NONLINEAR MODELS FOR MAJOR CROPS OF KERALA

By

JOSHY, C. G.

THESIS

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DECLARATION

I here by declare that this thesis entitled **"Nonlinear models for major crops of Kerala"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Joshy

JOSHY, C.G.

(2004-19-01)

Vellanikkara

19-03-07

CERTIFICATE

Certified that this thesis entitled **"Nonlinear models for major crops of Kerala"** is a record of work done independently by **Sri. Joshy, C.G**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to him.

Vellanikkara
19-03-07

S. Krishnan
Sri. S. Krishnan
(Chairperson, Advisory Committee)
Assistant Professor (Sel. Gr.)
Department of Agricultural Statistics
College of Horticulture
Vellanikkara, Thrissur.

CERTIFICATE

We the undersigned members of the Advisory Committee of **Sri. Joshy, C.G**, a candidate for the degree of Master of Science in Agricultural Statistics, agree that this thesis entitled "**Nonlinear Models for Major Crops of Kerala**" may be submitted by Sri. Joshy, C.G, in partial fulfilment of the requirement for the degree.

S. Krishnan 10/5/07

Sri. S. Krishnan
(Chairperson, Advisory Committee)
Assistant Professor (Sel. Gr.)
Department of Agricultural Statistics
College of Horticulture
Vellanikkara, Thrissur.

Dr. V.K. Gopinathan Unnithan
(Member, Advisory Committee)
Associate Professor and Head
Department of Agricultural Statistics
College of Horticulture
Vellanikkara, Thrissur.

10.5.07

Dr. E.K. Thomas
(Member, Advisory Committee)
Associate Professor and Head
Department of Agricultural Economics
College of Horticulture
Vellanikkara, Thrissur.

10/5/07

Smt. T. K. Ajitha
(Member, Advisory Committee)
Assistant Professor (S. S.)
Department of Agricultural Statistics
College of Horticulture
Vellanikkara, Thrissur.

J. Jayasankar 10/05/2007

(EXTERNAL EXAMINER)
(J. JAYASANKAR)
SENIOR SCIENTIST
FRA DIVISION
CMFRI
COCHIN - 18

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JOSHY, C.G.

Dedicated to
My Loving
Parents

CONTENTS

List of Abbreviations

TVM	-	Tiruvananthapuram
KLM	-	Kollam
PTA	-	Pathanamthitta
ALP	-	Alappuzha
KTM	-	Kottayam
IDK	-	Idukky
EKM	-	Ernakulam
TSR	-	Thrissur
PKD	-	Palakkad
MLPM	-	Malappuram
KKD	-	Kozhikode
WYD	-	Wyanad
KNR	-	Kannur
KSGD	-	Kasargode
ha	-	hectares
t	-	tonnes
mn	-	Million nuts
t / h	-	tonnes / hectare
n / h	-	Nuts / hectare
R^2	-	Variance explained
RMSE	-	Root mean square error
sqrt	-	Square root

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Introduction

1. INTRODUCTION

Agriculture continues to dominate the economic scene of India, accounting for about one-third of gross domestic product and one-fifth of the foreign exchange. This sector provides employment for more than seventy percent of the total labour force in the country. Furthermore, its forward and backward linkages with other sectors are also encouraging the total economy in the country. Therefore an accelerated pace of economic growth through sustained development of the agriculture is sina qua non and it should emerge from each state so as to achieve a massive revolution in the economic stature through agriculture.

Kerala a narrow strip of land on the south-western corner of Indian subcontinent was basically an agrarian economy, but has gone several phases of changes and shares a part in national economy through agriculture from agriculture output comprised from the fourteen districts. Kerala's geographical and physical features with rich water sources are suitable for the cultivation of a variety of crops. With her external orientation, she was exposed to cash crops, which later found domination in the cropping pattern. The most frequent crops grown in the different districts are perennials like coconut, rubber, pepper, cashew, coffee and cardamom; annuals like banana and tapioca; seasonal like paddy.

The undulating geographical structure of Kerala has led to the unequal distribution of area under cultivation among these crops. The main problem of cultivation of any crop in Kerala is the high cost of labour. The various pests and diseases that widely spread in the different crops coupled with inflation caused devastating economic injury on the farmers. As a survival mechanism farmers started shifting from uneconomic crops to economically viable crops. This shift was affected only with the existing cropped area with only least addition. When the economically viable crops that replaced the uneconomic ones were ready to be cropped most of them slipped into the uneconomic bowl. The injury suffered by the farmers was not in measurable terms. The various governmental agencies formed to override such an oscillating economic situation could not even help the farmers even the threshold. The study of the shift in area, production and productivity of the major crops of Kerala especially over the recent years will be must valuable. Appropriate modelling is the most suitable statistical tool as the data is time series in nature. Most of the time series data can well be described using nonlinear models. Many works have been done in the past on nonlinear modelling with the advance of computers the complexity of fitting nonlinear models to time series data has been minimised.

The present study was carried out with the objective to obtain suitable nonlinear models for estimating the growth of major crops with respect to area, production and productivity in the state as also in the different districts of Kerala and to have district wise comparison of the growth pattern. This would enable to identify the crops which are viable for further development with respect to area, production and productivity among the districts.

In order to accomplish the above mentioned objective four nonlinear models namely Monomolecular, Logistic, Gompertz and Mixed-Influence models were fitted by using Levenberg-Marquardt technique for the data on area, production and productivity of selected crops. When the four nonlinear models were found unsatisfactory either simple linear regression model or quadratic function model was used to study the nature of trend.

Limitations of the study

The study was based only on the secondary data collected from the 'Statistics for Planning' issues of Directorate of Economics and Statistics, Kerala state. As the formation of fourteen districts was completed only by 1980, time series data there after only was taken into consideration. There may other unattempted nonlinear models which may be more appropriate. But the study was confined to the aforesaid four nonlinear models only due to their broad practical utility and interpretability.

Review of Literature

2. REVIEW OF LITERATURE

Linear regression analysis is a very powerful technique and is extensively used in agricultural research. This methodology assumes a linear relationship between response and explanatory variables, which may not hold in many situations. Thus, the concept of nonlinear modelling comes in practice to explain the relationship between response and explanatory variables. Parameter estimation in both linear and nonlinear regression analysis can be carried out by the method of least squares, which minimises residual sum of squares. Nonlinear modelling was put in practice more frequently only after computers became popular. So most of the relevant literature are quiet recent.

Kvalseth (1985) discussed the various considerations and potentials in using R^2 as a measure of goodness of fit. While admitting that R^2 serves as a useful summary statistic for measuring model adequacy, he emphasized the necessity of additional analysis of the residuals

Semi logarithmic models used by Thomas *et al* (1991) showed a decreasing trend in area, production and productivity of different crops of Kerala.

Prajneshu and Sharma (1992) proposed a nonlinear statistical model to describe the path of adoption for high yielding varieties of food grains in the country. Nonlinear estimation procedures employed for fitting the model was thoroughly discussed. The model was used for proportion of area under high yielding varieties of wheat in Punjab from 1966 – 67 to 1986 – 87.

Kastelic et al (1993) gave a note on non-linear statistical models of allometric growth after conducting study of allometric growth of bone and body weight of pigs with nine models. Three models involved a single trait and the other models dealt with growth of two or more traits simultaneously. Because of size differences between body parts resulting in the size of random errors being dependent on the mean, the data were transformed. Logarithmic transformation greatly reduced the scaling effects. Growth rate of bones was shown to be slower than that in body weight. Significant differences in allometric growth parameters occurred between models.

Ajithkumar and Devi (1995) conducted a study by using semi log, exponential and linear models and opined that the variability in area was comparatively lower than that of production and productivity of tea in Kerala.

Stobbe et al (1996) conducted a study for the evaluation of selected nonlinear regression models in quantifying seedling emergence rate of spring wheat. In this study the relative effectiveness of the Gompertz, Logistic, and Weibull models in quantifying emergence rate of spring wheat was compared. Each of the models was fitted to daily-recorded emergence data. The analyses of stability and accuracy functions, residual sum of squares and variance showed that the Weibull model was not appropriate in quantifying rate of emergence. The Gompertz and Logistic models functioned in a similar way with great stability and accuracy in most cases. The Gompertz predictions most closely fitted the observed set of responses with residual points scattered around zero. For lognormally distributed emergence patterns common under field conditions, the Gompertz model provided the most appropriate characterization of emergence.

Non-linear mechanistic growth models including monomolecular, logistic, gompertz, mixed-influence and richards were used for describing state-wise production data of wheat during 1966-67 to 1992-93 in India. The parameters of these models were estimated using Levenberg-Marquardt procedure for non-linear estimation. The six major wheat-growing states considered were Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Rajasthan and Bihar. For each of these states, Logistic model gave a good description of the wheat-production data in the post green-revolution era. A comparative performance of various states for wheat production showed that Haryana performed the best, as reflected by its high intrinsic growth rate. (Prajneshu and Das (1998))

Velu (1998) fitted three mathematical models (Gompertz, Richard's and Logistic) to determine the critical weed competition period and its impact on crop growth by using total biomass produced by three green gram cultivars (Co 4, NARP 1 and Co GG 89047) at different stages of crop growth following herbicide treatment in field experiments. Gompertz model showed a high predictability (R^2) ranging from 95.6% to 99.9% for estimations of the total dry matter production of cultivars. Co 4 showed a comparatively higher R^2 for all models at all weed management levels with corresponding low values of Chi-square, Residual Sum of Squares and root mean squre deviation.

Prajneshu (1998) developed a nonlinear statistical model for describing the dynamics of aphid population growth. The model was applied to ten data sets using Levenberg-Marquardt procedure. Examination of residuals was carried out to study the validity of the underlying assumptions and subsequently goodness of fit statistic was computed. The model was found to be quiet successful in describing the dynamics of population growth.

Venugopalan and Prajneshu (1998) tried a comparative study of linear and non-linear parameter estimation procedures for allometric model describing the length-weight relationship. It was shown that the latter approach is the correct one from statistical point of view. It was demonstrated by an illustration that the proposed procedure might yield parameter estimates which were not only quantitatively different from the corresponding ones for linear estimation but also have a bearing on the biological interpretation.

Canacoo and Ahunu (1999) conducted a study to determine the best standard growth function for describing the growth of Ghanaian donkey. Weight-age data on 74 donkeys were used. Five models viz; Bertalanffy, Brody, Gompertz, Logistic and Richards were used to fit the data including birth weights and weights at various ages. All growth curves followed a characteristically sigmoid shape and appeared to provide a good fit to the donkey data as indicated by the high R^2 values. All models described early growth less adequately than later growth. The Logistic and Bertalanffy models underestimated mature weight, whereas Richards and Brody models overestimated it. However, the closest estimates were given by Bertalanffy and Richards models.

Borah *et al* (1999) used Linear, Exponential, Gompertz and Logistic mathematical models for studying body weight growth of broiler. The result indicated that Linear and exponential models had poor fits compared to Gompertz and Logistic models. The Gompertz model explained growth performance more precisely than the Logistic model.

Sharma *et al* (2000) conducted a study for the selection of statistical model to examine the growth pattern of area and production of rapeseed and mustard. He also made an attempt to fit non-linear regression options for estimating the parameters of all the selected models, i.e. Logistic, Gompertz and monomolecular model, for knowing the past and future growth pattern of the rapeseed-mustard group of crops. The information about the past and ongoing pattern of cultivation of rapeseed-mustard group of crops were collected for 30 years (from 1967-68 to 1996-97) with respect to area and production. The logistic model was found to be unrealistic for knowing the ongoing growth in area and production and in estimating the respective value for subsequent years. Whereas, for area, none of the models was found to perform satisfactorily. The Gompertz model was observed to be the most suitable with respect to production as indicated by the values of coefficient of determination of 66% and 0.4% growth rate in production.

Four non-linear mechanistic growth models viz. monomolecular, logistic, gompertz and mixed-influence models were used to examine the pattern of wheat productivity from 1973-74 to 1996-97 in Punjab, Haryana, Uttar Pradesh, Rajasthan and all-India. Out of the different models used, only the Logistic and Gompertz models fitted very well the five data sets; the monomolecular model could only be fitted to the wheat productivity data of Uttar Pradesh, while the mixed-influence model could only be fitted to the other four data sets. Comparison of collected data revealed that Haryana's performance (in terms of yield) was best among the major wheat growing states of India. Forecast values, computed on the basis of the selected models, indicate higher wheat productivity potentials for both Punjab and Haryana by year 2010 and 2020 compared to any other state. (Prajneshu and Das (2000))

Brody, Gompertz, Logistic, Richards and Von Bertalanffy models had been fitted to growth data in Nelore heifers. The age-weight data for this study came from

348 Nelore females. The parameters were estimated by the generalized least squares method using nonlinear regression models with autocorrelated errors. Models were compared by using coefficient of determination and biological interpretation of parameters was made. Brody and Richards models were indicated to be used in describing Nelore heifers' growth for their accuracy of fit and reasonable interpretation of parameters were made. (Mendes *et al* (2001))

Jaimes and Torres (2001) used epidemiological models for the analysis of the Pudricion Del Cogollo syndrome of oil palm (*Elaeis guineensis Jacq.*) in the piedmont of the eastern Colombian plains. Linear, exponential, monomolecular, logistic and gompertz models were used and the census data were grouped for analysis purposes into five, four, three and one-year periods. Criteria used to select the most appropriate model for each section and period under study were a high coefficient of determination (R^2) and an unbiased residual distribution. Logistic and Gompertz models were found most suited to the data.

Cho *et al* (2001) used four non-linear models (von Bertalanffy, Brody, Gompertz and Logistic models) which have three parameters to fit the weight-age data for five strains of female Korean Native Chicken and also carried out a comparison of nonlinear models for describing weight-age relationship in korean native chicken. Weight-age data for these analyses were collected from 300 pullets. Comparisons were made among these models for the goodness of fit, biological interpretability of the parameters and computational ease. The residual mean squares for all strains of korean native chicken were largest for the Brody model and smallest for the Gompertz model compared to other models within each strain. The residual mean squares for all models were smallest in the Grey-Brown strain and largest in the Red-Brown strain followed closely by the yellow-brown strain due to the fluctuations of body weights of mature chickens. Von Bertalanffy and Brody models underestimated weights at hatch and the Logistic model generally overestimated weights at early ages (prior to 6 weeks of age). Von Bertalanffy, Brody and Gompertz models, consistently underestimated weight at 21-27 weeks of age, except for the Yellow-Brown strain, but the differences of estimated weights from actual weights for Gompertz were smallest. Gompertz model showed the smallest residual mean squares and its biological interpretation for the parameter estimates or function was easier.

Therefore, Gompertz model was found to be the most appropriate for fitting the weight-age data of Korean native chicken.

Mello *et al* (2001) analysed two models (exponential and linear) for estimating intense rainfall and provided a comparison between them. Data of annual-daily-maximum rainfall (1914-1991) for Lauras, Minas Gerais, Brazil were used to derive the models. The exponential model provided a better estimation of intense rainfall. Thus, it could be recommended for application in watershed projects the linear model did not provide a reliable estimate of intense rainfall for the studied area.

Mishra (2002) worked out indices for Agricultural development in various districts/regions of the Kerala state using data from 1970-71 to 1997-98. Districts were classified into eight regions for the study. The compound growth rates of acreage as well as production of major crops were obtained. The method of least squares was used to describe the trend in acreage and production of the crops.

Sinha *etal* (2002) evaluated Logistic and Gompertz growth models to describe the pattern of powdery mildew (Oidium mangiferae) development on mango cultivars Dashehari and Amrapali. Quantitative information about the parameters concerning intrinsic infection rate and maximum mildew severity had been obtained. Area under disease progress curve was higher in Dashehari than in Amrapali. Maximum rate of disease growth was between seventh and eighth weeks after the initiation of the disease. This modelling effort was useful in developing strategies for the efficient management of powdery mildew disease of mango.

Ravichandran and Prajneshu (2002) used three types of structural time-series modelling for describing trend in sunflower yield during 1985-86 to 1997-98viz; local level model, local linear trend model, and local linear trend model with intervention (LLTMI). The performance of LLTMI was the best, based on a number of goodness-of-fit criteria, including Akaike information criterion, Schwartz-Bayes information criterion, and standard error. The forecast of sunflower yield using LLTMI for 1998-99 was 640 kg/ha, while that for 1999-2000 was 653 kg/ha.

Three non-linear models were used for describing weight-age relationships in N'Dama cattle. Comparisons were made among these models for computational difficulty, goodness of fit and lack of bias in estimate of mature weight. Brody's and Bertalanffy's growth models were easy and took less time to reach convergence in comparison to Richards' model. Richards' model with least residual mean squares was the best fit to the observed growth pattern of male and female N'Dama cattle. Bertalanffy's model had the best Asymptotic estimate (A) for males' data and could predict 99.40% of their mature weight, while Richards' model, which had the best asymptotic estimate in females could predict 99.43% of their mature weight. (Mgbere and Olutogun (2002))

Fujikawa et al (2003) developed a modified Logistic model for bacterial growth. The new model was described by a differential equation and contained an additional term for suppression of growth rate during the lag phase, compared to the original Logistic equation. The new model successfully described sigmoidal growth curves of Escherichia coli and Salmonella under various initial conditions. Further, Salmonella growth at varying temperature could be well simulated by the new model. These results indicated that the new model would be a useful tool to predict bacterial growth under various temperature profiles.

Prajneshu and Kandala (2003) developed a nonlinear Mixed Influence growth model. It was obtained by combining Logistic and nonlinear models. Proportion of area under high yielding varieties of wheat in the country during the post green revolution era was modelled using Levenberg- Marquardt technique. The model revealed very good fit for the data.

Venugopalan and Shamasundaran (2003) have brought out the necessity for nonlinear estimation procedure by pointing out the drawbacks of existing practice of using the transformed version of nonlinear models. They have discussed four different procedures and Levenberg-Marquardt technique was used to fit a nonlinear model for describing data pertaining to the period 1960-61 to 1976-77 on average fruit yield of coorg mandarin trees. Using the Gompertz model it was inferred that 94 percent of carrying capacity (maximum sustainable yield) had already been achieved by the year 1977.

Krishan *et al* (2003) conducted a study with the objective to select the best model (linear or non-linear) to be used in projecting future trends in egg and poultry meat production in India. Data on egg production (in millions) were collected from the State Department of Animal Husbandry in Uttar Pradesh, for the period from 1950-51 to 1995-96. Data on poultry meat production were collected from FAO Production Year Books for the period from 1971 to 1995, at a national level. The Richard model was found to be the best fit for egg production and the Hoerl model for poultry meat.

Lopez et al (2004) carried out a study of statistical evaluation of mathematical models for microbial growth. Nonlinear functions used were: three-phase linear, logistic, Gompertz, Von Bertalanffy, Richards, Morgan, Weibull, France and Baranyi. Statistical criteria used to evaluate model performance were analysis of residuals (residual distribution, bias factor and serial correlation) and goodness-of-fit. The models showing the best overall performance were the Baranyi, three-phase linear, Richards and Weibull models. The goodness-of-fit attained with other models could be considered acceptable, but not as good as that reached with the best four models. Overall, the Baranyi model showed the best behaviour for the growth curves studied according to a variety of criteria. The Richards model was the best-fitting for optical density data. The results indicated that the common use of the Gompertz model to describe microbial growth should be reconsidered critically, as the Baranyi, three-phase linear, Richards and Weibull models showed significantly superior ability to fit experimental data than the extensively used Gompertz model.

Fujikawa et al (2004) introduced a new Logistic model for bacterial growth. The model, which was based on the Logistic model, contains an additional term for expression of the very low rate of growth during a lag phase, in its differential equation. The model successfully described sigmoidal growth curves of Escherichia coli at various initial cell concentrations and constant temperatures. The model predicted well the bacterial growth curves, similar to the Baranyi model and better than the modified Gompertz model, especially in terms of the rate constant and the lag period of the growth curves. Using the experimental data obtained at the constant temperatures, the new logistic model was studied for growth prediction at a dynamic temperature. The model accurately described E. coli growth curves at various patterns of dynamic temperature.

Freitas (2005) used seven nonlinear models to determine the growth curves in animal production. The models used were viz; Brody, Richards, Von Bertalanffy and two alternatives of Gompertz and Logistic models and were fitted using Gauss Newton method for the weight-age data of eight animal species: freshwater prawn macrobrachium rosenbergii, pepper frog, rabbit, poultry, sheep, goat, pig and cattle.Results revealed that the Logistic method estimated the body weight in all species, while the Von Bertalanffy model was applicable only for freshwater prawn macrobrachium rosenbergii; Gompertz models were applicable to freshwater prawn macrobrachium rosenbergi, pepper frog, poultry, pig and cattle; for each species, at least two nonlinear models of the seven models were adequate to estimate their body weight because the coefficients of determination were greater than 92.0%..

According to Prajneshu (2005) statistical modelling plays a very important role in understanding the relationship among variables in fisheries and also in efficient fishery management. He emphasized four sub areas of statistical modelling, viz. length-weight relationship, age-length relationship, fish production and export over time, and catch-effort relationship. Some future research problems in Fuzzy methodology, nonlinear time-series analysis, growth models in random environment and multispecies fish modelling were also outlined.

Sengul and Kiraz (2005) used four different nonlinear models: (Gompertz, Logistic, Morgan-Mercer-Flodin and Richards) to define the growth curves of turkeys. A total of 288 turkey poults (144 males and 144 females) were used in this study.The coefficients of determination for these models were 0.9975, 0.9937, 0.9993 and 0.9966 for females and 0.9974, 0.9933, 0.9993 and 0.9969 for males, respectively. Considering the model selection criteria, the Gompertz, Logistic and Richards models seemed to be suitable for explaining the growth of Large White turkeys.

Ismail *et al* (2005) fiited nonlinear growth models for oil palm yield growth.Twelve nonlinear growth models and its partial derivatives for oil palm yield growth were presented in this study. The parameters were estimated using the Marquardt iterative method of nonlinear regression relating oil palm yield growth data. The best model was selected based on the model performance and it could be used to estimate oil palm yield at any age of oil palm. This study found that the Gompertz, logistic, log-logistic, Morgan-Mercer-Flodin and Chapman-Richard growth models had the ability for quantifying a growth phenomenon that exhibited a sigmoid pattern over time. Based on the statistical testing and goodness of fit, the best model was the Logistic model and followed by the Gompertz model, Morgan-Mercer-Flodin, Chapman-Richard (with initial stage) and Log-logistic growth models.

Materials and Methods

3. MATERIALS AND METHODS

The study was conducted using the secondary data pertaining to area, production and productivity of five major crops in each district of Kerala collected from 'Statistics for Planning' issues of Directorate of Economics and Statistics, Kerala state. According to the geographical and climatical conditions the area under cultivation of different crops varies in each district. The selection of major crops from each district was done on the basis of the cultivated area of the crops during the last five years (1999-2003). The five major crops under study in each district are given in the table below.

Table.1. Major crops in different districts of Kerala selected with respect to area under cultivation

District	Crops				
Thiruvananthapuram	Coconut	Rubber	Tapioca	Pepper	Paddy
Kollam	Coconut	Rubber	Tapioca	Paddy	Pepper
Alappuzha	Coconut	Paddy	Cashew	Tapioca	Rubber
Pathanamthitta	Rubber	Coconut	Tapioca	Paddy	Pepper
Kottayam	Rubber	Coconut	Paddy	Pepper	Tapioca
Idukky	Pepper	Rubber	Cardamom	Coconut	Tapioca
Ernakulam	Coconut	Rubber	Paddy	Pepper	Banana
Thrissur	Coconut	Paddy	Rubber	Pepper	Banana
Palakkad	Paddy	Coconut	Rubber	Banana	Pepper
Malappuram	Coconut	Rubber	Paddy	Cashew	Pepper
Kozhikode	Coconut	Rubber	Pepper	Paddy	Tapioca
Wyanad	Coffee	Pepper	Paddy	Banana	Coconut
Kannur	Coconut	Rubber	Cashew	Pepper	Paddy
Kasargode	Coconut	Rubber	Cashew	Paddy	Pepper

Data for the period from 1980-1981 to 2002-2003 were only considered for the study as the formation of fourteen districts of Kerala was completed only by 1980.Data on area and production of selected crops in each district were expressed in hectares and tonnes respectively except for coconut, for which area was expressed in hectares and production in million nuts.

3.1. Non Linear Growth Models

A non-linear regression model is one in which at least one of the parameters appears in non-linear form. Mathematically, derivatives of the expectation function with respect to at least one parameter is a function of parameter in non-linear models. Four non-linear mechanistic growth models have been fitted for estimating the growth of major crops with respect to area, production, and productivity in the state as also in different districts of Kerala and a District wise comparison of growth pattern were also done. The non-linear models used are given below.

3.1.1. Monomolecular model

This model describes the progress of a growth situation in which it is believed that the rate of growth at any time is proportional to the resources yet to be achieved, ie;

$dx/dt = r(c-x)$, --------------(1)

Where 'c' is the carrying size of the system. Integrating equation (1), we get

$X(t) = c - (c-b) \exp(-at) + e$, -------------- (2)

3.1.2. Logistic model

This model is represented by the differential equation

$dx/dt = r x (1-x/k)$ -------------- (3)

Integrating, we get

$X(t) = c/[1+b \exp(-at)] + e$, --------------(4)

The graph of X (t) versus't' is elongated S-shaped and the curve is symmetrical about its point of inflexion

3.1.3. Gompertz model

This model is also having a sigmoid type of behaviour and the differential equation for this model is $dx/dt = r\,x\,\log_e(c/x)$ ------------ (5)

Integrating, we get

$X(t) = c\exp[-b\exp(-at)] + e$, --------------- (6)

3.1.4. Mixed-Influence model

This nonlinear model is obtained by combining the well-known logistic and monomolecular models. The differential equation governing this model for describing growth of a variable 'x' is

$dx/dt = a(c-x)+b\,x(1-x/c)$, ------------- (7)

Integrating, we get

$X(t) = [c(a+bd) - a(c-d)\exp\{-(a+bc)t\}]/[(a+bd) + b(c-d)\exp\{-(a+bc)t\}]+e$ ---- (8)

Where X (t) represents area / production/ productivity of each crop at time't', 'a', 'b', 'c', 'd' are the parameters and 'e' is the error term. The parameter 'a' represents the intrinsic growth rate and parameter 'c' represents the carrying capacity for each model. The third parameter 'b' represents different functions of the initial values for x (0) for different models. Same thing was true for fourth parameter'd'.

Apart from the above mentioned nonlinear models, Quadratic function of the form $X(t) = b_0 + b_1 * t + b_2 * t^2$ and Simple linear regression of the form $X(t) = a + b^* t$ were tried for the data where nonlinear models were found not a good fit.

3.2.Estimation of Parameters of Non-Linear Models

As in linear regression, in non-linear case also parameters are estimated by the method of least squares. However, minimization of residual sum of squares yield normal equations, which are nonlinear in parameters. Since it is not possible to solve nonlinear equation exactly, the alternative is to obtain approximate analytical solutions by employing iterative procedure. Levenberg-Marquardt iterative procedure was used for fitting the models for area, production and productivity. With assigned initial values for the parameters of the model under consideration iteration procedure continued till the reduction in the residual sum of squares in consecutive iteration was found to be negligibly small.

Consider the model

$Y_i = f(x_i, \theta) + e_i$, i = 1,2,3- - - n

Where Y_i is the value of the i th dependent variable.

x_i is the value of the i th independent variable.

$\theta = (\theta_1, \theta_2, \theta_3, --- \theta_p)'$ are parameters.

e_i is the error term attached to the i^{th} unit. e_i's are assumed and follow $N(0,\sigma^2)$

The residual sum of squares is

$S(\theta) = \sum_{i=1}^{n} (Y_i - f(x_i, \theta))^2$

Let $\theta_0 = (\theta_{10}, \theta_{20}, \theta_{30}, --- \theta_{p0})'$ be the vector of initial parameter values. Then the algorithm for obtaining successive estimates is essentially given by

$(H+\tau I)(\theta_0 - \theta_1) = g$

$(\theta_0 - \theta_1) = (H+\tau I)^{-1} g$

Where

$g = \partial S(\theta)/\partial \theta \,/\, \theta = \theta_0$, $H = \partial^2 S(\theta)/\partial \theta \partial \theta' \,/\, \theta = \theta_0$

I is the identity matrix and τ is a suitable scalar.

All the procedures for nonlinear estimation require initial values of the parameters and the choice of initial values is crucial. The initial values were calculated by fitting the specified models for each crop using Newton-Raphson iterative procedure in STATISTICA (5.Statistical software). These initial values were used to fit the growth models using Levenberg-Marquardt method in SPSS(11.5).

3.3.Measures of goodness of fit of the models

The following measures of goodness of fit statistic are used to judge the adequacy of the fitted models.

3.3.1. Variance explained (R^2)

R^2 measures the proportion of variation in the dependent variable explained by the model and is expressed as

$R^2 = 1 - \{ \Sigma (Y_i - \hat{Y})^2 / \Sigma (Y_i - \overline{Y})^2 \}$

$= 1 -$ (Residual sum of squares / total sum of squares)

3.3.2 Root Mean Squared Error (RMSE)

Mean square error measures the sum of squared deviation of observations from the actual value and performance of the models were also evaluated by root mean square, which is expressed as

$\text{RMSE} = \text{sqrt} (\Sigma (Y_i - \hat{Y})^2 / n)$

The above criteria were used for selecting appropriate nonlinear model to describe the time series data on area, production and productivity. For selected models two parameters namely P and Q, where P is the ratio of the initial data value (1980-81) to the carrying capacity and Q (ratio of end data value to the carrying capacity, c) is the carrying capacity achieved by the end period (2002-03) were computed. The carrying capacity achieved Q along with the intrinsic growth rate measures viability for further improvement.

4. RESULTS AND DISCUSSION

The growth models namely Monomolecular, Logistic, Gompertz and Mixed-Influence were fitted to the secondary data on area, production and productivity for each crop in each district and to the state. Where, nonlinear models did not fit satisfactorily, either simple linear regression model or quadratic model were tried to explore the nature of trend. Before fitting the quadratic function outliers were identified and removed. Further based on the first order differences the shifts in trend were assessed and where ever necessary break points were identified. Generally Mixed-Influence model was a poor fit except for productivity. The results of the model fitting are given crop wise for all the districts along with the state.

4.1.Coconut

The parameters viz; intrinsic growth rate(a), carrying capacity(c) along with R^2, RMSE, achieved carrying capacity during initial(P) and end periods(Q) best fitting model for each district and the state for area, production and productivity are given in tables 1.a, 1.b and 1.c respectively. The parameters of quadratic function along with R^2 for area, production and productivity are given in tables 1.a1, 1.b1 and 1.c1.

4.1.1.Thiruvananthapuram

Area, production and productivity showed an increasing trend over time with frequent fluctuations.

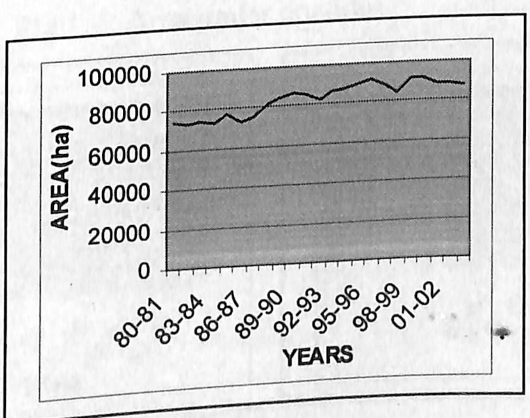


Fig 1.1. Area under coconut

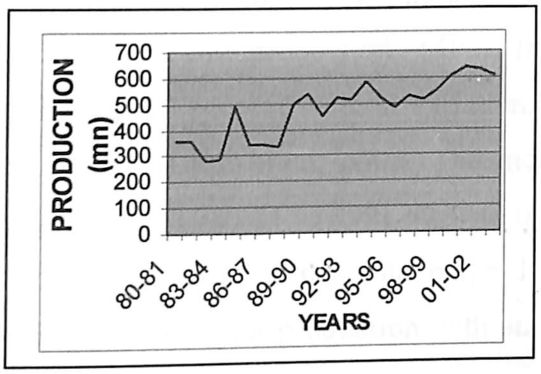


Fig 1.2. Production of coconut

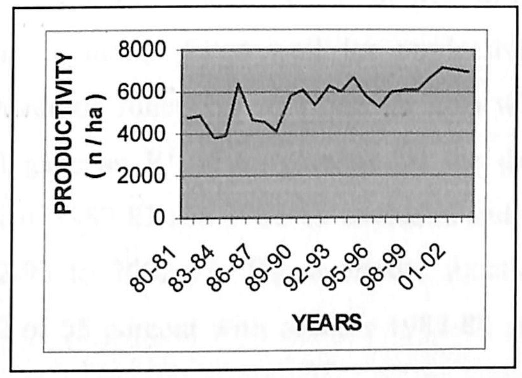


Fig 1.3. Productivity of coconut

The results indicated that Monomolecular was found suitable for area and production, which explained 82 percent and 76 percent respectively of total variation. Logistic model gave an R^2 of 62 percent for productivity.

4.1.2. Kollam

The time series data on area showed a sustainable trend in the district, while the data on production and productivity showed an increasing trend with fluctuations.

