Proceedings of the Pakistan Academy of Sciences: B Life and Environmental Sciences 60(1): 83-90 (2023)

ISSN (Print): 2518-4261; ISSN (Online): 2518-427X
http://doi.org/10.53560/PPASB(60-1)762

Pakistan Academy of Sciences

Research Article

Growth Analysis of Production of Food Crops and Population Growth for Food Security in Pakistan

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Abstract: Food availability is one of the important pillars of food security. It is essential to ensure food availability in the world to avoid starvation. The key concern of the present study is to integrate the fluctuations in the growth rate of the population and important food crop production using time series data from 1950-2021. Semi-log compound growth rate models are applied for the projection, Cuddy-Della and Valle instability index are used for the stability analysis, and decomposition analysis models are applied to determine the contribution of factors toward production. Semi log compound growth rate model indicates that the population of Pakistan is increasing rapidly, while the contribution of productivity and area of all food crops are not enough to meet food sustainability. The growth rate in the area and production of Wheat, Rice, and Maize are positive, while it is negative for Sorghum (jawar), Millet (bajra), and Barley. For areas, a low degree of instability is prevailing for Wheat, Rice, Maize, Sorghum (jawar), and population, while the medium is for Millet (bajra) and Barley. For yield, the degree of instability is low for all food crops except Maize, which lies in the medium instability index. Semi log compound growth rate model was found best fitted for area and productivity for all food crops, while for the production side, it is found best for Wheat, Rice, and Maize and bit fit for Sorghum (jawar), Millet (bajra) and Barley. Decomposition analysis model predicted that crop productivity is a major concern to attain food security in Pakistan.

Keywords: Food Crops, Food Security, Growth Rate, Instability, Non-Linear Model, Population.

1. INTRODUCTION

Agriculture is the biggest pillar of Pakistan's economy. World Food Summit, 1996 defines food security, as "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" [1]. FAO further characterized food security into four important pillars, "food availability, food access, food utilization, and food stability" [2-4]. These pillars of food security are interrelated with agricultural production [5]. Food availability is however a basic pillar of food security, which depends on the production of food crops [6]. In the context of food availability, Wheat, Rice, and Maize are considered staple food crops. Agriculture sector was contributing 53 % to Pakistan's GDP in 1949, but over time the share of agriculture in Pakistan's economy has reduced to 19.2 %, which has also reduced the share of the labor force engaged in agriculture from 65 % to 38.5 %. The growth rate of the population in Pakistan is high as compared to neighboring South Asian countries [7]. The high growth rate of the population is leading Pakistan towards a food shortage and may affect the adequate food availability for the growing population [7, 8]. According to UNO, MDGs, food security has become a global threat to the world, due to the expansion of the world population. Food requirements and population growth are directly interlinked with each other [9, 10]. In 2005-06, 16 % of the world population was hungry, and now it has become 21 %, especially in South Asian countries [11]. It is expected that in 2050, Pakistan will be 5th populous state in the world instead of

Received: October 2022; Accepted: March 2023
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6th, due to the high growth rate of the population [12]. In 1798, Malthus postulated the theory that the population of the world is increasing rapidly while agriculture production is not enough to meet the need for food for the world, and the world will have to face the sever food scarcity in near future [13, 14]. International organizations i.e. WHO, and FAO show their great concern for this terrible issue of food security [15]. The high growth of the population has become a major threat to food security which can be overcome by increasing agricultural output [16]. The world's population will reach 9 billion by 2050, and the major contribution to this increase will arise from developing countries [15, 17]. The world agriculture production of food should be increased by about 70 % to attain food security and for developing countries, it will double [18]. Murindahabi [19] applied compound growth rate, decomposition analysis, and instability measures, and concluded that there exists a positive and significant relationship between area and production of Rice, Wheat, Beans, Millet, Maize, Groundnut, and Peas. The area contributed majorly toward crop production. Agriculture sector has great potential to grow more food for the population. There should be enforced agriculture emergencies in developing countries like Pakistan. A comprehensive program is needed to increase agriculture productivity, and to make food security measures.

