THE COMPOSITION OF CHANGES IN FOODCROP PRODUCTION VARIABILITY IN CHINA, 1931-1985: A DISCUSSION OF WEATHER, POLICY, TECHNOLOGY, AND MARKETS

Bruce Stone
and
Scott Rozelle

International Food Policy Research Institute
1776 Massachusetts Avenue, N.W.
Washington, D.C. 20036

A paper prepared for the American Agricultural Economics Association Meetings, August 2-5, 1987, Michigan State University, East Lansing, Michigan

July 1987

THE COMPOSITION OF CHANGES IN FOODCROP PRODUCTION VARIABILITY IN CHINA, 1931-1985: A DISCUSSION OF WEATHER, POLICY, TECHNOLOGY, AND MARKETS

Bruce Stone and Scott Rozelle *

This paper examines foodcrop production variability in China during a fifty-five year period, primarily as revealed by a comparative analysis of production variance decomposition exercises for three sub-periods, 1931-37, 1952-57, and 1979-85. The purpose of the paper is to shed light on the relationship of weather to foodcrop production variability in China and, especially, on the causes of changes in the patterns of production variability among the sub-periods.

A comprehensive analysis of the importance of weather in Chinese agriculture goes far beyond the scope of the paper. Such an analysis should be conducted: (a) on a crop-specific basis; (b) on a highly disaggregated basis geographically; and (c) in collaboration with agro-climatologists and other crop scientists. This is because China is so large and climatically diverse, because the physiological relationships of weather and climate to crop yields at the farm level are so complex, so dependent on specific crops and varieties, and have changed considerably during the last three and one-half decades in China, and because the techniques normally employed by economists in analyzing the influence of weather on yields in China at the aggregate level are so fundamentally limited.[1]

---

* Bruce Stone is a research fellow at the International Food Policy Research Institute in Washington DC. Scott Rozelle is in the Agricultural Economics Department, College of Agricultural Life Sciences, Cornell University.

1 Support for the contention of physiological complexity is considerable among the agricultural scientific literature. Within the Consultative Group for International Agricultural Research alone, the agro-ecological zoning efforts conducted by a number of centers have provided a body of experience in linking physiological studies of stress resistance to climate data on a geographically diverse basis in a number of developing countries and within a context of rapidly changing seed technology. Recent attempts to combine a variety of approaches employed by agricultural scientists and economists in studying cereal yield variability appear in Hazell (1986) and Anderson and Hazell (1987). China's diverse agro-climatological environment and the changing varietal distribution of seed technology are delineated in considerable detail for wheat in Stone et al. (1985).

Without undertaking a comprehensive analysis, it is still possible to contribute to the discussion of weather and foodcrop production variability in China using variance decomposition techniques because that discussion to date among economists has been conducted on a highly aggregated basis, both geographically and in terms of crop composition. The principal contributors to the discussion have been Tang (1980, 1984), Kueh (1983, 1984a, 1986),[2] and Tang and Huang. Reference to disaggregated data appearing in these works have been anecdotal and hypothetical rather than a constituent part of their modeling or other formally quantitative analytic efforts.

A few efforts by climatologists and geographers to study the effect of changing weather patterns on Chinese yields have been published in English (e.g., Terjung et al. 1984a, 1984b, 1985; Wang and Mearns), but they have also used aggregate national yield data and, at best, anecdotal information on a more local basis. Their treatment of other economic and technological factors influencing yield is also less comprehensive. A new Chinese journal, *Nongye Qixiang* (Agricultural Meteorology), focuses on micro-data for a variety of crops and specific types of stress, but to date has included among its articles little formal attempt to relate this type of information to national production variability.

Stone and Tong (1985, 1987) initiated variance decomposition work for China using 1952-57 and 1979-83 provincial data for rice, wheat, and total foodcrops.[3] The main obstacle to conducting earlier, more extensive, and more detailed work of this sort has been the lack of sufficient data disaggregated by crop and province. Considerable disaggregated data exist in China, covering the entire People's Republic period and even at the county level. But these data cannot be released by Chinese institutions, which have not, themselves, conducted variance decomposition exercises. Reservations have also been expressed about the reliability of these data for the 1960s and 1970s

---

[2] A forthcoming book by Kueh was not yet available in time for this paper's preparation. In it, Kueh is expected to combine a more extensive discussion of these issues with the results of a variance decomposition exercise conducted by Stone and Tong (1985). The latter paper is briefly summarized in Hazell (1986); a revised version will be published in Anderson and Hazell (1987).

[3] The definition of "total foodcrops" used in Stone and Tong (1985 and 1987) and in the 1952-57 and 1979-85 exercises in this paper is identical to that of the Chinese term *liangshi*, which includes rice, wheat, corn, sorghum, millet, barley, oats, proso-millet, rye, other minor cereals, soybeans, other pulses (especially broad beans, mung beans, and field peas) and, valued at one-fifth natural weight, sweet potatoes and white potatoes. "Other foodcrops" in these exercises refers to total foodcrops minus rice and wheat. The crop coverage for exercises using 1931-37 data differs slightly (see below).

(see Stone and Tong 1985). However, since the initial work was done, two more years of recent data have become available in the latest editions of the *Agricultural Yearbook* (PRC Zhongguo Nongye Nianjian 1985, 1986), and some improvements in the original 1950s data base have become possible with further publication of provincial statistical compendia in recent years.

In addition, for greater perspective, changes in foodcrop production variance between the 1930s and the 1950s and between the 1930s and the 1980s were analyzed on the basis of the 1930s data organized in Crook (1986). The value of these present exercises, as supplements to the efforts of Tang, Kueh, and the climatologists, is that they make explicit the quantitative composition of changes in production variability among periods. Armed with this detailed understanding of the relative importance of the various categories of variance components, one is led to formulate rather different hypotheses about the underlying climatological, technological, and economic causes of changes in variability, even if these hypotheses, too, are not yet rigorously tested. In the process, a different notion of the underlying long-term components of trend in variability is developed than is portrayed by Kueh and by Tang, as well as a different impression of the relative success of Chinese efforts to control the influence of weather.

The next section describes the basic approaches employed by Tang and by Kueh and provides a sketch of their conclusions with respect to farm production variability. The following section provides a simple overview of foodcrop production variability over the 55-year period, generates some interpretive hypotheses for a few anomalous sub-periods, and places China's aggregate variability in international perspective. The succeeding five sections delineate the analysis of variance methodology, the data employed, some basic results of the analytical exercises, as well as some hypotheses aimed at explaining the patterns revealed in the decompositions. The final section concludes with an overall view of foodcrop production variability in China, its probable nature, future trends, and general significance.

A CRITICAL REVIEW OF METHODS AND CONCLUSIONS FROM TANG, KUEH, AND THE CLIMATOLOGISTS

A thorough discussion of the methodology and arguments forwarded by even the short list of researchers on China mentioned above cannot be attempted here. But a few observations on their approaches and conclusions with respect to variability are in order. First, the central foci of their researches are dissimilar. Tang's work emanates from his preoccupations with changes in total factor productivity in agriculture over time and his interest in separating the influences of weather variations from those of discreet policy cycles in China. Kueh is more directly concerned with weather as a source of foodcrop yield variability and the technological and socio-economic factors which have affected the *correlation* of weather and yield over time. Terjung and his colleagues are primarily interested in the gap between potential and actual average yields for various crops. Wang and Mearns note the relationship of yield anomalies and weather anomalies as an adjunct of their over-arching concerns with climate change and with the relationship among weather anomalies in different parts of the world.

Among a wide variety of input-output exercises conducted over a long period of time, Tang (1980 and 1984) are most germane to the variability issues. Both Eckstein (1975) and Tang (1980) agree that

> ... in determining the extent to which the quality of any one harvest is affected by weather, on the one hand, and by policy, on the other ... the sticking point has been weather.
>
> The real problem lies in our ignorance of crop-specific location-specific weather and yield relationships in agriculture .... And as it impinges on the farmer, weather is a complex multidimensional phenomenon that defies quantification that is meaningful and operational. Thus there is no weather index for any country, the U.S. included (Tang 1980, p. 344; 1984, p. 122).

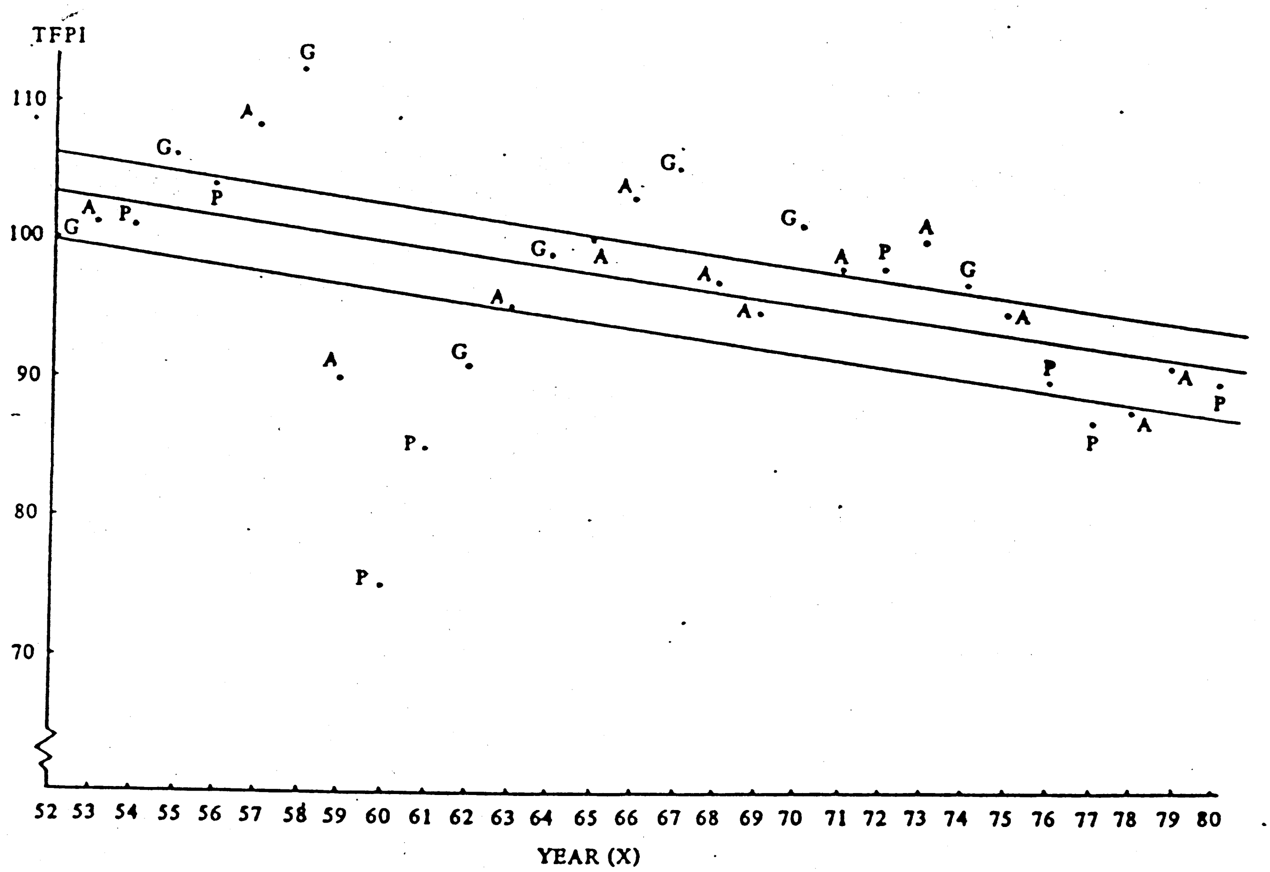
Tang's "crude separation of the influences of weather and policy cycles" (ibid.) uses a total factor productivity index, as the dependent variable, calculated by dividing gross value of agricultural production by an aggregate input index for the 1957-78 (Tang 1980) and 1952-80 (Tang 1984) periods. Three separate trend lines are fitted through "good," "average," and "poor" weather years, respectively. If these trend lines are roughly parallel (Figure 1), the three separate intercepts are used as weather dummies with an aggregate trend. The Cochrane-Orcutt successive differencing iteration technique is then used to remove serial correlation from the error terms and curves are generated that "swing up and down with the weather-specific information." Because the hypothesis of identical trends could not be rejected, Tang concludes that efforts on the part of the People's Republic administration to insulate agriculture from weather have not been successful. But because the intercepts are not far apart,[4] Tang also concludes "that weather has had rather modest influence on agricultural performance in China" (Tang 1980, p. 345; 1984, p. 125).

An alternative approach employed by Tang in both publications uses a Cobb-Douglas function of labor productivity (value added in agriculture per farm worker) explained by a time trend, two weather dummies, two weather-related time dummies, land/labor ratios and capital/labor ratios. Since the coefficients estimated for the weather-related time dummies are small and do not prove significant, and in particular,

---

[4] The calculated total factor productivity index intercepts (1952=100) for poor, average, and good years are 95.8, 102.0, and 105.1 in Tang (1980) and 99.9, 103.4, and 106.5 in Tang (1984).

Figure 1--Weather-Specific Trend Lines in Tang's Total Factor Productivity 1952-1980



Notes:

Default : good year.

TFPI = 106.530-6.607 (DP) - 3.155(DA) - 0.415 (X)

Where: TFPI = Total Factor Productivity Index

DP = Poor year dummy

DA = Average year dummy

X = year

Source: Tang (1984), p. 124.

because the time trend dummy for poor years is not even positive, Tang again concludes Chinese failure to insulate farm output from weather.

Major difficulties with these techniques include the choice of the aggregate dependent variable, the reliability and applicability of the constituent input series, and the arbitrariness of the weighting system adopted in aggregating the input series. Although Tang, like Solow (1957), claims "apparent insensitivity of results to large differences in weights," the exceedingly high index numbers reached for capital inputs (relative to their infinitesimal share in the farm production of China in the 1950s) can dwarf even this apparent insensitivity (Wiens 1983).

More important failures of these approaches specifically for analyzing variability, however, relate to (a) the very high degree of aggregation which leads Tang to confuse aggregate with local variability issues; (b) the circularity of the system dependent upon designation of "poor," "average," and "good" weather years;[5] (c) the inability of the method to accommodate very large variations in the severity of "poor" years such as those of 1960 and 1961; and (d) the choice of period in which those catastrophically poor years fall in the middle, coupled with the failure of the Cochrane-Orcutt method to fully adjust for the serial correlation endemic to such massive catastrophes.[6]

Tang's analysis leads him to conclude:

---

[5] Tang uses a USDA classification of poor, average, and good weather years initiated by Marion Larsen and B. F. Jones in the late 1960s. (For these and later sources, see Stone 1980, pp. 88-89). According to Frederic Surls, then with PRC section of Asia Branch, USDA, these are relatively "off the cuff" classifications, partially dependent on aggregate yield observations (at a July 21, 1983 seminar presentation by Y. Y. Kueh at USDA, Washington DC). See also Kueh's (1984) refutation below.

[6] 1960 and 1961 were years of catastrophic natural disasters apparently unprecedented in the twentieth century resulting in 16 to 64 million premature deaths depending upon method of calculation (Ashton et al., Stone 1987a). Li (1962), Chao (1970), and Lardy (1983) emphasize policy-induced difficulties. Walker (1984) demonstrates that even pre-Great Leap policies and events during the 1952-57 period were heading inexorably to an agricultural collapse which was accentuated by bad weather and disastrous Great Leap policies. Kueh (1984) reconfirms that weather in 1960 and 1961 was by far the worst in the later half of the twentieth century and that indeed even 1959 weather was poor. In addition, the massive starvation, and rural dislocation which ensued malnutrition, affected agricultural production through the mid-1960s and sabotaged the non-agricultural economy. Foodcrop production did not exceed that of 1958 until 1966, despite considerable evidence of technological development.

> Weather does not seem to loom as large as many may have thought as a factor with respect to total output, even less in relation to total factor productivity .... Famines tend to be localized and attract the attention of chroniclers for lack of transport and effective government. It is something of a paradox that, the government's herculean effort to modify and control "nature" notwithstanding, weather appears to matter as much as ever, in terms of its measured impact on agricultural productivity (Tang 1980, p. 347; 1984, p. 133).

The "speculative offsetting factors" Tang offers to explain China's "failure to weather-proof farming" emphasize his assumption that the conclusions derived from his aggregate methodology are equally applicable on a disaggregated basis.

Work by the climatologists cited appears to suffer from a lack of information on, and treatment of almost all non-weather or non-climate related sources of variations. Terjung et al. (1984a, 1984b, 1985) use climate data that are highly disaggregated geographically, distinguish between rainfed and irrigated conditions, and focus on specific crops, but the weather information is averaged over 25 years and has thus not been used to examine year-to-year variability. Even their basic data appear to be daily values averaged over perhaps a month, which are of very limited value in studying the relationship of weather to yields for most foodcrops in China.[7]

Although Wang and Mearns note that the problem of separating the effects on crop yields caused by fluctuations in climate from changes in relevant policy or technology is particularly acute in longitudinal studies of China (p. 43), their treatment of these issues is anecdotal. Little evidence is provided to support the hypothesis that the 1982-83 El Niño event is related to weather anomalies in China. And although the authors may be correct in linking their anecdotal yield information with these anomalies, it is difficult to persuade without more location-specific, if not crop-specific, data on technology (especially

---

[7] Their potential yield information probably comes from experimental farm data. Their actual yield information appears to be a heterogeneous collection of figures from various micro-sources spanning a decade during a very dynamic period. Their modeled relationship between these micro-data and aggregated values from FAO Production Yearbooks is not clear. In Terjung et al. (1985), for example, it appears that data from only four stations are ultimately used to model all rice production in China (Guangzhou, Shanghai, Changchun and Urumqi). Among many important omitted variables influencing yield, the inability to obtain crop-specific, location-specific fertilizer application data (Stone 1984b, 1986a, 1986b) and rapidly changing seed technology (Stone et al., Stone and Tong) eliminates much of the value of the disaggregated climate data.

fertilizer allocations) during such a dynamic period. Under such circumstances, the quantitative impact on yield of weather anomalies is impossible to measure even locally, let alone in the aggregate.

Kueh's (1983, 1984b, 1986) work is primarily based upon data published by the PRC State Statistical Bureau on area affected by natural disasters, such as that appearing in Table 1. These data are crudely weighted to make use of both *shouzai* (disaster-affected) and *chengzai* (severely disaster-affected) series.[8]

The percentage deviations for the middle-weighted series (L_c = 60 percent) are plotted in Figure 2 against the three weather categories adopted by Tang. Although some relationship is exhibited between the two approaches to aggregate weather categorization, there are many years for which conflicting conclusions would be reached about the relative aggregate favorability of weather. Kueh concludes:

> Measured against the *shouzai* area index, 13 different years out of the total of 27 included in this study may be classified as both poor and average; and in the same number of years may be said to be both average and good years. Moreover, 10 different years may be lumped into either of the two extreme weather categories of good and poor. The usefulness of the categorical weather index is therefore somewhat limited (Kueh 1984, p. 73).