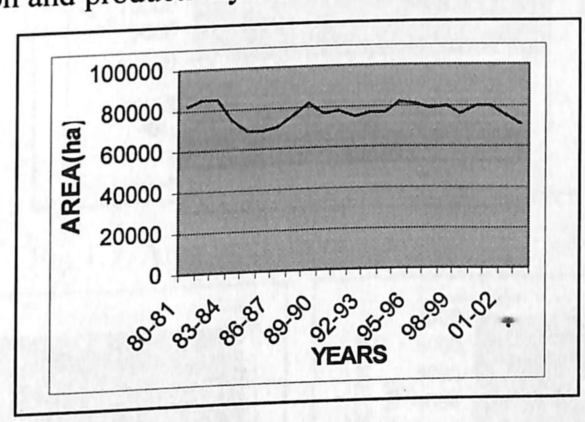


Fig 1.4. Area under coconut

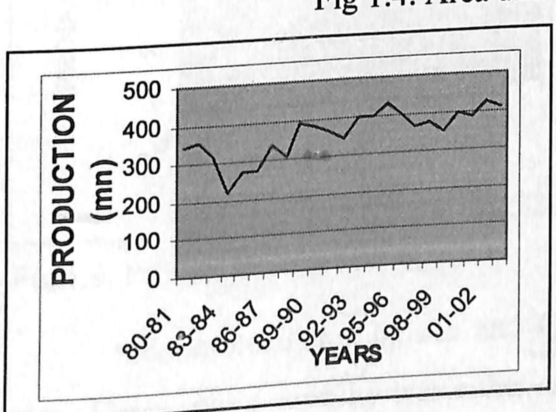


Fig 1.5. Production of coconut

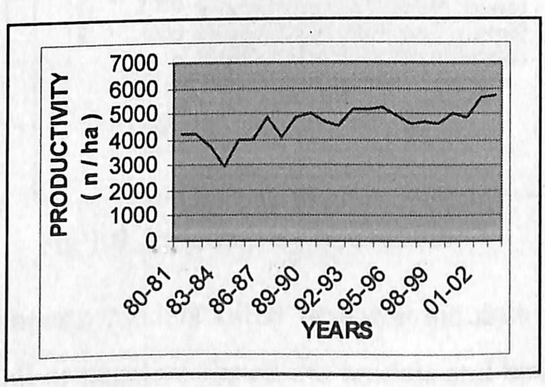


Fig 1.6. Productivity of coconut

All the nonlinear models along with the linear model did not fit well to the data of area and production. Mixed-Influence model fitted well for productivity explaining 58 percent of total variation. Quadratic function was fitted for area with 1992-1993 as the break point. The model gave an R^2 of 62 percent for the data ranging from 1980-81 to 1991-92 with outliers 1982-83 and 1988-89 excluded and an R^2 of 62 percent for the data range 1992-93 to 2002-03. The quadratic function depicted the data on production with an R2 of 55 percent with outliers 1983-84 and 1987-88 excluded.

4.1.3. Pathanamthitta

The data on area and production showed a decreasing trend, while the data on productivity showed a slow increasing trend.

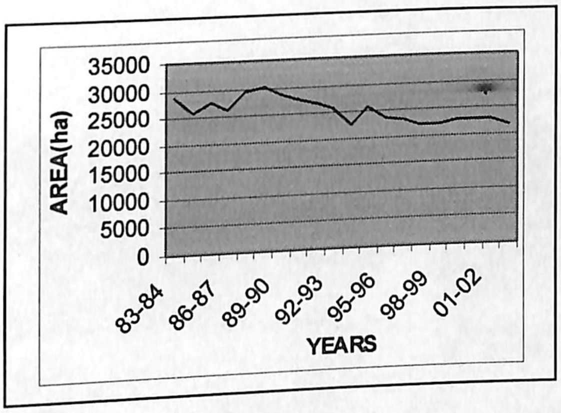


Fig.1.7. Area under coconut

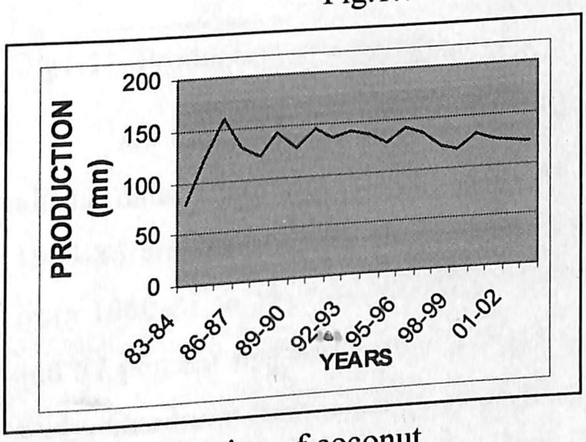


Fig 1.8. Production of coconut

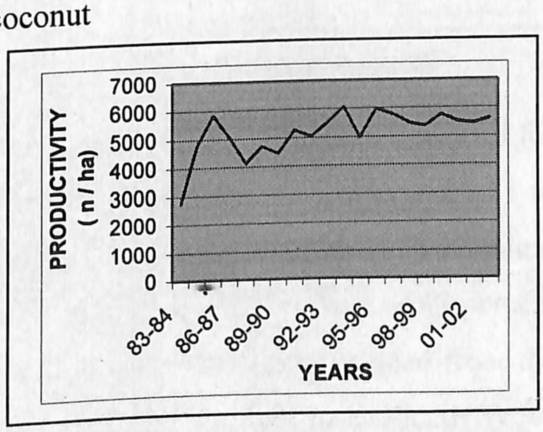


Fig 1.9. Productivity of coconut

Monomolecular, Logistic and Gompertz models fitted well for the data on area. The carrying capacity was either small or negative for all the models and hence Quadratic function was fitted for area with an R^2 of 70 percent. Monomolecular model explained 58 percent of total variation for production. Mixed-Influence model explained the data on productivity with an R^2 of 58 percent.

4. 1.4.Alappuzha

From the graph on area, production and productivity the visibility of a sustainable trend is evident.

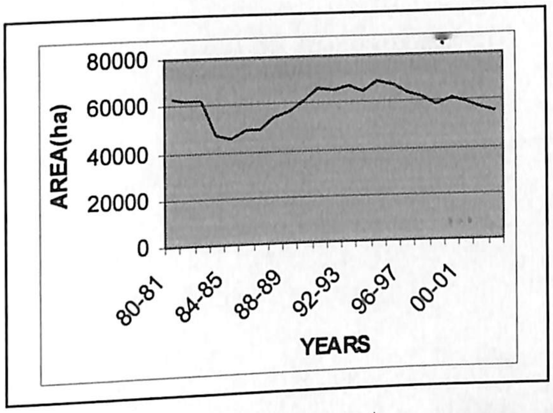


Fig1.10. Area under coconut

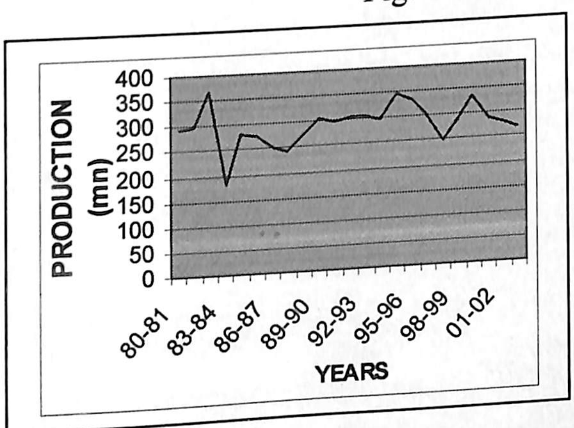


Fig1.11. Production of coconut

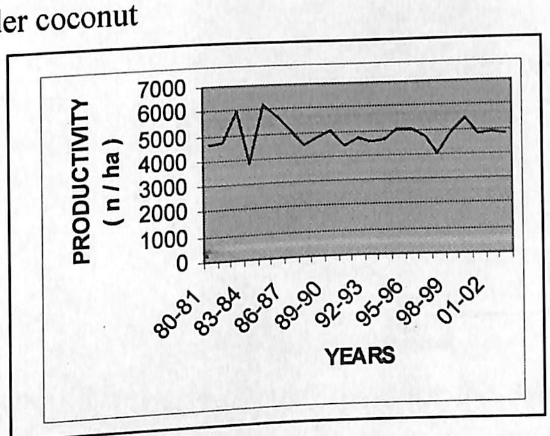


Fig1.12. Productivity of coconut

All the nonlinear models along with the linear model tried did not fit well for all the data. Quadratic function gave an R^2 of 75 percent for area from 1980-81 to 1985-86 and 83 percent for the data from 1986-87 to 2002-03. Data on production from 1980-81 to 1987-88 and from 1988-89 to 2002-03 gave R^2 values of 63 percent and 57 percent respectively with outliers 1983-84 and 1999-2000 excluded from the study. Quadratic function noticed an R^2 of 55 percent for the data on productivity for each of the break periods from 1980-81 to 1983-84 and 1984-85 to 2002-03 respectively with outliers 1982-83, 1984-85, 19997-1998 and 1999-2000 eliminated from the study.

4.1.5.Kottayam

The graph on area showed a declining trend while production and productivity showed an increasing trend with fluctuations.

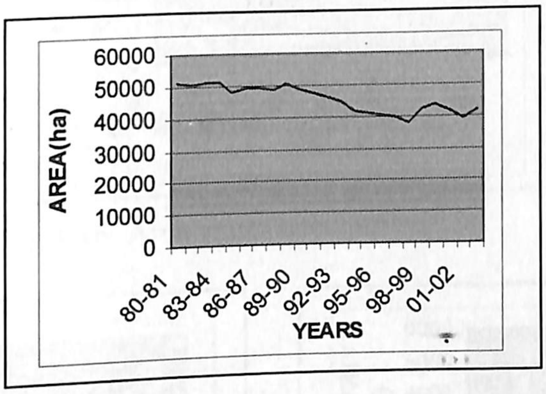


Fig 1.13. Area under coconut

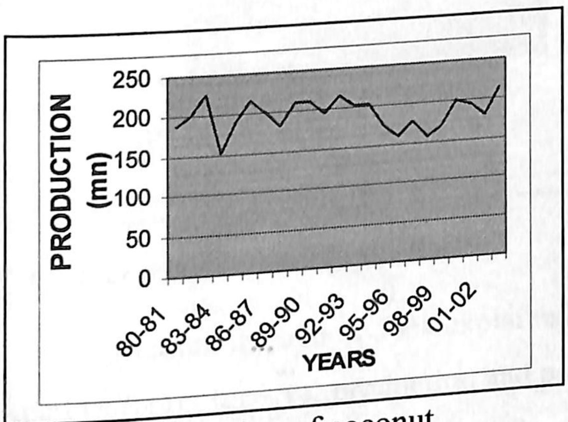


Fig1.14. Production of coconut

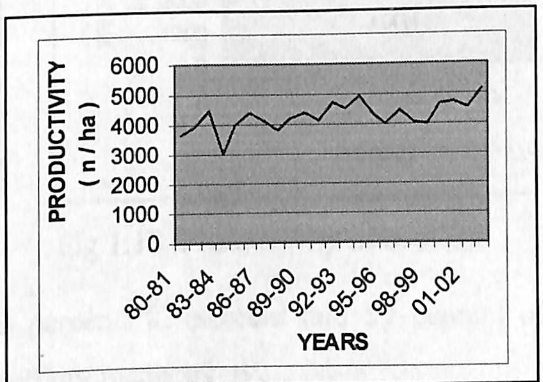


Fig 1.15. Productivity of coconut

Monomolecular, Logistic and Gompertz models fitted very well for the data on area with high R^2 values but as the values of carrying capacity were low, Quadratic model tried which explained 80 percent of total variation. However, none of the nonlinear models along with the linear model were found good fit for the data of production due to low R^2 values. Quadratic function fitted for the data on production with three break points with corresponding R^2 values of 54 percent, 57 percent and 61 percent. The data ranging from 1980-81 to 2002-2003 on productivity provided an R^2 of 56 percent with outliers 1982-83 and 1987-88 removed from the study.

4.1.6.Idukky

The graph on area and production showed an increasing trend, while the graph on productivity showed a non increasing trend.

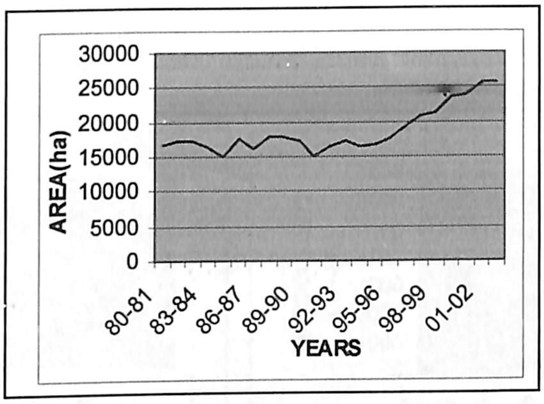


Fig 1.16. Area under coconut

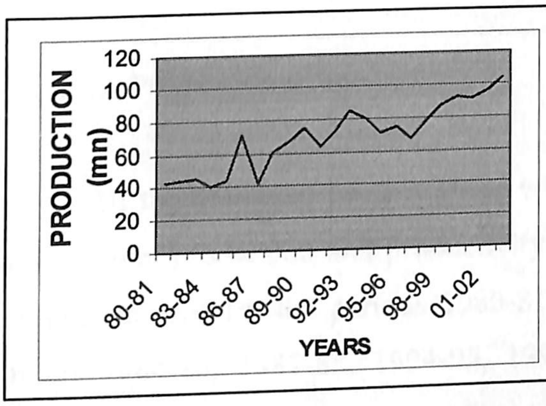


Fig1.17. Production of coconut

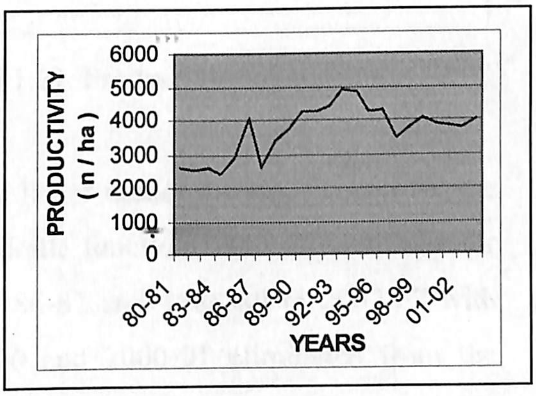


Fig 1.18. Productivity of coconut

Monomolecular model explained 60 percent, 83 percent and 59 percent of total variation for area, production and productivity respectively.

4.1.7.Ernakulam.

From the graph a sustainable trend for area under cultivation, production and productivity could be noticed.

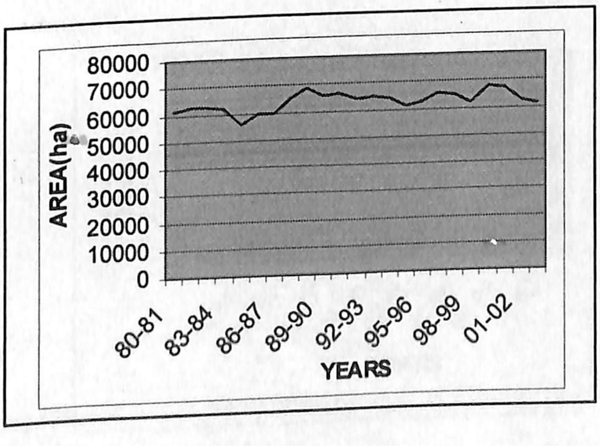


Fig 1.19. Area under coconut

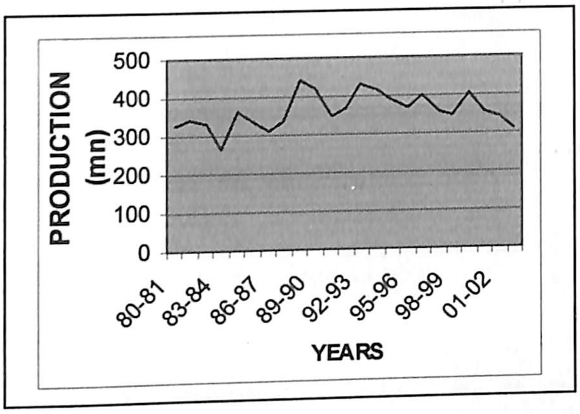


Fig 1.20. Production of coconut

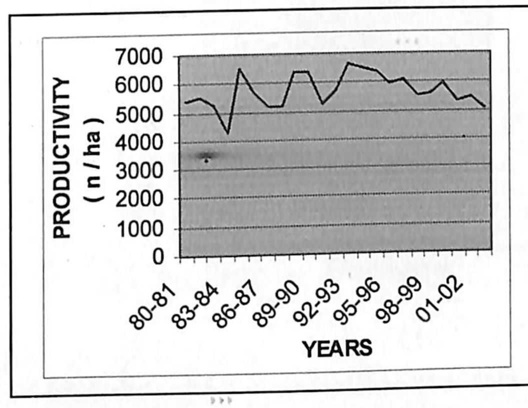


Fig 1.21. Productivity of coconut

All the nonlinear models along with the linear model did not fit well for the data on area, production and productivity. Quadratic function fitted differentially for the data on area for the periods 1980-81 to 1986-87 and 1988-89 to 2002-03 with outliers 1984-85, 1987-88, 1994-95, 1999-2000 and 2000-01 eliminated from the study. The R^2 values were respectively 88 percent and 66 percent. The quadratic model provided an R^2 of 58 percent for the data on production from 1980-81 to 2002-03 with outliers 1983-84, 1986-87, 1988-89 and 1989-90 omitted. The data on productivity from 1980-81 to 2002-03 gave an R^2 of 57 percent with outliers 1983-84, 1984-85, 1990-91 and 1991-92 not considered.

4.1.8.Thrissur

The graph on area, production and productivity showed a steady increasing trend

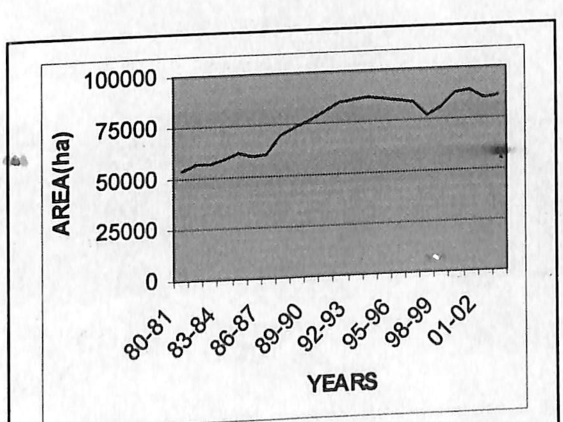


Fig1.22. Area under coconut

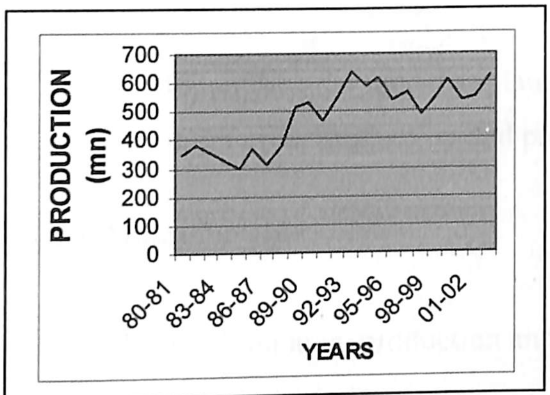


Fig 1.23. Production of coconut

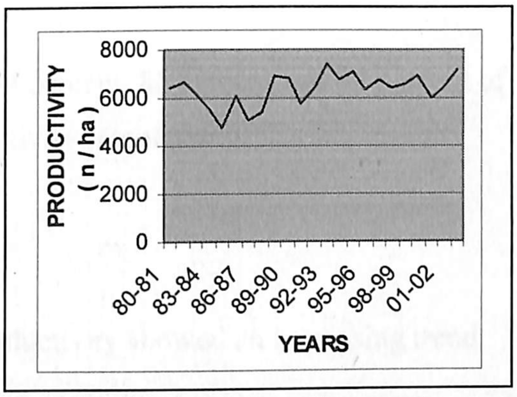


Fig 1.24. Productivity of coconut

Monomolecular model was the only model that fitted very well to the data of area with an R^2 of 87 percent. However, Monomolecular, Logistic and Gompertz models were good fit for the data on production. For productivity none of the models fitted well. Quadratic function gave R^2 values 55 percent and 53 percent for the same from 1980-81 to 1990-91 and 1991-92 to 2002-03 respectively with outliers 1981-82, 1984-85, 1988-89, 1992-93, 1995-1996 and 2000-01 not included.

4.1.9. Palakkad

The graph on area, production and productivity showed an increasing trend.

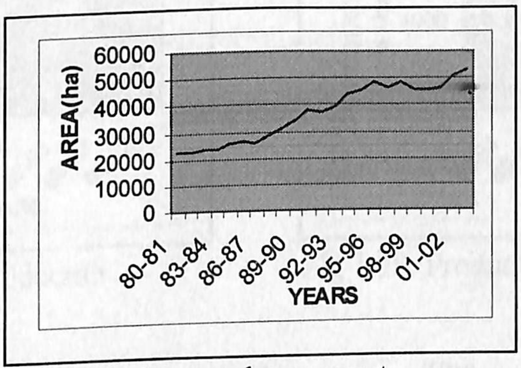


Fig 1.25. Area under coconut

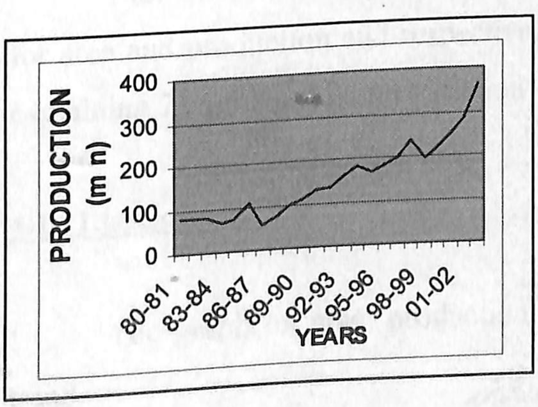


Fig 1.26. Production of coconut

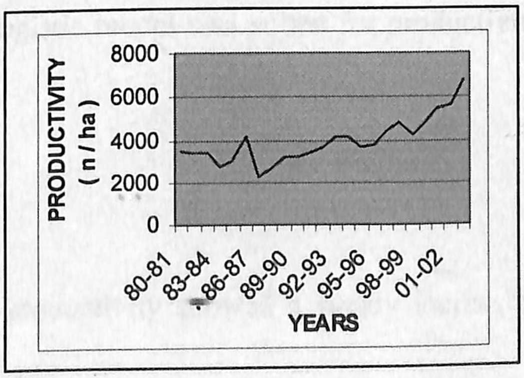


Fig 1.27. Productivity of coconut

Monomolecular model explained 94 percent, 86 percent and 64 percent of total variation for area, production and productivity respectively.

4.1.10. Malappuram

The graph on area, production and productivity showed an increasing trend.

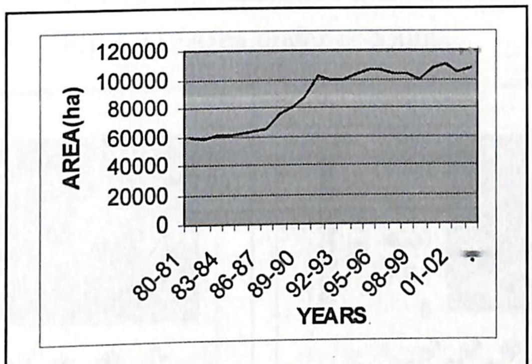


Fig 1.28. Area under coconut

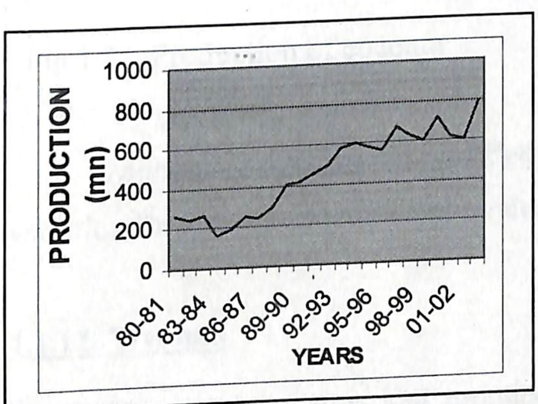


Fig 1.29. Production of coconut

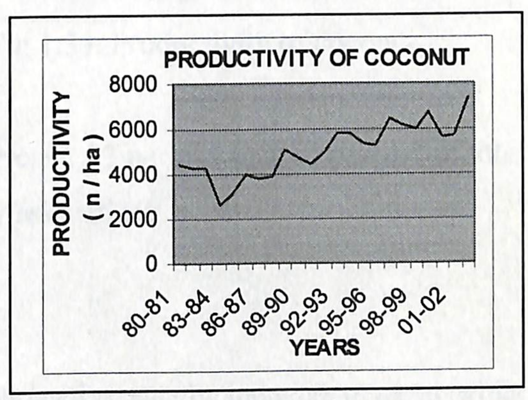


Fig 1.30. Productivity of coconut

Monomolecular model explained 89 percent and 88 percent of total variation for area and production and respectively. Logistic model was suited for productivity explaining 73 percent of total variation

4.1.11.kozhikode

The graph on area, production and productivity showed a steady increasing trend.

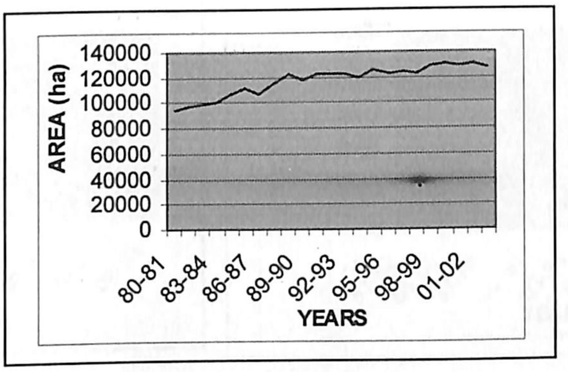


Fig 1.31. Area under coconut

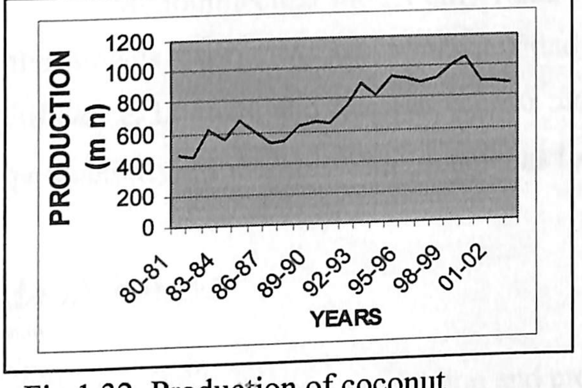


Fig 1.32. Production of coconut

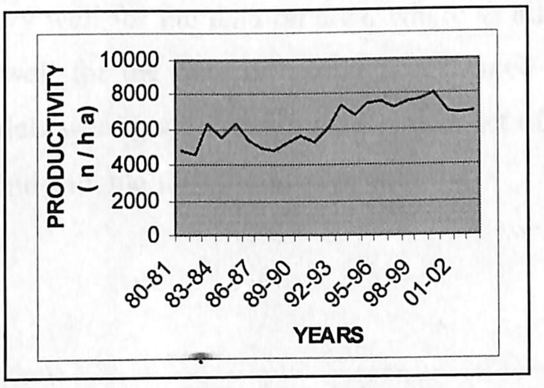


Fig 1.33. Productivity of coconut

Monomolecular model provided 94 percent, 83 percent and 64 percent of total variation for area, production and productivity respectively.

4.1.12. Wyanad

The graph on area and production showed a steady increasing trend while productivity showed an increasing trend with much fluctuation.

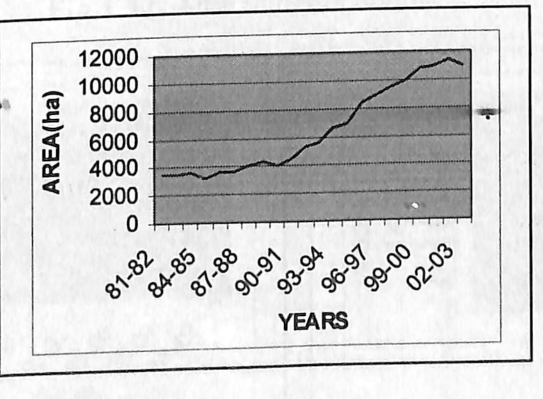


Fig 1.34. Area under coconut

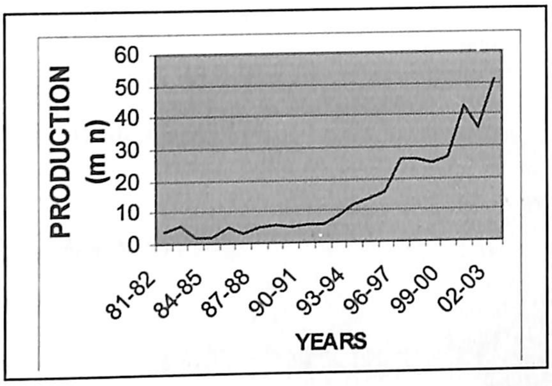


Fig 1.35. Production of coconut

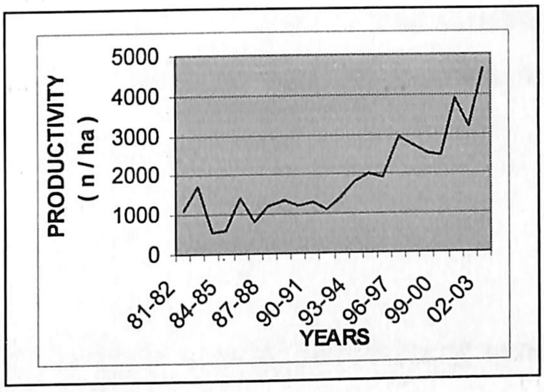


Fig 1.36. Productivity of coconut

Monomolecular model only fitted very well for the data on area, where as all the models except Mixed-Influence fitted well for the data on production. Mixed-influence, Logistic and Monomolecular models were good enough for the data set of productivity. Monomolecular model was found suitable for all sets of data.

4.1.13. Kannur

The graph on area, production and productivity showed an increasing trend

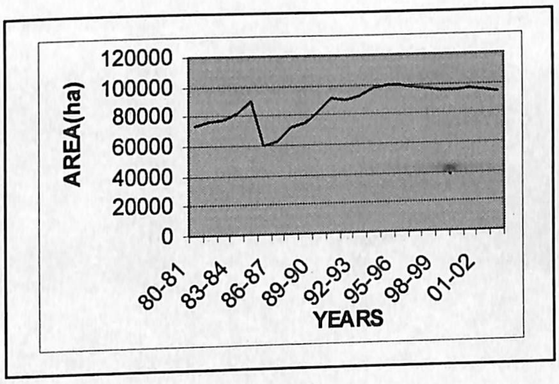


Fig 1.37. Area under coconut

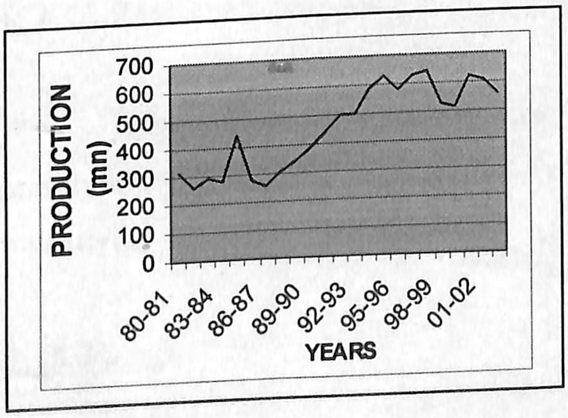


Fig 1.38. Production of coconut

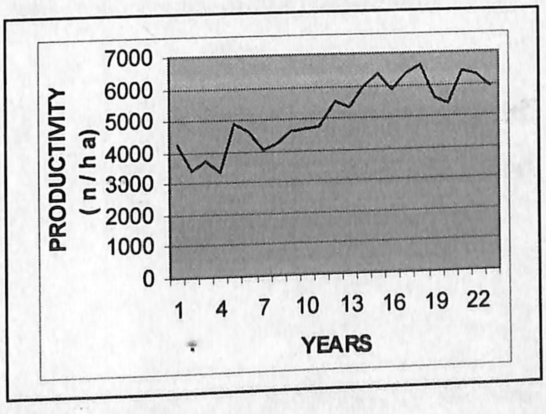


Fig 1.39. Productivity of coconut

Monomolecular model explained 57 percent and 76 percent of total variation for area and production respectively. Logistic model was suited for productivity explaining 71 percent of total variation.

4.1.14. Kasargode

The graph on area, production and productivity revealed an increasing trend with frequent fluctuations.

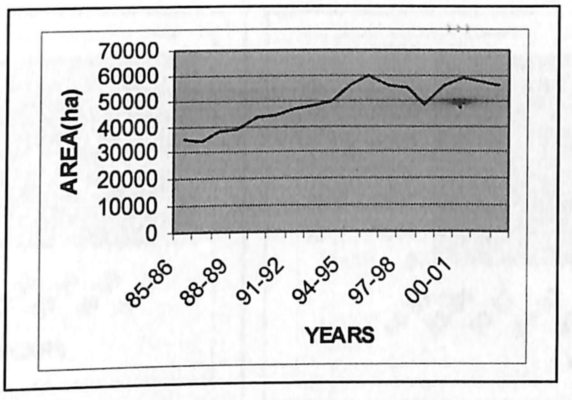
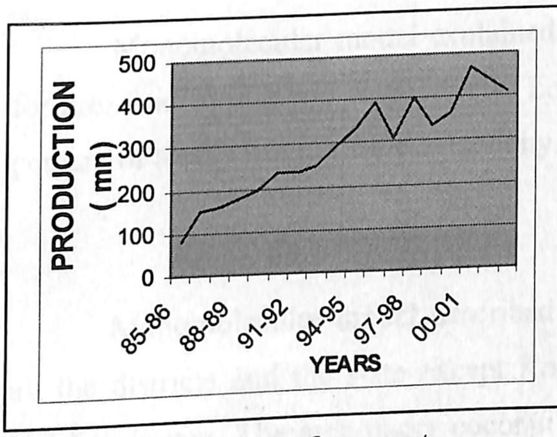


Fig 1.40. Area under coconut



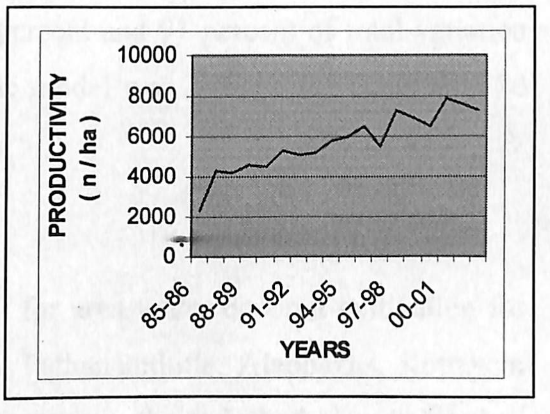


Fig 1.41. Production of coconut

Fig 1.42. Productivity of coconut

Monomolecular model was the suitable model, explaining 88 percent, 92 percent and 89 percent of total variation respectively for area, production and productivity.

