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HYVs and Instability in Sorghum and Pearl Millet Production in India

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Abstract

The following questions relating to coarse grain production instability in India are addressed in this paper: (1) has production instability in the major sorghum and pearl millet growing regions increased over time?; (2) has the change in production instability been directly caused by changes in means and variances of area and yield within regions or by their covariances across regions?; and (3) has the diffusion of HYVs positively influenced or conditioned the direct cause found in the (2)?.

Using a statistical decomposition analysis based on Hazell's earlier work, we find that (1) instability in sorghum and pearl millet production increased both absolutely and relatively between the pre- and post-green revolution periods (1956-57 to 1967-68 and 1968-69 to 1979-80), (2) increased production variance stemmed overwhelmingly from increased yield covariance among the sorghum and pearl millet producing regions, and (3) changes in HYV adoption, irrigated area, and increased rainfall covariance are positively associated with if not partially responsible for more covariate yields over time.

A mix of international trade and storage policies can cost effectively offset most if not all the instability costs of increasing yield covariance. If efficient policies are not forthcoming, investing in crop research to maintain and enhance resistance to yield reducers and to broaden genetic variability will have additional stability benefits over and above returns to increased production.

HYVs AND INSTABILITY IN SORGHUM AND PEARL MILLET PRODUCTION IN INDIA

Thomas S. Walker*

In its five crop improvement programs, ICRISAT invests heavily in screening and breeding for resistance to yield reducers. The social payoff to this research is derived primarily from productivity gains and secondarily from the extent that improved yield stability from more pest resistant and stress tolerant varieties is translated into increased regional and national production stability.

Results from several studies (Mehra 1981, Hazell 1982) suggest that instability in Indian foodgrain production is increasing. Between 1954-55/1964-65 and 1967-68/1977-78 the coefficient of variation of All-India total cereal production increased by about 50% from 4.0 to 5.9;the variance of All-India production increased by 342%. Peter Hazell (1982) has statistically partitioned the change in variance in total cereal production into four components: (1) production variances of individual crops within the same state; (2) covariance of production among crops in the same state; (3) covariances of production among states in the same crop; and (4) covariances of production among different crops in different states.

Hazell hypothesizes that if HYVs are a significant source of production instability then increased production variances within states should be large contributors to explaining increases in the variance of cereal production. But his results show that only about 18% of the increase in variance of total cereal production can be accounted for by changes in crop production variances. The remaining 82% is explained by changes in the covariance components particularly interstate covariances within crops which contribute 41% to the change in variance in total cereal production. Changes in yield covariances are much more important than changes in yield variances. Hazell concludes

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that the increase in instability in India's cereal production between the two periods cannot be attributed to HYVs but rather to other causes. He additionally draws the implication that there is reduced scope for yield-stabilizing varietal technologies to decrease production instability in Indian agriculture.

In a later paper comparing the U.S. and Indian experience, Hazell (1984) sees a greater role for HYVs to play in influencing yield covariances. He speculates that narrowing of the genetic base of maize hybrids has led to increased regional covariances and augmented production instability in corn production in the U.S. In this paper we provide firm statistical evidence that diffusion of sorghum (or jowar) and pearl millet (or bajra) hybrids are positively associated with if not partially responsible for increased production instability in the major growing districts in India. We use district data because they provide more degrees of freedom to better understand cause and effect in technologically related stability issues.

The first three sections of the paper are diagnostic. We find that the summary or immediate cause of rising instability in sorghum and pearl millet production is increasing interdistrict yield covariances over time. The next two sections focus on statistically testing likely explanations for increasing interregional yield covariances. We conclude with some implications for food security policy for sorghum and pearl millet production and consumption. This section is probably more important for what it does not say than for what it does.

