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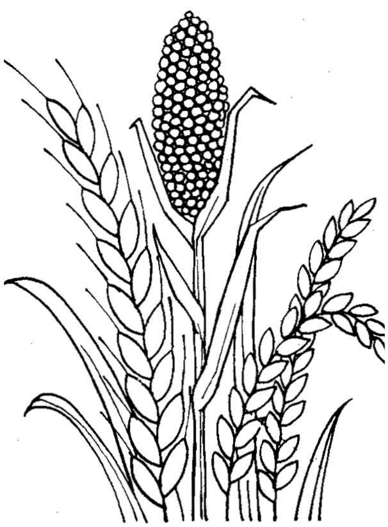

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YIELD UNCERTAINTY IN MAHARASHTRA AGRICULTURE

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One of the most disturbing problems of dry areas is uncertainty in yields. In the task of devising a suitable crop pattern for a region or a scheme of crop insurance, it is necessary to have an idea of the magnitude of uncertainty and its nature. Unfortunately we do not adequately have the needed data at farm, village or even taluka levels. We can, however, have an idea of uncertainty at district and State levels where due to aggregation and mutual offsetting the estimated uncertainty will be lower. Nevertheless, we can find some meaningful relationships with a bearing on uncertainty even at these levels. This paper tries to measure uncertainty in per hectare yields facing eight main crops at the State level and one crop at the district level. It also tries to see what difference irrigation makes to uncertainty and also whether any relationship emerges between uncertainty and yield rates. The crops selected are cotton, *tur*, groundnut, bajra, jowar, wheat, rice and sugarcane. Of these, the last is entirely irrigated and rice is grown only in areas of relatively assured water supply. The rest can be regarded as dry crops as irrigated area under them is meagre and, rainfall is low and less certain in areas they are grown. Cotton is selected for detailed analysis because it was found to have the maximum degree of uncertainty. The data used in the paper are mainly from Season and Crop Reports and District Census Hand-books.

I

Uncertainty can be measured only in terms of deviations from what can be regarded as normal yield which could be projected into the future reliably enough. Several alternative approaches to the determination of the normal could be thought of. The test for selection would be which one of them is subject to the least error; that is, which one is subject to the lowest coefficient of variation (CV) around the normal. We may speak of four alternatives here : (1) simple arithmetic average, (2) bulk average, (3) trend estimate, (4) five-year moving average. The arithmetic average cannot be accepted as the basis for normal yield when (*i*) there are one or two very abnormal observations, or (*ii*) there is a trend in the series, or (*iii*) when the frequency distribution is markedly skewed. The bulk aver-

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age is not merely an average of the modal class but an average of the bulk, say 80 per cent, of the observations such that extreme years which fall in frequency classes with the least number of observations will be avoided. Even this method cannot be considered satisfactory if there is a trend in the series.

When there is a trend, trend estimates could, of course, be regarded as normal yields for respective years and CV around them could be accepted as the measure of uncertainty. This CV would be less than the CV around simple average. We may note that whether the trend is statistically significant or not is a less important question compared to whether CV around it will be lower than the CV around the average. Of course, the lower its statistical significance the less will be the difference between the two CVs, and the less it would matter which one we take. The trend estimate can be badly affected by abnormal observations occurring at or near the end or the beginning of the series. As a result of the two drought years of 1965-66 and 1966-67, for example, no significant trend emerges in yield rates for crops even when the series include the latter good years; but a significant trend emerges for several crops when the drought years are omitted from the series (without altering the time-scale). In such a case, the trend estimates obtained through this modification would be more acceptable if the CVs around these are lower. The five-year moving averages also take note of the trend and are suggested as the basis for normal yield in the Model Pilot Scheme of Crop Insurance proposed by the Centre in 1967. The effect of abnormal observations would however be felt more on this average than on the average of larger series.

In view of the limitations of each of these alternatives presented, no *a priori* judgment can be made about their relative merits. We may, therefore, measure uncertainty through these different indicators for the eight main crops at the State level. CV need not be calculated in every case when, as in trend estimates, it is known in advance (due to their being very insignificant statistically) that CV in this respect is unlikely to be lower than any other CV. The results are presented in Table I (item 3). Different approaches give different CVs and, as stated earlier, we should select that normal yield which has the lowest CV around it. This, however, leads to a ticklish problem if there is a fairly significant negative trend, giving the lowest CV around trend estimate as has happened in the case of *tur*. How can we accept this measure in a developing economy with expectations of rising—or at worst, stagnant—yields? Can we safely project this trend and uncertainty around it into the future in spite of its statistical significance? In the case of *tur*, therefore, we are more inclined to accept the next lowest measure. All the measures of CVs thus accepted are shown in boxes in Table I. It may be noted that all the crops are presented in the table in the descending order of these CVs. This order is not disturbed even if we take CVs around simple averages only.

