APPLICATION OF REGRESSION MODELS TO ASSESS THE INTER-REGIONAL PERFORMANCE OF AGRICULTURE IN RAJASTHAN

राजस्थान में कृषि के अंतर-क्षेत्रीय प्रदर्शन के आकलन हेतु प्रतीपगमन निदर्शों का अनुप्रयोग

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Thesis

Doctor of Philosophy in Agriculture

(Agricultural Statistics)

2001

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Mrs. Azad Mordia

2001

Maharana Pratap University of Agriculture and Technology, Udaipur
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CERTIFICATE – I

Dated : 13/07/2001

This is to certify that, this thesis entitled, **"Application of Regression Model to Assess the Inter-regional Performance of Agriculture in Rajasthan"** submitted for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Agricultural Statistics**, embodies bonafide research work carried out by **Mrs. Azad Mordia** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee in the pre-thesis submission seminar held on 11-07-2001.

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1. INTRODUCTION

1.1 ORIGIN AND THEORETICAL BACKGROUND OF REGRESSION ANALYSIS :

The term regression was first introduced by a British anthropologist and meteorologist Sir Francis Galton (1822-1911) in a paper entitled "Regression towards Mediocrity in hereditary stature". Since then regression analysis has emerged as a powerful statistical tool. With the enhanced application of statistics in economics, planning, business management, industry, agriculture, insurance, astronomy, physical sciences, social sciences, biology, medical sciences, Psychology, education etc., the application of regression analysis in these areas of studies has become more pronounced.

The literal meaning of the word regression is stepping or returning back to the average value. Regression analysis 'as it is being used very frequently' means prediction of an unknown value of one variable from the known values of its associated variables. With the advancement of researches in the above subject matter areas, the study on the relationship between two or more variables has assumed greater significance. Prediction or estimation of the values in economics, social sciences, agriculture, business studies etc. is of paramount importance. Regression analysis has attained the status of such a scientific techniques for prediction.

Draper and Smith (1981) demonstrated various facets of regression analysis by revising their own earlier work in 1966 which they did for the chemical division of the American Society for Quality control.

The relationship between height (Y_1) and weight (Y_2) of adult males, was demonstrated through two regression equations of the type $Y_2=f(Y_1)$

and $Y_1 = g(Y_2)$. The simplest linear regression model was stated as $Y = \beta_0 + \beta_1 X + \varepsilon$,

Here, ε is called the error term which any individual Y may fall off the regression line. β_0 and β_1 are the parameters of the model viz., the intercept and slope respectively of the line. The available observations on X and Y are used to estimate the values of β_0 as $\hat{\beta}_0$ and β_1 as $\hat{\beta}_1$ using least square techniques. Thus, the finally estimated model is written as $\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X$

It is stated that there has been a dispute about who first discovered the method of least squares, which is still used in most of the practical problems. There are a number of references in scientific journals of ninteen sixties and seventies on the controversy concerning the least squares method.

The method of least squares is applied under certain assumptions on the error term and the estimates of least squares satisfy the so called BLUE property (Best, Linear, Unbiased). Here, it is assumed that the error term ε in the model has zero mean and constant variance.

Suppose there are n sets of observations on X and Y, say (X_1, Y_1), (X_2, Y_2) . . . . (X_n, Y_n).

The simple model is assumed as

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i \tag{1.1}$$

The sum of squares of deviation from the true line is given by,

$$S = \sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n} (Y_i - \beta_0 - \beta_1 X_i)^2 \quad (1.2)$$

The estimates $\hat{\beta}_0$ and $\hat{\beta}_1$ are obtained by solving the normal equations given by

$$\delta S/\delta\beta_0 = 0 \text{ and} \quad (1.3)$$

$$\delta S/\delta\beta_1 = 0 \quad (1.4)$$

The simple, but strong mathematical base of regression models gave rise to many multiple and complex regression models. In order to tackle regression problems using least square techniques, when the basic assumptions related to error term/ explanatory variables are violated, techniques like weighted least squares, restricted least squares etc. were evolved. During the course of regression application, methods to overcome problems like outliers, serial correlation, multicollinearity, heteroscedasticity were also evolved. The outlier is a peculiarity and indicates a data point which is not at all typical of the rest of data. Rules have been developed for rejecting outliers. The violation of the assumption that the errors are pair wise uncorrelated leads to the problem of serial correlation. There are a number of standard works on regression analysis published by various statisticians and Econometricians such as Draper and Smith (1981), Mendenhall and Mc Clave (1981), Seber (1977), Mentgomercy and Peck (1982), Ezckjel and Fox (1967), Wetherill (1986), Gunst and Mason (1980), Seber and Wild (1989) etc.

The matrix approach in regression analysis and the computer application and also the development of regression specific softwares have opened up the avenues for application of regression for a variety of purposes.

The most general type of linear model in variables $X_1, X_2, \ldots X_k$ can be written as

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \varepsilon \qquad (1.5)$$

The polynomial models of various orders were also subsequently evolved.

$$Y = \beta_0 + \beta_1 X_1 + \varepsilon \qquad (1.6)$$

is first order with one predictor variable.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \varepsilon \qquad (1.7)$$

is first order with k predictor variables

$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \varepsilon \qquad (1.8)$$

is second order with one predictor variables

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1^2 + \beta_4 X_2^2 + \beta_5 X_1 X_2 + \varepsilon \qquad (1.9)$$

is second order with two predictor variables

$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \varepsilon \qquad (1.10)$$

is third order with one predictor variables

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_1^2 + \beta_5 X_1 X_2 + \beta_6 X_2^2 + \beta_7 X_1^3 + \beta_8 X_1^2 X_2 + \beta_9 X_1 X_2^2 + \beta_{10} X_2^3 + \varepsilon \qquad (1.11)$$

is third order with two predictor variables

It is possible to have general second order and third order model for K variables on the above lines.

Normally when a second order model is not a good fit for the given situation, one may try a third order model and so on. However, it is cautioned not to add higher order predictor variables in the models in a routine manner. It is often more fruitful to try the effects produced by other transformations of the predictor variables (X), or transformations of the response variable (Y) or both. For example, a straight line fit of the response log Y versus X, if appropriate would usually be a preferred representation over a quadrate fit of Y versus X. There are models involving transformations other than integer powers. The two variable linear model is written as

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \qquad (1.12)$$

The reciprocal transformation of the predictor variables can be written as :

$$Y = \beta_0 + \beta_1(1/X_1) + \beta_2(1/X_2) + \varepsilon \quad (1.13)$$

The logarithmic transformation of the predictor variables can be written as

$$Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \varepsilon \quad (1.14)$$

The square root transformation of the predictor variables can be written as :

$$Y = \beta_0 + \beta_1 X_1^{1/2} + \beta_2 X_2^{1/2} + \varepsilon \quad (1.15)$$

There can be a number of such transformations.

As further development to regression analysis non-linear models were also introduced. The non-linear models can be divided into two types viz. (i) intrinsically linear models, (ii) intrinsically non-linear models. If a model is intrinsically linear, it can be expressed by suitable transformations of the variables in the standard linear form. For example the multiplicative model can be converted into linear form through logarithmic transformation of the predictor and response variables.

The multiplicative model,

$$Y = \alpha X_1^{\beta_1} X_2^{\beta_2} \ldots X_k^{\beta_k}.\varepsilon \quad (1.16)$$

can be transformed as,

$$\ln Y = \ln \alpha + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \ldots + \beta_k \ln X_k + \varepsilon \quad (1.17)$$

The transformed model can be estimated through least squares method by using log values of the variables under study. The other types of models used for various situations include

The exponential model

$$Y = e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2} . \varepsilon \quad (1.18)$$

takes the form,

$$\ln Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ln \varepsilon \quad (1.19)$$

The reciprocal model,

$$Y = 1/(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon) \qquad (1.20)$$

takes the form,

$$1/Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \qquad (1.21)$$

The use of dummy variables in regression to deal with data corresponding to specific blocks and also the whole range of data, made it necessary to introduce a factor which has two or more distinct level. This is done through introduction of dummy variables in the model.

Time trends in response data could be the resultant of a number of decisions taken over the time. In many practical situations like performance of agriculture, one may be interested in the time trend of response data. The regression models/trend lines may take the form as given in equation 1.1.

Abuse of regression from the unplanned data set has been made out by statisticians like G.E.P. BOX. The size of error is sometimes due to omission of important explanatory variables. The coefficient of visible variables in such cases may lead to misleading interpretations. Another problem is when the effective predictor variables are within quite small range and subsequently the corresponding coefficients may become non-significant. In other words, if an effective predictor variable is not varied much it will show little or no effect. The collinearity between different explanatory variables makes it difficult to see if changes in Y are associated with which of such variables.

There are a number of equally applicable approaches to pick up the best fit model. Some of these are briefly explained below as given by Draper and Smith.

(a) All possible Regressions :

This is a cumbersome procedure. All possible regression with the predictor variables are estimated and the best one is selected using the criteria of (i) the value of R^2, (ii) the value of residual mean squares.

(b) Best subset regression :

The number of best subsets of regressions from all possible regressions using the criteria of (i) maximum R^2 (ii) maximum adjusted R^2 ($\bar{R}^2$) and (iii) Mallows C_P statistic.

(c) The backward elimination procedure :

It makes it possible to have the 'best' regressions containing a certain number of predictor variables. The basic steps involve (i) a regression equation containing all variables is computed (ii) the partial F-test value is calculated for every predictor variable treating as if it were the last variable to enter into the regression equation (iii) the lowest partial F-value, F_L is compared with a pre-selected significant level F_0. If $F_L < F_0$, remove that variable which gave rise to F_L. If $F_L > F_0$, adopt the regression equation as calculated. This is stated as a satisfactory procedure when our interest is to see the variables in order without missing much. In this method one begins with the largest regression using all predictors and subsequently reduces the number of variables to a logical set.

(d) Stepwise regression :

It is very similar to backward elimination method. But it uses a different approach. Here variables are added stepwise until the regression equation is satisfactory. The order of insertion is based on the partial correlation coefficient as a measure of importance of variables not yet in the equation. That predictor having highest partial correlation coefficient with dependent variable is selected first.

Besides, there are methods like ridge regression, the method of prediction sum of squares as a criterion for selecting predictor variable (PRESS), the principal component regression on the lines suggested by Horold Hotelling and latent root regression method etc. These methods do not follow the least square technique of estimation. Practitioners like

Draper and Smith advocated the least square methods over other methods. Apart from the models linear in parameters as explained above, there are models with non-linear parameters. Iterative techniques are used for the estimation of non-linear models. Besides, there are computer calculations such as linearization, steepest descent and Marquardt's compromise methods to solve such problems. These methods are beyond the scope of present study. Thus, there exists adequate theoretical support for using regression analysis using ordinary least squares as a useful techniques to assess the performance of agriculture for any specified region which is dependent on many predictor variables.

1.2 UTILITY OF REGRESSION ANALYSIS IN REGIONAL PERFORMANCE OF AGRICULTURE :

In the broad sense, regression analysis is the processes of estimating functional relationship of the type : $y = f(x)$. The functional form $f(x)$ can be of any mathematical form such as linear, power, compound, exponential, logarithmic, quadratic, cubic, inverse, S-model etc. in single predictor variable or complex functions in many explanatory variables.

Depending upon the number of explanatory variables, the regression model can be either simple or multiple. The relationship between one explanatory and one dependent variable form the simple regression models. Whenever, there are two or more than two explanatory variables in the functional relationship, it is termed as multiple regression. The regression analysis in nutshell is the process of finding the best mathematical relationship between the response and predictor variables and also estimating the coefficients associated to the variables according to the functional forms.

The mathematical manipulations of the estimated coefficients of a regression model makes it possible to make use of regression analysis for forecasting, policy prescriptions, prediction etc. With the emergence of branches of learning like econometrics, the utility of regression has increased manifolds. Regression analysis has its utility in agriculture too, as in the case in any other field.

Regression analysis could be used as a major analytical technique to arrive at policy indicators for the sustainable development of agriculture. The sign and size of regression coefficients could be used to streamline policy formulations which may subsequently lead to sustainable development of state agriculture.

Regression models can be used in agriculture for a variety of purposes such as trend analysis of time series data, instability analysis by devising instability indices, production function analysis, cost function analysis, consumption function analysis, acreage response functions, effect of environmental factors on production, demand supply relationship and a variety of other analysis in agriculture.

However, numerous problems are encountered by the researchers in carrying out regression analysis in the field of agriculture. The 'ordinary least squares method is generally applied for the estimation of parameters included in the models. Since application of ordinary least square method is valid only under certain assumptions, the violation of these assumptions poses some or the other problems. The violation of constant variance of error term leads to the problem of heteroscedasticity. Similarly the violation of independence of subsequent values of error term leads to the problem of autocorrelation. In the case of multiple regression analysis using many explanatory variables, sometimes these explanatory variables get highly correlated to each other which in turn poses the problem of multicollinearity. The estimated parameter of multicollinear explanatory variables are prone to many inconsistencies.

1.3 IMPORTANCE OF PROPOSED INVESTIGATION ON PERFORMANCE OF RAJASTHAN AGRICULTURE :

Rajasthan agriculture often does not receive, the due importance despite the large contribution it makes to the national agricultural production pool. The state stands first in the production of bajra, rapeseed and mustard, guar, moth, spices like corriander, fenugreek and also wool. Besides, the state contributes remarkably to the production of cereals, pulses, oilseeds and other commercial crops. Over the years, the state has not only become self-sufficient, but also surplus in many commodities particularly for pulses and oil seeds, spices etc.

During the planned era of agricultural development, the strategic approach followed for the agricultural development included evolution of agricultural technology, devising effective input delivery system including extension services, the wide range of institutional set up and also the time to time policy interventions by the Government so as to ensure accelerated growth for the sector. These strategies did pay rich divident to Indian Agriculture. The Rajasthan agriculture is no exception to this phenomena. As a result of development in infrastructure like irrigation, transport, power etc. the agriculture sector of the state has emerged as vital and vibrant. The agro-climatic features including the natural factors resulted in the delineation of the state into various agricultural regions. Climatically the situations like arid or desertic, semi-arid, humid and sub-humid regions are prevalent in the state. Based on the basis of access to water resources, both irrigated and rainfed agriculture situations have emerged in the state. Again based on the source of irrigation, the irrigated regions can be further split into well irrigated (ground water) and canal-irrigated (surface water) regions. Besides, based on the precipitation rate, the rainfed agriculture can also be further classified as rainfed-dry, rainfed-humid, rainfed-sub humid etc. In other words, a variety of agricultural production systems is prevalent in the state of Rajasthan. Therefore, the assessment of the performance of agriculture in the state can be meaningfully done on regional basis.

As a result of developmental efforts, definite growth has been achieved in many components of agriculture. However, it is believed that the growth of agriculture in the state is associated with risk and instabilities. In other words, the growth of agriculture in most part of the state is coupled with instabilities.

The present study is an attempt as how regression analysis can be used to assess the performance of agriculture across different regions in the state. The data requirement for such studies could be available from the publications of Directorate of Economics and Statistics, Department of Agriculture, Revenue Board and other official records of Government of Rajasthan. It is pointed out here that National Sample Survey Organization, Government of India also generates data on land use, crop yields and other agricultural parameters based on the sampling techniques. For example, land use and yield surveys were included in the NSS survey round number 11^{th}, 12^{th}, 13^{th}, 14^{th}, 15^{th}, 16^{th}, 17^{th}, 18^{th}, 19^{th}, 20^{th}, 21^{st}, 22^{nd}, 23^{rd}, 24^{th}, 25^{th}, 26^{th}, 42^{nd} and 48^{th} of NSSO (out of 57 rounds completed upto year 2001). It is intended to apply the techniques of regression analysis for the purposes given below, the details of which are discussed in the chapter on methodology.

(a) Temporal trend models :

The identification of pattern of temporal trend of agricultural parameters like area, production, yield, land use etc. according to various temporal phases, as linear, power, compound, exponential, logarithmic, quadratic, cubic, inverse, S-model etc.

(b) Growth rate models :

The compound growth rates of agricultural parameters using equation of the form

$$Y_t = b_0 \, b_1^t \qquad (1.22)$$

CGR 'r' = (antilog b_1 – 1) x 100

(c) Instability analysis :

The instability index given by Cuddy and Della as :

$$\text{Instability index} = \text{C.V.}\sqrt{(1-R^2)}$$

which needs the value of R^2 which is outcome from the regression models.

(d) Forecast of instability scenario :

For those situations where linear trend is statistically significant it is possible to estimate two more trend equations for data corresponding to positive and negative deviation values. The slope and intercept of these two lines are used to forecast future instability.

(e) Acreage response models :

There are number of factors which may affect the farmers decision to allocate acreage under a particular crop. The pattern of acreage response model (current year area) could be attributable to factors like one year lagged area (A_{t-1}), one year lagged price of the concerned crop (P_{t-1}), one year lagged price of the competing crop (Pc_{t-1}), ratio of farm harvest price of selected crop to competing crop (Pr_{t-1}), one year lagged yield of concerned crop (Y_{t-1}), one year lagged yield of next competing crop (Yc_{t-1}), rainfall in the t^{th} year (R_t), one year lagged rainfall (R_{t-1}), total irrigated area in the current year (I_t), standard deviation of prices for the preceding three years (Sp_{t-1}) and standard deviation of yield for the preceding three years (Sy_{t-1}) etc.

(f) Fertilizer response models :

Agronomic and economic optima of fertilizer use are of great importance for policy prescriptions. Agronomic optima related to the level of fertilizer which gives the highest physical yield. The economic optima gives the highest profit maximising level of fertilizer dose which takes into consideration of the prices of both fertilizer and output.

(g) Production function models :

The coefficients of additive and multiplicative regression model give the rate of change and elasticities of input variables, respectively.

(h) Cost function models :

The average cost function which is to be a U-shaped curve can be expressed as a quadratic equation of output. The minimum of average cost is at dC/dQ=0 gives the output level at the minimum of average cost and hence can be used to assess the cost effectiveness of crop production in different region.

1.4 NEED FOR STATISTICAL EVALUATION OF INTER-REGIONAL PERFORMANCE OF AGRICULTURE IN RAJASTHAN :

Rajasthan agriculture has been responding to the agricultural technology, input delivery system, institutional set up for agricultural development and also policy interventions made from time to time by both central and state government. However, there are only very few evidences as how, in which direction and at what rate these parameters have been moving over the time. The green revolution being a major milestone in agricultural development, it is important to ascertain the path of movement of such agricultural parameters. Definitely, the agro-climatic characteristics prevalent in various regions of the state are expected to influence the nature of changes which can be captured through the best befitting trend models using time series data. The sign and size of estimated coefficients of appropriate models will throw light on the impact of developmental interventions according to the various agro-climatic regions of the state.

In such cases where the values of agricultural parameters are affected by a host of explanatory variables, the functional relationship as existing in different agro-climatic regions can be estimated through multiple regression models. For example, the changes in acreage under a crop over the period depends on changes in climatic factors, changes in technological factors, changes in policy parameters and changes in agricultural infrastructure set up. The regression models can be used to ascertain the rate of change over time with respect to such factors.

1.5 OBJECTIVES OF THE STUDY :

Keeping in view the complexities of state agriculture and utility of regression analysis to assess the performance of state agriculture on the above lines, the present study aims on the following specific objectives :

(i) To deal with the problem of model specification in the context of growth, instability, input response, acreage response and agricultural production of selected crops in selected agricultural situations.

(ii) To ascertain the goodness of fit of estimated regression models for growth, instability, acreage response and agricultural production of selected crops in selected districts;

(iii) To test the equality of estimated coefficients of the regression model between comparable situations,

(iv) To identify the problems due to violation of assumptions of error term in the estimation of regression models using ordinary least squares method and

(v) To apply the remedial measures to overcome the identified problems.

1.6 HYPOTHESIS :

Scientific research methodology warrants the postulation of research hypothesis so as to draw meaningful conclusions from the research thesis. Some stipulated hypothesis set for empirical probing for the present study are –

(i) The agricultural parameters like area, production and productivity of crops have registered varying responses over time as a result of changes in strategic planning for development.

(ii) The land use classes like forest, net sown area, grazing land etc. have registered positive growth with stability over the years.

(iii) The land use classes like culturable waste land, fallow land, barren land etc. have registered negative growth with stability.

(iv) The magnitude of growth vis-à-vis instability is not uniform over the years and across the regions.

(v) Comparable situation may emerge with uniform responses for agricultural parameters.

(vi) The acreage under crops is determined by climatic, technological and policy factors in all the regions of the state.

1.6 LIMITATIONS :

The whole study is based on the secondary data, published or unpublished. The accuracy of the results and implications drawn from the study depends on the accuracy of the data collected and the aggregates/ averages worked out by different data collection agencies.

1.7 CHAPTER SCHEME :

The study has been presented in five chapters. The first chapter deals with the introduction, importance, objectives, the limitations of the study etc. A comprehensive review of important relevant studies is given in chapter second. The third chapter is meant to explain methodology and specifications of the models for various purposes outlined in the study. Results and discussions are presented in chapter fourth. Summary and conclusions are presented in chapter fifth which is followed by a comprehensive bibliography at the end.

2. REVIEW OF LITERATURE

The present study mainly focus on assessment of performance of selected agricultural parameters using regression analysis as a technique for different agro-climatic regions of Rajasthan state. The studies reviewed could meaningfully be classified under three broad heads :

i) Reviews related to theoretical framework and associated issues on regression analysis.

ii) Reviews related to application of regression and empirical evidences in the field of agriculture.

iii) Reviews of literature on performance of Rajasthan's agriculture.

2.1 REVIEWS RELATED TO THEORETICAL FRAMEWORK AND ASSOCIATED ISSUES ON REGRESSION ANALYSIS :

The present study is an attempt to examine as how regression analysis can be used to assess the performance of agriculture under different situations prevalent in the state. Some of the works already conducted with regard to the theoretical development of regression are reviewed as under :

Durbin and Watson (1951) have suggested a test for testing serial correlation in least squares regression which is applicable for small samples. However, the test is appropriate only for the first-order autorgressive scheme ($u_t = \rho u_{t-1} + V_t$). The null hypothesis is

$$H_0 : \rho = 0$$

or H_0 : the u's ae not autocorrelated with first-order scheme. To test null hypothesis they used the statistic

$$d = \frac{\sum_{i=2}^{n}(Z_t - Z_{t-1})^2}{\sum_{i=1}^{n} Z_t^2}$$

They had established the upper and lower limits for the significant levels which are appropriate to test the hypothesis of zero first-order autocorrelation against the alternative hypothesis of positive first-order autocorrelation. They have tabulated upper and lower values at 5 per cent and 1 per cent level of significance.

Chow (1960) suggested a test of equality between coefficients obtained from different samples. Assuming that there are two samples on the variables y and X, the one contain n_1 observations and the other n_2 observations, which were used separately for the estimation of the relationship between Y and X. Two estimates were obtained for two periods, i.e.,

$$\hat{Y}_1 = \hat{b}_0 + \hat{b}_1 X_1$$

and $$\hat{Y}_2 = \hat{\beta}_0 + \hat{\beta}_1 X_1$$

Here, the null hypothesis was $b_i = \beta_i$

The pooled function for a sample of $(n_1 + n_2)$ observations was estimated as

$$\hat{Y}_p = \hat{a}_0 + \hat{a}_1 X$$

The unexplained variation is

$$\Sigma e_p^2 = \Sigma Y_p^2 - \Sigma \hat{Y}_p^2$$

For 1st and 2nd sample unexplained variations are

$$\Sigma e_1^2 = \Sigma y_1 - \Sigma \hat{y}_1^2$$

& $$\Sigma e_2^2 = \Sigma y_2 - \Sigma \hat{y}_2^2$$

The test is

$$F_{(k,n_1+n_2-2k)} = \frac{[\Sigma e_p^2 - (\Sigma e_1^2 + \Sigma e_2^2)]/k}{(\Sigma e_1^2 + \Sigma e_2^2)/(n_1 + n_2 - 2k)}$$

Where, $F_{cal} < F_{tab}$, H_0 is accepted.

Box and Hunter (1962) described a simple technique which is useful in model building. In this paper an statistical procedure was applied to the estimated parameters rather than observations directly. The nature of the defects interacting with the experimenter's technical knowledge could suggest changes and remedies leading to a new model which, in turn, is tentatively entertained, and submitted to a similar straining process.

Goldfield (1965) presented two exact tests for testing the hypothesis that the residuals from a least squares regression are homocedastic. He considered the regression model

$$Y_i = a_0 + a_1 X_{1i} + . . . + a_m X_{mi} + U_i$$

In this paper consequences of the violation of the assumption of homoscedasticity was assessed.

In this firstly, the observations are ordered according to the magnitude of the explanatory variable X. Secondly, a certain number 'c' of central observations is selected arbitrarily which can be omitted from the analysis. The remaining (n-c) observations are divided into two sub-samples of equal size i.e. (n-c)/2, here one includes small values of X and other includes large value of X. Thirdly, to each of sub-sample, separate regressions is fitted and sum of squared residuals from both sub samples i.e. Σe_1^2 and Σe_2^2 is obtained. The ratio of two variances

$$F^* = \frac{\Sigma e_2^2 \;/\; [\{(n\text{-}c)/2)\} - k]}{\Sigma e_1^2 \;/\; [\{(n\text{-}c)/2)\} - k]} = \frac{\Sigma e_2^2}{\Sigma e_1^2} \sim F_{\{n-c\}/2) - k,\ \{n-c\}/2) - k}$$

where 'k' is the total no. of parameters estimated in the model. The higher the observed F* ratio the stronger the heteroscedasticity of the U_i's.

Glejser (1969) performed the regression of Y on all the explanatory variables and the residuals, e's were computed. The absolute values of e's ($|e_i|$) are regressed on the explanatory variable with which $\sigma^2_{u_i}$ is thought on priori grounds, to be associated. The actual form of the regression is usually not known and hence experimented on various formulations, containing powers of X, for example

$$|e| = a_0 + a_1 X_j^2$$

$$|e| = a_0 + a_1 X_j^{-1} = a_0 + a_1 (1/X_j)$$

$$|e| = a_0 + a_1 X_j^{1/2} = a_0 + a_1 \sqrt{X_j}$$

and so on.

The form of regression which gives the best fit is chosen in the light of the correlation coefficient and the standard errors of the coefficients a_0 and a_1. Then heteroscedasticity is judged in the light of the statistical significances of a_0 and a_1, then any standard test of significance ($S_{\hat{b}_i}$, t, F) for these coefficient is performed and if they found significantly different from zero, accept that U_i's are heteroscedastic.

Brown (1970) studied simple comparisons of simultaneous regression lines. He assumed that x's and y's are linearly related in model.

$$Y_{iv} = a_i + b_i X_{iv} + e_{iv}$$

Where $(X_{iv}, Y_{iv}) = 1, n_i$ and $i = 1, k$

The fitting of several regression lines subject to an assumption of either parallelism of the lines or a common intercept and tested for the consistency of the assumption with observed data. He also used multiple regression to fit the model

$$Y_{iv} = \sum_{i=1}^{k} a_i z_{iv} + b X_{iv}$$

Hedyat and Robson (1970) analysed in a stepwise manner the residuals for testing homoscedasticity. They examined the n^{th} residual as the deviation of the n^{th} observation from the predicted value based on least squares fit to only the first n observations then the resulting sequence of residuals, appropriately normalized, are not mutually independent and homoscedastic but also independent of all the calculated regression function. He used the fixed effects linear models

$$Y = X\beta + \varepsilon$$

He concluded, if the error variance is monotonic function of mean then under certain regularity conditions, the calculated stepwise residuals are likewise monotonically heteroscdeastic. He used simple linear regression with equally spaced values of the independent variables which constitutes on such regular case, and a Monte Carle study of the "peak-test" of homoscedasticity. He concluded for small samples this stepwise residual are more sensitive to use.

Koutsoyiannis (1977) in his book in theory of Econometrics describes the mathematical background of the application of Ordinary Least Squares (OLS) in regression models. He suggested R^2 value as a statistical criteria for testing the goodness of fit of the model. Apart from the theoretical concept of application of analysis of variance in regression, there is a substantial coverage on the various problems arising out of the violations of assumptions of error term in a regression model.

The violation of the assumption of constant variance of the error term associated to each observation of the explanatory variable leads to the problem of heteroscedasticity. Under heteroscedastic situation of the error term, the estimation of the variance of the regression coefficient becomes problematic. Besides the OLS estimates may not satisfy the minimum variance property in the class of unbiased estimates. He had suggested the Spearman Rank Correlation test, the Goldfield and Quandt test and Glejsar test for testing the heteroscedasticy. For the problem of serial correlation/ autocorrelation which arises due to the violation of assumption on covariance of error values associated to different values of the explanatory variables, he suggested Durbin-Watson test. According to him as a consequence of multicollinearity, the estimates of the regression coefficients become indeterminate and the standard error of these estimates become infinitely large. The L.R. Klien's critera that collinearity is harmful if $r^2_{x_i\, x_j}$ is greater than $R^2_{y.x_1\, x_2\, \ldots\, x_k}$ has been advocated by him.

Intriligator (1978) elaborates linear regression model using matrix approach. The coefficient of determination R^2 is stated as a measure of explanatory power of the model. The problems of multicollinearity, heteroscedasticity and autocorrelation are covered in detail. The application of lagged variable as explanatory variables and the intricacy are also explained. Application of single equation estimation in case of household demand analysis, application to firms – production functions and cost functions are also discussed in detail. The estimation part of cost function in crop analysis are dealt in detail.

Assuming that cost is a function of output i.e.

$$C = C(y),$$

it is stated that

$$A\,C(y) = C(y)/y$$

$$M\,C(y) = d\,C(y)/dy$$

Where, A C(y) is the average cost and M C(y) is the marginal cost.

The graphical depiction of average cost curves and marginal cost curves as U-shaped curves has been made out by him.

Draper and Smith (1981) demonstrated various facets of regression analysis by revising their own earlier work in 1966, which they did for the chemical division of the American Society for Quality control. The revised, edition could be considered as a pioneering work in applied regression which begins with simple linear regression models in chapter one to non-linear estimation in chapter 10.

It was observed that the strong theoretical backing developed in the case of first order linear model and the concept of model adequacy and statistical test for lack of fit facilitated to the extension of a first order model with one predictor variable to a general model, linear in the parameters to be estimated and containing several predictor variables. The use of transformation of predictor variables and also the use of dummy variables and lagged variables in regression models made the regression analysis more complex and meaningful.

As further development to regression analysis they worked on non-linear models. The non-linear models can be divided into two types viz. (I) intrinsically linear models, (ii) intrinsically non-linear models. If a model is intrinsically linear, it can be expressed by suitable transformations of the variables in the standard linear form. For example the multiplicative model given as equation 15 can be converted into linear form through logarithmic transformation of the predictor and response variables.

The multiplicative model

$$Y = \alpha X_1^{\beta_2} X_2^{\beta_2} . X_k^{\beta_k} . \varepsilon$$

Transformed model

$$Y = \ln \alpha + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \dots \beta_k \ln X_k + \varepsilon$$

The transformed model can be estimated through least square method by using log values of the variables under study. The other types of models used for various situations include

The exponential model

$$Y = e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2} . \varepsilon$$

i.e. $\ln Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ln \varepsilon$

The reciprocal model

$$Y = 1/(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon)$$

$$1/Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$$

The use of dummy variables in regression to deals with data corresponding to specific blocks and also the whole range of data, made it necessary to introduce a factor which has two or more distinct level. This is done through dummy variable.

They put forward a set of statistical procedures for selecting predictor variables in regression analysis. All these procedures are followed by the applied statisticians. However, these methods do not necessarily lead to the same solution when applied to the some problem although for many problems the some answer is achieved. These methods include (i) all possible regressions using three criteria; R^2, s^2 and Mallows' cp. (2) best subset regressions using R^2, R^{-2} and Cp (3) backward elimination (4) stepwise regression (5) some variation on previous method (6) ridge regression (7) press-prediction sum of squares as a criteric for selecting predictor variables (8) principal components regression (9) latent root regression (10) stage wise regression.

Kvalseth (1985) suggested the coefficient of determination (R^2) is perhaps the single most extensively used measure of goodness of fit for regression models. Eight different expressions for R^2 are given in this article. He addressed the R^2 problem generally, compared various statistics for different types of models, pointed some common mistakes and provided a recommendation for the most appropriate and generally applicable R^2 statistic.

Liu Shu-ing (1996) investigated model selection for time series data based upon joint multi-period forecasts. Some popular selection criteria are applied to a suitable multivariate regression model to create new selection criteria. The proposed selection procedure performs more efficiently than the corresponding regular procedure, particularly when the data are generated from a high order autoregressive model.

Sutradhar (1996) suggested that the standard Bartlett's test (i.e. of Bartlett's 1937) would be highly misleading for testing the homogeneity of variances of several groups, when the observations in each group are autocorrelated. The corrected (for auto-correlations) Bartlett's test performs well in controlling the type I error rate, except for the cases with very large negative autocorrelations. This scroe test is more powerful than the Bartlett's test for all sample sizes.

2.2 APPLICATION OF REGRESSION AND EMPIRICAL EVIDENCES :

Growth rates and instability measures are considered as important tool to assess the performance and prospects of agricultural production and related aspect. In under developed economy, acreage response to changing prices and other factors has been a subject of considerable relevance for research. The review of studies conducted on growth rates instability measures, acreage response function, fertilizer response function etc. are presented in the forthcoming section.

Kumar (1959) worked out on economic aspects of fertilization and fitted Mitscherlick equation

$$Y = A\{1-10^{-C(x+b)}\}$$

Where, 'A' measures a maximum yield, C is the efficiency of the fertilizer and 'b' is soil content of the fertilizer in the control plateform assumable by the plants to determine the economically optimum rates of fertilizer use and found that optimal doses recommended by agronomist were never economically optimum.

Minhas and Vaidyanathan (1965) applied the technique of component analysis to estimate the contribution of various factors in the growth of production. The study was conducted on country level data for the period 1951-54 to 1958-61 for 28 major crops in 14 states. Growth in output was decomposed in area, yield, cropping pattern and interaction between yield and cropping pattern. They observed that area and yield attributed 45 and 46 per cent respectively to the growth of output.

Sen (1967) in his study analysed statistical trend and identified some factors which are to some extent responsible for dramatic growth in foodgrain production in Punjab-Haryana and Uttar Pradesh and the factors which acted as the constraints on the growth of foodgrain production in Punjab-Haryana and Uttar Pradesh and the factors which acted as the constraints on the growth of food grain production in rice productivity in states like West Bengal and Kerala.

The two types of curves, Exponential and Gompertz were used

Exponential – $Y_t^* = ab^t$

Gompertz – $Y_t^* = Ka^{bt}$

The result proved the Punjab (including Haryana) and to some extent Uttar Pradesh still enjoy the benefits of new technology injected into Indian agriculture, whereas West Bengal and Kerala have remained much behind the other two states in respect of agricultural growth and green revolution. In Punjab and to some extent in Uttar Pradesh, fertilizer consumption, percentage of irrigated area and the area under HYV have increased at a constant rate as compared to West Bengal and Kerala. It was concluded that, poor growth of fertilizer consumption, irrigation and HYV seed consumption, with poor resources of farmers and predominance of farm labourers in West Bengal might be working as constraints in the growth in these states.

Sidhu and Kaul (1971) conducted a study on acreage response to prices for major crops in Punjab.

The following Nerlovian type model used

$$Y_t^* = a_0 + a_1 P_{t-1} + a_2 \sigma P_{t-1} + a_3 U_t$$

$$(Y_t - Y_{t-1}) = b (Y_t^* - Y_{t-1})$$

Where,

Y_t = acreage under crop for the year t.

Y_{t-1} = lagged acreages

P_{t-1} = relative profitability of the crop for t-1

σP_{t-1} = standard deviation of P_{t-1}

CVP_{t-1} = Coeff. of variation of P_{t-1}

U_t = residual

They found that the groundnut, maize and desi cotton were relatively high risk crops, whereas wheat and paddy were relatively low risk crops. The coefficient of variation as a variable in place of standard deviation which had consistently given higher coefficient of determination. The improvement in results brought by inclusion of coefficient of variation as a variable was also reflected in coefficient of adjustment and in short run and long run elasticities.

Cummings (1975) carried out the analysis of supply response of Indian farmers taking wheat, barley, rice, jute, cotton, ground nut, sesamum and tobacco.

The following model by Nerlove's formulation of price expectation and area adjustment was used :

(1) $A_tD = a_0 + a_1 P_t^* + a_2 R_t^* + a_3 t + U_t$

(2) $P_t^* - P^*_{t-1} = b(P_{t-1} - P^*_{t-1})$

(3) $A_t - A_{t-1} = C\ (A_tD - A_{t-1})$

Where,

A_tD is the desired acreage in the crop.

P_t^* is the expected realised price

P_t^* is the trend variable

A_t and P_t are actual acreage and price respectively.

He revealed that in Tamil Nadu, groundnut was found less responsive but positive in north where their production was centered, while for sesamum a varied pattern of positive and negative coefficients were found. In Kerala, district level regression analysis for cotton, groundnut and sesamum growing districts have shows positive and significant effect of price. Maharashtra, Gujarat and Andhra Pradesh have shown positive response to price for both groundnut and sesamum. For Rajasthan sesamum has shown positive response to price. Cash crops had shown positive response in Punjab state. Groundnut and sesamum showed negative elasticity for Himachal Pradesh. For groundnut and sesamum, price response was found positive and statistically significant in West Bengal and Assam.

Vaidyanathan (1977) studied the causes of the non-fulfillment of targets and assessed the possibilities and constraints in increasing agricultural production at national level. He used the following relation to assess the sources of growth in food grain production.

$$P = P_a + P_i + P_c + P_f$$

Where, P is total increase in food grain production potential.

P_a is increased output due to area expansion.

P_i is increased output due to irrigation.

P_c is the effect of changes in cropping pattern.

P_f is additional production attributable to fertilizers.

The study concluded with pessimistic assessment of the prospects of accelerated growth for the decade 1988-1990.

Further to this attempt, Vaidyanathan (1977) again estimated growth rates for the periods 1945-75, 1949-64 and 1967-76. He used the following functions and tested goodness of fit for these functions.

(i) $\text{Log } Y = a + bt$ and

(ii) $\text{Log } Y = a + bt + ct^2$

The indices of aggregate real output, crop output and foodgrain output were used by him. The R^2 value for the second function was found slightly higher. The results showed that the growth was very slow and far below, what was targeted.

Jhala (1979) studied the supply response of groundnut in India covering the period 1951-52 to 1970-71, except when the data are not available for some regions.