Kueh also regresses grain yield deviations from a log-linear trend line[9] against the annual percentage deviations from the mean of disaster-affected area (Kueh 1983, p. 17), and interprets the r^2 = 0.39 as indicating that 39 percent of yield variation net of technological influences can be explained by weather changes. Since the r^2 value declines from 0.59 to 0.22 from sub-period 1952-66 to 1970-81, Kueh concludes that grain production was influenced considerably by weather in the 1950s and 1960s, but technological advances since the late 1960s have rendered average grain yields increasingly less vulnerable to weather. If a one-year yield deviation lag is added as an additional

---

[8] Weighted *shouzai* area = $[(A_s - A_c)\sqrt{L_n/L_c}] + [A_c\sqrt{L_c/L_n}]$ where A_s and A_c stand for the non-weighted yearly total of *shouzai* and *chengzai* areas and L_c and L_n the loss percentage for the *chengzai* and non-*chengzai* areas, respectively. L_n is assumed to be 15 percent; L_c is set at 55 percent, 60 percent, and 65 percent, alternatively (Kueh 1984b, p. 73).

[9] The trend line is regarded as a proxy for technological progress and is claimed to mirror the increased use of fertilizers as presented in Kueh (1984a).

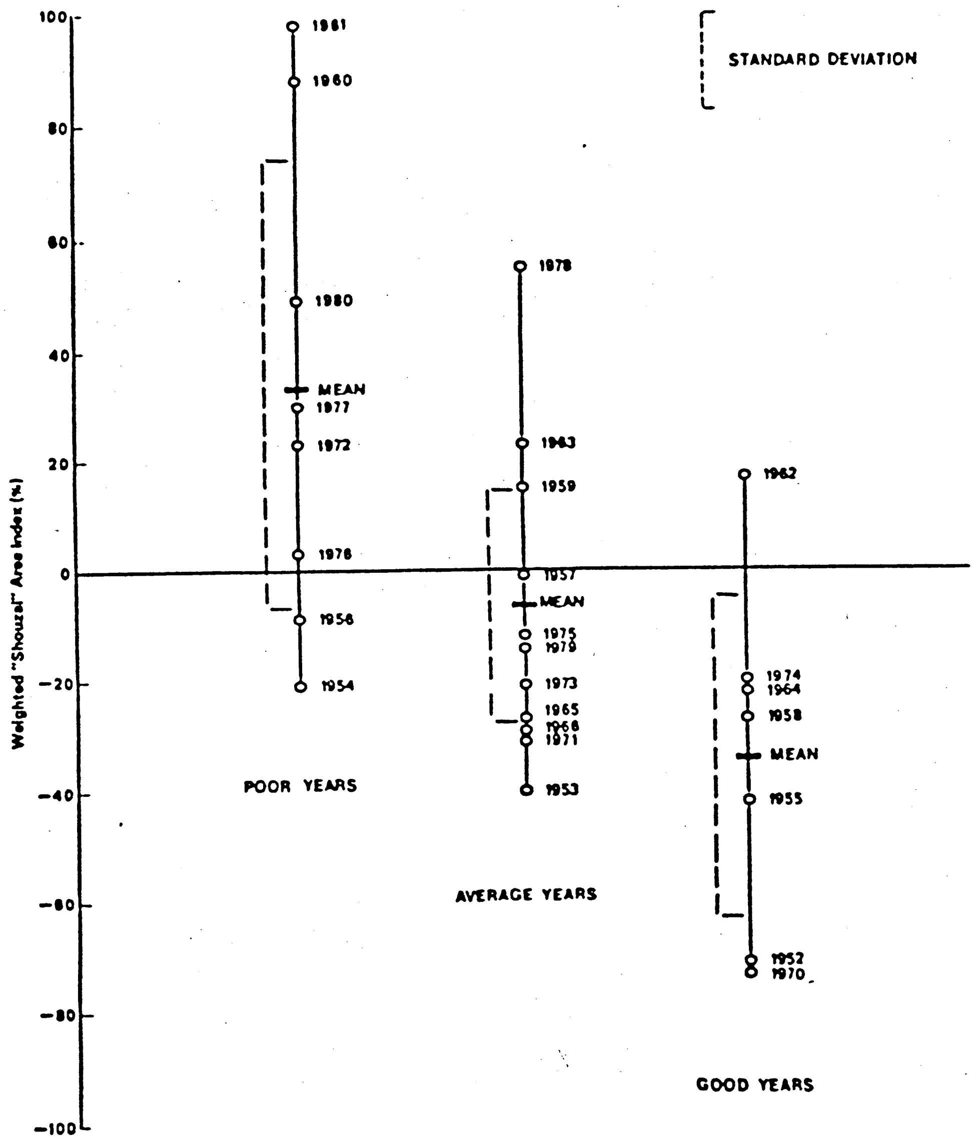
Table 1. Chinese Sown Area Affected by Natural Disasters, 1949-1985

Year	Total: Total Disaster Affected Crop Area[a]	Total: Severely Affected Area[b]	Total: Severely Affected Proportion of Total	Flooding: Disaster Affected Crop Area	Flooding: Severely Affected Area[b]	Flooding: Severely Affected Proportion of Total	Droughts: Disaster Affected Crop Area	Droughts: Severely Affected Area[b]	Droughts: Severely Affected Proportion of Total
	(million hectares)		(percent)	(million hectares)		(percent)	(million hectares)		(percent)
1949		8.53			8.53				
1950	10.01	5.12	51.1	6.56	4.71	71.8	2.40	0.41	17.1
1951	12.56	3.78	30.1	4.17	1.48	35.5	7.83	2.30	29.1
1952	8.19	4.43	54.1	2.79	1.84	65.9	4.24	2.59	61.1
1953	23.42	7.08	30.2	7.41	3.20	43.2	8.62	0.68	7.9
1954	21.45	12.59	58.7	16.13	11.31	70.1	2.99	0.26	8.7
1955	19.99	7.87	39.4	5.25	3.07	58.5	13.43	4.14	30.8
1956	22.19	15.23	68.6	14.38	10.99	76.4	3.13	2.06	65.8
1957	29.15	14.98	51.4	8.08	6.03	74.6	17.21	7.40	43.0
1958	30.96	7.82	25.3	4.28	1.44	33.6	22.36	5.03	22.5
1959	44.63	13.73	30.8	4.81	1.82	37.8	33.81	11.17	33.0
1960	65.46	24.98	38.2	10.16	4.98	49.0	38.13	16.18	42.4
1961	61.75	28.83	46.7	8.87	5.40	60.9	37.85	18.65	49.3
1962	37.18	16.67	44.8	9.81	6.32	64.4	20.81	8.69	41.8
1963	32.18	20.02	62.2	14.07	10.48	74.5	16.87	9.02	53.5
1964	21.64	12.64	58.4	14.93	10.04	67.2	4.22	1.42	33.6
1965	20.80	11.22	53.9	5.59	2.81	50.3	13.63	8.11	59.5
1966	24.21	9.76	40.3	2.51	0.95	37.8	20.02	8.11	40.5
1970	9.97	3.30	33.1	3.13	1.23	39.3	5.72	1.93	33.7
1971	31.05	7.45	24.0	3.99	1.48	37.1	25.05	5.32	21.2
1972	40.46	17.18	42.5	4.08	1.26	30.9	30.70	13.61	44.3
1973	36.49	7.62	20.9	6.24	2.58	41.3	27.20	3.93	14.4
1974	38.65	6.53	16.9	6.40	2.30	35.9	25.55	2.74	10.7
1975	35.38	10.24	28.9	6.82	3.47	50.9	24.83	5.32	21.4
1976	42.50	11.44	26.9	4.20	1.33	31.7	27.49	7.85	28.6
1977	52.02	15.16	29.1	9.10	4.99	54.8	29.85	7.01	23.5
1978	50.79	21.80	42.9	2.85	0.92	32.3	40.17	17.97	44.7
1979	39.37	15.12	38.4	6.76	2.87	42.5	24.65	9.32	37.8
1980	44.53	22.32	50.1	9.15	5.03	54.9	26.11	12.49	47.8
1981	39.79	18.74	47.1	8.62	3.97	46.1	25.69	12.13	47.2
1982	33.13	16.12	48.7	8.36	4.46	53.3	20.70	9.97	48.2
1983	34.71	16.21	46.7	12.16	5.75	47.3	16.09	7.59	47.2
1984	31.89	15.26	47.9	10.63	5.40	50.8	15.82	7.02	44.4
1985	44.37	22.71	51.2	14.20	8.95	63.0	22.99	10.06	43.8

Source: People's Republic of China, State Statistical Bureau (1984), p. 190; People's Republic of China, State Statistical Bureau of China (1986), p. 170.

[a] Natural disasters include floods, drought, frost, freezing, typhoons, and hailstorms.
[b] Severely affected areas are those where crop production is reduced by at least 30 percent relative to normal years due to the natural disaster.

Figure 2--Kueh's Weighted Shouzai Area Index Measured Against Three Weather Categories Constructed by Tang for China, 1952-30



Notes: For explanation see text.

Source: Kueh (1984b), p. 74.

explanatory variable to account for the cumulative weather impact,[10] the adjusted r^2 is 0.73 for the entire period, 0.87 for the sub-period 1952-66, and much lower for 1970-81.

Kueh also notes that although the weather instability index[11] declined only slightly (from 32.9 to 29.9) from 1952-66 to 1970-81, calculated average index values for foodgrain yield instability[12] declined from 7.18 to 2.19, implying decreasing vulnerability to weather. This declining correlation is nicely illustrated in Figure 3. The yield and weighted *shouzai* index values are typically on opposite sides of the mean, but the proportional relationship of yield response is declining and appears to break down altogether in the early 1980s.

A multiple regression of 1952-81 grain yields on the absolute deviations of the weighted weather-affected area from the 27-year mean and a supply series of organic and manufactured fertilizers gives an adjusted r^2 value of 0.98 with the coefficient of affected area having negative sign, but the simple regression of yield on fertilizer alone yields an r^2 value of 0.97 (Kueh 1983, p. 17). Kueh interprets this result to imply that although the weather still has an influence on

---

10 Kueh offers the following hypotheses explaining cumulative weather impact: "seed quality may deteriorate because droughts and floods are often followed by pests; seed reserve may be partially eaten up under subsistence conditions resulting in inadequate planting and thus lowering yield per hectare of area sown; lack of drainage facilities may result in prolonged inundation, and the absence of summer rains under a prolonged drought in the North China Plain (as in the case of 1959-61), for example, prevents the leaching of salts which normally accumulate during the dry months of the preceding winter and spring (Kueh 1983, p. 17). To Kueh's suggestions may be added rural dislocation, reduced labor productivity due to malnutrition, and the reflexive economic impact on non-agricultural sectors rebounding in generalized depression upon agriculture.

11 Expressed as the average of yearly percentage deviations of *shouzai* from the 1952-81 mean.

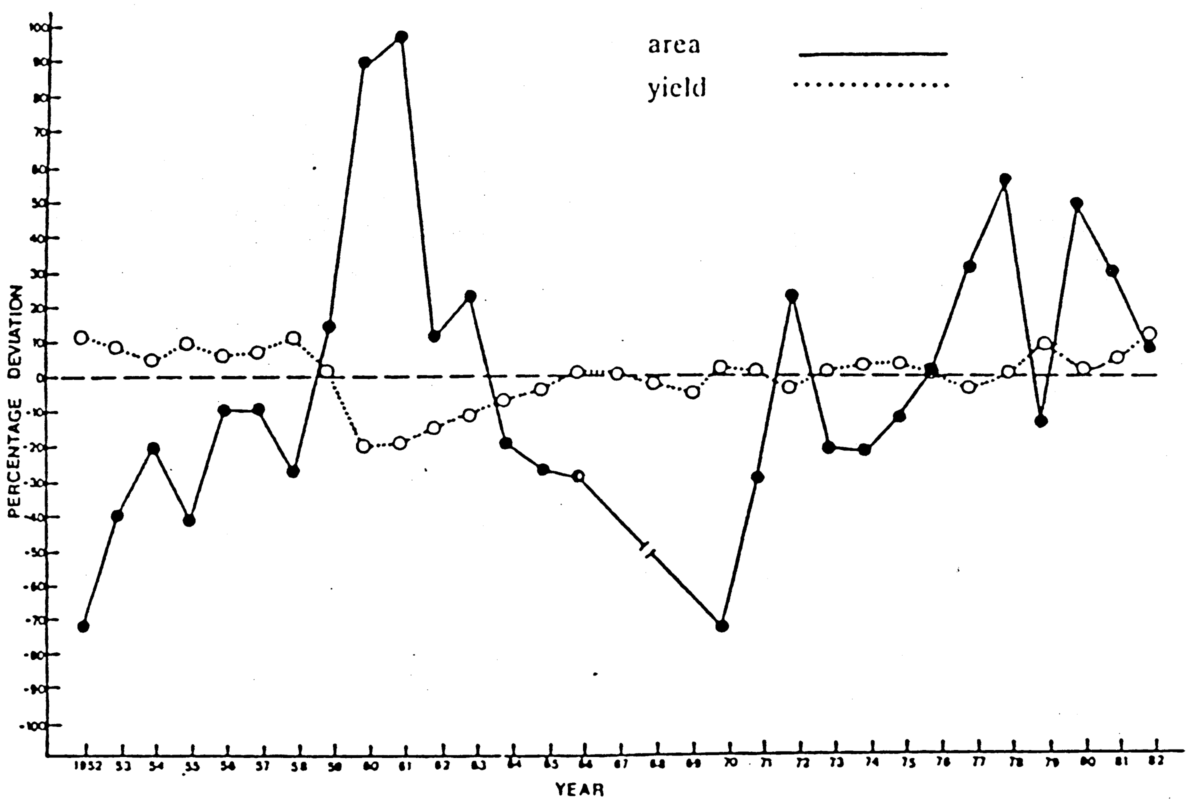
12 Average yield instability index values = $$\frac{\sum_{t=1}^{n} \left| \frac{Y_t - Y_t'}{Y_t} \right| \cdot 100}{N}$$

where

Y_t = aggregate foodgrain yield in year t
Y_t' = logarithmic least squares estimate of the trend grain yield value in year t
N = number of years in the sub-period

(Kueh 1983, pp. 16-17; 1984b, pp. 76-77).

Figure 3--Relationship of Aggregate Foodcrop Yield and Shouzai Area Deviations from Means, 1952-82



Note: Yearly percentage deviations of grain yield in China from log-linear trend values in relation to the deviations of the size of shouzai (natural disaster affected) areas from the long-term mean, 1952-82. For further explanation, see text.

Source: Kueh (1986), p. 101.

grain yield, the influence is not significant. His conclusions of the centrality of changes in fertilizer supplies in determining growth in Chinese foodcrop yields follows Stone (1980) and is further developed in Stone (1986a).

In order to quantify "policy influences," Kueh (1986) regresses his weather index and a "Maoist" dummy for 1958-60 and 1973-78 on grain yields. A negative sign for the dummy's coefficient is only obtained for the 1970-82 period and it is still less statistically significant than that of weather. Kueh concludes that "the Maoists were rather irrelevant as a yield determinant" and credits the "subsistence urge" of the Chinese peasants which "drives them to adopt whatever measures may be available to mitigate weather impact ... (and resist) adverse policy changes" (Kueh 1986, p. 103).

Finally, Kueh (1984b, 1986) reads in the *shouzai* data some cyclical pattern of climatic change:

> Nearly a decade of favorable weather in the 1950s gradually ended up in large-scale anomalies in the early 1960s. Thereafter the trend was reversed up to the positive climax in 1970 before the weather entered into another decade of deterioration. Initial information for 1983 and 1984 suggests that these years may signal the advent of another favorable weather cycle (Kueh 1986, p. 101).

In reviewing the aforementioned publications, it is difficult to disagree with Kueh's conclusion that weather has declined in importance in determining aggregate foodcrop production variability in China. And while it will be shown below that other factors have increased as sources of aggregate variability, it is difficult not to reject Tang's conclusion that People's Republic efforts to weather-proof Chinese agriculture have been wholly unsuccessful, even independent of these developments.

As to the exact importance of weather in Chinese agriculture, relative to other factors, it appears that no studies to date have successfully quantified this relationship. Although poor policy and administration were clearly contributory to agricultural catastrophes of the 1959-62 period, the importance of exceptionally poor weather in consecutive years was undoubtedly very great. In many other years, it is possible to demonstrate the influence of weather on aggregate production and yields. But that influence does not appear at all important in determining trend, and of some but limited importance to aggregate variability. This appears to be so despite the stubbornly high ratios of disaster-affected area and their severely affected proportions (Table 1).

A preferable interpretation is that trend growth rates in foodgrain production and marketed ratios were too slow to accommodate requirements given the distribution of that growth. And that has adversely influenced the rate of growth of non-agricultural sectors (Stone 1980, 1986c, 1987, Ishikawa 1986). Under these circumstances, even relatively small aggregate shortfalls, for whatever reason, are of some inflated economic significance.

In passing, it must be noted that the regression of Kueh's weather index on aggregate yield is also somewhat circular, and conclusions based upon these data must be examined with caution. *Chengzai* area and probably even *shouzai* area are defined in terms of actual yield loss, from whatever factors, both weather- and non-weather-related. There have been social, political, and economic incentives for local units and administrators to declare all yield losses as weather-related. Kueh's weather index is heavily weighted toward the *chengzai* series, for which this type of problem would be most severe. The *shouzai* series covers very large proportions of cultivated area and the *chengzai* (severely affected) proportion is fairly significant. Kueh is therefore regressing a multiple proportion of aggregate yield variability (including weather- and non-weather-related components) on total aggregate yield and calling this the influence of weather variability on yield variability. But it would be an overreaction to conclude, however,that his entire analysis based on these disaster-related area series is without value.

On the other hand, Kueh's exercise concluding little importance of policy to yield variability is too facile and minor to be taken seriously. Tang's arguments for policy cycles and their impact on agricultural production provide some different, even if not completely defensible, support for observations made by others (Eckstein, Skinner, and Winckler, Stone 1980). Among them, Tang and Skinner and Winckler have made the most interesting and energetic efforts. But even they leave much unanswered in detailing exactly how policy cycles affect farm production.

Finally, Kueh's suggestions about the existence of weather cycles in China and their importance in explaining aggregate yield variability would not sustain the scrutiny of agro-climatologists. Aside from the circular difficulties with the disaster-area classification mentioned above, consistency of this series among time periods is taken wholly on the basis of assumption.

The existence of cycles or longer-term trends in weather variability cannot be taken for granted. Rosenberg (1986) and Carter and Parry (1986) have reviewed a large number of studies by climatologists relating to changes in climatic variability over time. They have included no studies for China in their thorough reviews. Although this does not imply that no such studies exist within China, Chinese climatologists in touch with the international community do not appear to have mentioned them. In general, both studies seem to reject the notion that there is evidence for a consistent global pattern of change in variability over time.

There is some evidence of regional changes although it is often difficult to discern whether these are part of medium- or longer-term trends. A tendency toward decreased interannual mean monthly temperature variability between the 1930s and the 1970s was observed for the Midwestern United States, and a significant decrease in the mean diurnal temperature range has been observed over much of the United States and Canada during the 1941-80 period. The period 1937-45 was a particular calm period for seasonal temperature means in the United States, and the 1950s through the mid-1970s was relatively calm. Since then, variability in temperature has been greater; and it was especially great between 1895 and 1937. The recent increased irregularity of the Indian monsoon (1960s and 1970s relative to 1925-60) and the periodic intensification of Sub-Saharan drought within the 1875-1977 period have been related by researchers to El Niño/Southern Oscillation events. But many other studies show no regional evidence of changes in climatic variability.