4.1.15. Kerala

The time series data regarding the area, production and productivity showed an increasing trend.

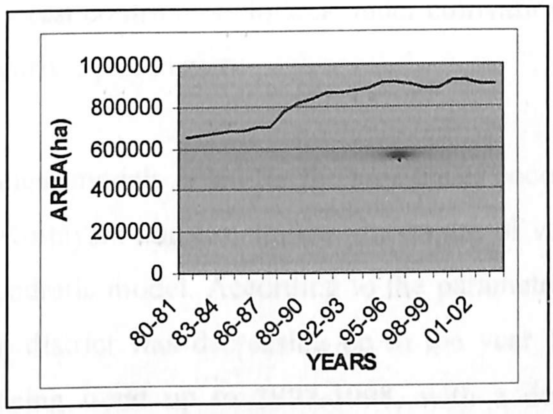


Fig 10.1. Area under coconut

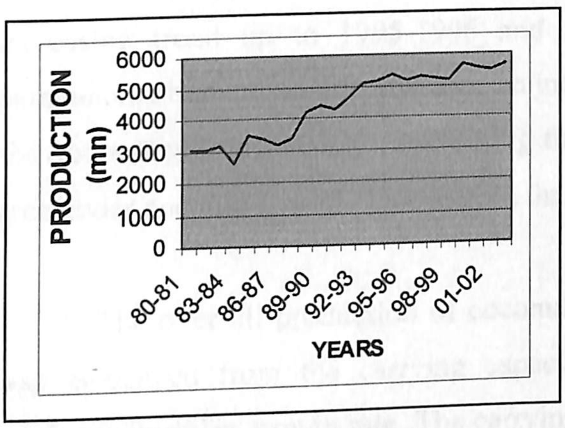


Fig 10.2. Production of coconut

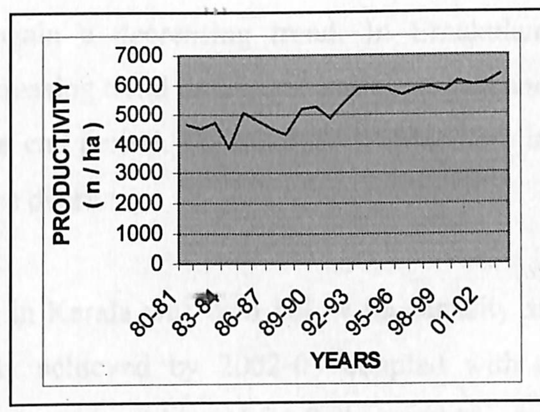


Fig 10.3. Productivity of coconut

Monomolecular model explained 92 percent and 91 percent of total variation for area and production respectively. Logistic model was suitable for explaining 80 percent of total variation for productivity.

Monomolecular model described well for area under coconut cultivation for all the districts and the state except Kollam, Pathanamthitta, Alappuzha, Kottayam and Ernakulam. The area under coconut cultivation in the state had already touched maximum as evidenced from the carrying capacity (91percent) achieved by 2002-2003. This achievement is substantiated by the high intrinsic growth rate. When we explore contribution by each district towards this achievement Thiruvananthapuram, Thrissur, Malappuram, Kozhikode and Kasargode contributed with their relatively high intrinsic growth rates. The carrying capacity achieved by 2002-2003 for Palakkad and Kannur districts were relatively low. So an addition in area under cultivation can be achieved through these districts but this additional phase might be extremely trailing because of their relatively low intrinsic growth rates. Idukky and

Wyanad districts were the poorest contributors to area under cultivation because their intrinsic growth rates were nearly equal to zero.

When the fitted nonlinear models failed for the area under coconut in Kollam, Pathanamthitta, Alappuzha, Kottayam and Ernakulam, the nature of variation in area was explored by fitting a Quadratic model. According to the parameters of quadratic function, the area in Kollam district was decreasing up to the year 1987-1988 and thereafter showed an increasing trend up to 1997-1998, with a decreasing trend henceforth. Alapppuzha district noticed a decreasing trend up to 1986-1987; an increasing trend up to 1995-1996 and again a decreasing trend. In Ernakulam parameters obtained on area revealed an increasing trend during the initial periods and showed a slight decreasing trend during the end period. To conclude the decrease in area under coconut is well evidenced in these districts

The over all production of coconut in Kerala was well below its capacity as was evidenced from the carrying capacity achieved by 2002-03 coupled with a moderate intrinsic growth rate. The carrying capacity achieved for Pathanamthitta and Thrissur were only the maximum. The coconut production in Thiruvananthapuram, Malappuram, Kozhikode, Kannur and Kasargode can be well improved based on their moderate intrinsic growth rate and the comparatively low achieved carrying capacity by 2002-03. For the districts Idukky, Palakkad and Wyanad innovative methods are to be resorted for improving coconut production.

When the fit of all nonlinear models failed the undulating tendency of coconut production in the districts Kollam, Alappuzha, Kottayam and Ernakulam were studied using Quadratic model. According to the parameters of quadratic function there was an increasing trend in Kollam district but the districts Alappuzha, Kottayam and Ernakulam had a decreasing trend.

The low production figures were mainly due to low productivity. This was justified by the fact that the achieved carrying capacity for coconut productivity by 2002-03 was moderately low for Kerala, even though the intrinsic growth rate was also moderate. The main contribution for over all productivity of Kerala came mainly from Kollam, Pathanamthiatta, Idukky, Kannur and Kasargode. There was much

Table1.a. Comparison of trend in area under coconut in different districts and the state using nonlinear models

Districts	a	c	P	Q	R^2	RMSE	Suitable model
TVM	.087	94011.16	.78	93	82	2901.46	Monomolecular model
IDK	.00032	1160034.1	.014	02	60	2163.37	Monomolecular model
TSR	.0985	98206.59	.55	87	88	4461.72	Monomolecular model
PKD	.0191	115775.18	.198	45	94	2607.38	Monomolecular model
MLPM	.0709	127925.19	.46	83	89	6757.46	Monomolecular model
KKD	.1079	133103.33	.70	95	94	2847.41	Monomolecular model
WYD	.00087	508394.09	.006	021	92	896.232	Monomolecular model
KNR	.0229	145353.15	.50	64	57	8332.66	Monomolecular model
KSGD	.1268	61288.82	.57	91	88	3129.49	Monomolecular model
Kerala	.0874	985569.15	.66	91	92	28791.5	Monomolecular model

Q and R^2 in percentage

Table 1.a1. Parameters of Quadratic function for area under coconut

		QUADRATIC FUNCTION		
Districts	Break periods	b_1	b_2	R^2
KLM	(80-92)	-4528.2	316.09	62
	(93-03)	7469.36	-218.85	62
PTA		-202.35	-9.058	70
ALP	(80-86)	-5796.2	270.76	75
	(87-03)	6723.38	-220.92	83
KTM		-774.68	7.801	80
EKM	(80-87)	1577.59	-249.05	88
	((89-03)	-894.74	15.884	66

R^2 in percentage

Table 1.b.Comparison of trend in Production of coconut in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
TVM	.0195	1216.06	.29	49	76	57.19	Monomolecular model
PTA	2.45	132.511	.59	92	58	10.84	Monomolecular model
IDK	.00209	1289.6	.033	08	83	8.25	Monomolecular model
TSR	.0676	689.97	.50	89	70	63.85	Monomolecular model
PKD	.00008	132695.8	.0006	02	86	31.42	Monomolecular model
MLPM	.0115	2543.42	.103	30	88	67.44	Monomolecular model
KKD	.0325	1515.28	.30	58	83	81.84	Monomolecular model
WYD	.00022	8750.48	.0004	05	79	6.896	Monomolecular model
KNR	.0311	1036.45	.30	54	76	71.07	Monomolecular model
KSGD	.0548	658.06	.12	62	92	32.99	Monomolecular model
Kerala	.0355	8541.09	.35	66	91	328.48	Monomolecular model

Q and R^2 in percentage

Table 1.b1. Parameters of Quadratic function for Production of coconut

		QUADRATIC FUNCTION		
Districts	Break periods	**b_1**	**b_2**	R^2
KLM		5.541	-.0488	55
ALP	(80-88)	22.33	-3.639	63
	(90-03)	23.72	-.7931	57
KTM	(80-88)	18.035	-2.692	54
	(89-95)	30.714	-1.452	57
	(96-03)	8.147	-.0645	61
EKM		10.38	-.3912	58

R^2 in percentage

Table 1.c. Comparison of trend in Productivity of Coconut in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
TVM	.0264	.0289	.166	24	62	6.5*10^-04	Logistic model
KLM	.03027	.0070	.60	82	57	4.4*10^-04	Monomolecular model
PTA	.892	.0053	.50	105	58	5.5*10^-04	Mixed-Influence model
IDK	.1918	.0042	.66	91	59	5.1*10^-04	Monomolecular model
PKD	.000058	2.118	.0016	.32	64	6.6*10^-04	Monomolecular model
MLPM	.0415	.0173	.10	42	73	6.2*10^-04	Logistic model
KKD	.01317	.01613	.29	43	64	6.9*10^-04	Monomolecular model
WYD	.000129	1.084	.001	.4	73	.058	Monomolecular model
KNR	.1456	.0064	.63	94	71	5.9*10^-04	Logistic model
KSGD	.0658	.0096	.24	76	89	5.1*10^-04	Monomolecular model
Kerala	.045	.0085	.54	75	80	3.2*10^-04	Logistic model

Q and R^2 in percentage

Table1.c1. Parameters of Quadratic function for Productivity of Coconut

		QUADRATIC FUNCTION		
Districts	Break periods	b_1	b_2	R^2
ALP	(80-94)	.0001	.00001	55
	(95-03)	-.0004	.0000094	55
KTM		.000049	.0000004	56
EKM		.0002	-.000008	57
TSR		.0003	-.000006	72

R^2 in percentage

scope for increase in productivity through proper management with sufficient attention given in Thiruvananthapuram, Palakkad, Malappuram and Kozhikode districts based on the achieved carrying capacity by 2002-03 and moderate intrinsic growth rates. For Wyanad productivity could be increased only through additional consistent effort and research.

The fluctuation for Alappuzha, Kottayam, Ernakulam and Thrissur districts was studied through Quadratic model. A slight increasing trend up to 1984-85 and afterwards a decreasing trend were pictured for Alappuzha. Kottayam expressed an increasing trend in coconut productivity through out the period and Ernakulam showed a decreasing trend. Parameters obtained on productivity from the Thrissur district evidenced that there was a decreasing trend during the initial period; an increasing trend up to 1991-1992 and a decreasing trend henceforth.

To conclude there was much scope for increase in production by resorting to improved methods of raising coconut productivity in promising districts rather than an increase in area which is far beyond the scope.

4.2. Rubber

The parameters viz; intrinsic growth rate (a), carrying capacity (c), along with R^2, RMSE, achieved carrying capacity during initial(P) and end period(Q) for the suitable model for each district and the state on area, production and productivity of rubber are given in tables 2.a, 2.b and 2.c respectively. The parameters of quadratic function along with R^2 for the data on area, production and productivity of rubber, whenever the other nonlinear models failed are given in tables 2.a1, 2.b1 and 2.c1.

4.2.1. Thiruvananthapuram

An increasing trend could be noticed from the graph regarding area, production and productivity.

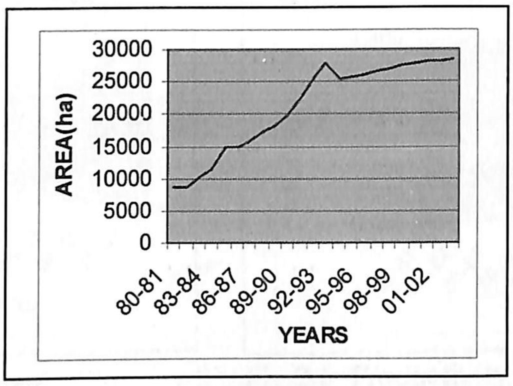


Fig. 2.1. Area under rubber

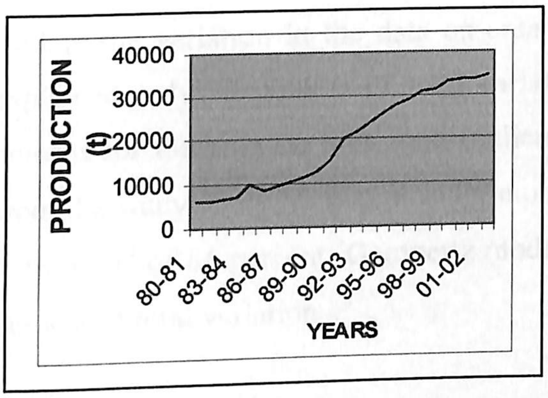


Fig 2.2. Production of rubber

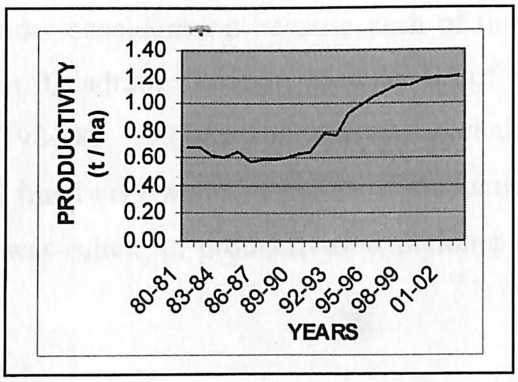


Fig 2.3. Productivity of rubber

Total variation explained by the Monomolecular model was 96 percent, 96 percent and 84 percent respectively for area, production and productivity.

4.2.2. Kollam

The time series graph on area, production and productivity showed an increasing trend.

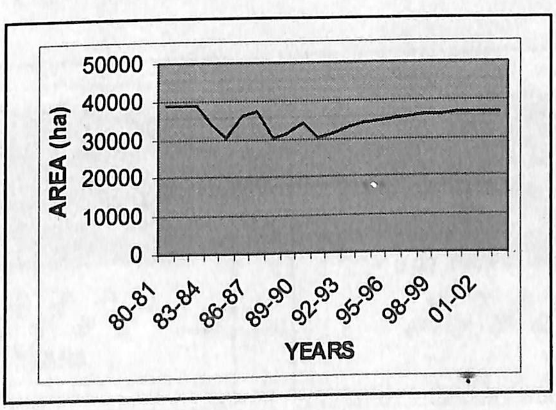


Fig 2.4. Area under Rubber

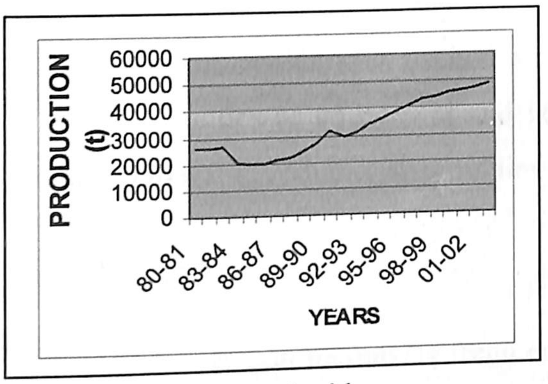


Fig 2.5. Production of rubber

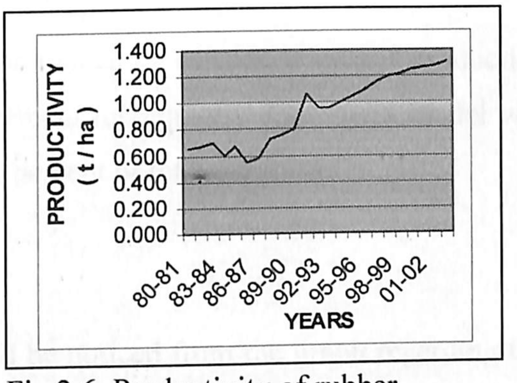


Fig 2.6. Productivity of rubber

All the nonlinear models along with the linear model were not good enough to explain the variation in the data on area under consideration because each of them explained only 22 percent of total variation. Quadratic function gave an R^2 of 61 percent for the data on area with outliers 1984-85, 1987-88 and 1990-91 excluded from the study. Only Monomolecular model fitted very well to the data of production with an R^2 of 86 percent. Gompertz model was suited for productivity explaining 95 percent of total variation.

4.2.3. Pathanamthitta

The graph on area, production and productivity showed an increasing trend.

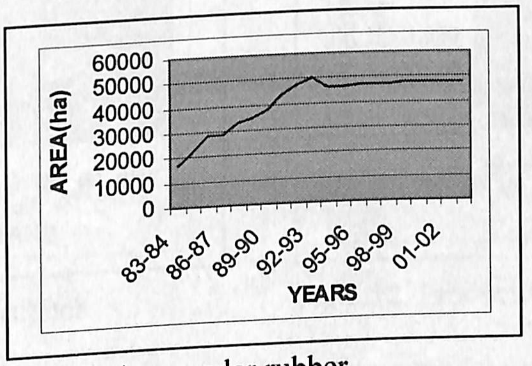


Fig 2.7. Area under rubber

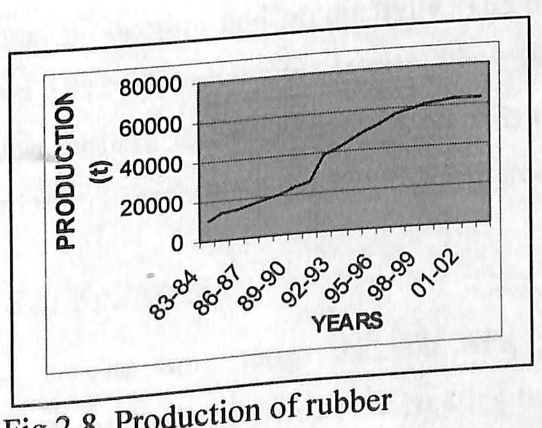


Fig 2.8. Production of rubber

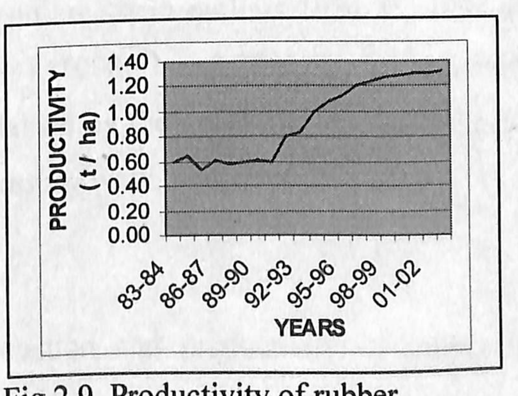


Fig 2.9. Productivity of rubber

Monomolecular model suited well for area under consideration and production with the R^2 values of 95 percent and 96 percent respectively. Gompertz model was found suitable for productivity providing 91 percent of total variation.

4.2.4. Alappuzha

A non increasing trend could be noticed from the graph regarding the area; production and productivity showed an increasing trend.

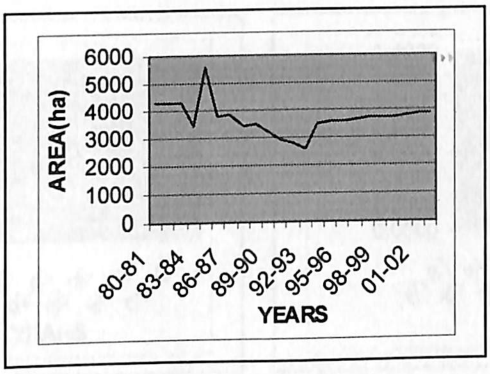


Fig 2.10. Area under rubber

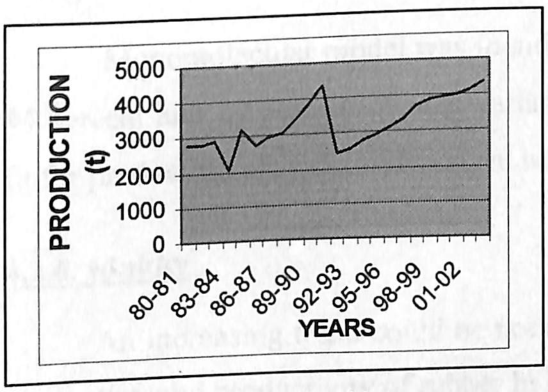


Fig 2.11. Production of rubber

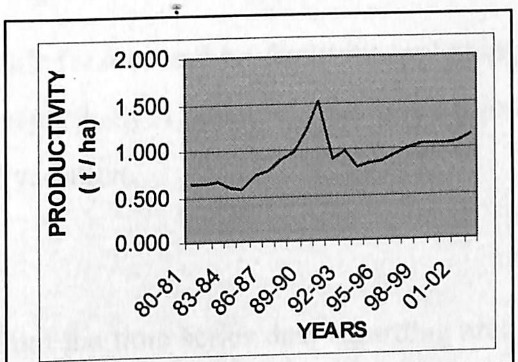


Fig 2.12. Productivity of rubber

All the nonlinear models along with the linear model gave poor R^2 values for area, production and productivity. The data on area with outliers 1984-85, 1991-92 and 1992-93; production with outliers 1983-84, 1990-91 and 1991-92; productivity with outliers 1989-90 and 1990-91 was explained by the quadratic function with R^2 values 63 percent, 64 percent and 80 percent respectively.

4.2.5. Kottayam

The time series data on area, production and productivity of rubber in Kottayam district showed an increasing trend.

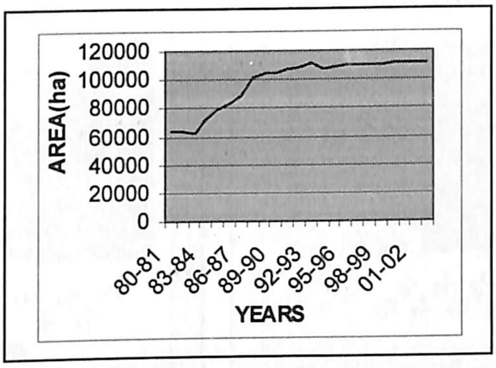


Fig 2.13. Area under rubber

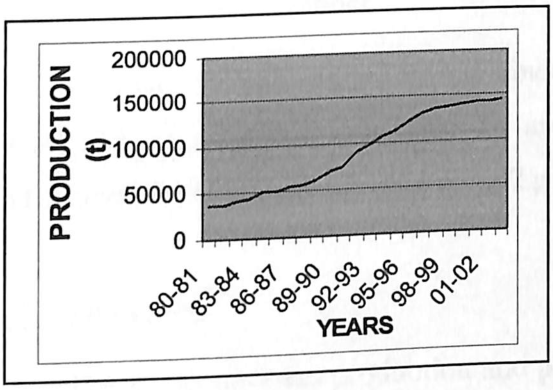


Fig 2.14. Production of rubber

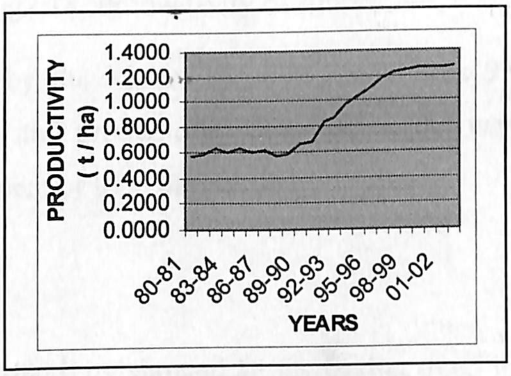


Fig 2.15. Productivity of rubber

Monomolecular model was found suitable for area and productivity explaining 94 percent and 89 percent of total variation respectively. Logistic model was a good fit for production providing 98 percent of total variation.

4.2.6. Idukky

An increasing trend could be noticed from the time series data regarding area, production and productivity of rubber in Idukky district.

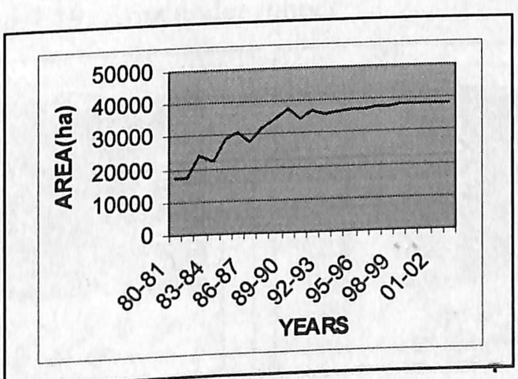


Fig 2.16. Area under rubber

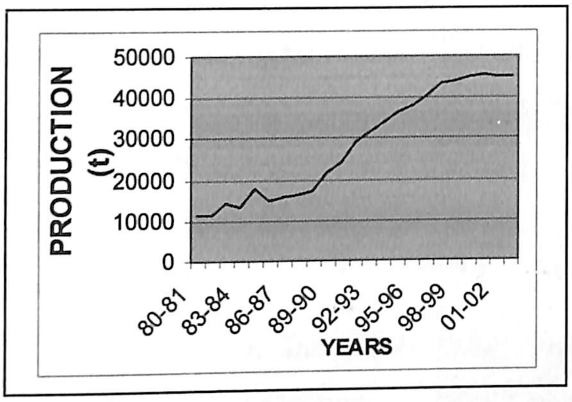


Fig 2.17. Production of rubber

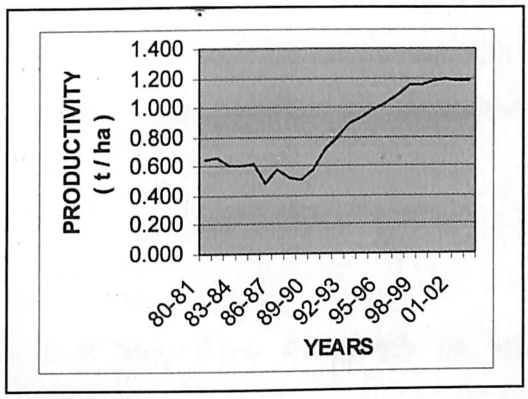


Fig2.18. Productivity of rubber

Amount of total variation explained by the Monomolecular model was 95 percent and 83 percent respectively for area and productivity. Logistic model was good enough for production explaining 97 percent of total variation.

4.2.7. Ernakulam

The graph on area, production and productivity showed an increasing trend in Ernakulam district.

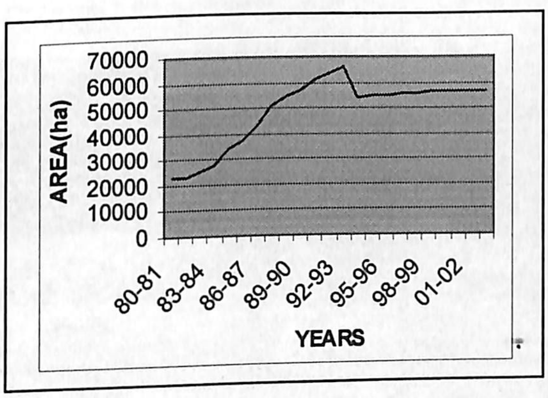


Fig 2.19. Area under rubber

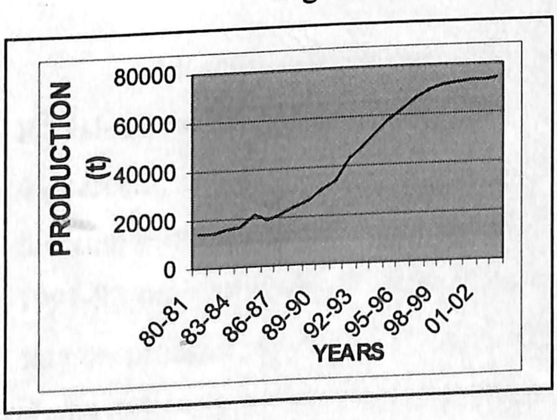


Fig 2.20. Production of rubber

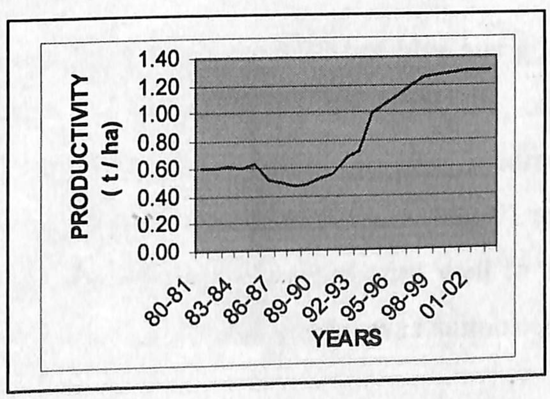


Fig 2.21. Productivity of rubber

A high R^2 value of 86 percent for monomolecular model revealed that the model fitted very well for area. Logistic model suited very well for production with an R^2 of 98 percent. Monomolecular model was found suitable for productivity explaining 79 percent of total variation.

4.2.8.Thrissur

An increasing trend could be noticed from the graph on area, production and productivity of rubber in Thrissur district.

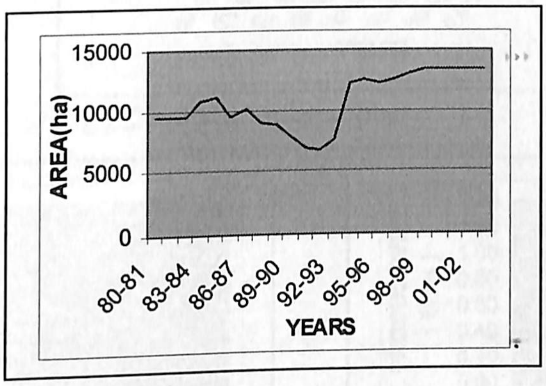


Fig 2.22. Area under rubber

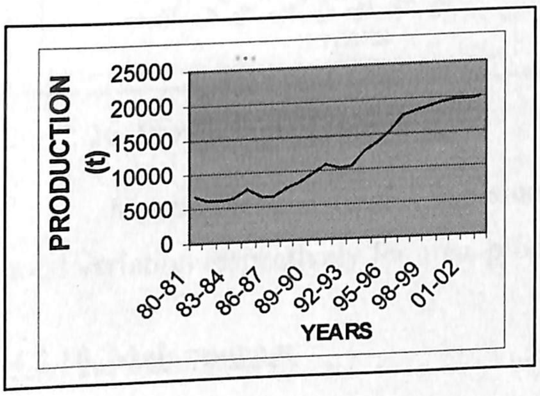


Fig 2.23. Production of rubber

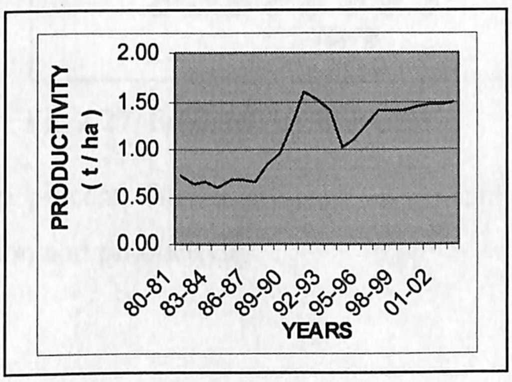


Fig 2.24. Productivity of rubber

All the nonlinear models along with the linear model did not give any good R^2 values for area; Monomolecular, Logistic and Gompertz models explaining only 43 percent, 46 percent and 46 percent of total variation respectively. The Quadratic function provided an R^2 of 66 percent for the data on area with outliers 1990-91 and 1991-92 omitted from the study. Monomolecular model only fitted very well to the data on production with an R^2 of 93 percent. Monomolecular model was suitable for productivity explaining 75 percent of total variation.

4.2.9. Palakkad

An increasing trend could be noticed from the graph regarding the time series data on the area, production and productivity of rubber in Palakkad district.

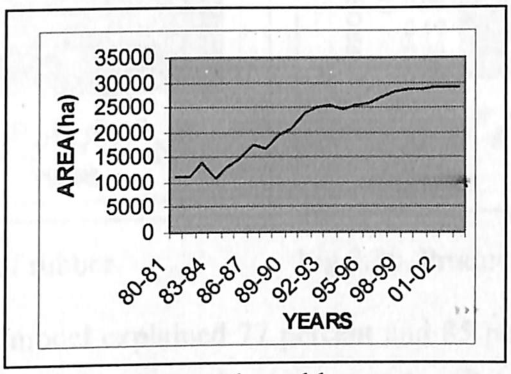


Fig 2.25. Area under rubber

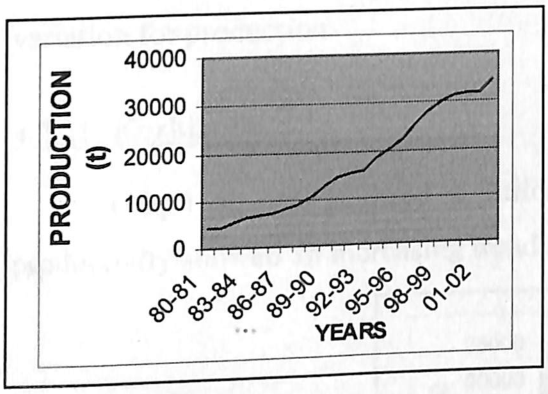


Fig 2.26. Production of rubber

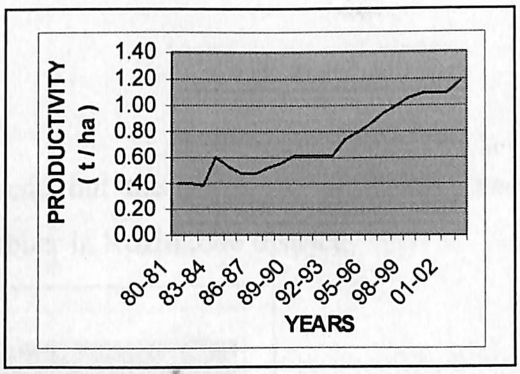


Fig 2.27. Productivity of rubber

Monomolecular model explained 96 percent, 94 percent and 92 percent of total variation respectively for area, production and productivity.