He used Nerlovian type model of the form

$$A_t^* = b_0 + b_1 P_{t-1} + b_2 Z_{t-1} + b_3 R_t + U_t$$

$$A_t - A_{t-1} = B (A_t^* - A_{t-1}), 0 < b < 1$$

$$A_t = C_0 + C_1 P_{t-1} + C_2 Z_{t-1} + C_3 R_t + C_4 A_{t-1} + V_t$$

Where,

A_t = Acreage under groundnut in the concerned region.

P_{t-1} = Farm harvest price

A_{t-1} = Average groundnut yield in the region

R_t = Rainfall in current year

He concluded that the expansion of groundnut acreage during the first two decades of planning came through the spread of groundnut acreage in newer area where farmers responded well to economic incentives, while in the traditional groundnut producing regions especially coming under "cotton tract" the farmers were indifferent to price incentives. The agro-climatic factors especially yield and the sowing period rainfall, seemed to exert a significant influence over groundnut acreage in India which could be seen from the fact that where farmers responded positively to economic incentives, the yield component played a more leading and significant role than the price component to revenue and where farmers were non-responsive to price movements, the sowing period rainfall seems to exert considerable influence on decision making.

Shriniwasan (1979) in a study examined the hypothesis of slow down in the growth of output since the middle sixties, compared to the first decade and a half after independence. Two trend functions-log linear and log-quadratic were estimated.

$$\text{Log } Y_t = a_0 + a_1 t$$

$$\text{Log } Y_t = b_0 + b_1 t + b_1 t^2$$

where 'Y_t' is the index of area or production or yield, under a crop, or a crop aggregate and 't' is the time.

These indices were supposed to reflect changes in coverage and methods of estimation, that had been made from time to time. The log-linear regression implies a constant growth-rate over the period of estimation while the log-quadratic regression permits a decreasing (b2 < 0 or inverted U-shaped curve) or increasing (b2 > 0 or U-shaped curve) growth rate. The results revealed that there has been a decline in the rate of growth of gross sown area, in particular under non-food crops, in the decade starting from 1967-68 compared to the 15 years ending in 1964-65. But the output and yield of the entire period 1949-50 to 1977-78 with no-evidences of either acceleration or retardation since 1967-68. The slowdown in the growth of crop-area in the period after mid-sixties compared to the earlier period was shared by almost all crops except wheat. Among cereals, the so called coarse grains actually lost area in the decade starting from 1967-68. It was again in wheat which showed faster growth in output and yield per unit area in the later decade compared to the earlier decade and a half. There was as yet no evidence for such a change in growth rate of output or yield per unit of area of rice, though jowar yield did faster in the later period. The study concluded that there was no green revolution as a whole but it was only a wheat revolution.

Bhatia (1981) studied (i) the growth rate of production and productivity of major foodgrains in India in two periods of time, viz., 1960-61 to 1978-79 and 1967-68 to 1978-79, (ii) the rate of growth of production and productivity of major cereal crops in different states, and (iii) the factors which determine the rate and pattern of growth of foodgrain production and productivity. Compound growth-rates were computed by fitting an exponential function of the form

$$y = AB^t,$$

where, y is index number of production/ productivity and 't' is the time. Productivity functions were fitted to the cross-section data of different states for the year 1976-77. The study revealed that the modern technology had helped in accelerating the rate of growth of production of foodgrains in India. While the growth rates of wheat and rice were reported to be quite encouraging, growth rates of production of pulses and maize were not found satisfactory. Results showed that about two third of growth of production of foodgrains has come through increase in productivity.

Ray (1981) in a study examined in the growth of area, production and yield of selected crops for the country as a whole. He introduced weather alongwith time trend and specified the following types of relationship.

$$Y = a_0 + a_1 t + a_2 \log W_t$$

Where,

Y stands for area (A_t), production (P_t) or yield (Y_t) on the year t and W_t represents rainfall in year t. The relationship are also without dummy variable to distinguish between pre and post HYV periods. For comparison purposes he also estimated the equation.

$$\text{Log } Y = a_0 + a_1 t$$

from which the unadjusted growth rate was calculated. he revealed that

(a) Rainfall has a statistically significant effect, on behaviour of area, production and yield.

(b) The weather corrected trend growth rates differ significantly from the unadjusted rates in 7 out 11 cases and

(c) The adjusted growth rates are, in general, higher than the unadjusted ones. Ray also reported the results of an extension of the above model incorporating prices as an additional explanatory variable and found the coefficient for prices to be generally positive and statistically significant in the case of area and production but apparently not for per hectare yields.

Singh and Sharma (1984) examined the regional and yearwise variations in the crop yield responses to the levels of fertilization in four regions of the state of Uttar Pradesh and suggested the levels of N, P, K which would optimize the yields of high yielding wheat and paddy crops in the respective regions. To capture the regional variation in the yield responses he used three sets of dummy variables, with a value one for an observation pertaining to a location and zero otherwise, the quadratic function i.e.

$$Y = a + b_1X + b_2X^2 + b_3C + b_4B + b_5W + b_6X_G + b_7X_B$$
$$+ b_8XW + b_9X^2C + b_{10}X^2B + b_{11}X^2W$$

Where,

Y is the yield of crops in quintals/ hectare,

X is the level of fertilizer in kilograms/ hectare,

C is the zero one variable for location in central region.

B is the zero one variable for location in Bundelkhand region.

W is the zero-one variable for location in Western region.

This results in differential marginal physical productivities of fertilizer input in the production of a particular crop. This may originate due to differences in the climatic conditions and soil compositions and other factors. All these lead to differential optimal fertilizer requirement to optimise the crop output in different regions. Fertilizer recommendations for high yielding wheat and paddy crops should, therefore, be based on detailed economic analysis rather than recommending a uniform dose for a crop in all regions.

Singh and Zilberman (1984) attempted a study on allocation of fertilizer among crops under risk by using quadratic programming approach. It revealed that risk caused by price instability resulting in variation in income from crop affected the allocation of fertilizers among the crops. Also, the low risk crops associated with low levels of fertilizers were in the optimal cropping plan in place of high risk crops. It was suggested that appropriate price and crop insurance policies should be implemented in order to stabilize income.

Flinn and Shakyan (1985) examined the factors influencing the adoption and adoption rates of fertilizer on wheat in the Easter Tarai of Nepal and estimated the probability of fertilizer adoption and the quantity of fertilizer used by the adopters. They also suggested that the factors related to fertilizer use on wheat were the area under wheat, extent of irrigation, transport cost and operators tenurial status. Owner farmers with larger area of wheat were reported to high level of use with high application rates than tenants with smaller areas. They further revealed that fertilizer adoption was sensitive to the cost of fertilizer procurement, implying that farmers in the area were responsive to the fertilizer price as reflected in procurement plus delivery cost.

Chowdhary and Sain (1986) revealed that the farm size does not stand as a barrier to use of chemical fertilizers and manures for the small farmers. Manures and fertilizers displayed both positive correlation with and a determining role in increasing per hectare farm investment, yield and fertilizer use pattern observed were in wheat (46.12 per cent) followed by maize (19.19 per cent) mustard (5.20 per cent) and gram (5.09 per cent) respectively. Multiple regression model was used to explain interfarm difference in the level of fertilizer use. All the chosen variables gross irrigated area, farmsize and level of education were found statistically non-significant.

Bandopadhyay (1989) estimated pattern, nature and rate of change in instability of wheat production in Punjab – Haryana and rice production in West Bengal. The period used for study was 1950-51 to 1984-85 which was subdivided into pre and post green revolution periods. For each sub-period the usual linear fit has been tried on annual data, total rice for districts of Punjab – Haryana.

In order to identify the fluctuations around the trend, sorting of (i) observed values which are higher than corresponding trend values was done A trend line, through each of these pairs of sets of observed values was fitted. For each of the trend lines, all usual tests of significance and goodness of fit were administered F-test was administered to test the hypothesis that positive and negative (higher of lower) trend lines are parallel, using the statistic

$$F = \frac{(^{**}R_{yy} - R_{yy})/(V^{**} - V)}{R_{yy}/V}$$

Where,

**Ryy =residual sum of squares due to linear fit on observed values

Ryy =residual sum of squares from positive trend line plus residual sum of squares from 'negative' deviation trend line.

if $F > F_{k-1,\ n-2k(a)}$

then null hypothesis is rejected at the given level of significance to find the nature of instability values of 't' at the point of intersection of positive and negative duration trend lines is computed.

$$Y(+) = a'' + b''t \quad \ldots (1)$$

$$Y(-) = a' + b't \quad \ldots (2)$$

If $t > 0$, then (1) and (2) converge in positive quadrant. If $t < 0$, then (1) and (2) diverge in positive quadrant value of t is estimated using the formula.

$$t = \frac{(a'' - a')}{(b' - b'')}$$

Again $$|\tan(\theta^{+} - \theta^{-}| = \frac{b'' - b'}{1 + b''.b'}$$

gives the rate per unit time at which (1) and (2) converge or diverge. Year to year fluctuations in wheat production in Punjab during post green revolution period whereas, instability in rice production in West Bengal was found to be increasing during the same period.

Lal (1989) studied the growth performance of rapeseed and mustard over time (1954-55 to 1984-85) in different state as well as in India. They also studied the determinants of supply response of rapeseed and mustard in Uttar Pradesh.

Nerlovain adjustment model was used to study the area response behaviour of the oilseeds crops.

$$A_t = a_0 + b_1 P_{t-1} + b_2 Y_{t-1} + b_3 P_{t-1} + b_4 Y_{t-1} + b_5 RL\ P_{t-1} + b_6 RL\ Y_{t-1} + b_7 A_{t-1} + V_t$$

where the explanatory variables are lagged area (A_{t-1}), lagged yield (Y_{t-1}), lagged absolute price of (P_{t-1}) of rapeseed and mustard as well as lagged price of substitute crop, wheat i.e. $P_{S(t-1)}$ and $Y_{S(t-1)}$ respectively, the relative yield (RLY_{t-1}) and relative price (RLP_{t-1}) of rapeseed and mustard to wheat.

Sharma *et al.* (1989) studied trends in area, production and yield of commercial crops in Indian Agriculture with special reference to oilseeds". The functional form of the following type was used to compute the growth rates

$$Y = ab^t$$

Where, Y is the area/production and yield, a is constant, t is number of years and b is trend value. The standard error has been estimated. The compound growth rate has been worked out as :

$$CGR = (b-1) \times 100$$

The study covered the period of 36 years from 1949-50 to 1984-85. The period was divided into pre-green revolution (I) from 1949-50 to 1965-66 and post green revolution period (II) from 1966-67 to 1984-85. The state wise analysis has been done for 15 years from 1970-71 to 1984-85. It was concluded from the analysis that the growth rates of production of different oilseeds crops either remained constant or declined in period (II) as compared to period (I) except in case of castorseed and sesamum where the growth rates of production were higher in period (II). It can be further concluded that high growth rates of areas under these crops were responsible for high growth rates of production in period (I) whereas the high yield rates contributed significantly towards high growth rates of production in period (II). Statewise analysis also reveals that in majority of the states, producing these crops, yield rates were higher compared to area for various oilseed crops, the different states should be considered for enhancing the oilseeds production in India.

Rao (1989) analysed the fertilizer use on groundnut in Andhra Pradesh. Data were drawn from the cost of cultivation scheme conducted by the Andhra Pradesh Agricultural University for the year 1984-85. Out of 217 groundnut producers 132 (62 per cent) of farmers were reported using fertilizers and 57.5 per cent of the area under the crop received fertilizer. For examining the association between fertilizer use and selected variables as irrigation, HYV's farm size, credit and season. Multiple regression model of the following form was used

$$Y = a + b_1 X + b_2 D$$

Where,

Y = yield/ha in kgs.

X = N + P + K/ha in kgs.

D = 0, if kharif

= 1, if rabi

Varghese and Yadav (1993) studied inter-tempered growth, instability and acreage response of major oilseeds crops in Rajasthan. The acreage response of mustard was largely determined by one year lagged area and price of mustard during the pre and the post-green revolution period. Over the period the influence of these factors has increased as evidenced by the higher value of the coefficients for these variables in the later period. In the case of groundnut, one year lagged area and one year lagged yield were found to have positive and insignificant influence on area allocation. In the crop of sesamum one year lagged yield of sesamum, one year lagged rainfall and one year lagged yield of bajra (competing crop) were found to have significant response towards area allocation.

Bastine and Palanisami (1994), analysed time series data for twenty five years (1965-66 to 1989-90) on major crops of Kerala viz., rice, tapioca, arecant, pepper, ginger, cashewnut, coffee, tea and rubber.

The model used to measure the contribution of area and productivity towards increasing production of major crops of the state was

$$P = A_0 (Y_n - Y_0) + Y_0(A_n - A_0) + AY$$

Where,

P = Change in production

A_0 = Area in the base year

A_n = Area in the current year

Y_0 = Yield in the base year

Y_n = Yield in the current year

A = Change in area $(A_n - A_0)$

Y = Change in the yield $(Y_n - Y_0)$

The result revealed that the value of the agricultural product per unit of land in Kerala is one of the highest in the country because of diverse crop combination.

Jha (1994) estimated instability in agriculture by coefficient of variation around trend (CV_t) in gross return, yield and farm harvest prices in Kurukshetra district for a period of 19 years (1972-73 to 1990-91). A linear trend was fitted to time series data and wherever the trend was significant the (CV_t) for unadjusted data was multiplied by the square root of the unexplained portion of the variation in the trend equation (Cuddy and Della, 1978). The expression for the same is :

Coefficient of variation around trend

$$(CV_t) = CV \sqrt{1-R^2}$$

The compound growth rates were worked out by using exponential function of the form

$$Y = ab^t$$

on yield prices and gross returns as dependent variable (Y) and time (t) as independent variable.

The study found that instability in gross return and yield largely declined over years. The decline in yield instability in crop viz., paddy and wheat was brought about with increased area under irrigation over years. He also inferred that with new technology, instability in agricultural income reduced with adequate irrigation facilities and consistent price policy.

Patel and Agarwal (1994) studied growth and instability in five major groundnut producing districts of Gujarat. They studied growth rates in area, production and productivity of groundnut. They also examined the extent of instability in production of groundnut and the sources of instability in production of groundnut. Growth rates of area, production and productivity of groundnut for two periods i.e. period I (1960-61) to (1969-70) and period II (1970-71) to (1988-89) we computed using the model :

$$Y_t = \beta_0 \beta_1^T U_t$$

The logarithmic transformation of this

$$\text{Log } Y_t = \text{Log } \beta_0 + T \text{ Log } \beta_1 + \text{Log } U_t$$

compound growth rate (r) is

$$r = (\beta_1 - 1)\, 100$$

Where, Y_t = index numbers of area/ production/ productivity.

T = Time variable in years,

β_0 & β_1 = Parameters to be estimated,

U_t = Error term with usual assumptions.

He found production was not encouraging one, growth rates were negative during both the time periods. He also found that the productivity was mainly responsible for stagnant production and higher magnitude of instability in groundnut production in Gujarat state.

2.3 REVIEWS RELATED TO PERFORMANCE OF RAJASTHAN'S AGRICULTURE:

In this section studies on various aspects of Rajasthan Agriculture are reviewed. Some of these are based on regression models, while other studies reviewed helped in getting proper insight into the development of agriculture of Rajasthan over the years.

Acharya and Agrawal (1976) worked out the supply response of commercial crops in Rajasthan. They included groundnut, sesamum, rapeseed and mustard, linseed, cotton, chillies, potato, sugarcane and tobacco in their study. Price of the crops, price of the competing crop, rainfall and area under high yielding variety programme for foodgrains were included as explanatory variables but had to use relative pice due to problems of multicollinearity. Price variability and yield variability were not taken as factors affecting acreage response. The study showed that the relative price had significant effect on area under oilseed. They used three acreage response models in their study as follows :

Model 1 $A_t = b_0 + b_t P_{t-1} + U_t$

Model 2 $A_t = b_0 + b_1 P_{t-1} + b_2 A_{t-1} + U_t$

Model 3 $A_t = b_0 + b_1 P_{t-1} + b_2 A_{t-1} + b_3 R_t + U_t$

Where, A_t is area, P_t is price and R_t is rainfall in t^{th} year.

Model 1 explained 35 per cent variation in rapeseed and mustard area and relative prices played significant role in area allocation under rapeseed and mustard. Model 2 explained 37 per cent variation in rapeseed and mustard area. Model 3 explained 65 per cent variation in rapeseed and mustard area in area allocation under the crop. Rainfall also showed significant positive role in area allocation under the crop short run elasticities for rapeseed and mustard, sesamum and oil seed was estimated as 1.77, 0.82 and 1.05 respectively.

Sharma and Rathore (1980) projected state-domestic product from agricultural origin as this domestic product at constant (1960-61) prices was considered as an aggregate indicator of agricultural growth in the state of Rajasthan. The projection was made using the following regression model.

$$Y = a + b X_t + CX_{t-1} + d I_A$$

Where, Y is state domestic product (agricultural), a is intercept, b is response coefficient of X_t, c is the response coefficient of X_{t-1} d is response coefficient of I_A, X_t is rainfall in corresponding year, X_{t-1} is rainfall with one year lag and I_A is irrigated (cropped) area.

The irrigated area was projected by fitting quadratic curve and the rainfall was projected by time series analysis, assuming the multiplicative model. The rainfall data did not show any trend. Thus, the cyclic components of the rainfall data were obtained. For this purpose, the periodicity of the cycle was estimated by periodiogram method. The cyclic components corresponding to the observed cycles were estimated by a harmonic analysis. The result revealed that agricultural product, in the state, may have fluctuating pattern in future.

Rathore and Varghese (1981) in their study on farm production in Rajasthan – A regional Analysis followed the agro-climatic regional pattern used by the Ministry of Agriculture, Government of India for the Cost study scheme. Using the farm data for the crop year 1979-80 collected in the centrally sponsored scheme on 'Cost of Cultivation Studies in Rajasthan', it was revealed that the mixed crop area exceeded the single crop area in zone 2 comprising of Barmer, Bikaner and Jaisalmer. The extent of total failure of crops was minimum in the Ganganagar zone. It was also found that the cost of seed exceeded the cost of other material inputs in most of the zones.

Rathore and Varghese (1982), tried to enlist various attempts made to delineate the state of Rajasthan into various agro-climatic regions. The ICAR in 1957 divided the state into four regions on the basis of physical features, crops and climate to investigate into methods and practices in farming. The Ministry of Agriculture, Government of India. In 1969 divided the state into nine agro-climatic regions on the basis of cropping pattern, soils, irrigation, rainfall etc. to implement the study on cost of cultivation studies. The Central Arid Zone Research Institute, Jodhpur, divided the state into five main and ten sub-zones on the basis of climatic factors, availability of water and cropping pattern. In order to study the agricultural credit institutional system in Rajasthan. The Reserve Bank of India in 1974 divided the state into four agro-climatic regions on the basis of physiography climate and soil. In the same year the National Council of Applied Economic Research, New Delhi dileneated the state into three agro-climatic regions on the basis of ecological factors and rainfall, to explain strategies and policies for agricultural and livestock development. In the year 1976, the National Commission on Agriculture (NCA) dileneated the state into eleven rainfall regions on the basis of average rainfall pattern. In the year 1980 ICAR reviewed team for implementing National Agricultural Research Project (NARP) in Rajasthan dileneated the state into five macro and nine micro regions on the basis of physiographic factors, rainfall, soil type, irrigation, cropping pattern etc.

Barla (1989) in his study on constraint to agricultural development in Rajasthan, reported the growth rates in area, production and productivity of cereals, pulses, oil seeds, cotton and sugarcane. The area of cereal crops recorded negative growth during 1967-1976 whereas, the area of pulses and sugarcane recorded negative growth during 1976-85. Similarly, the growth in productivity of pulses was negative during

1967-76 whereas, the growth rate in the productivity of pulses and sugarcane was negative during 1976-85. As far as the production is concerned all the commodities recorded positive growth during 1967-76. However, the growth rates in the production of pulses and sugarcane were negative during 1996-84. According to him, the response to the various doses of the chemical fertilizers will be different due to the diversified agro-climatic situation of the state.

Kalla (1989) in his paper on New Thrust to Agrarian development in Desert suggested short term measures for agricultural development in Rajasthan as (i) appropriate crop choices (ii) tapping of water for immediate consumption (iii) identification of location of general water resources, (iv) development of technologies for water storage and (v) intensive planning for Rabi crop cultivation. The medium and long term measures suggested by him included (i) identification of the causes of draught (ii) application of remote sensoring techniques to locate water resources (iii) development of technologies for arresting desertification and (iv) development of technology for desalinisation of water.

Narula (1989) in his paper on "A note on Agricultural development in Rajasthan observed that the output of rabi crops has shown substantial growth after 1966. It was also pointed out that there has been declination in the growth of rabi output since 1978-79, revealing a plateu in the production of rabi grains from eighties. It was pointed out by him in the exceptionally good years the kharif foodgrains of output was higher than that of rabi foodgrain output. It was further observed that regionally the most important contribution of agriculture has come from the eastern region of the state consisting of Alwar, Bharatpur, Jaipur and Sawai Madhopur. According to him the agricultural growth during fifties and early sixties was made possible because Rajasthan could liquidate gradually the Zagirdari, Zamidari and Biswedari systems and best Khatedari rights in over 42 lakh cultivators. Technological innovation, despite its size neutrality have tended to strenghten the powerful and rich against the vulnerable and the weak in respect of agricultural development in Rajasthan.

Acharya and Varghese (1991) in there study on structure of cost and cost functions in Crop Farming revealed that for wheat and barley there was no change in actual average yield between 1974-75 and 1983-84. But the potential cost minimising level has shifted upward. It was reported that the technological changes have not only pushed up the production possibility frontier but also brought down the minimum possible average cost of production in real terms. For barley crop it was observed that even at the existing level of technology, it was possible to increase the yield per hectare and reduce the cost of production. In the case of mustard, not only that the observed yield increased from 5.7 quintals in 1975-76 to 8.9 quintals in 1983-84, but the yield level at minimum possible cost also increased from 11.5 quintals to 23.7 quintals between these two periods. In the case of bajra the yield at minimum cost on the average cost function showed an upward shift function from 10.8 quintals per hectare in 1978-79 to 23 quintals per hectare in 1983-84.

Sharma and Varghese (1995) in there study on pilot study on cost of cultivation of rabi crops in Rajasthan revealed that the inter-farm yield instability was relatively low in the Flood Prone Eastern Plain of the state and was more under un-irrigated conditions. Mustard crop was identified as having distinct advantage of low input requirement, low cost of production, high profit margin and less yield risk.

Varghese (1999) brought out the disparities in agricultural parameters across agro-climatic regions in Rajasthan. The share of irrigated area to gross cropped area varied from 6.3 per cent in arid western plain to 61.17 per cent in the irrigated north-western plain of the state. The share of forest area to total geographical area according to agro-climatic regions revealed that the forest cover varied from 0.63 per cent in the arid western plain to 23.86 per cent in the humid south eastern plain. Similarly, the share of culturable waste land to the geographical area of the zones ranged from 0.89 per cent in the Transitional Plain of the Inland Drainage to 48.14 per cent in the Hyper-Arid Partially Irrigated Western Plain. Large inter-regional disparities in the share of net sown area to geographical area was also reported since it varied from 27.39 per cent in the Sub-Humid Southern Hills and Aravali Hills to 77.56 per cent in irrigated North Western Plain.

3. MATERIALS AND METHODS

The present study is focussed on the assessment of inter-regional performance of agriculture in Rajasthan using regression models. The temporal dimension and spatial coverage of the study and the analytical techniques used to achieve the stipulated objectives are spelt out in the forthcoming sections.

3.1 SPATIAL COVERAGE :

The agro-climatic regions delineated by the National Agricultural Research Project (NARP) during early eighties has been considered for the inter-regional analysis of the present study. For all purposes related to technological evaluation in agriculture and its transfer, these zones are currently used in the state. In fact, the location specific agricultural development strategy are divised and implemented according to these zones in the state. Based on land quality, geographical situation, cropping pattern, irrigation, moisture availability and other climatic factors there are five macro regions, four of which are further divided into two micro-regions each, making a total of nine agro-climatic regions in the state. For the purpose of the current study only the five macro regions have been considered. More details of the agro-climatic zones of the state are given in Table No. 3.1 and the geographical coverage of these zones could be seen from Fig. 1.

In order to make the study representative for these regions, one district each was selected from each of these macro regions. While selecting the districts it was kept in mind that the selected district is the true representation of the concerned agroclimatic region. Besides the non-bifurcation of the selected district to make newer districts over the years and also coverage of the whole district in a particular zone were

Fig. 1. Agro-Climatic Zones of Rajasthan

Table 3.1 : Geographical coverage and main features of agro-climatic zones

S. No.	Name of zone	Districts covered	Geo area ('000 ha)	% share to state	% share of gross irr. area to gross cropped area	Main crops	Normal rainfall (mm)
1.	Arid western plain (IA)	Barmer, part of Jodhpur, Bikaner, Jaisalmer & part of Churu	12367	36.13	6.78	Bajra, kharif pulses, guar	< 300
2.	Irrigated north western plain (IB)	Ganganagar & Hanumangarh	2063	6.03	61.17	Cotton, gram, wheat, rapeseed & mustard, guar	< 350
3.	Transitional plain of inland drainage (IIA)	Nagaur, Sikar, Jhunjhunu & part of Churu	3692	10.78	16.65	Bajra, guar, kharif pulses and gram	300 – 500
4.	Transitional plain of Luni Basin (IIA)	Jalore, Pali and part of Sirohi and Jodhpur	3014	8.80	33.70	Bajra, rapeseed & mustard, wheat, kharif pulses, sesamum, Jowar, guar, Spices, gram	300 – 500
5.	Semi-arid eastern plain (IIIA)	Ajmer, jaipur, Tonk & Dausa	3007	8.78	33.82	Rapeseed & mustard, wheat, bajra, jowar, gram & kharif pulses	500 – 650
6.	Flood prone Eastern plain (IIIB)	Alwar, Bharatpur, Dholpur & part of Sawai Madhopur	2331	6.81	40.69	Rapeseed & mustard, wheat, bajra, gram	500 – 650
7.	Sub-humid southern plain and Aravalli hills (IVA)	Bhilwara, Rajsamand and part of Chittorgarh, Udaipur and Sirohi	3209	9.37	38.07	Maize, wheat, gram, K.pulses, Jowar, rapeseed & mustard, groundnut, soyabean, barley	500 – 900
8.	Humid southern plain (IV B)	Banswara, Dungarpur & part of Chittorgarh & Udaipur	1878	5.48	27.50	Maize, wheat, Kharif pulses, rice, gram, soyabean, groundnut	700-1000
9.	Humid south eastern plain (V)	Bundi, Kota, Baran, Jhalawar and part of Sawai Madhopur	2682	7.83	46.94	Rapeseed & mustard, soyabean, wheat, spices, gram, maize and jowar	650-1000

ensured so that the time-series data for the selected districts are available for the entire time period. The brief particulars of the selected districts are given in Table 3.2.

Table 3.2 : The situational details of the selected districts

Zone	Name of district	Major crops	Climatic condition	Broad crop seasons	Source of irrigation	Extent of irrigated sown area
I	Barmer	Bajra (52.38%), Moth (21.71%), Guar (20.53%)	Arid	Kharif mono-cropped	Rainfed	4.55
II	Jhunjhunu	Bajra (40.3%), Moong (7.6%), Guar (7.0%), wheat (7.3%), Gram (7.4%), Rapeseed & mustard (16.1%)	Arid	Kharif and rabi crops	Rainfed and well irrigated	35.59
III	Alwar	Bajra (22.3%), wheat (20.5%), gtram (9.7%), rape seeds & mustard (31.9%)	Semi arid	Rabi and kharif crops	Well irrigated and rainfed	73.50
IV	Bhilwara	Maize (28.8%), wheat (24.2%), gram (9.4%)	Sub humid	Kharif and rabi crops	Rainfed and well irrigated	53.50
V	Bundi	Paddy (6.2%), maize (8.1%), soybean (11.9%), wheat (31.7%), rape seed & mustard (18.5%)	Humid	Rabi and kharif crops	Canal irrigated and well irrigated	74.86

Figures in parenthesis are percentage of area under crops to gross cropped area in the respective districts

3.2 TEMPORAL COVERAGE :

The regular time series data on various facets of agriculture are available from the year 1956-57 in Rajasthan. Over the years major milestones like green-revolution introduced for enhanced production of agricultural commodities made break-through in the performance of state agriculture. Therefore, the analysis of data for specific temporal phases was considered more meaningful. Three temporal phases ear-marked for the present study are as under :

1) Temporal phase First (TP_1) – 1956-57 to 1966-67
2) Temporal phase Second (TP_2) – 1967-68 to 1980-81
3) Temporal phase Third (TP_3) – 1981-82 to 1996-97

3.3 STUDY PARAMETERS :

Looking to the resources available to the researcher and the time constraint, it was felt necessary to confine the study to the selected parameters. One most important kharif and one rabi crop of each of the selected district were identified to assess the pattern of trend and other performance indicators area, production and productivity of these crops. For Barmer district in zone I, only bajra crop (kharif crop) was selected, since the area under rabi crop in this district was very meagre. For Jhunjhunu district in zone II, bajra in kharif, rape seed and mustard in rabi were selected. For Alwar district in zone III, bajra and mustard were selected. For Bhilwara in zone IV and Bundi in zone V, maize in kharif and wheat in rabi were selected. In Bundi Soyabean was the kharif crop with maximum area. But the data was available only for the last 10-12 years only. Hence maize crop was selected. Besides the data of all the nine land use classes were considered for the three temporal phases.

3.4 DATA AND ITS SOURCES :

The study is mostly based on secondary data and these data were collected from various published/ secondary sources. The sources of published data include (i) Statistical Abstracts of Rajasthan (published by Directorate of Economics and Statistics, Jaipur, (ii) The Agricultural situation in India (Published by Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India, New Delhi, (iii) Fertilizer Statistics, (Published by Fertilizer Association of India, New Delhi), (iv) District wise trends of Agricultural production (Published by Department of Agriculture, Govt. of Rajasthan, Jaipur), (v) Rainfall in Rajasthan (Directorate of Agriculture, Pant Krishi Bhavan, Rajasthan, (vi) Trends in Land use Statistics (Directorate of Agriculture, Rajasthan), (vii) Vital Agriculture Statistics (Directorate of Agriculture, Rajasthan, Jaipur). Besides, the farm level data of the centrally sponsored scheme on the cost of cultivation of principal crops in Rajasthan were also used for the present study.

3.5 ANALYTICAL TOOLS AND TECHNIQUES :

The present study is an attempt to ascertain as how the regression analysis can be used to assess the performance of agriculture in different agro-climatic situations of the state. The regression analysis has been used for the purposes as outlined below :

3.5.1 Assessment of the Pattern of Trend of Agricultural Parameters:

As a result of various policy decisions and other measures taken for the agricultural development in the past, the agricultural parameters like area, production and productivity of crops, land use pattern etc. are expected to form varying trend pattern of types such as linear, quadratic, cubic, exponential etc. In other words, the time series data on these parameters can be fitted into regression equations of the following type :

i)	$Y_t = b_0 + b_1 t$	(Linear)	(3.1)
ii)	$Y_t = b_0 t^{b_1}$	(Power)	(3.2)
iii)	$Y_t = b_0 b_1^t$	(Compound)	(3.3)
iv)	$Y_t = b_0 e^{b_1 t}$	(Exponential)	(3.4)
v)	$Y_t = b_0 + b_1 \ln(t)$	(Logarithmic)	(3.5)
vi)	$Y_t = b_0 + b_1 t + b_2 t^2$	(Quadratic)	(3.6)
vii)	$Y_t = b_0 + b_1 t + b_2 t^2 + b_3 t^3$	(Cubic)	(3.7)
viii)	$Y_t = b_0 + b_1 / t$	(Inverse)	(3.8)
ix)	$Y_t = e^{(b_0 + b_1 / t)}$	(S model)	(3.9)

3.5.2 Study on the Growth Rates of Agricultural Parameters :

Often compound growth rates which provide the rate at which the values are increased/ decreased at exponential fashion are used to assess the rate and direction of change of agricultural parameters.

The compound growth rate is derived from the exponential trend equation of the form

$$Y_t = a\, b^t$$

Where, $b = 1 + r$

r = Compound growth rate

3.5.3 Measurement of the Extent of Instability in Agriculture :

The element of risk or instability in agriculture may not be uniform for different regions. Therefore, some index for assessing the areas of more instability or less instability can be a matter of great concern when policy decisions for crop production are taken. There exists one such measure of instability using regression analysis. One of the commonly used measure of indices of instability is the method devised by Cuddy and Della i.e.,

$$\text{Instability index} = CV \times \sqrt{(1-R^2)}$$

where the value of R^2 is obtained from the linear trend equation (wherever it is significant) estimated for the parameter. Evidently estimation of trend equation is a part of regression analysis.

3.5.4 Prediction of Stability/ Instability :

The prediction of growth and instability is also important assuming that the climatic, environmental, technological and physical factors which existed in the past can continue to operate in the same fashion.

In order to ascertain the nature of growth and instability, the method used by Alok Bandopadhyay (1989) was tried. According to this method, wherever the trend line $Y = a + bt$ is statistically significant, the data corresponding to positive and negative deviations from the trend line can be sorted out. Two separate linear trend equations viz.,

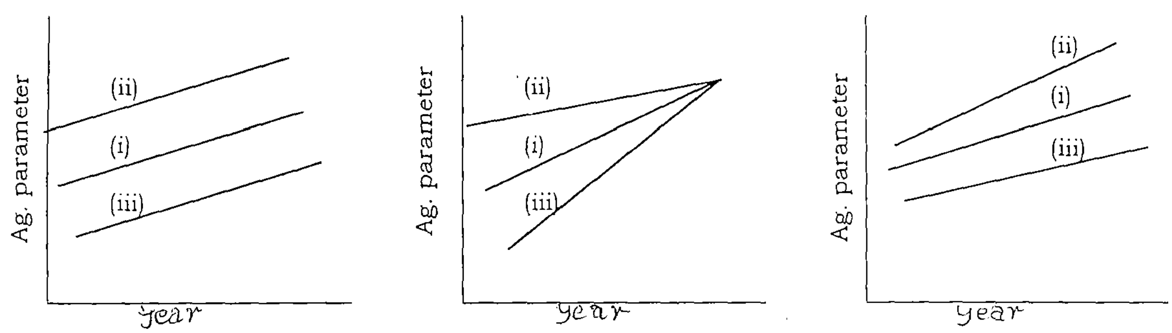
$$Y_t^+ = a^+ + b^+t \quad (3.10)$$

and $$Y_t^- = a^- + b^-t \quad (3.11)$$

can be estimated using data corresponding to positive and negative deviations separately. Here it is assumed that the positive deviation of yield data from trend line is due to the joint effect of a set of factors responsible for setting the observation at a higher level. Similarly, for the negative deviation also, another set of situation would have persisted.

There are three mutually exclusive possibilities for the nature of the trend lines corresponding to positive and negative deviation data as shown in Fig. (2) i.e. (i) corresponds to the situation where both the positive and negative deviation lines are parallel, (ii) corresponds to the situation where both the lines are convergent (iii) corresponds to the situation where both the lines are divergent. The year corresponding to the point of intersection of the trend lines representing positive and negative errors can be obtained. If $t_y > 0$, then the trend lines representing positive and negative errors were expected to converge in the positive quadrant, which means that the situation will stabilize in the years to come.

Fig. 2 : Nature of deviation trend lines of agricultural parameters



Case(1) Deviation lines parallel Case(2) Deviation lines converge Case(3) Deviation lines diverge

If $t_y < 0$, then the trend lines representing positive and negative errors are expected to diverge in the positive quadrant, which means that the situation will further instabilize in the years to come.

The hypothesis that the positive and negative trend lines are parallel to each other can be tested using the F-statistic where

$$F = \frac{(R_y - R_y^+ - R_y^-) \;/\; [(n-k-1) - (n - 2k)]}{(R_y^+ - R_y^-) \;/\; (n - 2k)}$$

which follows F distribution with n-k-1, n-2k degrees of freedom.

Where,

n = Number of observations

k = Number of parameters estimated

R_y = Residual sum of squares

R_y^+ = Residual sum of squares for the positive deviation set of data

R_y^- = Residual sum of squares for the negative deviation set of data

3.5.5 Acreage Response Functions for Crops :

Farmers response to the changes in prices in developing countries has been a topic of importance for research workers. The methodology used in such studies has undergone changes over time. Initially, researchers used one year lagged price as an explanatory variable in acreage response functions. Mark Nerlove in 1956 hypothesised that farmers react more on expected prices rather than last year's price and he introduced the concept of price expectation. The Nerlovian price expectation model later on was modified by incorporating more explanatory variables in the acreage response function. Such functions throw light on the performance of agricultural production through area, yield and other factors. The details of basic model by Nerlove on acreage as a function of price expectation is outlined below :

The outline of this model is on the following lines.

$$A_t = a + b\,P_t^* + Ut \qquad (3.12)$$

and $P^*_t = P^*_{t-1} + \gamma\,(P_{t-1} - P^*_{t-1}),\ 0 < \alpha < 1$

or $P^*_t - P^*_{t-1} = \gamma\,(P_{t-1} - P^*_{t-1}) \qquad (3.13)$

LHS is revision in price expectation

RHS is the error made in prediction during t-1 year.

Where,

At = Actual acreage under the crop in year t.

P^*_t = Expected price of the crop in year t

P^*_{t-1} = Expected price of the crop in year t-1.

γ = It indicates that only a fraction of last year error in price prediction is translated to this year 't'.

U_t = The error term.

a & b are parameters to be estimated.

Therefore,

$$P^*t = \gamma\, Pt-1 + (1-\gamma)\, P^*t-1$$

$$P^*_{t-1} = \gamma\, P_{t-2} + (1-\gamma)\, P^*_{t-2}$$

$$P^*_{t-2} = \gamma\, P_{t-3} + (1-\gamma)\, P^*_{t-3}$$

$$\therefore \quad P^*_t = \gamma\, P_{t-1} + (1-\gamma)\, [\gamma\, P_{t-2} + (1-\gamma)\, P^*_{t-2}]$$

$$= \gamma\, P_{t-1} + \gamma(1-\gamma)\, P_{t-2} + (1-\gamma)^2\, P^*_{t-2}$$

$$= \gamma\, P_{t-1} + \gamma(1-\gamma)\, P_{t-2} + (1-\gamma)^2\, [\gamma\, P_{t-3} + (1-\gamma)^3\, P^*_{t-3}]$$

$$= \gamma\, P_{t-1} + \gamma(1-\gamma)\, P_{t-2} + \gamma(1-\gamma)^2\, [\gamma\, P_{t-3} + (1-\gamma)^3\, P^*_{t-3}] + \ldots$$

$$= \gamma\, P_{t-1} + \gamma(1-\gamma)\, P_{t-2} + \gamma(1-\gamma)^2\, P_{t-3} + \ldots$$

There are three unknown parameters a, b & γ to be estimated. From equation (3.12) and (3.13) a, b & γ can be obtained.