More to the point, increased climatic variability does not necessarily mean increased variability in crop production or yields. Such a relation is most likely to be pronounced in marginal agricultural areas where the value of a particular climatic indicator is a predominant limitation on productivity. In China, such areas exist (were changes in climatic variability to be demonstrated), but they account for a small proportion of aggregate production for most crops. Both studies, as well as Oram (1985), seem to support the notion that intertemporal changes in agricultural sensitivity to climatic variability are apt to be more important sources of change in yield variability than changes in climatic variability *per se*, except in, and perhaps including, marginal farming areas. These shifts may be due to a variety of technological, economic, and social factors. Some of the most interesting sections of Kueh's (1983) article discuss such factors for the Chinese case. To these may be added related discussions for China by Stone (IFPRI/BIDS, Stone 1987a, Desai and Stone).

No one has attempted to discreetly quantify these influences which include several which have worked toward greater and several toward lesser sensitivity over time. Kueh and Stone seem to share the tentative impression that the net effect of such factors has tended to reduce Chinese sensitivity of aggregate production to weather variability during much of the People's Republic period, with some notable exceptions, but that this hypothesized trend may be shifting, at least temporarily, in the most recent period. Of greatest interest may be current shifts in the sensitivity of food consumption among vulnerable demographic groups to climatic or generalized production variability in China (Kueh 1983, Stone and Tong 1985, Stone 1986c, 1987a). These include not only Chinese in chronically impoverished and disaster-prone localities in China, but non-Chinese affected by significant increases in the variability of Chinese international traded volumes of farm commodities during the recent decade. But it is now appropriate to return to the principal task of providing a more precise understanding of the composition of increases in foodcrop production variance.

A BASIC SKETCH OF FOODCROP PRODUCTION VARIABILITY IN CHINA, 1931-85

The coefficient of variation (cv) is one simple but useful tool for comparing production variability among periods exhibiting large differences in mean production levels. Figures 4, 5, and 6 plot cvs of production, area, and yield for wheat, rice, maize, and total foodcrops for consecutive five-year periods against the mid-points of these periods. First of all, the late 1950s and early 1960s stand out as a period of particularly high variability for production, area, and yield of each individual crop and for total foodcrops. In addition, aside from this period, two general conclusions can be drawn about long-term trends in cvs: (a) the coefficients for area have, if anything, been falling during the 55-year period examined, although slightly rising coefficients during the past decade cannot be ruled out; (b) there is little evidence of single 55-year trends for the production and yield coefficients. There are, however, a few other peculiar sub-periods of higher cvs for particular crops.

It must be noted from Table 2 that foodcrop production variability for China as measured by the coefficient of variation is generally low relative to other even large countries and regions. This becomes even more obvious if the period extending from the late 1950s to the early 1960s is not used for the international comparisons. Since local yield losses of 60-100 percent are well documented in China historically (Buck 1937; Stone 1980, pp. 108-9), and continue in some parts of China even to the present, this suggests a greater degree of averaging out across China among localities experiencing good years and those experiencing poor years, than is typical elsewhere; or it may be evidence of a system in which the major production areas are relatively well insulated from shortfalls. These issues will be taken up in later sections. But before proceeding, it may be useful to discuss the few anomalous sub-periods exhibiting higher cvs for particular crops during the People's Republic period.[13]

The outstanding sub-period to explain is undoubtedly the late 1950s and early 1960s. The story behind these problems has received a great deal of scholarly attention which will not be reviewed. But a brief description of the major events is in order.

At the time, Chinese reports blamed the poor and erratic performance upon consecutive years of catastrophic weather. But the period of greater sown area variability appears to predate those for production and yield, and Western observers have emphasized the dis-

---

13 The succeeding discussion follows Stone and Tong (1987) which provides references. However, the hypotheses generated to account for the anomalous periods remain quite conjectural. In particular, data on input use by crop is essential to examination of these phenomena, especially in view of China's fertilizer distribution system characterized by a high degree of central allocation (Stone 1984b, 1986a, 1986b).

Figure 4 -- Coefficients of Variation for Yields of Foodcrops in China - 1931 to 1946, 1951 to 1985

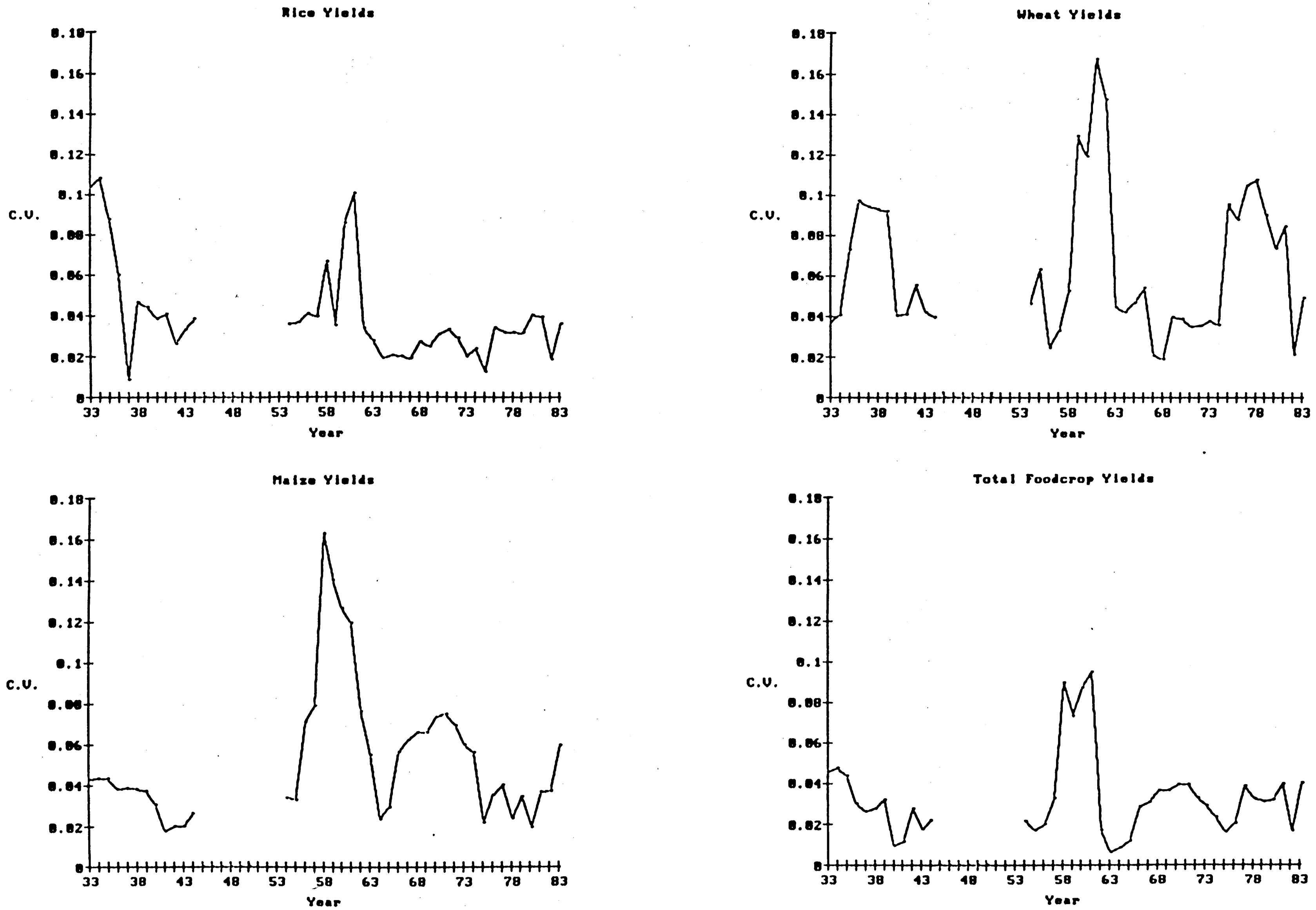


Figure 5 -- Coefficients of Variation for Sown Area of Foodcrops in China -
1931 to 1946, 1951 to 1985

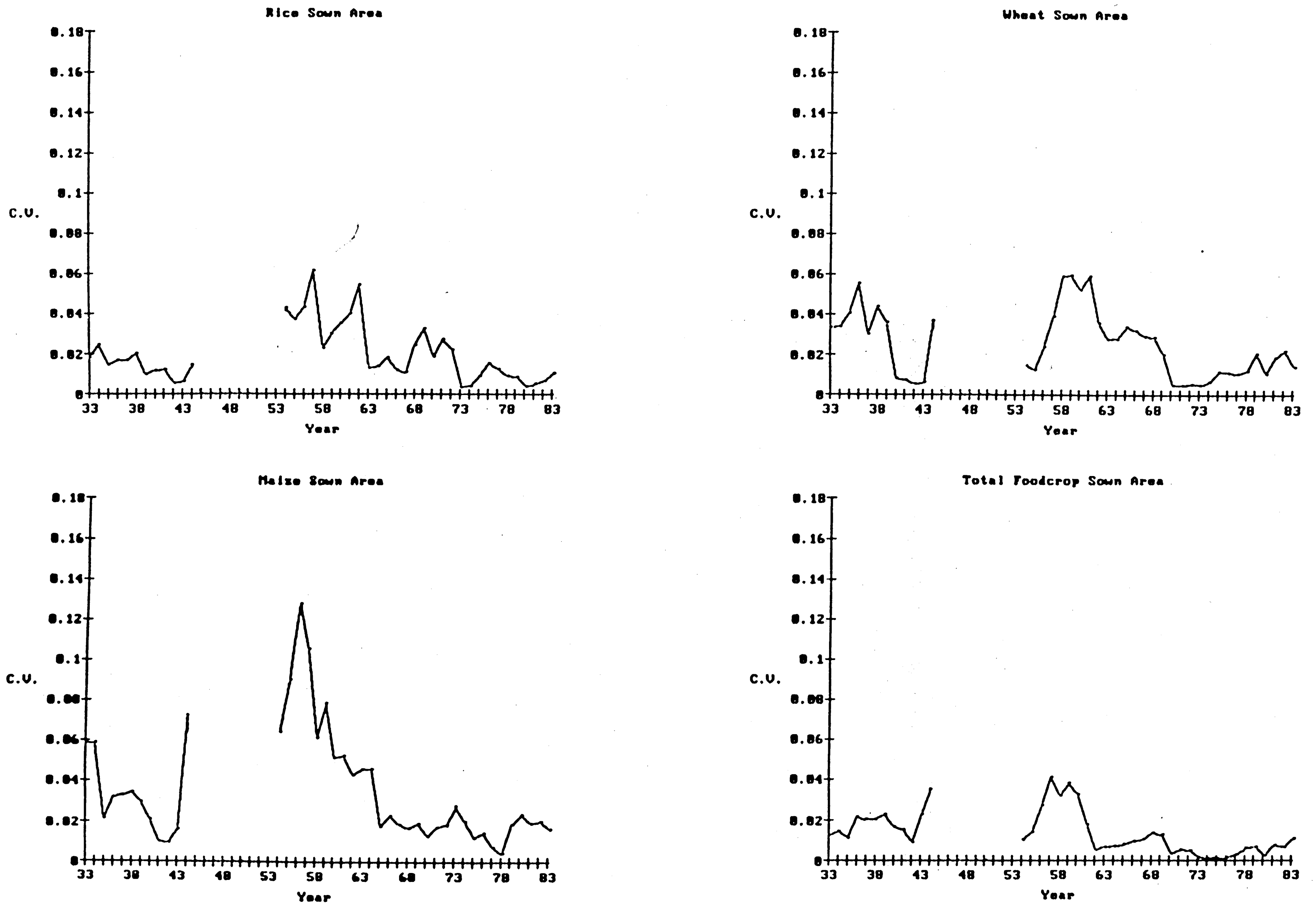


Figure 6 -- Coefficients of Variation for Production of Foodcrops in China - 1931 to 1946, 1951 to 1985

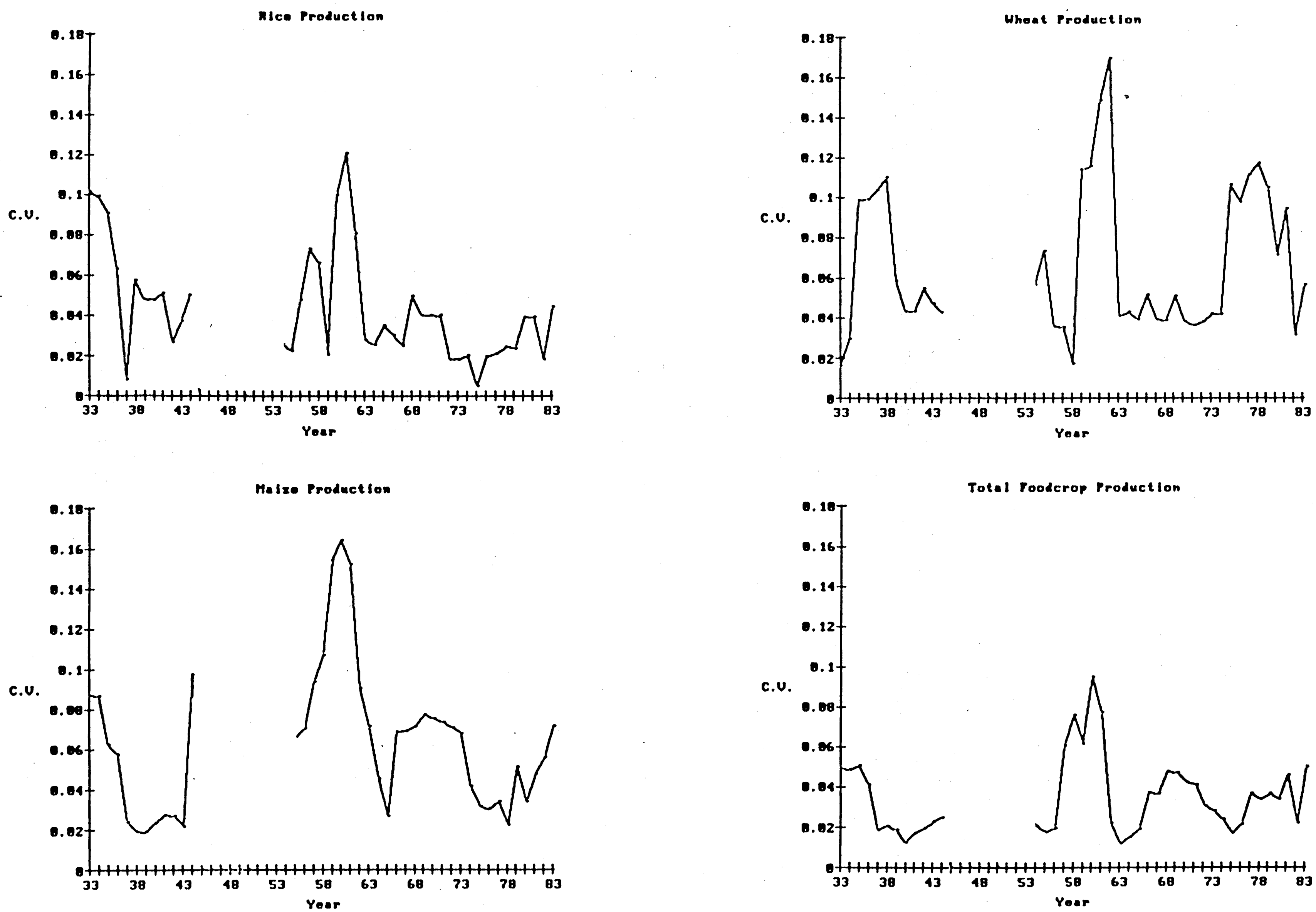


Table 2. Changes in the Mean and Variability of Total Cereal Production by Region: 1960/61-1970/71 to 1971/72-1982/83

Region	Average Production			Coefficient of Variation of Production			F-Ratio			Probability of 5 Percent Shortfall Below Trend	
	First Period	Second Period	Change	First Period	Second Period	Change	Production	Area Sown	Yield	First Period	Second Period
	(1,000 metric tons)		..........(per cent).............							(percent)	
Africa-rice	2,248	2,798	24.5	5.75	4.13	-28.2	0.81	3.25**	0.95	19.2	11.3
Africa-wheat/barley	5,661	7,251	28.1	28.12	18.45	-34.4	0.70	0.75	0.81	42.9	39.4
Africa-sorghum/millets	14,069	17,302	23.0	8.45	5.47	-35.3	0.63	0.87	0.29**	27.8	18.1
Africa-maize	27,015	34,618	28.1	7.17	7.81	8.9	1.96	0.78	2.03	24.2	26.1
USA	181,982	265,022	45.6	6.84	6.64	-2.9	1.97	1.24	8.23***	23.3	22.6
Canada	30,321	40,576	33.8	17.22	10.67	-38.0	0.68	0.22***	0.44*	38.6	31.9
C. America-rice	642	912	42.1	11.12	6.51	-41.5	0.68	1.81	0.20***	32.6	22.1
C. America-maize	12,678	18,377	45.0	5.51	9.75	76.9	6.66***	8.55***	3.94**	18.1	30.5
S. America-wheat/barley	19,439	26,234	35.0	10.85	12.35	13.8	2.39*	1.05	2.14	32.3	34.5
S. America-rice	2,741	4,186	52.7	3.74	9.35	150.0	14.23***	9.28***	11.04***	9.0	29.5
S. America-maize	18,222	28,402	55.9	4.90	8.23	68.0	6.78***	4.16**	2.56**	15.4	27.1
Oceania-wheat/barley	13,149	18,311	39.3	18.83	21.92	16.4	2.61*	1.61	1.64	39.4	40.9
S. Asia-rice	18,798	23,347	24.2	6.30	4.03	-36.0	0.63	0.32**	0.76	21.5	10.9
S. Asia-wheat/barley	11,227	17,073	52.1	7.74	3.05	-60.6	0.36*	4.05**	0.42*	25.8	5.1
India	74,752	104,000	39.1	7.65	5.42	-29.2	0.97	0.65	0.92	25.8	17.9
E. Asia-rice	35,505	50,798	43.1	4.17	3.86	-7.4	1.74	1.28	1.13	11.5	9.9
N. Asia-rice	19,832	17,620	-11.1	5.33	8.57	60.8	2.04	0.26**	4.96***	17.3	28.1
M. East-wheat/barley	23,699	31,681	33.7	5.99	8.18	36.6	3.33**	3.08**	2.84*	20.1	27.1
Europe-wheat/barley	142,430	192,104	34.9	3.84	4.96	29.2	3.03**	1.05	2.98**	9.7	15.6
Europe-wheat/barley	30,509	44,644	46.3	9.29	4.07	-56.2	0.41*	0.33**	0.39*	29.5	10.9
USSR	138,436	180,952	30.7	12.16	14.26	17.3	2.35*	1.28	1.69	34.1	36.3
World (excl. China)	829,215	1,133,902	36.7	2.78	3.37	21.2	2.75*	2.18	2.73*	3.5	6.9
China-rice	86,944	136,643	57.2	6.77	4.05	-40.1	0.81	0.37*	1.40	23.9	12.7
China-wheat	24,122	52,203	116.4	6.62	9.57	44.5	8.90***	0.90	6.07***	23.5	29.9
China-maize	25,402	51,735	103.7	7.33	5.63	-23.2	2.22	1.36	1.27	25.5	19.7
China-total foodcrops	200,387	305,845	52.6	4.27	4.15	-2.7	2.00	0.72	3.25**	14.1	13.2

Sources: For all but China, Hazell (1985), p. 150. The Chinese figures were computed for this paper based on PRC, State Statistical Bureau (1984, 1986).

