in the sample differed substantially in the amount of variability associated with their long-term rates of crop output growth, based upon the coefficients of variation derived from graph 1. The coefficient of variation around the trend line was nearly three times larger for Thailand than for the Philippines. For India and Peru, the variability was approximately two times as large as for the Philippines. There were significant differences among the countries in the variability attributable to the three primary components of crop output growth, as evidenced in graphs 2, 3, and 4. Analyzing each country individually, we found the variability associated with the contribution of area expansion was of primary importance as a source of variability in crop output growth in four of the six countries studied. The variability was particularly high for Thailand, with a

9/ The role of land expansion in increasing crop output in Thailand reflects a special rural development policy in that country. This will be considered in more detail in a later discussion.

10/ The positive effect of changes in the cropping pattern in India is of special interest. It will be considered in more detail in a later discussion.

Table 11--Relative importance of long-term changes in components of crop output growth by country 1/

Country	Crop output growth	Components of growth			
		Gross area	Yield	Cropping pattern	Interactions
		Percent			
Brazil	100(-)	43(-)	22(+)	28(-)	7(-)
India	100(-)	53(-)	19(-)	26(+)	2(-)
Mexico	100(-)	62(-)	27(-)	2(-)	9(-)
Peru	100(-)	60(-)	0	39(-)	1(+)
Philippines	100(+)	23(-)	66(+)	11(-)	0
Thailand	100(+)	57(+)	35(-)	0	8(-)

1/ The data presented above were derived by normalizing the percentage point differences (between the first and last interval values) shown in graphs 1-5. The algebraic signs in parentheses indicate whether the long-term effect on growth was positive (increased the rate of crop output growth) or negative (decreased the rate of crop output growth).

coefficient of variation of 13, followed by coefficients of 5.7 and 3.3 for the yield and croppping pattern contributions, respectively. Peru exhibited a similar pattern, with variability coefficients of 10.7, 5.3, and 4.7 associated with the area, yield, and cropping pattern contributions. In Mexico, the coefficient of variation for the area component was also high at 10, followed by coefficients of variation of 6.3 associated with the yield contribution and 4.3 for the cropping pattern contribution. A coefficient of variation of 7.7 for the area contribution was derived for the Philippines, with corresponding values of 6 and 2 for the yield and cropping pattern contributions, respectively.

In the remaining two countries, India and Brazil, the coefficient of variation of the yield component was greater than those of the other two growth component contributions. The variability of the yield contribution in India was 9.7, at least three times higher than the values associated with the other two components. The situation is similar in Brazil, which had a coefficient of variation of 8.7 for the yield contribution, 6.3 for area, and 2.3 for the cropping pattern contribution. In no country was the variability in the contribution of the cropping pattern predominant.

The analysis of the three categories of component contributions and the associated differences among the coefficients of variation for each of the six countries studied reveals that there were substantial differences in the variability of the contribution of area expansion to crop output growth. The variability was especially low for India, with a coefficient of variation of 3.3, and unusually high for Thailand with a coefficient of variation of 13. These results indicate that, in the long term, some countries have been able to expand crop area at a relatively constant, but decreasing rate, whereas other countries have experienced a rather erratic rate of growth in land area devoted to crop production.

Over the long term, there is less difference among countries in the variability in the effect of yield than in the effect of area. The coefficient of variation for the yield components varied from a low of 5.3 to a high of 9.7. Similarly, there was little difference across countries in the variability associated with the cropping pattern component. The coefficient of variation varied from 1.7 for India to 4.7 for Peru. In each country, this value was least significant relative to the coefficients of variation associated with the other two growth components. Thus, the differences among the sample countries in their rates of crop output growth are more a function of the variability in changes in area expansion than to changes in land area devoted to crops or in the cropping pattern.

Assessment of Long-term Crop Output Growth Prospects

Long-term crop output growth rates are a function of resource endowments and factor and product prices. The accounting methodology employed in this study does not consider these variables directly. Rather, it assumes that they are the determinants of the rates of crop output growth and that these effects are reflected in the performance of the crop sector in individual countries. To assess long-term crop output growth prospects, one must assume that these variables will continue to influence the rate of crop output growth. With this as the underlying assumption, a country level assessment of long-term crop output growth prospects is presented below.

Brazil

The area component of crop output growth has dominated the rate of crop output growth in Brazil over the last three decades. However, the contribution of this growth component has declined in the long term. At the same time, the yield component has shown an increase in its contribution to Brazil's rate of crop output growth. Nevertheless, it is still relatively small. There has been a long-term shift in the cropping pattern in Brazil that has tended to reduce the country's overall rate of crop output growth. Finally, there has been an interaction among the principal components (area, yield, and cropping pattern) that has also tended to reduce the long-term rate of crop output growth.