By equation 3.12,

$$A_{t-1} = a + b\, P^*_{t-1} + U_{t-1} \qquad (3.14)$$

$$\therefore \quad P^*_{t-1} = (1/b)\, A_{t-1} - (a/b) - (1/b)\, U_{t-1} \qquad (3.15)$$

Subtracting equation 3.14 from equation 3.12,

$$A_t - A_{t-1} = b(P^*_t - P^*_{t-1}) + U_t - U_{t-1} \qquad (3.16)$$

Substituting equation (3.13) in equation (3.16),

$$A_t - A_{t-1} = b[\gamma(P_{t-1} - P^*_{t-1})] + U_t - U_{t-1} \qquad (3.17)$$

Substituting equation 3.15 in equation 3.17,

$$A_t - A_{t-1} = b[\gamma\{P_{t-1} - ((1/b)A_{t-1} - (a/b) - (1/b)U_{t-1})\}] + U_t - U_{t-1}$$

$$= b[\gamma P_{t-1} - (\gamma/b)A_{t-1} + (a\gamma/b) - (\gamma/b)U_{t-1}] + U_t - U_{t-1}$$

$$= b\gamma P_{t-1} - \gamma A_{t-1} + a\gamma + \gamma U_{t-1} + U_t - U_{t-1}$$

$$= a\gamma + b\gamma P_{t-1} - \gamma A_{t-1} + [U_t - (1-\gamma)\, U_{t-1}]$$

i.e. $A_t = a\gamma + b\gamma P_{t-1} + (1-\gamma)A_{t-1} + [U_t - (1-\gamma)\, U_{t-1}]$

Let $\beta_0 = a\gamma$, $\beta_1 = b\gamma$, $\beta_2 = 1-\gamma$ and $K_t = U_t - (1-\gamma)\, U_{t-1}$

Thus,

$$A_t = \beta_0 + \beta_1 P_{t-1} + \beta_2 A_{t-1} + K_t \qquad (3.18)$$

As, $\beta_0 = a\gamma$, $\beta_1 = b\gamma$

$\beta_2 = 1 - \gamma$ or $\gamma = 1 - \beta_2$

$\therefore$ $\beta_0 = a(1-\beta_2)$

and $\beta_1 = b(1-\beta_2)$

The estimated values of γ, a and b are

$$\gamma = 1 - \beta_2$$

$$a = \frac{\beta_0}{1-\beta_2}$$

$$b = \frac{\beta_1}{1-\beta_2}$$

Many researchers have used the modified versions of adjustment lag model. They used many variables like yield, relative yield, rainfall, price, variability in price and yield etc. The modified Nerlovian acreage adjustment model is generally expressed as follows :

$$A^*_t = a + b\, P_{t-1} + U_t \qquad (3.19)$$

$$A_t - A_{t-1} = \eta\, (A^*_t - A_{t-1}) \qquad (3.20)$$

Where,

A^*_t = Desired acreage under the crop in year t

A_t = Actual acreage under the crop in year t

A_{t-1} = Actual acreage under the crop in year t-1

U_t = Disturbance term

η = Coefficient of adjustment, and a and b are parameters to be estimated.

Substituting (3.19) in (3.20),

$$A_t - A_{t-1} = \eta\,(a + bP_{t-1} + U_t) - \eta\, A_{t-1} \qquad (3.21)$$

$$A_t = a\,\eta + b\,\eta\, P_{t-1} + (1 - \eta)\, A_{t-1} + \eta\, U_t \qquad (3.22)$$

If $\beta_0 = a\eta$, $\beta_1 = b\eta$, $\beta_2 = 1\text{-}\eta$ and $K_t = \eta U_t$

then,

$$A_t = \beta_0 + \beta_1\, P_{t-1} + \beta_2\, A_{t-1} + K_t \qquad (3.23)$$

which is same except for the disturbance term.

Modification of the Acreage Response Function for the Present Study:

Farmer's decision to allocate acreage under a particular crop (pulses, cereals, oilseeds etc.) depends on a number of factors. Some of them are (i) lagged acreage under the crop, (ii) lagged price of selected crops, (iii) lagged price of competing crops, (iv) relative price of selected crops, (v) lagged yield of selected crops, (vi) lagged yield of competing crops, (vii) lagged relative yield of selected crops, (viii) current year rainfall, (ix) previous years rainfall, (x) total irrigated area in current year, (xi) variability in previous years yield of the concerned crop and (xii) variability in previous years prices of the concerned crop.

Competing crops were selected on the basis of correlation coefficient i.e. crops having highest negative correlation coefficient with the area under selected crop in the selected district was treated as the competing crop. Explanatory variables included in the model are given below :

A_{t-1} = One year lagged area of the selected crop.

P_{t-1} = One year lagged price of the selected crop.

Pc_{t-1} = One year lagged price of the net competing crop.

Pr_{t-1} = Ratio of lagged farm harvest price of selected crop to lagged farm harvest price of competing crop.

Y_{t-1} = One year lagged yield of the selected crop.

Yc_{t-1} = One year lagged yield of the next competing crop.

Yr_{t-1} = Ratio of lagged yield of selected crop to competing crop.

R_t = Rainfall in the current year (t^{th} year).

R_{t-1} = One year lagged rainfall.

I_t = Total irrigated area in current year (t^{th} year).

Sp_{t-1} = Standard deviation of prices for the preceding three years.

Sy_{t-1} = Standard deviation of yield for the preceding thee years.

Definition and Justification of the Explanatory Variables :

One year lagged price (P_{t-1}) :

The farm harvest price was used because the bulk of the crop output is marketed soon after the harvest. Farm harvest price is the average wholesale price at which the commodity is disposed of by the producers to the traders in the village site during the specified harvest period. The farm harvest price provide the approximate price realised by the farmers. One year lagged farm harvest price was included as an explanatory variable for A_t as acreage decisions are expected to be governed by the price level of the crop during previous year. A positive coefficient is expected for this variable

One year lagged price of competing crop (Pc_{t-1}) :

In this one year lagged farm harvest price was used which is based on the above logic. It is likely that the prices of competing crop effects inversely the acreage decision of farmers for a particular crop. A negative sign is expected for the coefficient of this variable.

Relative lagged price (Pr_{t-1}) :

The ratio of lagged farm harvest price of selected crop to lagged farm harvest price of the competing crop is known as relative lagged price. The impact of price on acreage allocation cannot the judged by absolute prices of that particular crop. So it becomes logical to include relative price which is the ratio of lagged price of the selected crop to that of competing crop.

$$\text{i.e.} \quad Prt\text{-}1 = \frac{P_{t-1}}{Pc_{t-1}}$$

A positive sign is expected for this variable in the model.

Variability in lagged price (Sp_{t-1}) :

To capture the influence of risk aversion attitude of the farmers, variability in prices was included in the model. Variability was measured as the standard deviation of absolute prices of preceding three years of the crop. As perceived by other researchers, logic behind inclusion of past three years price in the calculation of standard deviation was that the farmers do not look more longer past than previous three years for fluctuations in prices.

One year lagged yield (Y_{t-1}) :

It is one of the important non-price factor which affects decrease or increase in area under the crop. Average yield of a crop lagged by one year is obtained by dividing total production by area under the crop in that year. A positive correlation is expected between current year acreage A_t and Y_{t-1}. Studies have shown that one year lagged average yield provided a reasonable affects towards acreage allocation.

One year lagged yield of competing crop (Yc_{t-1}) :

Average yield of the competing crop lagged by one year is also an important non-price factor which affects acreage allocation decision of farmers. Between current year acreage and Yc_{t-1}, a negative correlation is expected.

Relative lagged yield (Yr_{t-1}) :

One year lagged relative yield of the crop was used to find the effect of acreage under a crop. It was obtained as ratio of one year lagged yield of a selected crop to one year lagged yield of the competing crop.

Variability in yield (Sy_{t-1}) :

Variability in yield represents the yield risk of the farmers. It is calculated as the standard deviation of yield for preceding three years. The logic for using three years was that the farmers do not consider more longer past than three years fluctuation in yield.

Rainfall (R_t) :

In the acreage decision of farmers weather plays a major role in rainfed areas. The annual rainfall of that agricultural year is used as a variable for estimating the acreage response function.

Lagged rainfall (R_{t-1}) :

The previous years rainfall supplements the current year irrigation facilities so it is expected to influence the acreage response of the farmers, particularly in well irrigated areas.

Irrigation (I_t) :

The irrigation factor is expected to have positive effect on both yield and area for most of the crops. Therefore, an attempt has been made to assess the impact of irrigation on the area under crops. Here, the total irrigated area which stands for the irrigation potential of that year was considered as an explanatory variables to decide on the current year acreage under the crop.

Hence the acreage adjustment model taking into considerations all possible factors can be written as :

$$A^*_t = a + b_1 P_{t-1} + b_2 Pc_{t-1} + b_3 Pr_{t-1} + b_4 Y_{t-1} + b_5 Yc_{t-1} + b_6 Yr_{t-1} + b_7 R_t + b_8 R_{t-1} + b_9 I_t + b_{10} Sp_{t-1} + b_{11} Sy_{t-1} \quad (3.24)$$

$$A_t - A_{t-1} = \eta (A^*_t - A_{t-1}) \quad (3.25)$$

$$A_t = \beta_0 + \beta_1 A_{t-1} + \beta_2 P_{t-1} + \beta_3 Pc_{t-1} + \beta_4 Pr_{t-1} + \beta_5 Y_{t-1} + \beta_6 Yc_{t-1} + \beta_7 Yr_{t-1} + \beta_8 R_t + \beta_9 R_{t-1} + \beta_{10} I_t + \beta_{11} Sp_{t-1} + \beta_{12} Sy_{t-1} \quad (3.26)$$

Where,

$\beta_0 = a\eta$ $\beta_1 = 1 - \eta$ $\beta_2 = b_1 \eta$ $\beta_3 = b_2 \eta$

$\beta_4 = b_3 \eta$ $\beta_5 = b_4 \eta$ $\beta_6 = b_5 \eta$ $\beta_7 = b_6 \eta$

$\beta_8 = b_7 \eta$ $\beta_9 = b_8 \eta$ $\beta_{10} = b_9 \eta$ $\beta_{11} = b_{10} \eta$

$\beta_{12} = b_{11} \eta$

Multiple linear regression function was fitted for estimating the coefficient of acreage response functions for selected crops for the period 1981-82 to 1996-97 for each of the district selected from each regions of the state. One important kharif crop and one rabi crop were taken but in case of Barmer only kharif crop bajra was taken. In some of the cases, the actual competing crops for kharif crops turned out to be rabi crops and that for rabi crops turned out to be kharif crops. This happens in mono-cropped situation where farmers can take either a kharif crop or a rabi crop, but not both. The major crops selected and also the competing crops in each of the selected districts are as under :

District	Selected crop	Competing crop
Barmer	Bajra	Sesamum
Jhunjhunu	Bajra	Rape Seed and Mustard
	Rape Seed and Mustard	Bajra
Alwar	Bajra	Rape Seed and Mustard
	Rape Seed and Mustard	Gram
Bhilwara	Maize	Jowar
	Wheat	Jowar
Bundi	Maize	Wheat
	Wheat	Maize

Elasticities from estimated acreage response function :

By definition, elasticity of y w.r.t. x when y = f(x) is given by,

$$e_{yx} = \frac{\%\text{ change in y}}{\%\text{ change in x}}$$

$$= \frac{\Delta y/y}{\Delta x/x}$$

$$= \frac{\Delta y}{\Delta x} \cdot \frac{x}{y}$$

$$= \frac{\Delta y/\Delta x}{y/x}$$

If the relationship between X and Y is

$$Y_i = b_0 + b_1 X_i + \varepsilon_i$$

then the estimated function

$$\hat{Y}_i = \hat{b}_0 + \hat{b}_1 X_i$$

is the equation of a line whose intercept is $\hat{b}_0$ and slope is $\hat{b}_1$. The coefficient $\hat{b}_1$ is the derivative of Y with respect to X. Therefore,

$$b_1 = \frac{dY}{dx}$$

is the rate of change in Y as X changes by a very small amount. The elasticity is defined by the expression

$$e_{yx} = \frac{dY/dX}{Y/X} \qquad (3.27)$$

Where,

e_{yx} = elasticity

Y = value of dependant variable

X = value of independent variable

The elasticity coefficient can be calculated as

$$e_{yx} = b_1 \cdot \frac{\overline{X}}{\overline{Y}} \qquad (3.28)$$

Where,

$\overline{X}$ = Average value of independent variable

$\overline{Y}$ = Average value of dependent variable

On similar lines elasticities can be calculated from the multiple linear regression model,

$$e_{yxi} = b_1 \frac{\overline{X}_i}{\overline{Y}}$$

3.5.6 Average Cost Function for crops:

Average cost function theoretically takes a U-shaped form (Quadratic) i.e. cost is a function of output in Quadratic form. Using the farm level data available in the cost study scheme quadratic functions of the form

$$C = \beta_0 + \beta_1 Q + \beta_2 Q^2 + \varepsilon \qquad (3.29)$$

was attempted to estimate the average cost function for the selected crops, when

C = Cost of production/ quintal (Rs/Qtls)

Q = Main output (grain) of the crop/ hectare (Qts/ha)

The minimum of the average cost curve gives the yield level at which the curve changes the curvature and the yield level achievable at minimum average cost. It was obtained by using the mathematical condition for minimum of a function.

i.e. if $y = f(x)$ minimum is at $dy/dx = 0$

3.5.7 Production Function for Crops :

Using the farm level data collected in the centrally sponsored cost of cultivation studies in Rajasthan, multiple linear and multiplicative type (Cobb-Douglas type) of regression models were estimated. The models used are as follows :

$$Q = b_0 + b_1 X_1 + b_2 X_2 + \ldots + b_k X_k + \varepsilon \qquad (3.30)$$

and $$Q = \beta_0 X_1^{\beta_2} X_2^{\beta_3} \ldots\ldots X_k^{\beta_k} . \varepsilon \qquad (3.31)$$

Where,

Q = the output/ hectare (Qtls/ha)

X_1 = Seed/ per hectare (kg/ha)

X_2 = Fertilizer/ hectare (kg/ha)

X_3 = Human labour hours/ hectare (hrs/ha)

X_4 = Bullock labour hours/ hectare (hrs/ha)

X_5 = Cost of irrigation/ hectare (Rs/ha).

$$b_i\text{'s} = \frac{\delta Q}{\delta X_i}$$ (i.e. rate of change in output due to unit change in X_i)

$$\beta_i\text{'s} = \frac{\delta Q}{\delta X_i} \times \frac{X_i}{Q}$$ (i.e. elasticity coefficient of Q w.r.t. X_i)

In fact equation no. (3.28) takes the additive form of the model when log values are taken for Q and X_i's.

3.5.8 Fertilizer Response Function :

Using the farm level data efforts were made to estimate the fertilizer response function as a quadratic function taking yield as dependent variable and fertilizer doses as predictor variable. The functional form is as under

$$Q = b_0 + b_1 F + b_2 F^2 + \varepsilon \qquad (3.32)$$

Here, an inverted U-shaped curve is theoretically presumed. Wherever such estimated functions are statistically significant, the optimum fertilizer dose for the maximum yield can be worked out using the mathematical condition that the first order derivative of the function is zero for the maximum point of the curve.

i.e. $$\frac{\delta Q}{\delta F} = 0$$

i.e. $$b_1 + 2\, b_2\, F = 0$$

$$F = \frac{-\, b_1}{2\, b_2}$$

gives the optimum output level of fertilizer.

3.5.9 Best Fit of the Estimated Models :

Draper and Smith had suggested various methods for selecting the best regression equation and also the number of explanatory variables in a model. They admit that there is no unique statistical procedure for achieving the goal and personnel judgement will be necessary. Out of the ten procedures advocated by them, the approaches like all possible regressions in trend analysis of agricultural parameters and backward elimination method for acreage response function were used in the present study. Besides, *a prior econometric criteria* like sign and size of the coefficients and statistical criteria like t-test for individual coefficient, F-test for overall significance of regression estimates and the value of coefficient (R^2) were considered in assessing the goodness of fit of regression on the lines suggested Koutsoyiannis and others.

3.5.10 The Equality of Estimated Coefficients of Linear Equations Obtained from Different Samples/ Situations :

Since in most of the cases area, production and yield of same crop in two districts were assessed for the same temporal phases, corresponding estimated relationships were obtained. Wherever both the relationships were linear, Chow's test of the following type on the lines suggested by Koutsoyiannis was conducted to test the significance of the coefficients between the districts.

The Chow's test is given by

$$F_{(k, n_1 + n_2 - 2k)} = \frac{[\Sigma e_p^2 - (\Sigma e_1^2 + \Sigma e_2^2)]/k}{(\Sigma e_1^2 + \Sigma e_2^2)/(n_1 + n_2 - 2k)}$$

where,

Σe_1^2 = error sum of squares for first sample

Σe_2^2 = error sum of squares for second sample

Σe_p^2 = error sum of squares for pooled sample

The observed F ratio is compared with the tabulated value of F with k and $(n_1 + n_2 - 2k)$ degrees of freedom.

3.5.11 Violation of Assumptions of Error Term and Remedial Measures :

The various models used for the analysis to assess the inter-regional performance of agriculture in Rajasthan assumed as in the case of other regression models, that the total variation in the dependent variable is split into two parts, i.e.

(1) the systematic variation or explained variation.

(2) the random variation or the unexplained variation.

i.e. the simple regression model takes the form

$$\underbrace{Y_i}_{\text{total variation}} = \underbrace{b_0 + b_1 X_i}_{\text{Explained variation}} + \underbrace{\varepsilon_i}_{\text{Unexplained variation}}$$

The general regression model with k explanatory variable is written as

$$\underbrace{Y_i}_{\text{total variation}} = b_0 \underbrace{+ b_1 X_{1i} + b_2 X_{2i} + \ldots + b_k X_{ki}}_{\text{Explained variation}} + \underbrace{\varepsilon_i}_{\text{Unexplained variation}}$$

In both the cases, the parameters are estimated using OLS method i.e. by minimising $\Sigma\varepsilon_i^2$. The assumptions in the above case include

(i) r_{xixj} (Correlation between explanatory variables) is not very high (in the case of multiple regression model).

(ii) Var (ε_i) = σ^2 (constant)

(iii) Cov ($\varepsilon_i \varepsilon_j$) = 0 for $i \neq j$ (serial independence of error).

The violation of assumption (i) poses the problem of multicollinearity, that for (ii) poses the problem of heteroscedasticity and that for (iii) poses the problem of auto correlation.

Detection and remedial measures of the problems

The assumption of constant variance of the error term was presumed valid for all the models as is being done by most of the researchers in view of the complexities of the remedial measures as it involves the transformation of the entire model.

The problem of multi-collinearity in the acreage response and production function models was detected through Klein's criteria by comparing $r_{x_ix_j}$ with $R^2_{y.x_1 x_2 \ldots x_k}$. The cases where $r^2_{x_ix_j} > R^2_{y.x_1 x_2 \ldots x_k}$ were treated as problem cases. The deletion of unimportant variables being possible through backward elimination was treated as the solution. The finally retained models were further checked for presence of multicollinearity between retained variables.

In the multiple regression models, the Durbin-Watson statistics was used to detect the problem. The problem of auto-correlation in the trend models was assessed by working out the correlation between ε_t and ε_{t-1} after getting the values of ε_t's as

$$\varepsilon_t = Y_t - \hat{Y}_t \qquad \text{(observed – estimated value)}$$

First order auto-correlation coefficient

$$\rho_{\varepsilon_t \varepsilon_{t-1}} = \frac{\Sigma \varepsilon_t \, \varepsilon_{t-1}}{\sqrt{\Sigma \varepsilon^2_t} \, . \, \sqrt{\Sigma \varepsilon^2_{t-1}}}$$

The transformation of variable/ respecification of the model is the remedy for auto-correlation. Since a number of transformed cases in the trend models were tried and those models which emerged with statistically significant coefficients were retained, the problem of auto-correlation was resolved.

4. RESULTS AND DISCUSSION

Spatial Spread :

The main theme of the present study is to assess the temporal and spatial performance of agricultural parameters in Rajasthan using regression analysis as a scientific technique. In a state like Rajasthan where agricultural activities are taken up under agro-climatically heterogenous situations, it is not only necessary but also meaningful to make such an assessment on regional basis. For the purpose of generating agricultural technologies and its dissemination, the state of Rajasthan is delineated into five macro agro-climatic regions, out of which four are divided into two micro regions each, making a total of nine micro regions. However, for the purpose of the current study only the five macro regions were taken into consideration.

In order to capture the spatial heterogenity, one district each was selected from each of the macro-agroclimatic regions, these are as under:

Macro Region	Selected District
I	Barmer
II	Jhunjhunu
III	Alwar
IV	Bhilwara
V	Bundi

While selecting the districts, the continuity of the district without any division into newer or districts and coverage of whole district in a particular zone were ensured. More details about the zones and the selected districts are given in chapter 3.

Temporal Dimensions :

Apart from the agricultural technologies, the other major aspect which influence the performance of agriculture is the policy interventions from time to time at government level for the development of agriculture. Even the technological intervention in agriculture corresponds to specific temporal phases. It is therefore necessary to make the assessment according to temporal phases. Three such phases have been identified as a part of methodology for the current study.

Phase I - Pre green revolution period (1956-1966).

Phase II - Post green revolution period (1967-1980).

Phase III - Recent period (1981-1997).

Agricultural Performance Indicators :

There are a large number of agricultural parameters corresponding to various agricultural aspects. However, keeping the limitations of the resources and time with the researcher only selected number of agricultural parameters were considered for its performance over time and across regions. The identified parameters are given in table 4.1.

Table 4.1 : Selected agricultural parameters in selected districts

Zone	Selected district	Selected crops	Identified agricultural parameters
	Barmer	Bajra	Area, production, yield and land use statistics
	Jhunjhunu	Bajra, rapeseed & mustard	Area, production, yield and land use statistics
	Alwar	Bajra, rapeseed & mustard	Area, production, yield and land use statistics
	Bhilwara	Maize, wheat	Area, production, yield and land use statistics
	Bundi	Maize, wheat	Area, production, yield and land use statistics

The results of the present investigation are discussed in the following sub sections.

i) Temporal trend of selected agricultural parameters.

ii) Growth rates of selected agricultural parameters.

iii) Instability measures of selected agricultural parameters.

iv) Growth vis-a-vis instability of selected agricultural parameters.

v) Prediction of Instability of selected agricultural parameters.

vi) Estimated acreage response functions of crops.

vii) Estimated cost functions of crops.

viii) Estimated production function of crops.

ix) Estimated fertilizer response functions of crops.

x) Test of Equality of estimated coefficients.

xi) Violations of assumptions of OLS method and remedial measures.

The focus of the present study is compressed in the first objective and the remaining objectives are supportive to it. As far as the discussion of results is concerned the characteristics of the estimated model and the goodness of fit are discussed simultaneously wherever possible. Similarly, the problems due to violation of assumptions and remedial measures are discussed together in 4.11.

4.1 TEMPORAL TREND OF SELECTED AGRICULTURAL PARAMETERS :

The time series data on area, production and yield of the identified crops in the selected districts and also the land use data were examined to locate the most befitting model for each parameter. The best model was identified in terms of the overall significance of the regression model, statistical significance of the coefficients appearing in the model, the value of coefficient of determination (R^2).

The algebraic forms of the models considered for each of the selected parameters are given in table 4.2.

Table 4.2 : Details of models for assessing temporal trend of selected agricultural parameters

S.No.	Name of the model	Algebraic form
1.	Linear model	$Y_t = b_0 + b_1t$
2.	Power model	$Y_t = b_0\ t^{b_1}$
3.	Compound model	$Y_t = b_0\ b_1^t$
4.	Exponential model	$Y_t = b_0\ e^{b_1 t}$
5.	Logarithmic model	$Y_t = b_0 + b_1 \ln(t)$
6.	Quadratic model	$Y_t = b_0 + b_1t + b_2t^2$
7.	Cubic model	$Y_t = b_0 + b_1t + b_2t^2 + b_3t^3$
8.	Inverse model	$Y_t = b_0 + b_1/t$
9.	S model	$Y_t = e^{(b_0+b_1/t)}$

Trend in Area, Production and Yield of Bajra Crop :

The details of the selected model for the bajra crop for three temporal phases regarding area, production and yield are given in Table 4.3.

Barmer : As far as Barmer is concerned, during the first temporal phase (1956-66), power model was found most befitting for area under bajra. However, for the second and third temporal bases, none of the models was found statistically significant for area under bajra crop. Incidently for production and yield also none of the models were found statistically significant.

Jhunjhunu : In case of Jhunjhunu, for area under bajra crop during the first temporal phase, S- model was found best fitted. For the second temporal phase cubic model fitted the best. No model was found statistically significant during the third temporal phase for area under bajra crop. Regarding production, the inverse model was found best fitted. None of the model was found statistically significant for second

Table 4.3 : Particulars of selected model for trend in area, production and yield of bajra crop

Particular	Phase	Districts						
		Barmer			Jhunjhunu			Alwar
		Model	R^2	F	Model	R^2	F	Model
Area	TP_1	**Power** $Bt = 795.09^{***} t^{0.11^{***}}_{(0.02)}$ (22.57)	0.8328	44.84***	**S Model** $B_t = e^{5.48^{***}_{(0.05)} - 0.43^{***}_{(0.13)}/t}$	0.5688	11.87***	□
	TP_2	□			**Cubic** $B_t = 148.67^{***} + 55.83^{**} t - 9.78^{***} t^2 + 0.45^{***} t^3$ (34.88) (19.44) (2.96) (0.13)	0.5768	4.54*	□
	TP_3	□			□			□
Production	TP_1	□			**Inverse** $B_t = 73.40^{***} - 51.47^{*}/t$ (9.02) (23.98)	0.3358	4.55*	□
	TP_2	□			□			□
	TP_3	□			□			□
Yield	TP_1	□			□			□
	TP_2	□			□			□
	TP_3	□			□			□

B_t stands for bajra crop

□ No model was found statistically significant

*** *Significant at 1 % level of significance*

** *Significant at 5 % level of significance*

* *Significant at 10 % level of significance*

and third temporal phases. Also, none of the models was found statistically significant in case of yield for bajra in Jhunjhunu district in all the three temporal phases.

Alwar : Incidently none of the models were found statistically significant in area, production and yield for bajra crop in Alwar district for all the three temporal phases.

Trend in Area, Production and Yield of Maize Crop :

The details of the selected model for the maize crop for the three temporal phases regarding area, production and yield are given in Table 4.4 and the corresponding graphical forms for third temporal phase are given in Fig. 3.

Bhilwara : The best fit for area under maize crop in Bhilwara during the first temporal phase was the logrithmic model. During the second temoral phase cubic model fitted the best. Remarkably, during the third phase a linear model was found as the best fit. From the graphical form it could be seen that area under maize crop has increased constantly over the years during the recent past. In case of production of maize during the first phase S-model was found as the best fit. While no models were found statistically significant during the second and third temporal phases. Regarding yield of maize during the first temporal phase S-model fitted the best and none of the models was found statistically significant for the second and third temporal phases.

Bundi : In Bundi district during the first temporal phase a power model was the best fit. While during the second temporal phase cubic model fitted the best. No model was found statistically significant during the third temporal phase. In case of production, S-model was found most befitting during the first temporal phase. While none of the models was found statistically significant for second and third temporal phases. Regarding yield, the cubic model was the best fit in the first temporal

Table 4.4 : Particulars of selected crop for trend in area, production and yield of maize crop

Particulars	Phase	Districts					
		Bhilwara			Bundi		
		Model	R^2	F	Model	R^2	F
Area	TP_1	**Logarithmic** $M_t = 73.68^{***} + 14.66^{***} \ln(t)$ (2.22) (1.27)	0.9363	132.35***	**Power** $Mt = 7.55^{***}\, t^{0.39^{***}}_{(0.004)}$	0.9194	102.66***
	TP_2	**Cubic** $M_t = 98.27^{***} + 13.86^{***}t - 2.20^{**}t^2 + 0.10^{***}t^3$ (8.27) (4.86) (0.74) (0.03)	0.5309	3.77*	**Cubic** $M_t = 20.24^{***} + 2.34 - 0.60t^2 + 0.04^{*}t^3$ (4.13) (2.30) (0.35) (0.02)	0.7501	10.0**
	TP_3	**Linear** $M_t = 130.47^{***} + 1.70^{***}t$ (4.51) (0.44)	0.4995	14.97***	□		
Production	TP_1	**S. Model** $M_t = e^{\underset{(0.05)}{4.76^{***}} - \underset{(0.14)}{1.03^{***}} / t}$	0.8633	56.85***	**S. Model** $M_t = e^{\underset{(0.07)}{3.12^{***}} - \underset{(0.18)}{2.44^{***}} / t}$	0.9534	184.24***
	TP_2	□			□		
	TP_3	□			□		
Yield	TP_1	**S. Model** $M_t = e^{\underset{(0.04)}{6.98^{***}} - \underset{(0.12)}{0.58^{***}} / t}$	0.7282	24.11***	**Cubic** $M_t = -377.19 + 680.76^{***}t - 96.65^{***}t^2 + 4.09^{***}t^3$ (241.93) (166.98) (31.63) (1.74)	0.8420	10.67***
	TP_2	□			□		
	TP_3	□			**Power** $M_t = 589.05^{***}\, t^{0.23^{*}}_{(0.13)}$ (156.29)	0.1824	3.30*

M_t stands for maize crop

□ No model was found statistically significant

*** *Significant at 1 % level of significance*

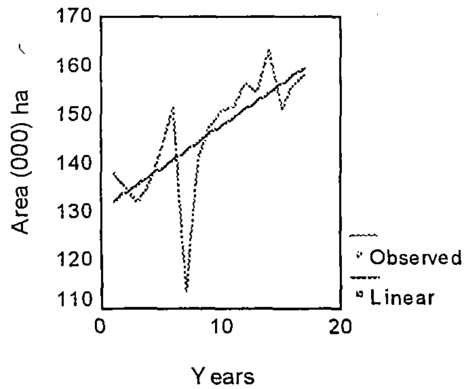
** *Significant at 5 % level of significance*

* *Significant at 10 % level of significance*

Fig 3: Graphical form of selected models for Maize crop in TP_3

Bhilwara | **Bundi**

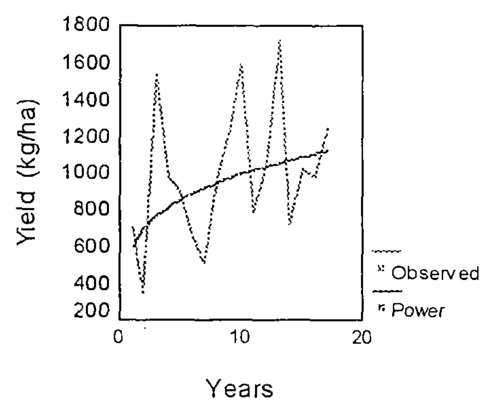
Area



□

Production □ □

Yield □



Years:- 1981=1,1982=2----------1997=17

□ No model was found statistically significant

phase. No model could be found statistically significant for the second temporal phase. While third phase was found to have power model as the best fit. The yield of bajra crop in Bundi was found increasing at decreasing rate during the recent past.

Trend in Area, Production and Yield of Wheat Crop :

The details of the selected model for the wheat crop for three temporal phases regarding area, production and yield are given in Table 4.5 and graphical representation of the models for the third temporal phase is given in Fig. 4.

Bhilwara : In the first temporal phase compound model, in the second phase power model and in the third phase linear model were found most befitting for area under wheat in Bhilwara. Remarkably, the area under wheat crop is found increasing at constant rate during the recent years in Bhilwara district. In case of production during the first temporal phase compound model and during the second phase logarithmic model fitted the best. However in the third phase quadratic model was best fitted with U-shaped pattern. The graphical form of the trend revealed that in recent past the production of wheat crop revived depression in Bhilwara district. Regarding yield no model was found statistically significant in the first temporal phase. In the second temporal phase S-model and in the third phase compound model were found best fitted. It may be noted that the yield of wheat crop is increasing at decreasing rate in Bhilwara district during the recent years.

Bundi : In case of area under wheat crop, the cubic model was best fitted in the first temporal phase, the power model in the second temporal phase and a cubic model in the third temporal phase. From the graphical form of the selected model in Bundi district for wheat crop it could be seen that the area has been increasing at a faster rate during the recent past. Regarding production, no model was found statistically

Table 4.5 : Particulars of selected crop for trend in area, production and yield of wheat crop

Particulars	Phase	Districts					
		Bhilwara			Bundi		
		Model	R^2	F	Model	R^2	F
Area	TP_1	**Compound** $W_t = 53.82^{***} \times 0.9749^{***\,t}$ (4.92) (0.01)	0.2777	3.46*	**Cubic** $W_t = 66.86^{***} - 15.48^{***}t + 3.45^{***}t^2 - 0.20^{***}t^3$ (5.11) (3.52) (0.67) (0.04)	0.8478	13.0***
	TP_2	**Power** $W_t = 39.50^{***}\ t^{0.26^{***}}_{(0.14)} / t$ (5.26)	0.5414	14.17***	**Power** $W_t = 63.77^{***}\ t^{0.08^{**}}_{(0.03)}$ (3.76)	0.3712	17.08***
	TP_3	**Linear** $Wt = 55.52^{***} + 3.16^{**}t$ (5.32) (1.13)	0.3441	7.87**	**Cubic** $W_t = 79.50^{***} + 4.34t - 0.76\ t^2 + 0.04^{*}t^3$ (8.80) (4.12) (0.52) (0.02)	0.7638	14.01***
Production	TP_1	**Compound** $W_t = 51.22^{***} \times 0.9674^{***}t$ (6.53) (0.02)	0.3733	5.36**	□		
	TP_2	**Logarithmic** $Wt = 31.92^{**} + 22.07^{***} \ln(t)$ (13.27) (6.81)	0.4666	10.50***	**Power** $W_t = 50.39^{***}\ t^{0.33^{***}}_{(0.07)}$ (6.72)	0.6634	23.65***
	TP_3	**Quadratic** $W_t = 130.35^{**} - 13.31\ t + 1.49^{**}\ t^2$ (47.48) (12.14) (0.66)	0.6641	13.84***	**Cubic** $W_t = 94.29^{**} + 37.50^{*}\ t - 5.04^{*}t^2 + 0.23^{**}t^3$ (42.43) (19.83) (2.52) (0.09)	0.8470	23.99***
Production	TP_1	□			□		
	TP_2	**S. Model** $W_t = e^{7.06^{***}_{(0.05)} - 0.36^{***}_{(0.15)} / t}$	0.3136	5.48**	**Power** $W_t = 789.27^{***}\ .\ t^{0.25^{***}}_{(0.04)}$ (69.61)	0.7208	30.98***
	TP_3	**Compound** $W_t = 1406.85^{***} \times 1.0336^{***}\ t$ (127.63) (0.01)	0.4814	13.92***	**Linear** $W_t = 1586.32 + 85.04^{***}t$ (196.93) (19.22)	0.5662	19.58***

W_t stands for wheat crop

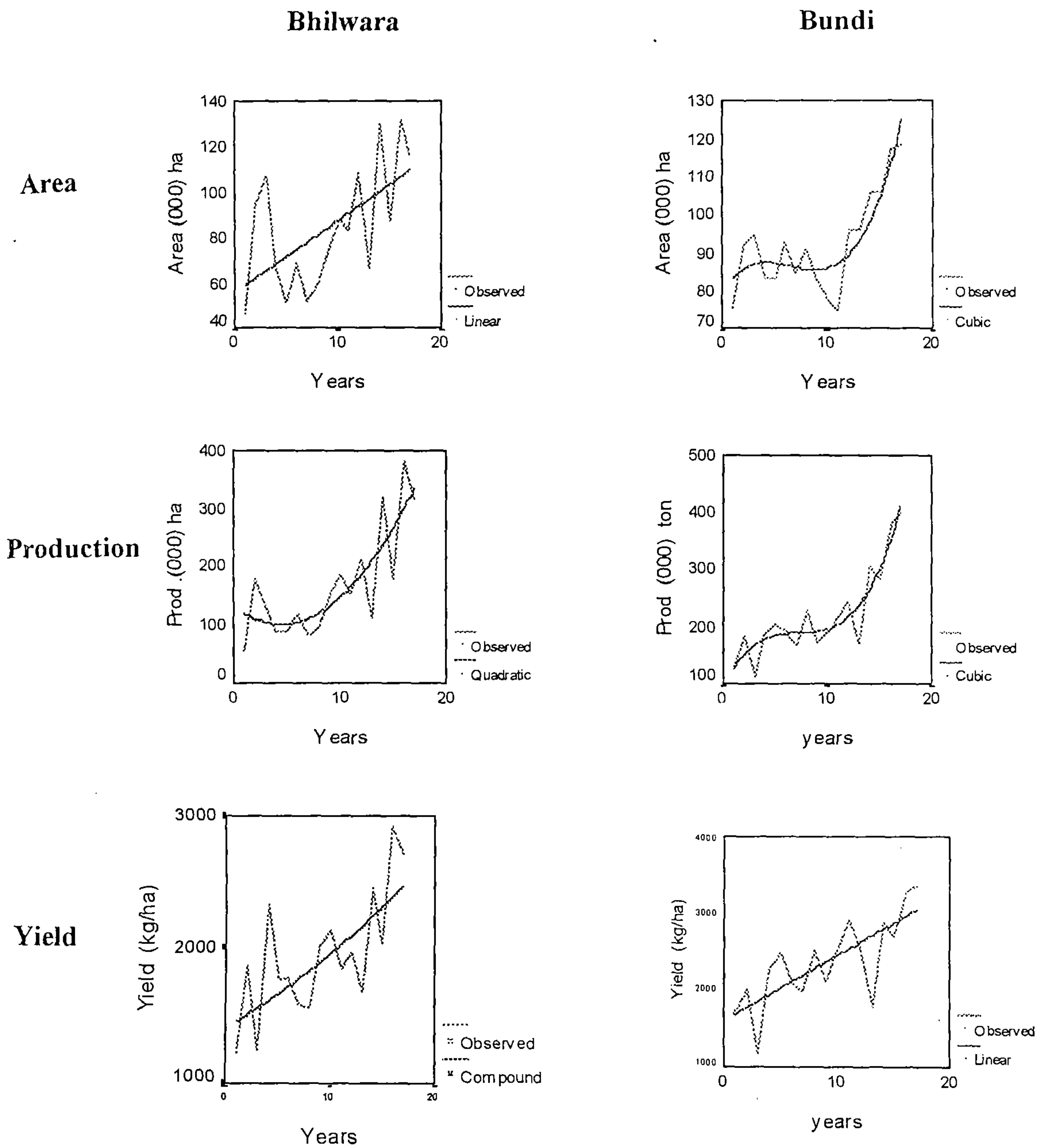
□ No model was found statistically significant

*** *Significant at 1 % level of significance*

** *Significant at 5 % level of significance*

* *Significant at 10 % level of significance*

Fig 4: Graphical form of selected models for wheat crop in TP_3



Years:- 1981=1,1982=2----------1997=17

significant for the first temporal phase in Bundi district. However, in the second phase, a power model and in the third temporal phase the cubic model fitted the best. It means that the production growth of wheat in Bundi district is more governed by the area growth. In case of yield, no model was found statistically significant during the first temporal phase. In the second temporal phase the power model and in the third temporal phase the linear model was found the best fit in Bundi district. It can be concluded that yield of wheat crop in Bundi in the third temporal phase is increasing at constant rate.

