III. METHODOLOGY

The methodology relating to the current study is discussed under the following titles:

A. Selection of the topic
B. Selection of the study area
C. Selection of the sample
D. Data base of the study
E. Theoretical background of the concept of efficiency
F. Concepts and definition used
G. Hypotheses tested and
H. Tools of analysis

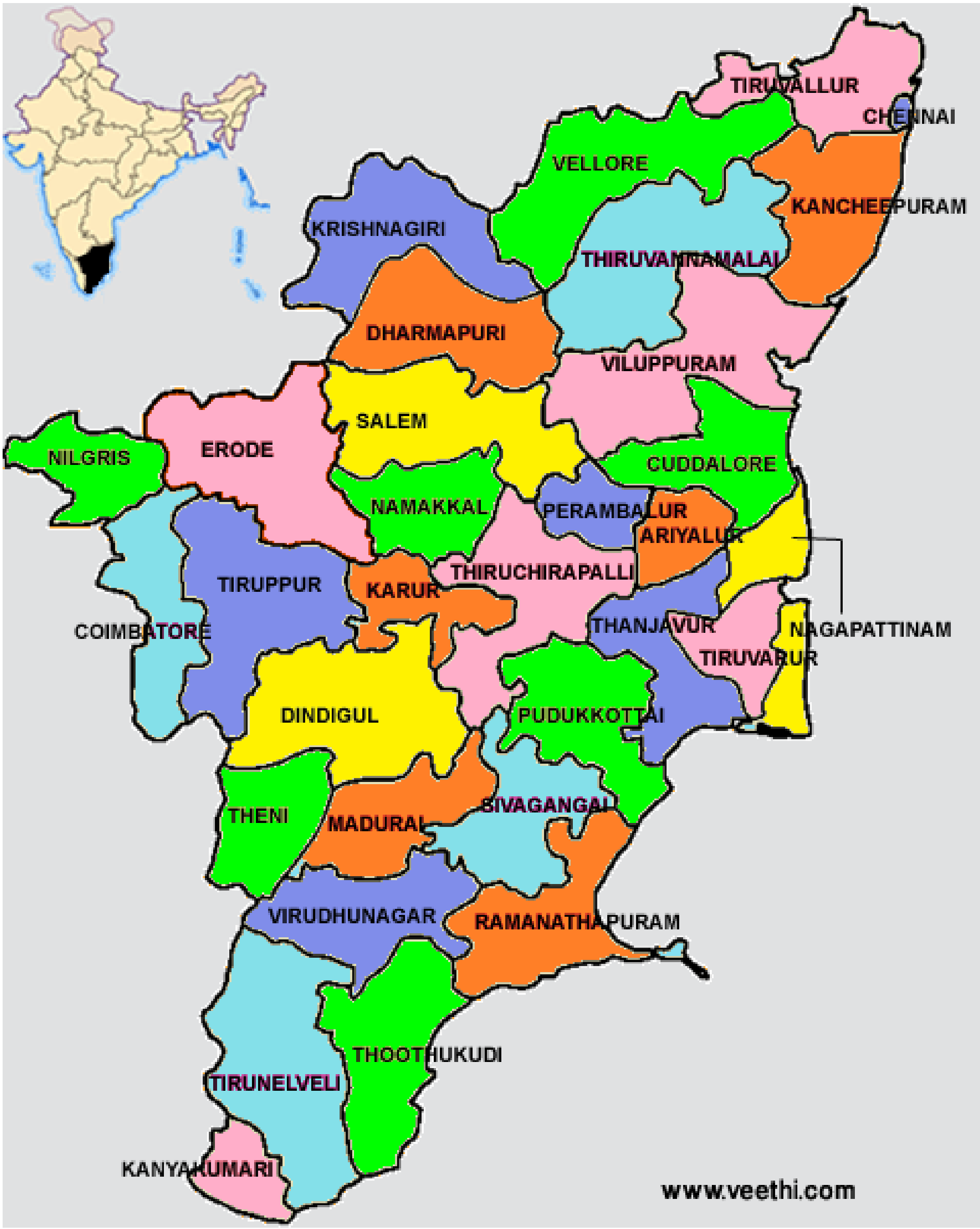
A. Selection of the topic

Tamil Nadu has historically been an agricultural state and is one of the leading producers of agricultural products in India. Tamil Nadu was India's fifth biggest producer of rice and the Cauvery delta region is known as the **Rice Bowl of South India**. The total cultivated area in the state is 5.60 million hectares. The state is the largest producer of bananas, flowers, tapioca, the second largest producer of mango, natural rubber, coconut, groundnut and the third largest producer of coffee, sapota, tea and sugarcane. Tamil Nadu sugarcane yield per hectare is the highest in India.