Note : ***, **, and * indicate statistically significant F-ratios (one-tail tests) at the 1, 5, and 10 percent confidence levels, respectively. The first period is from 1960/61 to 1970/71; the second period is from 1971/72 to 1982/83. "Foodcrops" are defined in note 3. Data are for total cereals if not specified.

locating policies of the Great Leap Forward period. Recent Chinese analysts have also emphasized policy-induced disaster (Kueh 1984b, p. 80), as have Walker (1984) and Lardy (1983).

During this period, the State Statistical Bureau was disbanded and reporting units came under considerable pressure to report policy successes. Orders for close planting resulted in soil erosion, and poorly designed and managed irrigation facility construction in 1958 and 1959 brought about an increase in salinization of an additional 1.3 million hectares in Hebei, Henan, and Shandong alone, as well as affecting north Anhui and Jiangsu. Despite reclamation efforts, most of these provinces did not regain their pre-1958 food production levels until the late 1960s or early 1970s, and have never fully recovered the previous area under cultivation (Stone 1983a). With grossly exaggerated reports of grain production growth in 1958 rolling in, the area sown with non-grain crops in 1959 was increased at the expense of grain. By the time the true grain production level was understood in April 1959, it was too late (Li 1962, Chao 1970, and Walker 1984). To make matters worse, 1959 yields were low, due to poorer weather. Devastating weather in 1960 and the political and administrative chaos precipitated by famine, had devastating effects on subsequent production.

In contrast to the period from the late 1950s to the early 1960s for which major increases in the cv were common to production, area and yield for each crop, major cv increases since the mid-1960s were confined to yield and production. The declining trend in the cvs for areas sown to grain, reflected even to the extent of declining cvs for each grain crop, may be ascribed to increasing administrative control over sown area in China and relatively stable markets provided by state for purchase of important foodcrops in the major growing areas.

The area cvs tended to increase after the mid-1970s, with increasing decentralization of production decisions to individual farm families. Yet the relative weakness of this increase is a testament to the inertia for control over areas operating through agricultural administration and perhaps embedded in farmers' own decisionmaking processes. Though the decontrol is genuine in principle, substantial sown area planning efforts continue in many regions.

Significant cv increases in production and area since the mid-1960s are confined to particular crops, unlike the initial period of instability. The marked increase in maize yield cvs during the 1960s and early 1970s is difficult to investigate due to lack of data. The pattern is not easily explainable by weather or rapid expansion into risk-prone farm areas. Most Chinese maize is subject to damage from frost, drought, heat and waterlogging, and area is concentrated in particularly risky regions (e.g., North and Northeast China). But wheat has also been grown in very risk-prone areas and irrigation of wheat did not accelerate until the 1970s, when its rising cv path paradoxically crosses the declining path for maize. This occurred just as total maize area began to expand rapidly and not onto particularly secure areas. But the decline in the maize yield cv during the 1970s does coincide with the introduction of disease-resistant varieties. Given the scanty data available, the following hypothesis may explain the path of maize yields and yield cvs.

Maize yield cvs increased rapidly in the 1950s, due to rapid growth in sown area concentrated in the Northeastern provinces of Liaoning, Jilin, and Heilongjiang and the adjacent North China provinces of Hebei and Shandong. Maize areas in these regions are highly risk-prone (Stone et al. 1985), and weather patterns are highly correlated, further accentuating the increase in cvs. Maize cvs continued to increase around the turn of the decade due to the various difficulties affecting all crops discussed above.

The anomaly then becomes, not the higher maize cvs of the later 1960s, but the sharp decline in cvs during the 1962-64 period to values below those of the 1950s. There is some statistical evidence that maize area was cut back sharply in 1962 in response to maize disease epidemic in 1961. While maize area recovered somewhat in 1963, it remained quite constant during 1963-65, and well below the aggregate levels of the middle and late 1950s. Weather, according to Kueh's (1984b and 1986) analyses, remained relatively favorable throughout this period and featured very similar and low aggregate estimates of gross crop damage. Subsequently, as maize area recovered in the Northeast, yield variability increased. The year 1966, in particular, was reported as one of especially widespread maize disease, while the increased weather variability and highly correlated weather patterns of the expansion region would contribute to higher cvs throughout the late 1960s.

Disease-resistant hybrids covered 40 percent of maize area by 1973 and 60 percent by 1978. With their success, maize area surpassed the 1950s peak years for the first time in 1974 and actually exceeded wheat area in a few years at the turn of the decade. Although irrigation of maize is increasing, most maize remains rainfed and the drop in cvs cannot be primarily ascribed to irrigation. It may be associated with the lower disease susceptibility of the single-cross hybrids, and rapid expansion of area into regions for which weather patterns are not correlated with those of the Northeast and the northeastern North China Plain.

Rapid dissemination of semi-dwarf wheat varieties and rapid area expansion in highly correlated areas may also explain the increase in wheat cvs in the mid-1970s and early 1980s. The principal growth region in the 1960s was North China, characterized by highly correlated internal weather patterns and increased irrigation of winter wheat. In fact, irrigation provision was often a requisite condition for winter wheat introduction in the North. However, more irrigated wheat did not necessarily provide greater stability against drought, the predominant yield risk in the region. Irrigation facilities may have proved unreliable: in some years providing much higher yields and in others, no change from the "unirrigated" state. This could be particularly destabilizing in the aggregate if "unreliability", as well as weather patterns, were highly correlated.

For surface irrigation there is considerable evidence that this is so. When winter wheat in North China requires irrigation, no rain usually means no river flow. The Yellow River remains the major exception, but its water has been difficult to use due to high silt content. The years 1976, 1977 and 1978 all had poor weather with the principal disaster areas falling within North China, and the principal disaster being drought.

Since a large portion of North China irrigation development has been tubewell construction during the late 1960s and 1970s, correlated yield failures may be due to a major administrative failure to deliver key requisite inputs. This could indeed have happened during the chaotic period associated with the "Gang of Four" successional struggle. For example, there is some evidence that agricultural users were among those most heavily penalized during the 1978 electrical shortage within the North and Northeast power grids, but the availability of detailed information on this type of topic is low.

Why have foodgrain production cvs not fallen during the past four decades? If the data midpoints in Figure 1 corresponding to the Great Leap Forward (1958-59) policies and the catastrophic weather (1960-61) are taken as an exceptional period of instability, then study must focus on the periods represented by the midpoints of 1954-56 and 1964-83, providing no clear evidence of long-term decline in cvs. Yet China's reduction of weather-related agricultural risk for thousands of localities, is well-known. Irrigated area increased from 16 to 45 million hectares (around 45 percent of cultivated area) and its security vastly improved. Flood control efforts have achieved considerable success. Modern varieties combining improved maximum yields with locality-specific weather and disease tolerances have been developed along with considerable breeding for earlier maturing varieties. The resulting aggregate multiple cropping index increased from 1.2 to 1.5, thereby reducing the annual aggregate production risk associated with very bad weather in any one season.

Consequently "high and stable yield" areas now comprise one-third of cultivated area, around one-half of sown area, and must account for not less than 3/4 of national grain production. On a local basis, 60-100 percent local yield failures, common during the 1930s and 1950s, appear to have been eliminated in most major producing areas, although they continue to menace more marginal localities. On an aggregate basis, the worst weather years since 1960-61 have been 1977, 1978, and 1980 (Kueh 1984b, p. 74). Although Kueh has estimated these disasters to have been only 35-60 percent of the severity and farmland coverage of the 1960-61 catastrophes, there was proportionally little aggregate grain production penalty. Why then have production cvs not declined since the 1950s? The succeeding sections will try to answer this question and will also attempt to clarify the issues relating to the increases in wheat production cvs since the early 1970s.

METHOD OF ANALYSIS

The analysis of changes in Chinese foodcrop production variance was conducted for three basic pairs of periods: (a) 1930s and 1950s; (b) 1950s and 1980s; and (c) 1930s and 1980s. Auxiliary runs were also conducted to (a) test the sensitivity of the results to the inclusion of certain newly released provincial data for 1957 which falls markedly below the official estimates released during 1957-58 for most provinces; and (b) to test the sensitivity of the results to the termination date of the 1980s period.

The methodology used for these pair-wise comparisons follows Hazell (1982, 1984, 1985) and Bohrnstedt and Goldberger. Let Q denote production, A the area sown, and y yields. Also, letting subscripts i and j denote crops, and h and k denote provinces, total foodcrop production for a country is $Q = \Sigma_h \Sigma_j A_{hj} y_{hj}$. Average production is

$$(1) \quad E(Q) = \Sigma_h \Sigma_j E(A_{hj} y_{hj}),$$

and the variance of production is

$$(2) \quad V(Q) = \Sigma_h \Sigma_k \Sigma_i \Sigma_j \operatorname{cov}(A_{hi} y_{hi}, A_{kj} y_{kj}).$$

The variance can be expanded as

$$(3) \quad V(Q) = \Sigma_h \Sigma_j V(A_{hj} y_{hj}) + \Sigma_h \Sigma_{i \neq j} \Sigma_j \operatorname{cov}(A_{hi} y_{hi}, A_{hj} y_{hj})$$

(Sum of individual crop variances within provinces) (Sum of intercrop covariances within provinces)

$$+ \Sigma_j \Sigma_{h \neq k} \Sigma_k \operatorname{cov}(A_{hj} y_{hj}, A_{kj} y_{kj}) + \Sigma_{h \neq k} \Sigma_k \Sigma_{i \neq j} \Sigma_j \operatorname{cov}(A_{hi} y_{hi}, A_{kj} y_{kj}).$$

(Sum of interprovince covariances within crops) (Sum of covariances between different crops in different provinces)

Each of the component terms can be expanded as follows:

$$(4) \quad E(A_{hj} y_{hj}) = \bar{A}_{hj} \bar{y}_{hj} + \operatorname{cov}(A_{hj}, y_{hj}),$$

and, following Bohrnstedt and Goldberger,

$$\begin{aligned}(5) \quad \operatorname{cov}(A_{hi} y_{hi}, A_{kj} y_{kj}) = {} & \bar{A}_{hi} \bar{A}_{kj} \operatorname{cov}(y_{hi}, y_{kj}) \\ & + \bar{A}_{hi} \bar{y}_{kj} \operatorname{cov}(y_{hi}, A_{kj}) + \bar{y}_{hi} A_{kj} \operatorname{cov}(A_{hi}, y_{kj}) \\ & + \bar{y}_{hi} \bar{y}_{kj} \operatorname{cov}(A_{hi}, A_{kj}) - \operatorname{cov}(A_{hi}, y_{hi}) \operatorname{cov}(A_{kj}, y_{kj}) + R,\end{aligned}$$

where $\bar{A}$ and $\bar{y}$ denote mean areas and yields, and R is a residual term consisting of higher-order cross moments.

The decomposition analysis partitions the changes in V(Q) and E(Q) between the first and second periods into constituent parts. This involves decomposing the changes in each of the terms in equations (1) and (3) with the aid of equations (4) and (5) and then summing up the changes in different components over provinces and crops. (For a full exposition of this method, see Hazell 1982).

Using equation (4) but ignoring crop and province subscripts for simplicity, average production in the second period is

$$(6) \quad E(Q_2) = \bar{A}_2\bar{y}_2 + \text{cov}(A_2, Y_2).$$

Each variable in the second period can be expressed as its counterpart in the first plus the change in the variable between the two.[14] Equation (6) therefore can be written as

$$(7) \quad E(Q_2) = (\bar{A}_1 + \Delta\bar{A})(\bar{y}_1 + \Delta\bar{y}) + \text{cov}(A_1, y_1) + \Delta\text{cov}(A, y).$$

The change in average production is then obtained from

$$(8) \quad \Delta E(Q) = E(Q_2) - E(Q_1) = \bar{A}_1\Delta\bar{y} + \bar{y}_1\Delta A + \Delta\bar{A}\Delta\bar{y} + \Delta\text{cov}(A, y).$$

There are four sources of change in $\Delta E(Q)$. Two parts, $\bar{A}_1\Delta\bar{y}$ and $\bar{y}_1\Delta\bar{A}$, arise from changes in the mean yield and the mean area. These "pure" effects arise even in the absence of other sources of change. The term $\Delta\bar{A}\Delta\bar{y}$ is an interaction effect and $\Delta\text{cov}(A, y)$ arises from changes in the covariability of areas and yields.

The change in the variance of production can be decomposed in an analogous way. Using equation (5), the change in each of the production variance and covariance terms can be decomposed as in Table 3.

THE DATA, IMPLICATIONS OF SELECTED DATA PERIODS, AND DETRENDING

The periods used for studying structural change in foodcrop production variance during the People's Republic period are 1952-57 and 1979-85. Data on Chinese production and sown area of foodcrops disaggregated by crop and by province are available in PRC Zhongguo Nongye Nianjian (1980, 1981, 1982, 1983, 1984, 1985, 1986).

The best published compendium of 1950s foodgrain production, area, and yield data is Walker (1984). But this material contains some

---

[14] An alternative procedure is to use period 2 as the base. However, as Hazell (1982) shows, this leads to a confounding of the pure and interaction effects.

Table 3. Components of Change in Production Covariances

Source of Change	Components of Change
Change in mean yields	$\bar{A}_{1i}\Delta\bar{y}_j cov(y_{1i},A_{ij}) + \bar{A}_{1j}\Delta\bar{y}_i cov(\bar{A}_{1i},\bar{y}_{1j})$ $+ [\bar{y}_{1i}\Delta\bar{y}_j + \bar{y}_{1j}\Delta\bar{y}_i + \Delta\bar{y}_i\Delta\bar{y}_j] cov(A_{1i},A_{1j})$
Change in mean areas	$\bar{y}_{1i}\Delta\bar{A}_j cov(A_{1i},y_{1j}) + \bar{y}_{1j}\Delta\bar{A}_i cov(y_{1i},A_{1j})$ $+ [\bar{A}_{1i}\Delta\bar{A}_j + \bar{A}_{1j}\Delta\bar{A}_i + \Delta\bar{A}_i\Delta\bar{A}_j] cov(y_{1i},y_{1j})$
Change in yield variances and covariances	$\bar{A}_{1i}\bar{A}_{1j}\Delta cov(y_i,y_j)$
Change in area variances and covariances	$\bar{y}_{1i}\bar{y}_{1j}\Delta cov(A_i,A_j)$
Change in area-yield covariances	$\bar{A}_{1i}\bar{y}_{1j}\Delta cov(y_i,A_j) + \bar{y}_{1i}\bar{A}_{1j}\Delta cov(A_i,y_j)$ $- [cov(A_{1i},y_{1i}) + \Delta cov(A_i,y_i)\Delta cov(A_j,y_j)$ $- cov(A_{1j},y_{1j})\Delta cov(A_i,y_i)$
Interaction between changes in mean yields and mean areas	$\Delta\bar{A}_i\Delta\bar{y}_j cov(y_{1i},A_{1j}) + \Delta\bar{y}_i\Delta\bar{A}_j cov(A_{1i},y_{1j})$
Interaction between changes in mean areas and yield variances	$[\bar{A}_{1i}\Delta\bar{A}_j + \bar{A}_{1j}\Delta\bar{A}_i + \Delta\bar{A}_i\Delta\bar{A}_j]\Delta cov(y_i,y_j)$
Interaction between changes in mean yields and area variances	$[\bar{y}_{1i}\Delta\bar{y}_j + \bar{y}_{1j}\Delta\bar{y}_i + \Delta\bar{y}_i\Delta\bar{y}_j]\Delta cov(A_i,A_j)$
Interactions between changes in mean areas and yields and changes in area-yield covariances	$[\bar{y}_{1j}\Delta\bar{A}_i + \bar{A}_{1i}\Delta\bar{y}_j + \Delta\bar{A}_i\Delta\bar{y}_j]\Delta cov(y_i,A_j)$ $+ [\bar{y}_{1i}\Delta\bar{A}_j + \bar{A}_{1j}\Delta\bar{y}_i + \Delta\bar{y}_1\Delta\bar{A}_j]\Delta cov(A_i,y_j)$
Change in residual	$\Delta cov(A_i y_i,A_j y_j)$ - sum of the other components

trended entries and other estimates made on bases unsuitable for a variance decomposition analysis. Additional material has been synthesized or adopted from scattered, recently published provincial statistical manuals cited among the references and from previous compendiums based on original sources (including Chen, SSRC, CIA, Wiens (1980), and Schuman). This time-consuming research has resulted in disaggregated series for 1952-57 of acceptable quality to attempt variance decomposition studies. Data reported by provincial authorities within the People's Republic period prior to 1952 and for 1958-61 are of much more questionable reliability (Wiens 1980, Stone 1983). Data for 1962-78 are in varying degrees superior to data for these past periods, but typically inferior to those for 1952-57 and 1979-85 in terms of availability, continuity, and reliability.

The data for the study, therefore, exhaust the only adequate disaggregated data available at the time the decomposition was conducted, of sufficient quality and continuity for a variance decomposition during the People's Republic period: 1952-57 and 1979-85. Even within these temporal limitations, data for a number of crops and provinces had to be excluded from the 1950s data and hence from the study, due to insufficiently independent estimates for consecutive years or other problems of reliability. The final data therefore cover only wheat (for 21 of 26 provinces), rice (for 18 provinces) and "other foodcrops" as a group.[15] It was possible to include, however, almost all the important wheat and rice producing provinces: (covering 97 percent of 1983 national production for wheat; 85-86 percent of national production of rice).

Six of the eight excluded provinces for rice are in the West or Northwest and produce very little. Rice is important, however, for the remaining two coastal provinces south of the Yangzi River in the East, Zhejiang and Fujian, which produced, respectively, 7.7 and 4.5 percent of national rice output in 1983. Of the five excluded provinces for wheat, none produced more than around one percent of national output, although wheat is a relatively important crop for two of the excluded western provinces, Qinghai and Ningxia.

In general, the newly published provincial material for 1952-57 is consistent with that published during and shortly after the period. However, a number of provinces have published new data for 1957 (previously believed to be the most reliable data year) which are substantially lower than those published earlier. The adopted data for 1952-56 have not been adjusted downward because newly published data for some provinces are not available for most or all of those years and, where available, downward adjustments do not seem to have been made by provincial statistical authorities.

---

15 See note 3 for "other foodcrop" inclusion. Sweet potato and white potato production is valued at one-fifth natural weight. For a list of included provinces, see Tables 6-8.

The more important question for the variance decomposition is not whether the newly published 1957 data are more accurate than the old figures, but whether they are more consistent with the 1952-56 figures, whatever the degree of accuracy. Since the answer to this question is unclear, separate runs have been conducted, including and excluding that subset of newly published 1957 provincial data which appears inconsistent with previously published data.

