Plant Archives Vol. 25, No. 1, 2025 pp. 1761-1769 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.1.255

SUSTAINABILITY CONCERN ON SUGARCANE PRODUCTION IN INDIA WITH SPECIAL REFERENCE TO UTTAR PRADESH INDIA

Aditya Bhooshan Srivastava[1], K.K. Singh[1], Ajeet Kumar[2], Pavan Kumar Singh[3], Bhartendu Yadav[4], Mahima Priyanka Neerugatti[1] and Sachin Kumar Verma[5*]

[1]Department of Agricultural Economics, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India.

[2]Department of Agriculture, Invertis Bareilly Uttar Pradesh, India.

[3]Department of Agriculture, Mangalayatan University, Aligarh, Uttar Pradesh, India.

[4]Department of Agricultural Economics and Extension, Lovely Professional University, Phagwara, Punjab, India.

[5]Technology Dissemination and Computational Biology Division, CSIR-CIMAP, Lucknow.

*Corresponding author E-mail: sachinssv974@gmail.com

(Date of Receiving-01-12-2024; Date of Acceptance-20-02-2025)

ABSTRACT

The study measures the sustainability in the area, production and yield of sugarcane in Uttar Pradesh and India as a whole, used the available secondary data from 1950- 51 to 2022-23, collected information from Agriculture Statistics at a glance and APY Statistics(www.dac.gov.in). The analysis periods have been classified into five sub-periods to determine the growth trend, decomposition analysis, the Cuddy Della Instability Index and sustainability index. The trend of sugarcane yield in India as a whole is found better than in Uttar Pradesh state in particular. The decomposition analysis result reveals that the interaction effect is responsible which means the combined effect of yield and area on sugarcane production. Instability analysis indicates that the level of instability in the area, production, and yield of sugarcane is almost stagnant in India, whereas the level of instability in the area, production, and yield of sugarcane has been drastically increased in Uttar Pradesh. There is no correlation between low growth rate and high instability, and vice versa. The study assessed the sustainability index for India and Uttar Pradesh, which originally declined suggesting enhanced sustainability but has since grown indicating unsustainability. Thus, this study indicates that increasing sugarcane output may be done by deploying high-yielding cultivars, adopting innovative farming practices, and optimizing water and soil management, thereby assuring profitability and sustainability.

***Key words*:** Coefficient of variation, Cuddy-Della index, Decomposition, Compound Growth rate, Sustainability index, Sugarcane.

Introduction

Sugarcane (*Saccharum officinarum*) is one of the most valuable crops in the world because of its advantageous position, wide range of uses in daily life, and industrial applications aimed at ensuring economic and nutritional sustainability. Sugar produce about 60% worldwide comes from sugar cane, with the remaining 40% coming from sugar beet. It is a tropical crop that matures in eight to twelve months. Mature cane reaches its maximal sugar concentration when it turns green, yellow, purple, or reddish in color. According to Nutrient Information from ESHA Research, sugarcane juice has 111.13 kJ (26.56 kcal) of energy per serving (28.35 grams), 27.51 grams of carbs, 0.27 grams of protein, 11.23 mg of calcium, 0.37 mg of iron, 41.96 mg of potassium, and 1.01 mg of sodium. One element that influences a person's or a group's socioeconomic situation is social class or rank. Usually, factors like money, employment, and education are taken into account while making a judgment. Sugarcane has made a major contribution to social development and the fight against poverty. Socioeconomic development is impacted by sugarcane

prices (Bharati *et al.*, 2018). In 2022-2023, sugarcane was grown on 5464 thousand hectares in India, yielding 85000 kg per hectare and producing 465049 thousand tons (Agricultural Statistics at a Glance, 2023).

