Vol XXXIII
No. 2

APRIL-
JUNE
1978

ISSN 0019-5014

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

INSTABILITY IN RAINFALL AND AGRICULTURAL YIELDS IN A DROUGHT-PRONE DISTRICT (TUMKUR)

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As many as 95 districts of India have been identified as drought-prone. They hold the key to the stability or otherwise of agricultural production of the country. The problem of droughts and drought-prone areas is increasingly engaging the attention of agricultural economists. Our understanding of the nature and magnitude of risk associated with rainfall, variation in crop yields and the impact of the former on the latter is, however, still inadequate. A better understanding of these related issues could help in assessing how far crop insurance, diversification of crops or such other measures (apart from irrigation) help farmers in facing instability. Crop insurance tailored to individual farmers is out of question at present. But, is at least a region-based scheme of cropwise insurance feasible?[1] Apart from the question of crop insurance, the behaviour of area under a crop or adoption of a more productive—but costlier—technology for a crop cannot be properly understood in the absence of some knowledge of instability of crop yields or of rainfall on which the crop has to depend. In planning for the agricultural development of a region, an understanding of the nature and impact of rainfall as a natural resource of the region is at least as much necessary as an understanding of its soils, terrain and water availability. It does not suffice to note the normal rainfall of a region; the risk of its failure and consequent risk of failure of different crops has also to be studied.

One more question—methodological in nature—is also involved. How can we study instability in crop yields or rainfall? Coefficient of variation (CV) is normally accepted as an indicator of instability. But how far is it adequate? We may also try probability of failure as another indicator and see if it further adds to our understanding of instability, apart from CV.

The present study is mainly exploratory and does not pretend to present final answers to the questions posed above. The broad questions posed above are faced in an exploratory way through confining ourselves at present only to the following issues:

(*a*) Analysis of the nature of variation in rainfall:

(*i*) Is the variation in annual rainfall a random phenomenon? If it is random, and no pattern is discernible, what is at least the frequency of failure of rainfall? (*ii*) What is the seasonal pattern of rainfall and how far is the

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1. For a distinction between individual approach and area approach in crop insurance, see V. M. Dandekar, "Crop Insurance in India", *Economic and Political Weekly*, Vol. XI, No. 26, June 26, 1976.

seasonal picture stable? Could the rainfall in the crucial season preceding sowing be used to predict annual rainfall? Rainfall data from 1925-26 to 1974-75 are studied for this purpose.

(*b*) Analysis of the variation in crop yields and impact of rainfall:

Our second objective is to study the instability in crop yields. This is done by studying the coefficient of variation in productivity per hectare adjusted for trend and the frequency and probability of crop failure. This would indicate the magnitude of yield uncertainty facing the farmer at district levels if not individually for each farmer. From the point of diversification of crop pattern to reduce risk, it would be interesting to know the correlation between variations in the productivity of crops. Crops having negative correlation could be combined to reduce the risk of loss. From the point of insurance and calculations of rates of premium, it is important to know what can be called as 'crop-loss ratio', which is a sum of the negative deviation in yields from the insured level of yield, expressed in relation to the sum of yields for the period studied. For actual insurance purposes, more sophisticated and detailed calculations may have to be done. Our purpose here is to broadly know what would be the premium burden on farmers in relation to their usual productivity if they accept crop insurance, if administrative and other costs are to be borne by the State, and if district as a whole is treated as the basis for insurance.

It would be equally interesting to know how much of the variation in productivity adjusted for trend can be explained in terms of variation in rainfall. Yields have to be adjusted for the trend, to net out technological advance. Yield data are available on a comparable basis for only 20 years since 1955-56. The impact of rainfall (annual, and alternatively, in crucial months) on individual crop yields can be studied through regression analysis. This could also enable us to identify crops sensitive to variation in rainfall. Apart from rainfall, factors like area under irrigation, temperature and attack of disease also affect crop yields. Whereas the influence of irrigation could be considered, the other factors could not be. The data on occurrence of diseases and the areas affected thereby year by year are not available and it is difficult to determine its impact. Though data are available on variation in temperature, its incorporation was difficult due to the limited degrees of freedom—the time-series data on yields being available only for 20 years. If temperature is to be taken, it is not sensible to explain only in terms of variation in annual average, since this variation over the years is not known to be significant. If it is to be considered at all, seasonwise (for months or quarters) maximum and minimum temperatures in different years have to be taken for each crop. That is, we need several variables to indicate temperature. Together with other variables this would seriously reduce the degrees of freedom. Moreover, it is doubtful if the whole exercise is worth doing. Variation in temperature independent of rainfall may be an important factor in other climatic regions including northern India, but this variation is not so extreme as to be a serious factor in Karnataka, particularly in the district studied. The variation in productivity adjusted for trend, unexplained by rainfall and irrigation, can be said to be due mainly to pests and diseases, variation in input use following price variations, and year to year shifts in area (under crops) involving differences in factors affecting productivity of land. Even if the impact of each of these factors cannot be isolated, we can at least broadly know how much of the variation is explained by rainall.