THE DIAGNOSTIC APPROACH

We rely on Hazell's (1982) decomposition methodology to identify components and sources of change in production instability in 48 sorghum and 40 pearl millet growing districts of India. Initially, we chose the 50 most important producing districts for each crop based on the latest area estimates for 1981-82 (Government of India, 1983). Information was not available for two sorghum and for 10 pearl millet growing districts in Haryana and Uttar Pradesh. The 48 sorghum districts contributed about 70% of both All India production and area; the 40 pearl millet districts accounted for about 70% of area and 60% of production. Two 12-year intervals, 1956/57-1967/68 abd 1968/69-1979/80 which roughly correspond to pre- and post-green revolution periods were selected for analysis. Districtwise area and yield data from the State Season and Crop Reports (see references) were linearly detrended for each period and their residuals were centered on the mean for each period. Detrended area and yield data were multiplied to give detrended production data for each time

period. Instability is measured by the change in production variance with respect to the first period.

For a given crop, the change in production variance can be partitioned into two broad components: (1) the sum of production variances within districts and (2) the sum of interdistrict production covariances (Hazell 1982, p. 21). Notationally, we have

$$V(Q) = \sum_i V(A_i Y_i) + \sum_{i \neq j} \sum Cov(A_i Y_i, A_j Y_j) \qquad (1)$$

where $V(Q)$ = total production variance

A_i = area planted in district i,

Y_i = yield of district i,

A_j = area planted in district j,

Y_j = yield of district j.

Each of these two terms can in turn be attributed to 11 sources (Hazell 1982, p. 20). For components of change in production variance these are changes in mean yield, mean area, yield variance, area variance and area-yield covariance; interactions between changes in mean yield and mean area, in mean area and yield variance, in mean yield and area variance, and mean area and yield and changes in area-yield covariance; and a residual component. Analogous components can also be statistically defined for the change in production covariance (Appendix Table A1).

INCREASED INSTABILITY IN SORGHUM AND PEARL MILLET PRODUCTION

Instability in sorghum and pearl millet production increased both absolutely and relatively from the first 12-year period to the second. For sorghum the coefficient of variation of linearly detrended production increased from 8.0 to 16.0%, for pearl millet the change was even more marked -- from 11.0 to 34.0% (Table 1).

Most of the major producing districts also experienced increased production instability. The coefficient of variation and variance of production increased in 31 and 36 of the 48 sorghum producing districts (Appendix Table A2). Thirty six and all 40 of the major pearl millet growing districts were characterized by greater relative and absolute production instability (Appendix Table A3).

Table 1. Instability in sorghum and pearl millet production in the pre- and post-green revolution periods.

Crop	Variance 1956-57 to 1967-68	Variance 1968-69 to 1979-80	Variance % change	Coefficient of variation 1956-57 to 1967-68	Coefficient of variation 1968-69 to 1979-80	Coefficient of variation % change
Sorghum	27565.6	1107019.6	4000	8.0	16.0	100
Pearl millet	62715.2	1043258.0	1663	11.0	34.0	209

SOURCES OF INCREASED PRODUCTION INSTABILITY

Increased production variance stemmed overwhelmingly from increased production covariance among major producing regions for both sorghum and pearl millet (Table 2). More than 90% of the increase in production variance for both crops is attributed to changes in interdistrict production covariances. Changes in within-district production variance do not contribute appreciably to the changes in production variance. In a highly disaggregated analysis like ours, this result is not that surprising because for each variance in equation (3) there are $r(r-1)/2$ production covariances and their sum should increase with the sum of the production variances (Hazell 1984).

What is surprising is that these changes should be so dominated by changes in yield covariances. For both crops changes in yield covariance have been largely responsible for the increase in changes in production variance (Table 3). Within each crop, the yields of sorghum and pearl millet have become increasingly covariate across districts and this increased yield covariance has led to increased production instability.

Changes in area-yield covariance also accounted for an appreciable share (about 14%) of increased production variance in pearl millet. Farmers are apparently planting more area to pearl millet in years when yields are higher. One explanation for this tendency is that farmers particularly those in Gujarat now have more water to plant irrigated summer bajra in more abundant rainfall years when rainfed yields are also heavier. A greater investment in irrigation and in HYVs has probably enhanced the potential for greater area-yield covariance. In contrast to bajra, little summer jowar is planted, and postrainy season (or rabi) sorghum is grown on residual soil moisture without irrigation.