As can be expected, sugarcane—the hundred per cent irrigated crop—has the least uncertainty and rice emerges as a distant next. In fact rice,

TABLE I—YIELD LEVELS, UNCERTAINTY AND GROWTH IN MAIN CROPS OF MAHARASHTRA
(DERIVED FROM STATE LEVEL DATA FOR 18 YEARS ENDING 1968-69)

	Cotton (lint)	*Tur*	Groundnut	Bajri	Jowar	Wheat	Rice	Sugarcane (*gur*)
1. Average Yield (kgs./hectare)	79	648	644	261	506	415	971	7418
2. Bulk Average (kg./hectare)	82	640	658	264	519	426	986	7506
3. Measures of uncertainty (per cent): Coefficients of variation around respective normal yields								
(*a*) Simple average	20·4	19·7	17·8	16·0	14·2	13·9	12·9	4·8
(*b*) Bulk average	19·9	20·0	17·5	15·8	14·1	13·9	12·7	4·9
(*c*) Trend estimate	—	14·0	—	15·2	14·3	13·6	—	4·6
(*d*) Modified trend estimate ..	—	14·0	19·1	15·2	13·9	13·6	14·0	4·7
(*e*) Five-year moving average ..	20·7	19·1	18·8	15·5	16·3	16·0	15·3	5·0
4. Per cent area irrigated	1·3	0·6	1·2	1·8	4·4	17·9	20·3	100·0
5. Trend per annum in yield (kg./hectare):								
(*a*) Linear trend	0·53†	−17·41*	Negligible	3·02†	4·12†	3·69†	Negligible	22·76†
as % at Mean	0·67	− 2·69	Negligible	1·16	0·81	0·89	Negligible	0·31
(*b*) Linear modified trend ..	0·72†	−14·81*	7·06†	3·99**	6·05**	4·97***	8·07***	32·55**
as % at Mean	0·90	−2·21	1·05	1·51	1·18	1·18	0·80	0·44

Note : (1) In calculating the coefficients of variation, the standard deviation uses proper degrees of freedom as devisor and not simply the total number of year (18).

(2) The modified trend excludes (without altering the time-scale) the abnormal drought years which are 1965-66 and 1966-67 for *tur*, groundnut and rice; only 1965-66 for cotton, bajri, jowar and wheat; and only 1966-67 for sugarcane.

* Significant at 1 per cent. ** Significant at 5 per cent. *** Significant at 10 per cent. † Not significant.

jowar and wheat do not show significant differences in this respect. The remaining crops which have an insignificant area under irrigation are more uncertainty prone (see Table I, item 4). The correlation coefficient between CVs and the percentage of area under irrigation was—0.9107, which is significant at 1 per cent level. This relation has obtained between different crops at the State level; whether it holds between different areas (districts) in the case of a single crop is another matter with which we deal later. The question of what difference irrigation makes to uncertainty in a crop is better tackled at more disaggregated levels.

We also find here that faster rate of growth in per hectare yields (see Table I, item 5) has taken place in crops with higher proportion of area under irrigation. The rank correlation[1] between the two turned out to be +0.9167, which is significant at 1 per cent level. This has also been reflected in the fact that negative rank correlation emerged between annual growth rate in yields and uncertainty. This was —0.7143, which is statistically significant at 5 per cent level. In this context, achieving higher rates of growth has been accompanied with lower uncertainty.

II

We may now take up cotton for detailed districtwise measurement of uncertainty. We may see to what extent this is greater at the district level compared to the State level and also see how the relationship between uncertainty on the one hand and irrigation and growth rate on the other obtains at district levels. Cotton is a dry crop with only 1.3 per cent of the area irrigated and subject to the greatest amount of uncertainty. It is grown mainly in 20 districts (shown in Table II). We limit ourselves here to only two measures of uncertainty—CV around simple average and CV around trend estimate. Bulk average was considered, but this did not give a lower CV for any district and was omitted. Modified trend estimate was not tried because, in the case of cotton, 1965-66 or 1966-67 or both could not be singled out as uniformly drought years. CVs were calculated around trend estimates only where the trend was statistically significant at least at 20 per cent level, for at a lower level of significance they cannot be expected to give a CV lower than that around the average. Also as before, no CV based on negative trend was accepted. Table II presents the CVs which are accepted and in brackets it has also been shown whether they are around the average (A) or trend estimates (T). Districts are arranged in the table in the descending order of uncertainty. The table also gives background idea regarding the area under cotton.