One of the approaches to a study of the impact of weather on crop yields is to explain residuals obtained through fitting production functions by means of weather variables.[2] Alternatively, production function itself can include properly specified weather variables.[3] Whatever the propriety of fitting production functions to cross-section secondary data at aggregative levels, its propriety is questionable when applied to time-series data.[4] Apart from the theoretical objections one can legitimately have against a time-series based production function, the limitations of data are also quite serious. The data on inputs other than land and labour are not available for all the years; even the data on labour are not strictly comparable between the Censuses.[5]

The region selected for the study is Tumkur district in Karnataka, forming part of the southern plains. The non-availability of the production data at sub-district levels does not enable us to carry out such studies at more disaggregated levels. Tumkur district lies between 12° 45′ and 12° 20′ north latitude and between 76° 20′ and 77° 31′ east longitude. It has an area of 10,597 sq. km. (according to the Surveyor General of India) and a density of population of 153 per sq. km. (in 1971). The district was selected for analysis as it is a typical rainfed region, representing neither a region of assured rainfall nor a region of very scanty rainfall. The district comes under drought-prone areas,[6] with its officially reported normal annual rainfall being only 688 mm. Its normal temperature varies from 15°—20°C in January to 37.5°—40°C in May. In 1974-75, the latest year for which detailed data were available at the time of writing, 13 per cent of its net own area was irrigated. Only 6.2 per cent of the former was double cropped; in the irrigated area, however, the proportion was higher, being 35.5 per

2. For such a study, see S. K. Mukhopadhyay: Sources of Variation in Agricultural Productivity—A Cross-Section Time-Series Study in India, The Macmillan Company of India Ltd., New Delhi, 1976; also his paper on "Effects of Weather on Agricultural Production—An Econometric Measure", presented at the Third World Congress of Econometric Society, Toronto, August 1975.

3. The need for including weather, even in farm level production functions, has been pointed out by V. M. Rao in "Farm Production Function Studies: Treatment of Weather and Selection of Functional Form", *Economic and Political Weekly*, Vol. V, No. 15, April 11, 1970.

4. This is particularly so if inputs tend to increase over time; the risk of spurious results could be greater here. Besides, production function assumes a given technology and given coefficients, whereas they cannot be assumed to be constant over time as time involves technological change.

5. The problems are not obviated in cropwise production functions fitted for inter-district data for a particular year for which labour data may be available. The use of labour has to be allocated cropwise. The data on fertilizer are also not available cropwise; the data on such inputs like manure are not available even aggregatively for all crops. Even if production function is fitted for total agricultural production, and some inputs like manure are ignored, this would amount to assuming that all districts are comparable in respect of farm structure, access to market, cost of inputs, soil, etc.

6. Nine out of its ten talukas are considered as drought-prone. The lone taluka not considered as drought-prone is Tumkur according to the Irrigation Commission (1972) and Turuvekere according to the Government of Karnataka.

cent. Percolation tanks are the major source of irrigation in the district, whose irrigation capacity is itself reported to be sensitive to variation in annual rainfall.

NATURE OF VARIATION IN RAINFALL

Though the agricultural year in India is taken to be from July to June, the relevant rainfall year is taken here to be from May to April. The rainfall in the pre-sowing season of May to June determines the moisture content of the soil and influences sowing decisions. The sowing operations of several crops start in June itself.

Since the rainfall data for the calendar year 1951 are not available, there is a gap in the series from 1925-26 to 1974-75 studied here. The data for the principal rainfall months of 1950-51 are available, enabling us to take this year into account except where the shares of month to annual total had to be studied. The year 1951-52 had, however, to be skipped completely. We have thus mostly 49 observations—and sometimes only 48—for the analysis of rainfall data.

The test of randomness[7] showed that variation in annual rainfall has been random and exhibits no trend or cycles of regular frequency or amplitude. The gaps between troughs or severe failures of rainfall are hardly regular. Failure of rainfall in any particular year cannot, therefore, be predicted from the trends or cycles in the past. We can, therefore, study only the magnitude of instability in rainfall and the risk associated with it. Instability here can be said to have two dimensions—one is the variability as measured by the coefficient of variation; second, is the nature of the probability distribution itself—*i.e.*, whether it is flat, peaked, skewed, or simply irregular, defying any set pattern. A dependence only on the coefficient of variation would hardly help in understanding the nature of variation in rainfall, as we shall soon see. Just as a relatively flat distribution is riskier than a peaked distribution, skewness to the left (showing higher probability of failure of rainfall) is a riskier situation than skewness to the right. However, the coefficient of skewness (along with its sign) does not throw much light when the distribution has no peak or has several peaks or is generally flat. In addition to studying the coefficients of variation, we may, therefore, study the probability distribution of ranges of rainfall (measured in percentage from the average) and note particularly the probability of rainfall falling below the normal (average) range in different principal months. This gives a better insight than the coefficient of skewness.