4.2.10. Malappuram

The graph on area, production and productivity of rubber in Malappuram district showed an increasing trend.

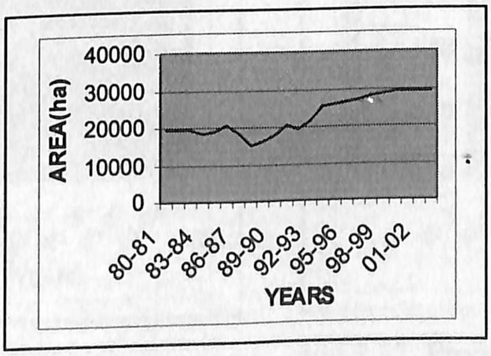


Fig 2.28. Area under rubber

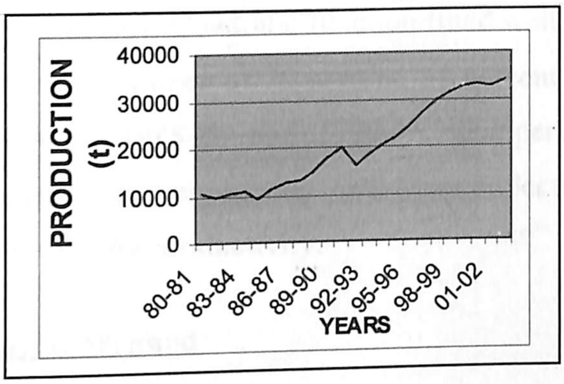


Fig 2.29. Production of rubber

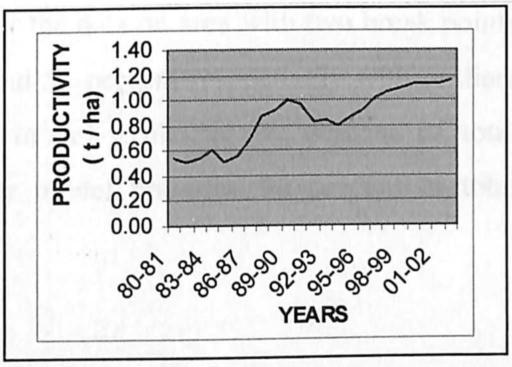


Fig 2.30. Productivity of rubber

Monomolecular model explained 77 percent and 85 percent of total variation for area and productivity respectively. Logistic model explained 96 percent of total variation for production.

4.2.11. Kozhikode

Graph on area showed a uniform trend but the graph on production and productivity showed an increasing trend for rubber in Kozhikode district.

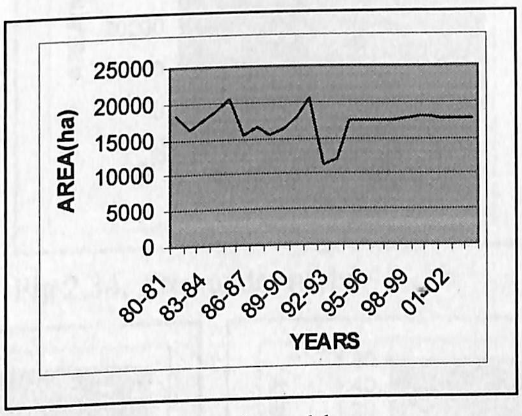


Fig 2.31. Area under rubber

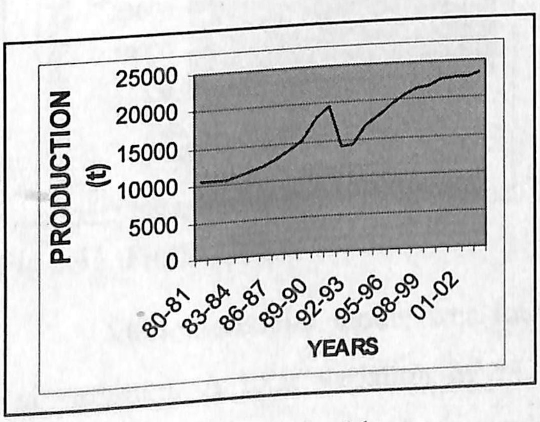


Fig 2.32.Production of rubber

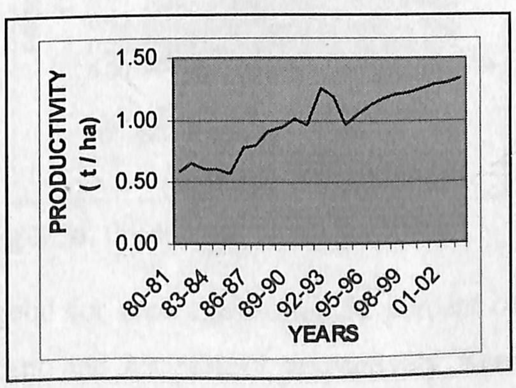


Fig 2.33. Productivity of rubber

All the nonlinear models along with the linear model did not fit well for area under rubber. Quadratic function fitted well for the data on area with two break points having R^2 values of 76 percent, 68 percent and 55 percent respectively with outliers 1984-85, 1985-86 and 1990-91. Gompertz model explained 90 percent of total variation for production and Monomolecular model provided 90 percent of total variation for productivity.

4.2.12. Wyanad

The crop was not taken into consideration from this district for the study

4.2.13. kannur

Graph on area showed a decreasing trend up to 1990-91 and gradually showed an increasing trend. An increasing trend for rubber in the district could be noticed from the graph regarding production and productivity.

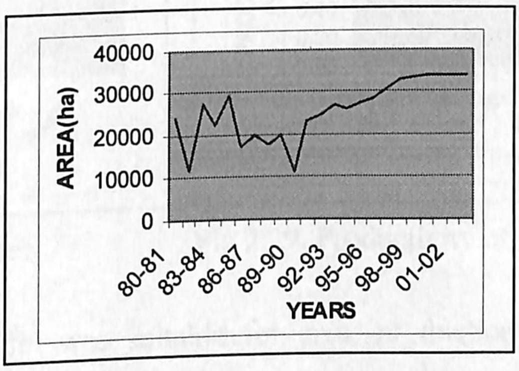


Fig 2.34. Area under rubber

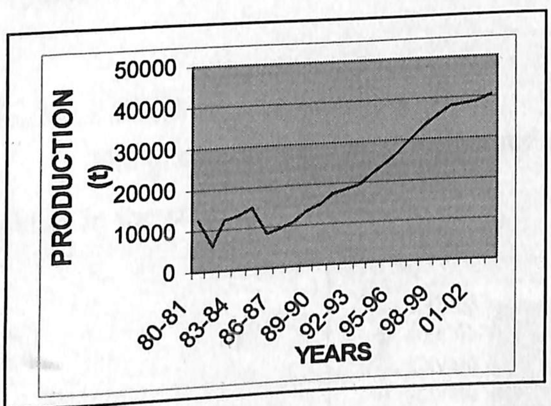


Fig 2.35. Production of rubber

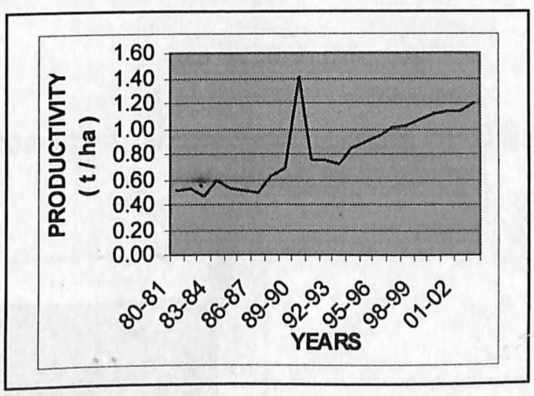


Fig 2.36. Production of rubber

Monomolecular model was found good for area explaining 54 percent of total variation. A total variation of 94 percent and 69 percent respectively were explained by the Gompertz model was suited for production and productivity.

4.2.14. Kasargode

An increasing trend could be noticed from the time series graph regarding area, production and productivity of rubber in Kasargode district.

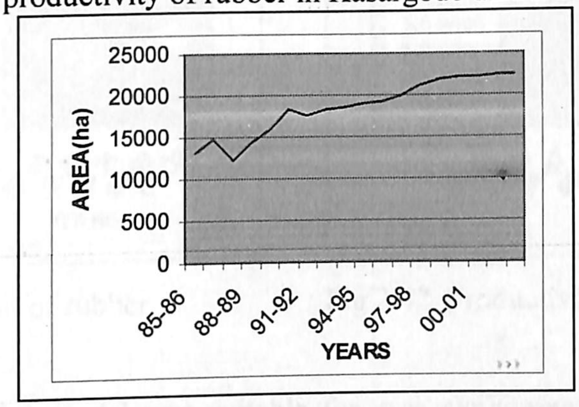


Fig 2.37.Area under rubber

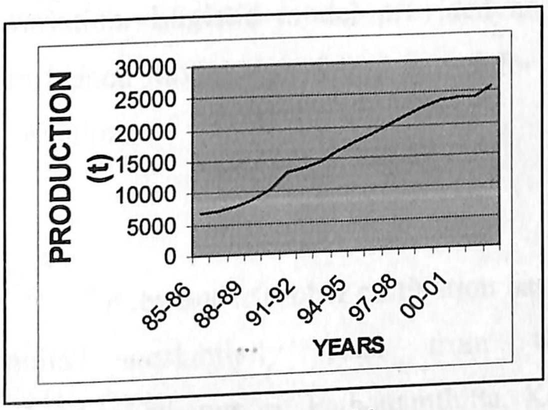


Fig 2.38. Production of rubber

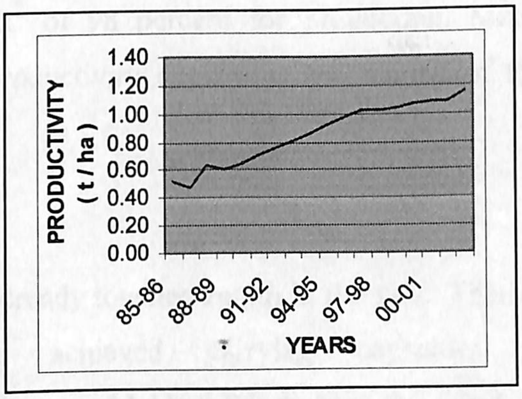


Fig 2.39. Productivity of rubber

Monomolecular model was suitable for area, production and productivity explaining 94 percent, 98 percent and 97 percent of total variation respectively.

4.2.15. Kerala

The graph on area, production and productivity showed an increasing trend for rubber in the state as a whole.

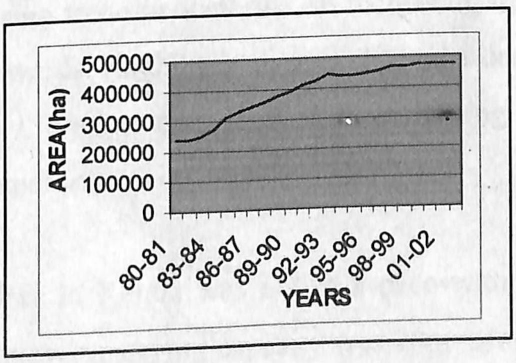


Fig 2.40. Area under rubber

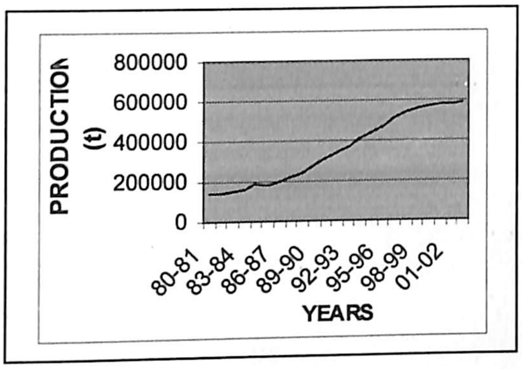


Fig 2.41. Production of rubber

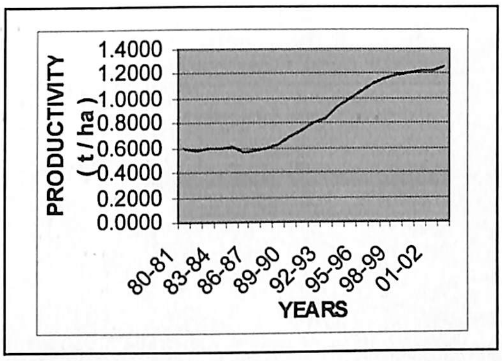


Fig 2.42. Productivity of rubber

Monomolecular model was suitable for area explaining 98 percent of total variation. Logistic model provided an R^2 of 98 percent for production. Mixed-Influence model was found suited for productivity explaining 99 percent of total variation.

Area under rubber cultivation has already touched zenith in the state. This was quite substantially read from the achieved carrying capacities for Thiruvananthapuram, Pathanamthitta, Kottayam, Idukky, Ernakulam, Palakkad and Kasargode districts. The area under cultivation in Malappuram and Kannur districts was extremely low based on their achieved carrying capacities but couldn't be further extended because of their extremely poor intrinsic growth rate. The differential in trend for area under rubber for Kollam, Alappuzha, Thrissur and Kozhikode were studied based on Quadratic function. Parameters of quadratic function in Kollam district revealed that there had a decreasing trend up to 1992-93 and afterwards showed an increasing trend. In Alappuzha district a decreasing trend was pictured up to 1992-93 and an increasing trend henceforth. An increasing trend was obtained for Thrissur from 1994-95 onwards. Kozhikode district showed a decreasing trend during the first two initial years and afterwards showed an increasing trend up to 1998-99 and a decreasing trend henceforth.

Production of rubber in Kerala was not in a pace with the extended rubber cultivation, though the achieved carrying capacity was 78percent by 2002-03 with an excellent intrinsic growth rate. The contribution towards a better production was

Table 2.a. Comparison of trend in area under rubber in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
TVM	.0828	33820.82	.25	84	96	1444.9	Monomolecular model
PTA	.2131	49588.12	.33	96	95	2285.78	Monomolecular model
KTM	.1597	115475.08	.54	96	94	4409.85	Monomolecular model
IDK	.1783	38993.2	.44	98	95	1598.78	Monomolecular model
EKM	.1914	59877.75	.38	94	86	5221.95	Monomolecular model
PKD	.0556	39192.5	.28	74	96	1435.75	Monomolecular model
MLPM	.00052	1220636.9	.015	.024	77	2396.16	Monomolecular model
KNR	.0013	370393.74	.06	09	54	5067.54	Monomolecular model
KSGD	.0561	29324.27	.45	76	94	395.68	Monomolecular model
Kerala	.0977	520884.9	.45	91	98	9629.41	Monomolecular model

Q and R^2 in percentage

Table 2.a1. Parameters of Quadratic function for area under rubber

		QUADRATIC FUNCTION		
Districts	Break Periods	**b_1**	**b_2**	**R^2**
KLM		-1004.9	40.308	61
ALP		-165.23	6.4039	63
TSR		-127.19	14.404	66
KKD	(80-84)	-3174.5	700.75	76
	(87-93)	4283.08	-254.6	68
	(94-03)	558.23	-14.19	55

R^2 in percentage

Table 2.b. Comparison of trend in production of rubber in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
TVM	.00064	2439848.61	.29	49	96	2194.1	Monomolecular model
KLM	.00211	666565.00	.56	66	86	3373.2	Monomolecular model
PTA	.14638	76908.44	.13	82	97	3124.96	Gompertz model
KTM	.155254	176344.58	.20	81	98	5657.3	Logistic model
IDK	.15774	56310.04	.20	80	97	2304.3	Logistic model
EKM	.1972	86771.74	.16	84	98	3272.0	Logistic model
TSR	.00069	1114439.22	.006	1.7	93	1468.0	Monomolecular model
PKD	.00143	3692119.8	.0012	.9	94	2174.5	Monomolecular model
MLPM	.09425	69378.63	.15	48	96	1644.9	Logistic model
KKD	.03124	58330.45	.18	40	90	1456.82	Gompertz model
KNR	.02032	967371.22	.012	4.2	94	2754.69	Gompertz model
KSGD	.00584	224048.15	.03	11.5	98	780.39	Monomolecular model
Kerala	.151	758297.7	.18	78	98	19741.6	Logistic model

Q and R^2 in percentage

Table 2.b1. Parameters of Quadratic function for production of rubber

	QUADRATIC FUNCTION		
Districts	b_1	b_2	R^2
ALP	-42.60	4.154	64

R^2 in percentage

Table 2.c. Comparison of trend in Productivity of rubber in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
TVM	.000098	338.53	0.002	0.4	84	.1047	Monomolecular model
KLM	.0249	4.63	0.142	28	91	.0810	Gompertz model
PTA	.0449	3.22	0.186	40	91	.0987	Gompertz model
KTM	.00027	149.5	0.004	0.9	89	.0988	Monomolecular model
IDK	.00038	93.08	0.007	1.3	83	.1151	Monomolecular model
EKM	.000095	457.3	0.001	0.3	79	.1592	Monomolecular model
TSR	.05569	1.947	0.369	76	75	.1806	Monomolecular model
PKD	.00024	154.8	0.003	.8	92	.0765	Monomolecular model
MLPM	.03221	1.805	0.304	64	85	.0921	Monomolecular model
KKD	.0494	1.731	0.341	77	90	.0857	Monomolecular model
KNR	.0475	1.9937	0.258	59	69	.1604	Gompertz model
KSGD	.0565	1.568	0.327	73	97	.1033	Monomolecular model
Kerala	.5776	1.24	.470	100	99	.0176	Mixed-Influence model

Q and R^2 in percentage

Table.2.c1. Parameters of Quadratic function for Productivity of rubber

	QUADRATIC FUNCTION		
District	**b**	**c**	**R^2**
ALP	.0244	-.0001	80

R^2 in percentage

streamlined only through Pathanamthitta, Kottayam, Idukky and Ernakulam districts. There existed ample scope for improvement in rubber production in Malappuram and Kozhikode districts as regards to the low carrying capacity achieved by 2002-03 and good intrinsic growth rates. The further improved production of rubber in Thiruvananthapuram, Kollam, Thrissur, Palakkad, Kannur and Kasargode districts was at a very slow rate. Though Alappuzha does not offer a congenial atmosphere for rubber production, there was a varied production of rubber even in this district. This was clearly brought out using Quadratic model.

The productivity of rubber may be deemed to have reached its maximum as evidenced from the 100percent achieved carrying capacity for Kerala by 2002-03. This achievement was mainly due to the extraordinary intrinsic growth rate of .5776. When the contribution by each district to this stature was analyzed only Thrissur, Malappuram, Kozhikode, Kannur and Kasargode had contributed their lots. In Kottayam, though production had reached its maximum, the low intrinsic growth rate of productivity indicated that the total area under rubber was not cropped uniformly even as the maximum area in that district was under rubber cultivation. Poor intrinsic growth rates of productivity of rubber in Thiruvananthapuram, Idukky, Ernakulam and Palakkad districts was in consonance with the comparatively low production of rubber. Though rubber was sparsely cultivated in Alappuzha as do the area under cultivation and production of rubber indicated the productivity of rubber was investigated Quadratic model.

Further increased production and productivity of rubber can be had only by crop replacement with economical plantation crops.

4.3. Paddy

As the values of 'a' and 'c' were either very low or negative for all nonlinear models tried over the districts and the state, simple linear regression model was fitted to explain the trend in area, production and productivity over all the districts and the state. The regression coefficients along with the R^2 of linear model are presented in table 3.a for the data on area, production and productivity. The results of nonlinear models were not considered because of inconsistency of results for all the districts.

4.3.1. Thiruvananthapuram

The time series data regarding the area and production of paddy showed a decreasing trend but the graph on productivity showed an increasing trend with many fluctuations in Thiruvananthapuram district.

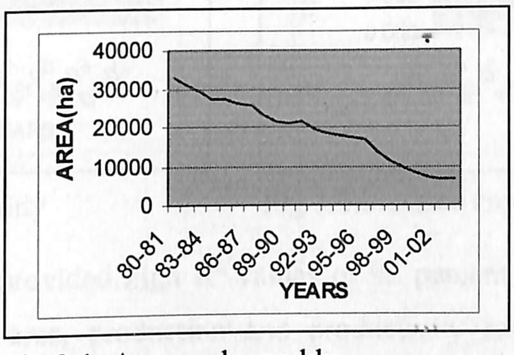


Fig 3.1. Area under paddy

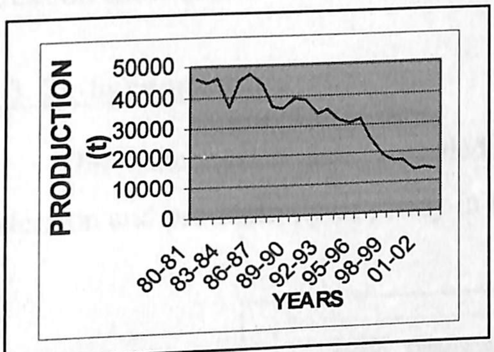


Fig 3.2. Production of paddy

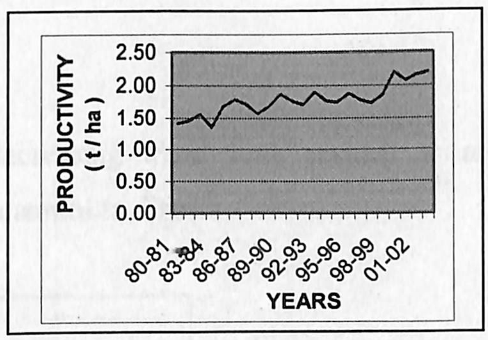


Fig 3.3. Productivity of paddy

The simple linear regression fitted for the data on area, production and productivity gave R^2 values of 98 percent, 89 percent and 72 percent respectively with the regression coefficients -1183.59, -1572.52 and .029

4.3.2. Kollam

The graph on area and production showed a decreasing trend while the graph on productivity showed an increasing trend in this district for paddy.

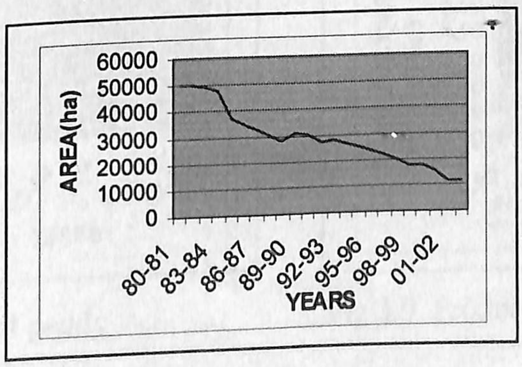


Fig 3.4. Area under paddy

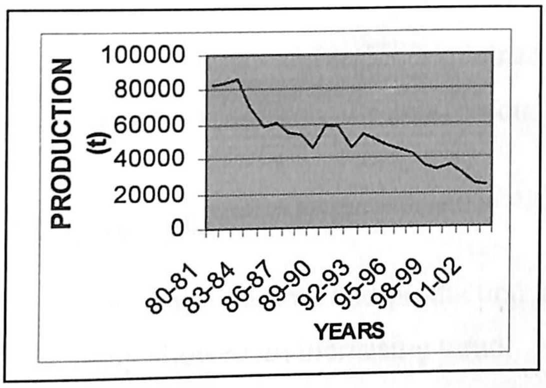


Fig 3.5. Production of paddy

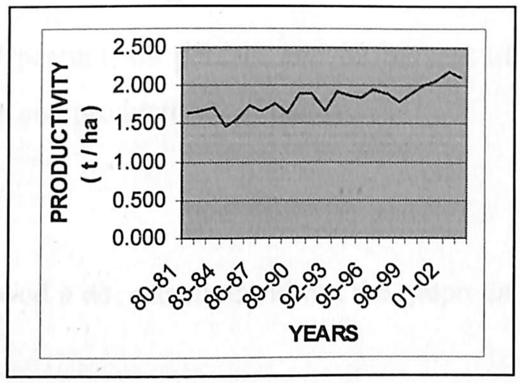


Fig 3.6.Productivity of paddy

The linear model provided high R^2 values of 92 percent, 87 percent and 71 percent for the data on area, production and productivity respectively with the regression coefficients -1677.65, -2407.79 and .023.

4.3.3. Pathanamthitta

The time series data revealed a decreasing trend with respect to area, production and productivity of paddy in Pathanamthitta district

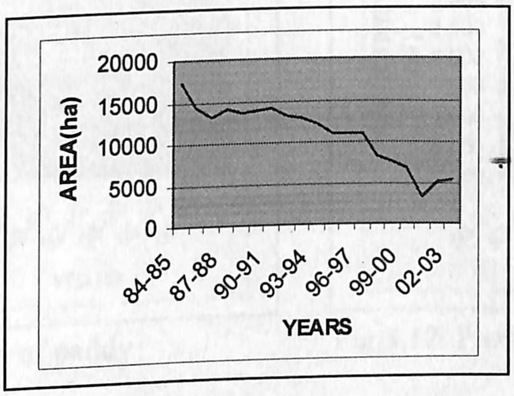


Fig 3.7. Area under paddy

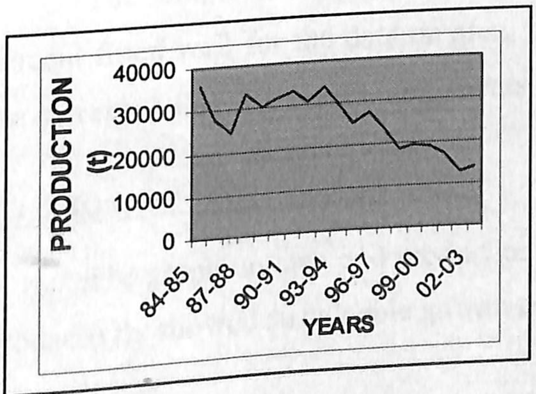


Fig 3.8. Production of paddy

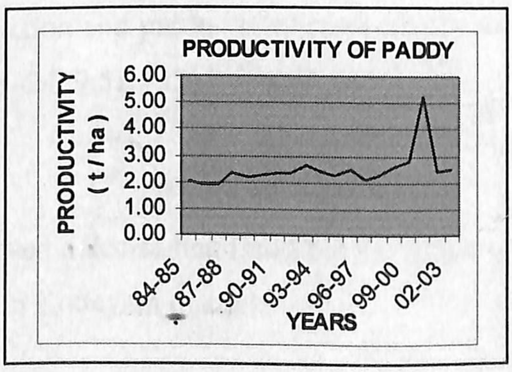


Fig 3.9. Productivity of paddy

Simple linear regression explained 87 percent, 69 percent and 52 percent of total variation respectively for area, production and productivity of paddy.

4.3.4. Alappuzha

The graph on area and production showed a decreasing trend but the graph on productivity showed an increasing trend.

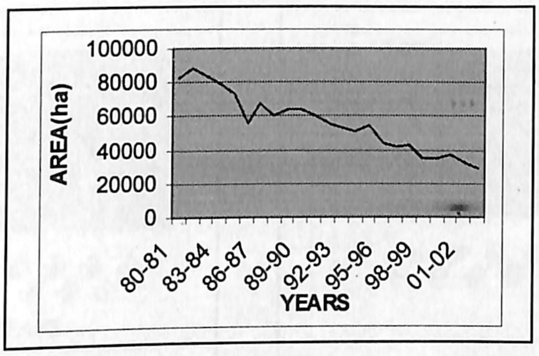


Fig 3.10. Area under paddy

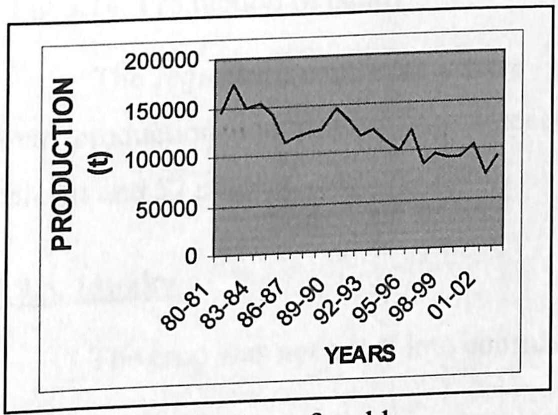


Fig 3.11. Production of paddy

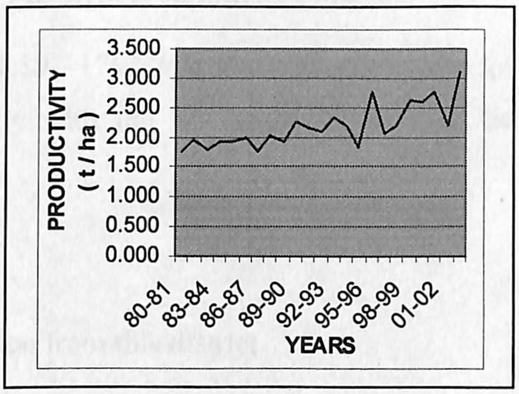


Fig 3.12. Productivity of paddy

The simple linear regression with R^2 values 92 percent, 74 percent and 57 percent fitted well for the data on area, production and productivity respectively and the corresponding regression coefficients were -2479.51, -3217.66 and .041.

4.3.5. Kottayam

The graph on area and production showed a decreasing trend but the graph on productivity showed sustainable growth trend in Kottayam district.

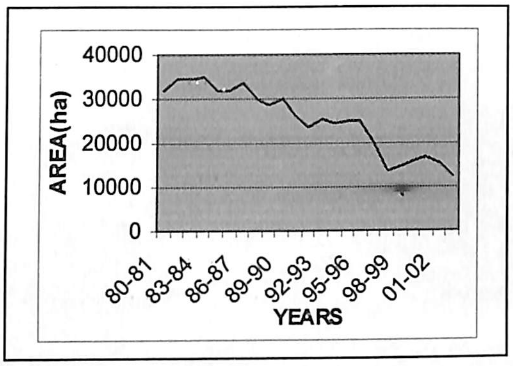


Fig 3.13. Area under paddy

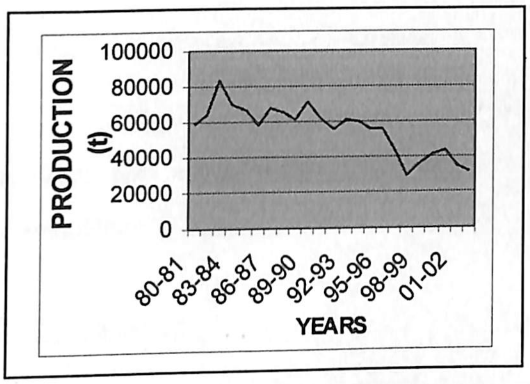


Fig 3.14. Production of paddy

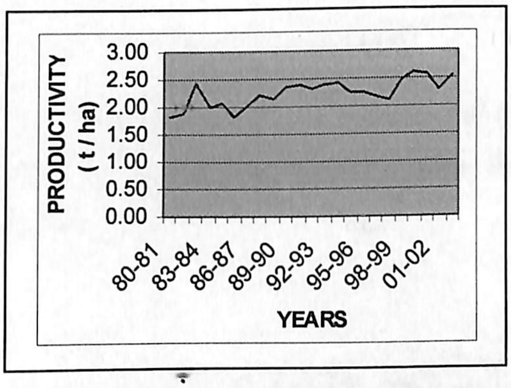


Fig 3.15. Productivity of paddy

The regression coefficients were -1051.19, -1767.74 and .023 respectively for area, production and productivity respectively with the R^2 values 92 percent, 74 percent and 57 percent.

4.3.6. Idukky

The crop was not taken into consideration from this district

4.3.7. Ernakulam

The time series data on area and production showed a decreasing trend while productivity showed a slow and steady increasing trend in Ernakulam district.

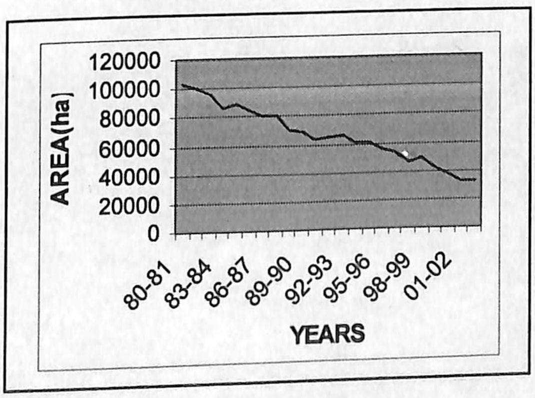


Fig 3.16. Area under paddy

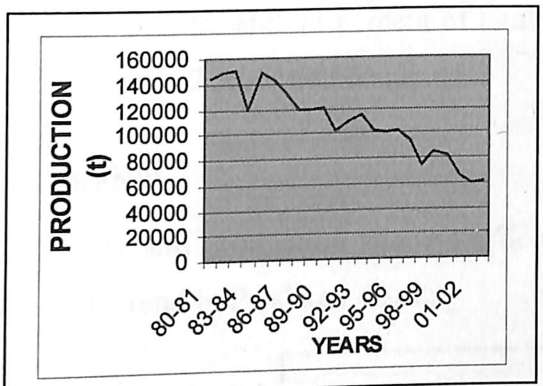


Fig 3.17. Production of paddy

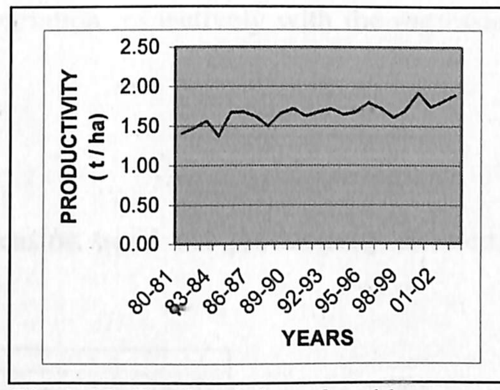


Fig 3.18. Productivity of paddy

Simple linear regression provided R^2 values of 98 percent, 91 percent and 63 percent for area, production and productivity of paddy respectively with the regression coefficients -3078.51, -4023.23 and .016.

4.3.8. Thrissur

The time series data regarding the area and production showed a decreasing trend, while productivity showed an increasing trend in Thrissur district also.