Agriculture is the primary occupation for 70 percent of the rural population in Tamil Nadu. Around 34 percent of the state’s population resides in urban areas while the remaining population resides in the rural areas. With change in science and technology, agricultural practices have undergone radical improvement since independence. The change is visible not only in agricultural practices but also in the type of crop grown. In Tamil Nadu, organic farming is practiced by around 3671 farmers. Also several training programmes have been conducted for these farmers (Thiripurasundari, 2013). Organic farming can ensure maintenance of soil health, protection of the environment and sustaining of crop productivity. It not only maintains ecological balance but also ensures sustainability in terms of food production and for human health safety. With this background an attempt has been made to compare organic and inorganic farming system in Tamil Nadu.

Figure - 1

Districts of Tamil Nadu



Erode

Vellore

Cuddalore

Thiruchirapalli

B. Selection of the study area

The present study was undertaken in 4 districts of Tamil Nadu among 32 districts namely Vellore, Tiruchirapalli (Trichy), Cuddalore, and Erode. These districts were selected purposively for the present study since they cover almost all area under agro-climatic zone and all types of soil with good rainfall.

Vellore district is primarily an agrarian district with majority of its population involved in agriculture. Soil type of this district is Laterite and the chief food grains cultivated are paddy, cholam, ragi and redgram. Vellore is also one of the top producers of sugarcane and coconut in the state. Oil seeds that are cultivated are groundnut, coconut, sunflower and gingelly.

In Erode or Periyar district agriculture sector is the most important income source. Red soil is found mostly in Erode district. Paddy, plantain, groundnut, cotton, turmeric, maize, coconut and sugarcane are some of the crops grown. With 43 percent share among the total production, the district is the top turmeric producer not only in Tamil Nadu but also worldwide and hence Erode is popularly known as "The Turmeric City". This district is also a leading producer of plantain, coconut and white silk. Anthiyur and Modachur shandy are famous for cattle-rearing.

Tiruchirapalli (Trichy) district lies at the heart of Tamil Nadu. The district has large cattle and poultry population. The major categories of soil in Trichy district are black soil and the major crops grown are rice, sugarcane, banana/plantain, coconut, cotton, betel, corn, groundnut. Trichy experiences a tropical savanna climate.

Cuddalore with 52 per cent share among the total production is the top cashew nut producer in Tamil Nadu and jack fruit, sugarcane production. The distribution of major soil types in Cuddalore district is coastal alluvial, sandy loam and clayey soils.

C. Selection of the sample

Multistage stratified random sampling technique was used to select sample farmers. The four districts of Tamil Nadu namely Trichy, Erode, Cuddalore and Vellore were selected purposively based on the prevailing soil type. Further the study area was stratified in to organic and inorganic farming. From each district, villages were selected on the basis of maximum area under organic and inorganic farmers in the area which constituted different farm sizes, to elicit information. List of organic crop growers were obtained from NGOs (Vanagam and Prabanjam) and list of inorganic crop growers were obtained from tahsil of the same villages. A pilot survey with an interview schedule covering a sample of 30 organic and inorganic farmers in Kanchipuram district was conducted in the month of December, 2012. Based on the results, interview schedule was reframed. The primary data was collected by direct interview method with well-structured schedule from the selected farmers in the year February, 2013 to November, 2013.

D. Database of the study

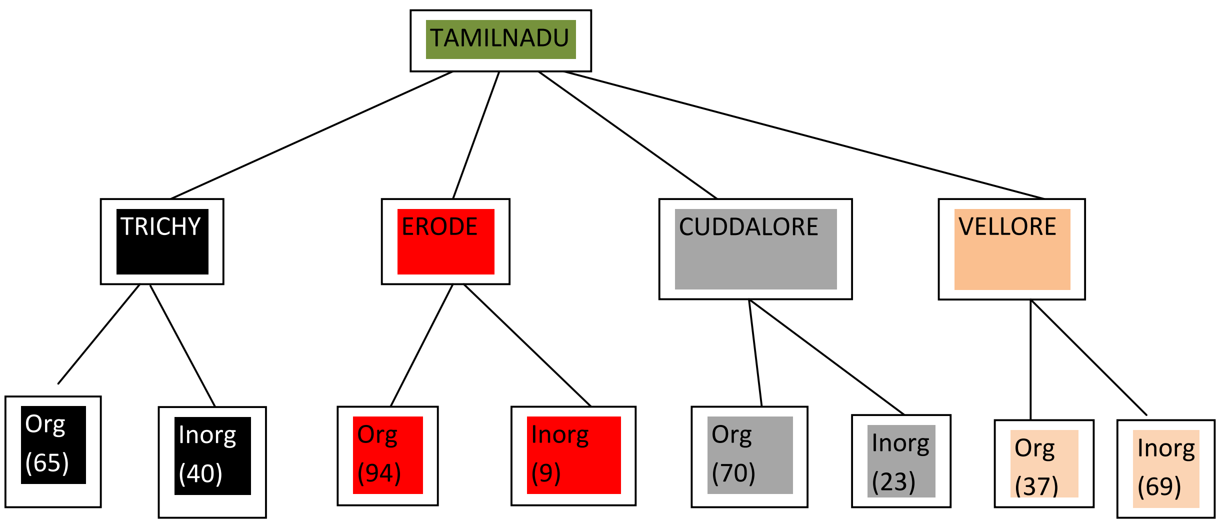
District-wise selection of villages along with number of organic and inorganic farmers is shown below.