The long-term rate of crop output growth in Brazil will most likely decline gradually. The area component has been the main contributor to crop output growth in the past, and its presently declining contribution suggests that high rates of growth in Brazil will be possible only if the yield component emerges as main source of output growth.

India

The yield component of crop output growth has dominated the rate of crop output growth in India. It has varied considerably over the 30-year period and reflects the large productivity gains in the late sixties and late seventies, as well as the intervening period of drought. In contrast to the unsteady yield effect, the gross area contribution to growth has suffered a steady decline.

Multiple cropping is important in India (table 12). The multiple cropping component of crop output growth shows that increases in cropping intensity over time have accounted for an average annual increase in output of about 0.41 percent (table 13). In relative terms, this is about 14 percent of the average crop output growth rate. Hence, it has been an important source of crop output growth. Moreover, the relative importance of multiple cropping as a source of crop output growth has increased steadily over the 1948-78 span.

The composite of the area, yield, and cropping pattern interaction for India is positive in six of the seven intervals (table 9). There is a particularly large interaction term for the 1966-70 interval which is associated with an exceptionally large primary yield contribution and an overall growth rate that is high (table 3). These relatively large and positive values may point to the special role of irrigation in India. Crop area expansion in paddy and wheat has involved not the opening of marginal lands but the opening of newly irrigated land with high yield potentials. The displaced traditional crops show area contraction without any gain in yields. The combined effect is a positive composite interaction statistic.

The cropping pattern components over the long term have tended to increase the overall rate of output growth in India. The explanation for this may be in the shift from coarse grains into the more valuable high-yielding varieties. Since this shift into high-yielding varieties represents an upward shift in the agricultural production function for India, it may be likened to a "windfall gain" and, therefore, may not continue.

Table 12--Index of cropping intensities

Year	India	Philippines
1950	1/1.116	1/1.26
1954	1/1.13	---
1958	1/1.143	---
1962	1/1.153	2/1.361
1966	3/1.150	3/1.385
1970	3/1.178	4/1.412
1972	---	4/1.446
1976	4/1.200	---

--- = Not available.

1/ Dana Dalrymple. Survey of Multiple Cropping in Less Developed Nations. U.S. Dept. Agr., Washington, D.C., 1971, p. 67 and p. 87.

2/ Dalrymple for 1960.

3/ Asian Development Bank. Asian Agricultural Survey. Manila 1976, pp. 410-411.

4/ Dharm Narian and Shyuamal Roy. Impact of Irrigation and Labor Availability on Multiple Cropping: A Case Study of India. International Food Research Institute Research Report #20, Washington, D.C. Nov. 1980, p. 9-10.

Table 13--Aggregate contributions of components and multiple cropping effect for India over 1950-74 1/

Interval	Compounded growth rate	Aggregate components: Net area	Yield	Cropping Pattern	Multiple cropping
		Percent/year			
1950-54	4.44	1.91	2.83	-.63	0.33
1954-58	2.58	1.45	.72	.12	.29
1958-62	3.84	.66	1.91	.41	.85
1962-66	.58	.06	.41	.17	-.06
1966-70	4.97	.38	3.39	.59	.61
1970-74	1.31	-.19	.81	.28	.41
Average	2.96	.71	1.68	.16	.41

1/ The procedure used to derive the data in this table uses aggregate components of growth. These are given in the Appendix.

The long-term prospects for crop output growth in India are unclear. However, a small variable yield effect, a negligible area component, and an exhausted cropping pattern component all weigh against India's achieving a high long-term rate of crop output growth.

Mexico

Both the area and yield component have been important determinants of the rate of crop output growth in Mexico and both have exhibited significant declines. Moreover, the cropping pattern and interaction components have tended to reduce the rate of crop output growth.

The prospects for the long-term rate of crop output growth in Mexico are unclear. All of the components of crop output growth have experienced long-term declines. If these trends continue, Mexico will continue to experience a long-term decline in its rate of crop output growth. The annual rate of crop output growth has decreased to a very low level. Whether this low rate of growth can be altered depends primarily on whether or not the country can alter the long-term trend in the declining contribution of the area component. To a lesser extent, it also depends on whether the long-term decline in the contribution of the yield component can be altered. If these two negative effects on the overall rate of crop output growth cannot be altered, the prospects are that the country will enter a period of negative rates of overall agricultural output growth unless the components of crop output growth could be stabilized.

