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Trend Analysis and Structural Break of Area, Production and Productivity of Paddy Crop in Two Major Districts of Uttarakhand

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ABSTRACT

This study examines the historical trends in paddy crop cultivation in two major districts of Uttarakhand namely Udham Singh Nagar and Nainital districts, over 21-years from 2000-01 to 2020-21. The analysis is based on secondary data collected from the Directorate of Economics and Statistics, Govt. of Uttarakhand, Uttarakhand. Various mathematical models, including Linear, Quadratic, Exponential, Loglogistic and Generalized Additive Models (GAM), were applied to the data to identify the best-fitted models. The selection of the best-fitted model was determined by considering criteria such as MAPE, RMSE, R^2 and Adjusted R^2. Additionally, residual assumption tests such as the Runs and the Shapiro-Wilks tests were conducted to ensure the robustness of the results. The findings of the study reveal distinctive trends in paddy crop cultivation in the districts considered for study Udham Singh Nagar exhibits a consistent and significant increase in the area, production and productivity of paddy crops. Nainital, however, experiences a declining trend in the area under paddy cultivation and production, while paddy crop productivity shows an upward trajectory. Structural changes were notably observed post-2000 in two districts, underscoring the study's significance. This research provides valuable insights into paddy crop dynamics in the districts. It helps us to determine when and whether there is a significant change in the area, productivity and production of paddy crops and helps us understanding the resulting consequences before and after the breakdown. This analysis provides valuable insights into the dynamics of paddy farming in these specific districts, offering a foundation for informed policy planning and agricultural management decisions. While this study does not include forecasting for the future, the historical trends identified herein contribute to a comprehensive understanding of paddy cultivation in Uttarakhand.

Keywords : Linear and nonlinear models, MAPE, Shapiro-Wilks test, Run test, Paddy, GAM, Structural breaks, Changes

RICE (*Oryza sativa*) is a vital global food crop with a rich history intertwined with the development of human civilization. It exhibits immense genetic diversity, reflecting various regional and ecological adaptations. Both African rice (*Oryza glaberrima*) and Asian rice (*Oryza sativa*) share a common ancestry, originating in West Africa and South/Southeast Asia. Rice cultivation thrives in India's diverse climates, spanning wide latitudes and altitudes up to 3000 meters, adapting to varied soils and semi-aquatic conditions. India, as the world's second-largest rice producer, significantly contributes to global food security. Rice is not only an energy source but also provides essential nutrients like magnesium, phosphorus, zinc and B vitamins. It plays a pivotal role in maintaining bone health, nervous system function and metabolism.

Uttarakhand, India's 27th state, was established in 2000, separating from Uttar Pradesh. Situated in the Himalayan region, it shares borders with Nepal, China, Himachal Pradesh and Uttar Pradesh. Covering an area of 53,204 square kilometres, Uttarakhand is predominantly forested (62%), leaving just 14 per cent available for agriculture. The *kharif* season witnesses more than half of the state's land dedicated to cereal cultivation, with rice as the primary crop. Uttarakhand produces approximately 5.5 lakh tonnes of rice annually on about 2.80 lakh hectares of land, with a fairly even split between plains and hills. While rice is grown in all 13 districts, Udham Singh Nagar leads with 33 per cent of the acres and nearly half of the state's rice production. Nainital, Hardwar and Dehradun contribute 22.2 per cent of the overall output but utilize 17.5 per cent of the land, with average productivity levels. The remaining nine districts, covering 49.2 per cent of the geographical area, produce 30 per cent of the total rice output. This shift is attributed to industrialization and land diversification in the plains since the state's inception (Mani *et al.,* 2013). In this paper linear and non linear models are applied, to study the trends in production of the paddy crop and developing a best statistical model for analysing the area, production and productivity in two major districts of Uttarakhand. Prior to deciding whether to fit a single or multiple regression models, the issue of how to test and determine whether there is a change in the structure or pattern of the data emerges. So to understand the data set's break points, the structural change is also studied in this paper.

Material and Methods

The secondary data on the area, production and productivity of paddy crop in two major districts of Uttarakhand was collected from the website *https://aps.dac.gov.in* and the Department of Economics and Statistics, Government of Uttarakhand for the period of 21 years from 2000-01 to 2020-21 was collected.

A trend refers to the overall direction that a data set takes over an extended time period, either increasing or decreasing. It highlights steady changes that occur in a time-series, disregarding any temporary fluctuations that may happen in between. Functional forms like Linear, Quadratic, Exponential and Generalised Additive Model (GAM) were fitted to the data under consideration and the best model was selected based on the highest coefficient of determination (R^2) for fitting the trend equations.

The functional forms of trend were :

Linear function $Y_t = a + bt + \varepsilon_t$ (Nini *et al.*, 2017)

Quadratic function $Y_t = a + bt + ct^2 + \varepsilon_t$ (Nini *et al*, 2017)

Exponential function = $ae^{bt} + \varepsilon_t$ GAM function (Hastie & Tibshirani, 1987)

Where,

Y_t represents the area or production of paddy in time period *t*

a is the intercept, represent the value at period $t = 0$

b is the parameter

$f(t) = \alpha_0 + b(t)\,\alpha$, represents the smooth function of the time t, where α is some parameter and *b(t)* are the basis function.

ε_t denotes the error term.

Goodness of fit

The 'Shapiro-Wilk test' was used to test each model's primary presumption that the error terms were normal.(Naveen *et al,* 2012). Non-parametric Run test was used to test the randomness/independence of the error term. (Kumar *et al*, 2012).