Table I presents monthwise average rainfall, monthwise shares in the annual total and the coefficients of variation in the same. Table II presents the frequency and probability distribution of rainfall in seven ranges of 20 percentage points of the average (for the period 1925-26 to 1974-75), both for annual rainfall and also rainfall in principal months from May to November (which together account for 92 per cent of the annual total on the whole).

7. *cf.* G.U. Yule and M. G. Kendall: An Introduction to the Theory of Statistics, 14th Edition, Charles Griffin, London, 1950, pp. 638-639.

TABLE I—MONTHWISE AVERAGE RAINFALL, SHARES OF MONTHS AND VARIATION THEREIN

	May	June	July	August	September	October	November
1. Average rainfall in (mm.) ..	97	59	63	88	132	156	51
2. CV (%) of (1)	61.6	46.0	51.9	71.2	52.2	52.0	89.0
3. Average share (%) in annual	13.5	8.6	9.0	12.5	18.9	21.4	7.1
4. CV (%) of (3)	48.9	42.1	52.2	65.3	52.3	48.7	85.6

	December	January	February	March	April	Annual total
1. Average rainfall in (mm.) ..	12	2.3	3.5	5.5	35	706
2. CV (%) of (1)	165	251	166	161	67.6	18.6
3. Average share (%) in annual ..	1.8	0.4	0.5	0.8	5.0	—
4. CV (%) of (3)	168	279	161	155	66.9	—

We have an interesting—though, complex—picture of instability in rainfall from these tables. Instability, as seen from the coefficient of variation (CV) in rainfall, is very high for individual months, particularly for the months which receive scanty rainfall. The CV of rainfall for December to March is between 160 to 251 per cent. For the other months, it is between 46 to 89 per cent, which also would indicate quite a high instability. Instability in the annual total, however, is much lower—lower than for any individual month—the CV being only 18.6 per cent. This is not surprising because even if rainfall fails in a particular month, it need not fail in the year as a whole; and, so it is for excess rainfall. The shares of individual months in the annual total are of interest here. The shares show almost as much variability as the absolute rainfall. Moreover, the variability in the former is strongly and positively correlated with the latter, the rank correlation between the two being as high as + 0.95. If the shares of months had been stable in the sense of having a low variability therein, the variability in the annual total rainfall would not have been so much lower than for any individual month.

TABLE II—FREQUENCY AND PROBABILITY DISTRIBUTION OF RAINFALL

Period		Rainfall ranges in per cent from the average								
		Below normal				Normal	Above normal			
		Below —50%	—50 to —30%	—30 to —10%	Sum of cols. (1) to (3)	—10 to +10%	+10 to +30%	+30 to +50%	Above +50%	Sum of cols.(6) to (8)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
May	F	6	10	10	26	8	6	3	6	15
	P	12.2	20.4	20.4	53.1	16.3	12.2	6.1	12.2	30.6
June	F	7	8	7	22	8	7	5	7	19
	P	14.3	16.3	14.3	44.9	16.3	14.3	10.2	14.3	38.8
July	F	3	15	12	30	4	3	3	9	15
	P	6.1	30.6	24.5	61.2	8.2	6.1	6.1	18.4	30.6
August	F	14	5	8	27	4	8	2	8	18
	P	28.6	10.2	16.3	55.1	8.2	16.3	4.1	16.3	36.7
September	F	11	4	4	19	11	5	4	10	19
	P	22.4	8.2	8.2	38.8	22.4	10.2	8.2	20.4	38.8
October	F	8	6	6	20	7	11	5	6	22
	P	16.3	12.2	12.2	40.8	14.3	22.4	10.2	12.2	44.9
November	F	18	3	6	27	5	3	1	13	17
	P	36.7	6.1	12.2	55.1	10.2	6.1	2.0	26.5	34.7
Annual	F	Nil	1	12	13	24	8	4	Nil	12
	P	Nil	2.0	24.5	26.5	49.0	16.3	8.2	Nil	24.5

F= Frequency in number; P= Probability in per cent.
Note:—Total frequency is 49 and total probability is 100 per cent.

The magnitude of risk of failure can be seen from Table II. For convenience, the table separately presents the probability of failure of rainfall (*i.e.*, of falling below 10 per cent of the average), and of excess rainfall (*i.e.*, of being above 10 per cent from the average), apart from the probability of rainfall in the normal range. Among the seven principal months, the probability of failure is highest for July (61 per cent), followed by August and November (over 55 per cent for both). On the other hand, it is lowest for September (nearly 39 per cent) followed by October (nearly 41 per cent). Incidentally, both September and October have the highest rainfall in the year, together accounting for over 40 per cent of the annual total. It is interesting that these months also have the lowest risk of failure of rainfall and hence more dependable. The crop pattern and sowing operations of the district are naturally adjusted to this factor. Though in terms of CVs, the instability is not lowest in these months, it is nevertheless lower than for eight other months of the year.

The two indicators of instability—CV and probability of failure—do not, however, necessarily go together. Taking the seven principal rainfall months, the correlation between rankings according to the two indicators turned out to be only + 0.24, which is very low and statistically not significant. That is how there is a need to have at least these two indicators of instability.