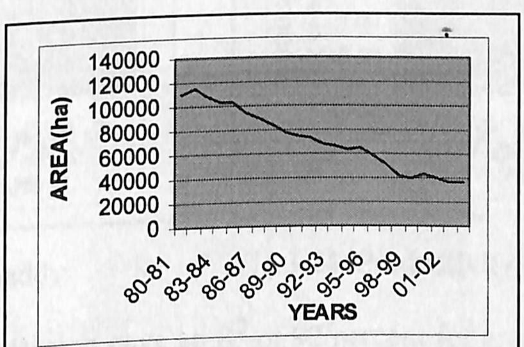


Fig 3.19. Area under paddy

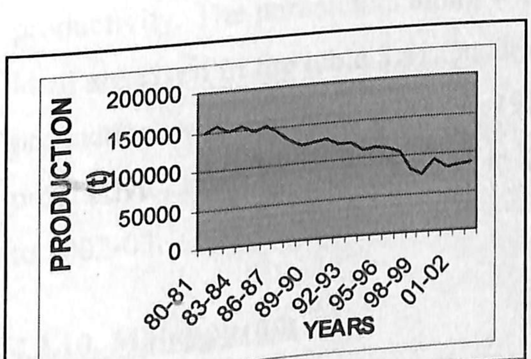


Fig 3.20. Production of paddy

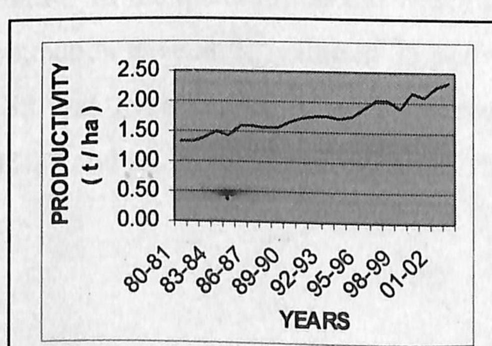


Fig 3.21. Productivity of paddy

Simple linear regression for area, production and productivity explained 97 percent, 91 percent and 93 percent of total variation respectively with the regression coefficients -3772.5, -3104.65 and .041.

4.3.9. Palakad

Area and production showed a decreasing trend but productivity showed a sustainable trend in Palakkad district.

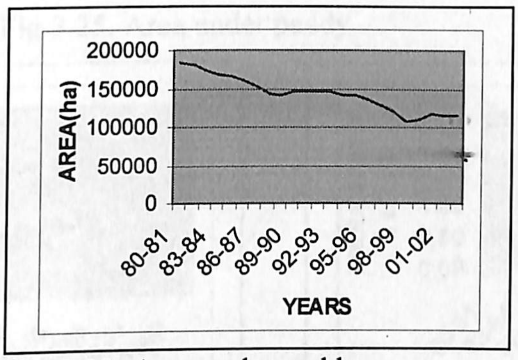


Fig 3.22. Area under paddy

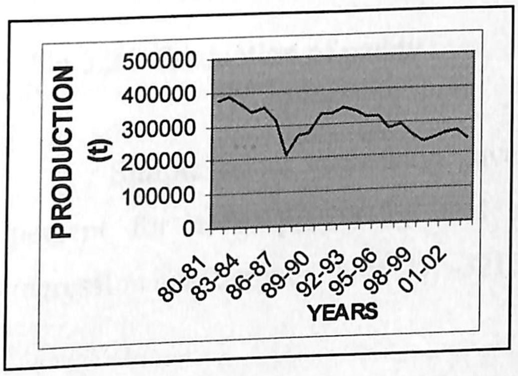


Fig 3.23. Production of paddy

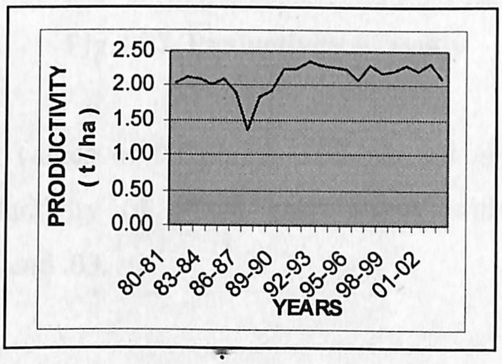


Fig 3.24. Productivity of paddy

Simple linear regression gave an R^2 of 92 percent for area with the regression coefficient -3154.67. Linear regression was not an ideal fit for production and productivity. The parameters along with the R^2 of the quadratic model which proved ideal are given in the table 3.a1.Quadratic function gave an R^2 value of 75 percent for production with outliers 1986-87, 1987-88 and 1988-89; an R^2 of 87 percent for productivity ranging from 1980-81 to 1986-87 and an R^2 of 52 percent from 1989-90 to 2002-03.

4.3.10. Malappuram

The graph on area and productivity showed a decreasing trend but the graph on productivity showed an increasing trend in Malappuram district.

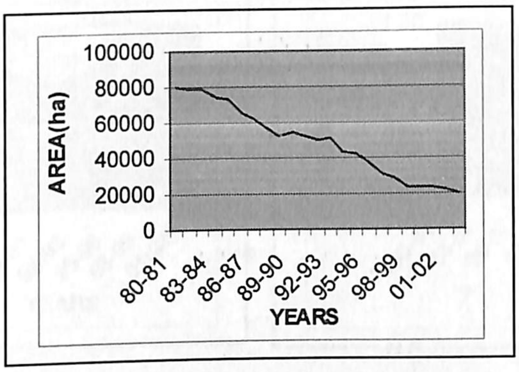


Fig 3.25. Area under paddy

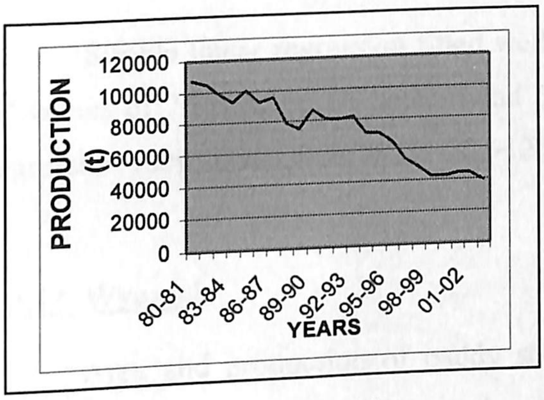


Fig 3.26. Production of paddy

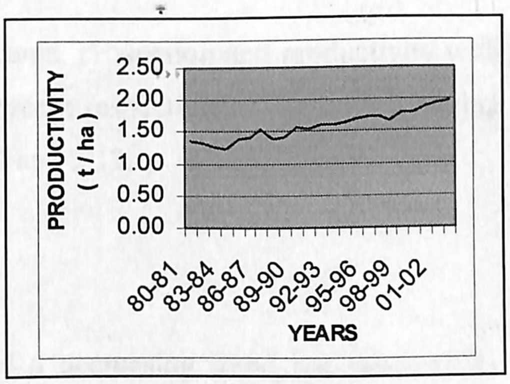


Fig 3.27. Productivity of paddy

Simple linear regression gave R^2 values of 98 percent, 93 percent and 92 percent for area, production and productivity of paddy respectively with the regression coefficients -2949.47, -3215.34 and .03.

4.3.11. Kozhikode

Area and production of paddy showed a decreasing trend while productivity showed an increasing trend in Kozhikode.

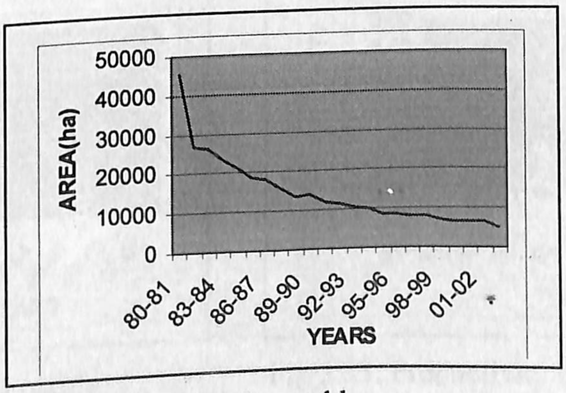


Fig 3.28. Area under paddy

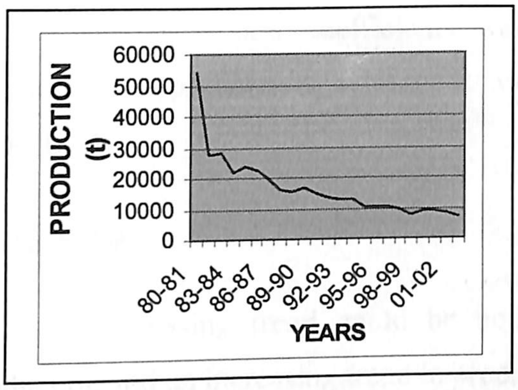


Fig 3.29.Production of paddy

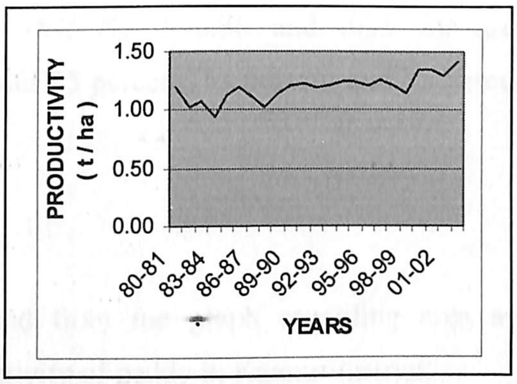


Fig 3.30. Productivity of paddy

Simple linear regression fitted well for area, production and productivity with R^2 values of 75 percent, 66 percent and 60 percent respectively. The corresponding regression coefficients were -1213.28, -1256.79 and .013.

4.3.12. Wyanad

Area and production of paddy showed a decreasing trend but productivity showed an increasing trend in Wyanad.

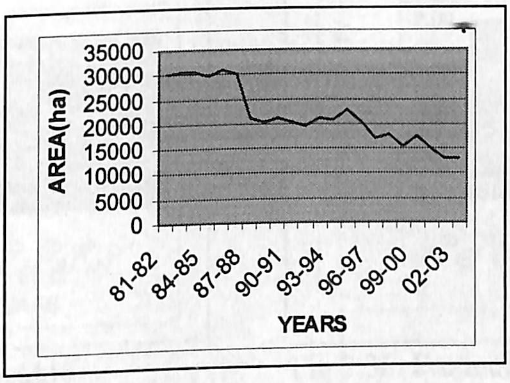


Fig 3.31. Area under paddy

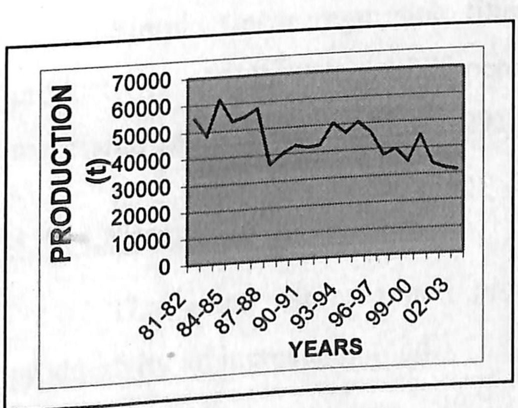


Fig 3.32. Production of paddy

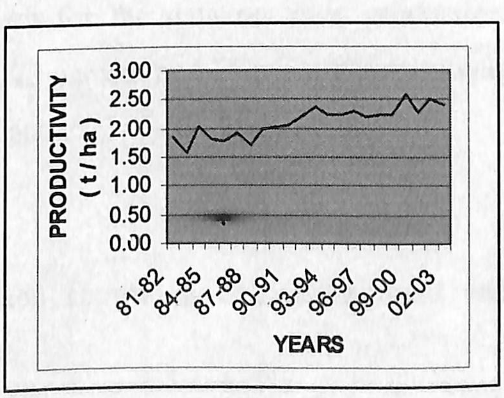


Fig 3.33. Productivity of paddy

The regression coefficients were -845.79, -990.36 and .035 for area, production and productivity with the R^2 values 85 percent, 53 percent and 75 percent respectively.

4.3.13.Kannur

A decreasing trend could be noticed from the graph regarding area and production and an increasing trend in productivity of paddy in Kannur district.

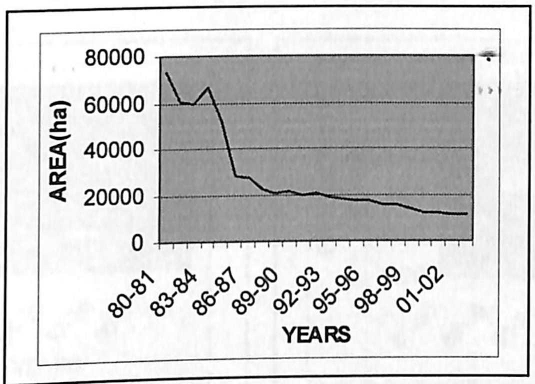


Fig 3.34. Area under paddy

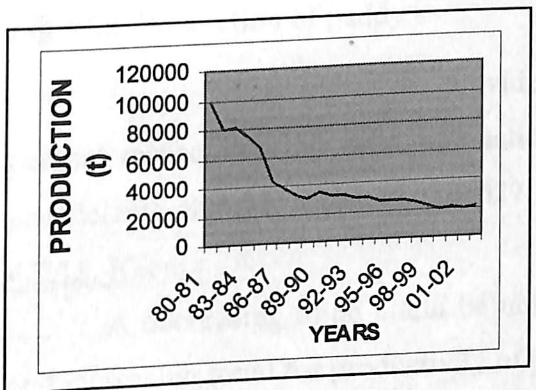


Fig 3.35.Production of paddy

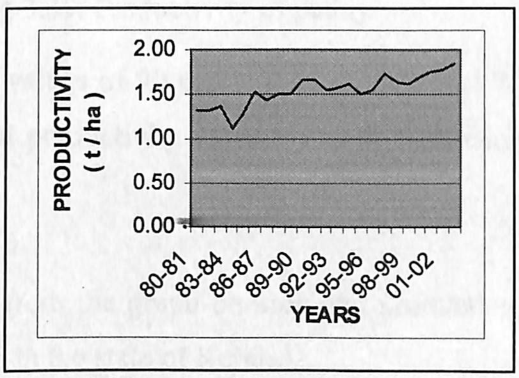


Fig 3.36. Productivity of paddy

Simple linear regression fitted well for the data on area, production and productivity with R^2 values of 70 percent, 73 percent and 75 percent respectively and regression coefficients -2457.03, -2919.87 and .023.

4.3.14.Kasargode

The graph on area and production showed a decreasing trend and the productivity an increasing trend.

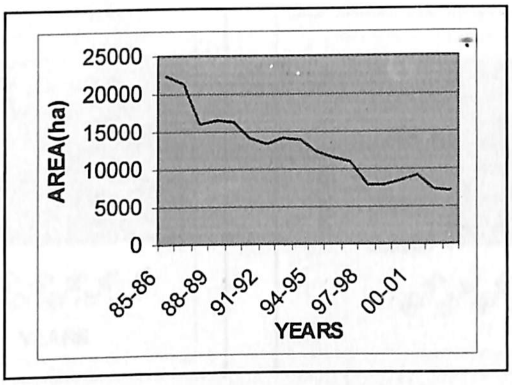
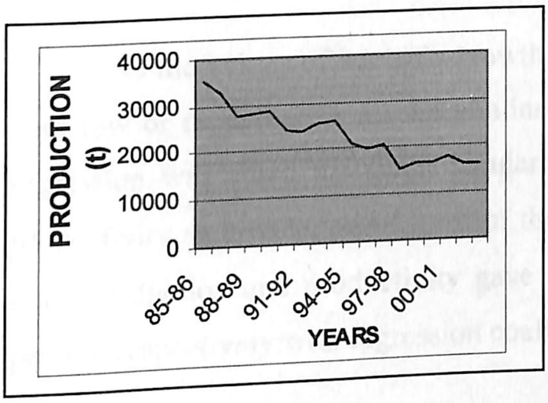


Fig 3.37. Area under paddy



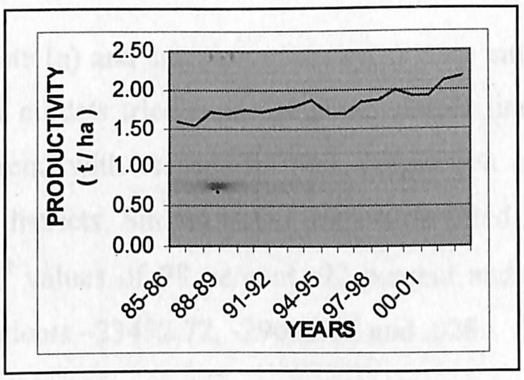


Fig 3.38. Production of paddy

Fig 3.39. Productivity of paddy

Simple linear regression provided R^2 values of 90 percent, 88 percent and 75 percent respectively for area, production and productivity of paddy with regression coefficients -806.71, -1108.45 and .027.

<u>4.3.15. Kerala</u>

A decreasing trend could be noticed from the graph on area and production, and increasing trend for productivity of paddy in the state of Kerala.

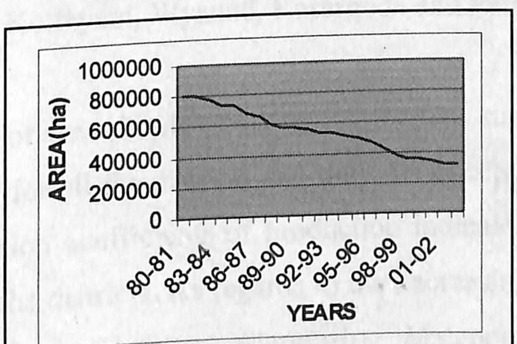


Fig 3.40. Area under paddy

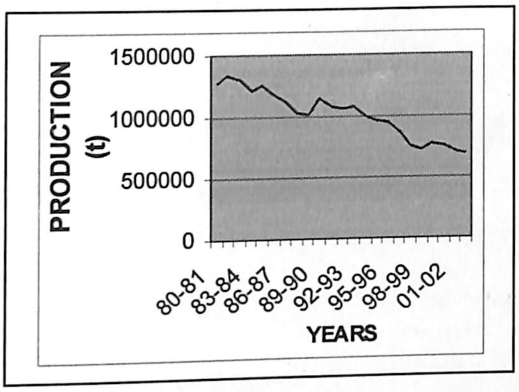


Fig 3.41. Production of paddy

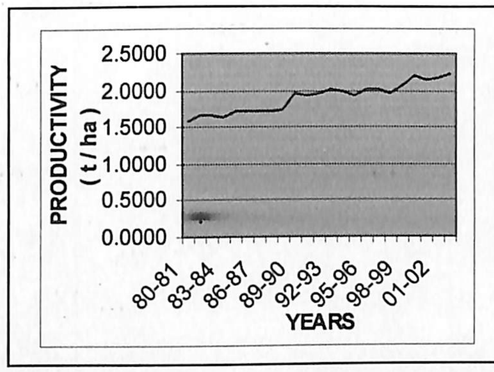


Fig 3.42. Productivity of paddy

As the values of intrinsic growth rate (a) and carrying capacity(c) were either very low or negative for all the nonlinear models tried over the state, simple linear regression was fitted to obtain secular trend with respect to area, production and productivity as in the case of most of the districts. Simple linear regression fitted for area, production and productivity gave R^2 values of 98 percent, 92 percent and 92 percent respectively with regression coefficients –23452.72, -29089.57 and .028.

Simple linear regression fitted well for the data on area of paddy for all the districts as also for the state. As all the regression coefficients were negative, it could be inferred that the area under paddy was steadily decreasing in all the districts. The near total effect of this trend was much evidenced from the regression coefficient for the state. The rank order of the districts in this aspect were Thrissur, Palakkad, Ernakulam, Malappuram, Alappuzha, Kannur, Kollam, Kozhikode, Thiruvananthapuram, Kottayam, Wyanad, Kasargode and Pathanathitta.

As in the case of area simple linear regression was suitable for Production and productivity of paddy for all the districts and the state except Palakkad. The negative sign of all the regression coefficients of production indicated that paddy production was decreasing in all the districts. As regards to the decreasing trend the rank order of districts was Ernakulam, Thrissur, Alappuzha, Malappuram, Kannur, Kollam, Kottayam, Thiruvananthapuram, Kozhikode, Kasargode, Pathanamthitta and Wyanad. The parameters of Quadratic function showed a decreasing trend in paddy production through out the period under investigation for the Palakkad district. The status of production in the state was an immediate consequence of this trend in the districts.

Table.3.a. Parameter(b) and R^2 of simple linear regression for Paddy, district wise and the state

Districts	Area		Production		Productivity	
	b	R^2	b	R^2	b	R^2
TVM	-1183.58	98	-1572.52	89	.029	72
KLM	-1677.65	92	-2407.79	87	.023	71
PTA	-639.81	87	-1072.62	69	.062	52
ALP	-2479.51	92	-3217.66	74	.041	57
KTM	-1050.09	90	-1767.74	69	.023	55
EKM	-3078.51	98	-4022.23	91	.016	63
TSR	-3772.57	97	-3704.65	91	.041	93
PKD	-3154.67	92	-4639.37	45	.014	17
MLPM	-2949.47	98	-3215.34	93	.03	92
KKD	-1213.28	75	-1256.79	66	.013	60
WYD	-845.79	85	-990.35	53	.035	75
KNR	-2457.03	70	-2919.87	73	.023	75
KSGD	-806.71	90	-1108.45	88	.027	75
Kerala	-23452.72	98	-29089.51	92	.028	92

R^2 in percentage

Table. 3. a1. Parameters of Quadratic function for paddy

District	Production			Productivity			
	b_1	b_2	R^2	b_1	b_2	R^2	Break periods
PKD	-4353.9	-39.05	75	.2676 .0517	-.0445 -.0019	87 62	(80-87) (88-03)

R^2 in percentage

In all the districts and also in the state regression coefficients were positive and small, indicating that there was small increasing trend in paddy productivity in consonance with the change in management practices. The ranked order of districts was Pathanamthitta, Thrissur, Alappuzha, Wyanad, Malappuram, Thiruvananthapuram, Kasargode, Kannur, Kottayam, Kollam, Ernakulam, and Kozhikode. The parameters of Quadratic function showed a decreasing trend in paddy productivity through out the period for the Palakkad district. The regression coefficient in the state was a summary of the stature in the districts.

Paddy cultivation is slowly drifting towards to a near extinction, a fact that is irreversible.

4.4. Pepper

The parameters viz; intrinsic growth rate (a), carrying capacity (c), along with R^2, RMSE, achieved carrying capacity during initial(P) and end periods(Q) for the most suitable model for each district and the state for area, production and productivity of pepper are given in tables 4.a, 4.b and 4.c respectively. The parameters of quadratic function along with R^2 for area, production and productivity of pepper in districts when the other models failed to describe the phenomenon are given in tables 4.a1, 4.b1 and 4.c1.

4.4.1.Thiruvananthapuram

A nondecreasing trend could be noticed from the graph on area and production but the graph on productivity showed a decreasing trend.

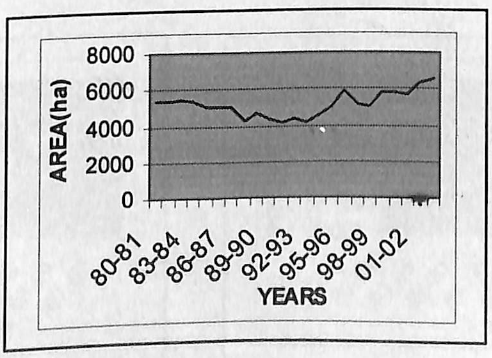


Fig 4.1. Area under pepper

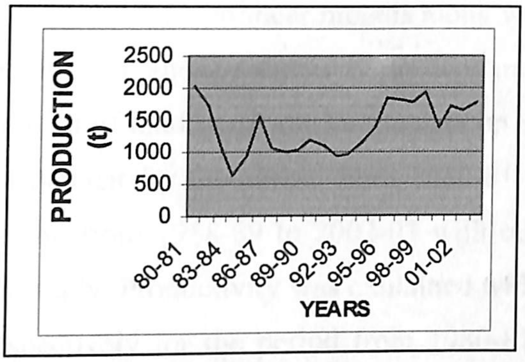


Fig 4.2. Production of pepper

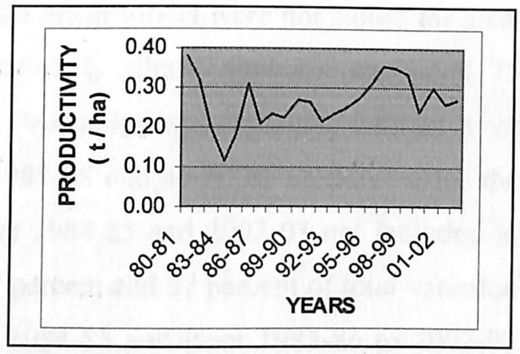


Fig 4.3. Productivity of pepper

All the four nonlinear models along with the linear model did not fit well for area, production and productivity. Quadratic function fitted well for area explaining 76 percent of total variation; for production explaining 52 percent of total variation with outliers 1983-84, 1985-86, 1991-92 and 1999-00 excluded from the study. The data on productivity was explained by the quadratic function with two break points explaining 51 percent, 66 percent and 82 percent of total variation respectively with outliers 1983-84, 1999-00 omitted from the study

4.4.2. Kollam

The time series graph on area showed an increasing trend and that on production and productivity showed a nondecreasing trend.

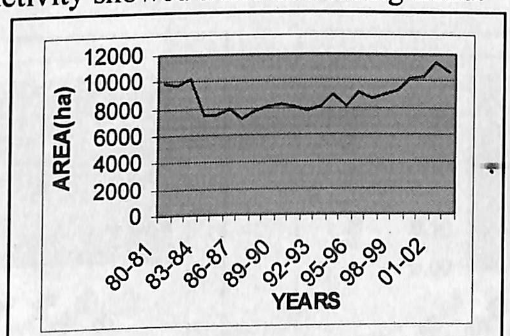


Fig 4.4. Area under pepper

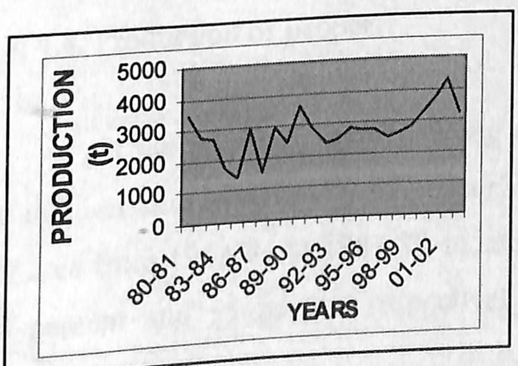


Fig 4.5. Production of pepper

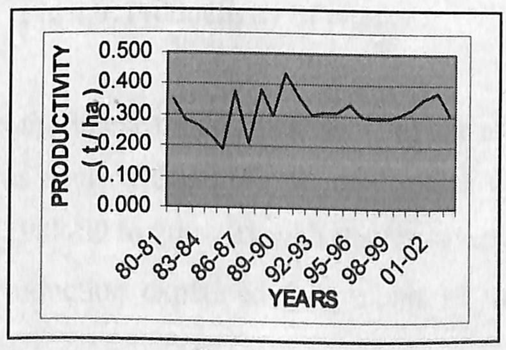


Fig 4.6. Productivity of pepper

All the nonlinear models along with the linear model were not suited for area, production and productivity in Kollam district. Quadratic function explained 75 percent of total variation for the data on area. Production was explained with an R^2 of 55 percent for the period from 1980-81 to 1987-88 and an R^2 of 63 percent for the period from 1988-89 to 2002-03 with outliers 1984-85 and 2002-03 not included in the study. Productivity was explained with 97 percent and 57 percent of total variation respectively for the period from 1980-81 to 1984-85 and from 1985-86 to 2002-03 with outliers 1986-87, 1989-90, 1990-91 and 2001-02 discarded from the study.

4.4.3. Pathanamthitta

The graph on area showed an increasing trend but the graph on production and productivity showed a nonincreasing trend.

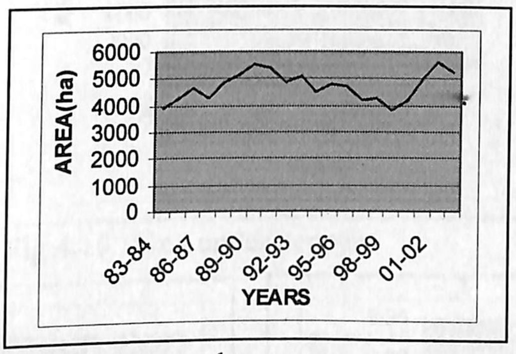


Fig 4.7. Area under pepper

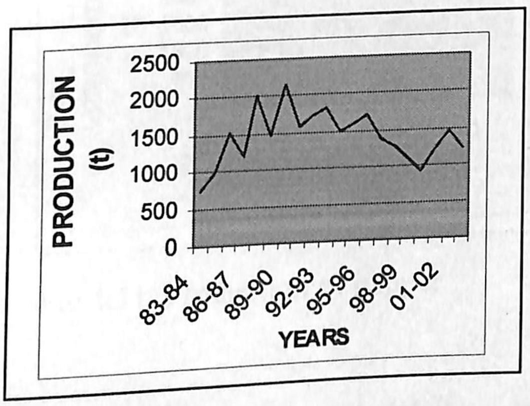


Fig 4.8. Production of pepper

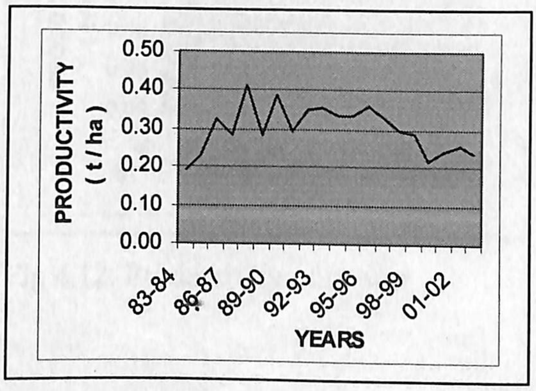


Fig 4.9. Productivity of pepper

All the nonlinear models along with the linear model were not suit for area, production and productivity of pepper in this district. Quadratic function fitted well for area from 1983-84 to 1987-88 and from 1988-89 to 2002-03 with the R^2 values of 65 percent and 55 percent respectively. Production explained 57 percent of total variation with the outliers 1984-85, 1986-87 and 1996-97 excluded from the study; and productivity explained 58percent of total variation.

4.4.4. Alappuzha

The crop was not taken into consideration in this district

4.4.5. Kottayam

The time series data on area, production and productivity showed a decreasing trend.

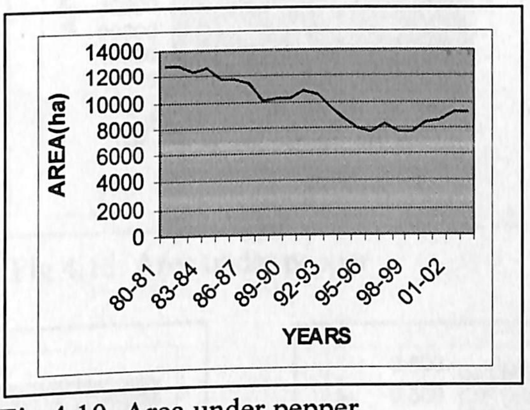


Fig 4.10. Area under pepper

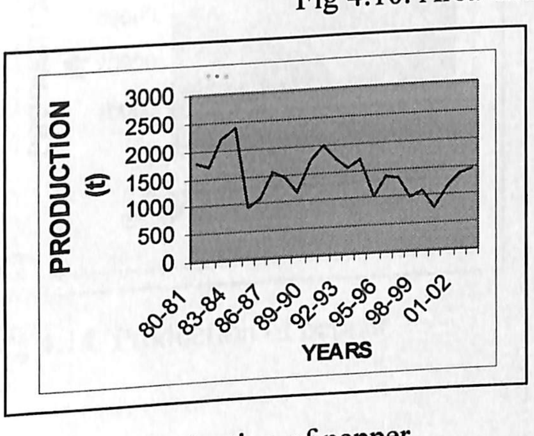


Fig 4.11. Production of pepper

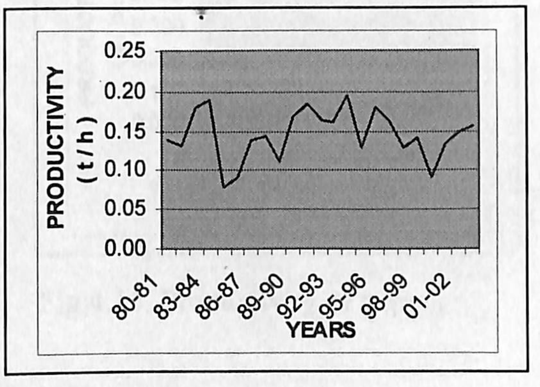


Fig 4.12. Productivity of pepper

Monomolecular model with an R^2 of 84 percent, Logistic and Gompertz models each with an R^2 of 83 percent fitted well for area under pepper in Kottayam district consideration but their carrying capacity were low. None of the nonlinear models was good for production and productivity. Quadratic function explained 86percent of total variation for the data on area and 51 percent of total variation for the data on production with outliers 1983-84, 1984-85, 1999-00 excluded from the study. Productivity explained 74 percent and 55 percent of total variation respectively for the periods 1980-81 to1988-89 and 1989-90 to 2002-03 with the outliers 1994-95, 1997-98, 1999-00 and 2000-01 omitted from the study.

4.4.6.Idukky

An increasing trend could be noticed from the graph on area, production and productivity of pepper in Idukky district.