Mean Average Percentage Error (MAPE)

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_t - \hat{Y}_t}{Y_t}\right| X\,100$$

Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(Y_t - \widehat{Y}_t\right)^2}{n}}$$

Coefficient of determination (R^2)

$$R^2 = \frac{RSS}{TSS} = 1 - \frac{ESS}{TSS}$$

Where,

ESS = Error sum of squares

RSS = Regression sum of squares

TSS = Total sum of squares

Y_t= Actual values

$\widehat{Y}_t$= Predicted values

n = number of observations

Based on the minimal MAPE value, maximum R^2 value and minimum RMSE value the best-fitted model was chosen from among the fitted models. (Kumar *et al*., 2012)

Structural Change

To understand the data set's breakpoints, it is crucial to understand the structural change. A structural break occurs when the course of a time series suddenly changes at a certain point. (Reddy *et al.,* 2000) A key assumption of regression modelling is that the pattern of data on dependent and independent variables stays constant across the whole data collection period. Under this premise, a single linear regression model is fit to the complete data set. The regression model is estimated and utilised for forecasting on the assumption that the parameters stay constant across the whole estimation and forecasting time period. When it is hypothesised that there is a change in the data pattern, it may not be acceptable to fit a single linear regression model; instead, it is necessary to run several regression models. Before choosing between multiple or single regression models, the question of how to assess and identify alterations in the data's structure or pattern arises. Such modifications are referred to as structural change and are defined by the modification of the model's parameters.

Estimation of Structural Break in Production, Area and Productivity of Paddy Crop in three districts of Uttarakhand

Supremum F test:

The Chow test can be applied to a time series model when you are aware of the potential change point. In the absence of information about the change point, however, one option is to calculate the *F* statistic and discover their maximum for each prospective change point. The resulting test statistic is called the Supr. *F* or supremum Wald test (sup F_t).

The Sup F test statistics are computed as follows:

Sup F = max Ft

Where F_t is calculated as:

$$F_t = \frac{RSS - ESS}{ESS(n-2k)}$$

Where n is the number of observations and k is the number of regressors in the model, Error Sum of Squares (ESS) and Restricted Sum of Squares (RSS)

Where F_t is the usual F statistic calculated at the change point *t*. We reject the null hypothesis of no change if this statistic is higher than some critical value. In Andrew's (1993) work, he documented the asymptotic critical values and utilized them as critical values for the evaluation. The estimated change point is then given the change (break) date in the time index that maximizes the F statistic.

Andrews (1993) created a variety of tests for detecting and estimating structural changes in cases where the specific dates of the breaks are not known, only the Sup *F* or Sup Wald test provides estimates of the break date. Here every break year with 15 per cent trimming is followed for 0.15 < TB < 0.85 T where T is the number of observations and Sup *Ft* is the maximum for all breaks necessary (Andrews *et al.*, 1993).

Student *t*-test to test for Significant differences between Pre break and Post break periods in Productivity and Area

Test Procedure:

Null Hypothesis (H_0) : No significant difference between before and after the break period.

Alternative Hypothesis (H_1) : There is a significant difference between before and after the break period.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \sim t_{(n_1+n_2-2)df}$$

If H_0 is accepted, then there is no significant difference between before and after the break period.

If H_0 is rejected, then there is a significant difference between before and after the break period.

Results and Discussion

Trend Analysis

Any time series data has a propensity to either get bigger or smaller over time. Trend refers to the propensity for data to increase or decrease over time. In order to estimate the trends in paddy output, area, production and productivity in two major Uttarakhand districts, annual data for the 21-year period from 2000-01 to 2020-21 was gathered.

Data depicted in Table 1 provides parameter estimates and their standard errors for four fitted models of paddy area in Udham Singh Nagar district. In Table 2, statistical tests and model adequacy standards

Table 1

Parameter estimates by different models for the area under paddy in Udham Singh Nagar district

Parameter (Area)	Model			
	Linear	Quadratic	Exponential	GAM
Intercept (a)	-1292123.80 **	102300.00 **	0.12	-1292123.77 **
	(1.753×10^{05})	(813.50)	(0.20)	(159953.16)
(b)	693.58 **	694.20 **	0.01 **	693.58 **
	(87.21)	(91.12)	(0.00)	(79.58)
(c)		0.66		
		(16.60)		

**Significant at 1 per cent level, *Significant at 5 per cent level, Figures in parentheses indicate standard errors.

Table 2

Test for randomness, normality of residuals and goodness of fit criteria of different models for the area under paddy in Udham Singh Nagar districts

Criterion (Area)	Model			
	Linear	Quadratic	Exponential	GAM
Runs test	-2.30 **	-2.30 **	-2.30 **	-0.46 NS
(*p*-value)	(0.02)	(0.02)	(0.02)	(0.64)
Shapiro-Wilk	0.98 NS	0.98 NS	0.98 NS	0.89 NS
(*p*-value)	(0.95)	(0.96)	(0.98)	(0.03)
RMSE	2301.94	2301.84	2302.10	1927.49
MAPE	1.89	1.89	1.89	1.36
R^2	0.77	0.77	0.77	0.84

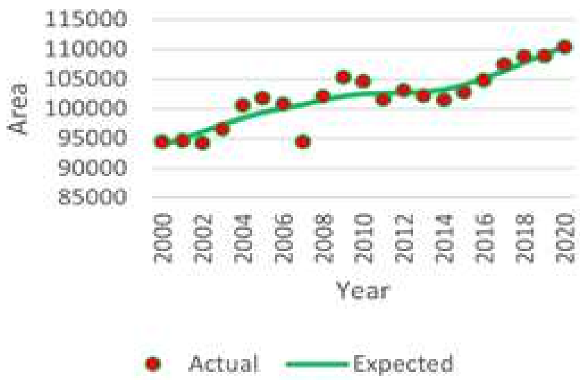

Fig. 1 : Trend values of paddy area in Udham Singh Nagar district of Uttarakhand

are presented. The linear, exponential and GAM models showed significance of all the parameter estimated at a 5 per cent significance level. Moreover, tests like Run's test and Shapiro-test Wilk's statistic were non-significant for all models, indicating a strong data fit. To determine the best model, MAPE and RMSE were utilized. The Generalized Additive Model (GAM) displaying the lowest MAPE value (1.36). High R^2 (0.84) and low RMSE (1927.49), confirming a GAM growth pattern for the paddy area in Udham Singh Nagar from 2000-01 to 2020-21 (as shown in Table 2). Additionally, Fig. 1 illustrates the trend values of paddy area in the Udham Singh Nagar district of Uttarakhand.