There is nevertheless an interesting point, which is seen from both the indicators. Just as CV in the annual rainfall is much lower than the same for any individual month, the risk of failure in annual rainfall is also lower than the same for any individual month. Table II makes an interesting reading in this respect. The probability distribution is peaked, and approximates to the normal distribution only in the case of annual rainfall, and not for any individual month. For the latter, the distribution follows no set pattern or shape, and looks quite irregular. The distributions have multiple peak points, each of which has a low level of probability on the whole.

Since both the variability and the risk of failure in the annual rainfall is less than the same for individual months, it would be interesting to study the probability of failure of rainfall in subsequent important months—given the failure of rainfall in the initial months of a rainfall year. This question has a practical significance. In case the rains fail in May and June, is it worthwhile to sow in July or August ? Or, if crops are sown in spite of the rains failing in the first four months (May to August), what chance has such a crop to survive which depends on the rainfall of subsequent months (September to December) ? An attempt to 'predict' rainfall of subsequent months from the rainfall in May and June, or July and August, was not successful through regression analysis, as it did not give statistically significant results. We can, however, study the conditional probability of failure of rainfall.

We find that rainfall failed (in the sense of being less than 10 per cent below normal) during May and June together, in 24 years out of 49. Out of these 24 years, rainfall failed in the subsequent months of July to December in 4 years, was in the normal range in 10 years and exceeded the normal range in 10 years. Given the failure of rainfall in May and June, the probability of its failure in the subsequent 6 months is thus 17 per cent, the probability that it is in the normal range is 41.5 per cent and the probability that it exceeds the normal range is also 41.5 per cent (or the total probability that it is either normal or exceeds it is as high as 83 per cent).

A similar exercise was tried taking the failure of rainfall in May to August as given. The probability of failure of rainfall in the subsequent four months (September to December), given this initial failure, turned out to be 25 per cent, the probability of normal range rainfall 30 per cent, and the probability of its exceeding the normal range 45 per cent. The total probability of rainfall being either normal or exceeding it was 75 per cent, given the failure of rains during May to August.

INSTABILITY IN CROP YIELDS

For an analysis of variation in crop yields, we have selected only five crops—*ragi*, jowar, *tur*, groundnut and rice. Rice is a type by itself, as it is almost entirely an irrigated crop, or grown in low lying wet lands. The others are mainly rainfed crops. Table III shows, *inter alia*, the proportion of these crops to gross sown area, their productivity per hectare, the proportion of irrigated area under these crops and trends in the productivity of these crops during the period 1955-56 to 1974-75.

Ragi is the most dominant crop of the district, accounting for 35 and 27 per cent of the gross sown area respectively in 1955-56 and 1974-75. Whereas groundnut and rice have gained relatively in the total sown area, the other three crops—*ragi*, jowar and *tur*—have lost, with their proportions showing a decline over the period. Among the four mainly rainfed crops, irrigated area under *tur* is highly erratic and marginal; no irrigated area has been reported under the crop since 1960-70. In fact, the crop shows some irrigated area only in 7 years out of 20. Even groundnut has only a small area irrigated, being only 5 per cent in 1974-75. While the irrigated area under *ragi* increased from 6.3 per cent in 1955-56 to 11.3 per cent in 1974-75, it declined under jowar from 11.4 per cent to 6.6 per cent between the same years. However, there is no smooth trend in either of the crops. The irrigated area under jowar has particularly witnessed wide variations, the proportions ranging from 0.9 per cent in 1961-62 to 39.7 per cent in 1968-69. As much as 94 per cent of area under rice was irrigated in 1955-56, which increased even further to 97 per cent in 1974-75.

A disturbing aspect of the situation is that *ragi*—a crop consumed mostly by the poor in the region—has progressed neither in terms of area nor in terms of productivity. Linear trends in the productivity of the other four crops are positive and also statistically significant; in the case of *ragi*, however, the trend is negative, though not statistically significant. Expressed in terms of percentages to the mean levels of productivity during the period, jowar has registered the highest rate of growth in productivity, being 8.2 per cent per annum, followed by *tur* (6.5 per cent), rice (6.1 per cent) and groundnut (3.9 per cent). The productivity of *ragi*, however, has declined by 1.4 per cent per annum, though this decline is not steady or smooth, as seen from the coefficient being statistically not significant. Looking at this against the background of decline in the area under *ragi*, it seems that fertile area is being progressively diverted from *ragi* to other crops—a trend, which is directly to the disadvantage of the poor. It can be seen from the table that in relative terms, productivity of *ragi* has declined more drastically. Its productivity (in physical units) was marginally better than that of even rice in 1955-56, but in 1974-75, it declined both absolutely and relatively. It suffered even in relation to other crops, as the latter have shown positive and significant trends in productivity.