Trend in Area, Production and Yield of Rape seed & Mustard Crop :

The details of the selected models for rape seed & mustard crop for three temporal phases in respect of area, production and yield are given in Table 4.6 and the graphical forms for the third temporal phase are given in fig.5.

Jhunjhunu : Regarding area, none of the model was found statistically significant during the first and second temporal phases. In the third phase, the quadratic model was found the best fit with U shaped curve. The graphical form of the curve reveals that the area under rape seed & mustard has been increasing at faster rate during the recent years. In case of production during the first phase a compound model was best fitted. No model was found statistically significant during the second temporal phase. However, in the third phase a quadratic model was best fitted with U-shaped pattern. It shows that production of rapeseed and mustard has been increasing at a pattern similar to that of area of it in Jhunjhunu district in recent years. For yield during the first temporal phase compound model and during the second temporal phase S-model were found most befitting. No model was found statistically significant in third temporal phase.

Table 4.6 : Particulars of selected model for trend in area, production and yield of rapeseed & mustard crop

Particulars	Phase	Districts					
		Bhilwara			Bundi		
		Model	R^2	F	Model	R^2	F
Area	TP_1	□			**Power** $R_t = 67.28^{***}\, t^{0.14^{**}}_{(0.06)}$ (7.52)	0.3598	5.06*
	TP_2	□			**Quadratic** $R_t = 44.58^{***} + 12.58^{**}t - 1.01^{***}t^2$ (14.58) (4.47) (0.29)	0.6277	9.27**
	TP_3	**Quadratic** $R_t = 31.53^{***} - 6.28^{***} + 0.67^{***}\, t^2$ (5.56) (1.42) (0.08)	0.9647	192.02***	**Cubic** $R_t = 70.40^{***} + 0.21\, t + 2.49^{*}\, t^2 - 0.12^{*}t^3$ (22.86) (10.68) (1.36) (0.06)	0.9266	54.73***
Production	TP_1	**Compound** $R_t = 3.01^{*} \times 0.8280^{***}t$ (1.40) (0.06)	0.4564	7.56**	□		
	TP_2	□			□		
	TP_3	**Quadratic** $R_t = 19.85^{***} - 4.41^{**}t + 0.49^{***}t^2$ (7.88) (2.02) (0.11)	0.8855	54.08***	**Quadratic** $R_t = 9.34 + 26.11^{***}\, t - 0.87^{**}\, t^2$ (26.49) (6.77) (0.37)	0.7768	24.37***
Yield	TP_1	**Compound** $R_t = 422.34^{**} \times 0.8634^{***}t$ (154.53) (0.05)	0.4517	7.41**	**Power** $R_t = 43.240^{***}\, t^{0.606^{***}}_{(0.056)}$ (5.016)	0.8926	11.32***
	TP_2	**S. Model** $R_t = e^{\underset{(0.12)}{6.33^{***}} - \underset{(0.35)}{1.24^{***}} / t}$	0.5089	12.44***	□		
	TP_3	□			□		

R_t stands for rapeseed and mustard crop

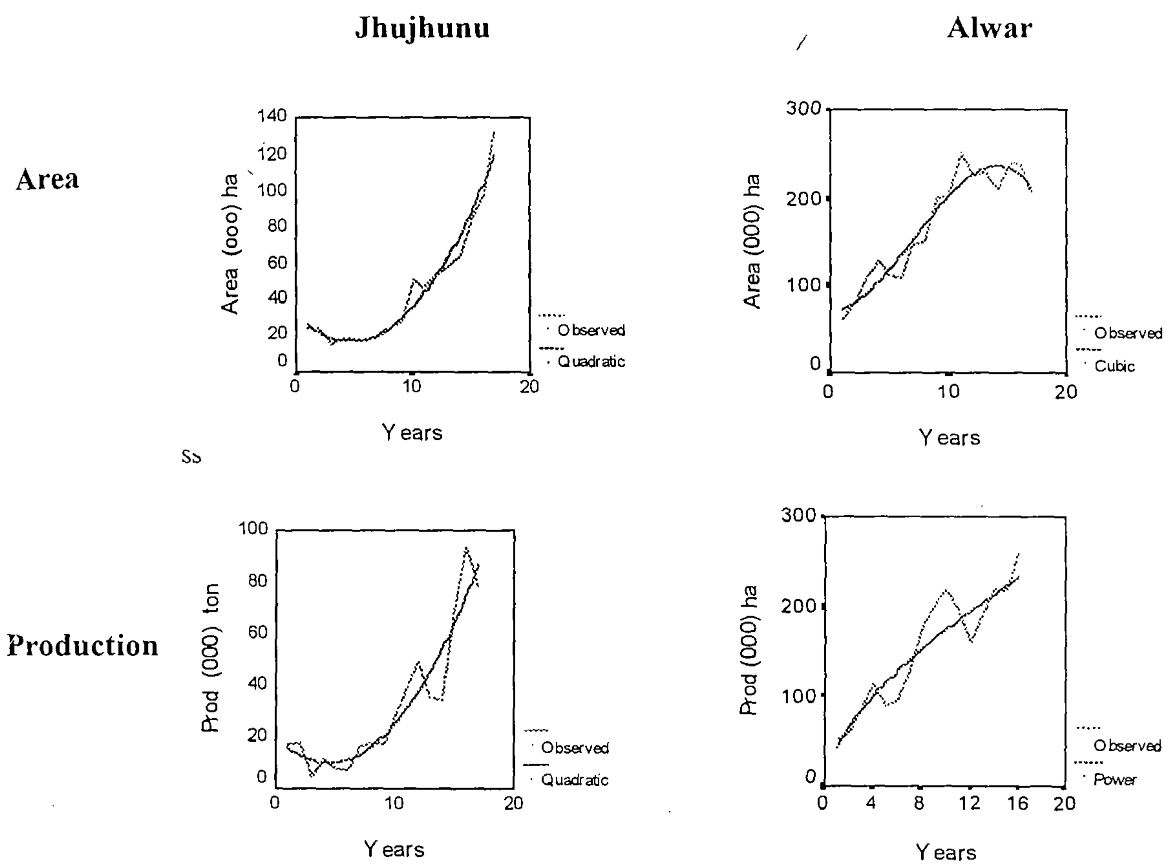
□ No model was found statistically significant

*** *Significant at 1 % level of significance*

** *Significant at 5 % level of significance*

* *Significant at 10 % level of significance*

Fig 5: Graphical form of selected models for Rape Seed &Mustard crop in TP_3



Yield ☐ ☐

Years:- 1981=1,1982=2----------1997=17

☐ No model was found statistically significant

Alwar : Regarding area in Alwar district during the first temporal phase a power model and during the second temporal phase – a quadratic model fitted the best while in the third temporal phase a cubic model was best fitted. Inter-temporal changes in the pattern of trend in area under rapeseed and mustard is evident from the best fitted models in all the three temporal phases. However, during the recent past the area which has been consistently increasing has started declining for the last few years in Alwar district.

In case of production, no model was found statistically significant in the first and second phase. However, in the third temporal phase a power model fitted the best. It may be noted that the production of rapeseed and mustard was increasing during the recent past in Alwar district. Regarding the yield of rapeseed and mustard in Alwar none of the models was found statistically significant in all the three temporal phases.

The temporal trend models found as the best fit for crop parameters during the three temporal phases are summarized in table 4.7.

Trend in Forest Area :

The details of selected models with respect to forest area in all the five selected districts over the three temporal phases are given in Table 4.8 and the graphical forms of selected models for third temporal phase are given in Fig. 6.

Barmer : In Barmer district, the cubic model was found most befitting for the first temporal phase for forest area. However, for the second and third temporal phases the quadratic model fitted the best. The shape of the curve of the quadratic model was found inverted U-shaped for the third temporal phase. It shows that the area under forest has been fluctuating over the period in this district. The distinct

Table 4.7 : Selected trend models of crop parameters for the three temporal phases.

S. No.	Crop	District	Particulars	Model situations in		
				TP$_1$	TP$_2$	TP$_3$
1.	Bajra	Barmer	Area	Power	NSM	NSM
			Production	NSM	NSM	NSM
			Yield	NSM	NSM	NSM
		Jhunjhunu	Area	S-Model	Cubic	NSM
			Production	Inverse	NSM	NSM
			Yield	NSM	NSM	NSM
2.	Maize	Bhilwara	Area	Logarithmic	Cubic	Linear
			Production	S-model	NSM	NSM
			Yield	S-model	NSM	NSM
		Bundi	Area	Power	Cubic	NSM
			Production	S-model	NSM	NSM
			Yield	Cubic	NSM	Power
3.	Wheat	Bhilwara	Area	Compound	Power	Linear
			Production	Compound	Logarithmic	Quadratic
			Yield	NSM	S-model	Compound
		Bundi	Area	Cubic	Power	Cubic
			Production	NSM	Power	Cubic
			Yield	NSM	Power	Linear
4.	Rapeseed & mustard	Jhunjhunu	Area	NSM	NSM	Quadratic
			Production	Compound	NSM	Power
			Yield	Compound	S-model	-
		Alwar	Area	Power	Quadratic	Cubic
			Production	NSM	NSM	Quadratic
			Yield	NSM	NSM	NSM

NSM denotes that no model was found statistically significant

Table 4.8 : Particulars of selected model for trend in forest area

Districts	TP₁ Model			TP₂ Model			TP₃ Model		
	Model	R^2	F	Model	R^2	F	Model	R^2	F
Barmer	**Cubic** $F_t = 2.68 + 5.54^{*}t - 0.98^{*}t^2 + 0.05^{**}t^3$ (5.63) (2.80) (0.43) (0.02)	0.7568	5.19*	**Quadratic** $F_t = 11.93^{***} - 0.06\,t + 0.03^{**}\,t^2$ (0.42) (0.13) (0.01)	0.9185	61.95***	**Quadratic** $F_t = 12.92^{***} + 2.06^{***}\,t - 0.09^{***}\,t^2$ (0.92) (0.25) (0.02)	0.9097	65.49***
Jhun-jhunu	**Cubic** $F_t = 30.14^{*} + 16.54\,t - 4.31^{*}t^2 + 0.25^{*}\,t^3$ (14.75) (10.18) (1.93) (0.11)	0.7685	7.74**	**S. Model** $F_t = e^{\underset{(0.02)}{3.58^{***}} - \underset{(0.06)}{0.19^{**}}/t}$	0.4353	9.25**	□		
Alwar	□			**Quadratic** $F_t = 19.94^{***} - 1.15^{**}\,t + 0.06^{*}\,t^2$ (1.59) (0.49) (0.03)	0.4003	3.67*	**Cubic** $F_t=22.22^{***}-5.33^{***}t+0.99^{***}t^2-0.03^{***}t^3$ (2.66) (1.32) (0.18) (0.006)	0.9821	219.51***
Bhilwara	**Cubic** $F_t = 126.62^{***}-61.81^{***}t+9.72^{**}t^2-0.46^{***}t^3$ (24.85) (17.15) (3.25) (0.18)	0.7438	6.77**	**Cubic** $F_t = 22.33^{*} - 6.11\,t + 1.90^{*}\,t^2 - 0.10^{***}\,t^3$ (12.19) (6.80) (1.03) (0.04)	0.8123	14.43***	**Quadratic** $F_t = 51.58^{***} + 1.32^{***}\,t - 0.04^{**}\,t^2$ (0.83) (0.23) (0.01)	0.9311	87.90***
Bundi	**Cubic** $F_t = 54.30^{***}+22.74^{**}t-5.94^{***}t^2 + 0.34^{**}t^3$ (13.30) (9.18) (1.74) (0.10)	0.9193	26.59***	**Cubic** $F_t = 55.75^{***}-17.66^{**}t+2.88^{**}t^2 - 0.08^{*}t^3$ (12.39) (6.91) (1.05) (0.04)	0.9623	84.98***	**Power** $F_t = 123.38^{***}\, t^{\underset{(0.003)}{0.04^{***}}}$ (0.78)	0.9418	226.72***

F_t stands for forest area

□ *No model was found statistically significant*

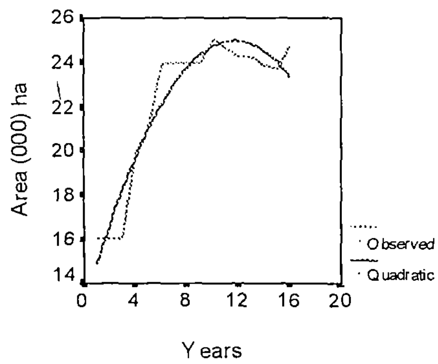
*** *Significant at 1 % level of significance*

** *Significant at 5 % level of significance*

* *Significant at 10 % level of significance*

Fig 6: Graphical form of selected models for forest area in TP_3

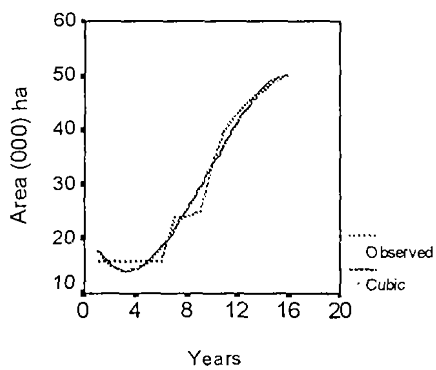
Barmer



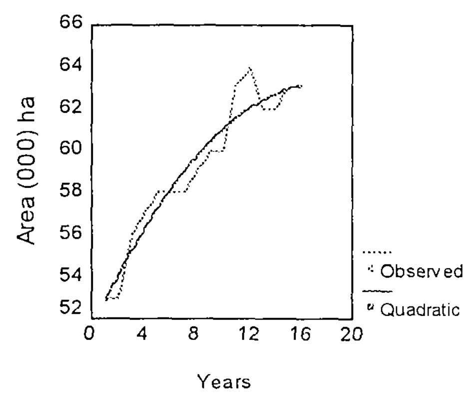
Jhujhunu

□

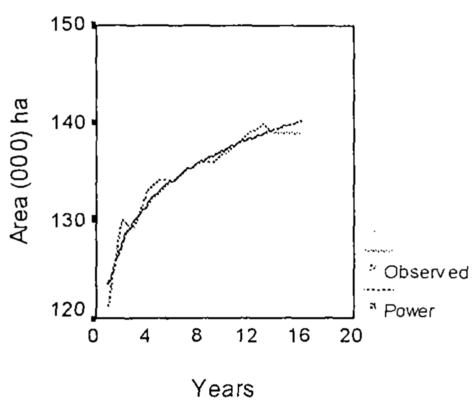
Alwar



Bhilwara



Bundi



Years:- 1981=1,1982=2----------1997=17

□ No model was found statistically significant

concavity of the curve during the last temporal phase indicates that the area under forest was on a decreasing pattern during the recent years.

Jhunjhunu : As far as the forest area of Junjhunu over time is concerned, it is evident that during the first temporal phase, a cubic model and during the second temporal phase S model was found most befitting. Incidently, none of the model was found statistically significant for the third temporal phase for forest area in Jhunjhunu.

Alwar : In case of Alwar no model was found statistically significant during the first temporal phase. In the second temporal phase, the quadratic model fitted the best. While in the third temporal phase the cubic model was best fitted. It may be noted that the momentum in the positive growth in the forest area in Alwar district during the recent past has slightly diminished.

Bhilwara : In Bhilwara district during the first and second temporal phases cubic models were best fitted. In the third temporal phase, the quadratic model was best fitted for forest area in Bhilwara. The curvature of the curve is such that the increasing trend at decreasing rate is likely to further fall in the years to come.

Bundi : During the first and second temporal phases the cubic model was found the best fit. The power model as the best fit in the third phase indicates that the area under forest was on an increasing trend, though the rate of increase is at the decreasing pattern in recent years in Bundi district. Wide inter-temporal fluctuations in the area under forest for the whole period is evident from the pattern of best fit models during the three temporal phases in Bhilwara district.

Trend in Land put to Non-Agricultural Uses :

The details of the selected model for land put to non-agricultural uses during the three temporal phases are given in Table 4.9 and graphical forms of the selected models for third phase are given in Fig. 7.

Table 4.9 : Particulars of selected model for trend in land put to non-agricultural uses

Districts	TP1			TP2			TP3		
	Model	R^2	F	Model	R^2	F	Model	R^2	F
Barmer	**Quadratic** NAV_t=54.93*** + 7.05***t – 0.68***t^2 (3.66) (1.40) (0.11)	0.8594	24.45***	**Cubic** NAV_t=63.11***-5.05**t+0.65**t^2-0.02*t^3 (2.86) (1.59) (0.24) (0.01)	0.8144	14.62***	**Quadratic** NAV_t=59.08*** + 2.02*** t – 0.08*** t^2 (1.27) (0.34) (0.02)	0.8783	46.91***
Jhun-jhunu	**Quadratic** NAV_t= 3.34*** + 1.53*** t – 0.10*** t^2 (1.13) (0.43) (0.04)	0.7057	9.59**	**Quadratic** NAV_t=7.11*** + 1.69*** t – 0.07*** t^2 (1.08) (0.32) (0.02)	0.8621	34.38***	**Cubic** NAV_t=17.06***-0.49t+0.11*t^2–0.004***t^3 (0.69) (0.33) (0.05) (0.001)	0.9002	37.21***
Alwar	**Cubic** NAV_t=33.91***+2.42*t-0.77***t^2+0.05***t^3 (1.26) (0.87) (0.16) (0.01)	0.9400	36.55***	**Cubic** NAV_t=40.76***-3.10**t+0.61***t^2-0.03**t^3 (2.04) (1.14) (0.17) (0.01)	0.8262	15.85***	**Cubic** NAV_t=43.96***+0.26t-0.09t^2+0.005**t^3 (0.75) (0.37) (0.05) (0.002)	0.7088	9.76***
Bhilwara	**Power** NAV_t= 35.22*** $t^{0.05***}_{(0.72)}$ (0.72)	0.6684	18.14***	**Quadratic** NAV_t= 34.21*** + 2.83***t - 0.10**t^2 (1.99) (0.61) (0.04)	0.8949	46.85***	**Quadratic** NAV_t= 54.39*** + 0.08 t + 0.03*** t^2 (0.75) (0.20) (0.01)	0.9222	77.07***
Bundi	**Compound** NAV_t= 34.53*** x 1.0032*** t (0.58) (0.02)	0.6376	4.11*	**Cubic** NAV_t=32.12***-4.66**t+0.82**t^2-0.03**t^3 (3.61) (2.01) (0.31) (0.01)	0.7830	12.03***	**Linear** NAV_t= 72.40*** - 1.36*** t (0.85) (0.09)	0.9453	241.84***

NAV_t stands for land put to non-agricultural uses

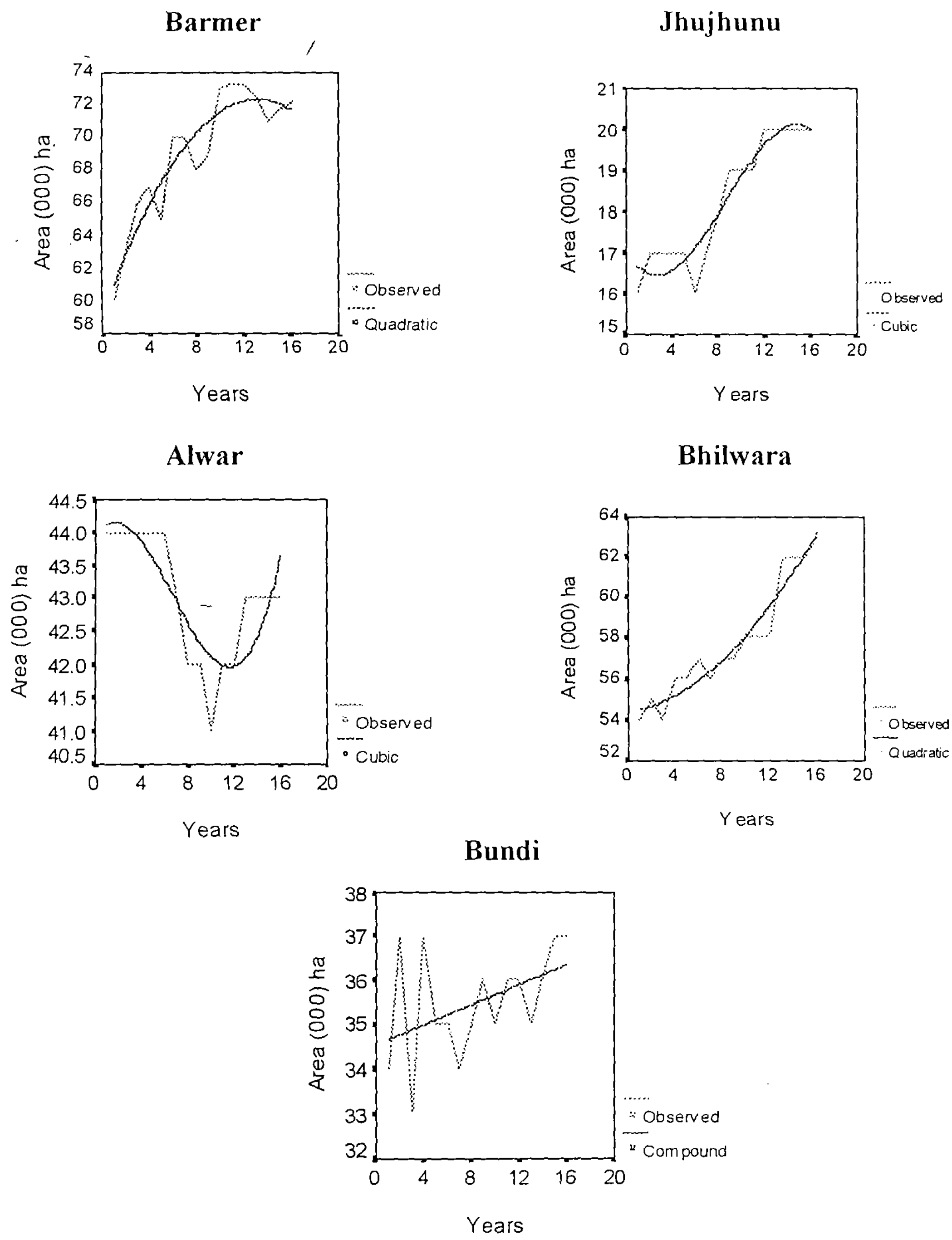
□ *No model was found statistically significant*

*** *Significant at 1 % level of significance*

** *Significant at 5 % level of significance*

* *Significant at 10 % level of significance*

Fig 7: Graphical form of selected models for land put to Non-Ag Uses in TP_3



Years:- 1981=1,1982=2----------1997=17

Barmer : In Barmer district, during the first temporal phase quadratic model and during the second temporal phase a cubic model were best fitted for land put to non-agricultural uses. During the third temporal phase a quadratic model fitted the best. The graphical form of the best fitted curve reveals that the increasing growth in the area under non-agricultural use has almost reached a pleatau in Barmer district.

Jhunjhunu : During the three specific tempral phases the land put to non-agricultural uses showed a fluctuating pattern. Quadratic model was best fitted during the first and second temporal phases. For the third phase, the cubic model fitted the best. This means that during the recent period land put to non-agricultural uses has been growing steadily with a slowness in the past few years.

Alwar : In case of Alwar during all the three temporal phases cubic model was found most befitting for land put to non-agricultural uses.

Bhilwara : The results of the estimated model for land put to non-agricultural uses in Bhilwara reveal that during the first temporal phase power model was best fitted, While in the second and third temporal phases quadratic model fitted the best. The graphical form for the third temporal phase clearly shows that there is increasing trend for land put to non-agricultural uses during the recent period in Bhilwara district. Again this could be attributable to the industrial development in Bhilwara district.

Bundi : For land put to non-agricultural uses in Bundi district during the first temporal phase a compound model and during the second phase a cubic model was found to be the best fit. Incidently, in the third temporal phase again the compound model fitted the best. This implies that land put to non-agricultural uses is on an increasing pattern in recent years in Bundi district.

Trend in Barren and Unculturable Waste Land :

The details of selected model for barren and unculturable waste land for three temporal phases are given in Table 4.10 and graphical forms are given in Fig. 8.

Barmer : During the first temporal phase no model was found statistically significant for area under barren and unculturable waste land in Barmer district. During the second phase the cubic model was best fitted. While in the third temporal phase a quadratic model with U shaped curve was found most appropriate. It can be concluded that area under barren and unculturable waste land in Barmer which was on a decreasing trend in the beginning of the third temporal phase has started increasing towards the later part of the third temporal phase.

Jhunjhunu : In Jhunujhunu district the cubic model was found most befitting during the first temporal phase for area under barren and unculturable waste land. In second phase an inverse model was found the best fit. No model was found statistically significant during the third temporal phase for area under barren and unculturable in Jhunjhunu district.

Bhilwara : During the first temporal phase the cubic model and during the second temporal phase the power model fitted the best for area under barren and unculturable waste in Bhilwara district. However, the third temporal phase showed a decreasing linear trend which means that this area was declining constantly in the recent years. It is a healthy indication that the land earmarked as barren and unculturable waste land is diverted for other purposes.

Bundi : In case of Bundi for area under barren and unculturable waste, no model was found statistically significant during the first temporal phase. During the second temporal phase a cubic model and for third temporal phase a quadratic model was found the best fit. The

Table 4.10 : Particulars of selected model for trend in barren and unculturable waste land

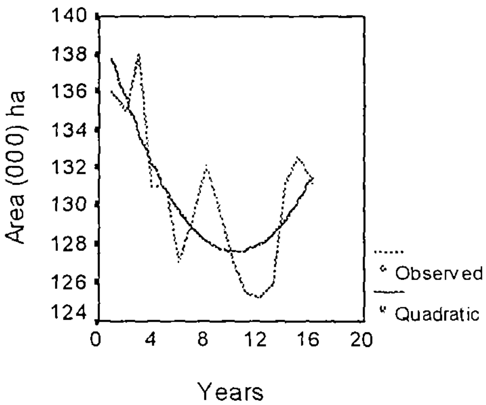
Districts	TP₁			TP₂			TP₃		
	Model	R^2	F	Model	R^2	F	Model	R^2	F
Barmer	▯			**Cubic** BUW_t=147.23***+5.87**t-1.13***t^2+0.05***t^3 (3.92) (2.19) (0.33) (0.01)	0.9030	31.03***	**Quadratic** BUW_t=140.03***-2.43***t+0.12***t^2 (2.09) (0.57) (0.03)	0.6393	11.52***
Jhun-jhunu	**Cubic** BUW_t= 30.48* - 15.48 t - 4.06*t^2 - 0.24*t^3 (15.32) (10.57) (2.0) (0.11)	0.7082	5.66**	**Inverse** BUW_t= 16.05*** + 14.84*** / t (0.51) (1.52)	0.8880	95.14***	▯		
Alwar	▯			**Cubic** BUW_t=136.17***+1.89t–0.52***t^2–0.02*t^3 (1.97) (1.10) (0.17) (0.01)	0.9333	46.66***	**Cubic** BUW_t=118.49***+5.14***t-0.88***t^2+0.03***t^3 (3.41) (1.69) (0.23) (0.01)	0.9624	102.38***
Bhilwara	**Cubic** BUW_t= 46.39 + 58.79***t – 8.68**-0.38**t^3 (25.41) (17.54) (3.32) (0.18)	0.7510	7.27**	**Power** BUW_t= 159.35*** $t^{0.07^{**}}_{(0.03)}$ (10.11)	0.2985	5.11**	**Linear** BUW_t= 185.40*** - 2.25***t (1.22) (0.12)	0.9582	321.08***
Bundi	▯			**Cubic** BUW_t=160.84***+19.60*t–3.75**t^2+0.13*t^3 (5.37) (8.57) (1.30) (0.06)	0.9587	77.33***	**Quadratic** BUW_t= 74.86 – 2.18**t + 0.05**t^2 (1.15) (0.31) (0.02)	0.9651	179.67***

BUW_t stands for Barren and Unculturable Waste

▯ *No model was found statistically significant*
*** *Significant at 1 % level of significance*
** *Significant at 5 % level of significance*
* *Significant at 10 % level of significance*

Fig 8: Graphical form of selected models for Barren and Unculturable Waste land in TP_3

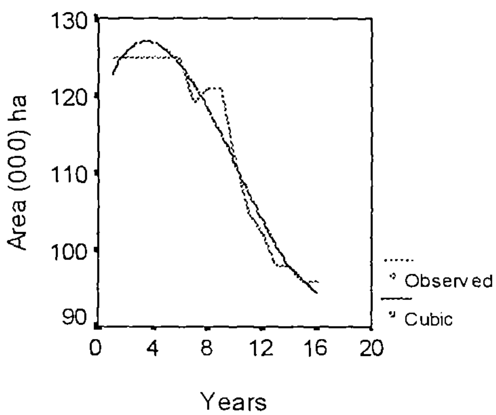
Barmer



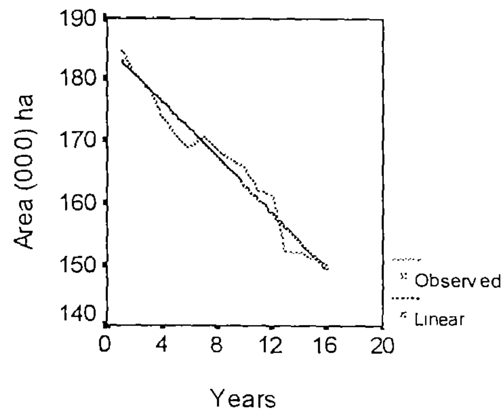
Jhunjhunu

□

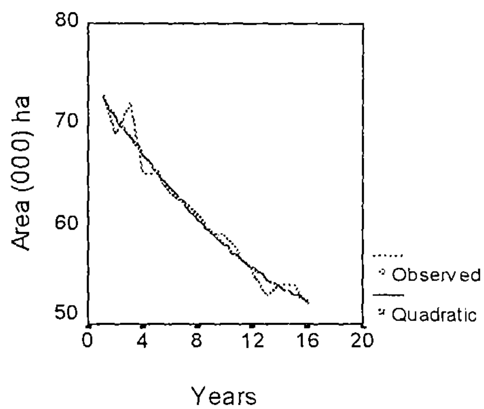
Alwar



Bhilwara



Bundi



Years:- 1981=1,1982=2----------1997=17

□ No model was found statistically significant

graphical form of the curve during the third temporal phase shows that the land under barren and unculturable waste has been decreasing over the years during the recent past.

Trend in Permanent Pastures and other grazing land :

The details of selected model for permanent pastures and other grazing land for the three temporal phases are given in Table 4.11 and graphical forms of the selected models are given in Fig. 9.

Barmer : In all the three temporal phases for area under permanent pastures and other grazing land, the cubic model was best fitted. In recent years the area under permanent pastures is on a decline, the curvature of the decline being shifted from convexity to concavity sometime during the end of eighties in Barmer district.

Jhunjhunu : In Jhunjhunu district for area under permanent pastures and other grazing land none of the model was found statistically significant during the first temporal phase. However in the second and third temporal phases the cubic model was best fitted. The graphical form of the curve shows that area under permanent pastures and other grazing land in Jhunjhunu district is also on a steady decrease over the years during the third temporal phase.

Alwar : During the first temporal phase compound model was best fitted for area under permanent pastures and other land in Alwar. In the second and third temporal phase cubic models were best fitted. It should be noted that during the recent years area under permanent pastures and other grazing land was on decreasing pattern in Alwar district.

Bhilwara : In Bhilwara during the first and second temporal phase, quadratic model fitted best for area under permanent pastures and other grazing land. No model was found statistically significant in the third temporal phase for area under permanent pastures and other grazing land in Bhilwara district.

Table 4.11 : Particulars of selected model for trend in permanent pastures and other grazing

Districts	TP1			TP2			TP3		
	Model	R^2	F	Model	R^2	F	Model	R^2	F
Barmer	**Cubic** PPG_t=2.30+83.05***t-11.36**t²+0.50*t³ (35.85) (24.77) (4.69) (0.26)	0.8492	13.14***	**Cubic** PPGt=201.55***-0.30t+0.36t²-0.02**t³ (2.23) (1.24) (.19) (.008)	0.9361	48.83***	**Cubic** PPG_t=219.79***-3.41*t+0.36*t²-0.02*t³ (2.56) (1.27) (0.17) (0.01)	0.7456	11.53***
Jhun-jhunu	□			**Cubic** PPG_t=45.62***+0.36*t-0.08**t²+0.003**t³ (0.31) (0.17) (0.03) (0.001)	0.8667	21.68***	**Cubic** PPGt=45.40*** - 0.12t - 0.07t² + 0.004*t³ (0.20) (0.35) (0.05) (0.002)	0.9188	45.27***
Alwar	**Compound** PPG_t = 10.91*** x 1.13***t (1.58) (0.008)	0.9649	247.50***	**Cubic** PPG_t=30.78***+6.09**t-1.11***t²+0.05**t³ (4.28) (2.39) (0.36) (0.02)	0.8625	20.90***	**Cubic** PPG_t=24.61***+0.40*t-0.07**t²-0.003**t³ (0.46) (0.23) (0.03) (0.001)	0.7417	11.48***
Bhilwara	**Quadratic** PPG_t = 75.59*** + 0.84t + 0.22**t² (2.41) (0.92) (0.07)	0.9727	142.45***	**Quadratic** PPG_t = 111.34*** - 0.53t + 0.09**t² (1.94) (0.60) (0.04)	0.8012	22.17***	□		
Bundi	**Quadratic** PPG_t=-12.28***+12.6***t-0.83***t² (4.16) (1.59) (0.13)	0.9228	47.82***	**Quadratic** PPGt = 30.04*** - 1.25***t + 0.05***t² (0.58) (0.18) (0.01)	0.9263	69.14***	**Cubic** PPG_t=22.52***+0.85**t-0.11*t²+0.004***t³ (0.72) (0.36) (0.05) (0.001)	0.5820	5.57**

PPG_t stands for permanent pastures and other grazing land

□ *No model was found statistically significant*

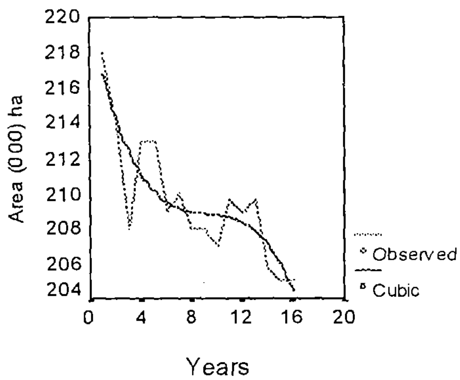
*** *Significant at 1 % level of significance*

** *Significant at 5 % level of significance*

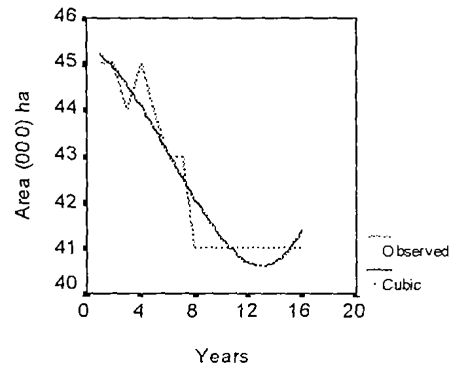
* *Significant at 10 % level of significance*

Fig 9: Graphical form of selected models for Permanent Pastures and other Grazing land in TP_3

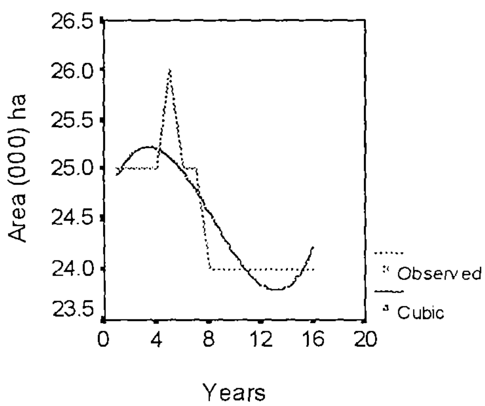
Barmer



Jhunjhunu



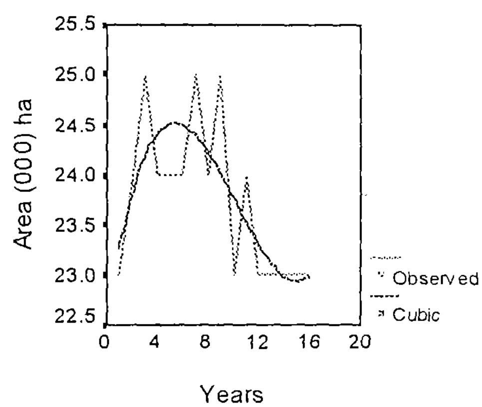
Alwar



Bhilwara

□

Bundi



Years:- 1981=1,1982=2----------1997=17

□ No model was found statistically significant

Bundi : As far as Bundi is concerned, during the first and second temporal phase the quadratic model fitted best for area under permanent pastures and other grazing land. A cubic model was found most befitting in the third temporal phase. The graphical form of the curve during this temporal phase reveals that the area under permanent pastures and other grazing land fluctuated during the early part and during the later part the fluctuation was coupled with falling area in Bundi district.

Trend in Culturable waste land:

The details of the selected model for the culturable waste land for three temporal phases are given in Table 4.12 and the graphical forms for the third temporal phase are given in Fig. 10.

Barmer : In Barmer district during the first temporal phase the cubic model was best fitted for area under culturable waste. In the second phase a linear model and in the third phase an exponential model fitted the best. The graphical form of the curve reveals that during the recent years area under culturable waste is continuously decreasing at increasing rate in Barmer.

Jhunjhunu : Incidently in all the three temporal phases cubic model fitted the best for area under culturable waste in Jhunjhunu. Too much fluctuation of area under culturable waste in the district over the years is evident. In a semi-arid/ desertic district such fluctuations in culturable waste land could be due to occasional diversion of desert area for crop production and other purposes depending on availability of rainfall.