Peru

The area, yield, and cropping pattern components all exerted a significant influence on the rate of crop output growth. However, while one growth component dominated the rate of crop output growth in Peru, the long-term decline in the rate of output growth there has been largely due to declines in the contributions of the area and cropping pattern components. The effect of changes in the yield and interaction components has been negligible.

Long-term decline in the rate of crop output growth in Peru will likely continue. The long-term trends in the contributions of the different growth components are unlikely to have a positive effect on the rate of crop output growth. The rate of crop output growth in Peru has reached a very low level. Whether it can be stabilized around this level or will decline still more is unclear.

Philippines

The Philippines was one of two countries in the sample of countries studied that experienced a long-term increase in the rate of crop output growth. The relative contribution of the area component is much greater than the yield component. The increase in the contribution of the yield component has increased the rate of crop output growth. Long-term changes in the contribution of the area component have tended to decrease the rate of crop output growth.

Multiple cropping is important in the Philippines. However, the lack of a consistent series of cropping intensity data for the Philippines precluded estimating a separate multiple cropping component of crop output growth. Nevertheless, for the intervals for which cropping intensity data for the Philippines are available, the increase in multiple cropping accounted for an annual growth rate of about 0.5 percent. This significant multiple cropping factor further decreases the importance of the area relative to the yield contribution to crop output growth.

The gradual long-term increase in crop output growth in the Philippines may not continue. The long-term increase identified in this study is due to the increase in the contribution of the yield component to overall crop output growth. However, there is a negative interaction among the area, yield, and cropping pattern components in six of the seven intervals in the Philippines (table 9).11/ This is in sharp contrast to India where there is a positive interaction among the components in six of the seven intervals. The difference is due to the way in which the high-yielding varieties were adopted in the two countries. In India, the high-yielding varieties stimulated a shift from one cropping pattern to another. In the Philippines, the effect appears in increased yields in the existing cropping pattern. That is, the adoption of the new technology did not result in a change in cropping pattern, but only increased yields within the existing cropping pattern.

11/ In only one interval, 1970-74, is the interaction positive. This interval marks the climax of a program to increase the area in irrigated high-yielding paddy varieties. The government subsequently launched a maize program which by the late seventies resulted in accelerated cropping of marginal lands.

If the rapid adoption of the high-yielding varieties is looked upon as a "windfall gain," and thus will have a declining effect over time, it appears unlikely that the Philippines can continue in the long term to increase its overall rate of crop output growth. With the area component continuing to exert a negative influence on the rate of crop output growth, and a likely decline in the contribution of the yield component, the rate of crop output growth in the long term will likely level off and possibly decline.

Thailand

Thailand is the second of the two countries in the sample of countries that exhibited a long-term increase in crop output growth. However, this trend is largely a function of expanding agricultural area which reflects a political decision to expand economic activity in the northern and northeastern part of the country. Once this strategy of agricultural development has run its course, the gradual long-term increase in the rate of crop output growth in Thailand may not continue. Before the seventies, paddy and rubber production virtually monopolized the agricultural sector. The positive interaction among the area, yield, and cropping pattern components for four of the five intervals before 1970 points to improved cultivation of enlarged rubber holdings as well as the opening of irrigated and chemically fertilized paddy lands (table 9). Beginning in the seventies, the source of increased crop output lay in the diversification of the crop sector--with maize, cassava, and sugar becoming more important--and the rapid expansion into rainfed areas in the northern and northeastern parts of the country. The major effect of this development strategy has been a sharp decline in the yields of the crops experiencing area expansion. This is reflected in the increasing large and negative CI statistic (table 9).

Once the policy of expanding agricultural output by expanding area has run its course, the prospects are for the long-term rate of crop output growth to stabilize and possibly decline. After the new area has been fully developed, the country will be forced into depending on its yield component to maintain or increase its rate of crop output growth; the long-term effect of this component has been negative.

Asia Region

In the region dominated by India but also represented by the Philippines and Thailand, the trend lines suggest that favorable prospects for production growth depend on shifts to higher value cereals that show rising yields. The regional decline in the gross area contribution is unlikely to be reversed. The declining trend of the yield component raises the possibility that shifts to more valuable crops will not be accompanied by rising yields and growth will be jeopardized.

The rate of crop output growth declined approximately 0.9 percent over the 30-year span considered, or about 0.3 percent per decade. If this rate of decline continues, it would take nearly nine decades for the rate of crop output growth for Asia to decline to zero.