We may now study the instability in crop yields. One dimension of this is the CV in the productivity of crops adjusted for trend. The CVs here are adjusted for linear trends, as they gave better fits than log-linear trends. The CV has been adjusted for trend even in the case of *ragi* where the trend proved to be statistically not significant, as the CV around the mean was found to be higher than the CV adjusted for trend. We prefer a measure

TABLE III—SOME IMPORTANT FEATURES OF SELECTED CROPS

Features	Period	*Ragi*	Jowar	*Tur*	Groundnut	Rice
1. Proportion of area under the crop to gross sown area (%)	1955-56 1974-75	34.9 26.7	7.2 4.7	2.8 1.7	5.0 10.4	6.7 10.1
2. Productivity in kg./hectare	1955-56 1974-75 Average	1,360 910 795	791 1,230 750	217 751 433	87 943 692	1,301 2,074 1,398
3. Proportion of area irrigated (%)	1955-56 1974-75	6.35 11.29	11.36 6.64	7.15 Nil	N.A 5.01	94.24 97.01
4. Linear trend in productivity (and t value) ..	1955-56 to 1974-75	—11.00† (—1.13)	61.41** (4.67)	28.17** (4.67)	27.32* (2.26)	85.45** (4.13)
5. Linear trend as % of mean	1955-56 to 1974-75	—1.38	8.19	6.51	3.95	6.11
6. CV (%) adjusted for linear trend	1955-56 to 1974-75	31.60	45.16	35.40	44.80	38.17
7. Probability of crop failure	1955-56 to 1974-75	0.40	0.50	0.45	0.35	0.30
8. Crop-loss ratio (%)	1955-56 to 1974-75	27.31	14.64	13.98	13.69	14.94

** Statistically significant at 1 per cent level; * Statistically significant at 5 per cent level; † Not significant.
N.A. = Not available.

of variation which is free from the variation on account of any trend (and hence not exaggerated by its presence). All crops—including surprisingly an irrigated crop like rice—have a high CV around trend, the lowest being 31.6 per cent for *ragi* and the highest being 45.2 per cent for jowar. In the case of rice, it is as high as 38.2 per cent.

The order of crops in terms of CV around trend is not the same as the order in terms of the probability of crop failure (see 7th row in Table III), indicating the need for more than a single measure of uncertainty. 'Crop failure' is taken to mean all those cases where the actual crop production is less than 10 per cent below the trend (linear) estimate for respective years. The probability of crop failure is simply the percentage of years of crop failure (thus defined) to the total number of years. In terms of this indicator of instability, jowar has the highest probability of crop failure (50 per cent) as in the case of the earlier indicator (CV around trend), and rice has the lowest probability of crop failure (30 per cent). Even the lowest probability among crops is high enough to cause anxiety, particularly as it happens to be an irrigated crop, for which the incidence of crop failure should have been lower still. Apart from the question of dependability of irrigation in areas reported as irrigated, other factors like water management, variation in input use and control of diseases may play an equally important role in affecting rice yields and variation therein.

The probability of crop failure by itself does not indicate the magnitude of crop-loss. We need another index for this, namely, 'Crop-loss ratio' (see the last row in Table III). Assuming a yield level of 10 per cent below the trend estimate for the respective years as the insured yield level, the sum of negative deviations below this insured level is expressed as per cent of the sum of actual yields for the whole period (all years) to arrive at this ratio. Ignoring the crop failures within 10 per cent from the trend estimate, the magnitude of severe crop-losses over a period is shown by this index in relation to the normal or average yield. This also indicates the relative premium burden on the farmers if a region (district)-based crop insurance scheme is in operation, ignoring administrative costs. We find here that *ragi* has the highest crop-loss ratio, being 27.3 per cent of average production. For the remaining four crops, the ratio is around 14 per cent only. This would mean that for these four crops (jowar, *tur*, groundnut and rice), though the probability of failure is high, the magnitude of crop-loss is not very high. For *ragi*, however, it is relatively quite high. This conspicuousness of *ragi* is not brought out either by the CV of its yield around trend or by the probability of crop failure. Could it be that the failure of area under *ragi* to increase during the period is in no small measure due to the high crop-loss ratio for this crop ? This issue is raised only as a hypothesis here, which could be tested by taking other factors like relative prices and relative technological change. Any way, *ragi* will have a high insurance burden if the scheme is implemented.

It may be noted here that instability in yields and crop-loss ratio may be much higher at the taluka or block levels, if regions smaller than districts are to be accepted for a region-based crop insurance scheme. This is because crop failure in one block may be offset by good crops in other blocks, so that at an aggregated higher level the degree of instability could be smaller than at disaggregated levels. A premium burden of even 10 or 15 per cent of output (it would be higher still relative to *net income*) may be considered heavy by farmers, even if they know that the premium paid would only be returned to them in the form of indemnity and would stabilise their income. Since at the village level, the crop loss-ratio would be higher still, they may find that even with high premium rates their incomes are not stabilised. If insurance is implemented only where the crop-loss ratio is low, it would mean that crop insurance is not given where it is needed most, but where it is needed least. One can therefore wonder if a cropwise insurance is feasible at all. An insurance scheme, covering a package of crops designed to stabilise incomes, could be considered as an alternative. That is, before insurance is provided, crop diversification also will have to be tried to reduce instability and risk. Insurance can then be given to cover instability which remains to be reduced even after other measure like diversification are tried.