Table 3, provides parameter estimates and their standard errors for four fitted models of paddy production in Udham Singh Nagar district. In Table 4, statistical tests and model adequacy standards are presented. The linear, quadratic and GAM models showed significance of all the parameter estimates at a 5 per cent significance level. Moreover, tests like Run's test and Shapiro-test Wilk's statistic were non-significant for all models, indicating a strong data fit. To determine the best model, MAPE and RMSE were utilized. The Generalized Additive Model (GAM) displaying the lowest MAPE value (3.28). High R^2 (0.91) and low RMSE (12999.30), confirming a GAM growth pattern for paddy production in Udham Singh Nagar from 2000-01 to 2020-21 (as shown in Table 4). Additionally, Fig. 2, illustrates the trend values of paddy area in Udham Singh Nagar district of Uttarakhand.

Table 5 provides parameter estimates and their standard errors for four fitted models of paddy

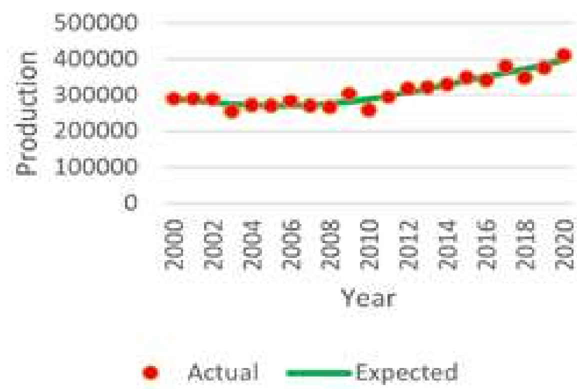

Fig. 2 : Trend values of paddy production in Udham Singh Nagar district of Uttarakhand

Table 3

Parameter estimates by different models for the production under paddy in Udham Singh Nagar district

Parameter (Production)	Model			
	Linear	Quadratic	Exponential	GAM
Intercept (a)	-1.185×10^{07} ** (1.775×10^{06})	2.283×10^{09} ** (4.104×10^{08})	3.726×10^{-13} (2.011×10^{-12})	-11852687.25 ** (1078748.62)
b	6051.00 ** (882.90)	-2.277×10^{06} ** (4.084×10^{05})	0.02053 ** (2.684×10^{-03})	6051.25 ** (536.69)
c		568.00 ** (101.60)		

**Significant at 1 per cent level, *Significant at 5 per cent level, Figures in parentheses indicate standard errors.

TABLE 4

Test for randomness, normality of residualsand goddness of fit criteria of different models for the production under paddy in Udham Singh Nagar districts

Criterion (Production)	Model			
	Linear	Quadratic	Exponential	GAM
Runs test	-0.92 NS (0.36)	-0.46 NS (0.64)	-0.92 NS (0.36)	0.00 NS (1.00)
Shapiro-Wilk (p-value)	0.95 NS (0.37)	0.95 NS (0.40)	0.96 NS (0.47)	0.97 NS (0.69)
RMSE	23304.81	14086.92	21739.28	12999.30
MAPE	6.01	3.84	5.54	3.28
R^2	0.71	0.89	0.75	0.91

TABLE 5

Parameter estimates by different models for the productivity under paddy in Udham Singh Nagar district

Parameter (Production)	Model			
	Linear	Quadratic	Exponential	GAM
Intercept (a)	-72.14 ** (18.18)	21300.00 ** (4975.00)	1.493×10^{-11} ** (8.776×10^{-11})	-72.14 ** (11.18)
b	0.04 ** (0.01)	-21.23 (4.771)	0.01 ** (0.00)	0.04 ** (0.00)
c		5.291×10^{-03} (1.187×10^{-03})		

**Significant at 1 per cent level, *Significant at 5 per cent level, Figures in parentheses indicate standard errors

productivity in Udham Singh Nagar district. In Table 6, statistical tests and model adequacy standards are presented. The linear, exponential and GAM models showed significant parameter estimates at a 5 per cent significance level. Moreover, tests like Run's test and Shapiro-test Wilk's statistic were non-significant for all models, indicating a strong data fit. To determine the best model, MAPE and RMSE were utilized. The Generalized Additive Model (GAM) displaying the lowest MAPE value (3.81). High R^2 (0.83) and low RMSE (0.13), confirming a GAM growth pattern for paddy productivity in Udham Singh Nagar from 2000-01 to 2020-21 (as shown in Table 6). Additionally, Fig. 3 illustrates the trend values of paddy area in Udham Singh Nagar district of Uttarakhand.

Table 7 provides parameter estimates and their standard errors for four fitted models of paddy area in Nainital district. In Table 8 statistical tests and model adequacy standards are presented. The linear and GAM models showed significant parameter estimates at a 5 per cent significance level. Moreover, tests like Run's test and Shapiro-test Wilk's statistic were non-significant for all models, indicating a strong data fit. To determine the best model, MAPE and RMSE were utilized. The Generalized Additive Model (GAM) displaying the lowest MAPE value (3.44). High R^2 (0.75) and low RMSE (586.94), confirming a GAM growth pattern for paddy area in Nainital from 2000 to 2020 (as shown in Table 8). Additionally, Fig. 4 illustrates the trend values of paddy area in Udham Singh Nagar district of Uttarakhand.