No.	Name of the district	Type of soil	Villages in respective districts	Number of inorganic farmers	Number of organic farmers
1.	Trichy	Black soil	Perugamani, Duraikudi, Kiliyur	40	65
2.	Erode	Red soil	Talavadi, Sujalkara, Susaipuram, Mettalvadi, Thottapuram	9	94
3.	Cuddalore	Sandy coastal alluviam soil	Vilangalpattu, Chokkankollai, Naduveerapattu, Singirikudi, Mazhavarayanallur, Keelakuppam	23	70
4.	Vellore	Laterite soil	Kathalampet, Lakshmipuram, Sathumadurai, Mothakkal, Kamasamudram	69	37
	Total			141	266

Figure - 2 explains the delineation of the study area.

Figure – 2

Delineation of the study area



E. Theoretical background of the concept of efficiency

Efficient resource utilisation helps generate surpluses which can be reinvested towards the creation of further resources. Hence, improvement in efficiency has an impact on the future productive capabilities of nations by providing higher levels of reinvestible surplus. There are a variety of notions of efficiency conceptualised by economists. A farm is considered technically efficient if it can produce the maximum feasible level of output from the inputs. It can be allocatively efficient if it can produce the maximum feasible output from the combination of minimum inputs, given the input prices. These concepts are implicit in the input and output correspondences as given in Shephard (1974).

Many attempts have been made by economists to quantify productive efficiency. They include the conceptualisation of efficiency as:

1) The difference between the values of the outputs and inputs in constant prices. Davis (1955) defined the absolute measure of efficiency E to be:

   $E = y - l - k - m$

   Where, y is the value of output and l, k,m are the values of different inputs at constant prices. This measure of efficiency is nothing more than a profit – cost analysis.

2) The ratio between the values of outputs and inputs.

   As in Schmookler (1952), Solow (1957), Kendrick (1961), efficiency can be quantified as the ratio between the values of outputs and inputs. This gives us the "partial Productivity" of each input since it is calculated by comparing output with each input (Kendrick, 1961). But this measure fails to give an overall measure of productive efficiency. The reason is that it does not take the composition of inputs or factor substitution into consideration. To solve this problem, Total Factor Productivity (TFP) was conceptualised. It is constructed by making an index that consists of a weighted average of inputs, using either relative prices or relative factor shares (Schmookler, 1952, Pagin, 1965, Bennett, 1967, Pack 1984).

   TFP, invariably a ratio between inputs and output can be expressed as TFP $= \frac{Y}{\Sigma(wi.Xi)}$ where Y is the level of production activity, X_i the quantity of input factor I and wi some appropriate weight, for I = 1,2, ….,n. The weights can be either exogenously given (Harris and Phillips, 1984, Tidrick, 1986, Jiang and Zou,1990) or statistically estimated (Nadiri and Schankerman, 1981, Green ,1983). Different methods have been developed to measure TFP like Kendrick Arithmetic method (Kendrick, 1961) and Solow's geometric index (Solow, 1957). But all these methods came under fire from Farrell (1957) who pointed to the inappropriateness of the 'weights'. He argued that the selection of weights will be at the convenience of the user and the introduction of prices as weights itself brings in an element of arbitrariness to the measure. Also, this measure fails to distinguish the effects of inefficiency from that of other factors, whether endogenous or exogeneous (Farrell, 1957, Barrow and Walkstaff, 1989).

These two conceptualisations of efficiency are termed as classical approach and the constraints in these led to the frontier approach to efficiency.

3) The ratio of actual output to the potential output.

This definition of efficiency stems from the production or cost frontier. A farm is inefficient if it lies below the production frontier or lies above the cost frontier. In terms of production function a farm is inefficient if:

$$Y_i < f(\underline{X}_i ; \underline{\beta}) \qquad (1)$$

Where Yi is the actual output and f(.) = y_{max} as given in equation (1). Now the residual ε_i, defined as ($Yi-y_{max}$) can give the efficiency ratio in a farm as:

$$\varepsilon_i = y_i / f(\underline{X}_i ; \beta) \qquad (2)$$

Similarly, Hamond (1986) gives the efficiency ratio in terms of a cost function. The function is specified as:

$$C_i > g(\underline{Z}_i ; \underline{\alpha}) \qquad (3)$$

Where ci is the average cost of the farm and g(.) = c_{min} is defined as the frontier (minimum) cost. Now, the residual, e'_{ii} defines the efficiency ratio of the farm as:

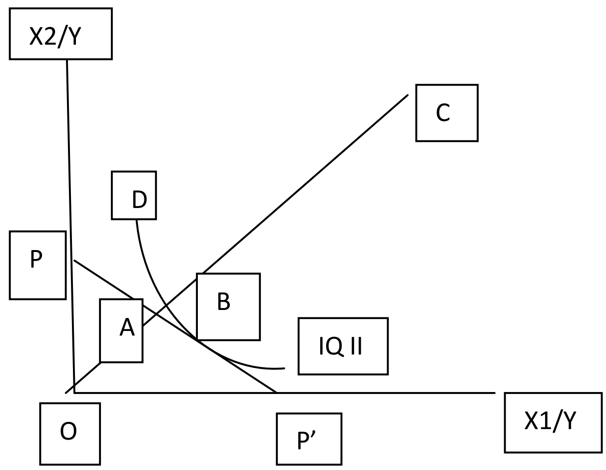
$$\Phi_i = g(\underline{Z}_i ; \underline{\alpha})/c_i \qquad (4)$$

This approach originated from Shepard (1953), Solow (1957) and Farrel (1957). The path breaking paper by Farell (1957) identified the technical and allocative efficiency in a farm. The figure explains it.

Figure - 3 explains the efficiency measurement of Farell.

Figure - 3

Farell Efficiency Measurement



In figure 1, the farm using only two inputs X1 and X2 to produce output y is presented. The production is specified as y = f (X1, X2) and it assumed that the returns to scale is constant, ie, linearly homogeneous. Then the production function can be specified as 1 = f (X1/y, X2/y). This enables to draw isoquant II’. Here the farm is producing unit-output at the point C. Technical efficiency, which is defined as the ratio of the actual to the potential, can now be stated as OB/OC. It is clear that:

$0 \leq TE \leq 1$

Now, the allocative efficiency can be specified given the iso-cost line PP’ which is defined by the ratio of factor prices. The allocative efficiency ratio can be given by OA/OB, whereby the farm is producing output in the most price efficient way. It can, now be seen that the overall efficiency is the product of technical and allocative efficiencies, ie,

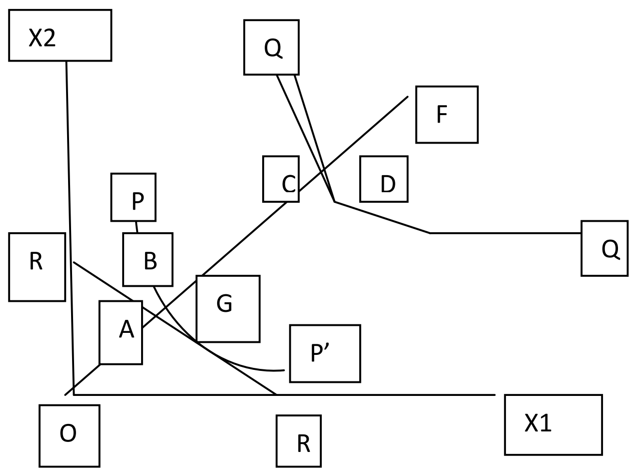
$OE = TE \,.\, AE$

ie, $OA/OC = OB/OC.\ OA/OB$

Later, Fare, Grosskopf and Lovell (FGL, 1985) have tried to decompose total efficiency further. They have shown that total efficiency can be split into purely technical, structural, scale and allocative components. This (FGL) decomposition of total efficiency can be explained with the help of Figure 4.

Figure - 4

FGL Efficiency Decomposition



Production is carried out with an inferior set of inputs, F, where the overall efficient input choice is G, given the iso-cost line RR and the longrun reference technology PP'. Overall Efficiency (OE) can be specified as:

OE = OA/OF < 1

Now, the pure technical component in overall efficiency is represented by OD/OF, ie,

PTE = OD/OF

The structural component (C), known as congestion, is due to production on a positively sloped stretch of the isoquant. Tinbergen (1985) identified it in the non-economic region and called it counter production. It can be specified as: C= OC/ OD

Scale efficiency (S) is defined as the discrepancy between the short run technology production, QQ and the long run technology production (ie, the constant returns to scale) PP. Therefore, S can be specified as

S = OB / OC

Allocative efficiency, which is price dependent and defined related to the isocost line RR is represented by

A = OA/OB

Now, the total efficiency can be seen as the multiplicative identity of all these components, ie, OE = PTE.C.S.A

ie, OE = (OA / OF) = (OD/OF). (OC/OD). (OB/OC).(OA/OB)

In the absence of price information, the OE measure reduces to Overall Technical Efficiency (OTE), which can be defined as:

OTE = (OB / OF) = (OD / OF). (OC / OD). (OB/OC)