While chosen solely on the basis of data availability, continuity and reliability, the two periods are fully appropriate for a comparison of pre-and post "green revolution" patterns. Seed selection and strain improvement along with organic fertilization had been traditional in Chinese agriculture. However, synthetic fertilizer application was not widespread in China until the late 1960s.[16]

Semi-dwarf rice varieties were first developed in Chinese research institutions during 1956-1959 and high-yield hybrid rice, a fully Chinese technical innovation, was first grown by farmers in 1975. Semi-dwarf wheat varieties from Chinese-Mexican crosses were initially planted on farmers' fields in 1973, although imported fertilizer-responsive varieties were used on farms at least by 1957 and Chinese research institutions and breeding stations were releasing their own varieties by 1960. Double-cross hybrid maize was released around 1958-59 and occupied a large share of maize area in the mid-1960s, but proved susceptible to disease over large areas in 1961 and 1966. New single cross maize hybrids were developed and released in the late 1960s and recovered to 40 percent of maize area by 1973 and 60 per cent by 1978.

By 1977, high-yielding dwarf rice varieties were sown on around 80 percent of China's rice area and in 1985 the proportion was around 95 percent. On-farm use of hybrid rice expanded quickly from its introduction in 1975 to 12.6 percent of rice area in 1978, 14.8 percent in 1979, 20.4 percent in 1983, and 26.4 percent in 1985. Hybrid area in 1986 may reach 36 percent and a new higher-yielding generation of hybrids are already being released (Stone 1984a, Stone and Tong 1985, 1987, PRC Zhongguo Nongye Nianjian 1984, 1986, PRC Xinhua 1987).

If semi-dwarf wheat can be construed to include all varieties under 105 cm at maturity, semi-dwarfs exceed 70 percent of Chinese wheat area. If the standard is 100 cm, the proportion is around 55 percent. If a standard of 85 cm is employed, the proportion is much smaller, but grew rapidly from 10 percent in 1980 to more than 30 percent in 1983.

Application of manufactured fertilizers averaged 0.6 kg/ha in 1952 and 2.4 kg/ha in 1957. By 1979 average rates reached 73 kg/ha, rising to 115 kg/ha by 1983 and 124 kg/ha by 1985. These exceed

---

[16] Unless itemized below, sources for the following material on HYV introduction are provided in Stone and Tong (1985, 1987).

average rates in most other nations (Stone 1986a, PRC State Statistical Bureau 1986, FAO 1984, pp. 44-55). Manufactured fertilizer is the principal purchased input in most Chinese provinces (PRC Zhongguo Nongye Jishu Jingji Shouce, pp. 640-666). All in all it is clear that the period 1952-57 pre-dates the "green revolution" in China and that, by 1979-85, the technical transformation of Chinese agriculture was already considerably advanced. The second period also falls within the peculiar years of higher wheat production cvs, while the first period considerably precedes them.

Both periods were marked by ongoing organizational change, but were clearly more internally uniform than the surrounding periods. The first period almost completely post-dates the land-to-tillers style land reform which had begun in areas under Communist Party control prior to 1949 and was completed during 1952. It also post-dates the basic re-establishment of markets following World War II and the Chinese Civil War. The data period ends prior to the formation throughout most of China of the people's communes and the radical policy initiatives of the Great Leap Forward (1958-59), as well as the unusually severe natural disasters which caused or seriously accentuated the famine of 1960-61. However, this first period spans the formation of agricultural cooperatives (1952-56), the establishment of a state grain market (1953), and the imposition of fixed quotas of grain to be delivered from each unit of farmland (1955) (Chao 1970, pp.44-68, Stone 1980, pp. 147-8). It also spans a period of some instability in purchase prices for cereals, although the cash costs for inputs were consistently minor throughout the 1950s (Stone 1980, Stone 1987b).

The beginning of the second period coincides with the initiation of major rural organizational reforms, a three-tiered structure for grain prices including free market cereals prices, and significant procurement pricing changes after the Cultural Revolution (Stone 1980, pp. 147-53). And while farm price and market structures remained reasonably constant during 1979-84, rapid growth in yields because of greater fertilizer availability allowed average and especially marginal prices many farmers faced, as well as the degree with which they interacted with private versus public markets, to change considerably during the period. The year 1985 was especially marked by the abolition of both the three-tiered price structure for farm goods, of compulsory fixed quotas (replaced by a contract system), as well as major adjustments in the effective marginal prices faced by farmers experiencing rapid growth in yields, and some other significant market changes, notably for manufactured fertilizers. A variety of difficulties were experienced in 1984 and especially in 1985 in the area of rural credit. Thus while 1952-57 and 1979-83 (or even 1979-84) are periods of greater internal consistency than somewhat longer or surrounding periods, such continuity is, of course, imperfect in both cases. Separate runs were conducted for 1952-57 against 1979-83, 1979-84, and 1979-85.

Due to major structural changes in Chinese agriculture during the 1960s and 1970s (Stone 1980), the factors governing trend increase in yields during the two data periods were thoroughly dissimilar. So separate linear trends were fitted to the two People's Republic periods for purposes of detrending.

In addition to the comparison of 1952-57 and 1978-85, comparisons of 1931-37 and 1952-57, and 1931-37 and 1979-85 were conducted. The 1931-37 data has been regrouped from a compilation by Crook (1986), which is based on data: (a) for China proper (excluding Manchuria, Tibet, Western Sichuan, and Xinjiang) estimated from surveys conducted by National Agricultural Research Bureau of the Nanjing Government; and (b) for Manchuria, estimated from survey data by the Japanese Manchukuo colonial administration and published in The Manchukuo Yearbook, 1942.

For rough provincial conformity among periods, combined data for Chahar and Suiyuan for 1931-37 have been compared with combined data for Hebei and Nei Mongol for 1952-57 and for Hebei, Nei Mongol, Beijing, and Tianjin data for 1979-85. Similarly, Manchurian data for 1931-37 have been compared with combined data for Heilongjiang, Jilin, and Liaoning for the two People's Republic periods. The portion of Jehol data not included in Manchuria is ignored. Finally, Jiangsu data for 1931-37 have been compared with Jiangsu data for 1952-57 and with combined data for Jiangsu and Shanghai for 1979-85. A total of 16 provinces or regions were included (see Tables 11 and 12).

The crop-wise comparison for the 1930s/1950s exercise could only be conducted using rice, wheat, and other foodcrops. "Other foodcrops" for 1952-57 are defined in note 3. For the 1930s, "other foodcrops" consist of sorghum, corn, soybeans, millet, sweet potatoes, proso-millet, barley, broad beans, oats, and sweet potatoes, excluding only a few minor categories such as rye, mung beans, field peas, and white potatoes for which data are not available. The 1930s/1980s comparison was conducted directly for eight crops: rice, wheat, sorghum, maize, soybeans, millet, potatoes, and "others" (consisting of proso-millet, broad beans, barley, and oats for the 1930s with the same minor crop exclusions); and total foodcrops (as defined in note 3) minus the other seven crops for 1979-85. Sweet potatoes (only) for 1931-37 were compared with sweet potatoes plus white potatoes for 1979-85 since white potato data for the 1930s are not available and because the aggregated potato category can only be split for 1983-85.

Not much will be made of these later comparisons using 1930s data, until further work is completed. This is because of three particular limitations. First, the 1930s data probably underestimate cultivated area to a much greater extent than does the 1952-57 data. The NARB cultivated area figure for China proper for 1933-37 is 65.7 million hectares as compared with: (a) 76.3-93.9 million hectares estimated under four different assumptions by Buck (1937); (b) a 1965 estimate of 85.2 million hectares for 1928-37 produced by T. C. Liu and K. C. Yeh; (c) 76.2 million hectares for 1946 estimated by the Directorate of Statistics of the post-war Republican government; (d) 80.5 million hectares undoubtedly underestimated by the People's Republic government for 1949; and (e) 89.8 million hectares for 1952 which the PRC may have only underestimated by a few million hectares (see Wiens 1980, p. 275-82; Stone 1983). Although the higher Buck figures almost certainly overestimate, the NARB figures no doubt underestimate considerably. This causes problems in parts of the decomposition of the change in variance between 1931-37 and 1952-57, although the problem can be more or less removed by adopting a comparison of variance decompositions for the two periods rather than a decomposition of the change in variance among periods.

The second problem is that there is quite likely a difference in the way statistics are generated between the 1930s and the 1950s, although this cannot be excluded for the 1950s and 1980s either. The particular concern with the earlier comparison is that the relationship between (relatively large) errors in production, area, and yield will differ markedly among the two periods. This could affect many of the terms in the decomposition of changes in variance. The problem will be somewhat reduced, but not eliminated, by substitution of a comparison of the patterns of variance in the two periods, as with the first difficulty.

The final problem relates specifically to the 1930s/1980s comparison. Not only are wholly statistical distortions apt to be more acute, but there are such a wide variety of technological, economic, and social factors influencing the analysis of changes in variances between these two distant periods that interpretation of the calculated components of the change in variance may be particularly speculative. Fortunately, the total increase in variance is so great that the role of the strongest components may come through clearly. The 1930s/1980s exercise was conducted for the sole purpose of taking a look at the comparison of the five non-fine-grain individual crop variances since data for these crops are insufficient to allow a 1950s/1980s or 1930s/1950s comparison.

RESULTS FROM THE 1950s/1980s CHANGE IN VARIANCE DECOMPOSITION PROCEDURES

The decomposition exercise of principal interest is that of the change in variance between 1952-57 and 1979-85. Table 4 provides descriptive statistics for the two periods. The variances naturally increase considerably because the production increase is so large. Note that even the cvs happen to have increased between these two particular periods, except for those of rice and wheat area, although they have generally increased from very small values to somewhat larger, but still small values, when compared internationally (Table 2). Recall from Figures 4, 5, and 6 that, had adequate data been available, periods could have been chosen which would have demonstrated increasing, decreasing, or similar values for any of the cvs. The exercise of interest is the decomposition of the substantially increasing variances.

Table 4. **Means, Variances, and Coefficients of Variation Around Trend for Various Foodcrops in China, 1952-57 and 1979-85**

	1950s Mean	1950s C.V.	1950s Variance	1950s Mean	1980s C.V.	1980s Variance
Rice						
Yield (kg/ha)	2,515	2.8	4,959	4,731	3.6	8,197
Area (1,000 hectares)	26,620	3.8	1,039,206	28,939	0.8	48,096
Production (tons)	66,930	3.1	4,200,448	136,956	4.2	32,773,800
Wheat						
Yield (kg/ha)	826	4.2	11,158	2,467	7.4	34,637
Area (1,000 hectares)	25,701	2.4	366,566	27,896	2.0	304,928
Production (tons)	21,230	5.2	1,206,618	68,863	8.6	35,097,260
Others[a]						
Yield (kg/ha)	1,094	3.1	6,079	2,470	4.8	14,573
Area (1,000 hectares)	70,802	0.6	207,872	50,619	1.3	409,557
Production (tons)	76,885	3.2	6,041,395	125,071	5.6	48,723,630

[a] These calculations are based on deducting rice and wheat from total foodcrop production and area.

Table 5 itemizes the contribution of various components of the increase in the variance of total foodgrain production between the two periods. Increases in interprovincial covariances account for 90.6 percent of the production variance increase for total foodcrops (Table 5), 87.8 percent for rice (Table 6), 84.6 percent for wheat (Table 7) and 72.6 percent for "other foodcrops" (Table 8). This is consistent with results obtained for India (Hazell 1982 and 1984), the United States (Hazell 1984), the Soviet Union (Nguyen), Syria, and Australia (Anderson and Hazell), though the effect appears particularly strong for China.

Unlike the United States and India, but like the Soviet Union, the Chinese cross covariance contribution (between different crops in different provinces) exceeds the within-crop covariance effect among provinces. This may represent a characteristic feature of central planning where state-supplied inputs are allocated for specific crops in provinces where authorities aspire to purchase marketable surpluses. The state may also contribute to this peculiar pattern of interprovincial correlation through fixed quotas for specific grains in each province to facilitate exports; through pricing policies which have provided much higher marginal returns to grain deliveries above assigned quotas; and by allocating fertilizers in exchange for desired commodities (Stone 1980, 1984b, 1986a,b).

The changes in provincial crop production variances account for only 7.1 percent of the change in the variance of total foodgrain production (1.7 percent from rice, 2.3 percent from wheat and 3.1 percent from other crops). This is a particularly small proportion compared with that found in other country studies. Also striking is the especially small contribution of intercrop covariances within provinces (2.3 percent), perhaps because intercrop covariances were already high in the first period.

The interaction effect between mean area levels and yield variances and covariances and the interaction effect between mean yield levels and area variances and covariances are offsetting and particularly important for rice (see Table 6). The positive value for the first of these interaction terms is not surprising. As area increases (onto less suitable and more poorly serviced lands) the variability of yields tends to increase. This first interaction effect is particularly strong but negative for "other crops" (Table 8). This may indicate that land going out of "other crop" production was relatively good land which left the remaining production of "other crops" in a more unstable state on average.

The second interaction term (between mean yields and area variances and covariances) is negative for the aggregated provinces in each crop category and may also reflect central planning effects. The impact is especially strong for rice. In provinces exhibiting rising yields, successful efforts were made to stabilize area to help guarantee procurement despite relatively low prices for rice (Stone 1987b). Conversely, in areas where effective control was achieved, state autho-

Table 5—Analysis of the Components of Change in the Variance of Total Grain Production in China, 1952-57 to 1979-85

	Changes in Mean Yields	Changes in Mean Areas	Changes in Yield Variances and Covariances	Changes in Area Variances and Covariances	Changes in Mean Yields and Mean Areas	Changes in Area-Yield Covariances	Interaction Terms Between: Mean Areas and Yield Variances and Covariances	Interaction Terms Between: Mean Yields and Area Variances and Covariances	Interaction Terms Between: Mean Yields Mean Areas and Area-Yield Covariances	Changes in Residuals	Total Contribution to Change in Variance of Production in China
Rice	1.0	0.0	1.0	-0.5	0.5	0.0	0.1	-1.1	0.4	0.1	1.7
Wheat	0.5	-0.0	1.5	-0.0	0.1	-0.0	0.1	-0.3	0.4	-0.0	2.3
Other	0.4	-0.5	5.4	-0.1	0.8	0.2	-2.8	-0.8	0.5	0.4	3.1
Total variances within provinces	1.8	-0.3	7.9	-0.6	1.4	0.2	-2.6	-2.2	1.3	0.1	7.1
Inter-crop covariance within provinces	-0.4	-0.0	1.7	0.1	-0.1	-0.0	0.2	1.0	-0.3	0.0	2.3
Inter-province covariance within crops	3.0	0.7	28.6	-1.6	5.0	-0.6	-6.1	-4.2	4.6	0.3	30.0
Covariance between different crops in different provinces	-3.0 60.6	-0.8	45.2	0.8	7.6	-0.6	-3.0	4.9	9.0	0.6	
All included provinces	1.5	-1.1	83.4	-1.2	14.0	-0.1	-11.6	-0.5	14.7	1.0	100.0

Note: See Table 3 for definition of the "Components of Change in Variance."

Table 6—Analysis of the Components of Change in the Variance of Rice Production by Province in China, 1952-57 to 1979-85

	Changes in Mean Yields	Changes in Mean Areas	Changes in Yield Variances and Covariances	Changes in Area Variances and Covariances	Changes in Mean Yields and Mean Areas	Changes in Area-Yield Covariances	Interaction Terms Between			Changes in Residuals	Total Contribution to Change in Variance of Production in China
							Mean Areas and Yield Variances and Covariances	Mean Yields and Area Variances and Covariances	Mean Yields Mean Areas and Area-Yield Covariances		
Hebei, Beijing Tianjin	466.7	-5.1	-71.6	-199.4	-153.3	254.2	-112.2	-670.8	562.2	29.2	0.0
Nei Monggol	-256.9	-7.2	143.0	393.3	-19.6	-462.0	-28.4	417.5	-127.2	47.5	0.0
Liaoning	160.4	69.6	51.4	-13.9	46.9	-50.2	173.5	-94.3	-242.9	-0.6	0.1
Jilin	-3570.7	-942.6	-243.4	921.0	140.4	324.2	-313.9	3132.6	700.2	-47.8	-0.0
Heilongjiang	13.5	10.1	16.0	-0.4	-2.1	25.6	14.4	-0.3	21.9	1.2	0.1
Jiangsu and Shianghai	6.3	7.2	35.7	-5.8	-4.5	20.0	24.9	-17.1	31.9	1.3	4.1
Anhui	-5084.4	-14.8	-998.8	2306.1	7.6	-826.7	-15.4	5858.2	-738.9	-392.9	-0.1
Jiangxi	a29.3	15.8	65.3	-10.3	-0.0	0.3	25.6	-27.9	0.4	1.4	0.5
Shandong	30.7	37.5	-0.2	11.2	14.3	-4.6	-8.9	118.3	-100.1	2.0	0.0
Henan	41.3	-0.3	119.4	-9.3	2.6	9.7	-26.3	-43.0	10.5	-4.6	0.1
Hubei	237.5	159.0	79.9	-53.4	40.4	-149.4	64.8	-109.9	-202.7	33.7	0.8
Hunan	15.3	19.6	11.5	-13.3	-6.0	41.3	6.7	-34.0	56.6	2.3	3.0
Guangxi	51.2	0.7	46.9	-18.7	-2.3	27.5	15.1	-59.8	37.3	1.9	2.5
Guangdong	15.3	-0.3	85.9	-2.0	0.1	19.3	-25.8	-8.0	16.5	-1.0	4.3
Sichuan	82.8	1.6	54.5	-93.9	15.1	164.1	-15.3	-176.9	72.3	-4.3	1.4
Guizhou	0.3	-0.3	117.8	0.2	-0.0	3.0	-21.3	0.1	0.6	-0.5	0.4
Yunnan	0.8	1.7	6.5	17.7	-0.5	39.3	1.1	14.5	18.2	0.5	0.9
Shaanxi	1.7	1.1	86.0	-0.2	0.1	-11.0	27.0	-0.2	-5.7	1.1	0.0
Inter-province covariances	42.9	2.4	61.6	-22.0	0.9	28.5	14.6	-58.0	28.9	2.0	82.5
All provinces	45.1	4.4	60.6	-22.7	-0.6	28.9	13.1	-59.2	28.3	2.3	100.0

Note: See Table [illegible] for definition of the "Components of Change in Variance."