Latin America Region

The contribution of the yield component has remained fairly steady over the last three decades in this region. If significant growth is to occur, yield-enhancing innovations will have to play a larger role than they have in the past to offset a continuing negative trend in the contribution of cropland expansion.

To the extent that the sharp downturn in the cropping pattern contribution is a result of a shift away from high unit value export crops that have fared poorly in the world market (hard fibers is an example), this component will unlikely rebound as a source of growth.

The rate of crop output growth declined nearly 3 percent over the 30-year span considered, or approximately 1 percent per decade. If this rate of decline continues, the rate of crop output growth for Latin America will decline to zero in slightly over two decades.

CONCLUSIONS

The components-of-growth type of analysis can be employed to analyze long-term sources of change in a country's rate of crop output growth. While several methodologies were considered at the beginning of the study, the Minhas formulation of the problem of measuring components of growth was found to be the most useful. It not only provides for estimating the contributions of three primary components of growth--area, yield, and cropping pattern--but it also provides for estimating the four interaction components among these primary components. Sufficient area, production, and price data exist in time series form to analyze the changing effects of components of growth over a long-term period (30 years in this study) in most of the developing countries outside of Africa.

The statistics generated in this type of study can be very useful in an analysis of long-term trends in crop output growth. They take account of components of change in crop output due to changes in all crops in the crop sector. The repeated application of the method to a sequence of intervals over a long period makes it possible to analyze the dynamic interaction of the components of crop output growth over time. This mechanism can then be used to determine how the relative importance of individual growth components changes through time, and thus to assess the prospects for long-term crop output growth in a country.

The results of the study lead to the following conclusions about the changing sources of growth over the 1948-78 period.

1. The rate of crop output growth has been declining across the sample of countries studied.

2. The contribution of the gross area component to crop output growth is declining sharply for both Latin America and Asia. The shrinking contribution of gross area expansion has been the main factor in declining growth rates of the regions and the overall sample. In addition, the relative importance of the area contribution also declined for the sample and for the Asian region. In Latin America expanding harvested area has easily remained the principal source of growth.

3. The contribution of the yield component to crop output growth has decreased over time. This conclusion holds for both regions. In relative terms, however, the yield

component has gained for the regions and the sample as a whole.

4. The effect of the cropping pattern component on growth over the long term considered in this study differs by region. In Latin America, crop shifts have generally depressed the rate of crop output growth while in Asia they are an increasingly important source of growth. For the entire sample, the absolute contribution and contribution relative to other components has shown a moderate rise with time.

5. The effect of the interaction among the primary components of growth on the rate of crop output growth is negligible. Thus, there is no evidence that the expansion of agricultural production into less productive areas is not being offset by technological changes that make the new areas as productive as existing areas.

6. The long-term rate of crop output growth will continue to decline in both Asia and Latin America because the declining contribution of the area component of crop output growth will not be offset by the increasing contributions of the other growth components. If current trends continue, it will take approximately nine decades for growth to decline to zero in Asia, but only two decades in Latin America.

The findings of this study lead to the following recommendations:

1. Policymakers can use the findings of this study to more fully assess appropriate policy action at national and international levels.

2. Additional analyses are needed for the Asia and Latin America to determine why the contribution of expanding agricultural land area to crop output growth is declining, and why the contribution of yield increase to crop output growth is so small.

3. A similar study is needed for a sample of African countries where historical series on agricultural production are sufficiently long. This would allow a more certain generalization of the study findings.

REFERENCES CITED

1. Bachman, Kenneth and Leonardo Paulino. Rapid Food Production Growth in Selected Developing Countries, 1961-76. Research Report No. 11, International Food Policy Research Institute, Washington, D.C., 1979.

2. Brown, Lester R. Building a Sustainable Society. Norton and Company, Inc., New York, 1981.

3. Council on Enviromental Quality and the Department of State. The Global 2000 Report to the President, Volume 1 and 2. CEQ, Washington, D.C., 1980.

4. Dregne, Harold E. Impact of Land Degradation on Future World Food Production, ERS No. 677, U.S. Department of Agriculture, Economic Research Service, Washington, D.C., 1982.

5. Eckholm, Erik, P. Losing Ground: Environmental Stress and World Food Prospects. Norton and Company, Inc., New York, 1976.

6. Food and Agriculture Organization. Agriculture: Towards 2000. Conference Report, Twentieth Session, Rome, 1979.

7. __________. Production Yearbooks for 1960, 1966, 1968, 1969, 1975, 1976, and 1979.