TABLE 6

Test for randomness, normality of residuals and goodness of fit criteria of different models for the productivity under paddy in Udham Singh Nagar districts

Criterion	Model			
	Linear	Quadratic	Exponential	GAM
Runs test (p-value)	-2.76 **	-0.46 NS	-2.76 **	0.46 NS
	(0.01)	(0.65)	(0.01)	(0.65)
Shapiro-Wilk (p-value)	0.96 NS	0.94 NS	0.96 NS	0.90 **
	(0.52)	(0.18)	(0.58)	(0.03)
RMSE	0.24	0.16	0.23	0.13
MAPE	6.46	4.72	6.20	3.81
R^2	0.47	0.75	0.50	0.83

**Significant at 1 per cent level, *Significant at 5 per cent level; NS: Non-Significant; Figures in parentheses indicate Probability value.

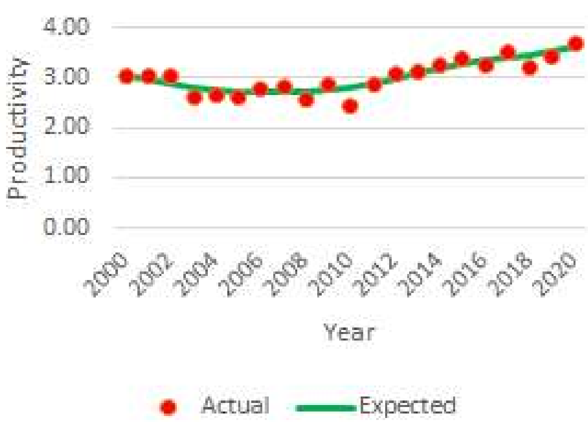

Fig. 3 : Trend values of paddy productivity in Udham Singh Nagar district of Uttarakhand

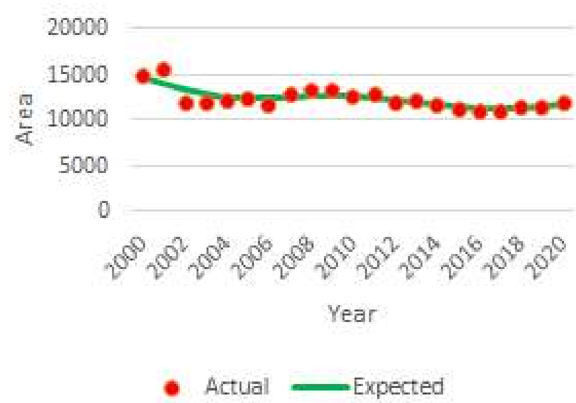

Fig. 4 : Trend values of paddy area in Nainital district of Uttarakhand

TABLE 7

Parameter estimates by different models for the area of paddy in Nainital district

Parameter	Model			
	Linear	Quadratic	Exponential	GAM
Intercept (α_0)	266489.70 **	2.729×10^{07}	1.591×10^{13}	266489.70 **
	(67180.51)	(2.490×10^{07})	(8.654×10^{13})	(48707.71)
α	-126.46 **	-27020.00	-0.01044 **	-126.45 **
	(33.42)	(24780.00)	(2.708×10^{-03})	(24.23)
β		6.69		
		(6.16)		

**Significant at 1 per cent level, *Significant at 5 per cent level, Figures in parentheses indicate standard errors

TABLE 8

Test for randomness, normality of residuals and goodness of fit criteria of different models for the area of Nainital

Criterion	Model			
	Linear	Quadratic	Exponential	GAM
Runs test (p-value)	-1.84 NS	-2.76 **	-1.84 NS	-0.92 NS
	(0.07)	(0.01)	(0.07)	(0.36)
Shapiro-Wilk (p-value)	0.97 NS	0.98 NS	0.97 NS	0.97 NS
	(0.64)	(0.86)	(0.70)	(0.67)
RMSE	882.18	854.66	876.98	586.94
MAPE	5.67	5.55	5.66	3.44
R2	0.43	0.46	0.44	0.75

**Significant at 1 per cent level, *Significant at 5 per cent level; NS: Non-Significant; Figures in parentheses indicate Probability value

TABLE 9

Parameter estimates by different models for the production under paddy in Nainital district

Parameter	Model			
	Linear	Quadratic	Exponential	GAM
Intercept (α_0)	-412256.90	1175728.50	0.03	-412256.87
	(251333.60)	(149087.00)	(0.23)	(207502.40)
α	221.8	-24609.90	0.01 **	221.78 **
	(125.0)	(28619.90)	(0.00)	(103.23)
β		955.90		
		(1157.80)		

**Significant at 1 per cent level, *Significant at 5 per cent level, Figures in parentheses indicate standard errors

Table 9 provides parameter estimates and their standard errors for four fitted models of paddy production in Nainital district. In Table 10 statistical tests and model adequacy standards are presented. The GAM models showed significant parameter estimates at a 5 per cent significance level. Moreover, tests like Run's test and Shapiro-test Wilk's statistic were non-significant for all models, indicating a strong data fit. To determine the best model, MAPE and RMSE were utilized. The Generalized Additive Model (GAM) displaying the lowest MAPE value (6.04). High R^2 (0.51) and low RMSE (2500.48), confirming a GAM growth pattern for paddy production in Nainital from 2000 to 2020 (as shown in Table 10). Additionally, Fig. 5 illustrates the trend values of paddy area in Udham Singh Nagar district of Uttarakhand.