It is the foremost need of the time, is to statistically measure the growth rate of the population and food crops to make assure food availability, and to elaborate the future food concerns. The present study statistically compared the population growth rate of six food crops (Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra), and Barley using the time series data comprise from 1950-2021, to address the food security situations in Pakistan. This study uses an exponential regression model (compound growth rate model), instability measure index (CDVI), and decomposition analysis model for area, productivity, and production of food crops (Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra), Barley along with the comparison of population, and statistically forecast the area, yield and production of food crops and population of Pakistan. This study will lead us to understand the true policy decisions to combat the food security measures in Pakistan.

2. MATERIALS AND METHODS

2.1 Data Collection and Measuring Scales

The seventy-two-year secondary time series data comprise from 1950-2021 is gathered from the Punjab agriculture marketing information service department, Pakistan bureau of statistics and crop reporting service agriculture department Punjab for the food crops (Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra) and Barley) of Pakistan. These are government organizations responsible for the collection and publication of statistical data for research and policymakers. The data measuring scale is applied as area sown in thousand acres, production in thousand tonnes and yield in mounds per acre (mds/acre).

2.2 Non-Linear Compound Growth Rate Regression Model (CGRM)

The non-linear compound annual growth rates regression model (CGRM) is used to elaborate the changes in food crops area, productivity, and production along with comparisons of population, and it is measured by log-linear function [20-22]

$$z_t = \mathrm{z}_0\,[1+r]^t \tag{1}$$

Where, "$\mathrm{z_t}$" shows food crops area/productivity/ production and population, "t" represents the time, "0" is used for the initial time, and "r" is used to indicate the growth rate of determinates. The slope measures the relative change in response variable for the absolute change accrues in feature and it measures the instantaneous rate of growth. Apply the natural log on equation 1

$$\mathrm{Ln(z_t) = Ln(z_0) + t\{Ln(1+r)\}} \tag{2}$$

$$Ln(z_t) = Y,\ Ln(z_0) = A_0,\ Ln(1+r) = V,$$
$$r = (exp^V - 1) * 100$$
$$Y = A_0 + Vt + \varepsilon \tag{3}$$

The following equation is applied to predict the parameter.

$$\mathrm{z_p = [z_c\,(1+V)^{tn1-tn2}]} \tag{4}$$

Where, "$\mathrm{z_p}$" stands the value of the response

variable at a projected time, "z_c" stands the actual value of response at the time "t", "V" stands for regression coefficients, and "tn1-tn2" stands the total no. of projected years.

2.3 Instability Analysis

Cuddy Della and Valle index (CDVI) is applied to measure the instability in time series data. It attempts to de-trend the coefficient of variation (CV) by R^2. The low value of CDVI elaborates on the low instability and vice-versa. Instability will be low if CDVI lies in 0≤CDVI≤15, medium if CDVI lies in 15.1≤CDVI≤30, and high if CDVI lies as CDVI>30 [23].

$$\text{CDVI} = \text{C.V} \times \left(\sqrt{1 - \text{R}^2}\right) \quad (5)$$

$$\text{C.V} = \frac{s}{\bar{x}} \times 100 \quad (6)$$

Where "s" stands for the standard deviation of the data and "x" stands the mean value of the data.

$$R^2 = 1 - \frac{\sum(y_i - \hat{y}_i)^2}{\sum(y_i - \bar{y}_i)^2} \quad (7)$$

$$R^2 = 1 - \frac{SSR}{SST} \quad (8)$$

Where "SSR" stands the sum of squares of regression and "SST" stands the total sum of squares,

$$R^2_{Adjusted} = 1 - \frac{(1-R^2)(n-1)}{n-k-1} \quad (9)$$

Where "n" stands the no. of observations and "k" stands the no. of predictors in the model.