The analysis thus far has allowed us to focus on the key empirical question: why have sorghum and pearl millet yields become increasingly covariate over time across districts? There are several possible interrelated answers to this question; some are measurable while others cannot be quantified. Three potential causes are relatively easy to quantify: (1) changes in rainfall covariance, (2) changes in irrigated area, and (3) diffusion of HYVs.

The simplest hypothesis on why detrended yields increasingly move together over time centers on changes in rainfall covariance (RFCOVCHG). A severe drought which Wolf Lajedinsky described as "never in a 100 years" occurred in 1972 in extensive sorghum and pearl millet growing tracts of peninsular India (Walinsky, 1977). It is likely that such an extremely adverse rainfall event whose total annual

Table 2. Contribution of within regional variance and between regional covariance to the change in variance in sorghum and pearl millet production.

Crop	Interdistrict production variance	Interdistrict production covariance
	%	
Sorghum	5.12	94.88
Pearl millet	7.90	92.10

Table 3. Contribution of different sources to increased interregional covariance in sorghum and pearl millet production.

Source	Sorghum	Pearl millet
	%	
Change in mean yield	1.69	0.71
Change in mean area	3.07	0.60
Change in yield covariance	83.95	54.17
Change in area covariance	0.10	2.22
Interaction between changes in mean yields and mean areas	0.04	-0.02
Change in area-yield covariance	-1.34	14.15
Interaction between changes in mean area and yield covariance	1.83	4.38
Interaction between changes in mean yield and area covariance	0.26	1.34
Interactions between changes in mean area and yield and changes in area-yield covariance	-0.75	5.99
Change in residual	6.04	8.53
Total	94.88	92.10

rainfall in the affected districts was only 20-30% of the long-term average would also be more covariate than more normal rainfall events.

Understanding the relationship between changes in irrigated area and yield covariance is more complex. Irrigation for a given level of technology makes the production environment more homogeneous thus reinforcing tendencies towards greater yield covariance. Irrigation also contributes indirectly to yield covariances by inducing greater adoption of improved varieties and hybrids and agronomic practices. We expect that those districts pairs having more irrigated area (SUMIRR) in the second period would be characterised by more covariate yields. Likewise, district pairs with greater differences in irrigated area in the second period are expected to have less covariate yields.

HYVs usually have a narrower genetic background than local varieties and land races. For example, the bulk of HYV sorghum area in India is planted to four hybrids, CSH-1, CSH-5, CSH-6, and CSH-9. The latter three descended from the same male parent CS3541. Most of the commercially available pearl millet hybrids originate from closely related seed parents. Although statistical evidence from secondary data is hard to find, it is also common knowledge that the first generation hybrids HB-1, HB-3, and HB-4 were extremely susceptible to downy mildew resulting in significant economic losses in the early 1970s (Kanwar, 1975).

We expect more covariate yields in districts which have proportionally adopted more HYVs. By the same token because the improved cultivars and local varieties are genetically dissimilar in their susceptability to different yield reducers, we anticipate less covariate yields in districts where the differences in adoption rates are greater. SUMADT indexes the sum over each district pair of the estimated rate of adoption of HYVs during the last three cropping years of the second period; DIFADT represents the absolute value of the difference in adoption rate for the same time period for each district pair. We expect that the change in yield covariance between each district pair is positively and negatively associated with SUMADT and DIFADT respectively.

The less tangible sources of changes in yield covariance are power and fertilizer shortages and greater economic growth and development. Power outages and fertilizer shortages are an appealing explanation because more subsidized inputs in the form of electricity, fuel, irrigation water, and fertilizer were used in the second period and because these shortages did cyclically and sporadically occur across regions (H. Ezekiel as cited in Hazell). But we would expect their influence to be much

more significant for the superior cereals, wheat and rice, that command a much larger share of these resources than coarse grains, sorghum and pearl millet.