8. Gotsch, Carl. Prices and Subsidies in Pakistan Agriculture. World Bank Staff Working Paper No. 387, Washington, D.C., 1980.

9. Minhas, B.S. "Measurement of Agricultural Growth," Indian Journal of Agricultural Economics, pp. 171-172, 1966.

10. Ministry of Agriculture and Cooperatives, Agricultural Statistics of Thailand: Crop Years 1974/75 and Crop Year 1978/79, Bangkok, 1976 and 1980.

11. National Economic and Development Authority. Philippine Statistical Yearbook 1980. Republic of the Philippines, Manila, 1981.

12. Secretaria de Agricultura y Recursos Hidraulicos. Consumos Aparentes de Productos Agricolas 1925-80. Mexico City, 1981.

13. Smith, V.K. ed. Scarcity and Growth Reconsidered. Johns Hopkins University Press, Baltimore, 1979.

14. Technical Committee, Directorate of Economics and Statistics. Construction of Agricultural Index Numbers in India. New Delhi, 1967.

15. U.S. Department of Agriculture. Agriculture in 26 Developing Nations, 1948-63. FAER No. 27, Economic Research Service, Washington, D.C., 1965.

16. __________. Growth of Crop and Livestock Output in Selected Developing Nations, 1948-65. Economic Research Service - Foreign 226. Washington, D.C., 1968.

17. __________. Economic Progress of Agriculture in Developing Countries, 1950-68. FAER No. 59, Economic Research Service, Washington, D.C., 1970.

18. __________. Agricultural Attache reports from Mexico City, 1950-80.

19. __________. Unpublished grain statistics, International Economics Division, Economic Research Service.

20. __________. World Indices of Agricultural and Food Production. Statistical Bulletins No. 669, 689, and 697. Economic Research Service, Washington, D.C., July 1981, August 1982, and June 1983.

APPENDIX

Aggregate contributions of area, yield, and cropping pattern components to crop output growth rate

Country and interval	Crop output growth rate	Aggregate components		
		Area contribution	Yield contributions	Cropping pattern contributions
			Percent/year	
Brazil:				
1950-54	2.87	3.68	-1.10	0.28
1954-58	6.24	4.87	1.12	.25
1958-62	4.82	4.17	.65	-.05
1962-66	2.28	1.81	1.01	-.54
1966-70	1.84	3.90	-1.18	.88
1970-74	4.54	2.51	2.32	-.30
1974-78	3.05	3.36	.06	-.31
India:				
1950-54	4.44	2.24	2.84	-.63
1954-58	2.58	1.74	.72	.12
1958-62	3.84	1.51	1.91	.41
1962-66	.58	-.29	.41	.17
1966-70	4.96	.99	3.38	.59
1970-74	1.31	.23	.86	.28
1974-78	3.40	.74	2.12	.54
Mexico:				
1950-54	7.51	4.46	2.88	.17
1954-58	6.52	4.20	2.29	3.26
1958-62	5.23	2.03	3.72	.52
1962-66	6.58	4.51	3.70	-1.63
1966-70	1.08	-1.08	1.58	.58
1970-74	2.22	1.67	.78	.23
1974-78	.73	.21	1.22	.27
Peru:				
1950-54	4.52	1.61	.78	2.12
1954-58	1.51	.73	-1.09	1.87
1958-62	6.70	4.84	1.58	.27
1962-66	.90	.25	.87	.22
1966-70	1.41	.99	.61	-.19
1970-74	-.67	-.87	.26	-.05
1974-78	-1.42	-1.78	.15	.21
Philippines:				
1950-54	4.24	3.61	.69	.24
1954-58	3.72	4.02	-.43	.13
1958-62	3.22	1.17	2.66	-.60
1962-66	2.76	2.14	.76	-.14
1966-70	3.89	1.68	1.98	.23
1970-74	5.50	3.89	1.76	.15
1974-78	4.31	2.85	1.70	2.46

Continued--

Aggregate contributions of area, yield, and cropping pattern components to crop output growth rate--continued

Country and interval	Crop output growth rate	Aggregate components: Area contribution	Yield contribution	Cropping pattern contribution
	Percent/year			
Thailand:				
1950-54	3.30	0.63	1.60	1.07
1954-58	.67	-.50	-.17	1.34
1958-62	9.18	6.49	1.89	.39
1962-66	3.46	2.62	1.45	.99
1966-70	4.36	4.16	.19	.01
1970-74	4.62	.53	1.83	1.13
1974-78	4.11	5.16	-2.19	1.14

*U.S. GOVERNMENT PRINTING OFFICE : 1984 O-420-932/2150