2.4 Decomposition Analysis Model

The production of the crop is the product functions of the area and yield of the respective crop. Decomposition analysis model is used to estimate the individual share of the area and yield towards the production [19]. The variation in production is the sum of individual share of area, yield, and their interaction effects which is measured as;

Production change = Yield effects + Area effects + Interaction effects

$$\Delta\text{P} = \text{A}_0\Delta\text{Y} + \text{Y}_0\Delta\text{A} + \Delta\text{Y}\Delta\text{A} \quad (10)$$

$$\text{Change in production} = \frac{(\text{Y}_c - \text{Y}_0) \times \text{A}_0}{\text{P}_c - \text{P}_0} \times 100$$
$$\frac{(\text{A}_c - \text{A}_0) \times \text{Y}_0}{\text{P}_c - \text{P}_0} \times 100 + \frac{(\text{Y}_c - \text{Y}_0) \times \text{A}_c - \text{A}_0)}{\text{P}_c - \text{P}_0} \times 100$$

Where "$\Delta P = P_C - P_0$" = Change accrue in production over a period of time, "$\Delta Y = Y_C - Y_0$" = Change accrue in productivity over the period, "$\Delta A = A_C - A_0$" = Change accrue in the area over time, "0" = base year, "c" = current year.

3. RESULTS AND DISCUSSION

3.1 Non-Linear Compound Growth Rate Regression Model (CGRM)

Food security is closely linked with the production of major food crop growth in Pakistan [24]. Wheat, Rice, and Maize are the staple food crop of Pakistan. Table 1, elaborates the coefficients of determinations, regression coefficients, CGR, predicted values, and regression diagnostics of fitted CGRM for the food crops area and population, while Table 2, shows these determinates for the food crops productivity and production. Wheat, Rice, and Maize crops are accounting 1.8 %, 0.5 %, and 0.7 % share of the GDP of Pakistan [25]. In 2021, Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra), and Barley are cultivated on 22655.66, 8242.56, 3503.51, 310.3, 865.87 and 103.39 thousand acres areas in Pakistan, while it was 10337, 2305, 989.63, 1361, 2368 and 497 thousand acres in 1950. Using the CGRM, the growth rates for area reported as 1.21 %, 1.61 %, 1.71 %, -1.39 %, -1.29 %, and -1.69 %, respectively for Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra) and Barley. The productivity in mds/acre of Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra), and Barley were 9.34, 8.59, 10.13, 4.9, 3.91, and 7.34 in 1950 and it is reported as 30.3, 25.54, 63.79, 7.73, 7.68 and 10.12 in 2021. The models predicted the growth rate for the productivity as 2.22 %, 1.71 %, 2.43 %, 0.50 %, 0.70 %, and 0.80 %, respectively for the Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra) and Barley crops. For the production side, Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra), and Barley reported 3862, 792, 401, 267, 370, and 146 thousand tonnes in 1950, and these crops accounting production as 27464.08, 8419.68, 8939.79, 95.97, 266.08 and 41.86 thousand tonnes for 2021. The fitted model predicted the production

Table 1. Fitted CGRM determinants for food crops area and population of Pakistan

	Area in acres all food crops						Population in million
	Wheat	Rice	Maize	Sorghum (Jawar)	Millet (Bajra)	Barley	
Adj R^2	0.916	0.931	0.965	0.734	0.637	0.679	0.993
MSE	0.006	0.009	0.005	0.029	0.039	0.059	0.002
F-Statistic	779.2**	957.4**	1553.0**	196.7**	125.8**	151.3**	9798.7**
Slope (β)	0.012	0.016	0.017	-0.014	-0.013	-0.017	0.028
t-Statistic	27.9**	30.9**	44.19**	-14.02	-11.2	-12.3	98.9**
CGR	1.21%	1.61%	1.71%	-1.39%	-1.29%	-1.69%	2.84%
1950	10337	2305	989.63	1361	2368	497	32.92
2021	22655.66	8242.56	3503.51	310.3	865.87	103.39	224.78
2030 (Predicted)	25223.27	9508.36	4077.48	273.32	769.67	88.61	288.20
2050 (Predicted)	32019.28	13061.10	5712.30	206.16	592.45	62.88	500.68
% Inc/Dec at 2030	11.33%	15.36	16.38	-11.92	-11.11	-14.30	28.21%
% Inc/Dec at 2050	41.33%	58.46%	63.05%	-33.56%	-31.58%	-39.18%	122.74%

** Shows the models and coefficient are statistically significant

Table 2. Fitted CGRM determinates for food crops productivity and production.