Economic development is also synonymous with increased covariance and interdependence. More literate and better educated agents have a greater capacity to process more and better quality information coming from more thoroughly linked factor and product markets. While the effect of these linkages are very real, they are also difficult if not impossible to quantify.

Another potential explanation for higher yield covariances is that sorghum and pearl millet is increasingly planted to more marginal land. The marginal land hypothesis is however more consistent with increasing production variances within districts than rising production covariances across regions.

DESCRIPTION OF THE DATA

The analysis is based on district pairwise observations. Taking combinations of the 48 sorghum and 40 pearl millet districts two at a time gives us 1128 observations for sorghum and 780 for pearl millet.

The independent variables, SUMADT, DIFADT, SUMIRR, DIFIRR, and RFCOVCHG are described in Table 4 together with the dependent variable, YCOVCHG. For about 66 and 78% of the pearl millet and sorghum district pairs, yield covariance increased in the second period. Wide ranging values for SUMADT and DIFADT reflect substantial interregional variation in HYV adoption. Large mean differences between SUMADT and SUMIRR also suggest that both sorghum and pearl millet hybrids have been planted extensively in dryland agriculture. Positive values for RFCOVCHG confirm our suspicions that total annual rainfall was more covariate in the second period. Rainfall became more covariate in the second period for 75% of pearl millet and 68% of the sorghum districts pairwise observations.

EMPIRICAL RESULTS

To assign greater importance to those district pairs where more sorghum and pearl millet is planted we do not treat each observation equally in the analysis but rather use classical weighted least squares where the weights are the mean proportions of area planted to the crop for each district pair relative to All India estimates of planted area during the last three cropping years of the second period. The weighted least squares regression estimates are

Table 4. Means and ranges of the data used to explain the increase in interregional yield covariance in sorghum and pearl millet production[a].

Variable name	Definition	Crop: Sorghum	Crop: Pearl millet	Expected sign
YCOVCHG	Change in yield covariance from the second period to the first	3919 (-42983 64226)	7137 (-125364 169428)	b
SUMADT[c]	Sum of district pairwise HYV area in % of total area planted to the crop	40.55 (0.08 111.54)	53.17 (0.00 186.00)	+
DIFADT[c]	Absolute value of the difference in % HYV area	17.47 (0.02 59.59)	30.11 (0.00 94.77)	-
SUMIRR[c]	Sum of district pairwise irrigated area in % of total area planted to the crop	10.28 (0.00 67.40)	8.45 (0.00 51.33)	+
DIFIRR[c]	Absolute value of the difference in irrigated area	7.50 (0.00 37.80)	6.13 (0.00 28.61)	-
RFCOVCHG	Change in total rainfall covariance from the second period to the first	7129 (-143500 102554)	12785 (-46511 123749)	+
Number of pairwise district observations		1128	780	

a. Ranges are in parentheses
b. Dependent variable
c. Mean value for each district for three cropping years from 1976-77 to 1978-79.

given in Table 5. They suggest a noisy data set. We are only able to account for about 7% of the variation in yield covariance changes in sorghum and about 4% in pearl millet. More importantly, the signs of the estimated coefficients are generally consistent with our expectations and for the most part are statistically significant ($P < .05$). Greater adoption of hybrids has increased interregional yield covoariances in both sorghum and pearl millet production. More covariate rainfall events have also led to significantly more covariate interregional yields. For sorghum changes in irrigated area behaves as expected; however, irrigation leads to reduced interregional pearl millet yield covariances. This puzzling result could stem from the fact that irrigated pearl millet often entails only one or two applications of water and is largely cultivated where water supply is most uncertain. A closer look at sourcewise changes in irrigated area could shed some light on this surprising finding.