India is the world's largest producer of sugarcane; the leading states are Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Bihar, Gujarat, Haryana, Punjab, and Andhra Pradesh. India is significantly dependent on sugarcane. A large number of agricultural laborers and about 6 million farmers work in the cane industry. In addition, around half a million skilled and semi-skilled people, the most of whom are from rural regions, are employed in India's largest agro-processing business, the sugar industry. The country's overall cane production is, on average, 60% made up of white sugar production. Approximately 15% to 20% of sugarcane is utilized in the production of Gur and Khandsari (Vishawajith *et al.*, 2016).

In Uttar Pradesh, during 2023-24 sugarcane was cultivated in an area of 2179 thousand hectares and production was 176706 thousand tones with the productivity of 81100 Kg. per hectares (Agricultural Statistics at a Glance, 2023). The output per hectare is low when compared to some of the major sugarcane-producing states in the nation. As a result, there is a shortage of sugarcane for sugar mills and a low total output. In an attempt to address this issue, high yielding, early maturing, high sucrose content sugarcane varieties that are resistant to pests and diseases are being developed. In order to fulfill the demands of a growing population and economy, it has developed into a complex scientific study with the goal of producing the greatest amount of agricultural produce in the least amount of time, area, and energy. A greater amount of sugar must be produced in the area that is accessible because of the rapidly growing population and rising per capita sugar consumption.

From a sustainability perspective, sugarcane output, production, and area growth rates should all be consistent or constant. However, the output and productivity of sugarcane need to be researched, as well as the reasons that contribute to the many variations and instability in the area. It is necessary to look at the decreasing production trend as it might have an impact on sugarcane producers' ability to compete in the future. The supply of sugarcane to the sugar mills and farm revenue are being severely impacted by the unpredictability of sugarcane output. It raises the risk associated with producing sugarcane, impacts price stability, and makes sugarcane producers more vulnerable (Chand and Raju, 2008). It refers to the fluctuations in sugarcane output that impact sugarcane prices and consequently impact the crop's profit margin and labor absorption rate.

According to Singh *et al.*, (2021), if the risk and volatility continued to rise, the sugarcane production system would become even less sustainable. In light of the increased volatility in sugarcane yield, productivity, and farm revenue that sugarcane growers and sugar mills are experiencing, these are the growing worries that are surrounding the situation. Several shifts have taken place in the sugarcane sector across the nation as a whole as a consequence of rapid investment, and it is imperative that these shifts be taken into consideration from a sustainability perspective.

Many studies have used same methodologies to measure the sustainability for instance studies were supported by Kumar and Singh, (2014) measure the Growth Rates in Area, Production and Productivity of Sugarcane in Haryana. Mishra *et al.*, (2015) Modeling and forecasting of wheat in India and their yield sustainability. Abnave, 2015 measure profitability of sugarcane cultivation in India. Vishwajith *et al.*, (2018) measure sustainability of crop yield. Abnave, 2019 were used statistical approach to measure the sustainability of Sugarcane in India and Maharashtra. Maurya et al., (2020) Growth and Decomposition a n alysis of Sugarcane Production in India. Wadghane, (2022) Sustainability management status of agro-ecosystems: A case study of sugarcane farmers Maharashtra, India.

Materials and Methods

Secondary data, were collected from various source like- Agricultural Statistics at a Glance and www.dac.gov.in (APY statistics), data pertains to period 1950-2022 regarding area, production, and yield of sugarcane for arriving analyzing Growth rate, Instability, Decomposition and Sustainability Index with application of time series analysis of data.

Period of secondary data

The period of study classified into five sub-periods to determine growth rate, instability, Decomposition and sustainability index of sugarcane production

Sub Period 1 (1950-1967): Spread of Sugarcane Factories, Introduction of Sugarcane Price Policies (SAP).

Sub Period 2 (1968-1985): Sugarcane Development Plan (1982), Prominent Role of the State, Technology Dissemination

Sub Period 3 (1986-2003): Early Economic Reform/ De-licensing and Decontrol of Sugar Sector (1998).