Table 11 provides parameter estimates and their standard errors for four fitted models of paddy productivity in Nainital district. In Table 12 statistical tests and model adequacy standards are presented. The linear, quadratic and GAM models showed significant parameter estimates at a 5 per cent significance level. Moreover, tests like Run's test and Shapiro-test Wilk's statistic were non-significant for all models, indicating a strong data fit. To determine the best model, MAPE and RMSE were utilized. The Generalized Additive Model (GAM) displaying the lowest MAPE value (4.56). High R^2 (0.76) and low RMSE (0.17),

Table 10

Test for randomness, normality of residuals and goodness of fit different production of Nainital Paddy district

Criterion	Model			
	Linear	Quadratic	Exponential	GAM
Runs test (*p*-value)	-0.92 NS (0.36)	0.00 NS (1.00)	-0.92 NS (0.36)	0.00 NS (1.00)
Shapiro-Wilk (*p*-value)	0.91 NS (0.07)	0.92 NS (0.38)	0.97 NS (0..7)	(0.74)
RMSE	3300.39	2873.92	3288.17	2500.48
MAPE	8.53	7.00	8.46	6.04
R^2	0.14	0.35	0.15	0.51

Table 11

Parameter estimates by different models for the productivity of paddy in Nainital district

Parameter	Model			
	Linear	Quadratic	Exponential	GAM
Intercept (α_0)	-90.51 **	12230.00 **	1.577×10^{-15}	-90.51 **
	(15.38)	(5118.00)	(8.649×10^{-15})	(14.14)
α	0.05 **	-12.21 **	0.02 **	0.05 **
	(0.01)	(5.09)	(2.726×10^{-03})	(0.01)
β		3.049×10^{-03} ** (1.267×10^{-03})		

**Significant at 1 per cent level, *Significant at 5 per cent level, Figures in parentheses indicate standard errors

Table 12

Test for randomness, normality of residuals and goodness of fit criteria of different models for the productivity of Paddy in Nainital district

Criterion	Model			
	Linear	Quadratic	Exponential	GAM
Runs test (p-value)	0.00 NS	-0.46 NS	0.00 NS	0.92 NS
	(1.00)	(0.65)	(1.00)	(0.36)
Shapiro-Wilk (p-value)	0.95 NS (0.38)	0.97 NS (0.74)	0.95 NS (0.31)	0.96 NS (0.46)
RMSE	0.20	0.18	0.20	0.17
MAPE	5.98	4.84	5.78	4.56
R2	0.66	0.74	0.68	0.76

**Significant at 1 per cent level, *Significant at 5 per cent level, Figures in parentheses indicate standard errors

Fig. 5 : Trend values of paddy production in Nainital district of Uttarakhand

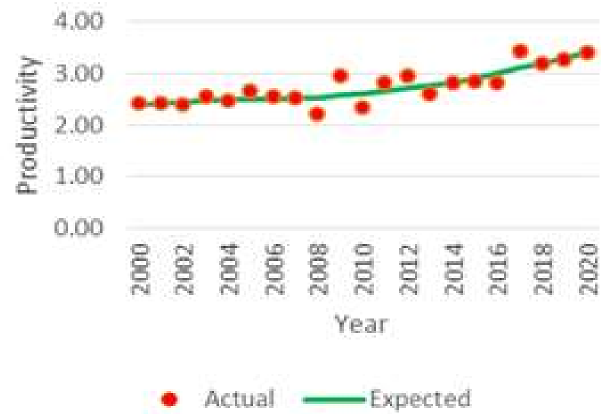

Fig. 6 : Trend values of paddy productivity in the Nainital district of Uttarakhand

confirming a GAM growth pattern for paddy productivity in Nainital from 2000 to 2020 (as shown in Table 12). Additionally, Fig. 6 illustrates the trend values of paddy area in Udham Singh Nagar district of Uttarakhand.

Results from trend analysis showed that both districts showed an increasing trend in paddy area, production and productivity, with Udham Singh Nagar, the GAM model trend exhibiting a notable rise and Nainital, the GAM model showing a more modest upward trend. In the districts of Udham Singh Nagar and Nainital, the GAM model was shown to be the best fit for all variables, demonstrating its efficacy in capturing the nuanced relationships in the data. The findings provide valuable insights for policymakers and stakeholders in the agricultural sector to make informed decisions and formulate effective strategies for paddy cultivation in Udham Singh Nagar and Nainital districts of Uttarakhand.

Structural Breaks

Structural breaks are valuable analytical tools for identifying critical junctures in the dynamics of area, production and productivity in paddy crop cultivation. They aid in pinpointing instances of substantial change and offer insights into the before-and-after scenarios surrounding these shifts. By detecting these structural breaks, we gain a deeper understanding of the transformative events or factors influencing the paddy crop's growth, helping us discern patterns and trends that might not be evident when viewing the data as a continuous stream. This approach is instrumental in deciphering the impact of various factors on paddy crop agriculture, enabling more informed decision-making and targeted interventions to address changes in area, production and productivity. In order to estimate the breaks in paddy output, area, production and productivity in two major Uttarakhand districts, annual data for the 21-year period from 2000-01 to 2020-21 was gathered.

A Structural Break in the Area of Paddy in Selected District of Uttarakhand

Table 13 and Fig. 7 show the structural change in the area of paddy crop in the district of Udham Singh Nagar. The structural break occurred in the year 2007-08 with the Supremum F-value of 29.2260. The mean area during the pre-break period was 97,607.57 ha whereas the mean area after the break was 1,04,144.1 ha. The difference in the mean area of paddy in Udham Singh Nagar was determined to be significant at a 1 per cent level of significance.

Table 13 and Fig. 8 show the structural change in the area of paddy crops in Nainital district. The structural break occurred during the year 2002-03with the Supremum F-value of 14.0860. The mean area during the pre-break period was 15,279 ha whereas the mean area after break was 11,992.63 ha. The difference in the mean area of paddy in Nainital was determined to be significant at a 5 per cent level of significance.