Among irrigated area, HYV adoption, and rainfall covariance, proportional changes in HYV diffusion exert the heaviest impact on interregional covariance changes. A proportional 10% increase in the summed rates of adoption leads to a 9% increase in the yield covariance between the two concerned sorghum producing districts. For pearl millet the elasticity of response to changes in summed adoption rates is 0.82.

CONCLUSIONS

Having shown that adoption of HYVs is positively correlated with if not partially responsible for increased sorghum and millet production instability, it would be facile to conclude that scientists in the sorghum and pearl millet All-India Coordinated Crop Improvement Programs should have released hybrids and varieties with a broader genetic background and should have pursued a more regional or location specific release strategy to mitigate the adverse effect of increasing interregional yield covariance and rising production instability. Such a conclusion would be unwarranted. Even with hindsight it is impossible to say whether the benefits from following a more regional release policy and emphasizing selection and breeding from genetically diverse populations would compensate for the productivity gains forgone from pursuing a more single-minded, national yield improvement strategy. Moreoever a judicious mix of international trade and storage policies can cost effectively offset most if not all the instability costs of increasing yield covariance. Whether or not the policy response has been efficient is a fruitful area for future research.

Table 5. Estimated coefficients of the determinants of changes in interregional yield covariance in sorghum and pearl millet production.

Variable	Crop	
	Sorghum	Pearl millet
SUMADT	88.60** (5.26)[a]	110.30** (4.61)
DIFADT	-58.90* (-2.24)	-112.50** (-3.84)
SUMIRR	99.90* (2.28)	-462.00** (-3.40)
DIFIRR	-213.70** (-3.61)	108.00 (0.65)
RFCOVCHG	0.07** (4.42)	0.14** (4.86)
Intercept	2295	7162
$\bar{R}^2$	.069	.041

a. t values are in parentheses; * and ** indicates statistical significance at the .05 and .01 levels.

In the absence of effective stabilization policies, the distributional impact of rising sorghum and pearl millet yield covariances will affect some groups much more than others. Most consumers of sorghum and pearl millet are also producers. They will be relatively insulated from the direct consequences of increased production instability arising from more covariate interregional yields. Only about 25% of sorghum and pearl millet production is marketed (ICRISAT 1978-79 Annual Report, p. 234); therefore, the burden of sharper price fluctuation in these thin markets will fall disproportionately on rural landless labor and urban households who on average allocate about 10% of their total expenditure to sorghum and pearl millet (Murty 1983). Because sorghum and pearl millet substitute in consumption for superior cereals -- cross price elasticities of demand are as high as .20 for the poorest income groups (Murty 1983) -- consumers of rice and wheat will also be indirectly affected. Going beyond these preliminary indications of impact would require a multicommodity dynamic simulation model.

As markets become better integrated over space and time, the payoff for decision makers in the central government to design and carry out efficient trade and storage policies to meet rising instability in coarse grain production will increase. If efficient policies are not forthcoming, investing in crop research to maintain and enhance resistance to yield reducers and to broaden genetic variability will have additional stability benefits over and above returns to increased production.

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Appendix Table A1. Components of change in production covariance.

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

[a] A denotes area sown; y, yield; and Cov, covariance. Subscripts i and j refer to districts and 1 denotes the first period.

Source: Hazell 1982, Table 18, p.47.

