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It is observed from Table III that the gross income variability, like yield variability, for *rabi* crops, in general, is lower than that of *kharif* crops. This indicates that the gross income variability is closely related to yield variability and the price variability exerts little influence on the expectations of the farmers in the Varanasi district.

Based on these variability indices for yields, prices and income, the farmers may choose the crops keeping in view their individual goals and the capacity to bear risk.

EFFECTS OF WEATHER UNCERTAINTY ON THE YIELD OF PADDY AND MANAGEMENT DECISIONS

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Variations in crop yields result mainly from two factors, *viz.*, those which are considered as controllable and those which are considered as uncontrollable. Among controllable factors can be included such things as seeds, fertilizer, and labour. Chief among uncontrollable factors is weather. Weather is a limiting factor in determining crop yield, particularly in India where nearly four-fifth of the cropped area depends on monsoon. Weather factor is important even in other countries where weather proofing devices have been evolved through the development of technology and extensive irrigation systems.

The term weather includes rainfall, temperature, humidity and other factors. The amount and distribution of rainfall, temperature and extent of humidity are highly variable. Under a given situation of soil, crop and climate complexes. rainfall is an important factor which affects the yield of a crop. The effects of rainfall may be direct or indirect. The direct effect is through precipitation and the indirect effect is through supplementing it by artificial irrigation. In this paper attempts have been made to assess both direct and indirect effects of rainfall on the yield of paddy grown under tank command in the Bangalore district.

Brief Description of the Area and Method of Paddy Cultivation

Bangalore district lies in the dry zone of Mysore State where water is the main limiting factor in the production of crops. Though the district receives the benefits of Ante-monsoon, South-east and North-west, monsoon rains and the annual precipitation is about 30", the rainfall is typically characterised as uneven, uncertain and inadequate and the district more often has to face the weather hazards.

Sandy loams and deep red soils of the laterite origin form the bulk of the soils in the district. Paddy is the principal crop raised under tank irrigation. The methods of paddy cultivation may be broadly divided into (*i*) Dry cultivation and (*ii*) *Puddle* cultivation. In the dry cultivation the crop depends partly on rainfall and partly on irrigation. The crop is raised about half way through as a dry crop mainly depending on rain, after which it is supplemented with irrigation till the crop is harvested. With the first good showers in June-July, paddy is sown broadcast. The crop is allowed to grow with the help of rain and no water is impounded till it is two to three months old. This method is popularly known as *punaji* cultivation. In this paper we mainly discuss the effect of weather (direct and indirect effects of rainfall) on the yield of *punaji* paddy.

With a view to ascertaining the variability of rainfall during different months in a year, thirty-two years monthly rainfall data from 1929 to 1960 as recorded at the Agricultural Research Station, Hebbal has been compiled and presented in the table. The different periods considered in this study are :

(*i*) July-November period—representing the crop growing period.

(*ii*) July-August period—representing the planting or sowing season.

(*iii*) October-November period—representing the critical period of growth.

(*iv*) April-November period—representing the pre-sowing and actual growth period of the crop.

(*v*) April-June period—representing the pre-sowing period of the crop.

The variability of rainfall has been assessed for each period of eight years and is tabulated in four groups.

TABLE I—VARIABILITY IN RAINFALL DURING DIFFERENT PERIODS IN A YEAR — 1929 TO 1960

S. No.	Year Groups	Coefficient of variability					
		January-December	July-November	July-August	April-November	October-November	April-June
		Annual rainfall	Crop growing period	Sowing period	Pre-sowing and crop growing period	Critical period of crop growth	Pre-sowing period
1.	1929-1936	16.44	26.48	55.48	14.55	39.15	20.32
2.	1937-1944	18.63	25.52	44.74	19.86	62.32	28.70
3.	1945-1952	19.50	16.78	17.95	19.40	33.03	33.14
4.	1953-1960	22.39	34.40	43.27	24.06	69.25	27.64
5.	1929-1960	19.37	26.61	46.67	19.77	54.17	30.72

The data reveal that there is not much variability in the annual rainfall—the coefficient of variability ranges from 16 to 20. The coefficient of variability is

particularly high during planting or sowing season, which varies from 17 to 55. Variability is also high during October-November which represents critical growing period of paddy.

Sample

The sample represents 27 cases of paddy farmers distributed in three villages selected for the Farm Management Studies in Bangalore, where attempts have been made to estimate the amount of rainfall received during the production period and the number of irrigations given to *punaji* or broadcast paddy. Rainfall record has been taken from the nearest meteorological station lying within 3 to 5 miles radius of the sample villages and the number of irrigations given has been actually recorded by the field investigators of the Farm Management Research Centre.

Objectives

The main purpose of this paper is to apprise the effect of rainfall on the yield of paddy and to suggest measures to meet the uncertainties. The two objectives set for discussion are (1) to delineate the effects of weather on yield and measure the extent of variability in yield explained by weather; and (2) to suggest management strategy to meet the weather uncertainty.

Discussion

Most suitable data for the purposes of such studies would be those obtained from experimental stations. If time series of yields for particular crops can be obtained from experimental plots where controllable variables have been held constant, the remaining variation in yield may be largely attributed to weather. But we rarely have such experimental data. In the absence of experimental data, we may have to be content with the time series data that represent the conditions of the region specifically selected for such study. Even these data were not available to us. In the absence of reliable data on time series, we had to fall back upon a year's data which have been obtained from the Farm Management Research Centre, Bangalore.