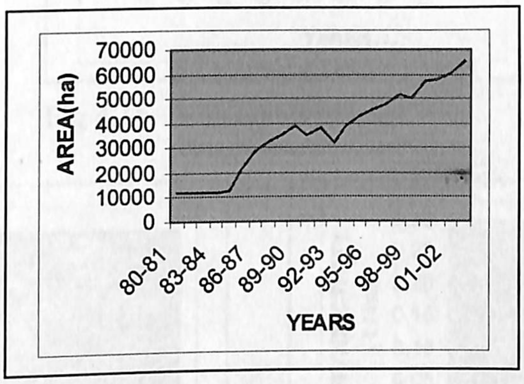


Fig 4.13. Area under pepper

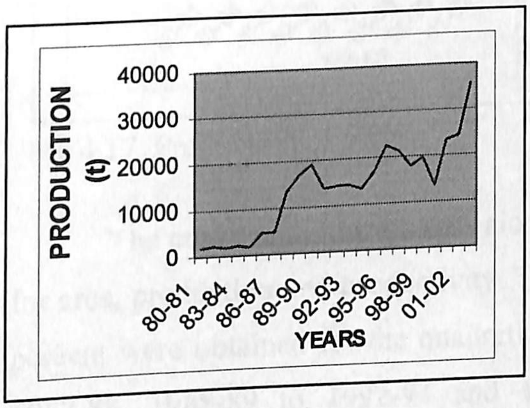


Fig 4.14. Production of pepper

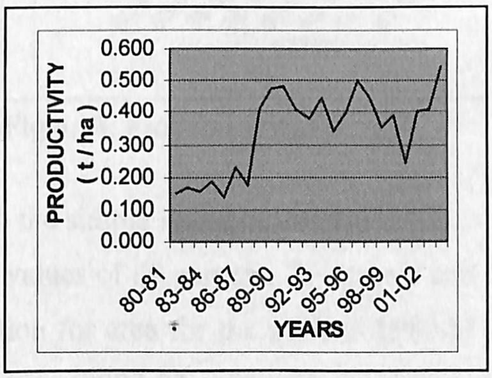


Fig 4.15. Productivity of pepper

Monomolecular model explained 95 percent, 79 percent and 58 percent of total variation for area, production and productivity respectively for pepper in Idukky district.

4.4.7. Ernakulam

The graph on area, production and productivity pictured a uniform nature.

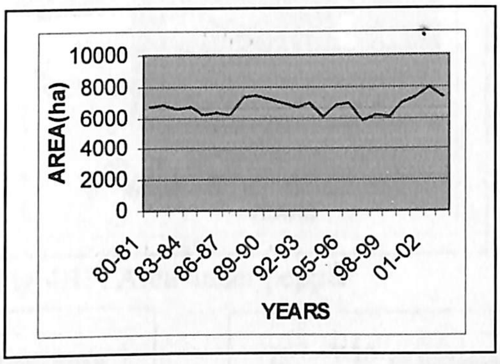


Fig 4.16. Area under pepper

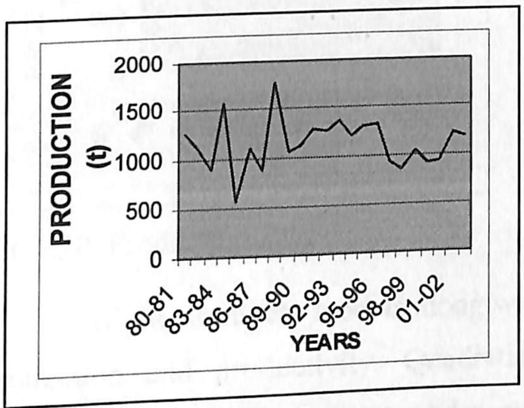


Fig 4.17. Production of pepper

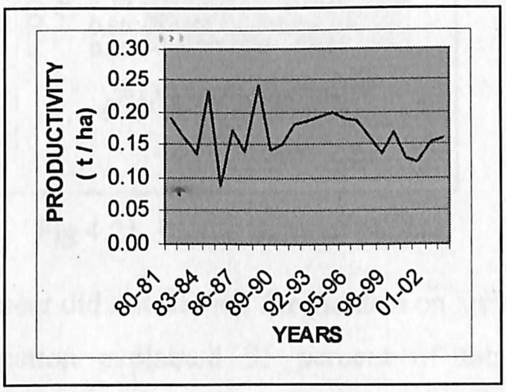


Fig 4.18. Productivity of pepper

The entire nonlinear models along with the simple linear model did not fit well for area, production and productivity. The R^2 values of 69 percent, 71 percent and 55 percent were obtained for the quadratic function for area for the periods 1980-81 to 1987-88, 1988-89 to 1992-93 and 1993-94 to 2002-03 respectively. Quadratic function explained 55 percent and 68 percent of total variation respectively for production from 1980-81 to 1988-89 and 1989-90 to 2002-03. Data on productivity explained 55 percent and 56 percent of total variation respectively for the periods 1980-81 to 1988-89 and 1989-90 to 2002-03 with outliers 1983-84, 1984-85 and 1987-88 excluded from the study.

4.4.8. Thrissur

A nondecreasing behaviour regarding the area, production and productivity could be noticed from the graph

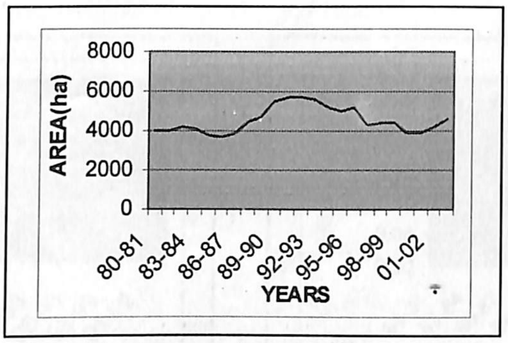


Fig 4.19. Area under pepper

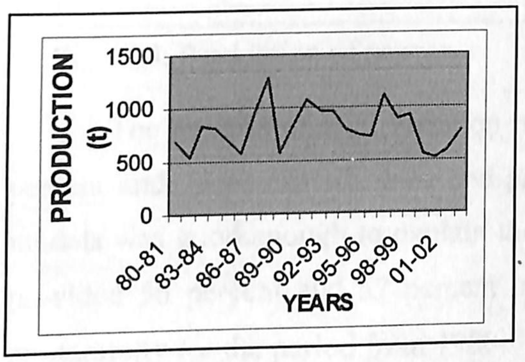


Fig 4.20. Production of pepper

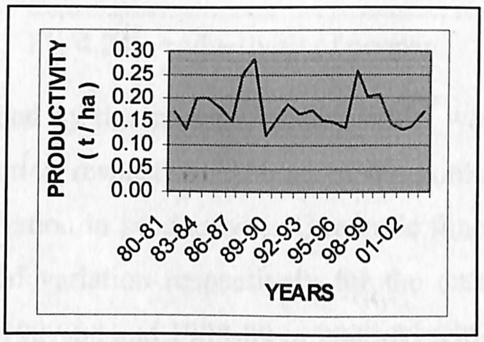


Fig 4.21. Productivity of pepper

All the nonlinear models along with linear did not fit well for the data on area, production and productivity. Quadratic function explained 55 percent of total variation for the data on area under cultivation. Data on production provided 96 percent and 69 percent of total variation respectively for the period from 1980-81 to 1986-87 and 1987-88 to 2002-03 with outliers 1981-82, 1984-85, 1985-86, 1988-89, 1990-91, 1996-97 and 1998-99 omitted from the study; data on productivity explained 58 percent and 54 percent of total variation respectively for the periods 1980-81 to 1987-88 and 1988-89 to 2002-03 with outliers 1981-82, 1986-87, 1987-88 and 2000-01 excluded from the study.

4.4.9. Palakkad

The time series data for area and production showed an increasing trend but with the graph on productivity showed a uniform nature.

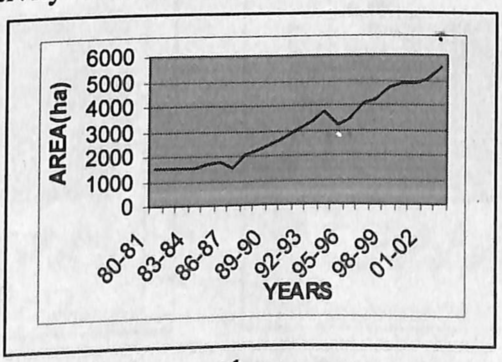


Fig 4.22. Area under pepper

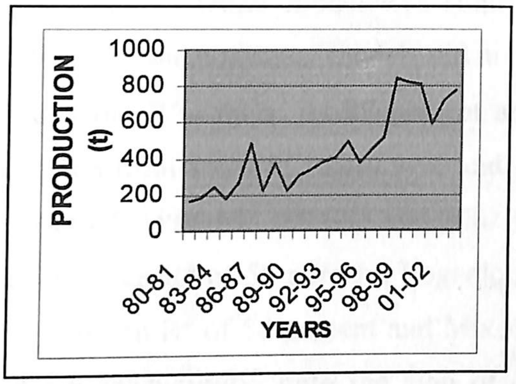


Fig 4.23. Production of pepper

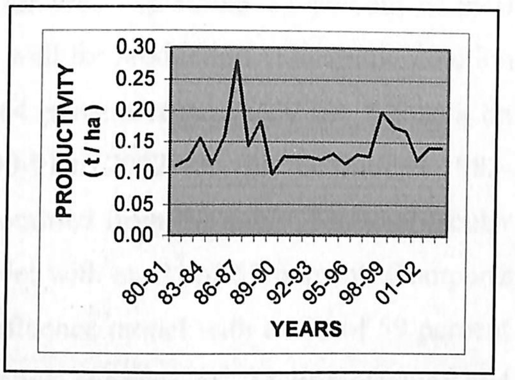


Fig 4.24. Productivity of pepper

The amount of total variation provided by the monomolecular model was 95 percent and 76 percent for area and production respectively. None of the nonlinear models was good enough to explain the variation in productivity. Quadratic function provided 56 percent and 57 percent of total variation respectively for the data on productivity for the period from 1980-81 to 1987-88 and 1988-89 to 2002-03 with the outliers 1985-86 and 1988-89 not included in the study.

4.4.10. Malappuram

The graph on area showed an increasing trend but the graph on production and productivity showed a decreasing trend

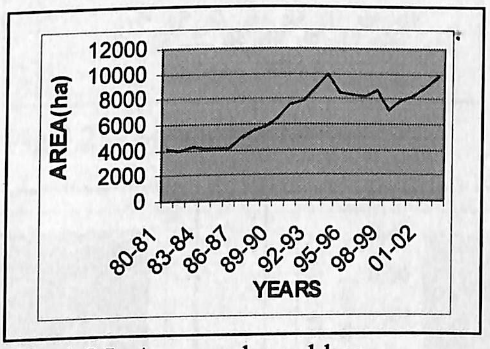


Fig 4.25. Area under rubber

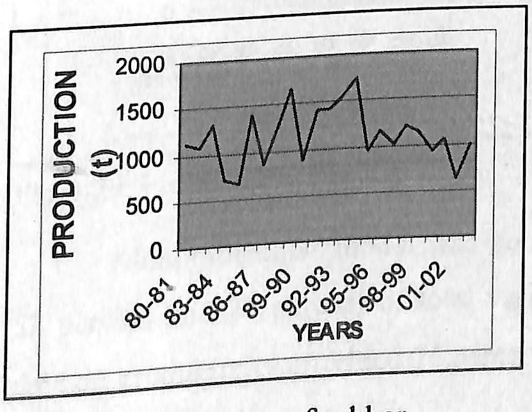


Fig 4.26. Production of rubber

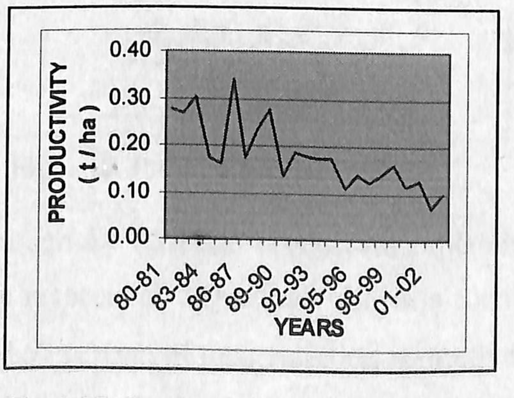


Fig 4.27. Productivity of rubber

Monomolecular model was suitable for area explaining 82 percent of total variation. All the nonlinear models did not fit well for production. Quadratic function provided the R^2 values of 87 percent and 64 percent respectively for the data on production from 1980-81 to 1989-90 and 1990-91 to 2002-03 with the outliers 1983-84, 1984-85, 1986-87, 1994-95 and 2002-03 omitted from the study. Monomolecular model with an R^2 of 59 percent, Logistic model with an R^2 of 57 percent, Gompertz model with an R^2 of 58 percent and Mixed-Influence model with an R^2 of 59 percent fitted for productivity, with the sign of carrying capacity of Monomolecular and Mixed-Influence model negative. Quadratic function explained 57 percent of total variation for the data on productivity with outlier 2001-02 excluded from the study.

4.4.11. Kozhikode

The graph on area, production and productivity showed a decreasing trend for pepper in Kozhikode district.

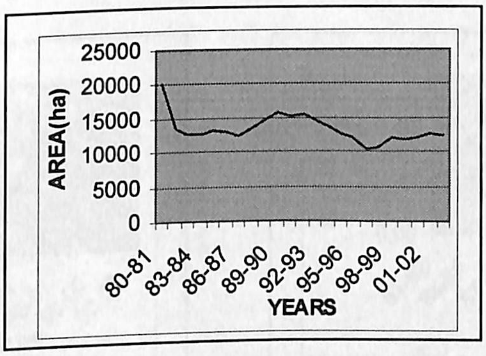


Fig 4.28. Area under rubber

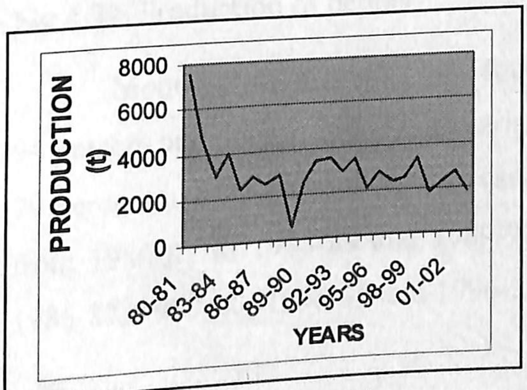


Fig 4.29. Production of rubber

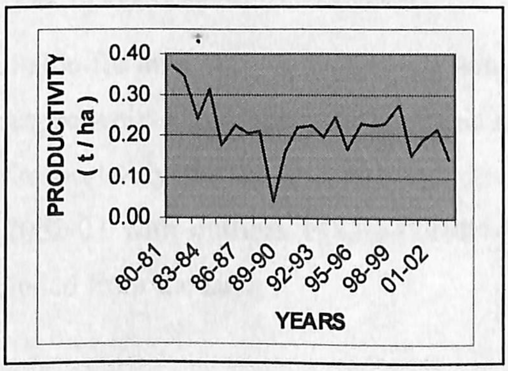


Fig 4.30. Productivity of rubber

Monomolecular model was good enough for area and production explaining 52 percent and 73 percent of total variation respectively. Quadratic function for the data on productivity provided 74 percent and 57 percent of total variation respectively for the periods 1980-81 to 1986-87 and from 1987-88 to 2002-03 with outliers 1988-89, 1989-90, 1994-95 and 1999-00 omitted from the study.

4.4.12. Wyanad

An increasing trend for area; a decreasing trend for production and productivity could be noticed from the graph.

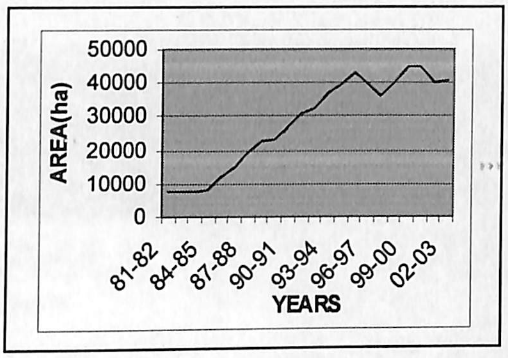


Fig 4.31. Area under pepper

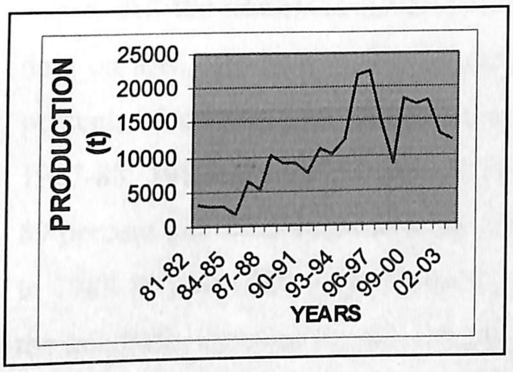


Fig 4.32. Production of pepper

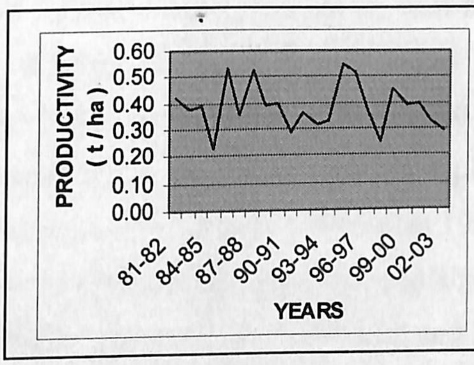


Fig 4.33. Productivity of pepper

Monomolecular model was found suitable for area and production explaining 94 percent and 66 percent of total variation respectively. Quadratic function explained 79 percent and 52 percent of total variation respectively for the data on productivity from 1980-81 to 1988-89 and 1989-90 to 2002-03 with outliers 1983-84, 1984-85, 1986-87, 1989-90, 1995-96 and 1996-97 excluded from the study.

4.4.13. Kannur

The time series data on area was uniform in nature where as production and productivity showed a decreasing trend.

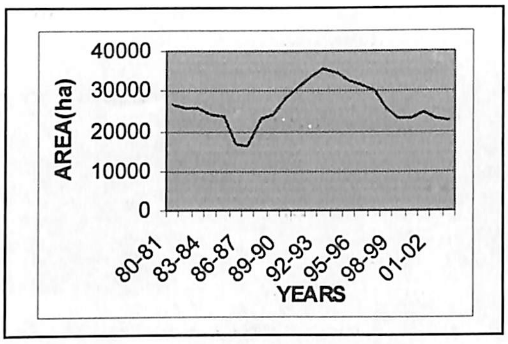


Fig 4.34. Area under pepper

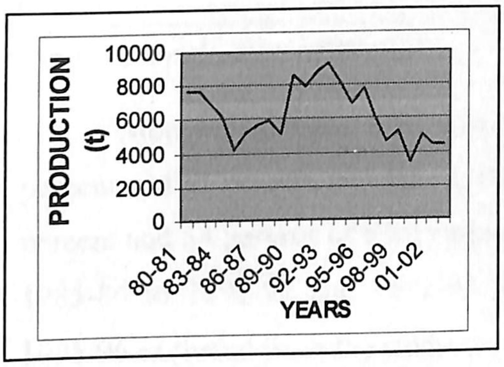


Fig 4.35. Production of pepper

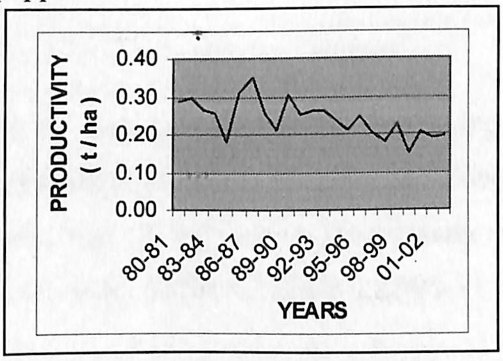


Fig 4.36.Productivity of pepper

All the nonlinear models along with the linear model did not fit well for the data on area, production and productivity. Quadratic function gave R^2 values of 93 percent, 96 percent and 92 percent respectively for the data on area from 1980-81 to 1987-88; 1988-89 to 1993-94 and 1994-95 to 2002-03. Data on production explained 89 percent and 81 percent of total variation respectively for the periods from 1980-81 to 1988-89 and 1989-90 to 2002-03. A total of 67 percent variation was explained by the quadratic function for the data on productivity with the outliers 1984-85 and 1986-87 in this district.

4.14. Kasargode

A slow increasing trend could be noticed from the graph on area and production but a uniform nature could be noticed from the graph on productivity.

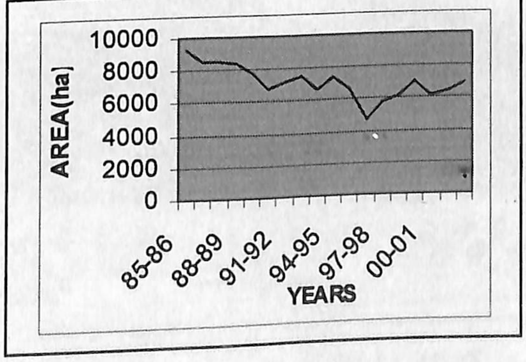


Fig 4.37. Area under pepper

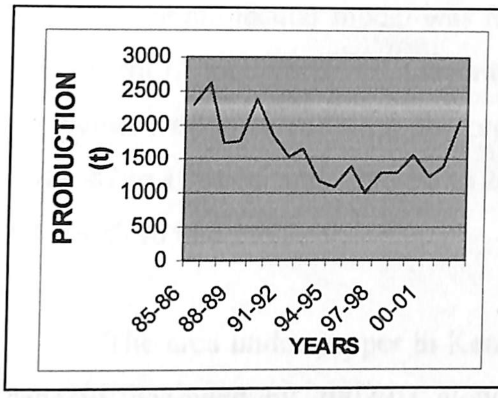


Fig 4.38. Production of pepper

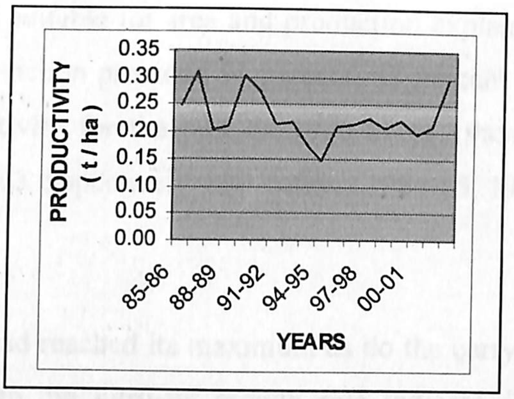


Fig 4.39. Productivity of pepper

Monomolecular model was suitable for area and production explaining 69 percent and 53 percent of total variation respectively. Quadratic function explained 99 percent and 54 percent of total variation respectively for the data on productivity from 1985-86 to 1991-92 and 1992-93 to 2002-03 with outliers 1986-87, 1990-91 and 1995-96 excluded from the study.

4.15. Kerala

The time series graph on area showed a steady increasing trend. The graph on production and productivity also showed an increasing trend with many fluctuations.

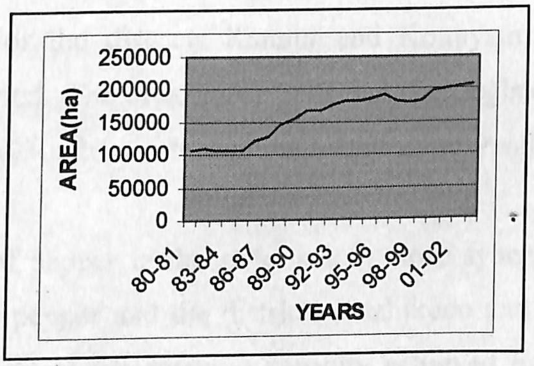


Fig.4.40. Area under pepper

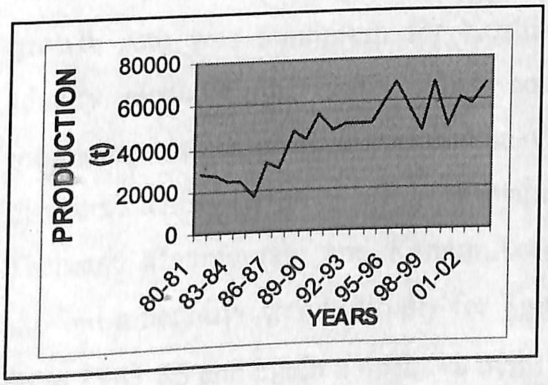


Fig 4.41. Production of pepper

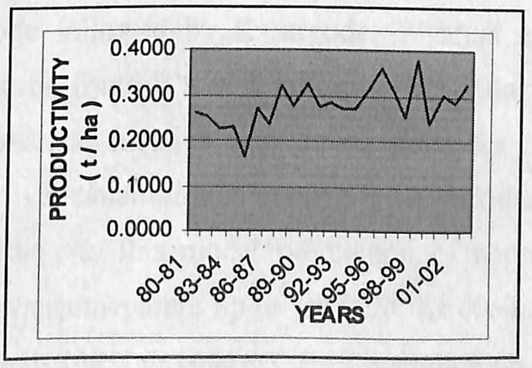


Fig 4.42. Productivity of pepper

Monomolecular model was found suitable for area and production explaining 93 percent of total variation. Quadratic function provided 91 percent, 53 percent and 64 percent of total variation for productivity for the periods 1980-81 to 1985-86, 1986-87 to 1994-95 and 1995-96 to 2002-03 respectively with outliers 1984-85, 1989-90, 1995-96 and 1998-99.

The area under pepper in Kerala had reached its maximum as do the carrying capacity achieved by 2002-03 along with the intrinsic growth rate indicate. The pepper cultivation in Malappuram, Kozhikode, Wyanad and Kasargode districts was widely spread as per the high intrinsic growth rate coupled with carrying capacity. Though the achieved carrying capacity for Idukky and Palakkad indicated that much more area under pepper cultivation was feasible in these districts, the near zero intrinsic growth rates was a negation. Quadratic function was considered to explore the pepper cultivation in the districts of Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Kottayam, Ernakulam, Thrissur and Kannur. According to parameters of this model the area under cultivation showed a negative trend initially for Thiruvananthapuram up to 1990-91, for Kollam up to 1990-91, for Pathanamthitta from 1986-87 to 1994-95, for Ernakulam up to 1995-96, afterwards showed an increasing trend. For the districts Kannur and Kottayam the trend was negative through out the period. The area under consideration registered a positive trend for Thrissur up to 1992-93, afterwards showed a decreasing trend.

Production of pepper in the state was in close synchronisation with the area under cultivation of pepper and the districts Kozhikode and Wyanad were the main bowls. For these districts the carrying capacity achieved by 2002-03 was low and hence they were viable for further improvement in pepper production. The intrinsic growth rate was maximum for Kozhikode followed by Kasargode, Wyanad and Idukky. Hence further improvement could be fruitful; it was minimum for Palakad indicating only a slow improvement. Quadratic function model was fitted for the districts Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam, Ernakulam, Thrissur, Malappuram and Kannur.According to this model production of pepper showed a negative trend initially for Thiruvananthapuram up to 1989-90, for Kollam up to 1985-86 and again a negative trend from 1988- to 1994-95, for Ernakulam up to 1985-86 and again a negative trend from 1994-95 to 2002-03, and an increasing trend

Table 4.a. Comparison of trend in area under pepper in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
IDK	.0068	387263.9	0.053	5	95	3902.28	Monomolecular model
PKD	.00022	89836.07	0.363	88	95	302.74	Monomolecular model
MLPM	.0657	11111.26	1.548	94	82	925.69	Monomolecular model
KKD	2.726	13042.37	0.121	67	52	1506.62	Monomolecular model
WYD	.06344	60816.34	0.957	81	94	3373.95	Monomolecular model
KSGD	.1955	6134.22	.1304	6007.99	69	663.95	Monomolecular model
Kerala	.0593	249601.35	.43	83	93	9830.99	Monomolecular model

Table 4.b. Comparison of trend in production of pepper in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
IDK	.01693	83346.19	0.021	1.7	79	4266.92	Monomolecular model
PKD	.00061	47496.46	0.004	1.6	76	114.1	Monomolecular model
KKD	.8262	2552.96	2.948	69	73	707.43	Monomolecular model
WYD	.0883	19591.17	0.157	61	66	3718.25	Monomolecular model
KSGD	.2466	1330.86	1.721	154	53	338.56	Monomolecular model
Kerala	.0587	79823.18	.36	84	93	7718.45	Monomolecular model

Table 4.c. The parameters a, c, P&Q for productivity of pepper in Idukky

Districts	a	c	p	Q	R^2	RMSE	Suitable model
IDK	.15812	.4409	..034	120	58	.0878	Monomolecular model

Q and R^2 in percentage

Table 4.a1. Parameters of Quadratic function for area under pepper

Districts		QUADRATIC FUNCTION		
		b_1	b_2	R^2
TVM		-261.5	12.66	76
KLM		-426.58	21.15	75
PTA	(81-85)	312.93	-19.07	65
	(85-03)	-529.98	19.54	55
KTM		-543.47	12.74	86
PKD		81.69	4.68	97
MLPM		535.24	-11.09	82
KKD	(81-89)	-1926.6	147.85	55
	(90-03)	-3914.0	104.62	77
WYD		3801.97	-78.35	95
KSGD		-532.42	19.83	74

Table 4.b1. Parameters of Quadratic function for production of pepper

Districts		QUADRATIC FUNCTION		
		b_1	b_2	R^2
TVM		-119.13	5.99	52
KLM	(81-88)	-732.21	78.22	55
	(89-03)	-405.66	14.77	63
PTA		140.32	-6.313	57
KTM		-57.33	1.33	51
EKM	(80-89)	-193.85	18.83	55
	(90-03)	184.11	-6.91	68
TSR	(81-87)	56.87	-1.32	96
	(88-03)	-128.57	3.08	69
MLPM	(81-90)	219.09	-21.05	87
	(91-03)	-70.55	.515	64
KNR	(81-89)	-736.26	42.37	89
	(90-03)	-387.95	-1.069	81

R^2 in percentage

Table 4.c1. Parameters of Quadratic function for productivity of pepper

Districts		QUADRATIC FUNCTION		
		b_1	b_2	R^2
TVM	(81-89)	-.0613	.0048	51
	(90-95)	-.1886	.0075	66
	(96-03)	.1311	.0036	82
KLM	(81-85)	-.0482	.0016	97
	(86-03)	-.0208	.0006	.57
PTA		.0284	-.0014	58
KTM	(81-89)	.033	-.0036	74
	(90-03)	-.0004	-.00005	55
EKM	(81-90)	-193.85	18.83	55
	(91-03)	184.11	-6.90	68
TSR	(81-88)	-.0219	.0037	58
	(89-03)	-.0188	.0005	54
PKD	(81-88)	.0072	.000014	56
	(89-03)	.0085	-.002	57
MLPM		-.010	.0001	56
KKD	(81-87)	-.0623	.0042	74
	(88-03)	.0282	-.001	57
WYD	(81-88)	-.0372	.0036	79
	(89-03)	.095	-.0031	52
KNR		-.0026	-.0001	67
KSGD	(80-86)	-.0599	.0092	99
	(87-03)	-.026	.0012	54
Kerala		.0518	-.0018	55

R^2 in percentage

henceforth. Pepper production registered a positive trend from 1985-86 to 1987-88 for Ernakulam, for Thrissur up to 1987-88 and a decreasing trend, again showed an increasing trend for the subsequent three years. The districts Kottayam and Kannoor showed a negative trend through out the period under investigation.

None of the nonlinear models could describe the productivity either in the state or in the districts in general except Idukky. The high intrinsic growth rate indicated that the achievable productivity had surpassed its capacity as evident from the achieved carrying capacity by 2002-03. The fluctuating trend in the productivity of pepper was analysed through Quadratic function model for the state and the districts except Idukky. As per the parameters of the Quadratic model pepper productivity noticed a positive trend up to 1984-85 and afterwards a negative trend for the state. Quadratic function registered a differential decreasing trend through out the period under investigation for the districts Kollam, Malappuram and Kannur. The districts like Thiruvananthapuram, Thrissur and Kasargode registered a negative trend during the initial period and an increasing trend henceforth. Pathanamthitta, Kottayam, Ernakulam, Kozhikode and Wyanad showed a positive trend during the initial period and afterwards a negative trend

...

Pepper in the state in general was vulnerable to multiplicity of devastating diseases coupled with interrupting spells of drought. Hectic survival activity is the need of the hour to maintain at least uniform production.

4.5. Tapioca

The parameters viz; intrinsic growth rate (a), carrying capacity (c), along with R^2, RMSE, achieved carrying capacity during initial(P) and end periods(Q) for the suitable model which showed good fit for each district and the state for area, production and productivity are given in tables 5.a, 5.b and 5.c respectively. The parameters of quadratic function along with R^2 for the data on area, production and productivity of tapioca in cases where the nonlinear models failed to describe the situation are given in tables 2.a1, 2.b1 and 2.c1.

4.5.1.Thiruvananthapuram

The graph on area and production showed a decreasing trend but the graph on productivity showed a sustainable growth trend.

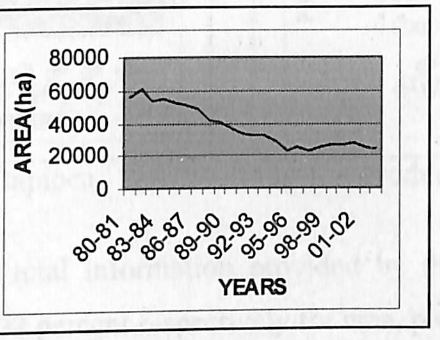


Fig 5.1. Area under tapioca

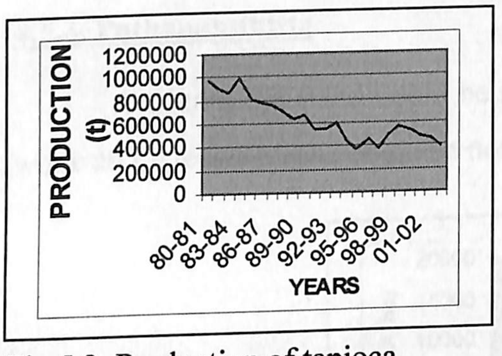


Fig 5.2. Production of tapioca

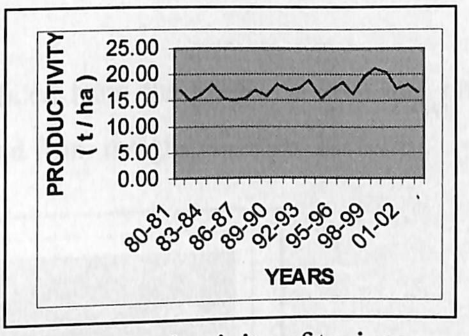


Fig 5.3. Productivity of tapioca

Monomolecular model fitted well with the R^2 values of 93 percent and 87 percent respectively for area and production. All the nonlinear models did not fit well for productivity. Quadratic function explained 57 percent of total variation with outliers 1980-81, 1983-84, 1993-94 and 2002-03 excluded from the study.