Sub Period 4 (2004-2022): Mature Economic Reform/ Sustainable Development Based Cropping System (SUBACS) (2000), New Sugarcane Policy

Overall Period: consist whole period from 1950-2022.

Methodology: Many statistical tools will be adopted to describe the above objective are.

Growth rate

Compound annual growth rate (CAGR) was estimated using the following functional form:

$\ln Y = a + bt$

Where, Y indicate time series data of area, production or yield of sugarcane - for which growth rate is calculated, 't' indicates trend term and 'a' indicate constant coefficient. The slope coefficient 'b' measures the relative change in Y for a given absolute change in the value of explanatory variable 't'. Compound annual growth rate can be calculated from the value

$CAGR = [\text{antilog } b - 1] \times 100$

The values of compound growth rates obtained were also tested for their significance using student 't' test.

Decomposition analysis

Minhas (1964); Nivetha and Uma (2021) used the Decomposition analysis model, which is shown below, to determine the relative contribution of area and yield to the overall output of the sugarcane crop.

$Po = Ao \times Yo$, and $Pn = An \times Yn$ ...(1)

Area, production, and productivity in the base year are;

Ao, Po, and Yo, respectively;

Whereas,

An, Pn, and Yn are the values of the relevant variable in the nth year item.

Where,

Ao and An = Area in the base year and nth year respectively;

Yo and Yn = yield in the base year and nth year respectively.

$Pn - Po = \Delta P$ $An - Ao = \Delta A$ $Yn - Yo = \Delta Y$ ...(2)

For equations (1) and (2) we can write;

$Po + \Delta P = (Ao + \Delta A)(Yo + \Delta Y)$

Hence,

$$P = \frac{A_0 \Delta Y}{\Delta P} \times 100 + \frac{Y_0 \Delta A}{\Delta P} \times 100 + \frac{\Delta Y \Delta A}{\Delta P} \times 100$$

According to Gaware *et al.*, (2022); Production = Yield effect + area effect + interaction effect

As a result, the overall change in production can be broken down into yield effect, area effect, and interaction effect due to yield and area changes.

Instability and It's Measure

For assessing the instability in the production, the index certain by Cuddy and Della (1978), and utilized by Srivastava *et al.*, (2022); Supriya *et al.*, (2023): $CV_t = (CV) \times \sqrt{1 - R^2}$

$$C.V. = \frac{\sigma}{\bar{X}} \times 100$$

Where, σ = Standard Deviation

$\bar{X} = Mean$;

R2 = means coefficient of determination of the variable's linear trend model;

CVt represent CV around trend

For the analysis the coefficient variant around trend is divided into three group which indicate the different range of instability (Pattnaik and Shah, 2015). The range of instability are as follow:

1. Between range 0 to 10 indicated low degree of instability;
2. Between range 10 to 20 indicated Moderate degree of Instability;
3. Greater than 20 indicated High degree of Instability.

Sustainability Index (SI)

For assured food and nutritional security yield sustainability of major crops is important. So, the measure of sustainability for specific purpose needs to be addressed properly Sahu *et al.*, (2005) $= \frac{Y_{max} - \bar{Y}}{\bar{Y}}$,

Where, $\bar{y}$ is the average yield of a treatment, and y_{max} is the maximum yield in any year. A sustainability index value closer to zero is the most desirable value.

Results and Discussion

Growth Trend Analysis

The examination of the growth trends in the area, production, and yield of sugarcane aims to understand the evolving patterns within the sugarcane crops in India, specifically in the state of Uttar Pradesh. Table 1 illustrates the annual compound growth rates of the area, production, and yield of sugarcane over different periods for both India and Uttar Pradesh.

Looking at the growth trend in area, production and yield of sugarcane in India and Uttar Pradesh state,

Table 1: Growth Rate of Area, Production and Yield of Sugarcane during 1950-51 to 2022-23.