	Productivity (Yield) in mds/ acre					
	Wheat	Rice	Maize	Sorghum (Jawar)	Millet (Bajra)	Barley
Adj R^2	0.949	0.898	0.818	0.644	0.635	0.719
MSE	0.012	0.014	0.054	0.005	0.014	0.012
F-Statistic	1324.7**	629.4**	319.9**	129.2**	124.4**	182.2**
Slope (β)	0.022	0.017	0.024	0.005	0.007	0.008
t-Statistic	36.3**	25.0**	17.8**	11.3**	11.1**	13.4**
CGR	2.22%	1.71%	2.43%	0.50%	0.70%	0.80%
1950	9.34	8.59	10.13	4.9	3.91	7.34
2021	30.31	25.54	63.79	7.73	7.68	10.12
2030 (Predicted)	36.87	29.72	78.97	8.08	8.18	10.87
2050 (Predicted)	56.97	41.64	126.90	8.93	9.40	12.75
% Inc/Dec at 2030	21.63	16.38	23.79	4.59	6.48	7.43
% Inc/Dec at 2050	87.96	63.05	98.93	15.56	22.42	26.00
	Production in tonns of all food crops					
	Wheat	Rice	Maize	Sorghum (Jawar)	Millet (Bajra)	Barley
Adj R^2	0.952	0.934	0.941	0.473	0.134	0.286
MSE	0.026	0.033	0.045	0.038	0.071	0.08
F-Statistic	1396.2**	1013.5**	1142.3**	64.7**	11.9**	29.4**
Slope (β)	0.034	0.033	0.041	-0.009	-0.005	-0.009
t-Statistic	37.3**	31.8**	33.7**	-8.04	-3.4	-5.4
CGR	3.46%	3.36%	4.19%	-0.9	-0.5	-0.9
1950	3862	792	401	267	370	146
2021	27464.08	8419.68	8939.79	95.97	266.08	41.86
2030 (Predicted)	37106.49	11277.13	12834.65	88.47	254.34	38.59
2050 Predicted)	72420.36	21587.63	28668.07	73.84	230.08	32.21

** Shows the models and coefficient are statistically significant

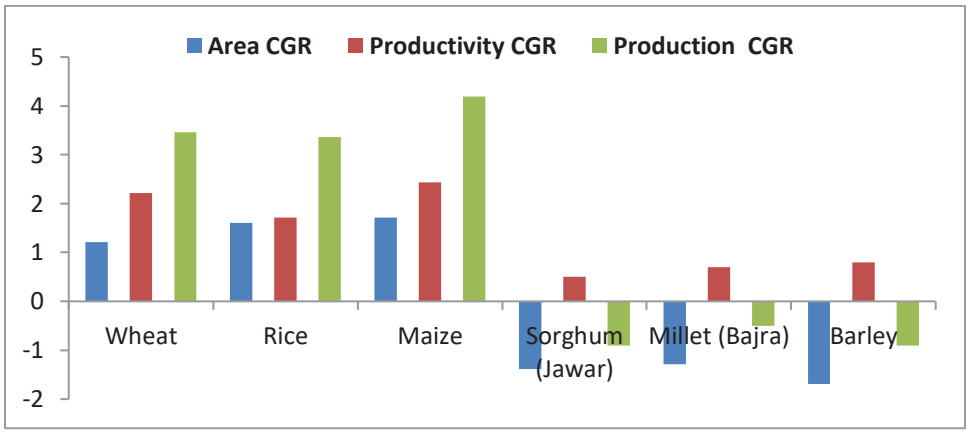

Fig. 1. Graph showing CGR for food crops

growth rate as 3.46 % for Wheat, 3.36 % for Rice, 4.19 % for Maize, -0.90 for Sorghum (jawar), -0.50 for Millet (bajra), -0.90 for and Barley. Figure 1, shows the graphical view of the growth rates of all the food crops. The population of Pakistan is reported 224.78 (million) in 2021, while it was 32.92 (million) in 1950. The CGRM reported a growth of 2.84 % for the population.