The frontier approach initiated by Farrell was essentially concerned with empirical matters, and in particular, with measurement (Burton and Weyman- Jones, 1992). As Farrell (1957) himself states his interest was "to provide a satisfactory measure of productive efficiency and to show how it can be computed in practice." But keeping a more inquisitive mind to understand the determinants of efficiency along with its magnitude, Leibenstein put forth a more comprehensive concept of efficiency. X- efficiency is the difference between efficient behaviour of farms assumed and their observed behaviour in practice. In 1978, Leibenstein in his book covered X - efficiency theory and development. He has mentioned that both X – efficiency and allocative efficiency must be analysed carefully and tried to separate demand for factors of production in the market place from the utilisation of these factors in terms of the effort inputs; Also equilibrium of factors depend on the productivity of these factors, thus the degree of X – efficiency of effort input use in firms. With these theoretical backgrounds the investigator applied Data Envelopment Analysis (DEA) technique for the following reasons.

The DEA technique involves the use of mathematical programming to estimate the efficiency of the agriculture / industry. DEA is a non-parametric, deterministic methodology for determining relatively efficient production frontier, based on the empirical data on chosen inputs and outputs of a number of entities called Decision Making Units (DMUs). From the set of available data, DEA identify reference points (relatively efficient DMUs) that define efficient frontier (as the best practice production technology) and evaluate the inefficiency of other interior points (relatively inefficient DMUs) that are below the frontier.

The DEA provides a measure of efficiency that allows intra-farm comparison, as the efficiency measure is a pure number. The main advantage of DEA is that unlike Stochastic Function Approach, it does not require apriority assumption about the analytical form of the production function. Instead, it constructs the best practice production solely on the basis of observed data and therefore the possibility of mis-specification of the production technology is minimized.

F. Concepts and definitions used

The concepts and definitions used in the study are explained as under:

a. Land preparation

This includes the cost of ploughing, tilling, digging the land incurred by the sample farmers.

b. Labour

The hired male and female labour was charged at the prevailing wage rates paid per day (eight hours) in the study area is included. The bullock labour was charged as per hiring rates prevailed in the villages. For family labour the wages were imputed at the same rates as those paid to hired human labour.

c. Fertilizer and plant protection chemicals

The cost of fertilizers and plant protection chemicals were considered on par with the amounts actually paid by the sample farmers.

d. Seed

Farm-produced seed has been valued at the prices prevalent at the time of sowing and purchased seeds have been considered at actual rates paid by the sample farmers.

e. Marginal Factor Cost (MFC)

Marginal factor cost refers to the price of per unit of input. If the MFCs of all the inputs expressed in terms of an addition, T_k, in calculating the ratio of MVP to MFC, the denominator will always be one, and therefore, the ratio will be equal to their respective MVP.

f. Miscellaneous costs

Miscellaneous costs include repair charges, irrigation, machinery, cost of food for livestock and veterinary charges.

g. Gross returns

Gross returns were computed on the basis of actual prices at which farmers sold their products and by-products.

h. Net returns

Net returns were calculated by deducting the total cost of cultivation from gross returns.

i. Cropping intensity

Since the occupancy of the land by the major crops assumed significance in the study, the investigator has computed cropping intensity using the following formula.

$$\text{Cropping intensity} = \frac{\text{Gross cropped area}}{\text{Net cropped area}} \times 100$$

G. Hypotheses tested

The null hypotheses tested in the study are given below:

1. Farmer’s decision to adopt or not to adopt organic farming is independent of the explanatory variables such as expenditure on land, labour, livestock, machinery, fertilisers, plant protection, seed and irrigation.
2. There is no difference in the resource use efficiency of both organic and inorganic farming system.
3. There is no significant difference between technical, scale, cost and allocative efficiency of organic and inorganic farming system.

H. Tools of analysis

In order to analyse the data, the following statistical tools were applied.

1. A Parametric Production Function Approach

Production function analysis is a powerful method for gaining insight into the contributions of various factors of production. A production function can be defined as the specification of the minimum input requirements needed to produce designated quantities of output, given available technology. The production function analysis was used to determine the resource-use efficiency based on returns to scale and the inputs used by the farmers. This was done with a view to determine the extent to which the important resources have been quantified to explain the variability in the gross returns of the farming systems and to determine whether the resources are being optimally used.

The C-D production function of the following form was fitted for organic and inorganic farming systems.

$$Y = aX_1^{b1}.X_2^{b2}\ X_2^{b2}.X_3^{b3}.X_4^{b4}.X_5^{b5}.X_6^{b6}\ .X_7^{b7}.X_8^{b8}.e^{u}$$

Where

Y = Gross returns (` /acre)

X_1 = Expenditure on Land (` /acre)

X_2 = Expenditure on labour (` /acre)

X_3 = Expenditure on livestock (` /acre)

X_4 = Expenditure on machinery (` /acre)

X_5 = Expenditure on fertilizers (` /acre)

X_6 = Expenditure on seeds (` /acre)

X_7 = Expenditure on plant protection (` /acre)

X_8 = Expenditure on irrigation (` /acre)

Expenditure on fertiliser and plant protecting inputs includes expenditure on vermi-compost, neem seed cake and panchagavya for organic farmers and expenditure on urea, DAP (Di Ammonium Phosphate), mancozeb and carbandizam for inorganic farmers.