4.5.2. Kollam

The time series graph on area and production showed a decreasing trend while the graph on productivity showed an increasing trend for tapioca in Kollam district.

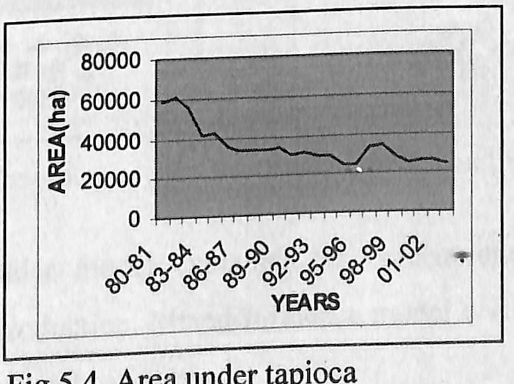


Fig 5.4. Area under tapioca

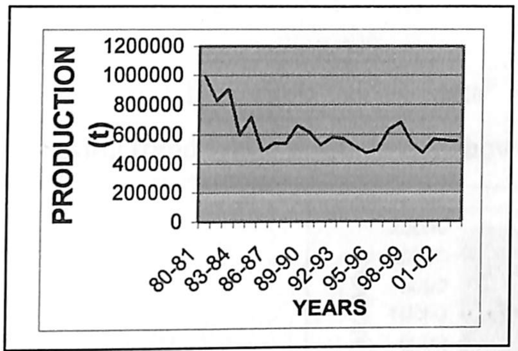


Fig 5.5. Production of tapioca

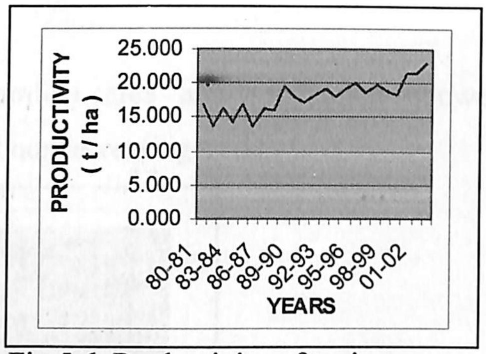


Fig 5.6. Productivity of tapioca

The amount of total information provided by the Monomolecular was 90 percent, 73 percent and 72 percent respectively for area, production and productivity.

4.5.3. Pathanamthitta

A decreasing trend could be noticed from the graph on area and production, while an increasing trend could be noticed from the graph on productivity.

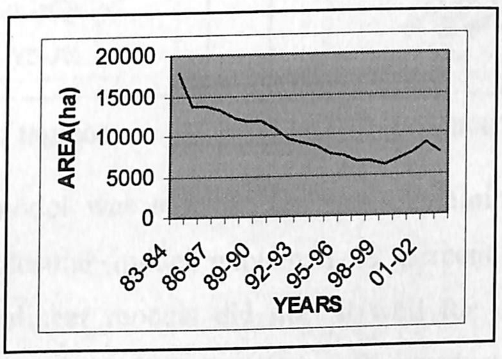


Fig 5.7.Area under tapioca

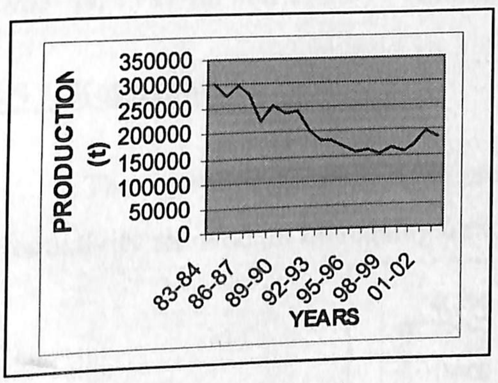


Fig 5.8. Production of tapioca

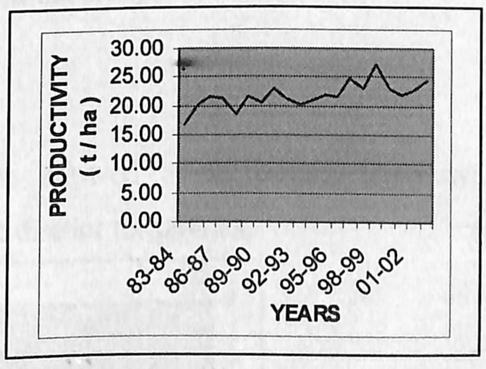


Fig 5.9. Productivity of tapioca

Monomolecular model explained 91 percent and 84 percent of total variation for area and production. Mixed-Influence model was suited for productivity explaining 50 percent of total variation.

4.5.4. Alappuzha

The time series data regarding area and production showed a decreasing trend while productivity showed nondecreasing trend.

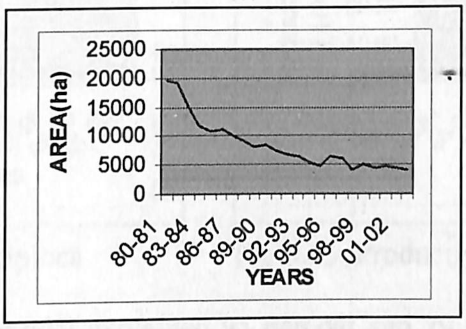


Fig 5.10. Area under tapioca

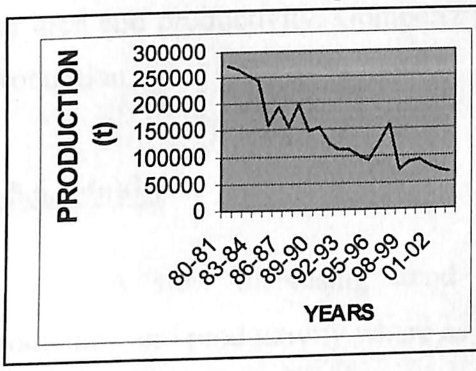


Fig 5.11. Production of tapioca

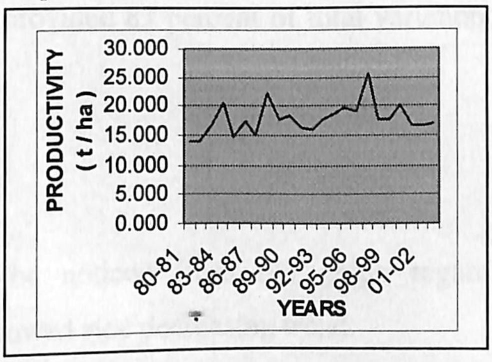


Fig 5.12. Productivity of tapioca

Gompertz model was suitable for area explaining 97 percent of total variation and Monomolecular model explained 89 percent of total variation for production. All the nonlinear models did not fit well for productivity. Quadratic function explained 55 percent of total variation for productivity with the outliers 1983-84, 1987-88 and 1996-97 eliminated from the study.

4.5.5. Kottayam

The graph on area and production showed a decreasing trend while productivity showed an increasing trend in the district for tapioca.

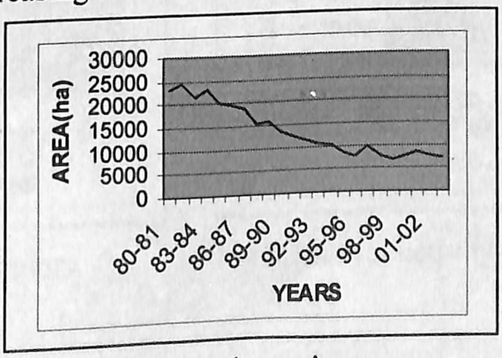


Fig 5.13. Area under tapioca

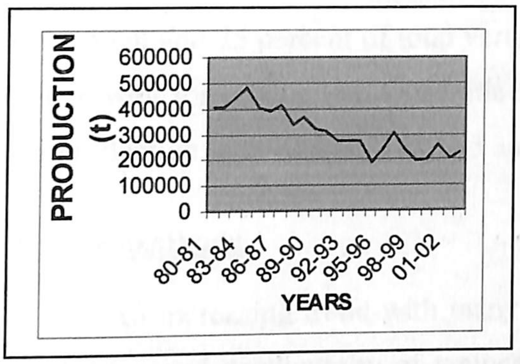


Fig 5.14. Production of tapioca

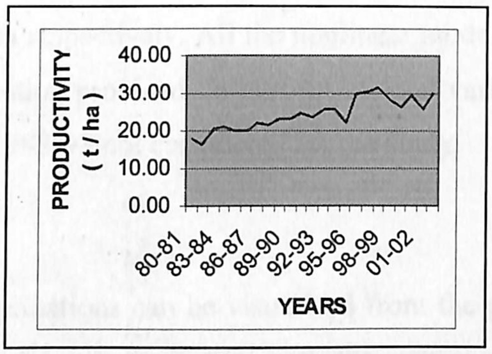


Fig 5.15. Productivity of tapioca

Monomolecular model explained 95 percent and 79 percent of total variation for area and productivity. Gompertz model provided 83 percent of total variation for production.

4.5.6. Idukky

A slow increasing trend could be noticed from the graph regarding production and productivity where as area showed sloe decreasing trend.

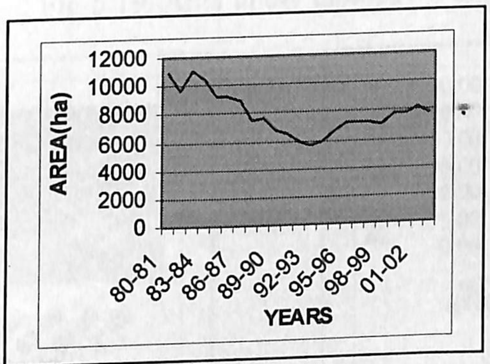


Fig 5.16. Area under tapioca

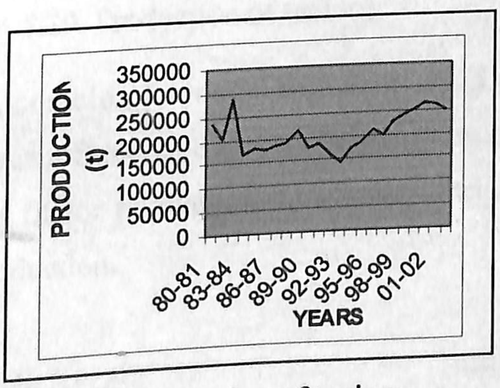


Fig 5.17. Production of tapioca

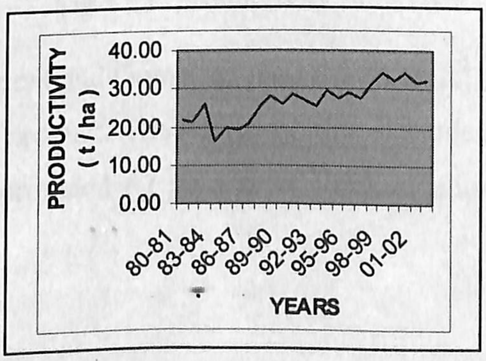


Fig 5.18. Productivity of tapioca

Monomolecular model was found suitable for area and productivity explaining 67 percent and 75 percent of total variation respectively. All the nonlinear models did not fit well for production. Quadratic function provided 76 percent of total variation for production with outliers 1982-83 and 1992-93 not considered for the study.

4.5.7. Kozhikode

An increasing trend with many fluctuations can be visualized from the graph production and productivity of tapioca in Kozhikode district with the area showing uniform trend.

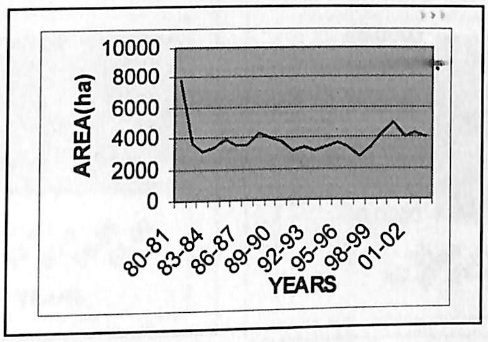


Fig 5.19. Area under tapioca

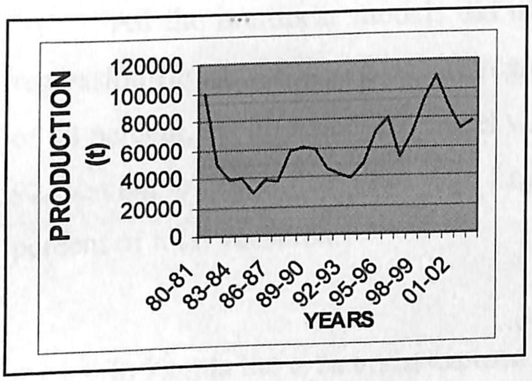


Fig 5.20. Production of tapioca

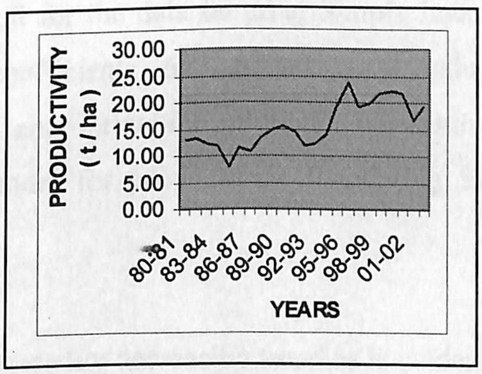


Fig 5.21. Productivity of tapioca

Monomolecular model with an R^2 of 75 percent and Gompertz model with an R^2 of 63 percent fitted well respectively for area and productivity. All the nonlinear models did not fit for production. Quadratic function provided 62 percent of total variation for production.

4.5.8. Kerala

The graph on area and production showed a decreasing trend, but the graph on productivity showed an increasing trend.

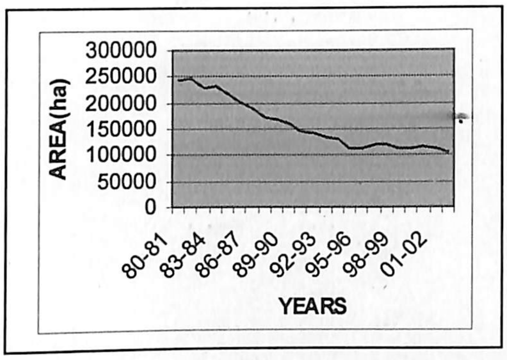


Fig 5.22. Area under tapioca

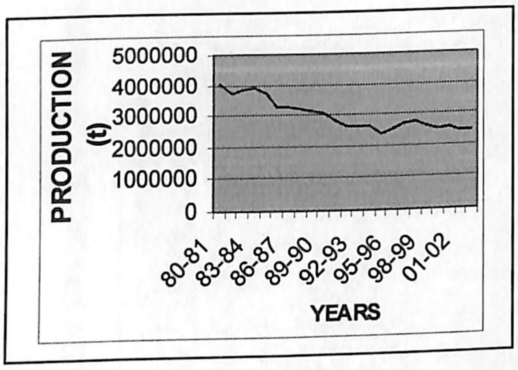


Fig 5.23. Production of tapioca

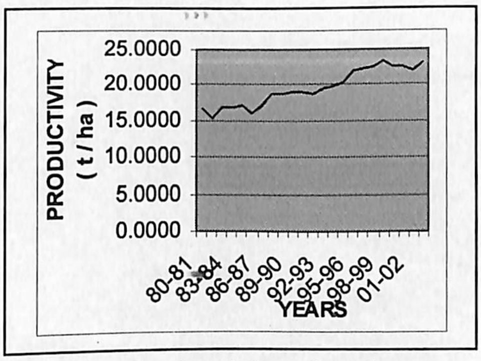


Fig 5.24. Productivity of tapioca

All the nonlinear models did not fit well for the data on area; Simple linear regression fitted well and gave the regression coefficients –6872.62 with an R^2 value of 90 percent. Monomolecular model was found appropriate for production explaining 92 percent of total variation and Logistic model for productivity elucidating 92 percent of total variation.

In Kerala the area under tapioca showed steadily decreasing trend as is evident from the simple linear regression model being most suited for the same. This fact was substantiated by the high intrinsic growth rates and over subscribed achieved carrying capacities for the contributive districts namely Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Kottayam, Idukky and Kozhikode.

Production of tapioca in Kerala over rode its maximum carrying capacity as could be read from the high intrinsic growth rate and achieved carrying capacity by 2002-03. Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha and Kottayam followed the suit to realize this. Production of tapioca in Idukky and Kozhikode

Table 5.a. Comparison of trend in area under tapioca in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
TVM	.0797	13191.19	4.29	181	93	3499.32	Monomolecular model
KLM	.2245	26925.77	2.19	89	90	3439.36	Monomolecular model
PTA	.1553	6329.49	2.83	120	91	968.63	Monomolecular model
ALP	.0879	3394.37	5.77	121	97	780.37	Gompertz model
KTM	.0733	1644.03	13.99	452	95	1332.02	Monomolecular model
IDK	.2163	6910.55	1.57	113	67	932.03	Monomolecular model
KKD	5.108	5671.10	1.37	0.70	75	512.31	Gompertz model

Q and R^2 in percentage

Table 5.a1. Parameter(b) and R^2 of simple linear regression of area under tapioca in the state

	b	R^2	Suitable model
Kerala	-6872.62	90	Simple linear model

R^2 in percentage

Table 5.b. Comparison of trend in Production of tapioca in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
TVM	.0938	332247.36	2.09	118	87	71655.72	Monomolecular model
KLM	.40174	549935.99	1.80	101	73	74311.23	Monomolecular model
PTA	.1342	148053.19	2.04	126	84	21002.12	Monomolecular model
ALP	.11182	60346.88	4.52	118	89	22631.15	Monomolecular model
KTM	.0057	392.91	1040.9	570	83	38119.82	Gompertz model
Kerala	.1051	2232146.5	1.81	108	92	155020.6	Monomolecular mode

Table 5.b1. Parameters of Quadratic function for production of tapioca

Districts	QUADRATIC FUNCTION		
	b_1	b_2	R^2
IDK	-9815.7	524.28	76
KKD	334.21	74.21	62

Table 5.c Comparison of trend in Productivity of Tapioca in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
KLM	.00029	1053.4	0.02	0.02	72	1.322	Monomolecular model
PTA	.159	28.68	0.59	0.85	50	1.703	Mixed-Influence model
KTM	.0454	36.67	0.59	0.87	79	2.011	Monomolecular model
IDK	.00083	802.87	0.02	0.04	75	2.633	Monomolecular model
KKD	.0563	39.04	0.33	0.50	63	2.82	Gompertz model
Kerala	.0431	34.93	.48	66	92	.7461	Logistic model

Table 5.c1. Parameters of Quadratic function for Productivity of Tapioca

Districts	QUADRATIC FUNCTION		
	b_1	b_2	R^2
TVM	.2683	-.0031	57
ALP	.5926	-.0184	55

Q and R^2 in percentage

districts could be described only through the Quadratic function. As regards to the parameters of Quadratic function a negative trend up to 1989-90 and thereafter a positive trend could be noticed for Idukky. Kozhikode showed a positive trend through out the period under exploration.

The productivity of tapioca in Kerala can be further improved when we conclude that the intrinsic growth was moderately high and the achieved carrying capacity by 2002-03 was only 60percent. In Pathanamthitta and Kottayam districts no more further improvement was possible, but productivity could be improved very much in the Kozhikode district on the conclusion based on the moderately high intrinsic growth rate and 50percent carrying capacity achieved by 2002-03. In Kollam and Idukky districts the intrinsic growth rate of productivity was extremely low. So further improvement in productivity was only through innovative efforts. The productivity of Tapioca in Thiruvananthapuram and Alappuzha were analysed through Quadratic function. Parameters of Quadratic function illustrated that there was a positive trend for Alappuzha up to 1996-97 and a negative trend henceforth. A positive trend was noticed through out the period for Thiruvananthapuram

In general production having reached a maximum value addition to the produce is the only way out by which we can think of maintaining a sustainable trend.

4.6. Cashew

None of the nonlinear models was good enough to explore the data on area, production and productivity. Quadratic model was tried for district wise as also state wise data and the parameters along with R^2 for area, production and productivity are depicted in 6.a1, 6.b1 and 6.c1.

4.6.1. Alappuzha

The graph on area showed a non decreasing trend where as production and productivity showed a decreasing trend.

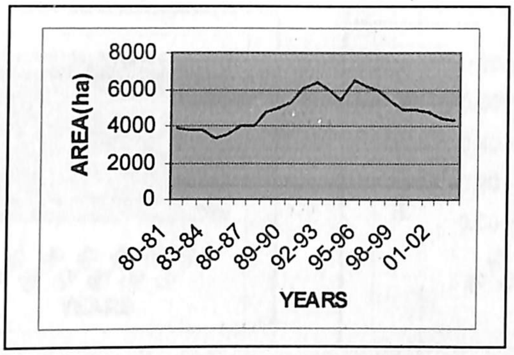


Fig 6.1. Area under cashew

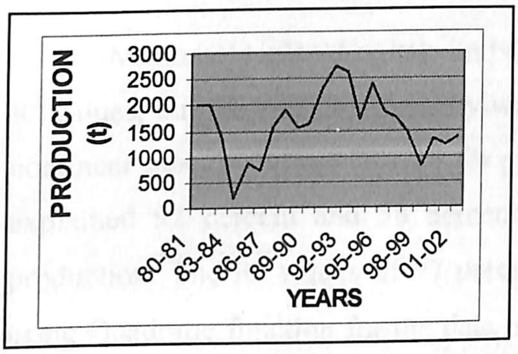


Fig 6.2. Production of Cashew nut

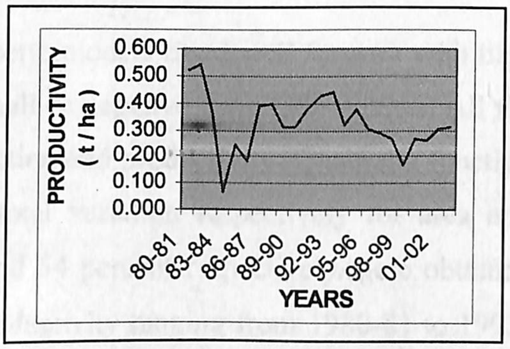


Fig 6.3. Productivity of cashew nut

All the nonlinear models along with the simple linear regression did not fit well for area, production and productivity. Quadratic model explained 71 percent of total variation for area. Data on production gave the R^2 values 75 percent and 58percent respectively for the period ranging from 1980-81 to 1986-87 and 1987-88 to 2002-03 with outliers 1983-84 and 1998-99 excluded from the study. Data on productivity explained 53 percent of total variation with the outliers 1981-82, 1983-84, 1984-85 and 1985-86 omitted from the study.

4.6.2. Malappuram

The time series data area and production showed a decreasing trend where as productivity revealed a uniform nature.

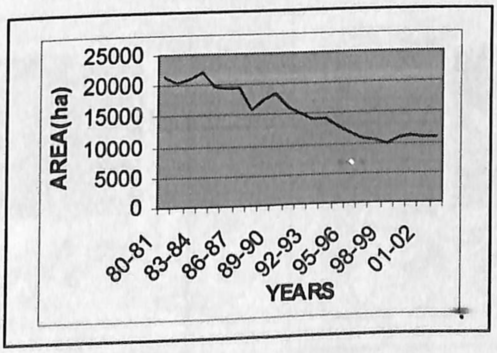


Fig 6.4. Area under cashew

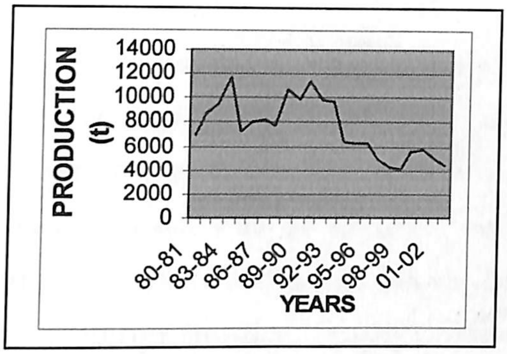


Fig6.5. Production of cashew nut

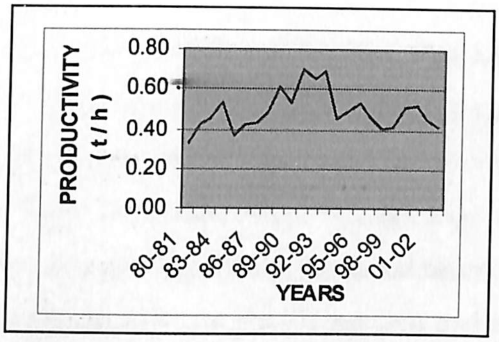


Fig 6.6. Productivity of cashew nut

Monomolecular, Logistic and Gompertz models fitted well for area with high R^2 values, but the carrying capacity was small or negative for all the models. All the nonlinear models did not fit well for production and productivity. Quadratic function explained 92 percent and 58 percent of total variation respectively for area and production. The R^2 values of 77 percent and 54 percent respectively were obtained using Quadratic function for the data on productivity ranging from 1980-81 to 1992-93 and from 1993-94 to 2002-03 with outliers 1997-98 and 1998-99.

4.6.3. Kannur

The graph on area and production showed a decreasing trend with that productivity showing a non decreasing trend.

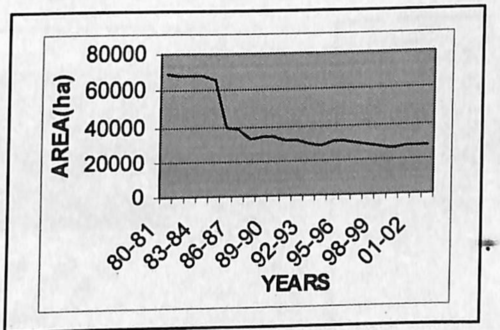


Fig 6.7. Area under cashew

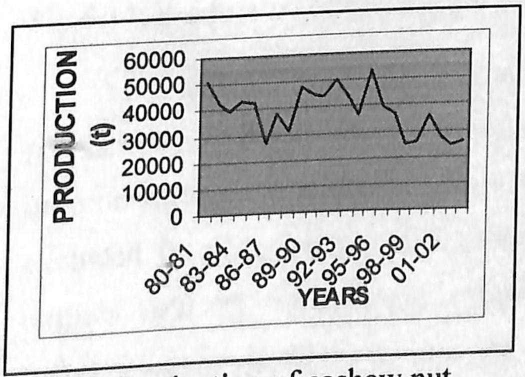


Fig 6.8. Production of cashew nut

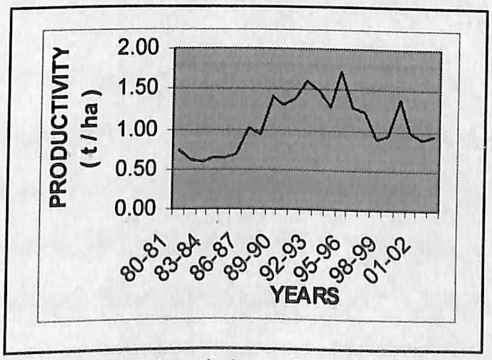


Fig 6.9. Productivity of cashew nut

Monomolecular, Logistic and Gompertz models fitted well for area with high R^2 values. Logistic model fitted with an R^2 of 77 percent for production, but the sign of intrinsic growth rate and carrying capacity of this model was negative. Mixed-Influence model with an R^2 of 57 percent fitted for productivity, but the sign of intrinsic growth rate of this model was negative. But all these results were not taken to explore further situation. Quadratic function explained 88 percent, 72 percent and 64 percent of total variation for area, production and productivity respectively. The outliers 1985-86, 1987-88 and 1994-95 were eliminated from the data on production.

4.6.4.Kasarcode

The time series graph on area, production and productivity showed a slight decreasing trend with much fluctuation.

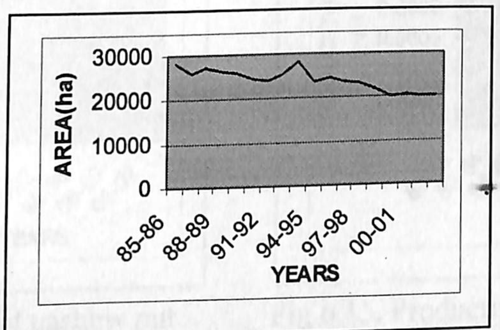


Fig 6.10. Area under cashew

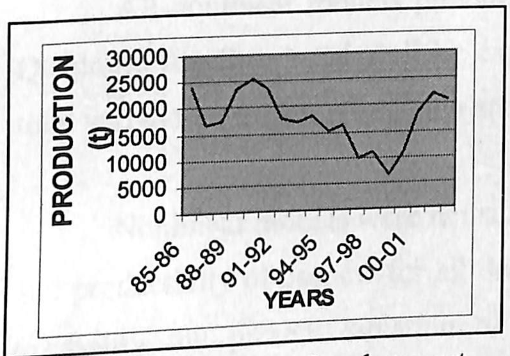


Fig 6.11. Production of cashew nut

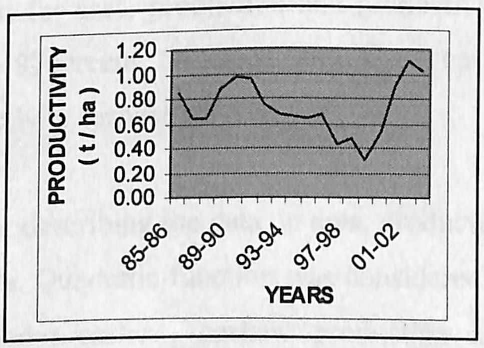


Fig 6.12. Productivity of cashew nut

All the nonlinear models were not good enough for area, production and productivity. Quadratic function provided 82 percent of total variation for area. Data on production gave an R^2 of 54 percent with outliers 1981-82, 1993-94 and 1994-95 excluded from the study; productivity explained 59 percent of total variation with outliers 1991-92, 1992-93 and 1994-95 eliminated from the study, where Quadratic function was attempted as a model fit.

4.6.5. Kerala

The time series data on area and production showed a decreasing trend while productivity revealed a uniform nature in the state.

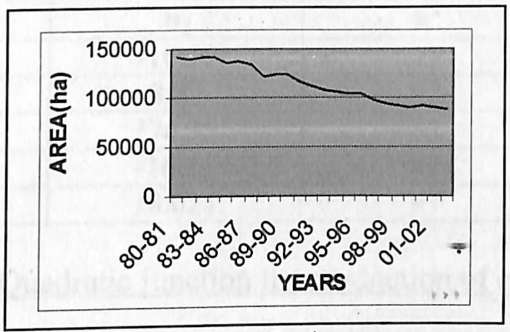


Fig 6.13.Area under Cashew

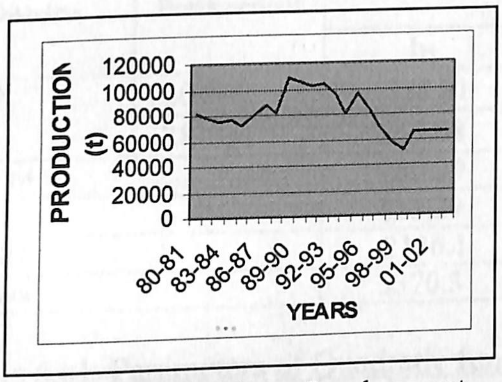


Fig 6.14. Production of cashew nut

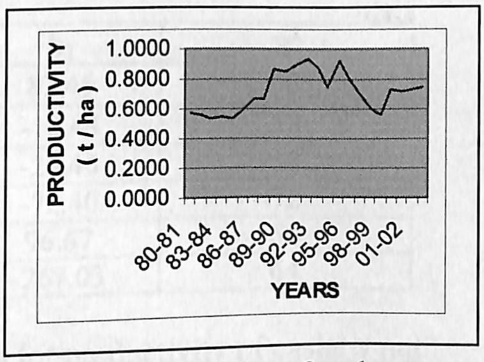


Fig 6.15. Productivity of cashew nut

All nonlinear models provide poor fit for area, production and productivity. Quadratic function fitted well by explaining 97percent, 64percent and 57percent of total variation for area, production and productivity respectively.

Nonlinear models were not suitable for describing the data on area, production and productivity of cashew for all the districts. Quadratic function was considered to exemplify the present situation of area under cashew, cashew production and productivity for the districts Alappuzha, Malappuram, Kannur and Kasargode as also Kerala.

Data on area initially showed an increasing trend for Alappuzha up to 1994-95, afterwards showed a decreasing trend. Kannur showed a decreasing trend up to 1997-98 and an increasing trend henceforth. The districts Malappuram and Kasargode

Table 6.a1. Parameters of Quadratic function for area under cashew

Districts	QUADRATIC FUNCTION		
	b_1	b_2	R^2
ALP	465.43	-16.46	71
MLPM	-801.13	8.97	92
KNR	-6182.2	176.35	88
KSGD	-140.15	-16.85	82
Kerala	-3283.9	18.025	97

Table 6.b1. Parameters of Quadratic function for production of cashew nut

Districts	Break periods	QUADRATIC FUNCTION		
		b_1	b_2	R^2
ALP	(80-87)	-828.81	83.45	75
	(88-03)	269.08	-10.43	58
MLPM		260.39	-20.46	58
KNR		815.29	-72.40	72
KSGD		-2136.1	96.67	54
Kerala		5370.3	-267.03	64

Table 6.c1. Parameters of Quadratic function for productivity of cashew nut

Districts	Break periods	QUADRATIC FUNCTION		
		b_1	b_2	R^2
ALP		-.0124	.0002	53
MLPM	(80-93)	.0025	.0018	77
	(94-03)	.1428	-.0039	54
KNR		.16	-.0058	64
KSGD		-.0378	.0026	59
Kerala		.0467	-.0016	57

R^2 in percentage

registered a negative trend through out the period. Area under cashew in Kerala showed a steadily decreasing trend.