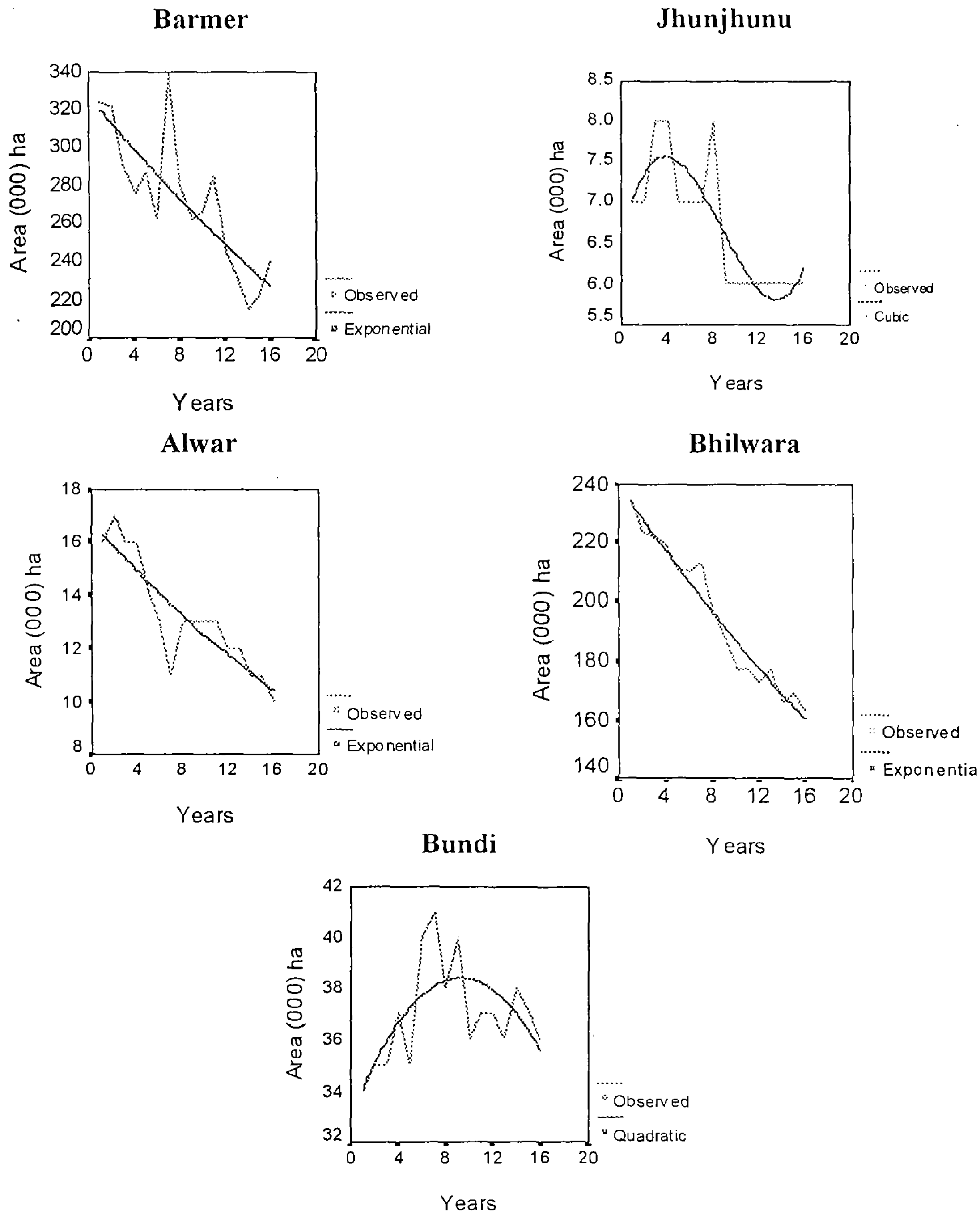
Alwar : During the first and second temporal phases quadratic models were best fitted for area under culturable waste in Alwar while in the third temporal phase an exponential model fitted the best. The graphical pattern indicates that the area under culturable waste is decreasing in Alwar district during the recent past.

Table 4.12 : Particulars of selected model for trend in culturable waste land

Districts	TP_1			TP_2			TP_3		
	Model	R^2	F	Model	R^2	F	Model	R^2	F
Barmer	**Cubic** CW_t=562.77***-204.13***t+33.66**t^2-1.53**t^3 (94.62) (65.30) (12.37) (0.68)	0.7243	6.13**	**Linear** CW_t=416.04*** - 4.90**t (18.37) (2.16)	0.3007	5.16**	**Exponential** CW_t=327*** $e^{-0.023^{***}t}_{(0.004)}$ (13.70)	0.6682	28.20***
Jhun-jhunu	**Cubic** CW_t=11.65*** + 0.80t - 0.23**t^2 + 0.01*t^3 (0.65) (0.45) (0.08) (0.005)	0.9694	73.89***	**Cubic** CW_t=5.34* + 1.75 t – 0.41*t^2 + 0.02*t^3 (2.27) (1.27) (0.19) (0.01)	0.6589	6.44**	**Cubic** CW_t=6.53***+0.59*t-0.10**t^2+0.004***t^3 (0.62) (0.31) (0.04) (0.001)	0.7039	9.51***
Alwar	**Quadratic** CW_t = 66.72*** + 0.62 t – 0.35*** t^2 (2.46) (0.94) (0.08)	0.9744	152.11***	**Quadratic** CW_t=34.76***-2.20***t+0.063***t^2 (0.78) (0.24) (0.02)	0.9800	269.11***	**Exponential** CW_t=16.74*** $e^{-0.03^{***}t}_{(0.004)}$ (0.66)	0.7903	52.77***
Bhilwara	**Compound** CW_t = 312.01*** x 0.05^{**t} (11.20) (0.02)	0.3640	5.15**	**Quadratic** CW_t = 351.16*** - 25.70*** t + 1.28*** t^2 (13.86) (4.24) (0.28)	0.8567	32.89***	**Exponential** CW_t=240*** $e^{-0.03^{***}t}_{(0.004)}$ (3.38)	0.9553	299.13***
Bundi	**Compound** CW_t = 77.33*** x 0.93^{***t} (0.72) (0.001)	0.9963	2387.90***	□			**Quadratic** CW_t = 32.98*** + 1.16*** t – 0.06** t^2 (1.39) (0.38) (0.02)	0.4273	4.85**

CW_t stands for culturable waste land
□ *No model was found statistically significant*
*** *Significant at 1 % level of significance*
** *Significant at 5 % level of significance*
* *Significant at 10 % level of significance*

Fig 10: Graphical form of selected models for Culturable Waste land in TP_3



Years:- 1981=1,1982=2----------1997=17

Bhilwara : In Bhilwara for area under culturable waste, in the first temporal phase a compound model in the second temporal phase quadratic model and in the third temporal phase an exponential model were found best fitted. The graphical form of the curve reveals that area under culturable waste has been decreasing continuously in Bhilwara district.

Bundi : During the first temporal phase, the compound model fitted the best for area under culturable waste in Bundi. No model was found statistically significant in the second temporal phase. In the third phase quadratic model with inverted U-shaped curve was best fitted. It reveals that the pattern of area under culturable waste in Bundi is decreasing in recent years.

4.1.6 Trend in Land Other than Current Fallow (old fallow) :

The details of the selected model for the land other then current fallow for the three temporal phases are given in Table 4.13 and the graphical forms are given in Fig. 11.

Barmer : In Barmer during the first temporal phase the cubic model was best fitted for land other than current fallow. However in the second temporal phase compound model fitted the best. No model was found statistically significant for third temporal phase for land other than current fallow in Barmer district.

Jhunjhunu : It is noteworthy that during the first temporal phase cubic model fitted the best. However in the second temporal phase the compound model was best fitted. A cubic model was again found best fitted during the third temporal phase for land other than current fallow. It may be noted that land other than current fallow was on a decline during the recent years in Jhunjhunu district.

Table 4.13 : Particulars of selected model for trend in land other than current fallow

Districts	TP_1			TP_2			TP_3		
	Model	R^2	F	Model	R^2	F	Model	R^2	F
Barmer	**Cubic** $OCF_t=347.65^{***}+184.40^{**}t-32.70^{**}t^2+1.52^{*}t^3$ (90.95) (62.77) (11.89) (0.65)	0.7884	8.69**	**Compound** $OCF_t=563.69^{***} \times 0.96^{***\,t}$ (73.11) (0.01)	0.4171	8.58**	□		
Jhun-jhunu	**Cubic** $OCF_t=10.80^{***}+0.37t-0.29t^2+0.02^{*}t^3$ (1.65) (1.14) (0.22) (0.01)	0.7868	8.61**	Compound $OCF_t=5.39^{***} \times 1.08^{***\,t}$ (0.53) (0.01)	0.8047	49.44***	**Cubic** $OCF_t=18.03^{***}-1.65^{*}t+0.26\,t^2-0.011^{**}t^3$ (1.76) (0.87) (0.18) (0.004)	0.6328	6.89**
Alwar	**Cubic** $OCF_t=5.98^{***}+1.40^{**}t-0.29^{***}t^2+0.01^{*}t^3$ (0.76) (0.53) (0.10) (0.005)	0.9118	24.11***	**Cubic** $OCF_t=3.57^{**}+0.71\,t-0.14\,t^2+0.01^{**}t^3$ (1.33) (0.74) (0.11) (0.004)	0.9752	130.97***	**Exponential** $OCF_t=22.35^{***}\,e^{\underset{(0.007)}{-0.03^{***}}t}$ (1.69)	0.5655	18.22***
Bhilwara	**Linear** $OCF_t=211.71^{***}-11.94^{***}t$ (10.33) (1.52)	0.8721	61.37***	**Cubic** $OCF_t=95.32^{***}-14.30^{***}t+2.13^{***}t^2-0.09^{***}t^3$ (6.07) (3.38) (0.51) (0.02)	0.7660	10.59***	**Compound** $OCF_t=51.15^{***} \times 1.0141^{**\,t}$ (2.44) (0.005)	0.3656	8.07**
Bundi	**Quadratic** $OCF_t=17.55^{***}-1.20^{***}t+0.07^{**}t^2$ (0.95) (0.36) (0.03)	0.7579	12.59***	**Power** $OCF_t=11.53^{***}\,t^{\underset{(1.06)}{0.22^{***}}}$ (1.27)	0.5502	14.68***	**Quadratic** $OCF_t=18.23^{***}+1.40^{***}t-0.08^{***}t^2$ (1.51) (0.41) (0.02)	0.4757	5.90**

OCF_t stands for land other than current fallow

□ *No model was found statistically significant*

*** *Significant at 1 % level of significance*

** *Significant at 5 % level of significance*

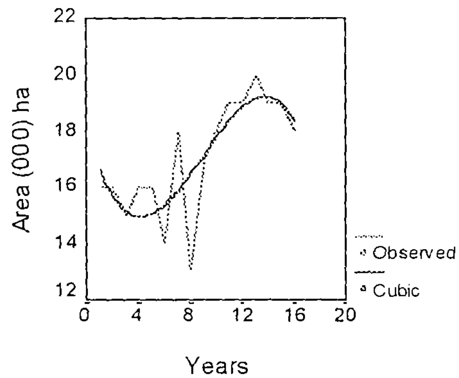
* *Significant at 10 % level of significance*

Fig 11: Graphical form of selected models for land other than Current Fallow in TP_3

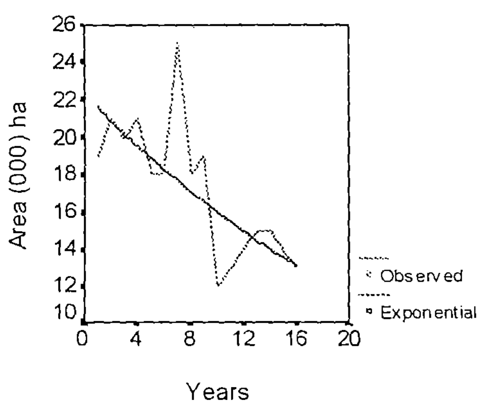
Barmer

□

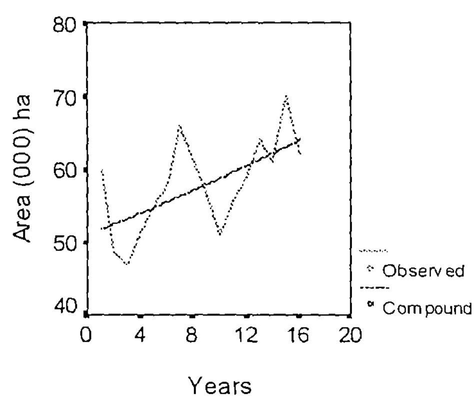
Jhunjhunu



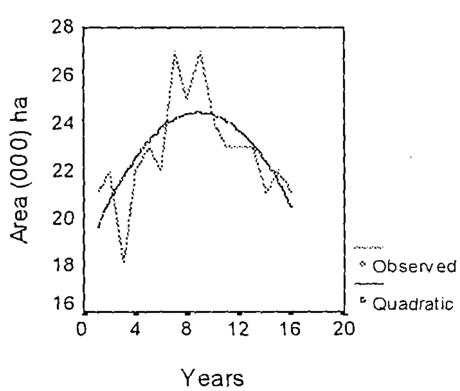
Alwar



Bhilwara



Bundi



Years:- 1981=1,1982=2---------1997=17

□ No model was found statistically significant

Alwar : During the first and second temporal phases cubic models fitted the best. However in the third temporal phase, an exponential model was best fitted.

Bhilwara : As for as Bhilwara is concerned a linear trend was best fitted during first temporal phase for land other than current fallow. Cubic model was best fitted in the second temporal phase. However, in the third phase compound model fitted the best. Hence, it may be noted that the land other than current fallow is increasing at decreasing rate in Bhilwara district in the recent past.

Bundi : In Bundi district for land other than current fallow, quadratic model in the first phase and a power model in the second phase fitted the best. However, in the third temporal phase again the quadratic model was found the best fit. The graphical form reveals that land other than current fallow was on a decreasing pattern in Bundi district.

4.1.7 Trend in Current Fallow Land :

The details of the selected model for the current fallow for three temporal phases are given in Table 4.14 and the graphical forms for third temporal phase are given in Fig.12.

Barmer : As far as current fallow land in Barmer over time is concerned quadratic model was found most befitting during the first temporal phase. In the second and third temporal phases no model was found statistically significant for current fallow land in Barmer district. Which indicates that the pattern of change in the current fallow did not fallow any definite pattern in these temporal phases in Barmer district.

Jhunjhunu : Incidentally none of the models were found statistically significant during the first temporal phase for current fallow land. However, in the second phase compound model was best fitted.

Table 4.14 : Particulars of selected model for trend in current fallow land

Districts	TP_1			TP_2			TP_3		
	Model	R^2	F	Model	R^2	F	Model	R^2	F
Barmer	**Quadratic** $CF_t = 614.63^{***} - 103.24^{***}t + 6.88^{**}t^2$ (76.92) (29.46) (2.39)	0.6908	8.94**	☐			☐		
Jhun-jhunu	☐			**Compound** $CF_t = 10.90^{***} \times 1.0699^{***\,t}$ (1.74) (0.02)	0.5196	12.98***	☐		
Alwar	**Cubic** $CF_t = 7.88^{***} + 1.62\,t - 0.53\,t^2 + 0.04^{*}t^3$ (2.48) (1.71) (0.32) (0.02)	0.7376	6.56**	**Quadratic** $CF_t = 20.96^{**} - 3.70\,t + 0.40^{**}\,t^2$ (8.98) (2.75) (0.18)	0.6180	8.90**	☐		
Bhilwara	☐			☐			☐		
Bundi	**Quadratic** $CF_t = 13.43^{***} - 1.99\,t + 0.28^{**}t^2$ (3.43) (1.31) (0.11)	0.7882	14.88***	☐			☐		

CF_t stands for current fallow land

☐ *No model was found statistically significant*

*** *Significant at 1 % level of significance*

** *Significant at 5 % level of significance*

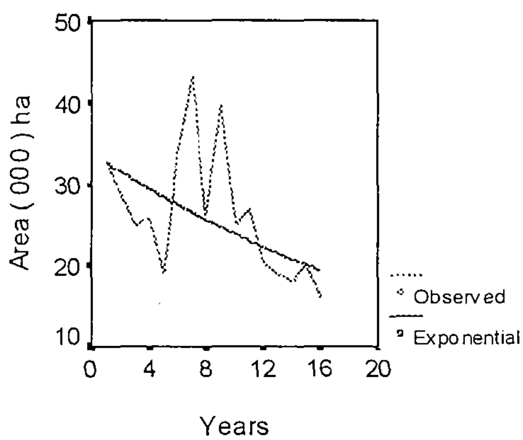
* *Significant at 10 % level of significance*

Fig 12: Graphical form of selected models for Current Fallow land in TP_3

Barmer □

Jhunjhunu □

Alwar



Bhilwara □

Bundi □

Years:- 1981=1,1982=2----------1997=17

□ No model was found statistically significant

Alwar : During the first temporal phase cubic model was best fitted for current fallow land. While in the second phase a quadratic model and in the third phase an exponential model were best fitted. Graphical form of the curve reveals a decreasing pattern of current fallow land in Alwar district.

Bhilwara : Incidently none of the models were found statistically significant during all the three temporal phases for current fallow land in Bhilwara district. It implies the erratic nature of current fallow in this sub-humid region.

Bundi : As far as current fallow in Bundi is concerned a quadratic model was best fitted during the first temporal phase. None of the models were found statistically significant during the second and third temporal phases for current fallow land in Bundi district.

4.1.8 Trends in Net Area Sown :

The detail of the selected models for the net area sown in the three temporal phases are given in Table 4.15 and the graphical forms for third temporal phase are given in fig. 13.

Barmer : In Barmer district, the quadratic model was best fitted for net area sown in the first temporal phase. However, in the second temporal phase the compound model was best fitted. No model was found statistically significant for the third temporal phase for net area sown in Barmer district. The erratic pattern in net sown area in this desertic district may be due to the errate nature of rainfall.

Jhunjhunu : During the first temporal phase cubic model was best fitted for net area sown in Jhunjhunu. While in the second temporal phase a quadratic model was best fitted. None of the models in the third phase was found statistically significant for net area sown in Jhunjhunu district.

Table 4.15 : Particulars of selected model for trend in net area sown

Districts	TP_1			TP_2			TP_3		
	Model	R^2	F	Model	R^2	F	Model	R^2	F
Barmer	**Quadratic** $NAS_t = 993.27^{***} + 85.97^{**} - 5.30^{**} t^2$ (63.50) (24.32) (1.97)	0.7469	11.80***	**Compound** $NAS_t = 949.22^{***} \times 1.04^{***\,t}$ (163.96) (0.02)	0.2102	3.19*	□		
Jhun-jhunu	**Cubic** $NAS_t = 439.38^{***} - 2.65\,t + 0.83^{**}t^2 - 0.05^{***}t^3$ (2.63) (1.82) (0.34) (0.01)	0.8774	16.70***	**Quadratic** $NAS_t = 447.09^{***} + 2.50^{*}t - 0.32^{**}t^2$ (5.50) (1.69) (0.11)	0.7889	20.55***	□		
Alwar	**Quadratic** $NAS_t = 442.45^{***} + 6.13^{***}t - 0.21^{*}t^2$ (3.55) (1.36) (0.11)	0.9478	72.59***	**Quadratic** $NAS_t = 473.36^{***} + 8.09^{**}t + 0.55^{***}t^2$ (8.90) (2.73) (0.18)	0.5718	4.91**	□		
Bhilwara	**Linear** $NAS_t = 211.45^{***} + 4.73^{***}\,t$ (5.40) (0.80)	0.7967	35.26***	□			**Linear** $NAS_t = 300.52^{***} + 4.24^{***}t$ (9.01) (0.93)	0.5964	20.69***
Bundi	Linear $NAS_t = 179.71^{***} + 2.93^{***}t$ (2.55) (0.38)	0.8710	60.77***	□			**Linear** $NAS_t = 231.31^{***} + 1.33^{**}\,t$ (4.01) (0.415)	0.4230	10.26***

NAS_t stands for net area sown

□ *No model was found statistically significant*

*** *Significant at 1 % level of significance*

** *Significant at 5 % level of significance*

* *Significant at 10 % level of significance*

Fig 13: Graphical form of selected models for Net Sown Area in TP_3

Barmer

□

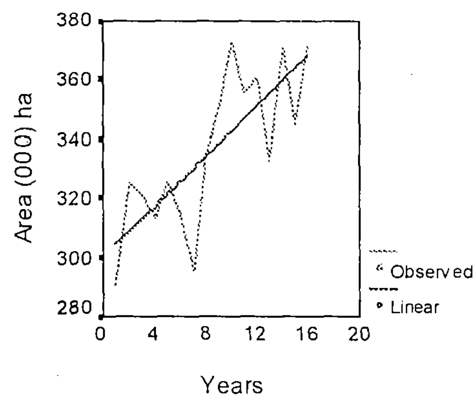
Jhunjhunu

□

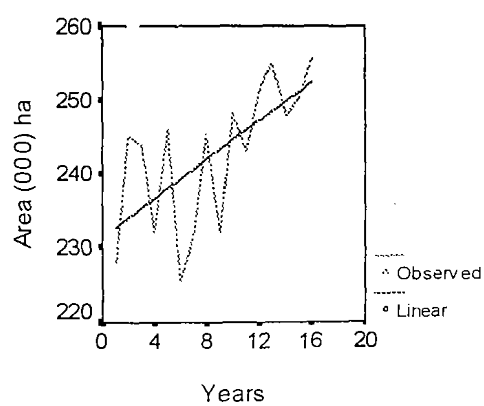
Alwar

□

Bhilwara



Bundi



Years:- 1981=1,1982=2----------1997=17

□ No model was found statistically significant

Alwar : It is noteworthy that the quadratic model was fitted the best during the first and second temporal phases for net area sown in Alwar. In the third temporal phase no model was found statistically significant for net area sown in Alwar district.

Bhilwara : During the first temporal phase a linear model was best fitted for net sown area in this district. While no model was found statistically significant for second temporal phase. Remarkably, in the third phase again a linear trend was found best fit with increasing pattern. Hence it can be concluded that net area sown is continuously increasing at a constant rate in recent years in the sub-humid district.

Bundi : In Bundi district for net area sown linear trend was found best fitted in first phase. None of the model was found statistically significant in second phase. In third phase again a linear trend was best fitted which showed increasing trend. It means net area sown has been increasing at a constant rate over the years in this humid district of Rajasthan.

The temporal trend models found as the best fit for land use class parameters during the three temporal phases are summarised in table 4.16.

Table 4.16 : Selected models of crend at unsolved cases for parameters related to land use classes

S. No.	District	Particulars	Model situations in		
			TP_1	TP_2	TP_3
1.	Forest	Barmer	Cubic	Quadratic	Quadratic
		Jhunjhunu	Cubi	S-model	NSM
		Alwar	NSM	Quadratic	Cubic
		Bhilwara	Cubic	Cubic	Quadratic
		Bundi	Cubic	Cubic	Power
2.	Land put to non-agricultural uses	Barmer	Quadratic	Cubic	Quadratic
		Jhunjhunu	Quadratic	Quadratic	Cubic
		Alwar	Cubic	Cubic	Cubic

S. No.	District	Particulars	Model situations in		
			TP_1	TP_2	TP_3
		Bhilwara	Power	Quadratic	Quadratic
		Bundi	Compound	Cubic	Compound
3.	Barren and uncultur-able waste land	Barmer	NSM	Cubic	Quadratic
		Jhunjhunu	Cubic	Inverse	NSM
		Alwar	NSM	Cubic	Cubic
		Bhilwara	Cubic	Power	Linear
		Bundi	NSM	Cubic	Quadratic
4.	Permanent pastures and other grazing land	Barmer	Cubic	Cubic	Cubic
		Jhunjhunu	NSM	Cubic	Cubic
		Alwar	Compound	Cubic	Cubic
		Bhilwara	Quadratic	Quadratic	NSM
		Bundi	Quadratic	Quadratic	Cubic
5.	Culturable waste land	Barmer	Cubic	Linear	Exponential
		Jhunjhunu	Cubic	Cubic	Cubic
		Alwar	Quadratic	Quadratic	Exponential
		Bhilwara	Compound	Quadratic	Exponential
		Bundi	Compound	NSM	Compound
6.	Land other than current fallow	Barmer	Cubic	Compound	NSM
		Jhunjhunu	Cubic	Compound	Cubic
		Alwar	Cubic	Cubic	Compound
		Bhilwara	Linear	Cubic	Compound
		Bundi	Quadratic	Power	Quadratic
7.	Current fallow land	Barmer	Quadratic	NSM	NSM
		Jhunjhunu	NSM	Compound	NSM
		Alwar	Cubic	Quadratic	Compound
		Bhilwara	NSM	NSM	NSM
		Bundi	Quadratic	NSM	NSM
8.	Net sown area	Barmer	Quadratic	Compound	NSM
		Jhunjhunu	Cubic	Quadratic	NSM
		Alwar	Quadratic	Quadratic	NSM
		Bhilwara	Linear	NSM	Linear
		Bundi	Linear	NSM	Linear

NSM denotes that no model was found statistically significant

4.2 GROWTH RATES OF SELECTED AGRICULTURAL PARAMETERS :

The present study aims to ascertain the growth pattern of parameters of selected crops and land use classes overtime. Growth rate gives a measure of both magnitude and direction of change in parameters of such crops and land use classes.

The compound growth rates were worked out from exponential trend equation of the form,

$$Y = a\,b^t$$

The compound growth rates are worked out using the formula :

$$r = (\text{Antilog } b - 1) \times 100, \quad \text{since} \quad b = 1+r$$

where,

r = compound growth rate

b = regression coefficient of the exponential relationship.

The compound growth rates have been chosen for discussion since performance of agriculture is generally assessed in terms of compound growth rates. The advantage of compound growth models in the interpretation of production of crop vis-a-vis area and yield is quite obvious since the compound growth rate of production equates with the compound growth rate of area and yield approximately, as a result of the mathematical postulation of production as the product of yield and area. The growth rate of area, production and yield of major crops and also of land use classes were computed on the basis of three temporal phases.

Growth Rates in Production of Bajra :

The growth rates of area, production and yield of bajra is presented in Table 4.17.

Table 4.17 : **Compound growth rate of bajra production in selected districts**

Districts	Temporal Phase	Compound growth rates (% per annum)		
		Area	Production	Yield
Barmer	TP_1	2.32	-5.60	-7.39
	TP_2	1.19	38.71	37.94
	TP_3	-0.89	8.08	9.13
Jhunjhunu	TP_1	3.07	6.20	2.91
	TP_2	-0.78	-8.81	-8.81
	TP_3	-0.10	2.17	2.28
Alwar	TP_1	1.10	1.98	1.0
	TP_2	-0.15	1.08	1.17
	TP_3	-0.48	1.70	2.16

When the temporal phase wise pattern is looked into, it could be seen that during first phase (TP_1), the growth in area was highest in Jhunjhunu followed by Barmer and Alwar. The production growth rate of bajra in Jhunjhunu was also highest as compared to Alwar and Barmer. This is mostly due to growth in area of 3.07 per cent per annum and in yield by 2.91 per cent per annum. Both area and yield are responsible for positive production growth of bajra in Jhunjhunu. In Alwar, the production growth was 1.98 per cent per annum which was again due to both area and yield. In Barmer, there was negative growth rate of 5.60 per cent per annum in production of bajra which was mainly due to negative growth in yield to the extent of 7.39 per cent per annum.

It is remarkable to note that during the second temporal phase, the production growth rate in Barmer was very much higher i.e. 38.71 per cent per annum as compared to Alwar and Jhunjhunu. This is mostly attributable to growth in yield i.e. 37.94 per cent per annum in Barmer.

However, in Alwar production growth was 1.08 per cent per annum and it was largely due to positive yield growth. In Jhunjhunu negative growth rate was recorded in production of bajra during TP_2 which was mainly due to negative yield growth during this period.

During the third temporal phase the production of bajra crop was highest in Barmer (8.08 per cent per annum) followed by Jhunjhunu (2.1 per cent per annum) and Alwar (1.70 per cent per annum). The positive production growth rate in Barmer was mainly due to yield growth of 9.13 per cent per annum. In Jhunjhunu and Alwar districts production growth rates were not very high.

It is significant to note that during the temporal phases first, second and third, the positive growth in the production of bajra was mainly due to increase in yield component.

4.2.2 Growth Rates in Production of Maize :

The growth rates of area, production and yield of maize are presented in Table 4.18.

Table 4.18 : Compound growth rate of maize production in selected districts

Districts	Temporal Phase	Compound growth rates (% per annum)		
		Area	Production	Yield
Bhilwara	TP_1	3.38	7.12	3.61
	TP_2	0.45	-0.23	-0.73
	TP_3	1.18	2.78	1.56
Bundi	TP_1	8.73	16.21	6.88
	TP_2	1.89	1.71	0.02
	TP_3	-0.75	2.67	3.45

During the first temporal phase, Bundi district showed highest production growth of 16.21 per cent per annum in maize as compared to

Bhilwara with 7.12 per cent per annum. Both area and yield attributed for the growth in production in both the districts.

During the second temporal phase, the growth rate in production was recorded as 1.71 per cent per annum in Bundi and in Bhilwara a negative growth of 0.23 per cent per annum. In Bundi, the positive growth in production is largely attributable to positive growth in area and in Bhilwara negative growth in production is largely attributable to negative growth in yield during the second temporal phase.

In third temporal phase, Bhilwara had slightly higher growth rate of production which was 2.78 per cent per annum compared to Bundi with 2.67 per cent per annum. In Bhilwara both area growth and yield growth have contributed for the positive growth in production, while in Bundi relatively higher growth in yield was the major factor.

4.2.3 Growth Rates in Production of Rapeseed and Mustard :

The growth rates of area, production and yield of rape seed and mustard is presented in Table 4.19.

Table 4.19 : Compound growth rate of rape seed and mustard production in selected districts

Districts	Temporal Phase	Compound growth rates (% per annum)		
		Area	Production	Yield
Jhunjhunu	TP_1	-4.10	-17.2	-13.66
	TP_2	-1.73	4.67	6.50
	TP_3	13.24	15.68	2.15
Alwar	TP_1	3.04	-1.23	-4.31
	TP_2	-4.78	-4.37	0.50
	TP_3	7.92	8.52	0.54

The temporal phasewise analysis of growth rate indicates that during the first phase negative growth rate in production of rapeseed and mustard was recorded both in Alwar and Jhunjhunu due to drastic negative growth in yield.

In second phase, a positive compound growth rate of 4.67 per cent per annum in production was recorded which was mainly due to yield growth of 6.50 per cent per annum in Jhunjhunu. However, during the same period, a negative production growth rate was recorded in Alwar which was largely due to area effect.

It is remarkable to note that during the third phase very high compound growth rate in production of rape seed and mustard was observed i.e. 15.68 per cent per annum in Jhunjhunu and 8.52 per cent per annum in Alwar. The positive growth in the production is largely attributable to the positive growth in area in both the districts during this temporal phase.

4.2.4 Growth Rate in Production of Wheat :

The growth rates of area, production and yield of wheat are presented in Table 4.20.

Table 4.20 : Compound growth rates of wheat production in selected districts

Districts	Temporal Phase	Compound growth rates (% per annum)		
		Area	Production	Yield
Bhilwara	TP_1	-2.51	-3.26	-1.07
	TP_2	4.52	7.21	1.69
	TP_3	3.89	7.50	3.36
Bundi	TP_1	1.31	1.05	-0.16
	TP_2	1.26	5.54	4.24
	TP_3	1.84	5.70	3.78

In the first temporal phase a positive compound growth rate of 1.05 per cent per annum in production of wheat was recorded in Bundi which was mainly due to area growth of 1.31 per cent per annum while in Bhilwara a negative growth rate of 3.26 per cent per annum in production was recorded during the same temporal phase.

It is significant to note that in second phase Bhilwara emerged with reversed growth scenario for the production of wheat which was mainly due area growth (4.52 per cent per annum) which was supplement by yield growth (1.69 per cent per annum). However, in Bundi the production growth rate was 5.54 per cent per annum which is less than that in Bhilwara district for the same period. But positive production growth in Bundi district is mainly due to positive growth in yield component by 4.24 per cent per annum supplemented by area growth by 1.26 per cent per annum.

For the third temporal phase, the growth rate in production of wheat was not only maintained but slightly improved over the previous temporal phases. Both area growth and yield growth are almost equally attributable in Bhilwara district. In Bundi district too, the production growth in wheat during the third temporal phase was higher than that for second temporal phase. Remarkably, in Bundi district the contribution of yield is much higher to the contribution of area. In the wheat growing districts of Bhilwara and Bundi the production growth rates for wheat are relatively high for which both area and yield have been contributing.

4.2.5 Growth Rates of land use Classes :

The compound growth rates in major land use classes for the three temporal phases are presented in Table 4.21.

Table 4.21 : Growth rates of land use classes in selected Districts

Item of land use	Temporal Phase	Compound growth rates (% per annum)				
		Barmer	Jhunjhunu	Alwar	Bhilwara	Bundi
Forest	TP_1	-2.42	-10.60	-0.14	-3.34	-11.19
	TP_2	2.37	0.29	-1.27	10.78	13.76
	TP_3	2.84	0.73	10.13	1.17	0.69
Land Put to Non-Ag. uses	TP_1	-1.85	4.88	-0.04	1.07	0.39
	TP_2	0.96	4.64	1.41	2.89	2.98
	TP_3	1.01	1.65	-0.26	1.0	0.32
Barren and unculturable land	TP_1	.08	11.09	-0.68	2.58	1.33
	TP_2	1.11	-2.50	-0.77	1.18	-8.02
	TP_3	-0.31	0.73	-0.68	-1.35	-2.20
Permanent pastures and other grazing land	TP_1	7.11	0.12	13.07	3.86	28.75
	TP_2	0.57	-0.24	-4.55	0.75	1.75
	TP_3	-0.28	-0.75	-0.42	.02	-0.35
Culturable waste	TP_1	3.41	-4.88	-6.96	0.97	-6.51
	TP_2	-1.24	-0.38	-5.38	-2.43	0.30
	TP_3	2.27	-1.85	-2.9	-2.49	0.28
Other than current fallow	TP_1	-3.02	-2.95	-4.94	-8.47	-2.54
	TP_2	-4.36	8.48	12.79	-1.60	3.91
	TP_3	0.73	1.72	-3.28	1.41	0.30
Current fallow	TP_1	-5.44	0.28	1.65	0.60	9.21
	TP_2	-2.54	6.99	10.65	2.04	1.83
	TP_3	-0.28	-2.34	-3.83	1.60	-2.32
Net area sown	TP_1	1.84	0.20	0.79	1.97	1.50
	TP_2	3.69	-.51	-0.04	-0.38	0.01
	TP_3	0.48	0.02	0.41	1.28	0.54

During the first temporal phase area under forest recorded negative growth rates of varying magnitudes in all the five districts. However, except for Alwar in all other districts area under forest was found to increase during the second temporal phase. It was as high as 13.76 per cent per annum in Bundi. On the contrary in Jhunjhunu district, the forest area was found increasing marginally at a compound growth rate of 0.29 per cent per annum. In the third temporal phase area under forest recorded a positive growth in all the five districts. However, the growth rates varied from 0.73 per cent per annum in Jhunjhunu to 10.13 per cent per annum in Alwar.

The growth rates of land put to non-agricultural uses revealed that during the first temporal phase there was a positive growth in Jhunjhunu, Bhilwara and Bundi. In Jhunjhunu it was to the tune of 4.88 per cent per annum. Negative growth was observed in Barmer and Alwar districts. During the second phase, positive growth was recorded for area under non-agricultural use in all the five districts. In the third temporal phase, all districts except Alwar recorded positive growth in area under land put to non-agricultural uses. In the districts of Jhunjhunu, Bhilwara and Bundi, positive growth rates in area under non-agricultural use was observed in all the temporal phases.

The phasewise analysis indicated that the barren and unculturable land increased with positive growth in all districts except in Alwar during the first phase. However, in second phase only Barmer and Bhilwara recorded positive growth. During the third temporal phase except Jhunjhunu, all other districts recorded negative growth. The negative growth in barren land during the third temporal phase indicates that barren land was put to other uses during this period.

During the first temporal phase pattern of change in permanent pastures and other grazing land emerged with positive growth in all the five districts. The growth rate in Bundi was the highest which was 28.75 per cent per annum. However in second phase Barmer, Bhilwara and Bundi recorded positive growth while Jhunjhunu and Alwar recorded negative growth in pasture land. In the third temporal phase all districts except Bhilwara recorded negative growth. Even the positive growth in Bhilwara was very meagre and to the tune of 0.02 per cent per annum. Land diverting from grazing land to other purposes is implied during the third temporal phase in all the districts, except Bhilwara.

During the first phase, area under culturable waste land showed positive growth in Barmer i.e. 3.41 per cent per annum and in Bhilwara it was 0.97 per cent per annum. However, in Jhunjhunu, Alwar and Bundi negative growth rates were recorded. In second temporal phase, all the districts except Bundi recorded positive growth rate. A similar situation was seen in the third temporal phase in Jhunjhunu, Alwar and Bhilwara.

The area under land earmarked as old fallow recorded negative growth rates in all the five districts during the first temporal phase. However, during the second temporal phase Alwar recorded the highest positive growth rate of 12.79 per cent per annum compared to 8.48 per cent per annum in Jhunjhunu and 3.91 per cent per annum in Bundi. Negative growth rate in old fallow was seen in Barmer and Bhilwara. In the third temporal phase all districts except Alwar recorded positive growth rates in old fallow land.

Incidently during the first temporal phase all districts except Barmer were found to have positive growth rates in area under current fallow. The highest growth rate was recorded in Bundi which was 9.21 per cent per annum. In the second temporal phase also all districts except Barmer were found to have positive growth rates in current fallow land. During the third temporal phase all districts except Bhilwara recorded negative growth rate in current fallow. Probably, the pressure on land under cultivation makes it necessary to cultivate as much land as possible. Hence, the trend in current fallow is on a decline during the recent past.

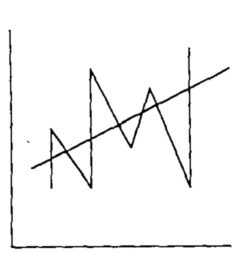
It may be noted that during the temporal phase first, net area sown recorded positive growth rate in all the five districts, though none of the districts showed very high growth rates. During the second temporal phase Barmer recorded positive growth rate of 3.69 per cent per annum and in the other districts either the net area sown normally declined or remained static over the years. Remarkably during the third phase all the districts emerged with positive growth rates in net sown area.