The Cobb-Douglas production function in the form expressed above was linearised into a logarithmic function with a view of getting a form amenable to practical purposes as expressed below.

$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 + e^u$

here,

ln = Natural logarithm

a = constant and efficiency parameter

$b_1, b_2, b_3 \ldots\ldots b_8$ = Regression coefficient or production elasticities.

Σb_i = Returns to scale

e^u = error term

$Y, X_1, X_2, \ldots\ldots\ldots\ldots X_8$, are as defined earlier.

b_i = Elasticity coefficient of respective i^{th} inputs

The estimated coefficients of the relevant independent variables were used to compute the Marginal Value Products (MVP) and their corresponding Marginal Factor Costs (MFC). The ratio of the MVP to MFC was used to determine the resource use efficiency as shown in the following equation.

r = MVP/MFC

here, r = Efficiency ratio (ratio of the MVP of an input and unit price of the input)

MVP = Marginal value product of a variable input.

MFC = Marginal factor cost (price per unit input)

The most reliable and most useful estimate of MVP is obtained by taking resources (X_i) as well as gross returns (Y) at their geometric means. Since, all the variables of the regression model were measured in monetary value, the slope coefficient of those explanatory variables in the function represented the MVPs, calculated by multiplying the production co-efficient of given resources with the ratio of geometric mean (GM) of gross return to the GM of the given resources, that is,

ln Y = ln a + bi ln Xi

Therefore,

dY/dXi = bi [Y/Xi] or, MVP (Xi) = bi [Y(GM)/ Xi (GM)]

here, Y(GM) = Geometric mean value of gross returns in rupees.

Xi (GM) = Geometric mean value of the i^{th} independent variable in rupees.

bi = Regression elasticity coefficient of production of i^{th} variable.

As the MFC is price of input per unit, the denominator will always be one for optimum allocation. Thus,

a) If r <1, it means the resource in question was over utilized hence decreasing the quantity used of that resource increases profit.

b) If r > 1, it shows that the resource was being under-utilized and increasing the quantity of used of that resource will raise profit level.

c) If r = 1, it means resource was being efficiently utilized.

Significance of R^2 was tested by F - test and student's t-test was used for computing significance of parameters of estimates. By testing the significance of each coefficient by t-test we can judge the importance of the corresponding factor in determining production. R^2 indicates the effectiveness of the model. The certainty of the results obtained obviously depends on the goodness of fit of the C-D model, which can be judged from the significance of the R^2 value.

Patil and Acharya (1974), Kademani (1983), Pokharkar (1989), Shareef (1992), Banik (1994), Nagaraj et. al (1998), Mohan (2005), Taru (2011) and Goswami (2012) have applied this tool in their study.

2. DEA Model

The data envelopment analysis technique uses linear programming methods to construct a non-parametric frontier. The technique also identifies efficient production units, which belong to the frontier, and inefficient ones, which remain below it. There are two approaches for estimating the efficiency of the farm in the DEA approach viz., the output-oriented efficiency and the input-oriented efficiency. In the output oriented approach, efficiency is determined by maximum output that can be produced from an input bundle. In the input-based measure, the efficiency of the firm is evaluated by the extent to which all inputs could be proportionally reduced without a reduction in the output. This study adopts the multi-stage DEA method to estimate efficiency of multiple inputs and output production process. DEAP 2.1 version was used to estimate the efficiency. The input oriented DEA model is used to estimate the technical, scale, cost and allocative efficiency of the farms in this study. Among number of DEA models, the two most frequently used ones (input oriented) CCR model (after Charnes, Cooper, Rhodes, 1978) and BCC model (after Banker, Charnes and Cooper, 1984) were used in the study. The output was measured in terms of gross returns and the inputs used were expenditure on land, labour, machinery, fertiliser, plant protection and other expenditures.

I. Technical Efficiency

Technical efficiency in a production unit refers to the achievement of the maximum potential output from given amount of factor inputs, taking into account physical production relationships.

(i) CCR Model

Charnes, Cooper and Rhodes introduced a measure of efficiency for each DMU that is obtained as a maximum ratio of weighted outputs to weighted inputs. This model assumes that the production technology presents constant returns to scale. The weights for the ratio are determined by a restriction that the similar ratios for every DMU have to be less than or equal to unity, thus reducing multiple inputs and outputs to single "virtual" output without requiring pre-assigned weights.