PERIODS	INDIA			UTTAR PRADESH		
	Area	Production	Yield	Area	Production	Yield
Period-I(1950 to 1967)	2.57(4.80)*	5.19(7.24)*	2.31(6.17)*	1.48(2.37)**	1.50(2.03)	0.01(0.04)
Period-II(1968-1985)	1.16(3.37)*	2.37(5.55)*	1.20(5.94)*	1.38(3.92)*	2.20 (4.47)*	0.81(2.53)**
Period-III(1986-2003)	1.06(7.47)*	2.29(5.18)	0.42(1.59)**	1.10(6.38)*	1.72(4.88)	0.61(2.29)**
Period-IV(2004-2022)	0.90(2.55)**	2.33(5.59)	1.42(8.19)**	0.31(2.07)*	2.65 (7.77)*	2.33(7.33)*
Period-V(1950 to 2022)	1.56(30.01)**	2.79(32.56)**	1.22(24.24)**	1.16(22.41)*	2.24(31.45)**	1.06(22.28)*
Note: Figures in parenthesis shows 't' values ** .05 level, *.01 level.						

reveals that the growth trend has been significant in all period of area under sugarcane in India and Uttar Pradesh. While in production the growth trend has been significant in all the three periods except the period III and period IV in India and except period I and period III in Uttar Pradesh under sugarcane. Similarly, growth trend has been significant in all the four periods in India and Uttar Pradesh, while in Uttar Pradesh except period I of the yield under sugarcane is non-significant.

During all four periods, the area under sugarcane saw increases with growth rates of 2.57 percent, 1.16 percent, 1.06 percent, and 0.90 percent, respectively. Simultaneously, the production of sugarcane exhibited significant growth over the same periods at rates of 5.19 percent, 2.37 percent, 2.29 percent, and 2.33 percent, respectively. The growth rate of yield showed a positive trend, indicating an increasing yield in India.

The growth rate of Uttar Pradesh sugarcane showed that the area under sugarcane expanded considerably in all four periods, with growth rates of 1.48 percent, 1.38 percent, 1.10 percent, and 0.31 percent, respectively. The growth rate of sugarcane production in Uttar Pradesh increased significantly for all periods, with the exception of the spread of sugarcane factories and early economic reform/de-licensing and decontrol of the sugar sector period, which was found to be positive but insignificant, whereas the growth rate of productivity was observed to be positive and significant.

Overall, the analysis reveals that both the area and production of sugarcane have shown positive growth trends in India and Uttar Pradesh over the study period, reflecting an increase in sugarcane cultivation. The yield of sugarcane has also exhibited a generally increasing trend, though the growth rates have varied across different time periods.

Sources of change in Sugarcane production

The analysis of the expansion of the area, production, and yields of the sugarcane crop reveals the comprehensive pattern of growth and the direction of changes. Nevertheless, this method fails to consider the specific impact of area and yield on the rise in sugarcane output. It is crucial to determine the sources of fluctuations in sugarcane production in order to pinpoint the specific factor that is causing a delay and to understand the underlying causes.

Moreover, it would facilitate the understanding of the elements that lead to the enhancement of sugarcane output. Therefore, it is crucial to carefully examine the origins of sugarcane agriculture. In order to examine the elements that affect sugarcane production, the overall change in output is split into three distinct effects: the influence of the area, the effect on yield, and the interaction effect. Table 2 presents the exact impact of the geographic location, crop yield, and their interaction on the variations in sugarcane production in India and Uttar Pradesh.

During periods I, II, and III, the growth in sugarcane output in India was mostly attributed to an increase in yield, resulting in a productivity contribution of around 61.38%, 58.63%, and 108.75% for this crop. However, starting with period IV, which is following period III, the area effect became the primary factor driving the development of sugarcane yield in India. During the whole time, namely period V, the interaction effect had the

Table 2: Decomposition of Change in Production of Sugarcane in India and Uttar Pradesh (in per cent).