4.3 INSTABILITY MEASURES OF SELECTED AGRICULTURAL PARAMETERS :

Regression analysis as a statistical technique is helpful in comparing the instability measures of agricultural parameters like area, production and yield between of crops and land use classes in different locations. In assessing the performance of agriculture both growth as well as instability measures are equally important. For all the positive parameters high positive growth coupled with low instability is very much warranted. On the contrary for all negative characteristics, negative growth is always a welcome preposition. It is possible to identify the growth vis-a-vis instability scenario for each of the agricultural parameters. The likely scenarios are shown in Fig. 14 (i) Positive growth with low instability, (ii) Positive growth with high instability, (iii) Negative growth with low instability, (iv) Negative growth with high instability, (v) Zero growth with high instability, (vi) Zero growth with low instability.

In this section efforts are made to assess the instability scenarios in area, production and yield of crops as well as land use classes for the

GROWTH VIS-A-VIS INSTABILITY SITUATIONS



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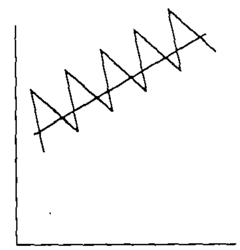

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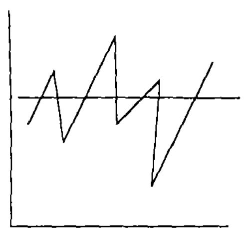

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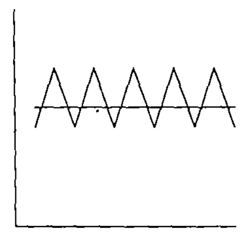

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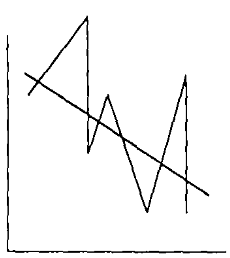

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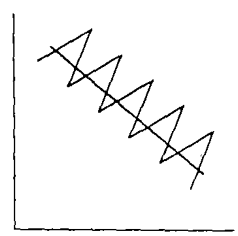

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Fig. No. 14.

selected districts during the last temporal phase. The instability indices for area, production and yield of selected crops in selected districts (wherever linear trend equation was found statistically significant) are given in Table 4.22.

Table 4.22 : Instability indices of crop in TP_3 (1981-1997)

Crop	District	Instability Indicies		
		Area	Production	Yield
Bajra	Barmer	13.73	81.00	80.50
	Jhunjhunu	4.51	54.74	52.08
	Alwar	14.28	43.89	28.73
Maize	Bhilwara	5.91	36.50	38.04
	Bundi	13.84	46.49	35.89
Rapeseed & mustard	Jhunjhunu	35.23	44.19	26.19
	Alwar	14.85	23.31	15.66
Wheat	Bhilwara	26.24	37.78	17.25
	Bundi	10.58	20.88	15.98

As far as area under bajra crop is concerned, Jhunjhunu was found to have least instability. As far as instability in production of bajra is concerned, Barmer, Jhunjhunu and Alwar remained in the descending order of instability magnitude. The instability measure in production of maize was more in Bundi as compared to Bhilwara. The inter district instability in area under maize was more in Bundi and that for yield was more in Bhilwara. Instability measures in area, production and yield of rape seed and mustard was less in Alwar as compared to Jhunjhunu. In case of wheat also Bhilwara was found to have higher magnitude of instability in area, production and yield as compared to Bundi.

The instability indices for land use classes of selected districts are given in Table 4.23.

Table 4.23 : **Instability Indices of Land Utilization Statistics in TP_3 (1981-1996)**

Item of land use	Instability Indices in Districts				
	Barmer	**Jhunjhunu**	**Alwar**	**Bhilwara**	**Bundi**
Forest	8.98	6.76	13.31	1.97	1.77
Land Put to Non-Ag. uses	2.95	3.17	1.85	1.72	3.06
Barren are unculturable land	2.49	19.68	8.11	1.35	2.57
Permanent pastures and other grazing land	1.01	NA	1.62	0.26	2.80
Culturable waste	7.95	9.97	7.31	2.67	0.58
Land other than current fallow	17.19	8.56	14.39	8.69	9.90
Current fallow	59.54	28.59	62.80	9.27	33.08
Net area sown	15.96	1.45	4.04	4.93	4.33

NA not worked out

As far as forest is concerned the highest inter-year instability was recorded in Alwar compared to other selected districts. In case of land put to non-agricultural uses instability measures in Barmer, Jhunjhunu and Bundi was more or less same and remained relatively more. However, in Jhunjhunu very high instability was recorded in area under barren and unculturable land. Among all the districts, Bundi recorded high instability compared to other districts in permanent pastures and other grazing land. As far as culturable waste land is concerned, the districts Jhunjhunu, Barmer and Alwar recorded more instability as compared to Bhilwara and Bundi. Very high instability measure were observed in old fallow land in the districts of Barmer and Alwar followed by Bundi, Bhilwara and Jhunjhunu. Under current fallow land the instability measures were more in Alwar and Barmer districts. The least instability in current fallow was observed in Bhilwara. In Barmer district instability was very high compared to other districts in net sown area.

4.4 GROWTH VIS-A-VIS INSTABILITY IN SELECTED AGRICULTURAL PARAMETERS :

The comparison of growth vis-a-vis instability measures for the agricultural parameters in the selected districts in the third phase helps to examine the growth pattern in relation to instability during the recent period.

The production and yield of bajra in Jhunjhunu district was one with high growth and high instability. Similar is the situation for bajra in Alwar district. For maize production also Bhilwara district emerged with high growth and high instability. However, area under maize in Bhilwara district followed the pattern of moderate growth with less instability. Area under maize in Bundi district was found to have negative growth with more stability. The production and yield of maize in Bundi district emerged with positive growth and high instability. The area, production and yield of rape seed and mustard in Jhunjhunu could be considered as with high growth and high instability. However, in Alwar district area and production of rapeseed and mustard could be considered with one having higher growth and less instability. Wheat production in Bhilwara district is one with more growth and more instability and that in Bundi district with high growth and more stability.

The forest area in Alwar district was found to have high growth rate coupled with high instability. The area under barren land in Jhunjhunu district was one with low growth and high instability. The culturable waste land in Barmer district was increasing with more growth rate and more instability, while that in Bhilwara district was decreasing with stability. The growth of fallow land in Alwar was one with high negative growth and high instability. The current fallow in Alwar and Bundi district was decreasing with high growth and high instability and that for Barmer district was decreasing with low growth and high instability. The nét sown area in Jhunjhunu, Alwar, Bhilwara and Bundi was one with low growth and low instability while that for Barmer was having low growth and relatively high instability.

4.5 PREDICTION OF INSTABILITY IN SELECTED AGRICULTURAL PARAMETERS :

It is possible to ascertain the likely instability pattern in agricultural parameters using the regression techniques when the linear trend equation is statistically significant. The data corresponding to positive and negative error terms can be sorted out. One can rationally assume that the positive errors are due to certain pushing factors and negative errors are due to the effect of pulling factors. The sign and size of the slope and intercept of the two regression lines representing the pulling and pushing factors can be used to assess the likely future pattern of instability. Let

$$Y_+ = a_+ + b_+t$$

be the line representing the pushing factors and

$$Y_- = a_- + b_-t$$

be the line representing the pulling factors

$$\text{then, } t_y = \frac{a_+ - a_-}{b_- - b_+}$$

can be used to assess the pattern of future instability/ stability in the agricultural parameters.

If 't_y' is positive it implies that instability will come down over the years and if 't_y' is negative it implies that instability will increase over the years to come.

The results of the above analysis is given in Table 4.24.

Table 4.24 : Prediction of instability of crop parameters for 3rd phase (1981-1997)

Crop	District	Particulars	Slope		Intercept		$t_y = \frac{a^+ - a^-}{b^- - b^+}$	Nature of trend lines	F-value
			b^+	b^-	a^+	a^-			
Maize	Bhilwara	Area	2.58	5.53	134.97	118.93	5.44	Convergent	9.13***
Rapeseed & mustard	Alwar	Area	18.29	21.70	115.80	37.65	22.92	Convergent	5.07**
		Production	15.39	15.75	131.46	32.0	276.28	Convergent	31.57***
Wheat	Bhilwara	Area	5.65	3.31	88.04	47.07	-17.51	Divergent	50.98***
		Yield	114.27	111.10	1648.0	1137.82	-160.94	Divergent	19.49***
	Bundi	Area	3.93	1.66	83.46	75.34	-3.57	Divergent	27.41***
		Yield	170.78	159.11	1632.4	1400.86	-19.84	Divergent	22.72***

*** *Significant at 1 % level of significance*
** *Significant at 5 % level of significance*

Table 4.25 : Prediction of instability in land use classes for 3rd phase (1981-1996)

Item of land use type	District	Slope		Intercept		$t_y = \frac{a^+ - a^-}{b^- - b^+}$	Nature of trend lines	F-value
		b^+	b^-	a^+	a^-			
Forest	Barmer	0.63	1.47	20.50	14.49	7.19	Convergent	5.44**
	Alwar	5.70	4.23	8.46	6.61	-1.26	Divergent	5.80**
	Bhilwara	1.07	1.60	54.39	52.07	4.38	Convergent	0.32
	Bundi	0.84	4.60	130.56	119.60	2.91	Convergent	4.81**
Land put to non-Ag uses	Barmer	1.08	1.76	65.79	59.56	9.16	Convergent	32.01***
	Jhunjhunu	0.54	0.63	16.21	15.04	13.0	Convergent	3.11
	Alwar	0.15	0.17	44.40	42.60	90.0	Convergent	41.0***
	Bhilwara	1.25	0.61	52.31	54.43	3.31	Convergent	1.72
Barren and unculturable land	Barmer	0.93	0.71	137.43	131.52	-26.86	Divergent	49.59***
	Alwar	5.02	3.31	131.86	132.89	0.60	Convergent	4.01*
	Bhilwara	3.38	5.40	187.67	180.40	3.60	Convergent	5.26**
	Bundi	4.69	1.62	77.07	69.80	-2.37	Divergent	5.54**

Item of land use type	District	Slope		Intercept		$t_y = \frac{a^+ - a^-}{b^- - b^+}$	Nature of trend lines	F-value
		b^+	b^-	a^+	a^-			
Permanent pastures	Barmer	1.37	0.56	217.81	210	-9.64	Divergent	42.33***
	Jhunjhunu	0.56	0.29	46.07	42.33	-13.85	Divergent	4.92**
	Alwar	0.29	0.15	25.86	25.08	-5.57	Divergent	4.06*
	Bundi	0.09	0.08	24.81	23.80	-1.00	Divergent	16.77***
Culturable waste	Barmer	14.21	9.66	350.50	302.39	-10.57	Divergent	22.32***
	Jhunjhunu	0.31	0.18	8.39	7.18	-9.31	Divergent	7.73**
	Alwar	0.88	0.65	17.71	15.57	-9.30	Divergent	3.62*
	Bhilwara	12.54	7.75	231.64	248.29	-3.48	Divergent	2.27
Land other than current fallow	Alwar	1.27	1.25	24.22	21.29	-146.5	Divergent	10.78***
	Bhilwara	1.80	1.53	56.87	46.40	-38.78	Divergent	41.48***
Net area sown	Jhunjhunu	0.44	0.49	15.60	13.80	36.0	Convergent	9.62***
	Bhilwara	6.76	7.91	316.98	286.63	26.39	Convergent	9.20***
	Bundi	1.45	2.46	241.82	221.61	20.01	Convergent	16.22***

*** *Significant at 1 % level of significance*
** *Significant at 5 % level of significance*
* *Significant at 10 % level of significance*

Under the existing situation area under maize in Bhilwara is likely to have less instability in the years to come. It is clear from the table that area and production of rapeseed and mustard in Alwar is also likely to have less instability in coming years. The area and yield of wheat in Bhilwara district is likely to have more instability in years to come. In Bundi district also the area and yield of wheat is likely to have more instability in years to come.

It is evident from Table 4.25 that the instability in forest area in Barmer, Bhilwara and Bundi is likely to come down and that in Alwar is likely to go up. Instability in the case of land put to non-agricultural use will reduce in times to come in Barmer, Jhunjhunu, Alwar and Bhilwara districts. In Barren and unculturable land, Barmer and Bundi districts are likely to have more instability in the years to come, whereas in Alwar and Bhilwara instability is likely to narrow down over time. It is clear from the table that instability in permanent pastures and other grazing land is likely to increase in Barmer, Jhunjhunu, Alwar and Bundi districts. Instability in the case of area under culturable waste is likely to be more in years to come in Barmer, Jhunjhunu, Alwar and Bhilwara districts. The data reveals that instability in land other than current fallow is likely to increase over time in Alwar and Bhilwara districts. The instability in the case of net area sown will decrease in future in Jhunjhunu, Bhilwara and Bundi districts.

4.6 ACREAGE RESPONSE FUNCTIONS :

Acreage response of a crop is largely determined by factors covered under traditional, technological, price and weather related aspects. The area under crop as a response variable can have predictor variables such as one year lagged area (A_{t-1}), one year lagged price of the concerned crop (P_{t-1}), one year lagged price of the competing crop (Pc_{t-1}), ratio of farm harvest price of selected crop to competing crop (Pr_{t-1}), one year lagged yield of concerned crop (Y_{t-1}), one year lagged yield of selected crop to competing crop (Yc_{t-1}), rainfall in the t[th] year (R_t), one year lagged rainfall (R_{t-1}), total irrigated area in the current year (I_t), standard deviation of prices for the preceding three years (Sp_{t-1}) and standard deviation of yield for the preceding three years (Sy_{t-1}) etc.

a) It helps to identify the factors responsible for inter-year/ inter-spatial variation in acreage under crops.
b) It helps to ascertain the magnitude and direction of factors responsible for changes in acreage under a crop.
c) It makes it possible to know the rate of change as well as elasticity of such factors determining the size of acreage under a crop.

The results on the estimated acreage response function in terms of the coefficients with specified variables for the selected crops are discussed in forthcoming sections.

Acreage response for bajra crop :

Acreage response model was estimated in Barmer, Jhunjhunu and Alwar districts keeping area under bajra as a response variable. In the initial run with all explanatory variables included in the model, none of the coefficients were found statistically significant in Barmer district. The estimated model is given in appendix 'A'. In Jhunjhunu district in the initial run with all the explanatory variables included in the model, the coefficients of lagged area of the concerned crop, lagged yield of a crop, lagged yield of a competing crop, relative lagged yield, lagged rainfall, total irrigated area, standard deviation of prices in the preceding three years were found statistically significant. In Alwar district in the initial run with all the explanatory variables included in the model, none of the coefficients were found statistically significant.

Subsequently, the regressions were run using backward elimination method. At the end of the process the finally estimated models are as under

(i) Barmer :

$$A_t = \underset{(93.135)}{1097.457^{***}} - \underset{(0.081)}{0.163^{*}} Pc_{t-1}$$

$$R^2 = 0.224,\ \bar{R}^2 = 0.169,\ F = 4.04^{*},\ \text{Durbin Watson} = 2.863$$

(ii) Jhunjhunu :

$$At = \underset{(44.626)}{403.745^{***}} - \underset{(0.135)}{0.524^{**}} A_{t-1} + \underset{(0.021)}{0.077^{**}} Pc_{t-1} + \underset{(29.032)}{82.669^{**}} Pr_{t-1}$$

$$+ \underset{(0.016)}{0.035^{*}} Y_{t-1} - \underset{(0.020)}{0.073^{**}} Yc_{t-1} - \underset{(8.381)}{35.662^{***}} Yr_{t-1} + \underset{(0.020)}{0.049^{*}} R_t$$

$$+ \underset{(0.040)}{0.238^{***}} R_{t-1} - \underset{(0.281)}{1.944^{***}} I_t + \underset{(0.168)}{1.252^{***}} Sp_{t-1}$$

$$R^2 = 0.923,\ \bar{R}^2 = 0.860,\ F = 10.21^{***},\ \text{Durbin Watson} = 2.351$$

(iii) Alwar :

$$At = \underset{(41.301)}{336.955^{***}} - \underset{(0.200)}{0.808^{**}} A_{t-1} - \underset{(0.060)}{0.126^{***}} P_{t-1}$$

$$R^2 = 0.561,\ \bar{R}^2 = 0.493,\ F = 8.30^{***},\ \text{Durbin Watson} = 2.038$$

Barmer :

The explanatory variable finally retained in the model included only lagged price of competing crop. This variable explained 22.40 per cent variation in the acreage under bajra during the reference period. Lagged price of competing crop was found to have negative association with current year area which is on the expected line. This means the price of competing crop has pulling effect on acreage under bajra.

The long run elasticity coefficient for bajra in Barmer in case of 'lagged price of competing crop' (Pc_{t-1}) was –0.1918 indicating that acreage is inelastic to lagged price of competing crop.

Jhunjhunu :

The finally included variables are lagged area under the crop, lagged price of the competing crop, relative lagged price of the crop, lagged yield of crop, lagged yield of competing crop, relative lagged yield of crop, rainfall, lagged rainfall, total irrigated area and variability in price. These variables explained 92.30 per cent variation in the acreage under bajra during the said period.

In Jhunjhunu district relative price of bajra with sesamum, lagged yield of bajra, current year rainfall and lagged rainfall were found to have positive and significant pushing effect on acreage under bajra. The lagged yield of competing crop of bajra in Jhunjhunu district was found to have negative association with acreage under bajra. However, the sign of coefficients like lagged area, price of competing crop and relative yield of bajra with competing crop were not consistent. The coefficient of total irrigated area with a negative sign is justifiable as access to irrigation goes up the area under bajra is likely to come down. The estimated elasticity coefficients with respect to statistically significant variables are given in Table 4.26.

All the positive elasticity coefficients lied between zero and one. Similarly all the negative elasticity coefficients lied between zero and minus one indicating that acreage is inelastic to any particular factor.

Alwar :

The finally retained variables in the model were lagged area and lagged price of the crop. These two variables explained 56.10 per cent variation in the acreage under bajra during the reference period. Both the variables i.e. lagged area and lagged price of bajra emerged with negative coefficients. The estimated elasticity coefficient for the significant variables are given in Table 4.27.

Table 4.26 : Estimates of elasticity coefficients for acreage response function for bajra in Jhunjhunu district (1981-97)

S.No.	Variables	Estimated elasticity coefficient
1.	Lagged area of crop (A_{t-1})	-0.3451
2.	Lagged price of competing crop (Pc_{t-1})	0.1414
3.	Lagged relative price of crop (Pr_{t-1})	0.0768
4.	Lagged yield of crop (Y_{t-1})	0.0405
5.	Lagged yield of competing crop (Yc_{t-1})	-0.1273
6.	Relative lagged yield of crop (Yr_{t-1})	-0.0685
7.	Current year rainfall (R_t)	0.0514
8.	Lagged rainfall (R_{t-1})	0.2468
9.	Total irrigated area (I_t)	0.4957
10.	Variability in price (Sp_{t-1})	0.0797

Table 4.27 : Estimates of elasticity coefficients for acreage response function for bajra in Alwar district (1981-97)

S.No.	Variables	Estimated elasticity coefficient
1.	Lagged area of crop (Y_{t-1})	-0.4486
2.	Lagged price of crop (P_{t-1})	-0.0883

The elasticity coefficients lied between –1 to 1 indicating that acreage under bajra is inelastic to both the factors.

Acreage response for maize crop :

Maize is an important kharif crop in the south and south eastern part of the state. Acreage response function was estimated in Bhilwara and Bundi districts. Initially, the acreage response function for the period 1981-1997 was run with all the explanatory variables included in the model. The coefficients of lagged area of the concerned crop, lagged price of a crop, lagged price of competing crop, relative lagged price of crop, lagged yield, relative lagged yield of crop, rainfall, irrigation and variability in price and yield were found statistically significant in Bhilwara district. In Bundi district, in initial run with explanatory variables included in the model none of the coefficients were found statistically significant. The estimated model is given in Appendix 'A'.

Using the backward elimination method, the finally estimated models are as follows :

(i) Bhilwara

$$At = \underset{(7.226)}{125.927^{***}} + \underset{(0.029)}{0.082^{**}}P_{t-1}$$

$$R^2 = 0.362,\ \bar{R}^2 = 0.317,\ F = 7.95^{**},\ \text{Durbin Watson} = 1.999$$

(ii) Bundi

$$At = \underset{(11.566)}{86.26^{***}} - \underset{(0.287)}{0.995^{***}}A_{t-1} + \underset{(0.004)}{0.016^{***}}Y_{t-1} + \underset{(0.003)}{0.016^{***}}Yc_{t-1}$$

$$- \underset{(0.004)}{0.011^{***}}R_{t-1} - \underset{(0.061)}{0.317^{***}}I_t - \underset{(0.006)}{0.016^{***}}Sy_{t-1}$$

$$R^2 = 0.827,\ \bar{R}^2 = 0.712,\ F = 7.20^{***},\ \text{Durbin Watson} = 2.366$$

Bhilwara :

The finally retained variable included only lagged price of the concerned crop. This variable explained 36.20 per cent variation in the dependent variable. The positive sign of the coefficient is quite logical in determining the area under maize.

The elasticity coefficient for maize in Bhilwara in case of 'Lagged Price of crop' (P_{t-1}) was 0.1320 which lied between zero and one indicating that acreage is inelastic to lagged price of a crop.

Bundi :

In Bundi district the retained variables included lagged area of the concerned crop, lagged yield of crop, lagged yield of competing crop, lagged rainfall, total irrigated area and variability in yield. These variables jointly explained 82.70 per cent variation in the acreage under maize during the reference period. The variables like lagged yield of crop and lagged yield of competing crop, emerged with positive sign. However, the variables like lagged area of a crop, lagged rainfall, total irrigated area and variability in yield have negative sign which means that these variables have inverse influence on area under maize in Bundi district.

The estimated elasticities of the significant variables are given in Table 4.28.

Table 4.28 : Estimates of elasticity coefficients for acreage response function for maize in Bundi district (1981-97)

S.No.	Variables	Estimated elasticity coefficient
1.	Lagged area of crop (A_{t-1})	-0.5005
2.	Lagged yield of crop (Y_{t-1})	0.2318
3.	Lagged yield of competing crop (Yc_{t-1})	0.5090
4.	Lagged rainfall (R_{t-1})	-0.1149
5.	Total irrigated area (I_t)	-0.8031
6.	Variability in yield (Sy_{t-1})	-0.0696

All the elasticity coefficients lied between −1 and +1 indicating that acreage of maize is inelastic to the factors.

Acreage response for rapeseed and mustard crop :

The acreage response function for rape seed and mustard crop was estimated in Jhunjhunu and Alwar districts. In the initial run, the acreage response function for the period 1981-1997 was run with all the explanatory variables included in the model, the coefficient of lagged rainfall was found statistically significant in Jhunjhunu district.

In case of Alwar, in the initial run, no coefficient was found statistically significant. The estimated models are given in Appendix A.

Subsequently, the regressions were run using backward elimination method. At the end of the process, the finally estimated models are :-

(i) Jhunjhunu

$$
\begin{aligned}
At = & -81.202^{***} + 0.066^{***}P_{t-1} - 0.024^{***}Yc_{t-1} \\
& \quad (5.692) \qquad\quad (0.006) \qquad\qquad (0.006) \\
& + 0.063^{***}R_t + 0.151^{***}R_{t-1} + 0.092^{***}Sy_{t-1} \\
& \quad (0.012) \qquad\quad (0.013) \qquad\qquad (0.025)
\end{aligned}
$$

$R^2 =$ 0.904, $\overline{R}^2 = 0.983$, F = 171.43***, Durbin Watson = 1.716

(ii) Alwar

$$
\begin{aligned}
At = & -67.244^{***} + 0.764^{***}A_{t-1} + 0.085^{***}Y_{t-1} + 0.145^{***}I_t \\
& \quad (29.935) \qquad (0.074) \qquad\qquad (0.036) \qquad\qquad (0.082)
\end{aligned}
$$

$R^2 =$ 0.9740, $\overline{R}^2 = 0.935$, F = 73.32***, Durbin Watson = 2.225

Jhunjhunu :

The finally retained variables included lagged price of a crop, lagged yield of a competing crop, rainfall, lagged rainfall and variability in yield. These variables together explained 90.40 per cent variation in the dependent variable. The variables like lagged price, current year rainfall, lagged rainfall and variability in yield were found to have positive and significant coefficients in determining acreage under rapeseed and mustard, which is theoretically consistent. Similarly the variables such as yield of competing crop was found to have negative association with current year area which is also on the expected line. The elasticity coefficient for the significant variables are given in Table 4.29.

Table 4.29 : Estimates of elasticity coefficients for acreage response function for rapeseed and mustard in Jhunjhunu district (1981-97)

S.No.	Variables	Estimated elasticity coefficient
1.	Lagged price of crop (P_{t-1})	0.9400
2.	Lagged yield of competing crop (Yc_{t-1})	-0.2221
3.	Current year rainfall (R_t)	0.5254
4.	Lagged rainfall (R_{t-1})	1.2128
5.	Variability in yield (Sy_{t-1})	0.2583

All the elasticity coefficient lied between –1 and +1 except lagged for rainfall, indicating that the acreage under mustard is elastic to this particular factor.

Alwar :

The finally retained variables included in the model to explain area allocation were lagged area of crop, lagged yield of crop and current year irrigation. All these variables together explained 99.40 per cent variation in the acreage under rapeseed and mustard during the said period. The coefficients of all these variables emerged with positive sign on the expected lines. The estimated elasticities for the significant variables are given in Table 4.30.

Table 4.30 : Estimates of elasticity coefficients for acreage response function for rapeseed and mustard in Alwar district (1981-97)

S.No.	Variables	Estimated elasticity coefficient
1.	Lagged area of crop (A_{t-1})	2.9949
2.	Lagged yield of crop (Y_{t-1})	1.8931
3.	Total irrigated area in the current year (I_t)	1.0369

Acreage under rapeseed and mustard is positively elastic to lagged area of crop, followed by lagged yield of crop and total irrigated area.

Acreage response for wheat crop :

Wheat is an important rabi cereal crop in the state. Acreage response function was estimated in Bhilwara and Bundi districts. Initially the acreage response function for the period 1981-97 was run with all the explanatory variables included in the model. None of the variables were found statistically significant in both Bhilwara and Bundi districts. The estimated models are given in Appendix 'A'. Using the backward elimination method, the finally estimated models are as follows:

(i) Bhilwara :

$$A_t = \underset{(12.179)}{-20.749^{***}} + \underset{(0.127)}{0.660^{***}}A_{t-1} - \underset{(0.016)}{0.064^{***}}Yc_{t-1} + \underset{(0.012)}{0.103^{***}}R_t$$

$R^2 =$ 0.9090, $\bar{R}^2 = 0.8860$, F = 39.72***, Durbin Watson = 2.374

(ii) Bundi :

$$A_t = \underset{(8.404)}{35.272^{***}} - \underset{(0.004)}{0.011^{***}}Yc_{t-1} + \underset{(0.006)}{0.022^{***}}R_t + \underset{(0.046)}{0.290^{***}}I_t$$

$R^2 =$ 0.8360, $\bar{R}^2 = 0.795$, F = 20.34***, Durbin Watson = 1.400

Bhilwara :

The finally retained variables in assessing the acreage under wheat in this district were lagged area of crop, lagged yield of competing crop and current year rainfall. All these variables contributed 90.90 per cent variation in the dependent variable. The coefficients of explanatory variables like lagged area of crop and current year rainfall emerged with positive sign. While the coefficient of lagged yield of competing crop was found with negative sign, as was found by other researchers.

The estimated elasticity coefficients for the significant variables are given in Table 4.31.

Table 4.31 : Estimates of elasticity coefficients for acreage response function for wheat in Bhilwara district (1981-97)

S.No.	Variables	Estimated elasticity coefficient
1.	Lagged area of crop (A_{t-1})	1.8313
2.	Lagged yield of competing crop (Yc_{t-1})	-0.7882
3.	Current year rainfall (R_t)	2.6434

It could be seen that the acreage under wheat is positively elastic to current year rainfall and one year lagged area of crop.

Bundi :

The finally retained variables included in the model are lagged yield of competing crop, current year rainfall and total irrigated area. All these variables jointly explained 83.60 per cent variation in the area under wheat in Bundi district of the state. The variables like current year rainfall and total irrigation of crop emerged with positive sign which is on the usual pattern. It revealed that more than current year rainfall and irrigated area more will be the area under wheat, while the lagged yield of competing crop was found with negative sign which clearly indicates that yield of competing crop has adverse effect on area under wheat in Bundi district. The elasticity coefficients for the significant variables are given in Table 4.32.

Table 4.32 : Estimates of elasticity coefficients for acreage response function for wheat in Bundi district (1981-97)

S.No.	Variables	Estimated elasticity coefficient
1.	Lagged yield of competing crop (Yc_{t-1})	-0.1166
2.	Current year rainfall (R_t)	0.1726
3.	Total irrigated area (I_t)	0.5544

The elasticity coefficients lied between –1 and +1 indicating that acreage is inelastic to any particular factor.

4.7 COST FUNCTIONS FOR SELECTED CROPS :

Theoretically, the cost of production of a firm/ farm is a function of output and the average cost curve is a U-shaped one, when average cost is regressed as a function of output. As the output increases, the average cost initially decreases and after reaching a limit, the average cost increases due to the reason that the fixed cost component has to be enhanced if output is to be increased beyond the capacity of the existing fixed resources. This proposition is true in agricultural cost curve too, since investment on irrigation structure, farm machines etc. has to be made to realise increased output from the existing land.

Using the farm level data collected in centrally sponsored study on cost of cultivation of principal crops in Rajasthan, efforts were made to estimate the average cost as a function of output of selected crops in quadratic form. Wherever the quadratic form of average cost function was statistically significant, efforts were made to work out the output level at the minimum point of the average cost. The estimated quadratic cost functions, the minimum average cost and the output level at the minimum of the average cost curve for the selected crops in selected district are presented in table 4.33.

The average cost function was statistically significant in the case of rapeseed and mustard in Jhunjhunu and Alwar districts and wheat crop in Bhilwara district. In all other cases, the stipulated U-shaped curve was not statistically significant. Remarkably, for Rapeseed and mustard the average cost reached the minimum point at 17.71 quintals/ hectare in Jhunjhunu district and 16.39 quintals/ hectare in Alwar district. The minimum average cost was Rs. 239.60/ quintals in Jhunjhunu and Rs. 192.56/ quintals in Alwar. For wheat crop, the minimum of average cost

Table 4.33 : Details of estimated cost function (1992-93)

Crop	District	Estimated average cost function	R^2	F-test	Yield level at minimum of average (q/ha)	Minimum average cost
Bajra	Barmer	$C = 365.70^{***} - 188.97\,Q + 38.37\,Q^2$ (88.11) (112.58) (28.92)	0.258	NS	NA	-
	Jhunjhunu	$C = 207.27^{**} - 39.39\,Q + 3.85\,Q^2$ (80.16) (34.31) (3.43)	0.081	NS	NA	-
Maize	Bhilwara	$C = 346.89^{***} - 35.76\,Q + 1.30\,Q^2$ (80.86) (20.86) (1.27)	0.453	NS	NA	-
	Bundi	$C = 128.46^{***} - 2.63\,Q + 0.03\,Q^2$ (24.32) (2.78) (0.07)	0.438	NS	NA	-
Rapeseed & mustard	Jhunjhunu	$C = 1008.22^{***} - 86.79^{***}Q + 2.45^{***}Q^2$ (83.45) (17.87) (0.80)	0.866	32.30***	17.71	239.60
	Alwar	$C = 974.45^{***} - 95.40^{***}Q + 2.91^{**}Q^2$ (143.17) (26.48) (1.11)	0.717	21.52***	16.39	192.56
Wheat	Bhilwara	$C = 516.42^{***} - 37.60^{***}\,Q + 0.94^{***}Q^2$ (62.79) (8.98) (0.30)	0.768	21.47***	20	140.42
	Bundi	$C = 261.47^{**} - 10.17\,Q + 0.16\,Q^2$ (116.27) (7.78) (0.13)	0.123	NS	NA	-

NS = Not Significant
NA = Not Applicable
*** *Significant at 1 % level of significance*
** *Significant at 5 % level of significance*
* *Significant at 10 % level of significance*

was achieved at 20 quintals/ hectare in Bhilwara district the corresponding average cost level is Rs. 140.42/ quintals. To assess the pattern of trend of cost functions the other models were also tried and are given in Appendix B.

4.8 PRODUCTION FUNCTION OF SELECTED CROPS :

Production function is a physical relationship of input and output and is denoted as,

$$Q = f(X_1, X_2, \ldots X_k)$$

Where,

Q = Output in physical form.

X = Input in physical form.

Generally, the following two forms of the production functions are used to assess the efficiency of the production system.

$$Q = b_0 + b_1 X_1 + b_2 X_2 + \ldots + b_k X_k + \varepsilon \qquad \text{(multiple linear)}$$

and $$Q = \beta_0 . X_1^{\beta_1} . X_2^{\beta_2} \cdots X_k^{\beta_k} \varepsilon \qquad \text{(Cobb-Douglas)}$$

The former type of model is additive (multiple linear) in nature whereas the latter one is multiplicative in nature and is known as Cobb-Dougles production function. The b_i's in first model are the partial derivatives of X_i's and gives the rate of change in output due to unit change in the concerned input. The β_i's in the second model stands for the elasticity coefficients i.e.

$$\beta_i\text{'s} = \frac{\delta Q / \delta X_i}{Q / X_i}$$

which measures the ratio of per cent change in output due to one per cent change in input. Keeping the input variables seed, fertilizer, man hours, bullock hours and irrigation charges as explanatory variables (inputs) both the types of production functions were estimated. In the case of Cobb-Dougles form of function the R^2 values were much less than that in the linear multiple model in most of the cases.

The multiple linear production function models of selected crops in selected districts were estimated through backward elimination process and are given in Table 4.34.

The estimated production function model with all input variables are given in Appendix 'C'. In the case of bajra in Barmer, seed was found to have positive and significant coefficient and human labour was found to have negative and significant coefficients. However, in Jhunjhunu human labour was found to have positive and significant coefficients. Hence the current production performance of bajra in Barmer and Jhunjhunu could not be considered as identical. Similarly, for maize crop human labour was having negative coefficient in Bhilwara. In Bundi, only coefficient of bullock labour was found to be positive and significant. The estimated production function for rapeseed and mustard in Jhunjhunu and Alwar revealed that the coefficient of seed is positive in Jhunjhunu whereas negative in Alwar. The other input variables having positive association on the production of rapeseed and mustard in Alwar were fertilizer and human labour. The estimated production function for wheat in Bhilwara and Bundi was found to have identical pattern in the sign of statistically significant coefficients. The fertilizer and human labour were found to have positive impact on production of wheat whereas bullock labour was found to have negative impact in the production of wheat in both the districts.

The elasticity coefficients of the significant input variables for selected crops in selected districts are given in table 4.35.

Human labour for bajra crop in Barmer and Jhunjhunu, bullock labour for maize in Bundi, seed for rapeseed and mustard in Alwar and human labour for wheat in Bhilwara were found elastic to the production of these crops.

Table 4.34 : Details of estimated production function by backward elimination method (1992-93)

Crop	District	Estimated production function	R^2	$\bar{R}^2$	Durbin-Watson
Bajra	Barmer	$Y = 0.513^{*} + 0.240^{***}X_1 - 0.012^{***}X_3$ (0.267) (0.080) (0.002)	0.717	0.684	1.515
	Jhunjhunu	$Y = 1.288 + 0.404^{*}X_1 + 0.0043^{***}X_3$ (0.997) (0.194) (0.001)	0.555	0.495	2.587
Maize	Bhilwara	$Y = 3.86 + 0.011^{**}X_3 - 0.02^{**}X_5$ (2.31) (0.004) (0.009)	0.416	0.338	2.416
	Bundi	$Y = -2.81 + 0.169^{***} X_4$ (0.169) (0.031)	0.695	0.671	1.006
Rapeseed & Mustard	Jhunjhunu	$Y = 2.092 + 1.575^{*}X_1$ (3.233) (0.875)	0.262	0.195	1.416
	Alwar	$Y = 20.097^{***} - 4.711^{***}X_1 + 0.120^{***}X_2 + 0.027^{***}X_3$ (6.558) (1.518) (0.016) (0.007)	0.810	0.775	2.257
Wheat	Bhilwara	$Y = 3.463 + 0.083^{*}X_2 + 0.027^{**}X_3 - 0.036^{**}X_4$ (3.791) (0.042) (0.009) (0.013)	0.645	0.556	1.583
	Bundi	$Y = 12.287^{***} + 0.044^{***}X_2 + 0.018^{***}X_3 - 0.026^{*}X_4$ (3.737) (0.012) (0.005) (0.013)	0.581	0.502	1.701

The variables Y = Yield (q/ha), X_1 = Seed (kg/ha)
X_2 = Fertilizer (kg/ha), X_3 = Man hour (Hrs/ha)
X_4 = Bullock hour (Hrs/ha), X_5 = Irrigation (Rs/ha)
*** Significant at 1 % level of significance
** Significant at 5 % level of significance
* Significant at 10% level of significance

Table 4.35 : Elasticity coefficients derived from production function

Crop	District	Variables	Elasticity
Bajra	Barmer	X_1	0.7446
		X_3	1.3988
	Jhunjhunu	X_1	0.4183
		X_3	1.4943
Maize	Bhilwara	X_3	0.6957
		X_5	0.1572
	Bundi	X_4	1.1385
Rapeseed & Mustard	Jhunjhunu	X_1	0.7412
	Alwar	X_1	1.9884
		X_2	0.3353
		X_3	0.7654
Wheat	Bhilwara	X_2	0.1789
		X_3	1.3935
		X_4	0.7799
	Bundi	X_2	0.2190
		X_3	0.4662
		X_4	0.1258

X_1 = Seed, X_2 = Fertilizer, X_3 = Man hour,

X_4 = Bullock hour, X_5 = Irrigation

4.9 FERTILIZER RESPONSE FUNCTION :

Theoretically as the fertilizer dose increases, the yield is expected to go up but beyond a stage, keeping other inputs like irrigation etc. fixed the yield is likely to fall. In such a situation ideally an inverted U-shaped curve is expected to operate.

The data of agronomic experiments in research stations were to be used to estimate the fertilizer response functions. But when the research scientists were contacted it was informed that normally they do not use doses beyond the recommended one. However, efforts were made to make use of farm level data of centrally sponsored Cost of Cultivation studies for estimating fertilizer response function. Only in the case of wheat in Bundi, the quadratic function having the inverted U-shaped curve were found statistically significant. The estimated fertilizer function is :

$$Q = 10.481^{***} + 0.319^{***}F - 0.001^{***}F^2$$
$$(2.824) \qquad (0.062) \qquad (0.0002)$$

$R^2 = 0.469$, Agronomic optima = 159.50

The optimum production of wheat in Bundi was found at 159.5 kg per hectare of fertilizer in nutrient form.