There are different approaches that might be used in fitting a trend to time series of crop yields. We may fit a simple or multiple linear trend or fit some non-linear mathematical function or use a moving average. For the purpose of this study we have used Cobb-Douglas production function, as the data include the inputs of water along with other inputs like seed, manure and labour. The equation fitted to the data is of the form of $y = ax_1^{b1} x_2^{b2} x_3^{b3} x_4^{b4} x_5^{b5} x_6^{b6} \ldots\ldots x_n^{bn}$ which when written in logarithms reduces to $\log y = \log a + b^1 \log x_1 + b_2 \log x_2 + \ldots\ldots\ldots\ldots b_n \log x_n$. The inputs used here include seed rate, manure, rainfall, number of irrigations, human labour and date of sowing. The equation obtained is $y = 79.66\ x_1^{0.82324}\ x_2^{-0.09299}\ x_3^{1.93801}\ x_4^{0.09516}\ x_5^{0.24539}\ x_6^{0.05482}$.

Where

y = Yield per acre of paddy in pounds

x_1 = Seed rate in pounds

x_2 = Manure in pounds

x_3 = Rainfall in inches

x_4 = Number of irrigations

x_5 = Human labour in man-days

x_6 = Date of sowing.

TABLE II—REGRESSION COEFFICIENTS, THEIR STANDARD ERRORS AND CORRESPONDING 't' (OBSERVED) VALUES

S. No.	Category inputs	Regression coefficient	Standard error	't' value observed	Significance
1.	Seed rate	— 0.823	—	—	—
2.	Manure	— 0.093	—	—	—
3.	Rainfall	+ 1.938	2.493	+ 0.777	Significant at 45%
4.	Number of irrigations ..	+ 0.095	0.017	+ 5.658	Significant at 1%
5.	Man-days of labour	+ 0.245	—	—	—
6.	Date of planting	+ 0.055	—	—	—
	Total	1.41715			

The sum of regression coefficients is equal to 1.41715 where rainfall and irrigation explain substantial portion of it. The 't' value shows that rainfall is significant at 45 per cent level and number of irrigations at 1 per cent level indicating that effect of rainfall (both direct and indirect) in determining the yield is very important.

Management Strategies to Meet Weather Hazard

There are several strategies suggested to meet the various uncertainties. In the context of the present discussion two measures are important, *viz.*, (1) diversification and (2) flexibility.

Diversification :—Diversification which refers to the producing of several crops is one of the measures to reduce yield and income variability, either in a given year or from year to year. Diversification is generally used as a means of using the resources most efficiently and of maximising profit. It may also, however, be used with advantage to meet uncertainty of crop yields by adding or substituting one or two major crops. Though in a dry zone the choice of crops is limited to one or two crops, diversification can be adjusted in areas like the one we have selected where it is possible to supplement rain water by artificial irrigation. In such area there is wide choice of crops. If the goal of the farmers is to produce grain crop mainly for home consumption, diversification can be resorted to either (*i*) by growing a short duration paddy crop or (*ii*) by substituting paddy by irrigated *ragi* and a rotation crop of legume. If the goal of the farmers is to maximise returns, the farmers may possibly produce vegetable crops which

have low requirement of water. Farm management results have shown that vegetable crops like cabbage, potato and onion can be produced most profitably.

Flexibility :—It refers to avoidance of rigid production methods. Under flexibility farm plans are kept fluid. There are three kinds of flexibilities, *viz.*, (*i*) time flexibility (*ii*) product flexibility and (*iii*) cost flexibility.

(*i*) Time flexibility is important in the production of paddy as the crop is highly season bound. If the rainfall is not sufficient at the crucial period of planting or sowing, its yields will be considerably affected. There is, however, scope to switch over to other crops if sufficient rains are not received during paddy sowing period.

(*ii*) Product flexibility refers to investing in resources which can be shifted back and forth between enterprises, with greatest ease. Paddy itself being a seasonal crop, we may consider the alternatives of a short duration paddy crop or another grain or vegetable crop of short duration.

(*iii*) Cost flexibility can be introduced by keeping the fixed and variable costs flexible. Farmers may attempt to make a cheap crop during unfavourable weather conditions. If a farmer decides to grow paddy in dry season, he may keep variable costs flexible by investing less on seed, fertilizer and labour.

It may be pointed out that it is very easy to recommend to farmers either to diversify or to have flexible plans and suggest measures in a general way. It is, however, very difficult to recommend specifically how to be flexible and what particular enterprises have to be included in diversification. If the strategy to meet the weather hazard is to be of a great value, it should be a more precise recommendation. For this purpose, the development of more precise managerial strategy is essential. This requires more knowledge concerning the relationship of production and the various attributes of weather. These relationships have to be estimated for different seasons of the year. Presently, not much work has been done in this field. Data presented in Table I broadly indicate that rainfall received during the planting or sowing season and also during the period of the critical growth of paddy crop has higher variability which is likely to have greater influence on the yield of paddy crop. Several critical studies have to be taken up before the scientists could predict the probable effect of weather hazard. To know this, agricultural economists have to work with agronomists and physical scientists for establishing needed relationships.