TABLE 13

Structural change of Area in selected districts of Uttarakhand

District	Sup F- Value	BreakYear in Area	Mean Area before break (ha)	Mean Area after the break (ha)	*t*-value
Udham Singh Nagar	29.23 **	2007-08	97,607.57	1,04,144.10	-3.93 **
Nainital	14.09 **	2002-03	15,279.00	11,992.63	10.52 *

*Significant at 5 per cent level, ** Significant at 1 per cent level, NS: Non-Significant

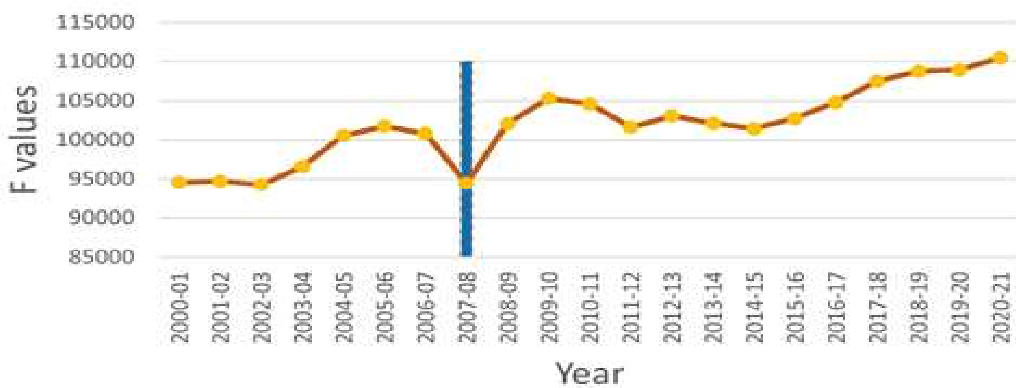

Fig. 7 : Structural break for Paddy area in Udham Singh Nagar district of Uttarakhand

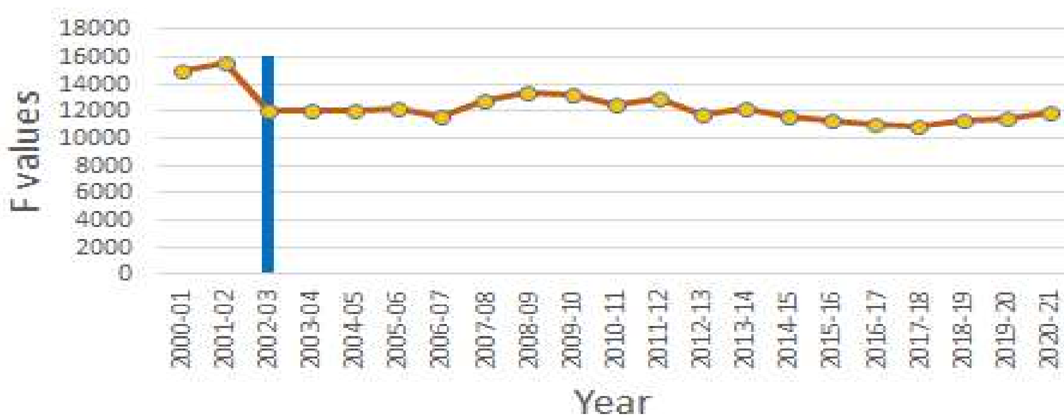

Fig. 8 : Structural break for Paddy area in Nainital district of Uttarakhand

TABLE 14

Structural break of production of paddy in selected districts of Uttarakhand

District	Sup F- Value	Break year in production	Mean production before break (tonnes)	Mean production after the break (tonnes)	*t*-value
Udham Singh Nagar	54.34 **	2011-12	276378.20	347686.20	-6.04 **
Nainital	10.15 *	2016-17	32606	36475	-2.21 NS

*Significant at 5 per cent level, **Significant at 1per cent level, NS: Non-Significant

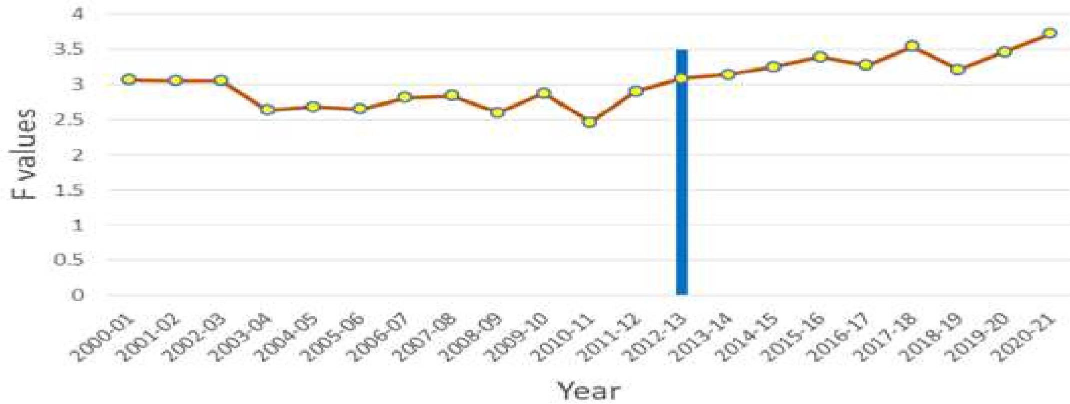

Fig. 9 : Structural break for Paddy productivity in Udham Singh Nagar district of Uttarakhand