4.10 TEST OF EQUALITY BETWEEN COEFFICIENTS OBTAINED IN DIFFERENT DISTRICTS

In the analysis of regression models using time series and cross-sectional data there is possibility of getting same type of model for two situations. It can be different temporal phases for the same agricultural parameters for the same location or two different locations for the same agricultural parameters. In most of the cases the type of the model itself changes over time and across regions. In such cases there is no need for testing the equality of the coefficients of the estimated models. However, when the same type of model is found the best fit for two phases of time or for two locations there is a need to test the equality of the coefficients of the model over time or across regions. Normally, the question is asked as whether the two estimated function are significantly different ?'. Referring G.C. Chow's (1960) paper "Tests of Equality between sets of coefficients in two linear regressions", Koutsoyiannis indicated the test procedure as under – Assuming that the estimated models are :

$$Y_1 = b_0 + b_1 X_1$$

$$Y_2 = \beta_0 + \beta_1 X_1$$

Where 'Y' is a linear function of X. The F-test derived by Chow is based on the error sum of squares of the two separate models as well as the same for the 'pooled' data for the two samples. If Σe_1^2 stands for error sum of squares for first sample, Σe_2^2 stands for error sum of squares for second sample and Σe_p^2 stands for error sum of squares for the pooled sample, the F-statistic takes the form

$$F = \frac{[\Sigma e_p^2 - (\Sigma e_1^2 + \Sigma e_2^2)]/k}{(\Sigma e_1^2 + \Sigma e_2^2) / (n_1+n_2-2k)}$$

which follows F distribution with K and $(n_1 + n_2 - 2k)$ degrees of freedom.

The linear models were worked out for area, production and productivity of crops in all the three temporal phases. In only two comparable situations, the linear models were found statistically significant. The equality of coefficients were tested using Chow's test. The null hypothesis is that the two estimated relationships do not differ significantly. The estimated equations are as under :

Crops	Particulars	Districts	Estimated Equations	F-test
Wheat	Area trend	Bundi	Y = 76.29 + 1.78 t	
		Bhilwara	Y = 55.521 + 3.16 t	9.29***
		Pooled	Y = 83.80 + 0.25 t	
	Yield trend	Bundi	Y = 1586.32 + 85.04 t	
		Bhilwara	Y = 1372.67 + 63.66 t	21.93***
		Pooled	Y = 2137.94 + 0.61 t	

In both the cases, the F-value was found highly significant which means that the slope and intercept of the trend lines for area as well as yield of wheat in Bundi and Bhilwara differed significantly. In other words, the slope and intercept of the trend lines in both the districts were not the same.

In the case of production function, the multiple linear regression model was worked out. Only in one situation using backward elimination method in Bhilwara and Bundi for wheat crop, comparable models were found. Again the Chow's test was applied to test the equality of coefficients. The null hypothesis is that the two estimated relationships do not differ significantly. The estimated equations are –

In Bhilwara, $Y = 3.463 + 0.083\ X_2 + 0.027\ X_3 - 0.036\ X_4$

In Bundi, $Y = 12.287 + 0.044\ X_2 + 0.018\ X_3 - 0.026\ X_4$

Pooled, $Y = 5.666 + 0.060\ X_2 + 0.026\ X_3 - 0.037\ X_4$

$F = 17.28^{***}$

Where, Y = yield (qts/ha), X_2 = Fertilizer kg/ha, X_3 = Man hour (hrs/ha), X_4 = Bullock hour (hrs/ha). In this case too, the F-value was found highly significant which implies that the two estimated relationships different significantly in terms of the magnitude of the parameters.

4.11 VIOLATION OF ASSUMPTION ON LINEAR STOCHASTIC REGRESSION MODEL MEASURES

(i) Multicollinearity Problem :

It is a problem due to high linear correlation between explanatory variables. When explanatory variables are perfectly corrected ($r_{xixj} = 1$) the estimation of the regression coefficient becomes indeterminate. If the explanatory variables are highly correlated than the standard errors of the estimated coefficients become large and consequently the estimated coefficients become non-significant.

Klien's criteria of detection of multicollinearity is that if $r^2_{xixj} > R^2_{y.x1\ x2\ ...\ xk}$, then multicollinearity may post harmful effects. Though there are many methods to overcome this problem generally the deletion of less important variable (having low partial correlation coefficient with dependent variable) is preferred. The backward elimination method starts with deletion of that explanatory variable which has the lowest partial correlation and the process is repeated till all the retained explanatory variables are statistically significant.

In the present study multiple regression models were used in estimating the acreage response function as well as the crop production functions. The correlation matrices of the variables are given in Appendix table 'D' for acreage response function models and appendix table 'E' for production function models.

The details of variables retained with statistically significant coefficients and those dropped from all variable model (having multicollinearity with one or the other variables in the case of acreage response function are given in table 4.36. It is evident that in none of the cases those pairs having high correlation between the variables did not appear in any of the models. Either both of such variables have disappeared from the model or atleast one variable is dropped from the finally selected model.

The details of variables retained with statistically significant coefficients and those dropped from all variable model (having multicollinearity with one or the other variables in the case of production function are given in table 4.37. In most of the cases at least one of the explanatory variables from the pairs having high correlation with other variables has been dropped. Thus the backward elimination method could resolve the problem of multicollinearity by dropping less important variables.

Table 4.36 : Detection of multicollinearity and remedial measures through deletion of less important variables in acreage response models

Crop	District	Set of explanatory variable with high correlation coefficient in all variable models	Variables dropped in the backward elimination method	Variables retained the backward elimination method
Bajra	Barmer	P_{t-1} & Pc_{t-1}	P_{t-1}	Pc_{t-1}
		P_{t-1} & I_t	I_t	
	Jhunjhunu	P_{t-1} & I_t	P_{t-1}	A_{t-1}, Pc_{t-1}, Pr_{t-1}, Y_{t-1}, Yc_{t-1}, Yr_{t-1}, R_t, R_{t-1}, I_t, Sp_{t-1}
	Alwar	P_{t-1} & Pc_{t-1}	P_{t-1}	A_{t-1}, P_{t-1}
		P_{t-1} & Y_{t-1}		
Maize	Bhilwara	P_{t-1} & Pc_{t-1}	Pc_{t-1}	P_{t-1}
	Bundi	P_{t-1} & Pc_{t-1}	P_{t-1}, Pc_{t-1}	A_{t-1}, Y_{t-1}, Yc_{t-1}, R_{t-1}, I_t, Sy_{t-1}
		Yr_{t-1} & Y_{t-1}	Yr_{t-1}	
		I_t & P_{t-1}		
		I_t & Pc_{t-1}		
Wheat	Bhilwara	P_{t-1} & Pc_{t-1}	P_{t-1}	A_{t-1}, Yc_{t-1}, R_t
		A_{t-1} & R_{t-1}		
	Bundi	P_{t-1} & Pc_{t-1}	P_{t-1}	Yc_{t-1}, R_t, I_t
		Yr_{t-1} & Yc_{t-1}	Yr_{t-1}	
		I_t & P_{t-1}		
		I_t & Pc_{t-1}	Pc_{t-1}	
Rapeseed & mustard	Jhunjhunu	P_{t-1} & A_{t-1}	A_{t-1}	P_{t-1}, Yc_{t-1}, R_t, R_{t-1}, Sy_{t-1}
		Pc_{t-1} & A_{t-1}		
		Pc_{t-1} & P_{t-1}	Pc_{t-1}	
		I_t & A_{t-1}	I_t	
		I_t & P_{t-1}		
		I_t & Pc_{t-1}		
	Alwar	P_{t-1} & A_{t-1}		A_{t-1}, Y_{t-1}, I_t
		Pc_{t-1} & A_{t-1}		
		Pc_{t-1} & P_{t-1}		
		Yr_{t-1} & Yc_{t-1}		

Note : Definition of variable as given in section 4.6

Table 4.37 : **Detection of multicollinearity and remedial measures through deletion of less important variables in production function**

Crop	District	Set of explanatory variable with high correlation coefficient in all variable models	Variables dropped in the backward elimination method	Variables retained after the backward elimination method
Bajra	Barmer	(X_1, X_3), (X_3, X_4)	X_4	X_1, X_3
	Jhunjhunu	(X_3, X_4)	X_4	X_1, X_3
Maize	Bhilwara	(X_1, X_4), (X_3, X_4) (X_1, X_5) (X_4, X_5)	X_1, X_4	X_3, X_5
	Bundi	(X_1, X_3), (X_1, X_4), (X_3, X_4)	X_1, X_3	X_4
Wheat	Bhilwara	(X_1, X_4), (X_3, X_4), (X_3, X_5), (X_4, X_5)	X_1, X_5	X_2, X_3, X_4
	Bundi	(X_1, X_2), (X_1, X_3) (X_2, X_3), (X_1, X_4) (X_2, X_4), (X_3, X_4) (X_1, X_5), (X_2, X_5) (X_3, X_5), (X_4, X_5)	X_1, X_5	X_2, X_3 X_4
Rapeseed & mustard	Jhunjhunu	(X_1, X_3), (X_3, X_5)	X_3, X_5	X_1
	Alwar	—	—	X_1 X_2 X_3

Note : Definition of variables as given in section 4.8

(ii) Autocorrelation Problem :

The serial independence of the successive values of the error term is an important assumption of OLS method. The violation of this assumption leads to over estimation of variances of OLS estimates and consequently the estimated coefficients may become statistically non-significant.

The presence of autocorrelation is generally detected through Durbin-Watson test

where $d = 2\,(1 - \hat{\rho})$,

where $\hat{\rho}$ is the coefficient of autocorrelation

When d = 2, there is no autocorrelation

d = 0, there is perfect positive autocorrelation

d = 4, there is perfect negative autocorrelation

d = 0-2, there is positive autocorrelation of varying degree

d = 2-4, there is negative autocorrelation of varying degree.

In the case of multiple regression models the calculated value of Durbin – Watson statistics was readily available (from the computer output). In the case of trend models (single explanatory variable case) the autocorrelation coefficient was calculated as under

$$\hat{\rho}_{\varepsilon_t \varepsilon_{t-1}} = \frac{\Sigma \varepsilon_t \varepsilon_{t-1}}{\sqrt{\Sigma \varepsilon^2_t} \cdot \sqrt{\Sigma \varepsilon^2_{t-1}}}$$

where $\varepsilon_t = Y_t - \hat{Y}_t$

The value of $\hat{Y}_t$ was obtained for the finally selected trend models for the period (TP_3) 1981-1997. Using the estimated value of ρ the Durbin – Watson statistic was calculated as

$$d^* = 2(1 - \hat{\rho})$$

then (i) If $d^* < d_L$ there is positive autocorrelation

(ii) If $d^* > 4 - d_L$ there is negative autocorrelation

(iii) If $d_u < d^* < (4 - d_u)$ there is no autocorrelation

(iv) If $d_L < d^* < d_u$ test is inconclusive

or $4 - d_u < d^* < 4 - d_L$ test is inconclusive

The application of transformation of variables which lead to respecification of the model facilitated to overcome the problem autocorrelation related to trend models.

For the multiple linear regression models for acreage response function and production function using backward elimination method the problem of autocorrelation was detected.

The pattern of autocorrelation in the estimated trend models in TP_3, acreage response function and production function are as under :

Positive autocorrelation cases :

Maize area in Bhilwara (1.10), wheat yield in Bhilwara (1.09), land put to non-ag uses in Bhilwara (1.58), net sown area in Bundi (1.08) production function of maize in Bundi (1.01).

Negative autocorrelation cases :

Rapeseed area in Jhunjhunu (2.99) and permanent pasture in Bundi (3.12).

No autocorrelation cases :

Maize yield in Bundi (1.70), wheat area (1.71) and production (1.80) in Bhilwara, wheat area (2.20), production (2.10) and yield (1.51) in Bundi, rapeseed production (1.45) in Jhunjhunu, rapeseed area (1.95) and production (1.75) in Alwar, forest area in Barmer (1.98), Alwar (2.21), Bhilwara (1.60) and Bundi (1.40), land put to non-ag uses in Barmer (1.79), Jhunjhunu (2.01), Alwar (1.96) and Bundi (1.59), barren land in Barmer (2.22), Alwar (1.74), Bhilwara (2.58) and Bundi (1.89), permanent pasture in Barmer (1.73), Jhunjhunu (2.25) and Alwar (1.80), culturable waste land in Barmer (1.48), Jhunjhunu (1.95), Alwar (1.40), Bhilwara (1.83) and Bundi (1.99), other fallow land in Jhunjhunu (1.75), Bhilwara (1.83) and Alwar (1.58), current fallow land in Alwar (1.40), net sown area in Bhilwara (1.75), acreage response of bajra in Alwar (2.04), acreage response of maize in Bhilwara (1.99), acreage response of rapeseed & mustard in Alwar (2.23) and Jhunjhunu (2.59), production function of maize in Bhilwara, production function of rapeseed and mustard in Jhunjhunu (1.42) and Alwar (2.26) and production function of wheat in Bundi (1.70).

Inconclusive cases :

Other fallow land in Bundi (1.11), acreage response of bajra in Barmer (2.86) and Jhunjhunu (2.35) acreage response of maize in Bundi (2.37) acreage response of rapeseed and mustard in Jhunjhunu (1.72), acreage response of wheat in Bhilwara (2.37) and Bundi (1.40), production function of Bajra in Barmer (1.52) and production function of wheat in Bhilwara (1.58).

Note : Figures in parentheses denotes d values*

Thus in most of the cases where transformation of the variable was applied the problem of autocorrelation was resolved. In few cases positive autocorrelation, in one or two cases negative autocorrelation was observed. There were some cases which remained inconclusive.

(iii) Heteroscedasticity :

The violation of the assumption of constant variance of the error term in the model over all explanatory variables leads to the problem of heteroscedastic disturbances. Due to this problem the test of significance of the regression coefficients becomes inapplicable since the standard error of the coefficient involve the value of variance of the error term. The minimum variance property of the OLS estimates is also not fulfilled due to this problem. The tests like Goldfield and Qnandt test, Glejser test are used to detect the problem. The theoretically suggested remedial measures include the transformation of the original model in such a way that the transformed disturbance term has constant variance. In the present study the assumption of constant variance of the error term was treated as valid as has been done by most of the researchers.

5. SUMMARY AND CONCLUSION

5.1 IMPORTANCE OF THE STUDY :

During the planned era of agricultural development, the strategic approach persuade for agricultural development included evolution of agricultural technology, devising of effective input delivery system including extension services, establishment of a wide range of institutional set up and also the policy intervention by the government so as to ensure the accelerated growth of the sector. These strategies did pay rich divident to the agricultural sector of the country. However, the rate of growth has not been uniform across different regions of the country. Even for a state like Rajasthan the diversified agro-climatic features resulted in imbalances in the growth and development of agricultural sector. Therefore, the performance of agricultural parameters across the agro-climatic regions and over the years is a topic of paramount importance.

The present study is an attempt for the assessment of inter-regional performance of agricultural parameters over the years using regression models. It is possible to apply regression techniques for analysing pattern of temporal trend, growth rates, instability measures of agricultural parameters etc. Besides it would be possible to identify factors responding to acreage allocation under various crops using regression analysis. The estimation of cost function, production function, fertilizer function etc. using cross-sectional data may provide meaningful inferences leading to policy directives for development of agricultural sector.

The mathematical manipulations of the estimated coefficient of the best possible regression model makes it possible to make use of the regression analysis for forecasting, policy interventions, prediction and a host of other purposes. Since, sustainable development of agriculture has become the need of the hour, it is important to assess the performance of crucial agricultural parameters on regional basis.

5.2 OBJECTIVES :

The specific objectives stipulated for the present study are as under :

(i) To deal with the problem of model specification in the context of growth, instability, input response, acreage response and agricultural production of selected crops in selected agricultural situations.

(ii) To ascertain the goodness of fit of estimated regression models for growth, instability, acreage response and agricultural production of selected crops in selected districts;

(iii) To test the equality of estimated coefficients of the regression model between comparable situations,

(iv) To identify the problems due to violation of assumptions of error term in the estimation of regression models using ordinary least squares method and

(v) To apply the remedial measures to overcome the identified problems.

5.3 METHODOLOGICAL APPROACH :

The spatial coverage of the study included the five macro zones delineated for the implementation of National Agricultural Research Project (NARP) during early eighties in Rajasthan. One district each was selected from each of the zones making the total number of selected districts to five. The selected districts are (i) Barmer from zone I, (ii) Jhunjhunu from zone II, (iii) Alwar from zone III, (iv) Bhilwara from zone IV and (v) Bundi from zone V. The coverage of the whole district in a particular zone and non-bifurcation of the selected districts over the years were the basis for selecting these districts. The study parameters included area, production and productivity of the most important one kharif crop as well as most important one rabi crop of the selected districts. Besides, the nine land use classes were also considered for temporal analysis. In order to make the time series analysis more meaningful three temporal phases viz., TP_1 (1956-57 to 1966-67), TP_2 (1967-68 to 1980-81), and TP_3 (1981-82 to 1996-97) were considered. The required data were collected from the published/ secondary sources.

The best model for temporal trend of the selected parameters was identified from amongst the standard models such as linear, power, compound, exponential, logarithmic, quadratic, cubic, inverse and S-model type by taking into consideration the value of coefficient of determination (R^2), the overall significance of the estimated regression model as evidenced through F-test and also the statistical significance of the individual coefficients using t-test. The compound growth rates were worked out from the compound model of the type : $Y_t = b_0 \, b_1^t$, where $b_1 = 1 + r$, 'r' being the compound growth rate per annum. The instability index was worked out using the value of coefficient of determination of linear trend equation (wherever such trend equations were found significant) and also the corresponding values of coefficient of variation of the concerned parameter. Using the slope and intercept of trend lines corresponding to positive and negative error values, the pattern of future instability was also predicted.

The acreage response function was estimated using the time series data in respect of acreage under selected crops (A_t) in selected districts as a function of one year lagged area (A_{t-1}), one year lagged prices of the concerned crop (P_{t-1}), one year lagged prices of the competing crop (Pc_{t-1}), ratio of farm harvest price of selected crops to competing crops (Pr_{t-1}), one year lagged yield of concerned crop (Y_{t-1}), one year lagged yield of the next competing crop (Yc_{t-1}), ratio of lagged yield of selected crop to competing crop (Yc_{t-1}) rainfall in the current year t^{th} year (R_t), one year lagged rainfall (R_{t-1}), total irrigated area in the year (I_t), standard deviation of prices for the preceding three years (Sp_{t-1}), standard deviation of yield for the preceding three years (Sy_{t-1}) etc. Multiple linear model with 'A_t' as response variable and the above twelve factors as explanatory/ predictor variables were estimated initially and the refined final model was arrived at using the backward elimination method of estimation.

Using the farm level data of selected farmers of the selected region for the crop year 1992-93 collected under centrally sponsored cost of cultivation studies in Rajasthan the production function, cost function as well as fertilizer response function were estimated for each of the selected crops. The multiple linear and Cobb-Douglas form of production function were estimated. The average cost function was estimated using cost of production as quadratic function of output (U-shaped curve) which is considered as theoretically consistent. Similarly for fertilizer response function also was estimated as quadratic equation (inverted U-shaped). The overall goodness of fit was adjudged in terms of the value of coefficient of determination (R^2), the overall significance of the regression using the ANOVA in regression and also on the basis of statistical significance of individual coefficients.

All the estimated models in its final form were used to assess the inter-regional performance of selected agricultural parameters. The sign and size of the regression coefficients and also the finally accepted graphical form of the curves were the basis for adjudging the performance of selected agricultural parameters in different regions.

In most of the cases area, production and yield of the same crop were studied in two districts. Wherever linear models were found statistically significant in both the districts the equality of estimated coefficients between districts was tested using F-statistic on the lines suggested by Chow. The possible problems like multicollinearity, and autocorrelation in the OLS method of estimation were assessed and the remedial measures wherever possible were incorporated during the course of the analysis.

The temporal data on area, production and productivity of bajra crop failed to satisfy any of the functional forms indicating wide inter-year fluctuations which are irregular in nature in all the three districts representing the zones I, II and III. Out of the two districts considered for the maize crop, the area under maize was found increasing in a linear fashion in Bhilwara district during the third temporal phase. In the first and second temporal phases too increasing trend in area could be visualized. The yield of maize crop in Bundi was found increasing at decreasing rate during the recent past. The definite temporal trend pattern in area, production and yield of wheat crop in all the three temporal phases in Bundi and Bhilwara was obvious since one or the other form of the models was found the best fit. Remarkably, during the recent past (TP_3), increasing trend in area, production and yield with varying rate of change could be visualized. In Jhunjhunu district, during the recent past, the area and production of rapeseed and mustard have been increasing on a similar fashion following quadratic form of trend equation, indicating that the rape seed and mustard production in Jhunjhunu is more governed by the area component. Different pattern of inter-temporal trend in area under mustard was evident. The production of rapeseed and mustard in Alwar district during the recent past indicated increasing trend in production during the later part of the temporal phase and the same situation in area was also observed which implies that the increase in production was due to increase in area.

As far as forest area is concerned increasing trend in the third temporal phase in Alwar, Bhilwara and Bundi is evident, while in Barmer it has been decreasing after reaching a peak. The land put to non-agricultural use during the later part of third temporal phase was found with increasing trend in all the selected districts which shows diversion of more land for purposes like houses, building, road etc. On the expected lines, the barren and unculturable waste land has been decreasing in districts like Alwar, Bhilwara and Bundi. However, the same in Barmer was found increasing in the later part of TP_3.The fall in permanent pasture and grazing land in Barmer, Jhunjhunu, Alwar and Bundi was evident. The culturable waste land has been decreasing in exponential fashion in Barmer, Alwar and Bhilwara while the culturable waste land in Jhunjhunu district followed a cubic form of equation with increase in later part of TP_3. In Bundi the quadratic form of trend pattern showed a decline in culturable waste land towards the later part of TP_3.The old fallow land was found with different pattern in different districts–cubic in Jhunjhunu, exponential (negative) in Alwar, compound in Bhilwara and quadratic in Bundi. The net sown area in Bhilwara and Bundi was found increasing on a linear fashion.

The absence of appropriate land use planning strategy is quiet evident in all the five selected districts. It is necessary to establish appropriate balance between various land use classes for establishing balanced eco-system Rajasthan.

Area instability in bajra was maximum in Jhunjhunu and yield of bajra was most stable in Alwar district. Yield of maize was found more stable in Bundi as compared to Bhilwara district whereas area under maize was more stable in Bhilwara. For area, production and yield of rapeseed and mustard, Alwar faired better over Jhunjhunu. Similarly for wheat, instability in area, production and yield was more in Bhilwara as compared to Bundi.

Forest area was found with more stability in Bundi. The land use classes like land put to non-agricultural uses, permanent pastures were found to have more temporal consistency in all the districts. The current fallow land was found to have maximum instability in Alwar and maximum stability in Bhilwara. Similarly the net sown area showed the highest instability in Barmer district.

The production of bajra in Jhunjhunu and Alwar and maize in Bhilwara was having high growth coupled with high instability. The decline in area under maize in Bundi was more stable. High growth coupled with high instability in area, production and yield of rapeseed and mustard in Jhunjhunu district was observed. On the other hand high growth coupled with stability could be observed in Alwar district in area and production of rapeseed and mustard. Wheat production in Bhilwara district was having high growth and high instability and that in Bundi was having high growth and more stability.

The forest area in Alwar district was found to have high growth and high instability. The barren land in Jhunjhunu was having low growth with high instability. The culturable waste land in Barmer was having high growth and high instability. The fallow land in Alwar was decreasing over the years with high instability. The net sown area in Barmer district was found to have low growth but high inter-year instability.

The analysis of futuristic pattern of instability revealed that area under maize in Bhilwara, area and production of rapeseed and mustard in Alwar are likely to stabilize over the years whereas area and yield of wheat in Bhilwara is likely to have more instability in future. Similarly, area and yield of wheat is likely to have more instability in Bundi district.

The instability in the forest area in Barmer, Bhilwara and Bundi is likely to come down and that in Alwar is expected to go up. There is likelihood for land put to non-agricultural uses to stabilize in the years to come. The likely increase in the instability of barren and uncultivated land in Barmer and Bundi was noticed. The instability is likely to increase in Barmer, Jhunjhunu, Alwar and Bhilwara in the case of culturable waste land. The increased instability in old fallow land in Alwar and Bhilwara districts and the increased stability in the net sown area in Jhunjhunu, Bhilwara and Bundi districts also emerge from the analysis. The pattern of future instability/ stability in the land use classes is indicative of the need to have systematic land use planning in Rajasthan so as to ensure sustainability in the agricultural sector.

The area under bajra in Barmer district was found to have pulling effect from prices of sesamum which is the competing crop of bajra. The one year lagged area of bajra was found to have negative association with current year (t^{th}) area under bajra in Jhunjhunu and Alwar. It implies that a good bajra area year is followed by a bad bajra area year in these two districts. In Jhunjhunu district the negative sign for the coefficient of total irrigated area implies that as the irrigated area goes up bajra area comes down. This could be attributable to the replacement of kharif cereal bajra by other crops to meet the food and fodder security consideration. All the explanatory variables in the acreage response function of bajra in all the selected districts were found to be inelastic.

Only lagged prices of maize appeared as a significant variable in deciding the acreage of maize in Bhilwara district, whereas, the acreage under maize in Bundi is determined by the factors such as lagged area and yield of maize, lagged yield of competing crop, lagged rainfall, total irrigated area and variability in yield.

The factors responding to acreage under rapeseed and mustard in Jhunjhunu included one year lagged price, one year lagged yield of competing crop, current year rainfall, one year lagged rainfall and variability in yield, whereas, the explanatory factors responsible for acreage under mustard in Alwar included one year lagged area, one year lagged yield and current year irrigated area. In Jhunjhunu district price, technological and weather factors have significant influence in determining area under rapeseed and mustard. The contributing factors in the area allocation under rapeseed and mustard in Jhunjhunu and Alwar were different.

The performance of crop sector in terms of acreage under crop was found to be influenced by different factors in different regions. In Alwar district acreage under rapeseed and mustard was found to be elastic to lagged area of crop, lagged yield of crop and irrigated area in long run.

Theoretically postulated U-shaped average cost functions could be found significant only in the case of rapeseed and mustard crop in Jhunjhunu and Alwar districts and for wheat crop in Bhilwara district as far as cost efficiency is concerned Alwar is more efficient over Jhunjhunu for rapeseed and mustard crop.

The production performance of selected crops in selected district through production function approach keeping same set of input variables revealed that in most of the cases, the predictor variables (inputs) attributable to the production performance are different. The input seed of bajra was found to have positive association of production in both Barmer and Jhunjhunu. The human labour was found to have negative association with bajra in Barmer but positive association for bajra in Jhunjhunu. In the case of maize in Bhilwara, the use of human labour is positively associated with production, whereas irrigation is negatively associated with production. In the case of rapeseed and mustard, its production is positively associated with seed in Jhunjhunu district. The production of rapeseed and mustard in Alwar district is positively associated with fertilizer and human labour and negatively associated with the seed rate. In both Bhilwara and Bundi, the input variables accounting for production were found to have same sign. Fertilizer and human labour were having positive association whereas bullock labour was found to have negative association with production of wheat in both the districts.

The optimum production of wheat in Bundi was found at 159.5 kg per hectare of fertilizer application in nutrient form.

The performance of most of the agricultural parameters was assessed using regression models, each for at least two districts. In most of the cases, the best model selected varied between districts for the same parameter however in the case of area and yield of wheat in Bundi and Bhilwara districts, same type of linear models were found significant. The F-test conducted for testing the equality of coefficients between districts revealed that the slope and intercept between the districts were not the same. The production function of wheat in Bhilwara and Bundi were similar in terms of the type of input variables as well as the sign of its coefficients. However, the test of significance for equality of coefficients revealed that the coefficients differed between districts. The dropping of variables through backward elimination process helped to overcome the problem of multicollinearty to a great extent. Similarly, the transformation of time variable and respecification of trend models helped to overcome the problem of autocorrelation.

5.4 CONCLUSIONS :

(1) In most of the cases for agricultural parameters, different type of trend models could be found significant in the three temporal phases indicating that the pattern of performance of agricultural parameters over the temporal phases has been different in the state. It also indicates the varying pattern of responsiveness to different plans and programmes launched for the development of agricultural sector.

(2) The lack of fit of any of the trend models for agricultural parameters like area, yield and production of rainfed crops particularly bajra is conclusive of erratic responsiveness over time by these agricultural parameters.

(3) In the case of maize, one or the other model was found significant in the first temporal phase in Bhilwara and Bundi to explain the trend pattern of area, production and yield. However in the third temporal phase except for area in Bhilwara and yield in Bundi, in all other cases no model was found significant indicating irregular pattern for maize crop parameters.

(4) During the third temporal phase declining trend of forest area in Barmer, increasing trend of land put to non-agricultural uses in all the five districts, the declining trend for pasture and grazing land in all the districts during the latter part of the third temporal phase, the increasing trend of fallow land in Bhilwara, the irregular pattern of current fallow land in all the five districts, the erratic pattern of net sown area in Barmer and increasing trend in net sown area in all other districts warrant the seed to have regular land use planning strategy for the state to make the natural resource base more strong for the sustainable development of agricultural sector.

(5) During the third temporal phase, the production growth of bajra in Barmer, Jhunjhunu and Alwar, that of maize in Bundi and that of

wheat in Bhilwara and Bundi through yield growth indicates the positive role of agricultural technology in enhancing the production of these crops in these area. However, the growth in production achieved largely through area component for rapeseed and mustard indicates that the production growth achieved for mustard in Rajasthan was at the cost of other crops. Mostly the higher prices could be the season for such large area substitution in favour of mustard crop.

(6) The production and yield of bajra were prone to high inter-year instability, but area was relatively stable in bajra growing districts of Barmer, Jhunjhunu and Alwar.

(7) The production and yield of maize also were prone to high inter-year instability, but area was more stable in the maize growing districts of Bhilwara and Bundi.

(8) For rabi crops like wheat and mustard, the inter-year production instability is attributable to both area and yield instability. For mustard, area instability in Jhunjhunu and for wheat area instability in Bhilwara were found higher over yield instability.

(9) Relatively, the inter-year instability was not very high in various land use class in all the selected districts. Among various land use classes, the inter-year instability was more for current fallow followed by old fallow in all the selected districts.

(10) Production of bajra in Jhunjhunu and maize and wheat in Bhilwara emerged with high growth and more inter-year instability during the third temporal phase. The area, production and yield of mustard emerged with high growth coupled with high instability. All such cases warrant strategies to minimize inter-year instability. It is all the more important since area and yield of wheat in Bhilwara and Bundi are likely to have more instability in the years to come, other factors remaining the same.

(11) In land use classes like barren land, pasture land, culturable waste land, fallow land etc. inter-year instability measures are expected to further widen.

(12) More predictability could be visualized in acreage under rabi crops through factors attributable to it in rabi crops. However, such consistency could not be observed in the case of kharif crop.

(13) Alwar district was found more cost efficient for R&M Crop as compared to Jhunjhunu.

(14) Human labour for bajra crop in Barmer and Jhunjhunu (through labour intensive operations), bullock labour for maize in Bundi for such operations like well irrigation using bullock power), seed for rapeseed and mustard in Alwar and human labour for wheat in Bhilwara were found elastic for the production of these crops.

(15) The peak yield of 36 qt/ha for wheat in Bundi was obtainable at fertilizer dose (nutrient form) of 159.5 kg/ha.

(16) Even in such cases where same type of trend equations (linear) was found significant for area and yield of wheat in Bundi and Bhilwara, the slope and intercepts were found significantly different between the two districts. In the case of production function of wheat in Bhilv.ara and Bundi, the coefficients of estimated model with same set of explanatory variables differed significantly.

(17) The problem of autocorrelation could be detected through autocorrelation coefficient/ Durbin-Watson test and could be resolved through transformation of variables and respecification in the case of trend models. Similarly, the problem of multicollinearity could be detected through Klein's criteria and eliminated through deletion of unimportant variable applying backward elimination method of estimation.

LITERATURE CITED

Acharya, S.S. (1989). "Socio-Economic Impact of 1987 Draught in Rajasthan", Project Report, Department of Agricultural Economics, Rajasthan College of Agriculture, Udaipur pp1-195.

Acharya, S.S. and Agarwal, N.L. (1976). "Supply Response and Growth Rate of Commercial Crops. A case study of Rajasthan", The Economic Times, Bombay, Vol. 16, July 29 pp5-8.

Acharya, S.S. and Varghese, K.A. (1991). "Structure of Cost and Cost Function in Crop Farming", Final report of ICAR Adhoc Scheme taken up in the Department of Agricultural Economics, Rajasthan College of Agriculture, Udaipur pp1-182.

Bartlett, M.S. (1937). "Properties of Sufficiency and Statistical tests," Proceedings of the Royal Society, A., 160, 318-335.

Bandopadhyay, A. (1989). "Growth and instability in the production of main crops : West Bengal, Punjab and Haryana, 1950-51 to 1985-86, a note", Indian Journal of Agricultural Economics, 44(2) pp168-176.

Barla, C.S. (1989). "Constraints to Agricultural Development in Rajasthan", paper published in the Edited book by Ashok Bapna on "Development of Rajasthan Challenges and Response", Published by Society of International Development (SID), Rajasthan Chapter, Jaipur, pp. 194-213.

Bastine, C. Latha and Palanisami, K. (1994). "An analysis of Growth trend of Principal crops in Kerala", Agricultural Situation of India, Vol. XLVIII(K) pp. 885.

Bhatia, M.S. (1981). "Statewise variations in Growth of Food-grain Production in India", Agricultural Situation in India, August,1981 (XXXVI) pp379-384.

Box, G.E.P. (1966). "Use and Abuse of Regression," Technometrics, 8, 625-629.

Box, G.E.P. and Hunter, W.G. (1962). "A Useful Method for Model – Building" Technometrics, Vol. 4, No. 3, Aug. (1962) pp. 301-318.

Brown, B.W. (1970). "Simple Comparisons of Simultaneous Regression lines", Biometrics, Vol. 26, pp. 143-144.

Chow, G.C. (1960). "Tests of Equality between sets of coefficients in two Linear Regressions", Econometrica, vol. 28, pp. 591-605.

Chowdhary, S. and Sain, K. (1986). Fertilizer use as a means of Capital formation in agriculture, Indian Journal of Agril. Economics, 41(4), pp. 511-512.

Cobb, C.W. and Dougles, P.H. (1928). "A theory of Production". American Economic Review, Vol. 18 (March Supplement) : 139. Reprinted in Heady E.O. and J.L. Dhillon (1988), Op. cit.

Croxton F.E. and Cowden D.J. (1965). "Applied General Statistics", Sir Issac Pitman & Sons Ltd. London.

Cuddy and Della, V. (1978). "Measuring the instability of time series data", Oxford Bulletin of Economics and Statistics, Feb., 1978.

Cuming, J.T. (1975). "The Supply responsiveness of Indian Farmers in the Post Independence Period. Major Cereals and Cash Crops", Indian Journal of Agricultural Economics, Vol. XXX(1) pp. 25-40.

Draper, N.R. & Smith, H. (1981). Applied Regression Analysis, John Wiley & Sons.

Durbin J. and Watson G.S., (1951) "Testing for Serial Correlation in Least-squares Regression", Biometrika, Vol. 37, pp. 409-428 and Vol. 38, pp. 159-178.

Ezckjel, M. and Fox, K.A. (1967). "Method of Correlation and Regression Analysis – Linear and Curvilinear," John Wiley and Sons.

Flinn, J.C. and Shabyn, P.B. (1985). "A Tobit Analysis of the Adoption and Use Rates of Fertilizer on Wheat in Eastern Tarai of Nepal", Indian Journal of Agril. Economics, 11(3) pp. 52-57.

Glejser, H. (1969). "A New Test for Heteroscedasticity", Journal of the American Statistical Association, Vol. 64, pp. 316-23.

Goldfield, S.M. and Quandt, R.E. (1965). "Some tests for Homo-scedasticity", Journal of the American Statistical Association, vol. 60, pp. 539-47.

Gujarati, D. (1978). "Basic Econometrics", Mc-Graw Hill Kogakusha, Ltd.

Gunst, R.F. and Mason, R.L. (1980). "Regression Analysis and its Application", A Data-Oriented Approach, New York, Marcel Dekker.

Hedyat, A. and Robson, D.S. (1970). "Independent Stepwise Residuals for testing Homoscedasticity", Journal of the American Statistical Association, Vol. 65, pp. 1573-1581.

Intriligator, M.D. (1978). "Econometric Models, Techniques, and Applications", Prentice-Hall of India, New Delhi.

Jeeba,(1994). "Zonal Analysis of Agricultural Growth and Instability in Rajasthan", Ph.D. thesis, Department of Agricultural Economics, Rajasthan College of Agriculture, Udaipur.

Jha, B.K. (1994). "Growth and instability in Agriculture Associated with New Agricultural Technology–District level Evidence", Agricultural Situation in India, Vol. XLIX(7) pp. 517-520.

Jhala, M.L. (1979). "Farmer's Response to Economic Incentives : An Analysis of Inter-regional Groundnut Supply Response in India", Indian Journal of Agricultural Economics, Vol. XXXIV(1) pp55-67.

Kalla, J.C. (1989). "New Thrust to Agrarian Development in Desert". Paper Published in the Edited book by Ashok Bapna on "Development of Rajasthan Challenges and Response", Published by Society of International Development (SID), Rajasthan Chapter, Jaipur, pp.179-185.

Kennedy, W.J. and Bancroft, T.A. (1971). "Model building for prediction in regression based upon repeated significance tests", Annals of Mathematical Statistics, Vol. 42, No. 4 pp. 1273-1284.

Klein, L.R.(1976). "A Textbook of Econometrics", Printice Hall of India, New Delhi.

Kleinbagum, D.G. and Kupper, L.L. (1978). " Applied Regression Analysis and Other Multivariable Methods", Duxbury Press.

Kontsoyiannis, A. (1977). "Theory of Econometrics", McMillan Press Ltd.

Kumar, B.V. (1959). "Economic Aspects of Fertilization", Indian Journal of Agril. Economics, 14(1), pp. 68-72.

Kumpawat, B.S. (1995). "Effectiveness of Price and Technology in the production of major Crops in Rajasthan", Ph.D. thesis, Department of Agricultural Economics, Rajasthan College of Agriculture, Udaipur.

Kvalseth, T.O. (1985). "Cautionary Note About R^2", The American Statistician, Nov.Vol. 39, No. 4 (Pl-I), pp.279-285.