Data on production showed initially a positive trend for Malappuram up to 1986-87, for Kannur up to 1985-86 and there after noticed a decreasing trend. In kasargode a negative was observed up to 1991-92, after wards showed an increasing trend. In Alappuzha initially a negative trend up to 1984-85 and there after showed an increasing trend up to 1992-93 and a decreasing trend henceforth. The production of cashew nut in Kerala though showed an increasing trend up to 1990-91, it decreased afterwards.

Data on productivity showed a decreasing trend through out the period for Alappuzha. Initially a positive trend was registered for Malappuram up to 1998-99, for Kannur up to 1994-95 and there after showed a decreasing trend. Kasargode showed negative trend initially up to 1987-88 and an increasing trend henceforth. Productivity of cashew nut in Kerala showed a positive trend up to 1994-95 and there after decreasing trend.

Cashew is a dollar earning crop, the cultivation practices of cashew is not related to this phenomenon. Though there are corporations and research institutions working for the betterment of cashew production are there in Kerala, the impact is only seemingly realistic.

4.7. Banana

The parameters viz; intrinsic growth rate (a), carrying capacity (c), along with R^2, RMSE, achieved carrying capacity during initial(P) and end periods(Q) for the suitable model which showed good fit for each district and the state for area, production and productivity are given in tables 7.a, 7.b and 7.c respectively. The parameters of quadratic function along with R^2 for productivity of banana when the other models failed to describe the situation are given in the table 7.c1.

4.7.1. Ernakulam

The graph on area and production showed an increasing trend but the graph on productivity showed a non increasing trend.

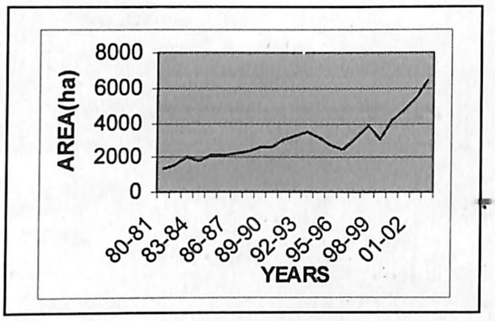


Fig 7.1. Area under banana

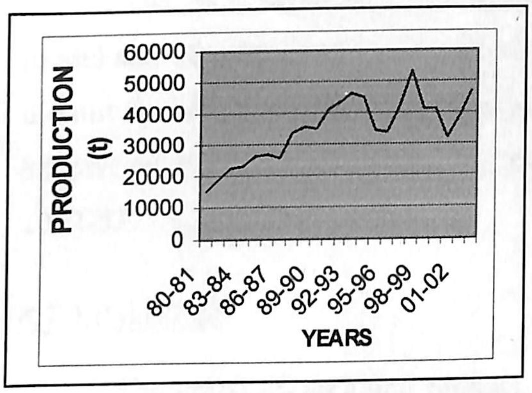


Fig 7.2. Production of banana

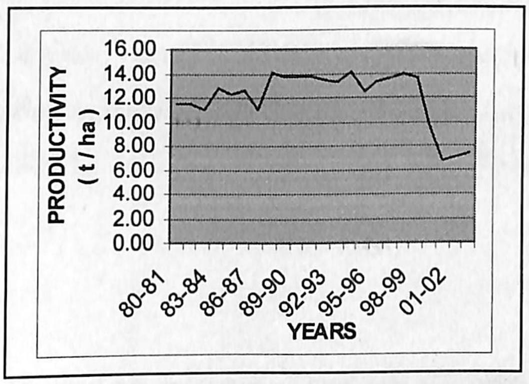


Fig 7.3. Productivity of banana

Monomolecular model gave most suitable fit for area and production by revealing 77 percent and 75 percent of total variation respectively. All the nonlinear models did not fit well for productivity. Quadratic function explained 71 percent of total variation for productivity.

4.7.2.Thrissur

The graph on area showed an increasing trend; production showed a uniform nature and productivity showed a decreasing trend.

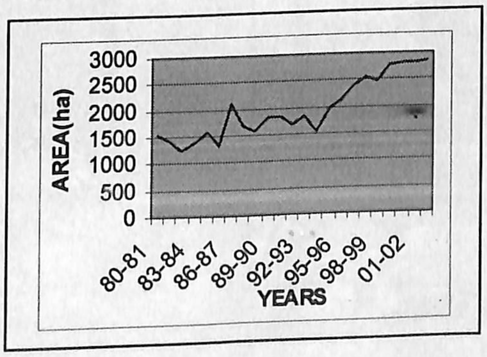


Fig 7.4. Area under banana

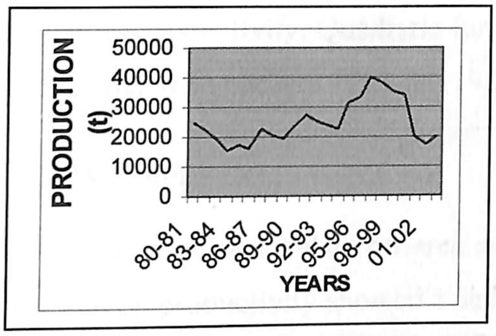


Fig 7.5. Production of banana

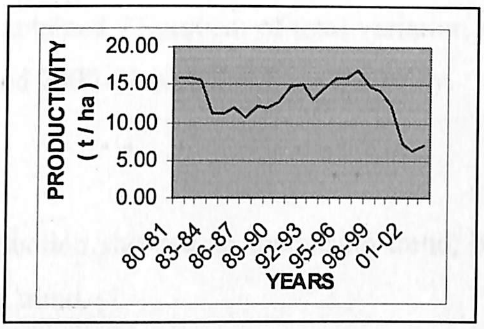


Fig 7.6. Productivity of banana

The total variation explained was 81 percent for area using Monomolecular model and 88 percent for production using Gompertz model. All the nonlinear models did not fit well for productivity. Quadratic function provided R^2 values 56 percent and 88 percent for productivity ranging from 1980-81 to 1993-94 and from 1994-95 to 2002-03.

4.7.3.Palakkad

The graph on area and productivity showed an increasing trend but the graph on productivity showed a decreasing trend.

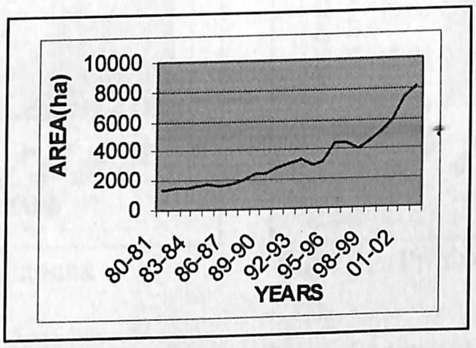


Fig 7.7. Area under banana

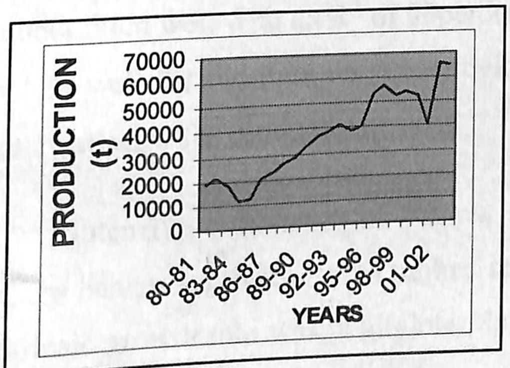


Fig 7.8. Production of banana

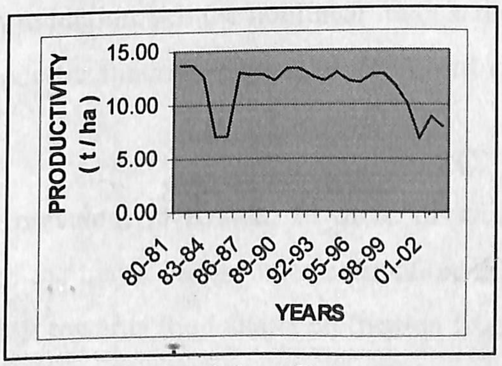


Fig 7.9. Productivity of banana

Monomolecular model was suitable for area and production explaining 86 percent and 87 percent of total variation respectively. All the nonlinear models did not fit well for productivity. Quadratic function explained 77 percent of total variation for productivity with outliers 1983-84, 1984-85 and 2000-01excluded from the study.

4.7.4. Wyanad

The time series data on area and production showed an increasing trend, but the graph on productivity showed a decreasing trend.

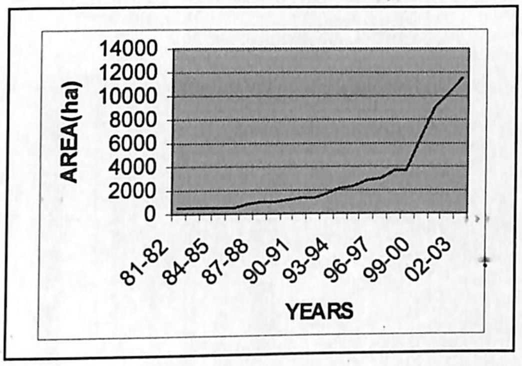


Fig 7.10. Area under banana

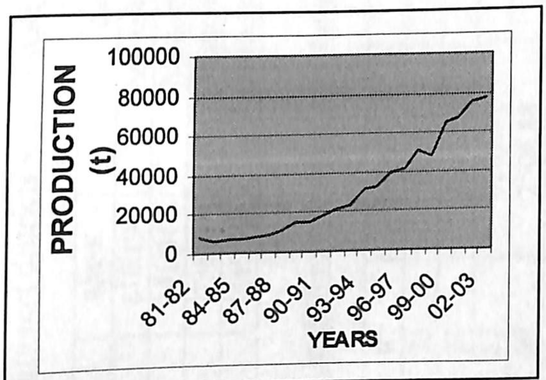


Fig 7.11. Production of banana

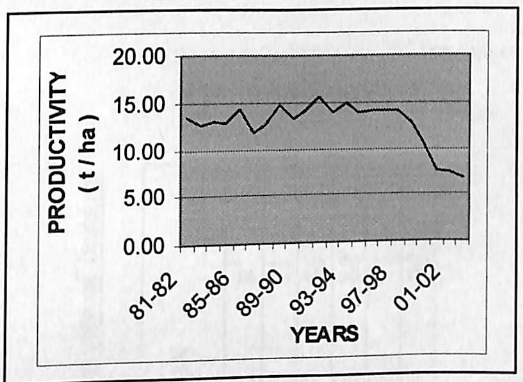


Fig 7.12. Productivity of banana

Monomolecular fitted well with an R^2 of 71percent for area and Logistic model fitted well with an R^2 of 99percent for production. All the nonlinear models did not fit well for the data on productivity. Quadratic function explained 75percent of total variation for productivity.

Intensive cultivation of banana is not prevalent in Kerala. In those districts where banana cultivation was ranked as one of the major crops under cultivation, the intrinsic growth rate was negligible. So the shift towards the banana cultivation from other crops was very rare. The production figures of banana pointed out the concentration of banana production in Ernakulam district followed by Thrissur. Though high intrinsic growth rate was evidenced for Wyanad district, the achieved carrying capacity by 2002-03 was only 50 percent. Thrissur and Palakkad with a

Table 7.a. Comparison of trend in area under banana in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
EKM	.00031	521444.36	0.003	1.2	77	616.19	Monomolecular model
TSR	.00013	391319.41	0.004	.7	81	241.04	Monomolecular model
PKD	.00035	753192.11	0.002	1	86	738.7	Monomolecular model
WYD	.00018	2395877.36	0.0002	.5	71	1848.37	Monomolecular model

Table 7.b. Comparison of trend in production of banana in different districts and the state using nonlinear model

Districts	a	c	P	Q	R^2	RMSE	Suitable model
EKM	.15456	43814.19	0.34	107	75	523.17	Monomolecular model
TSR	.0669	32264.65	0.76	62	22	6603.85	Monomolecular model
PKD	.0139	197259.36	0.10	33	87	6262.91	Monomolecular model
WYD	.1698	154801.08	0.05	50	99	2506.88	Logistic model

Q and R^2 in percentage

Table 7.c1. Parameters of Quadratic function for Productivity of banana

Districts	Break periods	QUADRATIC FUNCTION		
		b_1	b_2	R^2
EKM		.8954	.-.0426	71
TSR	(80-94)	-1.44	.093	56
	(94-03)	4.32	-.151	88
PKD		.236	-.017	77
WYD		.855	-.0458	75

R^2 in percentage

comparatively low intrinsic growth rate also not achieved the maximum carrying capacity. These figures indicate that banana production can be improved in Wyanad followed by Thrissur and Palakkad districts.

Banana is an annual crop subject to the vagaries of wind and monsoon. So productivity of banana is dependent even on these weather parameters which may exhibit frequent shifts. Productivity could be well described only using Quadratic function model. According to this model the data on productivity showed a positive trend initially for Ernakulam up to 1990-91, for Palakkad up to 1986-87, for Wyanad up to 1989-90 and there after registered a negative trend. Thrissur district showed a decreasing trend up to 1987-88 and there after noticed an increasing trend up to 1994-95 and a decreasing trend henceforth.

4.8. Coffee

The parameters viz; intrinsic growth rate (a), carrying capacity (c), along with R^2, RMSE, achieved carrying capacity during initial(P) and end periods(Q) for the most suitable model which showed good fit for the data on area, production and productivity of Wyanad district are given in table 8.a, 8.b and 8.c respectively.

4.8.1. Wyanad

The time series graph on area, production and productivity showed an increasing trend

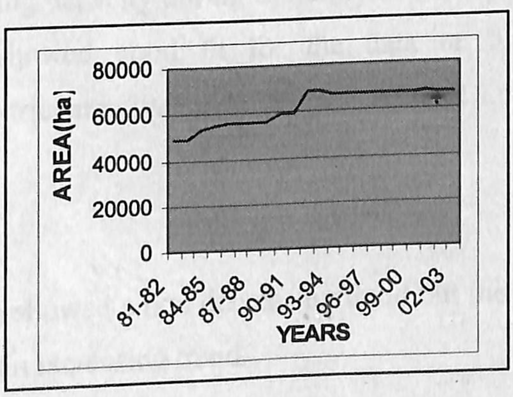


Fig 8.1. Area under coffee

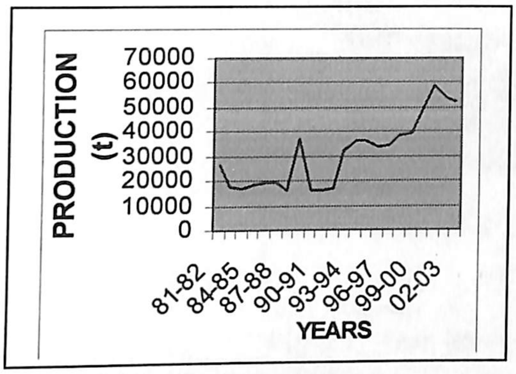


Fig 8.2. Production of coffee

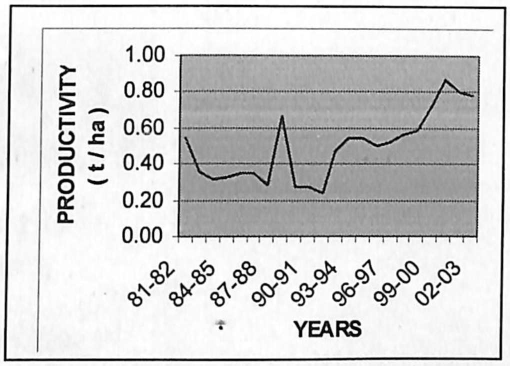


Fig 8.3. productivity of coffee

Monomolecular model explained 87 percent, 72 percent and 53 percent of total variation for area, production and productivity respectively.

Monomolecular model was found suitable for area under coffee in Wyanad district. As the values of intrinsic growth rate and carrying capacity achieved by 2002-03 was moderately high indicating that further increase in area of coffee was not viable. At the same time production and productivity could be increased as regards to the lower values of achieved carrying capacity by 2002-03, but will not be fruitful due to the lower intrinsic growth rates. So new innovative methods are to be resorted to castle better achievement in the future.

4.9. Cardamom

The parameters viz; intrinsic growth rate (a), carrying capacity (c), along with R^2, RMSE, achieved carrying capacity during initial(P) and end period(Q) for the most suitable model which showed good fit for the data on area, production and productivity of Idukky district are given in table 9.a, 9.b and 9.c respectively.

4.9.1. Idukky

The graph on area showed a non decreasing trend but the graph on production and productivity showed an increasing trend.

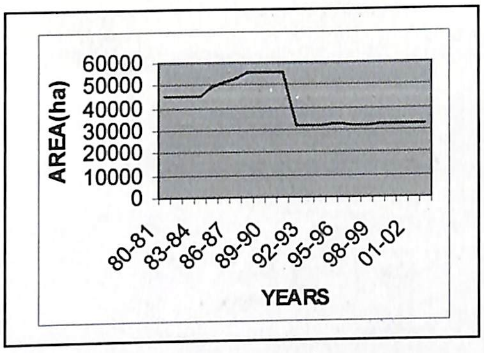


Fig 9.1. Area under cardamom

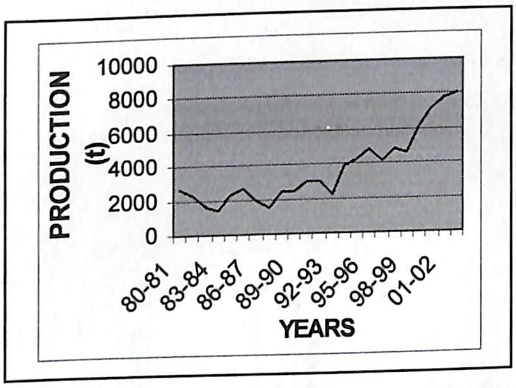


Fig 9.2. Production of cardamom

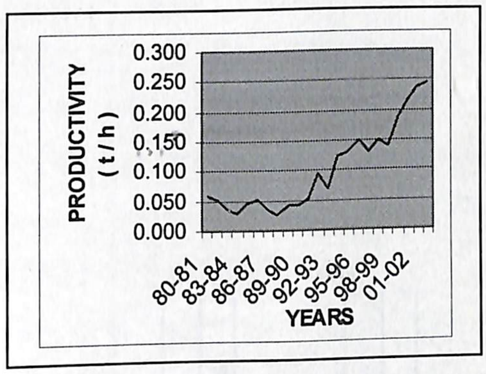


Fig 9.3. Productivity of cardamom

None of the nonlinear models was suitable for area. Quadratic function explained 63 percent of total variation for area under consideration. Monomolecular model provided 78 percent and 58 percent of total variation for production and productivity respectively.

A negative trend was seen throughout the period under investigation for area under cardamom in Idukky district by using the Quadratic function model. Monomolecular model was good enough for describing production and productivity of cardamom. The achieved carrying capacity by 2002-03 was low for production and productivity with a high intrinsic growth rate only for productivity indicating that the cropped area under cardamom was either not cropped uniformly or management practices were very poor leading to an extraordinary low figure of production. Kerala has a bright future for cardamom from this district provided sufficient care and attention is given to the crop with the different governmental agencies in this field coming to the categorical support of the farmers.

Table 8.a. Parametric values for area under coffee

District	a	c	P	Q	R^2	RMSE	Suitable model
WYD	.1063	71522.45	.68	93	87	2543.39	Monomolecular model

Table 8.b. Parametric values for production of Coffee

District	a	c	P	Q	R^2	RMSE	Suitable model
WYD	.00044	4117412.8	.0064	2	72	7713.59	Monomolecular model

Table 8.c. Parametric values for productivity of Coffee

District	a	c	P	Q	R^2	RMSE	Suitable model
WYD	.000068	309.27	..0017	.25	53	.1356	Monomolecular model

Table 9.a. Parametric values for area under cardamom

District	b_1	b_2	R^2	Suitable model
IDK	-187.6	-35.14	63	Quadratic model

Table 9.b. Parametric values for Production of Cardamom

District	a	c'	p	Q	R^2	RMSE	Suitable model
IDK	.0001	2560301.4	.001	.34	78	980.92	Monomolecular model

Table 9.c. Parametric values for Productivity of cardamom

District	a	c	P	Q	R^2	RMSE	Suitable model
IDK	.1581	.4409	.133	55	58	.0878	Monomolecular model

Q and R^2 in percentage

To sum up in brief the agricultural scenario of Kerala with respect to the crops studied is extremely grim. Paddy production in the state should be held at least uniform without allowing nosedive. Among the plantation crops cashew has to be given extreme attention to prevent the same from extinction. Rubber is one of the few gifted plantation crops which receives sufficient attention from all the corners. Even with this attention the production has not been satisfactory. We can hope that atleast this crop will improve in the future. Still worse is the situation of coffee when compared to cardamom. Hectic survival activity is a necessity for maintaining at least a uniform production of coffee. The production coconut can be improved only through the protection of the crop in general coupled with an appropriate management practice that will raise the productivity. If pepper cultivation is not given extreme attention a situation might reach where pepper will be an alien crop of Kerala. The crop had in the recent past suffered a multiplicity of negative impacts by way of devastating diseases coupled with interrupting spells of drought. It is better that we save existing crop and then think of raising the same in an economic manner. The seasonal crop tapioca can be given a boost by only value addition methods to the produce. The annual crop banana also be given better attention in a similar manner.

Whatever be the methods resorted for improving the agricultural scenario of Kerala in general, a realistic betterment will be only through the production of crops that meets sufficient international requirement especially because of the free trade in the world.

5. SUMMARY

Linear as well as nonlinear models play an important role in agriculture to explore the relationship between the dependent and explanatory variables. The extent of suitability of these models has been assessed in this study using secondary data on area, production and productivity of five major crops (table 3.1) in each district and the state for the period 1990-91 to 2002-03 collected from the 'Statistics for Planning' issues of Directorate of Economics and Statistics, Kerala state.

Four nonlinear mechanistic growth models namely Monomolecular, Logistic, Gompertz and Mixed-Influence models were fitted for the data on area, production and productivity by using Levenberg-Marquardt technique. When the aforesaid nonlinear models were found unsatisfactory either simple linear regression or quadratic model was tried to explore the nature of trend. The best fitting model was selected based on variance explained (R^2) and RMSE to describe the time series data on area, production and productivity. For the selected models two parameters namely P and Q, where P is the ratio of the initial data value (1980-81) to the carrying capacity,c; and Q (ratio of end data value to the carrying capacity, c), the carrying capacity achieved by the end period (2002-03) were computed. The carrying capacity achieved (Q) along with the intrinsic growth rate measures the viability for further improvement. The summary of the results obtained is presented crop wise and district wise along with state stature.

The area under coconut showed an increasing trend over the state with Thiruvananthapuram, Idukky, Thrissur, Palakkad, Malappuram, Kozhikode, Wyanad, Kannur and Kasargode districts contributing positively; Kollam, Alappuzha and Ernakulam maintaining a uniform tempo and Pathanamthitta and Kottayam showing a decreasing trend. As regards to production, Alappuzha, Kottayam and Ernakulam showed a uniform trend while Pathanamthitta showed a decreasing trend. The productivity of coconut showed an increasing trend in all the districts as also in the state except for Alappuzha and Ernakulam where a uniform trend was noticed.

Monomolecular model was the most suitable model for describing area under coconut in all the districts and the state except Kollam, Pathanamthitta, Kottayam and Ernakulam, for which quadratic function was the appropriate model to describe the nature of variation. Among all these districts only Palakkad and Kannur districts had the potential to have more area under coconut cultivation because their achieved carrying capacities by 2002-03 were relatively low. The quantum of addition of area to cultivation will only be at a staggered rate because of the relatively low intrinsic growth rates. As in the case of area Monomolecular model was the most suited model for production for all the districts as also the state except Alappuzha, Kottayam, Ernakulam and Thrissur, for which quadratic model was the appropriate one. The carrying capacity achieved by 2002-03 with respect to the production of coconut in Kerala was poor for the state as also the districts except Pathanamthitta and Thrissur. The coconut production in Trivamdrum, Malappuram, Kozhikode, Kannur and Kasargode districts can be well improved based on their moderate intrinsic growth rate and carrying capacity by 2002-03. Monomolecular model was suited for productivity of coconut for Kollam, Idukky, Palakkad, Kozhikode, Wyanad and Kasargode districts; Logistic model was suited for Trivandrum, Malappuram, Kannur and the state as a whole; Quadratic model was suited for the rest of the districts. The carrying capacity achieved by 2002-03 was low for the state and also for most of the districts. There was much scope for increase in productivity through proper management with sufficient attention given in Thiruvananthapuram, Palakkad, Malappuram and Kozhikode districts based on the moderate intrinsic growth rate and the carrying capacity achieved by 2002-03. For Wyanad productivity could be increased only through additional effort and research.

An increase in coconut production can be achieved by raising the productivity of coconut through innovative methods rather than bringing more area under coconut, which is least feasible in promising districts.

The area under rubber showed an increasing trend in most of the districts except Kozhikode, which maintained a sustainable trend, and Alappuzha a decreasing trend with a summary of an increasing trend in the state as a whole. However, through an increasing trend in productivity, production also showed an increasing trend. This phenomenon was well described by the Monomolecular model for area under rubber in all the districts as also in the state except Kollam, Alappuzha, Thrissur and Kozhikode districts. But the production of rubber was described by the Monomolecular model only in the Thiruvananthapuram, Kollam, Thrissur, Palakkad and Kasargode districts. Gompertz model described well the production of rubber in Pathanamthitta, Kozhikode and Kannur districts, where as Logistic model described the same in rest of the districts and the state. Monomolecular model again showed its prominence in describing the productivity of rubber in all the districts except Kollam, Pathanamthitta and Kannur where Gompertz replaced the same; with the Mixed-Influence model ascerting its stake for the state as whole. For Alappuzha district quadratic function was tried to study the variation in production and productivity of rubber where none of the nonlinear models was found unsatisfactory.

The achieved carrying capacity for Thiruvananthapuram, Pathanamthitta, Kannur and Kasargode districts as regards to the area under rubber cultivation was maximum where as the same figures were comparatively low for Malappuram and Kannur districts, with a tally of high achieved carrying capacity for the state as a whole. The contribution towards a better production was not coming forth from all the districts that were better contributors to area except Pathanamthitta, Kottayam, Idukky and Ernakulam districts contributing an achieved carrying capacity of 78 percent by 2002-03 coupled with an excellent intrinsic growth rate for the state. Malappuram and Kozhikode districts were most feasible districts for improved rubber production through their low achieved carrying capacities and good intrinsic growth rates. The productivity of rubber in contrast which had reached the maximum carrying capacity for the state with an extraordinary intrinsic growth rate of .5776 was supported by Thrissur, Malappuram, Kozhikode, Kannur and Kasargode districts.

Rubber cultivation can be made economically viable through crop replacement.

A steady decrease in the area and production was noticed in all the districts where paddy cultivation was feasible, submerging the state figures in the same fashion but with a slow increasing trend of productivity blockading the steep fall. Since the trend noticed was secular, only linear models were realistic in most of the situations except for the production and productivity figures of paddy in Palakkad district where quadratic function fitted very well indicating a vibrating decreasing trend through out the period.

Paddy cultivation is becoming extinct in most of the districts is the conclusion beyond doubt.

The area under cultivation as also production of pepper showed an increasing trend in Kollam, Idukky, Palakkad and Wyanad districts. The same trend was noticed for the state as a whole. A uniform trend in area and production of pepper was noticed for Thiruvananthapuram, Pathanamthitta, Ernakulam and Thrissur districts. With a uniform trend of area under pepper the production seemed to be decreasing in Kannur. All the parameters namely area, production and productivity showed a decreasing trend for Kozhikode district. The area and production showed a decreasing trend for Kottayam and Kasargode districts where as the productivity showed an increasing trend in Kottayam and a uniform trend in Kasargode. The productivity of pepper on a state basis showed uniform trend. Though the area and production of pepper showed an increasing trend, productivity showed only a uniform trend.

With a mix up of increasing and decreasing trends as a whole monomolecular model was the apt model for describing area under pepper for the districts for Idukky, Palakkad, Malappuram, Kozhikode, Wyanad and Kasargode, and for describing production for the districts of Idukky, Palakkad, Kozhikode, Wyanad and Kasargode. Monomolecular model also described the area and production for the state but could not describe the productivity pattern. Monomolecular model was the most suitable model for Idukky district for productivity of pepper. Based on the parameters of the model area and production of pepper in the state had reached a maximum as read from the carrying capacity achieved with a good intrinsic growth rate. Pepper cultivation in Malappuram, Wyanad and Kasargode districts was widely spread as could be read from table 4.a. Further inference was that Idukky and Palakkad districts did not have viability for an increased area under cultivation according to the parameters in table 4.a. The production could be improved in Kozhikode, Kasargode, Wyanad and Idukky districts as per the parameters read from table 4.b. The most undescribed feature of pepper was with respect to productivity as the monomolecular model indicated that productivity reached the maximum in Idukky distrit.

Quadratic model was fitted for the data on area, production and productivity of pepper, wherever nonlinear models failed to describe, so as to explore the intriguing facts. According to the parameters of the quadratic model initially a negative trend noticed for Thiruvananthapuram, Pathanamthitta, Ernakulam and Thrissur districts for area and production of pepper, afterwards showed a positive trend. For the districts Kannur and Kottayam the trend was negative through out the period for area and production of pepper. As per the parameters of the Quadratic model, pepper productivity noticed a positive trend up to 1984-85 and afterwards a negative trend for the state. Quadratic function registered a differential decreasing trend through out the period under investigation for the districts of Kollam, Malappuram and Kannur. The districts of Thiruvananthapuram, Thrissur and Kasargode registered a negative trend during the initial period and an increasing trend henceforth. Pathanamthitta, Kottayam, Ernakulam, Kozhikode and Wyanad showed a positive trend during the initial period and afterwards a negative trend.

Efforts have to be taken to protect the crop first from the severe diseases as also the vagaries of the nature.

The area and production of tapioca showed a decreasing trend in all the districts where it was identified as a cultivable crop except for Kozhikode where area showed a uniform trend and the production an increasing trend. These facts justified that the area under tapioca as such is decreasing. Monomolecular model was the suitable model for describing area under tapioca for the all the districts except Alappuzha and Kozhikode where Gompertz model fitted well. Simple linear regression model fitted well for the state for area under tapioca. Monomolecular model fitted well for production of tapioca for the districts of Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha and also for the state. Gompertz model was suited for Kottayam. Quadratic function was tried for Idukky and Kozhikode districts. For productivity Monomolecular model was suited for the districts of Kollam, Kottayam and Idukky; Gompertz model for Kozhikode and Logistic model for the state as a whole. Quadratic model was used for the districts Thiruvannthapuram and Alappuzha. The parameters of the model bring out the fact that area, production as also productivity has reached a uniform platform.

Commercial cultivation in Kerala will bring a better future for tapioca.

In those districts where cashew cultivation is prevalent, area, production and productivity was decreasing as could be read from the graph. The same was true for the state as a whole. As none of the nonlinear models were suited to describe the area, production and productivity, only the fluctuating trend could be studied using quadratic model. The main reason for the sorry state of affairs could be the neglect of the crop in general, where only resources are being tapped and no surveillance measures under taken.

The major contributive districts for the banana crop showed an increasing trend for area as also for production where as such a trend was unreachable as regards productivity. Monomolecular model was the most apt model to study the trend with regards area and production, except for Wyanad district where Logistic model was suited for production of banana. The parameters of the suitable model and the achieved carrying capacity indicated that banana production could be improved in Wyanad followed by Thrissur and Palakkad districts. None of the nonlinear models were found suitable for productivity of banana in all the districts where quadratic model was tried to explore the situation.

The data on area, production and productivity of coffee in Wyanad district was well described by the monomolecular model. The carrying capacity achieved by 2002-03 was maximum for area and minimum for production and productivity. So further increase in production and productivity of coffee in this district was viable, it can be achieved by introducing new innovative methods. In the case of cardamom, in Idukky district monomolecular model fitted well for production and productivity. Quadratic model was found suitable for area. According to the parameters of the monomolecular model further increase in production and productivity was viable in this district

In general only planned protective measures can save the crops which are facing severe threats with respect to area under cultivation. Whatever crops are being cultivated management of the crop at the right place will make cultivation of the same profitable. It is not only the cash crops that are important, every crop that we cultivate has to be protected from devastating diseases. Uniformity of the seeding material as also the most promising varieties have to be propagated through a streamlined governmental set up.

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Abstract

NONLINEAR MODELS FOR MAJOR CROPS OF KERALA

By

JOSHY, C. G.

ABSTRACT OF THE THESIS

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COLLEGE OF HORTICULTURE

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KERALA, INDIA

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ABSTRACT

Nonlinear modeling techniques are the most suited tools for describing any time series phenomenon. Among the various nonlinear models in vogue monomolecular, logistic, gompertz and mixed-influence models find a prominent place. With this idea the agricultural scenario of Kerala was measured through the three important descriptors namely area, production and productivity of the major crops viz; coconut, rubber, paddy, pepper, tapioca, cashew and banana for all the districts and the state as such. Monomolecular model was the most apt model in most of the cases. The data sets were further explored based on the carrying capacity achieved by 2002-03 coupled with intrinsic growth rate. When none of the nonlinear models were found satisfactory either simple linear regression model or quadratic model was tried to explore the nature of trend.

Coconut production was found to have reached its near maximum in all the districts where it was a major crop but the productivity figures gave a warning note for increasing the productivity. Rubber was found to be one of the most gifted crops, which was not devoid of proper attention. Even with this stature, production of rubber can be improved through uniform management practices. Usually nonlinear and quadratic models aptly describe a time series data on crop production. It is astonishing that simple linear regression model aptly described the paddy production in the state. The regressive value of the regression coefficients indicated that paddy production in the state is facing extinction.Paddy production in the state has at least to be protected. The lack of fit of most of the nonlinear models and even quadratic models to the data of pepper production indicate the various devastating hazards that the crop faced with. These contrasting features bring out the fact that pepper cultivation be not allowed to be toyed with. The area specific crops like cashew, cardamom, coffee and banana be made nonspecific through innovative technologies. A concerted effort with valid stresses specific to each crop will make the agricultural scenario bright.