The efficiency measure is then a function of weights of the "virtual" input-output combination. Formally, the efficiency measure for the DMU can be calculated by solving the following mathematical programming problem:

$$\max h_0(u,v) = \frac{\sum_{r=1}^{S} u_r Y_{ro}}{\sum_{i=1}^{S} v_i x_{io}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Subject to

$$\frac{\sum_{r=1}^{S} u_r Y_{rj}}{\sum_{i=1}^{m} v_i xi_j} \leq 1, j = 1,2......, j_o,......,n..(2)$$

$u_r \geq 0$, r = 1,2,...., s .... (3)

$v_i \geq 0$, j = 1,2,...., m ....(4)

where X_{ij} is the observed amount of input of the i^{th} type of the DMU ($X_{ij} > 0$, i = 1,2,......n, j = 1,2,.....n) and y_{rj} = the observed amount of output of the r^{th} type for the j^{th} DMU (Yrj > 0, r = 1,2,.....s, j = 1,2,...n).

The variables u_r, and vi are the weights to be determined by the above programming problem. However, this problem has infinite number of solutions since if (u*, v*) is optimal then for each positive scalar α (αu*, αv*) is also optimal. Following the Charnes - Cooper transformation (1962), one can select a representative solution (u,v) for which

$$\sum_{i=1}^{m} v_i x_{io} = 1 \quad .... (5)$$

to obtain a linear programming problem that is equivalent to the linear fractional programming problem (1) - (4). Thus, denominator in the above efficiency measure h_0 is set to equal one and the transformed linear problem for DMU can be written.

$$\max z_0 = \sum_{r=1}^{S} u_r Y_{ro} \quad .... (6)$$

Subject to

$$\sum_{r=1}^{S} u_r Y_{rj} - \sum_{r=1}^{m} v_i x_{ij} \leq 0, j = 1,2,..., n ....(7)$$

$$\sum_{r=1}^{m} v_i x_{io} = 1 \quad .... (8)$$

$u_r \geq 0$, r = 1,2,...., s .... (9)

vi ≥ 0, i = 1,2,...., m .... (10)

For the above linear programming problem, the dual can be written (for the given DMU) as:

$$\min z_0 = \Theta_o \qquad \text{.....................} \quad (11)$$

Subject to

$$\sum_{j=1}^{n} \lambda Y_{rj} \geq Y_{ro}, r = 1,2,....,s \text{ ....} \quad (12)$$

$$\Theta o x_{io} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0, i = 1,2,...,m \qquad \text{.....................} \quad (13)$$

$$\lambda_j \geq 0, \quad j = 1,2,...,n \qquad \text{.....................} \quad (14)$$

Both of the above linear problems yield the optimal solution Θ*, which is the efficiency score (so-called technical efficiency or CCR efficiency) for the particular DMU and repeating them for each DMU_j , j = 1,2,....n efficiency scores for all of them are obtained. The value of Θ is always less than or equal to unity (since when tested, each particular DMU is constrained by its own virtual input-output combination too). DMUs for which Θ* ≤ 1 are relatively inefficient and those for which Θ* = 1 are relatively efficient, having their virtual input-output combination points laying on the frontier. The frontier itself consists of linear facets spanned by efficient units of the data and the resulting frontier production function (obtained with the implicit constant returns to scale assumption) has no unknown parameters.

(ii) BCC model

In order to account for the effects of imperfect competitive markets in the maximization process, the DEA model for variable returns to scale (VRS) was developed by Banker, Charnes and Cooper (BCC). Since there are no constraints for the weights λj, other than the positivity conditions in the problem (11) - (14), it implies constant returns to scale. For allowing variable returns to scale, it is necessary to add the convexity condition for the weights, λj, i.e. to include in the model (11) - (14) the constraint:

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad \text{....................} \quad (15)$$

The resulting DEA model that exhibits variable returns to scale is called BCC model, after Banker, Charnes and Cooper (1984). The input-oriented BCC model for the DMU_0 can be written formally as:

$$\min z_0 = \Theta o \qquad \text{....................} \quad (16)$$

Subject to

$$\sum_{j=1}^{n} \lambda_r Y_{rj} \geq Y_{ro} r = 1,2,...,s \qquad \text{.....................} (17)$$

$$\Theta_o x_{io} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0, i = 1,2,...,m \qquad \text{.....................} (18)$$

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad \text{.....................} (19)$$

$$\lambda_j \geq 0, \quad j = 1,2,...,n \qquad \text{.....................} (20)$$

Running the above model for each DMU, the BCC efficiency scores are obtained (with similar interpretation of its values as in the CCR model). These scores are also called "pure technical efficiency scores", since they are obtained from the model that allows variable returns to scale and hence eliminate the "scale part" of the efficiency from the analysis. Generally, for each DMU the CCR efficiency score will not exceed the BCC efficiency score, what is intuitively clear since in the BCC model each DMU is analyzed "locally" (i.e. compared to the subset of DMUs that operate in the same region of returns to scale) rather than "globally".

II. Scale efficiency

For a particular DMU, the scale efficiency is defined as a ratio of its overall technical efficiency score (measured by the CCR model) and pure technical efficiency score (measured by the BCC model).