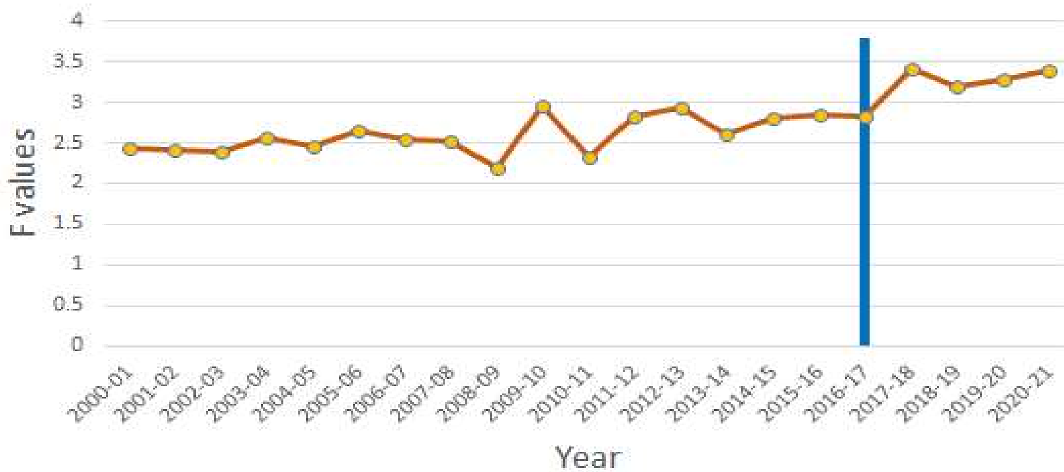

Fig. 10 : Structural break for Paddy productivity in Nainital district of Uttarakhand

Structural Break in Production of Paddy in the Selected District of Uttarakhand

Table 14 and Fig. 9 show the structural change in the production of paddy crops in Udham Singh Nagar district. The structural break occurred during the year 2011-12 with a Supremum F-value of 54.34. The mean production during the pre-break period was 276378.20 tonnes whereas the mean production after the break was 347686.20 tonnes. The difference in the mean production of paddy in Udham Singh Nagar was determined to be significant at 1 per cent level of significance.

Table 14 and Fig. 10 shows the change in production of paddy crop in Nainital district. The break occurred during the year 2016-17 with the Supremum F-value of 10.15. The mean production during the pre-break period was 32606 tonnes whereas the mean production after the break was 36475 tonnes. The difference in the mean production of paddy in Nainital was found to be non-significant.

A Structural Break in Productivity of Paddy in the Selected District of Uttarakhand

Table 15 and Fig. 11 show the structural change in the productivity of paddy crops in Udham Singh Nagar district. The structural break occurred during the year 2012-13 with the Supremum F-value of 37.22. The mean productivity during the pre-break period was 2.80 tonnes per ha whereas the mean productivity after break was 3.34 tonnes per ha. The difference in the mean productivity of paddy in Udham Singh Nagar was determined to be significant at a 1 per cent level of significance.

TABLE 15

Structural break of productivity of paddy in selected districts of Uttarakhand

District	Sup F- Value	Break year in productivity	Mean productivity before break (tonnes/ha)	Mean productivity after the break (tonnes/ha)	*t*-value
Udham Singh Nagar	37.22 **	2012-13	2.80	3.35	-6.06 **
Nainital	37.01 **	2016-17	2.59	3.22	-5.19 **

*Significant at 5 per cent level, **Significant at 1per cent level, NS: Non-Significant

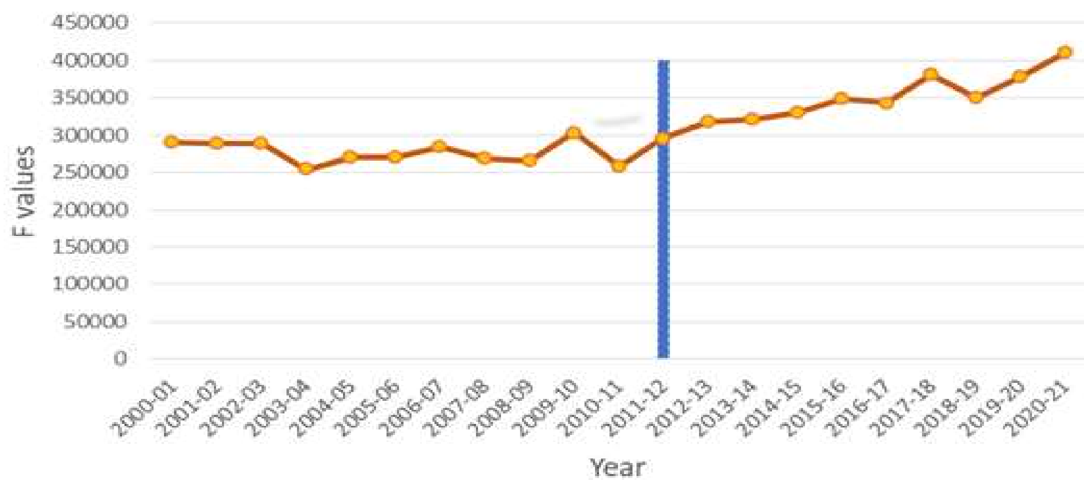

Fig. 11 : Structural break for Paddy production in Udham Singh Nagar district of Uttarakhand