Table 7—Analysis of the Components of Change in the Variance of Wheat Production by Province in China, 1952-57 to 1979-85

	Changes in Mean Yields	Changes in Mean Areas	Changes in Yield Variances and Covariances	Changes in Area Variances and Covariances	Changes in Mean Yields and Mean Areas	Changes in Area-Yield Covariances	Interaction Terms Between: Mean Areas and Yield Variances and Covariances	Interaction Terms Between: Mean Yields and Area Variances and Covariances	Interaction Terms Between: Mean Yields Mean Areas and Area-Yield Covariances	Changes in Residuals	Total Contribution to Change in Variance of Production in China
Hebei, Beijing Tianjin	110.1	1.1	44.1	-0.6	-0.5	5.8	28.3	-5.9	17.8	-0.0	5.5
Shanxi	36.7	-26.6	163.9	-10.5	-9.5	-12.6	-61.5	-76.8	-16.1	13.0	0.1
Nei Monggol	16.9	74.8	23.4	-0.2	7.3	-26.1	51.2	-0.2	-47.3	0.2	0.0
Liaoning	-881.2	32.0	-302.2	97.8	3.2	-9.9	284.2	874.5	2.3	-0.8	-0.0
Jilin	1456.0	556.9	243.8	-126.2	122.8	-510.1	201.6	-712.9	-1264.8	132.8	0.0
Heilongjiang	11.8	4.8	15.4	-1.3	0.1	0.2	70.5	-4.1	0.7	1.9	1.1
Jiangsu and Shanghai	68.2	-1.9	62.7	-3.9	2.2	15.2	-13.2	-75.9	46.2	0.2	1.0
Anhui	52.1	-27.9	143.1	-1.5	-1.8	9.2	-63.5	-34.3	24.3	0.2	0.4
Jiangxi	31.7	-15.3	166.1	-6.7	-2.7	-3.5	-51.4	-10.2	-1.1	-6.8	0.0
Shandong	3.7	-0.8	68.9	0.7	0.0	10.9	-13.8	7.9	23.7	-1.3	6.1
Henan	78.8	-4.0	131.1	-3.8	-3.1	-4.7	-32.0	-52.0	-10.9	0.8	2.4
Hubei	9.7	2.2	39.8	-3.2	-3.7	13.9	27.5	-17.7	32.5	-1.1	0.3
Hunan	90.2	-3.3	54.3	-15.8	0.4	29.9	-15.0	-73.9	30.8	2.4	0.0
Guangxi	-1460.6	-122.1	-136.5	311.2	-262.8	-164.0	132.8	1677.6	92.5	32.0	0.0
Guangdong	56.9	-3.7	99.5	6.0	1.4	-23.2	-48.9	26.8	-14.8	-0.1	0.0
Sichuan	2.0	1.6	16.6	1.6	0.5	6.4	38.1	9.2	23.7	0.2	1.0
Guizhou	71.0	32.9	0.9	35.5	8.2	-32.7	2.7	50.7	-69.5	0.2	0.0
Yunnan	4.1	10.2	28.3	8.2	0.1	-17.9	89.5	11.0	-37.8	4.4	0.0
Shaanxi	-4.2	2.0	82.3	0.2	-0.1	7.3	3.8	0.5	7.1	1.2	0.6
Gansu	38.5	8.1	58.1	-7.3	2.1	3.0	14.7	-15.6	3.0	-4.7	0.1
Xinjiang	-0.3	92.7	1.8	3.8	-2.9	-1.2	5.9	3.9	-2.5	-1.1	0.0
Inter-province covariances	14.8	1.1	64.9	0.2	0.6	5.4	8.9	-0.8	13.3	1.5	81.1
All provinces	7.9	0.8	65.0	-0.0	0.4	5.6	8.1	-2.8	13.9	1.2	100.0

Note: See Table 3 for definition of the "Components of Change in Variance."

Table 8—Analysis of the Components of Change in the Variance of Other Foodcrops Production by Province in China, 1952-57 to 1979-85

	Changes in Mean Yields	Changes in Mean Areas	Changes in Yield Variances and Covariances	Changes in Area Variances and Covariances	Changes in Mean Yields and Mean Areas	Changes in Area-Yield Covariances	Interaction Terms Between: Mean Areas and Yield Variances and Covariances	Interaction Terms Between: Mean Yields and Area Variances and Covariances	Interaction Terms Between: Mean Yields Mean Areas and Area-Yield Covariances	Changes in Residuals	Total Contribution to Change in Variance of Production in China
Hebei, Beijing Tianjin	66.0	-9657.9	-72.9	-596.3	1137.8	6378.7	30.9	-2941.3	5410.1	345.0	0.0
Shanxi	112.8	-22.3	185.8	-23.8	19.8	5.6	-72.3	-117.5	5.0	6.9	0.1
Nei Monggol	-29.3	59.8	17.5	0.9	4.3	33.7	-7.5	1.8	10.2	8.5	-0.4
Liaoning	0.1	-1.4	150.5	0.5	0.1	16.4	-80.7	2.4	11.4	0.8	5.5
Jilin	-0.3	-1.2	133.6	0.2	0.4	10.5	-54.9	0.8	9.9	0.9	7.8
Heilongjiang	-0.5	-1.0	59.1	-1.7	0.1	31.2	-2.2	-2.2	15.3	2.0	3.5
Jiangsu and Shianghai	4657.6	47.6	2033.4	-670.7	1874.7	978.3	-1507.9	-8117.7	817.4	-12.8	0.0
Anhui	-32.8	129.5	-82.6	3.9	3.4	1.5	59.8	13.9	0.2	3.1	-0.4
Jiangxi	-216.7	38.3	172.6	146.1	-78.8	-198.4	-121.8	386.8	-6.7	-21.4	-0.0
Shandong	-103.7	-136.1	740.7	-7.5	74.3	62.2	-509.5	-52.5	36.0	-3.9	0.8
Henan	2.5	-6.3	231.6	-0.4	2.0	14.2	-150.9	-2.0	5.9	3.4	3.2
Hubei	-121.9	66.2	26.0	39.3	4.9	-2.7	-18.1	107.0	-0.2	-0.5	-0.4
Hunan	2.4	104.7	242.6	40.3	-50.1	-166.5	-131.7	132.6	-66.4	-7.9	-0.0
Guangxi	-98.2	46.1	25.8	32.7	7.5	26.9	-11.0	61.7	7.7	0.8	-0.0
Guangdong	-25.1	77.6	40.1	7.4	4.9	15.2	-27.5	9.9	-2.1	-0.5	-0.0
Sichuan	60.0	-23.2	29.3	24.2	-2.9	-45.9	-6.9	118.8	-51.6	-1.8	0.1
Guizhou	17.6	0.1	76.2	-4.6	0.0	8.8	5.0	-13.6	9.3	0.9	0.1
Yunnan	8.1	6.2	-1.3	-49.7	-8.3	122.8	-0.4	-67.9	91.8	-1.1	0.1
Shaanxi	36.0	-2.1	99.3	-21.7	7.5	48.9	-25.2	-87.4	45.6	-0.8	0.4
Gansu	68.7	-141.0	695.9	-53.3	-1.8	85.8	-471.9	-61.1	-14.5	-6.9	0.0
Xinjiang	73.6	58.6	-88.9	-50.0	-28.5	136.9	-97.1	-77.7	179.2	-6.0	0.0
Inter-province covariances	-8.3	-1.9	142.8	1.5	2.3	17.7	-67.8	5.3	8.0	0.2	79.6
All provinces	-4.1	-5.1	149.7	0.3	3.4	19.2	-72.7	-1.0	9.8	0.4	100.0

Note: See Table [illegible] for definition of the "Components of Change in Variance."

rities focused current inputs and infrastructural investments, thereby raising yields. In any event, several items in the decomposition suggest relative success in crop-wise area stabilization between the 1950s and the 1980s.

All these results for the country as a whole remained relatively constant whether the 1979-83, 1979-84, or 1979-85 period was used, although the production cv for the period changed from 4.93 percent to 4.67 percent to 5.20 percent with these adjustments. The choice of 1957 data also mattered little to the values of the decomposition components although the 1952-57 cv increased from 2.09 percent to 2.69 percent (a 28 percent increase) with the substitution of only the new 1957 data for a small number of provinces for which they were available.

The most important result of the variance decomposition is the particular dominance of the interregional covariances, especially among yields. This is very likely the reason that the cvs for yield and production of total foodgrains, as well as of the individual grains, do not appear to have declined during the past more than three decades (Figure 6). The most plausible explanation for this increase in interprovincial covariances is that Chinese farmers are now much more responsive to central policy and to national market influences in general.

Issues relating to the genetic base for high-yielding crop varieties constitute an input-related variant of this central policy theme. It has been suggested for the United States and for the Soviet Union (Hazell 1984 and Nguyen) that many regionally adapted varieties of a crop were replaced by a very few higher-yielding varieties sown broadly across regions, and this development may have contributed to increased inter-regional correlations in yield and hence to increased aggregate variance. Comparing the 1960s in China (a period of particular national production variability but poor provincial data) with the 1950s, the proportions of wheat, rice, and maize area planted with just a few closely related varieties increased very dramatically. Since the 1960s, however, more regionally adapted high-yielding varieties have proliferated, somewhat reducing the area sown with any single variety. Difficulties associated with central authorities promoting overly rapid and intensive adoption of specific high-yielding varieties have been documented for maize in the 1960s (Wiens 1978, p. 677, Stone 1980, pp. 157-158), and for hybrid rice in the late 1970s and early 1980s (Stone 1984a). But it may be more valuable to focus attention on wheat for which the yield and production cvs increased most notably between 1952-57 and 1975-83.

During the late 1970s and early 1980s, exactly nine varieties accounted for 13.5 million hectares (one-half of national wheat sown area) in a few of the major wheat growing zones; and a number of these varieties have closely related genealogies (Stone et al. 1985). But although the numbers of varieties were considerably fewer than during the 1950s, they were more numerous and had been bred with greater experience and attention to disaster risks than those of the the 1960s.

Examining Table 9, it is immediately clear that a much greater number of provincial yield (and even production) variances tested as non-homogenous between the periods in the case of wheat than for rice and for "other crops". Of those testing non-homogenous, only two recorded declines in variance (neither significant at the 1 percent level): for yields, only Anhui and Jiangsu; for production, only Anhui and Yunnan. Contrasting sharply with the results for rice and for "other crops", all of the largest five wheat producers (accounting for a total of 62 percent and each exceeding 7.3 percent of national production in 1979-83) exhibited significant increases in production variability.

Among the next nine provinces of intermediate importance for wheat (each with 1.2 to 7.3 percent of national production), production variability increases were not significant at the 5 percent level only for Xinjiang, Shanxi and Anhui. 81.5 percent of Xinjiang's farmland and virtually all Xinjiang wheat is irrigated, by far the highest proportion in China (Stone et al. 1985). The performance of Shanxi and Anhui may be related to the unusually high cv in the first period for both provinces (25 percent), coupled with relatively large wheat area reductions (21 and 26 percent), augmented by irrigation expansion.

But from Table 7 it is clear that it is not the individual province changes in production variance, but the increased interprovincial covariances that account for most (81 percent) of the increased aggregate wheat production variance.

HYPOTHESES EXPLAINING INCREASED INTERPROVINCIAL CORRELATIONS AND YIELD VARIABILITY

In Table 10, detrended pair-wise yield correlations for the 1979-83 period have been calculated for only those provinces contributing more than one percent to the increase in national wheat production variances. These provinces also happen to be the five largest wheat producers and five provinces within which wheat production increased most between the two periods. Although there was a decrease in wheat yield cv between the two periods for Jiangsu (and increases for each of the other provinces), the actual yields among all these provinces are highly correlated in the 1979-83 period. This includes some of the most distant pairs of provinces such as Jiangsu and Sichuan, and Hebei and Sichuan for which reliability of the correlation appears quite high. In fact, the least correlated and least reliable correlation is for the adjacent provinces of Jiangsu and Shandong. (In other cases, of course, adjacent provinces are highly correlated with high reliability). Although some of these provinces have highly correlated weather patterns, this relationship does not include all of those with highly correlated yields during the period. Two imporant conclusions may be drawn from examination of Tables 7 and 10: (a) Those provinces that

Table 9. Provinces Exhibiting Variance Changes Between 1952-57 and 1979-83

	Production				Area				Yield			
	Total Grains	Rice	Wheat	Other	Total Grains	Rice	Wheat	Other	Total Grains	Rice	Wheat	Other
National	**	*	**	**	**			*	**	**	**	**
Hebei, Beijing, Tianjin		*	**					*			**	
Shanxi		n.a.		*		n.a.			*	n.a.	*	*
Nei Monggol			*								*	
Liaoning	**			**	**			**	**		**	**
Jilin	**		**	**			**		**			**
Heilongjiang	*		**								**	
Jiangsu, Shanghai	**	**	**						**		*	
Anhui	*								*		*	
Jiangxi											**	
Shandong	**	**	**			**					**	
Henan		**	*	**	**				**	**	**	**
Hubei			**						*		**	
Hunan	*				*			*			*	
Guangxi									*			
Guangdong	**	**		*				*	**	**	**	*
Sichuan			**						*		**	
Guizhou	**								**	**		
Yunan	**	**	*			**	**		*	**	**	**
Shanxi		**	*	**					*	**	*	
Gansu		n.a.	*			n.a.			*	n.a.	**	
Xinjiang	**	n.a.				n.a.			*	n.a.		

Note: **, * indicate statistically significant F ratios (one-tailed tests) at 1 and 5 percent confidence levels, respectively.

This table has not yet been prepared for the 1979-85 period, but the results of the decomposition comparing 1952-57 with 1979-83, 1979-84, and 1979-85 were strikingly similar.

Table 10. Wheat Yield Correlation Coefficients Among 5 Major Producing Provinces, 1979-83

	Hebei	Jiangsu	Shandong	Henan	Sichuan
Hebei(+ Beijing & Tianjin)	1.00	0.71	0.96	0.92	0.80
	0.00	0.11	0.00	0.00	0.05
Jiangsu (+ Shanghai)	0.71	1.00	0.48	0.65	0.79
	0.11	0.00	0.33	0.16	0.06
Shandong	0.96	0.48	1.00	0.88	0.66
	0.00	0.33	0.00	0.02	0.15
Henan	0.92	0.65	0.88	1.00	0.61
	0.00	0.16	0.01	0.00	0.19
Sichuan	0.80	0.79	0.66	0.61	1.00
	0.05	0.06	0.15	0.19	0.00

Note: The upper number represents the correlation; the lower number the percent level of "significance".

This table has not yet been prepared for the 1979-85 period. It is expected, however, that these correlations will increase with the inclusion of 1985 and 1986 data, in view of the temporary moratorium on new fertilizer import contracts imposed by the central government during the second half of 1985 (Stone 1986b).

are individually contributing the most to increased wheat production variance are not only China's largest wheat producers, but exhibit highly correlated wheat yields in the second period, and so are apt to be major contributors to the increased interprovincial yield correlations that are the predominant factor associated with increased wheat production variability; (b) While correlated weather patterns and the similar response of similar varieties may explain some of the yield correlation among these major wheat growing provinces in the 1979-83 period, these factors certainly do not explain all of the yield correlation, nor is there convincing evidence to suggest that they would explain most of the increased correlation between the two periods.

What, then, could be the cause of increased wheat yield correlation among major wheat-growing provinces, to the extent that it is not due to weather and similarity among the varieties sown over broad areas? Among the input-related hypotheses, the high correlation among distant provinces, such as Sichuan and Hebei, would argue against linked irrigation or regional power grid allocation being the dominant cause, although these again cannot be ruled out within the North China provinces. Little is known about difficulties with the seed distribution system, but some documentation related to synthetic fertilizer use is available.

The particularly rapid rate of growth of fertilizer use has elsewhere been established as a principal contributory factor to increased foodgrain yields since the 1960s and especially since the mid-1970s. Among foodgrains, wheat has been a high priority crop upon which yield-increasing attention has been focused (Stone 1987, Stone 1986a). Wheat yields grew most rapidly in these major wheat-producing provinces but failed to reach the 1979 level in 1980 and 1981, resuming rapid growth in 1982 and 1983. 1980 was a poor weather year for China's main wheat producers, but 1981 was not (Kueh 1984b). When the state budget collapsed between 1980 and 1981 under the weight of unmanageable food subsidies and overexpansion of capital construction (Stone 1987, Stone 1985), one of several adjustment measures (also aimed at alleviating foreign exchange difficulties) was curtailment of imports, including fertilizers. Thus international imports of fertilizers, though growing rapidly over the period, fell in 1981.

This decline began in late 1980, in time to affect the winter wheat crop. Between October 1980 and January 1981, procurement and sales of manufactured fertilizer (both imported and domestically produced) by the central marketing organization were consistently 4 to 19 percent below equivalent month data for the previous year (PRC Zhongguo Guojia Tongjiju, pp. 312-3). Imports constituted 14-19 percent of total Chinese application during the period, but considerably more for these intensive user provinces, and applications of imported fertilizers were indeed concentrated on cotton and wheat. The import data for Hebei and Sichuan are difficult to evaluate, but it appears that aside from those provinces, Shandong, Henan and Jiangsu are three of the four largest importers of fertilizers domestically and internationally.

Although ideal provincial data are not yet available, the only other post-1978 year in which there was a fall in national fertilizer imports (and also, in this case, national production) was 1985, the only other year registering a decline in wheat yields. In 1985, there were numerous systemic changes in farm product markets, in the fertilizer market, in pricing related to both and in cash and credit availability, each affecting the levels of fertilizer use (Stone 1986b). 1985 was also a year, however, in which *shouzai* area ("affected by natural disasters") increased, including area in major wheat-growing provinces (Table 11).

The variability in wheat yields of the major producing provinces and the high correlations among their yields since 1979 may indeed be at least partly related to irregularities in the institutional behavior affecting chemical fertilizer supply and purchase. Whether such difficulties were also contributory during the remainder of the high cv period (1974-78) is even more difficult to verify, but 1974-76 was a foreign exchange conservation period during which time imports were reduced somewhat, while 1977 and 1978 were the worse weather years in wheat-growing regions since 1960-61.

VARIANCE DECOMPOSITIONS INVOLVING 1930s DATA

Several serious problems discussed above remain with produced materials to date inhibiting clear interpretation of much of the decomposition of changes in variance from the 1930s to the 1950s and 1980s. Glancing at Table 12, immediately noticeable are the large negative values for changes in mean area and the large positive values for changes in yield variances and covariances and for interaction between mean areas and yield variances and covariances. Since the production variance actually *declined* between the 1930s and the 1950s (cvs declined and mean production remained relatively constant), the table is indicating that the latter two components contributed to that *fall* in variance, while the increase in mean area worked against it, tending to increase variance. But since the increase in mean area between the two periods was largely illusory, due to substantially more serious statistical underreporting in the first period, the actual importance of the area components cannot be judged, and their dominance will distort most of the values in the decomposition, especially mean area and its interaction terms. What can probably be salvaged is the contribution to the decline in production variance provided by the change in "pure" within-province production variances for rice, wheat, and other crops. Although these values would change somewhat with proper area data, their relative magnitude would remain as would the conclusion that general yield stabilization has contributed to variance decline, especially for rice. More investigation of the 1930s conditions and a decomposition of the pattern of, rather than the change in, variance are called for.

Table 13 shows the results of the analysis of production variance change between the 1930s and 1980s. Although these results are

Table 11. Total Area Covered by Natural Disaster in China, 1983 - 1985

Province	Total Disaster Area 1983	1984	1985
		(1,000 hectares)	
National	34,713	31,890	44,370
Beijing	162	180	140
Tianjin	268	290	160
Hebei	2,869	3,020	2,210
Shanxi	1,740	1,920	2,130
Nei Monggol	1,758	1,520	2,400
Liaoning	1,001	2,140	2,000
Jilin	658	1,420	3,210
Heilongjiang	1,953	1,530	4,210
Shanghai	81	0	50
Jiangsu	1,982	1,090	800
Zhejiang	967	460	430
Anhui	1,799	1,620	1,960
Fujian	678	300	370
Jiangxi	1,353	460	950
Shandong	3,227	2,550	4,080
Henan	1,907	3,230	3,700
Hubei	2,215	490	1,500
Hunan	1,997	2,390	2,320
Guangdong	1,279	1,160	1,900
Guangxi	786	1,070	1,140
Sichuan	1,435	1,590	3,440
Guizhou	833	600	1,290
Yunnan	1,091	650	1,010
Xizang	158	30	30
Shaanxi	1,544	1,190	1,790
Gansu	596	650	620
Qinghai	111	100	120
Ningxia	116	140	130
Xinjiang	149	100	280

Sources: People's Republic of China, State Statistical Bureau, Statistical Yearbook of China 1984 (Hong Kong: Economic Information and Agency, 1984); People's Republic of China, State Statistical Bureau, Statistical Yearbook of China 1985 (Hong Kong: Economic Information and Agency and Beijing: China Statistical Information and Consultancy Service Centre, 1984); People's Republic of China, State Statistical Bureau, Statistical Yearbook of China 1986 (Oxford: Oxford University Press, 1986).