From his angle, we can study how far the variation in crop yields is positively associated. Crops having a negative correlation would be ideal for combination to reduce income instability, other factors being given. Crops having a positive correlation, on the other hand, could increase the instability in incomes, and are not a desirable combination. From this angle, Table IV may be of interest.

TABLE IV—CORRELATION COEFFICIENTS BETWEEN CROP YIELDS ADJUSTED FOR TREND (TAKING 20 YEARS ENDING 1974-75)

	Jowar	*Tur*	Groundnut	Rice
Ragi	0.354†	0.372†	0.252†	0.672***
Jowar	1.0	0.396*	0.049†	0.508**
Tur	—	1.0	—0.0004†	0.416*
Groundnut	—	—	1.0	0.235*

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

This table is only illustrative, and for actual policy purposes a much bigger table involving many more crops may be required. Moreover, the data from several districts may have to be studied to see if the correlations are accidental or stable. (This is being done in the larger State level project referred earlier.) As it is, there is no negative correlation between any of the five crops such as can be combined for the purpose of spreading the risk of crop failure. On the other hand, positive correlation is significant between *ragi* and rice, jowar and rice, *tur* and rice, and jowar and *tur*. On the whole, positive correlation dominates the picture. If this is so, even the scope for crop diversification for risk spread seems to be limited. Whatever the correlation, raising drought resistant second crops admittedly supplements the income of farmers. From this angle, cultivation of cowpeas (or *alsande*) in *rabi* has been recommended for the region by agricultural scientists as a second crop to *ragi* (a *kharif* crop), both being rainfed crops. In the absence of adequate data, however, it is difficult to establish if the variations in the productivities of the two crops would also go together temporally or are negatively related. The question may be important for small farmers, who need extra confidence to raise a second crop in a year—the *kharif* season of which may have witnessed a crop failure. One can similarly suggest a combination of dairy, poultry, piggery, etc., with agriculture. Even here, one cannot perhaps be too sure that crop failures would not adversely affect these enterprises, quite apart from the ability of individual farmers (particularly small farmers) to acquire the resources to run an economically viable package of multiple enterprises.

IMPACT OF RAINFALL ON CROP YIELDS

An interesting aspect of the situation is that instability in crop yields is lower than the same in monthwise rainfall, whether instability is measured by CV or probability of failure. The instability in crop yields, however, is higher than in annual rainfall. Even if monthwise rainfall is more important in crop prospects than annual rainfall, it is rather heartening that instability in crop yields is not as high as instability in monthwise rainfall. Crops survive to some extent and grow even if rains fail in a certain month if this shortfall is made good in other months. The crops may have a certain amount of drought resisting capacity, though this should not be exaggerated. This would mean that we should not over-emphasize the importance of monthwise rainfall in affecting crop prospects. The annual rainfall also comes into its own, though singly it may not determine the crop prospects. We may have to find a way of taking into annual rainfall and also its monthwise spread; where the crop is seasonal, rainfall during the whole of the crop season could be taken in the place of annual rainfall.

The variables tried in the regression exercises are as follows. The annual rainfall (in mm.) is considered in terms of two variables, X_1 and X_2 to test the presence of discontinuity in the impact of rainfall at a certain critical level. This critical level is assumed to be the average or normal rainfall itself. For years when the annual rainfall is normal or below normal, X_1 represents the actual annual rainfall and X_2 would be zero. For years when the annual rainfall is above normal, X_1 represents the average or critical annual rainfall and X_2 would represent the difference between the average and the actual rainfall.[8] (As an alternative, the rainfall during the period from June to November, was also taken. Since this exercise did not give statistically significant result, this variable has been dropped here.)

Seasonal or monthwise deviation of rainfall during a period (rainfall year or the crop season taken, as the case may be) can be represented by what can be called as an index of seasonal deviation in rainfall (X_3).

8. This technique to test discontinuity has been tried earlier by A. R. Khan and A. H. M. N. Chaudhury in "Marketable Surplus Function: A Study of the Behaviour of West Pakistan Farmers", in Tara Shukla (Ed): Economics of Underdeveloped Agriculture, Vora & Co., Bombay, 1969, pp. 210-236.

The Index[9] may be defined as $= \sqrt{\frac{\Sigma x_i^2 . y_i}{n^2 . 100}}$, where

x_i = Deviation of rainfall in month 'i' from the average or normal rainfall in month 'i';

y_i = Average or normal percentage share of month 'i' in the total rainfall of the period (one year or crop season) for which the index is derived;

i = Respective months of the period for which the index is derived (*i.e.*, from May to April where the whole rainfall year is taken);

n = 12 where the whole rainfall year is taken.