III. Cost Efficiency

The standard measure of cost efficiency is obtained via two stage process. i) Estimate the minimum price-adjusted resource usage given technological constraints, and (ii) compare this minimum to actual, observed costs. Cost efficiency can be measured if input prices are available in addition to output and input data.

Let $x = (x_1, \ldots x_k) \varepsilon R_+^k$ denotes a vector of inputs and $y = (y_1, \ldots y_m) \varepsilon R_+^m$ denote vector of outputs. Formally, the cost efficiency model can be specified as:

$$\text{Min}_{z,x} \sum_{j=1}^{m} w_{jo} x_j \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

$$\text{Subject to} \quad z.Y \geq y_0$$

$$z.x \leq x_0$$

$$zi \geq 0$$

$$\sum_{i=1}^{n} z_i = 1$$

where Y is an n x m matrix of observed outputs for n farms and x is an n x k matrix of inputs for each farm. z is a l x n vector of intensity variables and

$w = (w_1, \ldots w_k) \varepsilon R_+^k$ denoted input prices. The constraints of the model (21) define the input requirement set given by:

$$L(y) = (x.\ z.\ y \geq y_0,\ z\,x \leq x,\ z_i \geq 0,\ \sum_{i=1}^{n} z_i = 1) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (22)$$

The input requirement set specifies a convex technology with Variable Returns to Scale (VRS), which is imposed by the constraint $\sum_{i=1}^{n} z_i = 1$. Leaving the constraint out of the model changes the technology to Constant Returns to Scale (CRS). To estimate cost efficiency of both the farming systems, the input prices were taken into account.

IV. Allocative Efficiency

Allocative efficiency is defined as a ratio of cost efficiency score to technical efficiency score. Both under CRS production technology and VRS production technology, this efficiency score was estimated for the present study. Efficiency scores are estimated using the computer program, DEAP Version 2.1.

Shenggen Fan (1999), Cisilino et al (2003), Revilla et al (2005), Abedullah (2006), Nitiphong (2007), Roy et al (2009), Himayatullah et al (2011), Rahman (2012), Rangalal (2013) and Elhendy et al (2013) were some economists who analysed the efficiency using DEA approach in agriculture.

3. **Discriminant Analysis**

Discriminant analysis being a multivariate extension of the univariate analysis compares the distribution of one or more variables for different groups or populations which are known and identified and mutually exclusive. Discriminant analysis thus attempts to determine which continuous variables discriminate between two or more naturally occurring groups. It could then be used to determine which variables are the best predictors specifically, it shows whether or not two (or more) groups are significantly different from each other with respect to mean of a given variable(s). If the mean for a variable is significantly different in different groups, then this variable discriminate between the two groups. It is used primarily to classify and or make predictions in problems where the dependent variable appears qualitative in nature. The estimation process of the coefficients is aimed at getting the best possible discrimination between the two groups.

To identify the dominant factors which influence the gross returns at overall level and for individual farming system (organic or inorganic) in the selected districts of Tamil Nadu, three different functions were estimated by taking gross returns of the farming system as dependent variable and expenditure on land, human labour, livestock (fodder and veterinary charges), machinery (power and fuel charges), seed, fertiliser, plant protection and irrigation as independent variables. In case of expenditure on fertiliser and plant protecting inputs, expenditure on vermicompost, neem seed cake, panchagavya has been used for organic farmers and expenditure on Urea, DAP (Di Ammonium Phosphate), Mancozeb, Carbandizam etc. has been used for inorganic farmers. A SPSS 16.0 statistical software (statistical package for social sciences) was used to carry out the analysis. Wilk's lambda and 'F' statistics were derived to find out whether the means of the two groups differ significantly. Using canonical discriminant function, coefficient of selected variables discriminating within the groups and at overall level were found out. The functional form is represented as follows.

Function-I (Inorganic farming)

$$Z_1 = L_1X_1 + L_2X_2 + L_3X_3 + L_4X_4 + L_5X_5 + L_6X_6 + L_7X_7 + L_8X_8$$

Function II (organic farming)

$$Z_2 = a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5 + a_6X_6 + a_7X_7 + a_8X_8$$

Function III (Overall level)

$$Z_3 = b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8$$

Where

Z_1 = Discriminant scores for the gross returns of inorganic farming system (2 for above average and 1 for below average)

Z_2 = Discriminant scores for the gross returns of organic farming system (2 for above average and 1 for below average)

Z_3 = Discriminant scores for the gross returns of overall farming system (2 for organic farming and 1 for inorganic farming)

Xi = Expenditures incurred by the farmers

L_i = Co-efficients of the independent variables in the function-I

a_i = Co-efficients of the independent variables in the function-II

b_i = Co-efficients of the independent variables in the function-III

4. Other tools

Besides the above mentioned tools, the investigator had calculated simple percentages. Diagrams were used in the appropriate places.