It may be observed that even the lowest magnitude of uncertainty in a district (*viz.*, 23.31 per cent in Aurangabad) is higher than the State level

1. In ranking according to percentage growth rate in yields, we first took only the statistically significant trends (per cent at the mean) and gave ranks in descending orders; then we took trend rates which were not statistically significant and continued the same rankings.

TABLE II—DISTRICTWISE YIELD LEVELS, UNCERTAINTY AND GROWTH IN COTTON
(DERIVED FROM DATA FOR 18 YEARS ENDING 1968-69)

District		Average yield (kgs./hectare)	Uncertainty (coefficient of variation in %)	Linear trend per annum in yield as % at mean	Area irrigated (per cent)	Mean area under cotton in 100 hectares (and its percentage to total cropped area)
1. Sangli	..	134	49·95 T	3·33†	31·4	51 (0·8)
2. Satara	..	100	45·41 A	—0·02†	91·7	24 (0·3)
3. Chanda	..	58	44·15 A	2·21†	—	256 (4·1)
4. Osmanabad	..	60	39·36 T	4·18**	0·3	641 (6·0)
5. Poona	..	214	38·98 T	3·16†	81·6	49 (0·5)
6. Ahmednagar	..	115	38·97 T	3·55***	20·6	393 (3·0)
7. Nasik	..	133	36·76 T	2·68†	22·5	120 (1·2)
8. Bhir	..	71	34·27 T	2·87***	1·6	697 (8·8)
9. Sholapur	..	179	34·22 T	2·54†	47·0	117 (1·0)
10. Dhulia	..	95	34·16 A	1·51†	1·3	859 (11·3)
11. Buldana	..	82	32·23 A	—0·65†	0·3	2535 (36·5)
12. Nanded	..	69	31·80 T	3·09***	Negligible	1947 (27·2)
13. Jalgaon	..	104	31·36 A	0·38†	1·0	2299 (27·2)
14. Akola	..	79	28·84 A	—2·16†	Negligible	3176 (41·1)
15. Yeotmal	..	78	28·53 A	—0·04†	0·2	2944 (39·2)
16. Wardha	..	64	28·08 A	—0·93†	0·3	1586 (38·5)
17. Amraoti	..	84	27·58 A	—0·06†	0·1	3355 (49·0)
18. Nagpur	..	72	25·10 A	0·55†	0·7	741 (13·8)
19. Parbhani	..	63	24·38 T	1·98†	0·1	2315 (24·4)
20. Aurangabad	..	71	23·31 A	0·57†	1·2	2036 (15·5)

T = Coefficient of variation around trend estimate; calculated where positive trend is significant at least at 20 per cent level, and accepted if lower than coefficient of variation around average.
A = Coefficient of variation around simple average.
† Not significant. ** Significant at 5 per cent. *** Significant at 10 per cent.

uncertainty (*viz.*, 19.19 per cent). The range of uncertainty is also fairly wide, extending upto nearly 50 per cent (in Sangli). If we take the first ten districts with higher uncertainty, only one is in the category of having adequate rainfall (above 1,150 mm.), two have moderate rainfall (between 750 and 1,150 mm.) and the remaining seven have inadequate rainfall (less than 750 mm.). Among the next ten districts with lower uncertainty, only one (Aurangabad) has inadequate rainfall, one has adequate rainfall and the remaining eight have moderate rainfall. We thus see that in districts with inadequate rainfall, the magnitude of uncertainty is higher.

Does irrigation make any difference? We find that only in six districts, a significant part of the area under cotton is irrigated, others having less than 2 per cent or negligible portion of the area irrigated. It may be noted that all these six districts are in the upper half of the districts with higher uncertainty. To add to this feature, we find by taking only these six observations, that the coefficient of correlation between the area irrigated under cotton and uncertainty is only +0.1654 which is not statistically significant.[2] The impression that irrigation did not have a significant impact on inter-district variation in uncertainty is, therefore, unmistakable. This is in sharp contrast to the picture which emerges at the State level in inter-crop comparison. In fact the two situations are different. From the present situation, we cannot say that irrigation makes no difference to uncertainty. Different districts are subject to different magnitudes of uncertainty in rainfall which could have a significant impact on the availability of irrigation water also. As such, the difference in the overall uncertainty in yield between regions cannot be expected to be much influenced by the difference in the proportion of area irrigated, unless adequacy and reliability of irrigation also are taken into account.