PERIODS	INDIA			UTTAR PRADESH		
	Area	Yield	Production	Area	Yield	Production
Period-I(1950 to 1967)	32.21	**61.38**	6.40	31.40	**69.77**	-1.17
Period-II(1968-1985)	33.95	**58.63**	7.42	42.85	**48.27**	8.89
Period-III(1986-2003)	-6.86	**108.75**	-1.89	30.18	**63.48**	6.33
Period-IV(2004-2022)	**51.47**	32.51	16.02	**68.71**	23.42	7.87
Period-V(1950 to 2022)	21.62	30.75	**47.46**	30.88	33.65	**35.48**
Note: Sum of all three effect = 100						

Table 3: Instability in Area, Production and Yield of Sugarcane in India and Uttar Pradesh.

Field of Measurement	Measurement Statistics	Period I	Period II	Period III	Period IV	Period V
INDIA						
AREA	R^2	0.589	0.411	0.777	0.272	0.936
	CV	17.300	9.544	10.944	9.115	32.165
	CV_t	11.088	7.326	5.166	7.777	8.137
PRODUCTION	R^2	0.741	0.654	0.626	0.667	0.949
	CV	30.162	15.386	14.623	15.635	52.036
	CV_t	15.336	9.056	8.941	9.027	11.751
YIELD	R^2	0.685	0.690	0.140	0.264	0.924
	CV	14.510	7.726	5.990	9.049	24.987
	CV_t	8.140	4.301	5.556	7.761	6.889
UTTAR PRADESH						
AREA	R^2	0.274	0.479	0.715	0.199	0.919
	CV	14.665	10.500	6.886	3.733	24.226
	CV_t	12.496	7.582	3.680	3.342	6.895
PRODUCTION	R^2	0.212	0.560	0.582	0.778	0.959
	CV	17.178	15.621	11.427	17.308	24.785
	CV_t	15.250	10.362	7.391	8.158	5.019
YIELD	R^2	0.002	0.309	0.232	0.757	0.839
	CV	6.829	7.988	6.526	15.446	24.785
	CV_t	6.829	6.641	5.720	7.619	9.945

greatest impact on sugarcane output, followed by the yield effect and then the area effect. The decomposition analysis shows that in Uttar Pradesh state, similar to India as a whole, the yield effect (69.77%, 48.27%, and 63.48%) had the greatest impact on the growth of sugarcane output, followed by the area effect (31.40%, 42.85%, and 30.18%), and the interaction effect (-1.17%, 8.89%, and 6.33%) during periods I, II, and III. The significant increase in sugarcane production was mostly driven by the yield expansion from period I to period III. However, during period IV (2004 to 2022), the expansion of sugarcane cultivation area in India, particularly in Uttar Pradesh, had a big role in influencing the output growth.

The yield effect was historically the primary factor driving maximum production in India and Uttar Pradesh. This was due to factors such as improved agricultural practices, technological advancements, and favorable weather conditions, which resulted in higher yields despite the fact that the area under cultivation was not the primary driver of production.

However, after Period III (1986–2003), the area impact became more significant in for maximum sugarcane production in India and Uttar Pradesh. The shift can be attributed to changes in land usage, the expansion of sugarcane cultivation into new areas, and adjustments to the environmental conditions that were suitable for the growing area can all be connected to this shift in emphasis away from focusing just on yield increase strategies. Increases in the area dedicated to sugarcane growing have an impact on output levels. This growth was caused by several things, such as improving irrigation methods, addressing power shortages, and replacing diesel pumps with solar pumps, among other new technologies.

In Period V (1950-2022) the interaction effect is responsible which means the combined effect of yield and area on sugarcane production. It suggests that the relationship between yield and area is not linear but the impact of each factor on production depends on the other factors.