Table 13—Analysis of the Components of Change in the Variance of Total Foodcrop Production in China, 1931-37 to 1979-85

	Changes in Mean Yields	Changes in Mean Areas	Changes in Yield Variances and Covariances	Changes in Area Variances and Covariances	Changes in Mean Yields and Mean Areas	Changes in Area-Yield Covariances	Interaction Terms Between: Mean Areas and Yield Variances and Covariances	Interaction Terms Between: Mean Yields and Area Variances and Covariances	Interaction Terms Between: Mean Yields Mean Areas and Area-Yield Covariances	Changes in Residuals	Total Contribution to Change in Variance of Production in China
Rice	1.4	4.0	-0.6	-0.4	0.1	-0.1	-2.6	-1.0	-0.2	0.1	0.7
Wheat	0.9	0.3	1.0	-0.1	0.0	0.1	0.5	-0.4	0.2	0.0	2.6
Sorghum	0.1	-0.1	0.5	-0.0	-0.0	0.1	-0.4	-0.0	-0.0	0.0	0.2
Corn	0.1	0.4	0.2	0.1	0.0	0.1	2.3	0.6	1.1	0.1	5.0
Soy bean	0.0	-0.1	-0.0	-0.0	0.0	-0.1	0.0	-0.0	0.0	0.0	-0.1
Millet	0.0	-0.1	0.1	-0.0	-0.0	0.0	-0.1	-0.0	-0.0	0.0	0.0
Potatoes	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3
Other	0.6	-0.1	2.8	-0.2	0.0	0.0	-2.2	-0.6	0.0	-0.0	0.3
Total variances within provinces	3.2	4.5	3.9	-0.6	0.1	0.2	-2.4	-1.4	1.2	0.2	9.0
Inter-crop covariance within provinces	1.7	0.1	1.6	-0.6	0.5	0.6	3.7	-1.8	1.6	0.3	7.0
Inter-province covariance within crops	4.6	10.4	1.5	-2.4	-1.1	3.3	-1.1	-5.0	6.3	0.5	17.1
Covariance between different crops in different provinces	7.2	-3.8	13.7	0.3	-0.0	3.6	33.1	1.0	10.8	0.9	67.0
All included provinces	16.8	11.3	20.7	-3.3	-1.1	7.5	33.3	-7.1	20.0	2.0	100.0

Note: See Table 3 for definition of the "Components of Change in Variance."

Table 12—Analysis of the Components of Change in the Variance of Total Foodcrop Production in China, 1931-37 to 1952-57

	Changes in Mean Yields	Changes in Mean Areas	Changes in Yield Variances and Covariances	Changes in Area Variances and Covariances	Changes in Mean Yields and Mean Areas	Changes in Area-Yield Covariances	Interaction Terms Between: Mean Areas and Yield Variances and Covariances	Interaction Terms Between: Mean Yields and Area Variances and Covariances	Interaction Terms Between: Mean Yields Mean Areas and Area-Yield Covariances	Changes in Residuals	Total Contribution to Change in Variance of Production in China
Rice	-0.6	-20.8	8.6	-0.4	-0.0	3.4	16.9	-0.4	2.3	-0.1	8.9
Wheat	0.4	-2.8	2.5	0.1	0.0	0.8	1.8	0.0	0.1	-0.0	2.9
Other	0.5	-7.5	-6.8	-14.4	-0.2	-14.9	7.9	8.6	14.4	16.0	3.6
Total variances within provinces	0.3	-31.0	4.2	-14.7	-0.2	-10.7	26.6	8.2	16.8	15.9	15.4
Inter-crop covariance within provinces	-0.2	-6.9	7.1	5.3	-0.2	-0.1	5.8	-0.8	0.3	-2.8	7.3
Inter-province covariance within crops	5.4	-53.2	43.3	-4.4	0.1	-0.8	54.7	-5.8	-2.7	-12.0	24.5
Covariance between different crops in different provinces	3.0	-16.5	30.2	9.2	-1.4	20.3	9.4	-2.9	2.8	-1.4	52.8
All included provinces	8.5	-107.6	84.7	-4.6	-1.6	8.8	96.4	-1.3	17.1	-0.4	100.0

Note: See Table 3 for definition of the "Components of Change in Variance."

affected by the same limitations, they are not dominated by them because of the overwhelming increase in absolute variance between the two periods due to the very substantial increase in mean production. The large contribution (84.1 percent) of the interprovincial covariance terms[17] is no doubt fairly robust. The intercrop covariances within provinces form a greater proportion of the increased variance than for the 1950s/1980s comparison because those covariances were already large in the 1950s. But the reason for conducting this exercise was to catch a glimpse at the individual crop decompositions. Table 14 provides the means and cvs for each of the crops in the two periods. It is interesting to note that while the variances, of course, increased substantially between the two periods (except for soybeans and "other" crops for which mean production declined), the yield cvs declined or remained constant for each of the crops, maize being the principal exception.

For wheat (and rice), as with the 1950s/1980s comparison, most of the increase in variance (81 percent; 90 percent for rice) is accounted for by increases in covariances among provinces (with changes in *yield* covariances comprising more than half of this total, and changes in mean yields and increased covariance between mean area and yield variances comprising most of the remainder) (Table 15). The largest provincial contributors to increased variance were Shandong and Hebei where wheat production grew most rapidly, with most of the remainder provided by Jiangsu, Sichuan, Anhui, Shaanxi, and the Manchurian provinces.

But for maize, 69 percent of the increased variance was contributed by Manchuria alone, while only 25 percent was due to greater covariances among provinces (Table 16). It is important to note that increased yield variance (and increased area variance) alone were minor contributors to Manchuria's maize production variance growth. The largest contributors were among the interaction terms. Especially, as mean area planted with maize increased in Manchuria, yield variance *increased*, suggesting rapid expansion into more risk-prone areas. The same term was also most important for Shandong and Henan, the only other provinces individually contributing more than one percent to total maize production variance growth.

For sorghum, Manchuria was again of overwhelming importance as a contributor to increased production variance. In this case, however, the interaction term between mean area and yield variance was very large and *negative*, while the term for change in yield variance was very large and positive. This suggests that sorghum was eliminated from less risky farm areas (as its area *decreased*, yield variance grew), with better farming areas probably growing more wheat and maize. These areas, though suitable for sorghum cultivation, may have been less hospitable to the new wheat and maize HYVs. The interprovince

---

17 (17.1 percent for interprovince covariance within crops plus 67.0 percent for covariance between different crops in different provinces.)

Table 14. Detrended Means, Coefficients of Variation, and Variances for Various Years in China, 1931-37 and 1979-85

	1930s Mean	1930s C.V.	1930s Variance	1980s Mean	1980s C.V.	1980s Variance	Percent Change in Variance
		(percent)			(percent)		
Rice							
Yield (kg/ha)	2,516	8.7	47,837	4,815	3.6	30,047	-37.2
Area (1,000 hectares)	15,516	3.7	333,871	26,220	0.7	33,687	-89.9
Production (1,000 tons)	39,001	8.3	10,415,677	126,127	4.1	26,741,382	156.7
Wheat							
Yield (kg/ha)	1,057	7.6	6,453	2,497	7.6	36,013	458.1
Area (1,000 hectares)	20,255	3.8	592,423	26,530	2.0	281,536	-52.5
Production (1,000 tons)	25,491	9.7	6,113,884	66,371	8.8	34,113,169	458.0
Sorghum							
Yield (kg/ha)	1,379	5.9	6,611	2,736	6.4	30,901	367.4
Area (1,000 hectares)	7,914	2.4	35,926	2,575	7.8	40,341	12.3
Production (1,000 tons)	10,904	5.4	351,084	7,059	12.2	742,148	111.4
Maize							
Yield (kg/ha)	1,413	3.2	2,078	3,422	5.4	34,718	1570.9
Area (1,000 hectares)	5,705	5.0	80,686	17,920	1.6	84,693	5.0
Production (1,000 tons)	8,073	7.8	392,256	61,358	6.6	16,221,071	4035.3
Soybeans							
Yield (kg/ha)	1,154	7.2	6,837	1,202	4.9	3,470	-49.2
Area (1,000 hectares)	8,613	2.1	32,622	7,248	5.7	168,949	417.9
Production (1,000 tons)	9,946	8.6	735,723	8,698	4.2	134,602	-81.7
Millet							
Yield (kg/ha)	1,229	4.9	3,662	1,652	5.0	6,897	88.3
Area (1,000 hectares)	7,593	0.4	1,137	3,844	5.3	41,256	3529.9
Production (1,000 tons)	9,332	5.1	225,713	6,363	9.9	398,747	76.7
Potato							
Yield (kg/ha)	1,572[a]	6.4	10,075	2,894[b]	3.8	11,891	18.0
Area (1,000 hectares)	2,030[a]	3.7	5,792	8,878[b]	3.1	74,674	1189.3
Production (1,000 tons)	3,192[a]	7.3	54,788	25,702[b]	5.3	1,850,008	3276.6
Others							
Yield (kg/ha)	1,085[c]	6.3	4,661	1,494[d]	5.5	6,671	43.1
Area (1,000 hectares)	13,810[c]	4.1	3,790,013	8,345[d]	1.8	21,817	-99.4
Production (1,000 tons)	15,008[c]	5.9	5,725,853	12,476[d]	6.9	739,979	-87.1

[a] These calculations are based on data for sweet potatoes only. Sweet potato production was 80 percent of the production of sweet potatoes and white potatoes combined during 1952-57. Survey data cited in Buck (Study vol., p. 212) implied that white potatoes were planted on only 12 percent of the area planted with sweet potatoes and white potatoes combined in the 1930s.

[b] These calculations are based on data for sweet potatoes and white potatoes combined.

[c] Other grains include proso-millet, barley, field peas, broad beans, mung beans, rye, and oats.

[d] These calculations are based on deducting the crops included in this table from total foodcrop production and area.

Table 15—Analysis of the Components of Change in the Variance of Wheat Production by Province in China, 1931-37 to 1979-85

							Interaction Terms Between				
	Changes in Mean Yields	Changes in Mean Areas	Changes in Yield Variances and Covariances	Changes in Area Variances and Covariances	Changes in Mean Yields and Mean Areas	Changes in Area-Yield Covariances	Mean Areas and Yield Variances and Covariances	Mean Yields and Area Variances and Covariances	Mean Yields Mean Areas and Area-Yield Covariances	Changes in Residuals	Total Contribution to Change in Variance of Production in China
Manchuria	23.1	27.5	20.3	-5.8	-3.5	4.0	42.6	-20.0	10.9	1.0	1.2
Jiangsu and Shanghai	13.8	-0.4	70.9	-0.7	0.1	15.9	-17.3	-4.3	21.5	0.4	1.2
Anhui	4.4	35.3	11.2	0.4	-0.6	9.6	14.0	1.7	24.8	-1.0	0.5
Jiangxi	-0.7	73.1	-17.3	40.5	2.1	-120.9	16.0	-2.2	87.5	21.9	-0.0
Shandong	11.7	0.0	48.3	-0.6	-0.2	13.4	7.0	-4.2	26.0	-1.4	7.1
Henan	707.0	-201.4	-112.4	97.8	-69.7	451.3	-17.0	718.5	953.0	-12.9	-0.2
Hubei	18.0	10.1	44.9	-2.6	2.3	1.3	32.3	-6.3	2.0	-2.1	0.3
Hunan	15.7	-4.0	22.9	-24.0	0.1	95.8	-1.8	-9.1	12.1	-7.8	0.0
Guangdong	1.0	0.2	33.4	49.8	-0.0	-23.7	11.7	37.6	-12.4	2.4	0.0
Sichuan	-1.5	33.6	-0.0	2.1	-6.8	21.4	-0.2	2.9	48.9	-0.4	1.1
Guizhou	-53.7	500.3	-294.5	678.5	4.9	-85.6	-475.1	-187.0	-32.1	44.2	0.0
Yunnan	-0.6	58.7	8.7	15.8	-2.6	-7.9	31.2	4.8	-11.4	3.2	0.0
Shaanxi	24.7	90.6	6.8	-0.7	15.4	-9.5	16.5	-4.5	-39.8	0.5	0.7
Gansu	-0.3	68.8	-1.5	0.3	-7.4	6.9	-13.1	1.3	45.7	-0.7	0.2
Shanxi	28.7	-7.4	113.6	-0.5	-2.4	-0.2	-33.6	-3.8	-0.4	5.9	0.3
Hebei	16.6	3.3	32.0	-1.7	0.7	3.8	42.4	-9.4	10.9	1.4	6.8
Inter-province covariances	16.9	10.6	42.5	-0.6	5.0	6.6	25.1	-6.2	-1.8	1.8	80.7
All provinces	20.0	10.9	41.8	-0.9	4.2	6.1	24.2	-7.8	-0.0	1.5	100.0

Note: See Table 3 for definition of the "Components of Change in Variance."

Table 16—Analysis of the Components of Change in the Variance of Maize Production by Province in China, 1931-37 to 1979-85

	Changes in Mean Yields	Changes in Mean Areas	Changes in Yield Variances and Covariances	Changes in Area Variances and Covariances	Changes in Mean Yields and Mean Areas	Changes in Area-Yield Covariances	Interaction Terms Between: Mean Areas and Yield Variances and Covariances	Interaction Terms Between: Mean Yields and Area Variances and Covariances	Interaction Terms Between: Mean Yields Mean Areas and Area-Yield Covariances	Changes in Residuals	Total Contribution to Change in Variance of Production in China
Manchuria	0.6	3.2	3.1	2.4	-0.4	3.1	44.9	12.5	28.4	2.3	69.1
Jiangsu and Shanghai	551.5	104.5	-352.8	-35.7	-0.7	40.2	-67.0	-197.7	71.8	-14.1	0.0
Anhui	2.5	16.2	-3.3	22.2	0.8	5.0	-10.3	57.6	14.4	-5.1	0.1
Jiangxi	2594.0	3312.5	-643.6	-1405.2	305.4	-2238.6	-600.8	-908.6	-1767.3	1452.2	0.0
Shandong	38.0	24.7	12.1	-2.7	12.9	-10.9	151.0	-19.9	-104.8	-0.4	1.3
Henan	4.7	20.3	5.8	1.3	0.5	2.5	32.5	11.5	17.9	2.9	2.0
Hubei	14.1	176.8	-4.6	-0.8	-16.6	2.2	-82.7	-3.3	19.8	-4.9	0.0
Hunan	0.8	48.8	5.2	-1.0	0.8	-4.5	55.5	-0.2	-12.3	7.0	0.0
Guangdong	-70.8	-132.1	1.8	73.8	-20.8	45.2	16.6	45.3	140.2	0.8	0.0
Sichuan	162.3	738.5	-92.4	40.3	98.7	-104.1	-471.8	69.9	-322.2	-19.3	0.2
Guizhou	3.3	42.0	1.2	1.3	4.0	3.1	23.7	2.1	20.4	-1.2	0.3
Yunnan	71.5	53.5	-0.4	-9.2	15.5	2.1	-3.6	-41.6	13.8	-1.5	0.1
Shaanxi	1.0	15.4	2.5	0.6	-0.6	-0.4	86.4	2.4	-5.6	-1.6	0.7
Gansu	16.2	8.8	12.2	-2.0	4.3	-5.7	98.7	-5.9	-28.2	1.6	0.5
Shanxi	-0.8	11.8	6.2	5.4	-4.9	-1.1	28.8	64.7	-8.3	-2.0	0.1
Hebei	153.7	189.7	12.8	2.6	79.8	-58.0	109.2	14.9	-407.3	2.7	0.3
Inter-province covariances	18.4	-3.8	6.7	-6.6	4.3	1.7	85.0	-28.6	24.0	-1.1	25.6
All provinces	6.7	4.3	4.0	0.0	1.4	2.2	55.5	1.5	23.0	1.3	100.0

Note: See Table 3 for definition of the "Components of Change in Variance."

covariance term and most of the pure provincial contributions were negative, primarily reflecting declining sown area, with the exception of Shanxi, which exhibited a pattern identical to that of Manchuria in terms of the discussed components.

AN AMENDED VIEW OF FOODCROP VARIABILITY IN CHINA

This study of foodcrop production variability in China, founded upon a decomposition of changes in production variances into their discreet components and supportive investigations, has led to conclusions about its predominant modern causes which differ from those prominent in the economic literature on China. Increased variability in China is mostly a function of increased production (and especially yield) covariances among provinces within the country, rather than of increased variability at the local level. This is a natural development common to many countries in recent decades and accompanies national market development and integration. However, it appears to be particularly prominent in countries engaged in a substantial degree of central planning. The recommended interpretation is that while areas experiencing bad harvests tended to average out with those experiencing good harvests within each year during the 1930s and 1950s, this occurs to a lesser extent in the 1980s. Yields in major producing areas are apt to move together in response to national policy changes, changes in input supply and allocation patterns, and so forth.

This tendency has *not* resulted in large increases in foodcrop production *covariances* over time, despite the much greater dependence of current high yields on state-supplied inputs and much greater responsiveness to national policy. This is because foodcrop sown area stabilization efforts have been relatively successful, though yield cvs have not come down. It is also because Chinese efforts at insulating foodcrop production from weather adversity in major growing areas has been so successful. Coefficients of variation for aggregate foodcrop production in China of the 1980s are low relative to other large regions of the world. While production cvs have grown since the 1950s, they are still relatively low and are no higher than those of China in the 1930s.

These conclusions differ from those expressed by Tang (1980, 1984) who regards China as having failed to "weather-proof" its agriculture, and they differ from those of Kueh (1983, 1984b, 1986) who seems to argue that weather has played a fairly important (although declining) role in explaining changes in aggregate production. Obsessive concern about the impact of weather cycles on aggregate production is also likely to be misplaced. Except for the late 1950s and early 1960s, these conclusions support Tang (ibid.) in his statement that the role of weather has been somewhat overrated in the literature discussing modern Chinese foodcrop production in the aggregate.

This is not to maintain that weather is not of predominant and legitimate concern to individual farmers in China, as elsewhere, and to

This is not to maintain that weather is not of predominant and legitimate concern to individual farmers in China, as elsewhere, and to larger aggregations of farmers, whatever their means of sharing risk, who are trapped in China's more risk-prone farming areas (Stone 1980, 1986a,c, 1987a, Lardy 1983). The vulnerability of such groups to weather risk is a very appropriate and important policy concern and is being addressed in a variety of ways: (a) by considering at least selective migration; (b) by encouraging rather than discouraging non-agricultural economic activities; (c) by greater public assistance to protect local consumption from actual harvest losses in chronically impoverished and risk-prone areas; (d) by increased allocation of yield-increasing inputs and research activities emphasizing both stress resistance and yield growth under chronically adverse conditions.