Appendix Table A2. Changes in instability in major sorghum producing districts

District	Area[a]	%[b]	Coefficient of variation of detrended production 1956-57 to 1967-68	1968-69 to 1978-79	% change	Variance of detrended production 1956-57 to 1967-68	1968-69 to 1978-79	% chan[ge]
Sholapur	755400	4.67	21	36	71.43	3969.0	8174.0	105.9
Ahmednagar	565400	3.50	19	32	68.42	2267.7	5263.5	132.1
Osmanabad	542500	3.36	19	35	84.21	2204.3	10553.5	378.8
Poona	486600	3.01	19	25	31.58	814.5	1768.2	117.0
Bhir	415500	2.57	19	38	100.00	1209.7	4883.2	303.7
Parthani	350100	2.17	28	30	7.14	2159.5	3517.7	62.9
Mahbubnagar	334900	2.07	27	25	-7.40	1100.9	1242.6	12.9
Aurangabad	321000	1.94	9	26	188.90	451.1	2891.0	540.9
Nanded	292800	1.81	25	36	44.00	1929.8	4810.8	149.3
Akola	282000	1.75	26	25	-3.85	1234.1	3856.4	212.5
Yeatmal	272200	1.68	32	23	-28.12	1930.7	5698.7	195.2
Buldhana	259400	1.60	61	30	-50.82	10199.0	4692.3	-54.0
Dharwar	257773	1.60	21	16	-23.81	1395.0	1176.5	-15.7
Jalgaon	257400	1.59	30	36	20.00	2201.5	4378.5	98.9
Satara	248600	1.54	21	22	4.76	620.5	1082.4	74.4
Raichur	246334	1.52	16	14	-12.50	360.6	420.3	16.6
Bijapur	237136	1.47	18	19	5.56	1810.5	2280.0	25.9
Adilabad	225900	1.40	19	16	-15.78	819.7	443.1	-45.9
Sangli	220200	1.36	16	28	75.00	935.8	1658.1	77.2
Nagpur	216500	1.34	17	29	70.60	272.9	1053.0	285.9
Kurnool	212800	1.32	10	17	70.00	280.6	895.8	219.2
Gulbarga	314336	1.95	9	26	188.9	451.1	2891.2	540.9
Amravathi	197100	1.22	19	29	52.63	364.0	1604.8	340.9
Belgaum	194427	1.20	21	20	-4.76	1281.6	889.2	-30.6
Ujjain	190200	1.18	27	31	14.81	614.0	1064.0	73.3
Guna	185300	1.15	26	38	46.15	410.9	789.0	92.0
Kammam	184600	1.14	20	29	45.00	294.8	1399.5	374.7
Dhulia	178100	1.10	19	28	47.37	309.0	671.3	117.2
Mandsaur	176300	1.09	28	33	17.86	551.8	1100.9	99.5
Rajghar	170700	1.06	16	33	106.25	199.0	912.6	358.6
Knargone	164800	1.02	35	20	-42.86	1062.1	442.7	-58.3
Medak	164200	1.02	30	17	-43.33	638.1	249.6	-60.9
Shajpur	150900	0.93	26	25	-3.85	614.0	792.9	29.1
Warangal	147500	0.81	18	23	27.78	195.2	558.9	186.3
Hyderabad	128600	0.79	27	16	-40.74	260.8	113.4	-56.4
Wardha	128000	0.79	28	30	-7.14	346.7	638.1	84.0
Bellary	127912	0.79	11	25	127.30	100.2	1587.2	1484.0
Tirchirapally	124000	0.77	17	18	5.90	212.3	278.2	31.0
Dewas	123900	0.77	29	26	-10.34	513.9	493.3	-4.0
Nalgonda	122900	0.76	30	30	0	620.5	229.8	-63.0
Knandwa	120800	0.75	22	15	-31.82	260.5	164.1	-37.0
Cuddapah	117100	0.72	23	42	82.60	121.7	533.6	338.5
Mahesna	115851	0.72	35	28	-20.00	273.2	252.5	-7.6
Coimbatore	112000	0.69	7	29	314.30	135.7	1405.2	935.5
Bidar	110038	0.68	22	36	63.64	177.2	1082.4	510.8
Anantapur	105500	0.65	25	23	-8.00	330.5	216.7	-34.4
Bahruch	102102	0.63	22	23	4.50	80.3	130.6	62.6
Bhandara	31300	0.19	12	21	75.00	4.1	6.5	59.3

a. Taken from the Agricultural Situation in India, September 1983.
b. To All-India 1981-82 area of 16,158,400 hectares.