Instability analysis

The Cuddy and Della (1978) approach was employed in India and Uttar Pradesh to assess the volatility of sugarcane area, production, and yield. The coefficient of variation (CV) is a more comprehensive choice, but it should be used appropriately when dealing with time series that include a trend variable. The approach developed by Cuddy and Della in 1978 relies on the assumption of a linear pattern. However, it is difficult to identify a linear pattern in time series data that spans a lengthy period of time. In this study, our objective was to introduce nonlinearity into the trend model. We then calculated the coefficient of determination from this well-fitted model to obtain the CV_t value for different sequences. We have named this measure the modified Cuddy and Della measure. The study employed the Cuddy and Della (1978)

metric to assess non-linearity in the trend model, specifically in relation to the linearity assumption of the Cuddy and Della model. The R^2 value in the Cuddy and Della model and the modified Cuddy and Della model may vary. The de trend coefficient of variation is assessed in five periods to analyse instability. These periods are as follows: period 1 from 1950-1967, period 2 from 1968 to 1985, period 3 from 1986 to 2003, period 4 from 2004 to 2022, and period 5, which covers the entire period from 1950 to 2022. The findings of this activity will be examined in the subsequent subsection.

In which from Table 3 clearly depicted that the coefficient of variant around trend (CV_t) in the area of sugarcane has decreased from 11.088 (period 1) to 5.166 (period 3) after period 3 *i.e.*, period 4 the instability is increasing 7.777, indicating that the highest instability was sown in period 1 from 1950 to 1967 in India, but the coefficient of variant around trend (CVt) in Uttar Pradesh has also decreased from 12.496 (period 1) to 3.342 (period 4), indicating that the area is becoming stable.

While in production showed that coefficient of variant around trend (CV_t) decreased from 15.336 (period 1) to 8.941 (period 3) and then instability increased in period 4 (9.027), indicating that the highest instability was depicted in period 1 from 1950 to 1967 in India. Similarly, the instability in Uttar Pradesh is decreased from 15.250 (Period 1) to 7.391 (Period 3) and then instability increased in period 4 (8.158), indicating slight increase in instability in period 4 from 2004-2022.

However, in yield, coefficient of variant around trend (CV_t) is slightly decreased from 8.140 (period 1) to 4.301 (period 2), after that the instability started increasing from period 3 to period 4, whereas the instability in Uttar Pradesh has decreased from 6.829 (period 1) to 5.720 (period 3) after that instability started increasing in period 4 (7.619), indicating that the instability is lowest in period 3 from 1986-2003.

It has been observed that the degree of instability in the area, production, and yield of sugarcane remains relatively unchanged across India. However, there has been a significant increase in the level of instability in the production and yield of sugarcane specifically in Uttar Pradesh. The unpredictability in the sugarcane area, production, and productivity has a direct impact on the livelihoods and wellbeing of the sugarcane growers. The risk associated with cultivating sugarcane crops in Uttar Pradesh is evidently higher and has been consistently growing over time. The sugarcane agriculture in Uttar Pradesh is becoming unsustainable due to the rising risk and decreasing yield of the crop.