It may be observed that the index is somewhat like a weighted standard deviation, the weights being the normal percentage share of different months in the total normal rainfall for the period taken. The index would take the value of zero if, during the concerned year, rainfall in every month is the same as the normal for respective months. The index has separate values for each year. It enables us to simultaneously take the total rainfall and also its seasonal variation in a single equation. Apart from the difficulty of taking individual months' rainfall as separate variables when the number of total observations are very limited, such an approach ignores the fact that crops may to some extent survive a deficiency in the rainfall of a particular month if it is offset in other months. Our approach, however, would allow for such an effect, as annual rainfall is taken as a separate variable without involving duplication. Incidentally, as expected, there was no correlation between this index and the annual rainfall, being only 0.013. Our one more independent variable is :

X_4 = Proportion of irrigated area under the concerned crop (per cent). (There was no question of adjusting this variable for trend, as there was no significant trend in this for any crop.)

Y = Productivity of the concerned crops in kg. per hectare, adjusted for trend (dependent variable).

The results of the regression exercises are presented in Table V for each of the five selected crops, separately. It may be noted that multicollinearity was not serious enough to distort our results. Inter-correlations were hardly significant statistically except in two cases,[10] and even in these two cases, they were not so high as to make multicollinearity a serious issue.

It may be seen that the regression coefficient for X_1 (annual rainfall upto the average level) is positive and statistically significant in every equation for every crop. For the excess rainfall above this level (X_2), however, the coefficient is generally negative and even statistically significant. It is only for

9. The index has been designed by the senior author primarily for the larger State level study referred earlier.

10. The correlations between independent variables are as follows:

	X_2	X_3	X_4 (*ragi*)	X_4 (jowar)	X_4 (*tur*)	X_4 (rice)
X_1	.370	—.270	.152	.172	.198	.677*
X_2	1.0	.271	—.243	—.359	.274	—.070
X_3		1.0	—.480*	.029	.152	—.347

*Except for these two, others are not statistically significant.

groundnut that it is positive, but it is not significant. Barring a few cases, in the majority of equations the coefficient for X_2 is statistically significant even while having a negative sign. Until the results for other districts are examined, no further comment can be hazarded on this result. The broad impression, however, does emerge that excess rainfall (above average level) need not necessarily be welcome for the crops, just as deficient rainfall adversely affects crop prospects, at least as far as the annual rainfall is concerned.

The coefficient for the index of seasonal deviation (X_3) is generally not statistically significant. In the case of *tur*, however, the coefficient for X_3 emerged as significant in two equations (Equation Nos. 8 and 9) and in both cases it has unexpectedly a positive sign. In the remaining three crops—jowar, groundnut and rice—the coefficient is statistically very weak and undependable. It is difficult to generalise about even the expected impact of seasonal deviation (isolated from the magnitude of annual rainfall) on crop yields. If crops survive seasonal droughts and seasonal excesses make up for seasonal droughts (provided that both the seasonal droughts and excess rainfall are not intense and prolonged—in which case they may well affect the magnitude of annual rainfall), thus offsetting each other, we have no reason to expect the coefficient for seasonal deviations to be clear and conclusive or statistically significant. The inconclusive results can, however, be taken as corroborating the indirect evidence obtained earlier based on the probability of crop failures being much less than the probability of failure of monthwise rainfall, indicating the ability of crops to survive seasonal droughts.

Surprisingly, the proportion of irrigated area under respective crops (X_4) also does not give conclusive results. It is only in the case of jowar that it emerged with a positive and statistically significant coefficient (see Equation No. 6). This variable could not be used for groundnut at all because of the non-availability of the data for a few years; any way, the proportion was only marginal even in years for which the data were available. Except for the equation referred for jowar, inclusion of this variable has not added significantly to R^2. Our results for crops other than jowar need not be interpreted to imply absence of effect of irrigation on their output per hectare. Variations in the extent of irrigation, however, do not appear to explain the variations in the yields of these crops over the years. We may recall here that rice is almost a fully irrigated crop, and the lack of significance for the coefficient of proportion of irrigation in the equations for rice may be due to the very limited variation in the variable over the years. If irrigation or assured water is not expected, rice would not be grown at all; the role of variation in the proportion of irrigated area is therefore naturally very little in this crop. In the case of *ragi* and *tur*, the area under irrigation is not large enough to be a significant factor to influence yield variability on the whole. They are rainfed crops, and whatever irrigation may be reported under these crops may not be of dependable nature. An area may be nominally under irrigation, but the area statistics tell little about adequacy and regularity of irrigation. This is so particularly for rainfed crops like *ragi* and *tur*. It is only in the case of jowar that variation in the proportion of irrigated area is