The fitted CGRM shows explained variation as 91.6 %, 93.1 %, 96.5 %, 73.4 %, 63.7 %, 67.9 %, and 99.3 % respectively for foods crops (Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra) and Barley) areas and population of Pakistan. Fitted models show explained variations as 94.9 %, 89.8 %, 81.8 %, 64.4 %, 63.5 %, and 71.9 % for productivity, and 95.2 %, 93.4 %, 94.1 %, 47.3 %, 13.4 % and 28.6 % for productions of Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra) and Barley. F-statistic shows all fitted CGRM is significant. The t-statistic shows regression coefficients are significant for all food crop productivity. The regression coefficients were found significant for the area and production of Wheat Rice and Maize crops and insignificant for the Sorghum (jawar), Millet (bajra), and Barley. Fitted population regression coefficients were found significant. The slope and CGR for area and production were found negative for Sorghum (jawar), Millet (bajra), and Barley, and positive for Wheat, Rice, and Maize crops. The slope and CGR were found positive for the productivity of all food crops. The population will reach 288.20 (million) by 2030 and 500.68 (million) by 2050. CGRM was found best fitted for the area and productivity of all food crops. For the production side, CGRM, the best fit for Wheat, Rice, and Maize and bit fit for Sorghum (jawar), Millet (bajra), and Barley crops. Keeping in view of major food crops (Wheat, Rice, and Maize crops) and the population of 2050, the increase in population is 81.41 %, 64.28 %, and 59.69 % greater than from the Wheat, Rice, and Maize area. The area under Sorghum (jawar), Millet (bajra), and Barley were reported to decrease by 33.56 %, 31.58 %, and 39.18 %, while the population is increasing by up to 122.74 % by 2050. The increase in population reported 34.78 %, 59.69 %, 23.81 %, 107.18 %, 100.32 %, and 96.74 % greater than from Wheat, Rice, Maize, Sorghum (jawar), Millet (bajra) and Barley crops productivity up to 2050. The increase in population is greater than the increase in area and productivity of all food crops which shows the expected food stress for Pakistan.

3.2 Growth Rate and Instability Measures of Food Crops

Table 3 shows the instability analysis using the Cuddy Della and Valle index (CDVI) and coefficient of variations for food crops and the population of Pakistan. Regarding the area of food crops, low instability was found for Wheat, Rice, Maize, and Sorghum, while medium for Millet and Barley. The instability was found lower in all food crop productivity except for Maize, which is medium. For production side instability, all food crops lie in the medium instability index except Wheat, which lies in the lower instability index. The coefficient of variation indicates high inconsistency for population compared with area and productivity of food crops.

3.3 Decomposition Analysis Model for Area and Productivity towards Production

Production is the sum of the product of area and productivity (area*productivity). Decomposition model is used to determine the contribution of area and productivity toward production. It is shown in Table 4, Figure 2, that productivity is the main contributor to change in all food crop production as compared to the area. For Wheat, Rice, and Maize, productivity effects were found 18.24 %, 6.28 %, and 12.96 % greater than from area. The contribution of the area is low as compared to productivity (Productivity effects> Area effects) and in some cases, the crop area is critically negative for Sorghum (jawar), Millet (bajra), and Barley. The area and productivity both collectively contribute towards production and accounting 43.76 % share of Wheat, 52.76 % of Rice, and 63.20 % of Maize. The interaction effects were found negative for Sorghum (jawar), Millet (bajra), and Barley crops. Productivity contributes an upswing for all food crops. Interaction effects for Sorghum (jawar), Millet (bajra), and Barley were found negative due to the negative growth rate for the area of these crops.

Table 3. CDVI for the food crops area, productivity, and production

	Area		**Productivity**		**Production**		**Population**	
	CDVI	CV	CDVI	CV	CDVI	CV	-	-
Wheat	6.80 %	23.5 %	9.8 %	43.1 %	13.50 %	60.0 %	-	-
Rice	8.50 %	32.6 %	10.6 %	32.3 %	15.3 %	59.5 %	-	-
Maize	6.43 %	34.4 %	29.18 %	60.0 %	25.50 %	105.2 %	-	-
Sorghum (Jawar)	14.76 %	28.6 %	6.8 %	10.9 %	17.50 %	24.2 %	-	-
Millet (Bajra)	19.69 %	32.6 %	12.3 %	16.8 %	24.30 %	26.1 %	-	-
Barley	19.70 %	34.8 %	10.4 %	19.6 %	25.10 %	29.8 %	-	-
CDVI	-	-	-	-	-	-	4.44 %	
CV	-	-	-	-	-	-	53.3 %	