Even in the aggregate, certain crops have undergone periods of higher coefficients of production variation. While all crops were affected by the 1958-62 period in terms of production, area, and yield, subsequent higher production cvs have been related primarily to temporarily higher yield cvs for a particular crop. These instances would include the increase in maize cvs during the mid-1960s to early 1970s and the increase in wheat cvs from the mid-1970s through the early 1980s. Since these periods coincide with the introduction of a generation of HYVs for these crops, it is not impossible that the HYVs were not only substantially higher yielding, but more susceptible to weather stress and disease. It is also quite possible that they were pushed into more risk-prone and poorly serviced areas due to the enthusiasm for their proven fertilizer-responsive capabilities. This is particularly likely for maize, especially in the Northeastern provinces. Thus weather may continue to play an important role in variability, but via complex interaction with technology and state area expansion programs. Disclosure of the record of crop-wise fertilizer allocations would also be illuminating.

It is important to note that much aggregate foodcrop production variability is induced by public sector activity, both inadvertent and deliberate. Yet variability in China remains a problem. Despite low cvs and relatively insulated production in major growing areas, the absolute variance is still large. With a dynamic system for generating supply growth, poor quantitative precision in policy adjustment, particularly inadequate development of independent markets and poor understanding of, and experience with how to develop demand, an intermittent cycle of costly surpluses and clumsy overreaction via state policy adjustment on the supply side can continue into the future. This is not only expensive for the state and for the economy, and shortchanges those who still lack adequate food, but is economically destabilizing for especially smaller developing countries dependent on food imports or upon export of a few vulnerable economic crops.

An aggressive policy to develop domestic demand is an effective alternative, since many of the albeit expensive market infrastructure-related investments consistent with such a policy would have profoundly beneficial synergistic effects through the economy. Although China has appropriate to proceed further. It therefore appears likely that trend growth in foodcrop production supply will decrease in the future, while variability may increase to some extent. Finally, although decentralization of decisionmaking and of institutional adjustment processes would hardly be undertaken for this specific purpose in China, this research shows that some decentralization in critical sectors may be the most powerful tool to limit inadvertent and unwanted foodcrop production variability.

Although there appears to have been some record of policy and foodcrop production cycles, the importance of policy goes beyond rural disturbance associated with periodic political struggles in China. A variety of policy and investment initiatives, and established institutions spanning decades have served to make Chinese food production less weather sensitive and to concentrate production in less sensitive areas (Kueh 1983, IFPRI/BIDS, Desai and Stone). The centralist complex of policies and institutions, on the other hand, have tended to increase variability by increasing the simultaneity of all policy adjustments and their effects. Other discreet policy initiatives have had more temporarily destabilizing effects, either positive, negative or, in successive years, both. In the future, policy-induced variability is liable to increase as the Chinese government struggles to deal with temporary problems of oversupply and supply adjustment while endeavoring to develop the dynamics of demand in a system historically geared toward demand suppression and dynamic supply.

REFERENCES

Anderson, J. R., and P. B. R. Hazell, eds. Variability in Cereal Yields and Implications for Agricultural Research and Policy. Baltimore MD: Johns Hopkins University Press, 1987 (forthcoming).

Anhui Jingji Nianjian Bianjibu (Anhui Economic Yearbook Editorial Department). Anhui Jingji Nianjian (Anhui Economic Yearbook). Hefei: Anhui Renmin Chubanshe (Anhui People's Press), 1984.

Ashton, B., K. Hill, A. Piazza, and R. Zietz. "Famine in China, 1958-61." Population and Development Review 10 (1984): 613-45.

Bohrnstedt, G. W., and A. S. Goldberger. "On the Exact Covariance of Products of Random Variables." J. Amer. Statist. Assoc. 64 (1969: 1439-42.

Buck, J. L. Land Utilization in China, 3 vols. Nanking: University of Nanking Press; and Chicago IL: University of Chicago Press, 1937.

Carter, T. R., and M. L. Parry. "Climatic Change and Yield Variability." Summary Proceedings of a Workshop on Cereal Yield Variability, ed. P. B. R. Hazell, pp. 47-70. Washington DC: International Food Policy Research Institute, 1986..

Central Intelligence Agency. Agricultural Acreage in Communist China, 1949-68: A Statistical Compilation. Washington DC, 1969.

Chao, K. Agricultural Production in Communist China, 1949-1965. Madison WI: University of Wisconsin Press, 1970.

Chen, N. R. Chinese Economic Statistics: A Handbook for Mainland China. Chicago IL: Aldine, 1967.

China, Republic of. China Agricultural Estimates, 1931-1946. National Agricultural Research Bureau, Department of Agricultural Economics.

Dalrymple, D. G. High Yielding Rice Varieties in Developing Countries. Washington DC: Agency for International Development, 1986a.

Dalrymple, D. G. High Yielding Wheat Varieties in Developing Countries. Washington DC: Agency for International Development, 1986b.

Desai, G. M., and B. Stone. "Fertilizer Market Development and National Policy in China and India: A Comparative Perspective." A paper prepared for the 1987 IFA-FADINAP Southeast Asia and Pacific Regional Fertilizer Conference, Kuala Lumpur, July 22-25, 1987.

Eckstein, A. China's Economic Development. Ann Arbor MI: University of Michigan Press, 1975.

Food and Agriculture Organization of the United Nations. Fertilizer Yearbook 1983. Rome: FAO, 1984.

Guangdongsheng Tongjiju (Guangdong Province Statistical Bureau). Guangdongsheng Tongji Nianjian, 1984 (Guangdong Province Economic Yearbook, 1984). Hong Kong: Xianggang Jingji Daobao Chubanshe (Hongkong Economic Reporter Press), 1984.

Guangxi Jingji Nianjian Bianjibu (Guangxi Economic Yearbook Editorial Department). Guangxi Jingji Nianjian 1985 (Guangxi Economic Yearbook 1985). Nanning: Guangxi Jingji Nianjian Bianjibu (Guangxi Economic Yearbook Editorial Department), 1985.

Guizhousheng Shehui Kexueyuan (Guizhou Province Academy of Social Sciences), Guizhousheng Jihua Weiyuanhui (Guizhou Province Planning Committee), and Guizhousheng Tongjiju (Guizhou Province Statistical Bureau), ed. Guizhou Jingji Shouce (Guizhou Economic Handbook). Guiyang: Guizhou Renmin Chubanshe (Guizhou People's Press), 1985.

Hazell, P. B. R. Instability in Indian Foodgrain Production. Research Report No. 30. Washington DC: International Food Policy Research Institute, 1982.

________. "Sources of Increased Instability in India and U.S. Cereal Production." American Journal of Agricultural Economics 66 (1984): 303-11.

________. "Sources of Increased Variability in World Cereal Production since the 1960s." Journal of Agricultural Economics 36 (1984): 145-59.

________, ed. Summary Proceedings of a Workshop on Cereal Yield Variability. Washington, DC: International Food Policy Research Institute, 1986.

Hebeisheng Tongjiju (Hebei Province Statistical Bureau) and Hebeisheng Shehui Kexueyuan Jingji Yanjiusuo (Hebei Province Academy of Social Science, Institute of Economics), ed. Hebei Jingji Tongji Nianjian 1985 (Hebei Economic Statistics Yearbook, 1985). Beijing: Zhongguo Tongji Chubanshe (Statistics Press of China), 1985.

He Gang et al., eds. Zhongguo Nongyebu [Chinese Ministry of Agriculture], Zhongguo Nongye Nianjian 1984 [Agricultural Yearbook of China 1984]. Beijing: Nongye Chubanshe [Agricultural Publishing House], 1984.

Heilongjiangsheng Tongjiju (Heilongjiang Province Statistical Bureau), ed. Heilongjiangsheng Jingji Tongji Ziliao (Heilongjiang Province Economic Statistics Information). Harbin: Heilongjiangsheng Renmin Chubanshe (Heilongjiang People's Press), 1984.

International Food Policy Research Institute and Bangladesh Institute of Development Studies. Fertilizer Pricing Policy and Foodgrain Production Strategy in Bangladesh vol. 1. Summary Report, pp. ______. Washington DC: IFPRI, 1985.

Ishikawa, S. "Patterns and Processes of Intersectoral Resource Flows: Comparison of Cases in Asia." A paper prepared for a Symposium Celebrating the Twenty-Fifth Anniversary of the Economic Growth Center, Yale University, on the Current State of Development Economics: Progress and Perspectives, New Haven, April 1986.

Jiangsusheng Tongjiju (Jiangsu Province Statistical Bureau). Jiangsu Jingji Tongji Ziliao (Jiangsu Economic Statistical Information), n.d. (photocopy).

Kueh, Y. Y. "Fertilizer Supplies and Foodgrain Production in China, 1952-1982." Food Policy 9 (1984a): 219-31.

________. "A Weather Index for Analyzing Grain Yield Instability in China, 1952-81." The China Quarterly 97 (1984b): 68-83.

________. "Weather Cycles and Agricultural Instability in China." Journal of Agricultural Economics 37 (1986): 101-4.

________. "Weather, Technology, and Peasants' Organization as Factors in China's Food Grain Production, 1952-1981." Economic Bulletin for Asia and the Pacific 34 (1983): 15-26.

Lardy, N. R. Agriculture in China's Modern Economic Development. Cambridge MA: Cambridge University Press, 1983.

Li, C. M. The Statistical System of Communist China. Berkeley CA: University of California Press, 1962.

Liaoning Jingji Nianjian Bianji Weiyuanhui (Liaoning Province Economic Yearbook Editorial Committee), ed. Liaoning Jingji Tongji Nianjian 1983 (Liaoning Economic Statistics Yearbook, 1983). Shenyang: Liaoning Renmin Chubanshe (Liaoning People's Press), 1984.

The Manchukuo Yearbook Company. Manchukuo Yearbook, 1942. Hsinking, Manchukuo: The Manchukuo Yearbook Company, 1942.

Mehra, S. Instability in Indian Agriculture in the Context of the New Technology. Research Report No. 25. Washington DC: International Food Policy Research Institute, 1981.

Nguyen, H. P. "Sources of Increased Instability in Soviet Grain Production in the 1970s." An unpublished paper prepared for the International Food Policy Research Institute/Deutsche Stiftung fur Internationale Entwicklung Workshop on Sources of Increased Variability in Cereal Yields, Feldafing, Federal Republic of Germany, November 26-29, 1985.

Oram, P. A. "Sensitivity of Agricultural Production to Climatic Change." Climatic Change 7 (1985): 129-52.

People's Republic of China, State Statistical Bureau. Statistical Yearbook of China 1986. Oxford: Oxford University Press, 1986.

________. Statistical Yearbook of China 1984. Hong Kong: Economic Information and Agency and Beijing: China Statistical Information and Consultancy Service Centre, 1984.

________. Statistical Yearbook of China 1983. Hong Kong: Economic Information and Agency, 1983.

________, Nongye Jishu Jingji Shouce Bianweihui (Agricultural Technical and Economic Handbook Editorial Committee). Nongye Jishu Jingji Shouce (Agricultural Technical and Economic Handbook). Beijing: Nongye Chubanshe (Agricultural Publishing House), 1983.

________, Xinhua (New China News Agency), news bulletin, Beijing, February 23, 1987.

________, Zhongguo Nongye Nianjian Bianji Weiyuanhui (Chinese Agricultural Yearbook Editorial Committee), ed. Zhongguo Nongye Nianjian, 1980 (Chinese Agricultural Yearbook, 1980). Beijing: Nongye Chubanshe (Agricultural Press), 1980.

________. Zhongguo Nongye Nianjian, 1981 (Chinese Agricultural Yearbook, 1981). Beijing: Nongye Chubanshe (Agricultural Press), 1981.

________. Zhongguo Nongye Nianjian, 1982 (Chinese Agricultural Yearbook, 1982). Beijing: Nongye Chubanshe (Agricultural Press), 1982.

________. Zhongguo Nongye Nianjian, 1983 (Chinese Agricultural Yearbook, 1983). Beijing: Nongye Chubanshe (Agricultural Press), 1983.

________. Zhongguo Nongye Nianjian, 1984 (Chinese Agricultural Yearbook, 1984). Beijing: Nongye Chubanshe (Agricultural Press), 1984.

________. Zhongguo Nongye Nianjian, 1985 (Chinese Agricultural Yearbook, 1985). Beijing: Nongye Chubanshe (Agricultural Press), 1985.

________. Zhongguo Nongye Nianjian, 1986 (Chinese Agricultural Yearbook, 1986). Beijing: Nongye Chubanshe (Agricultural Press), 1986.

________, Zhongguo Guojia Tongjiju (State Statistical Bureau of China). Zhongguo Maoyi Wujia Tongji Ziliao (Statistical Materials and Trade and Prices). Beijing: Zhongguo Tongji Chubanshe (Statistical Publishing House of China), 1984.

Rosenberg, N. J. "A Primer on Climatic Change: Mechanisms, Trends, and Projections." Discussion Paper Series No. RR86-04. Washington DC: Resources for the Future, 1986.

Schuman, R. "Estimates of Grain Output in the People's Republic of China, 1949-1981." Unpublished data compendium, International Food Policy Research Institute, Washington DC, 1983.

Shanghaishi Tongjiju (Shanghai Municipality Statistical Bureau), ed. Shanghai Tongji Nianjian 1983 (Shanghai Statistical Yearbook 1983). Shanghai: Shanghai Renmin Chubanshe (Shanghai People's Press), 1984.

Sichuansheng Tongjiju (Sichuan Province Statistical Bureau), ed. Sichuan Tongji Nianjian, 1983 Nian (Sichuan Statistical Yearbook, 1983). Chengdu: Qianjin Yinshuachang (Forward March Printing Factory), 1984.

Skinner, G. W., and E. A. Winckler. "Compliance Succession in Rural Communist China: A Cyclical Theory." A Sociological Reader on Complex Organizations, ed. A. Etzion, pp. 410-38. New York: Holt, Rinehart, and Winston, 1969.

Social Science Research Council. Provincial Agricultural Statistics for Communist China. Ithaca NY: SSRC Committee on the Economy of China, 1969.

Solow, R. M. "Technical Change and the Aggregate Production Function." Rev. Econ. and Statist. 39 (1957): 312-20.

Stone, B. "China's 1985 Foodgrain Production Target: Issues and Prospects" in A. M. Tang & Bruce Stone. Food Production in the People's Republic of China. Research Report No. 15. Washington DC: International Food Policy Research Institute, 1980, pp. 83-178.

________. "The Chiang Jiang Diversion Project: An Overview of Economic and Environmental Issues." Long Distance Water Transfer: A Chinese Case Study and International Experiences, ed. A. K. Biswas, D. K. Zuo, J. E. Nickom, C. M. Liu, pp. 194-214. Dublin: Tycooly International Publishing Ltd., 1983a.

________. "The Basis for Chinese Agricultural Growth in the 1980s and 1990s: A Comment on Document No. 1, 1984." The China Quarterly no. 101 (1985): 114-21.

________. "Chinese Fertilizer Application in the 1980s and 1990s: Issues of Growth, Balance, Allocation, Efficiency and Response." China's Economy Looks Toward the Year 2000, vol. 1, The Four Modernizations, ed. U.S. Congress Joint Economic Committee, pp. 453-96. Washington, DC: U.S. Government Printing Office, 1986a.

________. "Chinese Socialism's Record on Food and Agriculture." Problems of Communism, September-October (1986c): 63-72.

________. "Fertilizer Marketing and Allocation in China." A paper prepared for the World Bank, Washington DC, June 1984b.

________. "Foodcrop Production and Consumption Performance in China and India." A paper prepared for the Annual Meeting of the American Association for the Advancement of Science, Chicago, February 15, 1987a.

________. "Relative Foodgrain Prices in the People's Republic of China: Rural Taxation through Public Monopsony." Food and Agricultural Price Policy in Developing Countries, ed. J. W. Mellor and R. Ahmed. Baltimore MD: Johns Hopkins University Press, 1987b (forthcoming).

________. "Systemic and Policy Adjustment in the Administration of Chinese Fertilizer Development." Paper prepared for the World Bank, Washington DC, June 12, 1986b.

________. "Trends in Chinese Hybrid Rice Production." Unpublished paper, International Food Policy Research Institute, Washington DC, April 16, 1984a.

________. "The Use of Agricultural Statistics: Some National Aggregate Examples and Current State of the Art." Chinese Agricultural Economy, ed. R. Barker, R. Sinha, and B. Rose, pp. 205-49. Boulder CO: Westview Press, 1983.

Stone, B., C. Greer, Z. Tong, C. Friedman, M. McFadden, and M. Snyder. "Agro-Ecological Zones for Wheat Production in China: A Compendium of Basic Research Materials." Washington DC: International Food Policy Research Institute, 1985 (unpublished draft).

Stone, B., and Z. Tong. "Changing Patterns of Chinese Cereal Production Variability During the People's Republic Period." An unpublished paper prepared for the International Food Policy Research Institute/Duetsche Stiftung für Internationale Entwicklung Workshop on Sources of Increased Variability in Cereal Yields, Feldafing, Federal Republic of Germany, November 26-29, 1985.

________. "Changing Patterns of Chinese Cereal Production Variability During the People's Republic Period." Variability in Cereal Yields and Implications for Agricultural Research and Policy, ed. J. R. Anderson and P. B. R. Hazell. Baltimore MD: Johns Hopkins University Press, 1987 (forthcoming).

Tang, A. M. An Analytical and Empirical Investigation of Agriculture in Mainland China, 1952-1980. Taipei: Chung-Hua Institution for Economic Research, 1984.

________. "Trend, Policy Cycle, and Weather Disturbance in Chinese Agriculture, 1952-1978." American Journal of Agricultural Economics 62 (1980): 339-48.

Tang, A. M., and C. J. Huang. "Changes in Input-Output Relations in the Agriculture of the Chinese Mainland, 1952-79." Agricultural Development in China, Japan, and Korea, ed. C. M. Hou and T. S. Yu, pp. 319-48. Taipei: Academica Sinica, 1982.

Terjung, W.H., J. T. Hayes, H. Y. J., P. A. O'Roorke, and P. E. Todhunter. "Actual and Potential Yields for Rainfed and Irrigated Maize in China." International Journal of Biometeorology 28 (1984a): 115-35.

________. "Actual and Potential Yields for Rainfed and Irrigated Wheat in China." Agricultural and Forest Meteorology a31 (1984b): 1-25.

________. "Potential Paddy Rice Yields for Rainfed and Irrigated Agriculture in China and Korea." Annals of the Association of the American Geographers 75 (1985): 83-101.

Walker, K. R. Food Grain Procurement and Consumption in China. Cambridge MA: Cambridge University Press, 1984.

Wang, S. W., and L. O. Mearns. "The Impact of the 1982-83 El Niño Event on Crop Yields in China." The Societal Impacts Associated with 1982-83 Worldwide Climate Anomalies, ed. M. Glantz, R. Katz, and M. Krenz. Boulder CO: National Center for Atmospheric Research, 1987.

Wiens, T. B. "Agricultural Statistics in the People's Republic of China." Quantitative Measures of China's Economic Output, ed. A. Eckstein, pp. 44-107 and 275-326. Ann Arbor MI: University of Michigan Press, 1980.

________. "Evolution of Policy and Capabilities in China's Agricultural Technologies." Chinese Economy Post-Mao, ed. U.S. Congress Joint Economic Committee , pp. 671-703. Washington DC: U.S. Government Printing Office, 1978.

________. "Technological Change." Chinese Agricultural Economy, ed. R. Barker, R. Sinha, and B. Rose, pp. 99-121. Boulder CO: Westview Press, 1983.