Lal, S.K. (1989). "Growth and Area Response of Rapeseed and Mustard", Agricultural situation in India, Vol. XLIV(7) pp. 577.

Liu Shu-ing, (1996). "Model selection for multi-period forecasts." Biometrika Vol. 83(4) pp861-873.

Mendenhall, W. and Mc Clave, J.T. (1981). "A Second Course in Business Statistics : Regression Analysis," Dellea Publishing Company Sen Francisco.

Minhas, B.S. and Vaidyanathan, A. (1965). "Growth of crop output in India 1951-54 to 1958-61 : An analysis by component elements", Journal of the Indian Society of Agricultural Statistics, 18(2), pp. 230-252.

Montgomercy, D.C. & Peck, E.A. (1982). "Introduction to Linear Regression Analysis", John Wiley & Sons.

Narula, D.D. (1989). "A Note on Agricultural Development of Rajasthan – Some Policy Issues" paper published in the Edited book by Ashok Bapna on "Development of Rajasthan Challenges and Response", Published by Society of International Development (SID), Rajasthan Chapter, Jaipur, pp. 186-193.

Nerlove M. (1956), "Estimates of Elasticities of Supply of Selected Agricultural Commodities", Journal of Farm Economics, vol. 38.

Patel, G.N. and Agarwal, N.L. (1994). "Growth and instability in Production of Groundnut in Saurashtra Region of Gujrat", Agricultural Situation in India, Vol. XLIX(1) pp. 171-175.

Rao, B.C. (1989). "Fertilizer Use on Groundnut in Andhra Pradesh an Analysis of Associated Factors", Agricultural Situation in India, 43(12) pp. 1017-1021.

Rao, C.R. (1973). "Linear Statistical Inference and its Applications", 2nd ed. New York : Wiley.

Rathore, B.S. and Varghese, K.A. (1982). "Agro-Climatic Regions and Agricultural Production in Rajasthan Research Bulletin, Department of Agricultural Economics, Rajasthan College of Agriculture, Udaipur, pp. 1-68.

Rathore, B.S. and Varghese, K.A. (1982). "Farm Production in Rajasthan – A regional Analysis", Research bulletin, Department of Agricultural Economics, Rajasthan College of Agriculture, Udaipur, pp. 1-95.

Rawlings, J.O. (1988). "Applied Regression Analysis", A research Tool wads Worth & Brooks/Cole, Statistical probability series.

Ray, S.K. (1981). "Weather, prices and fluctuations in Agril. Production", Indian Economic Review, 16(4), pp. 251-278.

Seber, G.A.F. (1977). "Linear Regression Analysis", New York, John Wiley & Sons.

Seber, G.A. and Wild, C.J. (1989). "Nonlinear Regression," Wiley Series in Probability and Mathematical Statistics.

Sen, S.R. (1967). "Growth and Instability in Indian Agriculture", Journal of the Indian Society of Agricultural Statistics, (19) pp. 1-25.

Sharma, P.M. and Rathore, B.S. (1980). "Long term prospects of Agricultural Growth in Rajasthan. An aggrative approach", Indian Journal of Agricultural Economics 35(4) pp. 30.

Sharma, P.M. and Varghese, K.A. (1995). "Pilot-Study on Cost of Cultivation of Rabi Crops in Rajasthan (1994-95) Research report of the state sponsored study by the Department of Agricultural Economics, Rajasthan College of Agriculture, Udaipur, pp. 1-72.

Sharma, S.K., Sharma, H.R. and Sharma, R.K. (1989). "Trends in Area, Production and Yield of Commercial crops in Indian Agricultural with special Reference to Oilseeds", Agricultural Situation in India, Vol. XLIV(7) pp. 581.

Shriniwasan, T.N. (1979). "Trends in Agriculture in India 1949-50 to 1977-78", Economic and Political Weekly, 14 (30,31 & 32) special August.

Sidhu, D.S. and kaul, J.L. (1971). "Acreage Response to Prices for Major Crops in Punjab: An Economic Study", Indian Journal of Agricultural Economic, Vol. XXVI(4) pp. 427.

Singh, B.K. and Sharma, J.S. (1984). "Economical Optimal fertilizer requirements for wheat and paddy crops in different regions of Uttar Pradesh", Indian Journal of Agril. Economics, 39(4) pp. 639-648.

Singh, C. and Zilberman D. (1984). "Allocation of Fertilizer Among Crops Under Risk – A Quadratic Programming Approach," Indian Journal of Agricultural Economics, 39(1) pp. 77-84.

Sutradhar, B.C. (1996). "Score Test versus Bartlett type Modified Test For Testing Homogeneity of variances with Autocorrelated Errors," Sankhya : The Indian Journal of Statistics Vol. 58, Series B, Pt I, pp.10-27.

Tomar, B.S. (1989). "Growth of Area, Production and productivity of important crops in Haryana", Agricultural Situation of India, Vol XLIV(1) pp. 13.

Vaidyanathan, A. (1977a). "Performance and prospects of crop production in India", Economic and Political Weekly. 12 No. (33 & 34). Special August.

Vaidyanathan, A. (1977b). "Constraints on growth and policy options", Economic and Political Weekly, 12 No. 51 Dec. 17.

Varghese, K.A. (1999). "Disparities in Agricultural and Demographic Features Across Agro-climatic Regions in Rajasthan", Paper published in the Edited book on 'Rajasthan Ecology, Culture and Society' by M.K. Bhasin and Veena Bhasin and published by Kamla Raj Enterprises, pp. 85-91.

Varghese, K.A. and Yadav, D.P. (1993). "Inter Temporal Growth, Instability and Acreage response of major oilseeds crops in Rajasthan", Indian Journal of Agricultural Economics, Vol. 48(3) pp. 440.

Wetherill, G.B. (1986). "Regression Analysis with Applications", Chapman and Hall.

ABSTRACT

Application of Regression Models to Assess the Inter-Regional Performance of Agriculture in Rajasthan

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The thesis entitled "**Application of Regression Models to Assess the Inter-Regional Performance of Agriculture in Rajasthan**" has been an attempt to enlist spatial and temporal pattern of performances of selected agricultural parameters. The districts of Barmer, Jhunjhunu, Alwar, Bhilwara and Bundi represented five distinct agro-climatic region of Rajasthan. The period 1956-1966, 1967-1980 and 1981-1997 represented the three specific temporal phases of agricultural significance. The area, production and yield of bajra, maize, wheat, rapeseed and mustard and also the nine land use classes of these districts were the major agricultural parameters included for the study. The analytical aspects like temporal trend, growth rates, instability, acreage response functions, production functions, cost functions, fertilizer response functions etc. were covered.

The changes in the best fit trend models for the same agricultural parameters across regions and over the time indicate shifting pattern of performance of the selected agricultural parameters according to different plans and programmes launched for agricultural development in the past. The lack of fit of any models to describe the trend pattern of rainfed crops like bajra and maize shows the irregular responsiveness of such crops in the past. It shows that strategic approach is needed to

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regularize the production performance of rainfed crops in Rajasthan. This is all the more important since three fourth of agriculture in the state is taken-up under rainfed condition.

The declining trend of forest area in Barmer, increasing trend of land put to non-agricultural uses and pasture land in all the five selected districts, the increasing trend of fallow land in Bhilwara and the irregular pattern of net sown area in Bhilwara call for regular land use planning strategy in Rajasthan to make the agricultural development a sustainable one.

The increased production of crops like bajra, maize and wheat could be attributable to impact of agricultural technology and that for rapeseed and mustard is attributable to area substitution from other crops. High inter-year instability was noticed in production and yield of bajra and maize. The area growth in these crops was more stable. The inter-year production instability in wheat and mustard is attributable to both area component and yield component. The land use classes, other than fallow land, was found more stable over the time in most of the regions.

Area and yield of wheat in Bhilwara and Bundi are likely to have more instability in the years to come. Similarly, barren land, pasture land, culturable waste land and fallow land are expected to have mere instability in the years to come. The acreage under rabi crops were found more predictable in terms of yield related technological factors, price related policy dimensions and rainfall and other weather related factors.

Bundi district was found more cost-effective for the production of maize. Human labour input for bajra in Barmer and Jhunjhunu and seed input for mustard in Alwar and human labour input for wheat in Bhilwara were found more elastic for the production of these crops in these districts. The highest yield of wheat attainable in Bundi was 36 Qt/ha with 160 kg/ha of fertilizers.

The varying responsiveness by agricultural parameters across regions and overtime was quite obvious from the results.

सारांश

राजस्थान में कृषि के अंतर-क्षेत्रीय प्रदर्शन के आकलन हेतु प्रतीपगमन निदर्शों का अनुप्रयोग

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"राजस्थान में कृषि के अंतर–क्षेत्रीय प्रदर्शन के आकलन हेतु प्रतीपगमन निदर्शों का अनुप्रयोग" शीर्षकीय शोध चयनित कृषि के स्थानिक एवं कालिक प्रतिरूप के प्रदर्शन को सूचीबद्ध करने का एक प्रयास था। बाड़मेर, झुंझुनू, अलवर, भीलवाड़ा एवं बूंदी जिलों ने राजस्थान के पांच विभिन्न कृषि–जलवायु क्षेत्रों का प्रतिनिधित्व किया। कृषि सार्थकता के तीन विशिष्ट कालिक प्रावस्थाओं का निरूपण, काल 1956–1966, 1967–1980 व 1981–1997 ने किया। बाजरा, मक्का, गेहूं, तारामीरा एवं सरसों के क्षेत्र, उत्पादन व उपज तथा चयनित जिलों के नौ भूमि उपयोग वर्ग अध्ययन के मुख्यकृषि के रूप में सम्मिलित किये गये। कालिक प्रवृति, वृद्धिदर, अस्थिरता, एकड़नाम, प्रतिवचन फलन, उत्पादन फलन, मूल्य फलन, उर्वरक प्रतिवचन फलन आदि विश्लेषित अभिमुखताओं के अंतर्गत थे।

क्षेत्र एवं काल पर समान कृषि के श्रेष्ठतम आसंजन प्रवृति निदर्श में परिवर्तन पूर्व में कृषि विकास के लिए क्रियान्वित विभिन्न योजनाओं व कार्यक्रमों के अनुरूप चयनित कृषि के प्रदर्शन का विस्थापन प्रतिरूप इंगित करता है। वर्षापोषित फसलों जैसे बाजरा व मक्का के प्रवृति प्रतिरूप की संख्या में किसी निदर्श का आसंजन अभाव पूर्व में इन फसलों की अनियमित प्रतिवचनता को प्रदर्शित करता है। यह राजस्थान में वर्षापोषित फसलों के उत्पादन प्रदर्शन को नियमित करने का नीतिगत उपगमन दर्शाता है। यह इसलिए अधिक महत्त्वपूर्ण है क्योंकि राज्य में तीन चौथाई कृषि, वर्षा पोषित स्थिति में की जाती है।

बाड़मेर में वनक्षेत्र की ह्रासमान प्रवृति, सभी पांच चयनित जिलों में भूमि की गैरकृषि उपयोग व चारागाह भूमि की बढ़ती हुई प्रवृति, भीलवाड़ा में बंजर भूमि की बढ़ती हुई प्रवृति तथा भीलवाड़ा में शुद्ध बुवाई क्षेत्र का अनियमित प्रतिरूप राजस्थान में सतत् कृषि विकास के लिए नियमित भूमि उपयोग योजना नीति की आवश्यकता बताता है।

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बाजरा, मक्का व गेहूं की फसलों के उत्पादन में बढ़त को कृषि तकनीक के प्रभाव के रूप में देखा जा सकता है एवं तारामीरा व सरसों में उत्पादन बढ़त दूसरी फसलों से क्षेत्र प्रतिस्थापन के कारण है। बाजरा एवं मक्का के उत्पादन व उपज में उच्च अंतर वार्षिक अस्थिरता देखी गयी। इन फसलों में वृद्धि अधिक स्थिर थी। गेहूं व सरसों में अन्तरवार्षिक उत्पादन अस्थिरता, क्षेत्र घटक एवं उपज घटक दोनों के कारण हैं। अधिकांश क्षेत्रों में बंजर भूमि के अलावा भूमि उपयोग वर्ग कालांतर में अधिक स्थिर पाया गया।

भीलवाड़ा एवं बूंदी में गेहूं के क्षेत्र व उपज में आने वाले वर्षों में अधिक अस्थिरता हो सकती है। इसी तरह अनुपजाऊ भूमि, चारागाह भूमि, संवर्धन योग्य पड़त भूमि व ऊसर भूमि में आने वाले वर्षों में अस्थिरता अपेक्षित है। रबी फसलों के एकड़नाप का उपज सम्बंधित तकनीकी कारकों, मूल्य संबन्धित नीति आयामों, वर्षा एवं अन्य मौसम सम्बंधी कारकों के संदर्भ में अधिक पूर्वानुमान लगाया जा सकता है।

मक्का के उत्पादन में बूंदी जिला अधिक मूल्य प्रभावी पाया गया। बाड़मेर व झुंझुनू में बाजरा में मानव श्रम निवेश एवं अलवर में सरसों में बीज निवेश तथा भीलवाड़ा में गेहूं में मानव श्रम निवेश इन फसलों के उत्पादन में अधिक लचीले पाये गये। बूंदी में गेहूं की उच्चतम उपज 36 क्विंटल प्रति हेक्टेयर 160 किलो प्रति हेक्टेयर उर्वरकों के साथ थी।

परिणामों से क्षेत्रों एवं समय पर कृषि की परिवर्ती प्रतिवचनता स्पष्ट दिखती है।

APPENDICES

Appendix A
Acreage Response Models for all variables

Crop	District	Competing Crop	Model	R^2
Bajra	Barmer	Sesamum	$A_t = 2268.78 - 0.167A_{t-1} + 1.55\,P_{t-1} - 1.48Pc_{t-1} - 3361.20\,Pr_{t-1} - 1.134\,Y_{t-1} + 2.88Yc_{t-1} + 13.66Yr_{t-1}$ (1012.03) (0.41) (3.43) (1.16) (3878.41) (1.05) (1.29) (10.60) $- 0.29R_t - 0.05R_{t-1} + 8.44I_t + 9.21Sp_{t-1} + 1.08Sy_{t-1}$ (0.37) (0.78) (5.79) (9.06) (2.06)	0.815
	Jhunjhunu	Rapeseed & Mustard	$A_t = 445.809^{***} - 0.598^{**}A_{t-1} - 0.01P_{t-1} + 0.053Pc_{t-1} + 62.265Pr_{t-1} + 0.050^{*}Y_{t-1} - 0.09^{**}Yc_{t-1}$ (76.67) (0.178) (0.133) (0.052) (69.703) (0.018) (0.02) $+ 0.056R_t + 0.196^{**}R_{t-1} - 1.695^{***}I_{t-1} + 1.524^{***}Sp_{t-1} - 0.041Sy_{t-1} - 39.110^{***}Yr_{t-1}$ (0.025) (0.044) (0.286) (0.216) (0.023) (8.00)	0.978
	Alwar	Rapeseed & Mustard	$A_t = 634.071 - 1.268A_{t-1} - 0.070P_{t-1} - 0.105Pc_{t-1} + 5.571Pr_{t-1} + 0.371Y_{t-1} - 0.367\,Yc_{t-1} - 281.224Yr_{t-1}$ (608.124) (0.649) (0.726) (0.240) (427.336) (0.637) (0.697) (475.414) $+ 0.011R_t - 0.025R_{t-1} + 0.319I_t + 1.46Sp_{t-1} + 0.04Sy_{t-1}$ (0.057) (0.075) (0.422) (0.830) (0.165)	0.825
Maize	Bhilwara	Jowar	$A_t = -\,564.533^{**} - 1.440^{***}A_{t-1} - 3.666^{**}P_{t-1} + 4.528^{**}Pc_{t-1} + 708.719^{**}Pr_{t-1} + 0.048^{**}Y_{t-1}$ (173.003) (0.227) (0.908) (1.088) (164.283) (0.011) $-\,0.074Yc_{t-1} - 3.447^{*}Yr_{t-1} - 0.107^{**}R_t + 0.011R_{t-1} + 0.585^{***}I_t - 0.980^{**}Sp_{t-1} + 0.034^{**}Sy_{t-1}$ (0.035) (1.221) (0.019) (0.016) (0.085) (0.306) (0.008)	0.977
	Bundi	Wheat	$A_t = 140.206 - 1.129A_{t-1} + 0.166P_{t-1} - 0.119Pc_{t-1} - 40.638Pr_{t-1} + 0.027Y_{t-1} + 0.010Yc_{t-1}$ (69.962) (0.623) (0.263) (0.154) (87.03) (0.028) (0.007) $-14.262Yr_{t-1} - 0.003R_t - 0.013R_{t-1} - 0.366I_t - 0.024Sp_{t-1} - 0.018Sy_{t-1}$ (31.768) (0.004) (0.012) (0.297) (0.258) (0.010)	0.941

Crop	District	Competing Crop	Model	R^2
Wheat	Bhilwara	Jowar	$A_t= -2.329+0.661A_{t-1}+0.298P_{t-1}-0.429Pc_{t-1}-22.760Pr_{t-1}+0.010Y_{t-1}-0.052Yc_{t-1}$ (185.21) (0.591) (0.508) (0.796) (111.850) (0.018) (0.072) $+0.086Yr_{t-1}+0.076R_t-0.017R_{t-1}+0.165I_t-0.145Sp_{t-1}-0.012Sy_{t-1}$ =(0.443) (0.039) (0.063) (0.187) (0.446) (0.057)	0.949
	Bundi	Maize	$A_t=42.162-0.083A_{t-1}+0.129P_{t-1}-0.132Pc_{t-1}-3.604Pr_{t-1}-0.011Y_{t-1}-0.024Yc_{t-1}$ (59.706) (0.444) (0.214) (0.288) (60.534) (0.013) (0.019) $-0.673Yr_{t-1}+0.024R_t+0.018R_{t-1}+0.447I_t-0.060Sp_{t-1}-0.006Sy_{t-1}$ (5.96) (0.011) (0.023) (0.220) (0.099) (0.028)	0.935
Rapeseed & mustard	Jhunjhunu	Bajra	$A_t=-60.069+0.366A_{t-1}+0.068P_{t-1}-0.102Pc_{t-1}-0.558Pr_{t-1}-0.009Y_{t-1}-0.025Yc_{t-1}$ (62.910) (0.322) (0.110) (0.299) (20.785) (0.018) (0.020) $0.754Yr_{t-1}+0.061R_t-0.145^*R_{t-1}-0.049I_t+0.024Sp_{t-1}+0.077Sy_{t-1}$ (2.933) (0.028) (0.61) (0.478) (0.063) (0.044)	0.933
	Alwar	Gram	$A_t=22.133+0.983A_{t-1}+0.015P_{t-1}-0.119Pc_{t-1}-37.919Pr_{t-1}+0.116Y_{t-1}-0.088Yc_{t-1}$ (474.84) (0.741) (0.389) (0.284) (179.279) (0.061) (0.085) $-38.067Yr_{t-1}-0.008R_t+0.009R_{t-1}+0.343I_t+0.039Sp_{t-1}+0.129Sy_{t-1}$ (45.23) (0.103) (0.062) (0.393) (0.239) (0.235)	0.981

*** *Significant at 1 % level of significance*
** *Significant at 5 % level of significance*
* *Significant at 10% level of significance*

Appendix B
Particulars of best selected models in estimating cost function (1992-93)

Crop	District	Selected model	R^2	F
Bajra	Barmer	**Inverse** C = 99.207** + 111.80**/Q (40.98) (43.20)	0.271	6.70**
	Jhunjhunu	□		
Maize	Bhilwara	**Compound** C = 291.75*** x 0.9149*** Q (59.50) (0.02)	0.465	13.92***
	Bundi	**Linear** C = 120.63*** - 1.62*** Q (11.76) (0.52)	0.431	9.87***
Rapeseed & Mustard	Jhunjhunu	**Quadratic** C = 1008.22*** - 86.79*** Q + 2.45 Q^2 (83.45) (17.87) (0.80)	0.866	32.30***
	Alwar	**Inverse** C = 32.41** + 2775.40***/Q (12.58) (362.14)	0.765	58.74***
Wheat	Bhilwara	**Quadratic** C = 516.42*** - 37.60*** Q + 0.94*** Q^2 (62.79) (8.98) (0.30)	0.768	21.47***
	Bundi	□		

□ *No model was found statistically significant*
*** *Significant at 1 % level of significance*
** *Significant at 5 % level of significance*
* *Significant at 10 % level of significance*

Appendix C
Details of estimated production function for all variables (1992-93)

Crop	District	Estimated production function	R^2
Bajra	Barmer	$Y = 0.506^{***} - 0.232^{***}X_1 + 0.009X_3 + 0.021^{*}X_4$ (0.260) (0.078) (0.003) (0.010)	0.749
	Jhunjhunu	$Y = 1.25 + 0.402\ X_1 + 0.004\ X_3 + 0.004\ X_4$ (1.07) (0.201) (0.003) (0.032)	0.565
Maize	Bhilwara	$Y = 6.89 - 0.103\ X_1 + 0.013\ X_3 - 0.014\ X_4 - 0.014\ X_5$ (5.43) (0.168) (0.108) (0.034) (0.024)	0.433
	Bundi	$Y = 1.28 - 0.03\ X_1 - 0.013\ X_3 + 0.225\ X_4$ (7.49) (1.38) (0.31) (0.064)	0.721
Rapeseed & Mustard	Jhunjhunu	$Y = -5.89 + 2.245^{**}X_1 - 0.014\ X_3 + 0.054\ X_4 - 0.006\ X_5$ (7.14) (0.930) (0.012) (0.398) (0.005)	0.529
	Alwar	$Y = 22.233^{***} - 4.883^{***}X_1 + 0.107\ X_2 + 0.027\ X_3 - 0.004\ X_5$ (6.537) (1.477) (0.018) (0.006) (0.003)	0.833
Wheat	Bhilwara	$Y = -1.932 + 0.038\ X_1 + 0.081\ X_2 + 0.025^{**}X_3 - 0.031\ X_4 + 0.001\ X_5$ (12.239) (0.084) (0.048) (0.011) (0.020) (0.010)	0.653
	Bundi	$Y = -20.260 + 0.107\ X_1 + 0.050^{**}X_2 + 0.017^{***}X_3 - 0.028^{*}X_4 + 0.271^{*}X_5$ (30.254) (0.122) (0.017) (0.006) (0.014) (0.264)	0.614

The variables Y = Yield (q/ha), X_1 = Seed (kg/ha)
X_2 = Fertilizer (kg/ha), X_3 = Man hour (Hrs/ha)
X_4 = Bullock hour (Hrs/ha), X_5 = Irrigation (Rs/ha)
*** *Significant at 1 % level of significance*
** *Significant at 5 % level of significance*
* *Significant at 10% level of significance*

APPENDIX D

Zero order correlation matrix of selected variables in the estimation of acreage response function of Bajra in Barmer

	A_t	A_{t-1}	P_{t-1}	Pc_{t-1}	Pr_{t-1}	Y_{t-1}	Yc_{t-1}	Yr_{t-1}	R_t	R_{t-1}	I_t	Sp_{t-1}	Sp_{t-1}
A_t	1	-0.302	-0.425	-0.473	0.015	-0.241	-0.121	-0.080	0.024	-0.171	-0.186	-0.214	-0.291
A_{t-1}		1	-0.138	-0.201	0.205	0.227	0.061	0.446	-0.022	-0.049	-0.315	-0.234	-0.291
P_{t-1}			1	0.932**	0.419	0.213	0.483	-0.107	0.265	0.478	0.864**	0.642**	0.351
Pc_{t-1}				1	0.080	0.223	0.492	-0.110	0.178	0.496	0.748**	0.739**	0.380
Pr_{t-1}					1	0.32	0.150	0.012	0.253	0.120	0.471	-0.009	-0.028
Y_{t-1}						1	0.727**	-0.064	-0.053	0.720**	-0.067	0.213	-0.130
Yc_{t-1}							1	-0.384	0.201	0.576*	0.237	0.270	0.117
Yr_{t-1}								1	0.144	-0.170	-0.166	0.001	-0.476
R_t									1	-0.138	0.408	0.149	-0.198
R_{t-1}										1	0.192	0.685**	0.101
I_t											1	0.429	0.261
Sp_{t-1}												1	0.048
Sy_{t-1}													1

Zero order correlation matrix of selected variables in the estimation of acreage response function of Bajra in Jhunjhunu (1981-97)

	A_t	A_{t-1}	P_{t-1}	Pc_{t-1}	Pr_{t-1}	Y_{t-1}	Yc_{t-1}	Yr_{t-1}	R_t	R_{t-1}	I_t	Sp_{t-1}	Sp_{t-1}
A_t	1	-0.089	-0.084	-0.148	0.266	-0.362	-0.121	-0.218	-0.190	-0.303	-0.243	0.277	0.112
A_{t-1}		1	-0.287	-0.102	-0.416	0.203	0.102	0.047	-0.345	-0.204	-0.307	0.075	-0.086
P_{t-1}			1	0.880**	-0.152	-0.173	0.150	-0.231	0.750**	0.380	0.868**	0.651**	0.447
Pc_{t-1}				1	-0.571*	0.051	0.148	-0.078	0.571*	0.365	0.842**	0.755**	0.559*
Pr_{t-1}					1	-0.447	-0.136	-0.272	-0.047	-0.110	-0.241	-0.423	-0.329
Y_{t-1}						1	0.070	0.754**	-0.185	0.547	0.087	-0.206	-0.180
Yc_{t-1}							1	-0.490	0.465	0.168	0.231	0.252	-0.201
Yr_{t-1}								1	-0.314	0.288	-0.129	-0.305	-0.071
R_t									1	0.204	0.597*	0.375	0.186
R_{t-1}										1	0.713**	0.068	-0.105
											1	0.590*	0.387
p_{t-1}												1	0.714**
y_{t-1}													1

Zero order correlation matrix of selected variables in the estimation of acreage response function of Bajra in Alwar (1981-97)

	A_t	A_{t-1}	P_{t-1}	Pc_{t-1}	Pr_{t-1}	Y_{t-1}	Yc_{t-1}	Yr_{t-1}	R_t	R_{t-1}	I_t	Sp_{t-1}	Sp_{t-1}
A_t	1	0.644**	-0.097	-0.127	0.171	-0.428	-0.294	-0.357	0.062	-0.077	-0.298	0.135	0.197
A_{t-1}		1	-0.396	-0.360	-0.090	0.556**	0.378	0.438	-0.440	0.121	0.038	-0.099	-0.252
P_{t-1}			1	0.932**	-0.097	0.136	0.054	0.136	0.592*	0.065	0.691**	0.464	-0.097
Pc_{t-1}				1	-0.411	0.140	0.198	0.064	0.601*	0.154	0.772**	0.586*	-0.029
Pr_{t-1}					1	-0.131	0.484	0.117	-0.029	-0.154	-0.461	-0.447	0.056
Y_{t-1}						1	0.586*	0.851**	0.168	0.434	0.196	0.255	-0.360
Yc_{t-1}							1	0.081	-0.058	-0.001	0.427	0.131	0.040
Yr_{t-1}								1	0.247	0.534*	-0.033	0.262	-0.420
R_t									1	0.138	0.153	0.334	-0.017
R_{t-1}										1	0.147	0.262	-0.286
I_t											1	0.311	-0.278
Sp_{t-1}												1	0.131
Sy_{t-1}													1

Zero order correlation matrix of selected variables in the estimation of acreage response function of Maize in Bhilwara (1981-97)

	A_t	A_{t-1}	P_{t-1}	Pc_{t-1}	Pr_{t-1}	Y_{t-1}	Yc_{t-1}	Yr_{t-1}	R_t	R_{t-1}	I_t	Sp_{t-1}	Sp_{t-1}
A_t	1	0.402	0.602	0.662	-0.489	0.152	-0.112	0.438	0.372	0.096	0.566	0.415	0.132
A_{t-1}		1	0.650	0.670	-0.354	0.150	0.077	0.241	0.090	0.389	0.489	0.403	0.123
P_{t-1}			1	0.976	-0.262	-0.171	-0.146	0.228	0.253	0.270	0.523	0.708	-0.173
Pc_{t-1}				1	-0.454	-0.144	-0.199	0.394	334	0.183	0.550	0.735	-0.145
Pr_{t-1}					1	-0.200	0.108	-0.624	-0.321	0.131	-0.287	-0.315	-0.159
Y_{t-1}						1	0.608	-0.145	0.094	0.322	0.078	-0.195	0.319
Yc_{t-1}							1	-0.611	-0.259	0.774	-0.168	-0.338	-0.021
Yr_{t-1}								1	0.436	-0.514	0.261	0.233	0.019
R_t									1	-0.047	0.649	0.394	0.014
R_{t-1}										1	0.262	-0.043	-0.027
I_t											1	0.495	-0.111
Sp_{t-1}												1	-0.212
Sy_{t-1}													1

Zero order correlation matrix of selected variables in the estimation of acreage response function of Maize in Bundi (1981-97)

	A_t	A_{t-1}	P_{t-1}	Pc_{t-1}	Pr_{t-1}	Y_{t-1}	Yc_{t-1}	Yr_{t-1}	R_t	R_{t-1}	I_t	Sp_{t-1}	Sp_{t-1}
A_t	1	0.204	-0.338	-0.201	-0.431	0.082	-0.124	0.069	-0.127	-0.340	-0.414	-0.317	-0.396
A_{t-1}		1	-0.320	-0.160	-0.443	0.520	-0.009	0.308	-0.276	0.074	-0.275	-0.178	-0.013
P_{t-1}			1	0.939	0.120	0.149	0.626	-0.157	0.213	-0.141	0.998	0.602	0.333
Pc_{t-1}				1	-0.213	0.320	0.640	-0.072	0.146	-0.209	0.928	0.685	0.306
Pr_{t-1}					1	-0.449	-0.211	-0.131	0.226	0.188	-0.050	-0.226	-0.054
Y_{t-1}						1	-0.123	0.822	0.194	0.021	0.225	0.326	0.157
Yc_{t-1}							1	-0.596	-0.127	0.041	0.711	0.389	0.414
Yr_{t-1}								1	0.253	0.066	-0.131	0.027	0.108
R_t									1	-0.222	0.178	0.314	0.211
R_{t-1}										1	-0.048	-0.219	0.042
I_t											1	0.735	0.437
Sp_{t-1}												1	0.291
Sy_{t-1}													1

Zero order correlation matrix of selected variables in the estimation of acreage response function of rapeseed and mustard in Jhunjhunu (1981-97)

	A_t	A_{t-1}	P_{t-1}	Pc_{t-1}	Pr_{t-1}	Y_{t-1}	Yc_{t-1}	Yr_{t-1}	R_t	R_{t-1}	I_t	Sp_{t-1}	Sp_{t-1}
A_t	1	0.957	0.840	0.875	0.229	0.291	0.105	-0.149	0.665	0.712	0.975	-0.021	0.276
A_{t-1}		1	0.852	0.912	0.169	0.284	0.051	-0.129	0.693	0.598	0.954	-0.071	0.246
$^{?}_{t-1}$			1	0.880	0.537	0.148	0.051	-0.142	0.571	0.365	0.842	-0.009	0.058
$'c_{t-1}$				1	0.085	0.150	-0.173	0.029	0.750	0.380	0.868	-0.002	0.114
$_{t-1}$					1	0.036	0.477	-0.378	-0.125	0.137	0.224	0.104	-0.054
$_{1}$						1	0.070	0.423	0.465	0.168	0.231	0.321	0.142
$_{t-1}$							1	-0.701	-0.185	0.547	0.087	-0.011	0.032
$_{1}$								1	0.293	-0.495	-0.201	0.454	-0.123
									1	0.204	0.597	0.128	-0.067
										1	0.713	-0.139	0.252
											1	-0.139	0.238
												1	0.048
													1

Zero order correlation matrix of selected variables in the estimation of acreage response function of rapeseed and mustard in Alwar (1981-97)

	A_t	A_{t-1}	P_{t-1}	Pc_{t-1}	Pr_{t-1}	Y_{t-1}	Yc_{t-1}	Yr_{t-1}	R_t	R_{t-1}	I_t	Sp_{t-1}	Sp_{t-1}
A_t	1	0.942	0.802	0.849	-0.250	0.391	-0.158	0.192	0.263	0.156	0.694	0.444	-0.369
A_{t-1}		1	0.828	0.892	-0.257	0.189	-0.178	0.158	0.352	0.163	0.569	0.386	-0.370
P_{t-1}			1	0.833	0.142	0.195	0.006	0.020	0.601	0.154	0.732	328	-0.114
Pc_{t-1}				1	-0.392	0.195	-0.093	0.050	0.345	0.189	0.600	0.288	-0.102
Pr_{t-1}					1	-0.119	0.098	-0.025	0.214	-0.162	0.165	-0.197	-0.050
Y_{t-1}						1	0.142	0.192	-0.058	-0.001	0.423	0.259	-0.293
Yc_{t-1}							1	-0.865	0.003	0.689	0.080	-0.044	0.298
Yr_{t-1}								1	-0.086	-0.730	0.105	0.128	-0.459
R_t									1	0.138	0.098	0.282	0.174
R_{t-1}										1	0.170	-0.119	0.073
I_t											1	0.113	-0.356
SP_{t-1}												1	0.139
Sy_{t-1}													1

Zero order correlation matrix of selected variables in the estimation of acreage response function of wheat in Bhilwara (1981-97)

	A_t	A_{t-1}	P_{t-1}	Pc_{t-1}	Pr_{t-1}	Y_{t-1}	Yc_{t-1}	Yr_{t-1}	R_t	R_{t-1}	I_t	Sp_{t-1}	Sp_{t-1}
A_t	1	0.190	0.721	0.638	0.265	0.194	-0.288	0.457	0.834	0.114	0.844	0.456	-0.317
A_{t-1}		1	0.409	0.455	-0.185	0.499	0.636	-0.268	-0.138	0.841	0.259	0.324	-0.148
$_{t-1}$			1	0.977	-0.109	0.417	-0.248	0.397	0.426	0.161	0.610	0.647	-0.185
c_{t-1}				1	-0.298	0.495	-0.199	0.425	0.334	0.183	0.550	0.617	-0.146
r_{t-1}					1	-0.493	-0.114	-0.196	0.364	-0.636	0.231	0.091	-0.338
$_{-1}$						1	0.286	-0.055	-0.029	0.564	0.256	0.353	0.006
$_{t-1}$							1	-0.665	-0.259	0.774	-0.168	-0.264	-0.270
$_{-1}$								1	0.409	-0.526	0.253	0.161	0.022
									1	-0.047	0.679	0.204	-391
										1	0.262	0.181	-0.205
											1	0.484	-0.322
1												1	0.070
													1

Zero order correlation matrix of selected variables in the estimation of acreage response function of wheat in Bundi (1981-97)

	A_t	A_{t-1}	P_{t-1}	Pc_{t-1}	Pr_{t-1}	Y_{t-1}	Yc_{t-1}	Yr_{t-1}	R_t	R_{t-1}	I_t	Sp_{t-1}	Sp_{t-1}
A_t	1	0.656	0.666	0.737	-0.180	0.413	-0.096	0.312	0.509	-0.072	0.755	0.077	0.356
A_{t-1}		1	0.541	0.601	-0.106	0.270	0.146	0.120	0.368	0.328	0.623	0.106	0.617
P_{t-1}			1	0.939	0.230	0.640	0.320	-0.028	0.146	-0.209	0.928	0.225	0.269
Pc_{t-1}				1	-0.101	0.626	0.149	0.111	0.213	-0.141	0.938	0.189	0.369
Pr_{t-1}					1	0.230	0.438	-0.332	-0.231	-0.171	0.071	0.082	-0.155
Y_{t-1}						1	-0.123	0.391	-0.127	0.041	0.711	-0.012	0.472
Yc_{t-1}							1	-0.838	0.194	0.021	0.225	-0.090	-0.005
Yr_{t-1}								1	-0.201	0.259	0.085	0.121	0.097
R_t									1	-0.222	0.178	-0.202	0.248
R_{t-1}										1	-0.048	-0.045	0.382
I_t											1	0.142	0.443
SP_{t-1}												1	-0.060
Sy_{t-1}													1

** *Significant at 1% level of significance*
* *Significant at 5% level of significance*

APPENDIX - E

Zero-order correlation matrix of selected crops in the estimation of production function

Bajra crop

Barmer

	Y	X_1	X_3	X_4
Y	1	.303	0.754**	.722*
X_1		1	0.743**	0.560*
X_3			1	0.793**
X_4				1

Jhunjhunu

	Y	X_1	X_3	X_4
Y	1	0.527*	0.653**	0.579*
X_1		1	0.280	0.268
X_3			1	0.851**
X_4				1

Maize crop

Bhilwara

	Y	X_1	X_3	X_4	X_5
Y	1	-.442	0.468	0.565*	-0.416
X_1		1	0.003	-0.768**	0.904**
X_3			1	0.516*	0.058
X_4				1	-0.720*
X_5					1

Bundi

	Y	X_1	X_3	X_4
Y	1	0.530*	0.634*	0.834*
X_1		1	0.752**	0.701*
X_3			1	0.860**
X_4				1

Rapeseed and mustard

Jhunjhunu

	Y	X_1	X_3	X_4	X_5
Y	1	0.512	-0.081	0.253	-0.234
X_1		1	-0.596*	-0.289	-0.422
X_3			1	0.458	0.712*
X_4				1	0.359
X_5					1

Alwar

	Y	X_1	X_2	X_3	X_5
Y	1	-0.307	0.752**	0.086	-0.501*
X_1		1	-0.143	0.352	0.011
X_3			1	-0.339	-0.529*
X_4				1	0.179
X_5					1

Wheat

Bhilwara

	Y	X_1	X_2	X_3	X_4	X_5
Y	1	0.459	0.617*	-0.086	-0.321	0.362
X_1		1	0.553*	-0.587*	-0.698*	0.570*
X_2			1	-0.477	-0.596*	0.407
X_3				1	0.943**	-0.648*
X_4					1	-0.770*
X_5						1

Bundi

	Y	X_1	X_2	X_3	X_4	X_5
Y	1	0.167	0.404	0.116	-0.109	-0.113
X_1		1	0.774**	-0.780**	-0.747**	-0.889**
X_2			1	-0.702**	-0.713**	-0.850**
X_3				1	0.900**	0.864*
X_4					1	0.842**
X_5						1

The variables Y = Yield (q/ha), X_1 = Seed (kg/ha), X_2 = Fertilizer (kg/ha), X_3 = Man hour (Hrs/ha), X_4 = Bullock hour (Hrs/ha), X_5 = Irrigation (Rs/ha)

*** Significant at 1 % level of significance

** Significant at 5 % level of significance

* Significant at 10% level of significance