Table 4. Decomposition analysis for area and productivity share toward production

	Area effects	Productivity effects	Interaction effects
Wheat	19.48 %	37.72 %	43.76 %
Rice	20.48 %	26.76 %	52.76 %
Maize	11.92 %	24.88 %	63.20 %
Sorghum (Jawar)	-43.00 %	32.17 %	-24.84 %
Millet (Bajra)	-28.69 %	43.60 %	-27.65 %
Barley	-53.86 %	25.76 %	-20.40 %

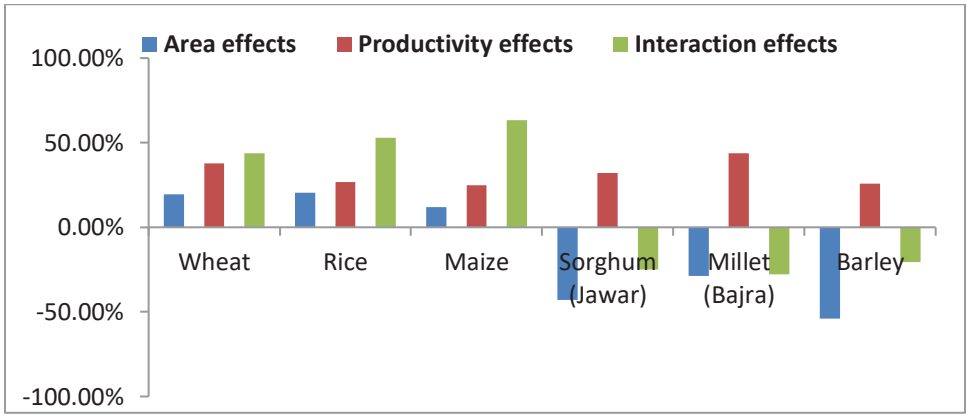

Fig. 2. Graph showing the decomposition analysis model for food crops

4. CONCLUSION & RECOMMENDATIONS

Food availability is one of the important pillars of food security. It is essential to steer the strategies to ensure food availability. The population of Pakistan is increasing rapidly, while the productivity and area of all food crops are not enough to meet food sustainability. The key concern of the present study is to statistically analyze the growth rate of the population and important food crop production fluctuations using time series data comprise from 1950-2021. The growth rate in area and production of Wheat, Rice, and Maize are positive, while negative for Sorghum (jawar), Millet (bajra), and Barley. The growth rate is positive for all food crops' productivity. The growth rate in area and productivity of all food crops is less than the growth rate of the population. The degree of instability is low for the area of Wheat, Rice, Maize, and Sorghum (jawar), while medium for Millet (bajra) and Barley. Low degree of instability prevails for the productivity of all food crops except Maize, which is medium. The production side instability is medium for all food crops except Wheat, which is low. Decomposition analysis model indicates productivity is a major concern to increase the production of crops to meet the challenge of food security in Pakistan. CGRM is best fitted for the area and productivity of all food crops. The population will increase by 81.41 %, 64.28 %, and 59.69 % greater than from Wheat, Rice, and Maize areas up to 2050. The area under Sorghum (jawar), Millet (bajra), and Barley are reported to decrease, while the population is increasing by about 122.74 % by 2050. The increase in population is greater than the increase in area and productivity of all food crops which shows the expected food stress for Pakistan. The comparison of instability, growth and decomposition analysis for food crops and population will lead the government to lay out direction-oriented policies to attain food sustainability for future food security concerns. The comparison of decomposition analysis will lead the government to that productivity enhancement is a major concern to ensure food availability in Pakistan. The comparison of area and productivity will lead the government to rationalize the policies by keeping in view the expected increase and decrease across the years. This study could also enhance to compare the periodic comparisons and some other linear and nonlinear models could also be applied to compare the results of fitted models.

5. ACKNOWLEDGEMENTS

The authors would like to appreciate the strong data collection mechanisms and efforts of the team of CRS is a considerable good asset for our sweet homeland Pakistan.

6. CONFLICT OF INTEREST

The authors declared no conflict of interest

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