Appendix Table A3. Changes in instability in major pearl millet producing districts

District	Area[a]	%[b]	Coefficient of variation of detrended production 1956-57 to 1967-68	Coefficient of variation of detrended production 1968-69 to 1978-79	Coefficient of variation of detrended production % change	Variance of detrended production 1956-57 to 1967-68	Variance of detrended production 1968-69 to 1978-79	Variance of detrended production % change
Barmer	1095866	9.40	43	91	111.63	4341.5	21324.7	391.2
Jodhpur	626354	5.37	46	94	104.35	1456.2	10500.1	621.1
Nagaur	502739	4.31	27	41	51.85	461.4	2172.5	370.9
Churu	419092	3.59	37	68	83.78	360.2	2100.4	483.1
Jalore	365820	3.14	47	117	148.94	1006.2	8301.0	725.0
Nasik	362600	3.11	19	34	78.95	457.1	1982.9	333.8
Banaskantha	334815	2.87	30	56	86.67	1151.2	13689.0	1089.1
Ahmednagar	314200	2.29	15	43	186.67	103.2	1371.2	1228.7
Bikner	251037	2.15	52	84	61.54	107.7	280.2	160.2
Jaipur	248355	2.13	26	40	53.85	804.3	2272.4	182.5
Jhunjhuna	232904	2.00	35	74	111.43	463.9	1687.6	263.8
Sikar	230583	1.98	23	50	117.39	306.6	1120.9	265.6
Jaisalmer	183617	1.57	51	109	113.73	76.6	112.4	46.7
Mehsana	181188	1.55	32	36	12.50	1081.8	4778.9	341.8
Poona	178700	1.53	17	21	23.53	112.6	163.8	45.5
Alwar	174327	1.42	25	57	128.00	187.7	1648.4	778.2
Bijapur	166500	1.43	20	28	40.00	80.1	366.7	357.8
Kaira	164160	1.41	34	41	20.59	595.4	3690.6	519.9
Bharatpur	163168	1.40	29	45	55.17	274.6	1207.6	339.8
Bhavnagar	154075	1.32	31	43	38.71	589.5	3911.3	563.5
Aurangabad	151800	1.30	20	44	120.00	72.3	806.0	1014.8
Madhapur	137790	1.18	33	52	57.58	307.0	1232.0	301.3
Dhulia	124600	1.07	23	27	17.39	192.7	441.4	129.1
Bhir	122700	1.05	16	57	256.25	10.6	684.3	6355.7
Nalgonda	120100	1.03	33	36	9.09	195.7	110.2	-43.7
Satara	117200	1.00	20	37	85.00	81.2	137.6	69.5
Pali	107909	0.93	35	107	205.71	47.5	1173.0	2369.5
Jalgaon	107200	0.92	27	27	0.00	37.5	146.9	291.7
Kutch	102466	0.88	36	57	58.33	287.3	1064.5	270.5
Sangli	102200	0.88	16	32	100.00	10.6	33.6	217.0
Gulbarga	90623	0.78	31	39	25.80	46.5	480.9	934.2
S.Arcot	87000	0.75	26	25	-3.85	44.0	278.2	532.3
Raichur	86288	0.74	30	26	-13.33	16.7	95.5	471.9
Tiruchirapally	81000	0.69	12	26	116.67	60.8	261.1	329.4
Belgaum	80637	0.69	26	43	65.38	22.8	83.7	267.1
Amreli	78184	0.67	26	35	34.61	128.4	1233.4	860.6
Surendranagar	77866	0.67	32	70	118.75	51.1	814.5	1493.9
Ganganagar	77421	0.66	70	45	-35.71	251.9	320.0	27.0
Morena	68500	0.59	25	43	72.00	271.6	652.8	140.4
Ahmedabad	63724	0.55	34	53	55.88	90.3	882.1	876.9

a. Taken from the Agricultural Situation in India, August 1983.
b. To All-India 1981-82 area of 11,660,400 hectares.