To get an idea of what difference irrigation makes to the degree of uncertainty, we have to obtain yield uncertainties separately for irrigated and unirrigated areas. Unfortunately, on the basis of published figures, separate actual yields for these areas cannot be directly worked out.[3] We may, however, get a fair idea of the difference in the uncertainties in the two areas by fitting a linear regression equation as we have done below for Sholapur (as an example):

$$Y = 32.26 + \underset{(0.97)}{2.60\,X_1} + \underset{(0.51)}{0.44\,X_2} \qquad R^2 = 0.3300$$

where Y is total output of cotton (lint) in quintals for different years (18 observations), X_1 and X_2 are area irrigated and unirrigated respectively in hundred hectares.[4] The marginal (average) yield per hectare of irrigated and unirrigated areas could, therefore, be taken as 260 and 44 kg. respectively. Their standard errors, given in brackets, expressed as percentage over them

2. In calculating this correlation, it would have been meaningless to include the other districts, all with insignificant proportion of area irrigated. These could not also be clubbed together as a seventh observation, because the mean CV for them was not statistically significant and, therefore, unacceptable.

3. The "current yield" rates published in the Season and Crop Reports are used for working out production estimates only in the case of non-survey crops, and hence do not represent actual yields for other crops (these other crops include all the eight main crops taken here).

4. When 'time' was taken as a catch-all variable which could reflect some technological advance, the equation turned to be:

$$Y = -6{\cdot}15 + \underset{(0{\cdot}99)}{2{\cdot}49\,X_1} + \underset{(0{\cdot}63)}{0{\cdot}71X_2} + \underset{(4{\cdot}04)}{3{\cdot}20\,T} \qquad RR^2 = 0{\cdot}3588$$

In this case, CV around the average yield in the irrigated areas (249 kgs.) is 39·79 per cent and the same in the dry areas (average yields 71 kgs.) is 87·89 per cent. With the influence of time netted out, the differences between the two areas in respect of both yield and uncertainty are a little narrowed down.

(reciprocal of t) could be taken as coefficients of variation which are found to be 37.30 per cent and 117.91 per cent. Such an equation can thus be used to broadly show the difference in the two types of areas in a given district both in respect of yield per hectare and variability or uncertainty in the same.

We can now see if the relationship observed in the inter-crop picture at the State level between uncertainty and growth in yields per hectare obtains here as well. We may first observe here that unlike in the inter-crop picture, the question of association between irrigated area and growth in yield rates does not arise significantly in this case when 14 out of 20 districts have negligible area irrigated under cotton. Irrigation is not expected, therefore, to be a major factor in inter-district differences in the yield rates. We find that the rank correlation between uncertainty and annual growth in yield per hectare as per cent at the mean[5] is positive at 0.5368, which is significant at 5 per cent level. With varying magnitudes of uncertainty in the inter-district picture which is not materially influenced by irrigation, we cannot conclude from the above correlation that increasing the per hectare yield has not contributed towards reducing uncertainty. We shall instead say that higher uncertainty in a district has not prevented it from achieving a higher growth rate in yields. We find this positive relation—though not very strong—emerging even between uncertainty and the level of average yield. The correlation coefficient was 0.3822 which is significant at 10 per cent level. In the inter-region picture, therefore, we do not find a high level of yield being associated with a lower magnitude of uncertainty.

These findings in the inter-region picture—that regions which have higher levels of yields and have registered higher rate of increase in yields have also a higher level of uncertainty in general—have an important implication for crop insurance. To the extent increased cultivation of cotton and investment therein were discouraged by higher magnitude of uncertainty in areas which have good growth potential for cotton, a scheme of crop insurance could, by reducing the risks involved, create conditions for realising this potential. One more implication of such a situation for crop insurance would be that if uniform premium rates are imposed in all regions, they would be like a regressive tax with the farmers in low yield regions paying more through premia than they would receive through indemnities, financing in the process a part of the indemnities paid to the farmers in high yield regions.

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5. We may note that the percentage yield increases are not here a reflection of the possibility that a given absolute increase in yield shows a higher percentage growth at lower levels. In fact the rank correlation between the level of yield and growth rate in yield was positive at 0·8482 which is significant at 1 per cent level.

We may add that in giving ranks in this or other rank correlations in this paper, same rank is given to 2 values which are the same or nearly the same and the next rank number is skipped.