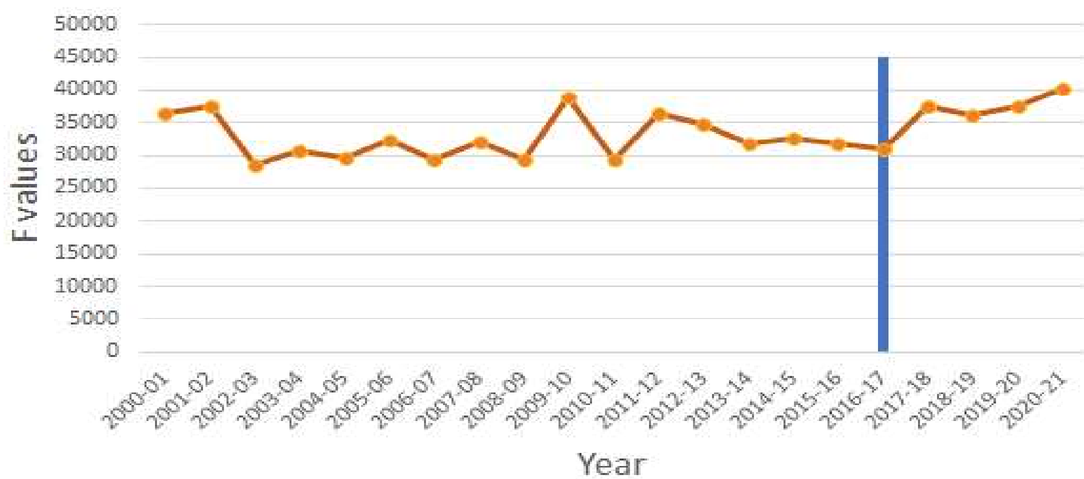

Fig. 12 : Structural break for Paddy production in Nainital district Uttarakhand

Table 15 and Fig. 12 show the change in the productivity of paddy crops in Nainital district. The break occurred during the year 2016-17 with the Supremum F-value of 37.02. The mean productivity during the pre-break period was 2.59 tonnes per ha whereas the mean productivity after the break was 3.22 tonnes per ha. The difference in the mean productivity of paddy in Nainital was determined to be significant at 1 per cent level of significance.

Paddy Area cultivation in Udham Singh Nagar District experienced a substantial decline starting from the 2007-08 period. Possible reasons for this decrease could include a shift in land use towards other crops, urbanization or changes in government policies. There was a corresponding drop in production in 2008-09, which may indicate a decrease in the overall efficiency of paddy production due to elements such as evolving agricultural methods or unfavourable weather conditions. The increase in productivity after a break in 2012-13 suggests that, during this period, farmers might have adopted more efficient cultivation practices or technologies.

In Nainital District, in the period 2002-03, there was a significant drop in the area under paddy cultivation. The reasons for this change could be various, including potential shifts in land use, government policies or local economic conditions. Correspondingly, there was a drop in paddy production in 2016-17. This may indicate a decrease in the overall efficiency of paddy production due to elements such as evolving agricultural methods, unfavourable weather conditions, or reduced cultivation area. In 2012-13, there might have been the adoption of new agricultural technologies or practices that improved the productivity of paddy cultivation. Farmers may have started using better seeds, more efficient irrigation methods or modern farming equipment, leading to higher yields.

In the present study, trends in area, production and production of paddy crop in selected districts of Uttarakhand were studied using linear, quadratic, exponential and log-logistic, monomolecular and Generalised Additive model (GAM) models. For paddy crop, the GAM model was a good fit for area, production and productivity in Udham Singh Nagar district. The GAM model was found to be a good fit for area, production and productivity of paddy in Nainital district. The structural break of area, production and productivity of paddy in Udham Singh Nagar district was observed during the 2007-08 period, 2011-12 period and 2012-13 respectively. In Nainital district, the structural break of area, production and productivity of paddy was observed during the 2002-03 period, 2016-17 period and 2016-17 respectively.

In conclusion, the analysis revealed the trends and structural changes for paddy crop in Uttarakhand districts. In the districts of Udham Singh Nagar and Nainital, the GAM model was shown to be the best fit for all variables, demonstrating its efficacy in capturing the nuanced relationships in the data. The findings provide valuable insights for policymakers and stakeholders in the agricultural sector to make informed decisions and formulate effective strategies for paddy cultivation in Udham Singh Nagar and Nainital districts of Uttarakhand.

References

Andrews, Donald, W. K., 1993, Tests for parameter instability and structural change with unknown change point. *Econometrica.*, **61** (4) : 821 - 856.

Bhagyalakshmi, K.V. and Srikanthamurthy, P. S., 2013, Economic water use efficiency in crops under tank rehabilitation interventions of JSYS in Chickballapur district. *Mysore J. Agric. Sci.*, **47** (1) : 158 - 164.

Hastie, T. and Tibshirani, R., 1987, Generalized Additive Models: Some Applications. *J. Am. Stat. Assoc.*, **82** (398) : 371 - 386.

Kumar, T. M., Gowda, C. S., Munirajappa, R. and Surendra, H. S., 2012, Nonlinear statistical growth models for describing trends in area under coffee production in India. *Mysore J. Agric. Sci.*, **46** (4) : 745 - 750.

Mani, S. C., Agarwal, P. K. and Singh, D. K., 2013, status paper on rice in Uttarakhand. *Rice knowledge management portal,* Directorate of Rice Research, Rajendranagar, Hyderabad.

Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Available at: *https://aps.dac.gov.in*. [October 14 2023].

Naveen, K., Mallikarjuna, G. B., Jayadeva, H. M. and Bhairappanavar, S. T., 2012, Statistical analysis of natural resources utilizing maize-urdbean intercropping system based on area × time equivalent ratio (ATER). *Mysore J. Agric. Sci.*, **46** (2) : 281 - 285.

Nini, A., Corradini, C., Guo, D. and Grieve, J., 2017, The application of growth curve modelling for the analysis of diachronic corpora. *Language Dynamics and Change*, **7** (1) : 102 - 125.

Reddy, D. R. B. and Achoth, L., 2000, Dynamics of the cropping pattern changes in Karnataka: a Markov chain approach. *Mysore J. Agric. Sci.*, **34** (4) : 376 - 381.