TABLE V—REGRESSION EQUATIONS FOR THE IMPACT OF RAINFALL ON PRODUCTIVITY PER HECTARE ADJUSTED FOR TREND

Equation No.	Crop	Constant	Regression coefficients of				R^2	Durbin-Watson statistic
			X_1	X_2	X_3	X_4		
1	*Ragi*	—1247.20** (—2.820)	+3.110*** (4.636)	—1.167* (—1.857)	—	—	0.559	1.911
2	,,	—987.0* (—1.767)	+2.870*** (3.848)	—0.942† (—1.347)	—24.380 (—0.778)	—	0.575	2.009
3	,,	—1093.79* (1.828)	+2.823*** (3.686)	—0.870† (—1.202)	—16.655† (—0.482)	+12.15 (0.591)	0.584	2.002
4	Jowar	—1307.50* (—1.826)	+3.198*** (2.943)	—2.082* (—2.045)	—	—	0.364	1.049 P
5	,,	—1653.36* (—1.817)	+3.517** (2.894)	—2.382* (—2.091)	+32.393† (0.635)	—	0.379	1.169 I
6	,,	—1800.21** (—2.867)	+3.466*** (4.139)	—1.129† (—1.350)	+11.836† (0.334)	+18.79*** (4.326)	0.724	1.707
7	*Tur*	—291.70† (—0.869)	+1.151** (2.258)	—1.139** (—2.385)	—	—	0.317	2.101
8	,,	—719.19* (—1.834)	+1.545*** (2.950)	—3.057*** (—3.500)	+40.033* (1.818)	—	0.435	2.081
9	,,	—878.96* (—2.119)	+1.753*** (3.174)	—1.732*** (—3.291)	+41.725* (1.904)	+9.761† (1.126)	0.478	1.894
10	Groundnut	—1058.06† (—1.561)	+2.591** (2.519)	+0.377† (0.391)	—	—	0.330	1.686
11	,,	—691.38† (—0.805)	+2.252* (1.964)	+0.695† (0.647)	—34.348† (—0.714)	—	0.351	1.647
12	Rice	—3022.17*** (—3.316)	+6.757*** (4.887)	—2.604* (—1.857)	—	—	0.5847	1.649
13	,,	—2945.03** (—2.513)	+6.685*** (4.271)	—2.537† (—1.730)	—7.226† (—0.110)	—	0.5851	1.644
14	,,	—2458.64*** (—2.041)	+8.790*** (3.963)	—3.418** (—2.158)	—10.955† (—0.170)	—20.322† (—1.312)	0.628	1.833
15	,,	—2578.12** (—2.716)	+8.887*** (4.274)	—3.515** (—2.450)	—	—20.207† (—1.347)	0.627	1.839

Note:—***Significant at 1 per cent level; **Significant at 5 per cent level; *Significant at 10 per cent level; †Not significant.
P=Positive serial correlation present; I = Inconclusive; (No serial correlation is present in other values of Durbin-Waston statistic).
Figures in brackets are 't' values.

significant enough to affect yield variability on the whole. The impact of irrigation on jowar yields may be conspicuous also because high-yielding varieties of jowar are planted when irrigation is available. High-yielding varieties were not popular in the case of *ragi* and *tur* during the period under study. The impact of irrigation cannot, therefore, be easily generalised at least from time-series data; circumstances peculiar to each crop have to be taken into account.

Looking at the values of R^2, we find that on the whole a large part of the the variations in the crop yields (adjusted for trend) is left unexplained. The highest R^2 obtained among the equations was 0.724 (in the case of jowar), followed by 0.63 (in the case of rice). Though one might feel that specification of rainfall in terms of more variables could improve the results, it is suggested at least as a hypothesis by these results that a significant part of instability in crop yields may be due to factors other than rainfall. This is evident particularly in the case of *tur* and groundnut where much less than half of the variation is explained by rainfall. Even in the case of jowar where the R^2 is the highest, the proportion of irrigated area explains yield variation almost as much as rainfall does (comparing the R^2 in Equation No. 5 with the same in Equation No. 6). Though in the case of *ragi* and rice, more than half of the variation is explained by rainfall, the unexplained variation is over 40 per cent. It would mean that efforts for controlling factors other than rainfall could also materially reduce instability. Apart from pests and diseases, variation in the use of inputs like manure and fertilizers and area shifts may account for some variation particularly if differences in soil fertility are involved in area shifts.[11] If area shifts are accompanied by compensating measures for supplying soil nutrients, some of the adverse variations could be controlled.

No claim is made here that our findings are definitive. They need further testing. One point that has emerged here particularly needs further attention as it has a great practical significance. Weather has often been credited with being the most important—if not the sole—determinant of crop instability, so much so that even week-by-week regularity of rainfall is considered essential for stability of yields. Quite apart from the fact that nature can never offer such a paradise, this is not even borne out by evidence. Crops have some ability to survive moderate seasonal droughts and weather explains only a part of crop instability. Though rainfall is admittedly important, the impact of its failure (by a given magnitude) can vary from year to year and from region to region, and is compounded by lack of proper management of soils and water. There is obviously scope for human action to reduce the impact of failure of rainfall and to reduce crop instability in general (apart from irrigation). One may however legitimately doubt how far this scope can be exploited under an individual-farm oriented approach (as against a collective approach to soil and water management).

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11. Extension of foodgrains to submarginal lands with poor soils or lacking moisture is mentioned by S. R. Sen as an important factor in making them susceptible to droughts. See his, Instability and Growth in Indian Agriculture, Mukhopadhyay, Calcutta, 1971, p. 14.