The primary factor contributing to the rise in the volatility of the sugarcane area and production during period IV appears to be the severe water scarcity resulting from erratic rainfall patterns. Additionally, the sugarcane crop was adversely damaged by an outbreak of whitefly illness. Moreover, the degree of volatility has increased due to the ambiguity surrounding the price of sugarcane in the primary sugar-producing regions of India (MoA, 2014). During period IV, there was substantial variation in the amounts of sugarcane that sugar mills in Maharashtra paid to sugarcane producers. During the period of 2004-05, sugar mills compensated producers with Rs.135 per quintal. This amount drops down to Rs.93 per quintal during 2006-08, but then increased to Rs.235 per quintal in 2011-12. According to the CACP Report, Uttar Pradesh, the state with the highest sugarcane output, has shown a steady and continuous increase in prices from Rs.104 to Rs.240 per quintal throughout the 2013-14 Sugar Season, with little variations. Following the 2008-09 year, there was a substantial rise in the Statutory Minimum Price (SMP) / Fair and Remunerative Price (FRP) from Rs. 81.18 per quintal to Rs. 129.84 per quintal. By the fiscal year 2012-13, it has increased even further to Rs. 210 per quintal. Over time, the difference between the total amount owed and the total amount actually paid by sugar mills to sugarcane producers has been increasing. The advancement is detrimental to both sugar mills and producers. The increasing number of unpaid sugarcane debts is a long-standing issue that has persisted for more than a day or a year. The issue mostly emerged after the national government replaced the Statutory Minimum Price (SMP) with the Fair and Remunerative Prices (FRP) for sugarcane in 2009-10. The outstanding debt owed to the sugarcane producers rose from around 3 percent in 2008-09 to more over 50 percent in 2014-15, and then declined to roughly 30 percent in 2017-18. The sudden and unpredictable changes in price have caused the instability of sugarcane. The volatility in sugarcane production in India and Uttar Pradesh is mostly attributed to reasons such as limitations in irrigation, fluctuations in prices, and a decline in yield rates during period IV. The main determinant of the low instability witnessed during period III in India is the confluence of little precipitation and a sluggish rate of expansion.

Association between Growth Rate and Instability

Table 4 categorizes different periods by combining various types of growth rates and instability indexes in sugarcane output in India and Uttar Pradesh. In terms of area, all eras fell under the low growth rate and low instability group in India. In terms of production, the relationship between growth rate and instability of

Table 4: Association between Growth Rate and Instability of Sugarcane Production in India and Uttar Pradesh State.

Type of Association	INDIA			Uttar Pradesh		
	Area	Production	Yield	Area	Production	Yield
High growth rate and High instability						
Medium growth rate and High instability						
Low Growth Rate and High Instability						
High Growth Rate and Moderate Instability						
Medium Growth Rate and Moderate Instability		I				
Low Growth Rate and Moderate Instability	I	V		I	I, II	
High Growth Rate and Low Instability						
Medium Growth Rate and Low Instability						
Low Growth Rate and Low Instability	II, III, IV,V	II, III, IV	I, II, III, IV,V	II, III, IV,V	III, IV, V	I, II, III, IV,V

Note: *High Instability* (*greater than 20 per cent*), *Moderate Instability* (*10-20 per cent*), *Low Instability* (*less than 10 per cent*), *Low growth rate* (*less than 3 per cent*), *Medium growth rate* (*3-6 per cent*) *and, High growth rate* (*6 per cent and above*)

sugarcane production in India was as follows: periods II, III, and IV had low growth rates and low instability, period I had a medium growth rate and moderate instability, and period V had a low growth rate but moderate instability. In terms of yield, all five eras in India were classified as having a low growth rate and low instability. This leads us to the conclusion that India had a low growth rate and a low level of instability.

In the case of Uttar Pradesh, the association between growth rate and instability with regard to area, Period II, Period III, Period IV and period V fell under the low growth rate and low instability category, while period I recorded low growth rate and moderate instability category of association.

As for the association between growth rate and instability with regard to production of sugarcane is found mixed, period I and II recorded low growth rate and moderate instability, while period III, IV and V recorded low growth rate and low instability.

As for the association between growth rate and instability with regard to yield, period I, II, III, IV and V were found to low growth rate and low instability category of association in Uttar Pradesh.

It has been observed that there is a correlation between the level of instability and the growth rate. Specifically, when the growth rate is low, the instability is also low, and when the growth rate is large, the instability is also high. No correlation has been shown between a low growth rate and high instability, and vice versa. The interconnections between the growth rate and instability are being referred to. Both entities are exhibiting motion along the same trajectory, and the level of instability will be elevated when the pace of development is likewise elevated. Consequently, none of the five eras in India and the state of Uttar Pradesh exhibited a well-placed period with both low risk and strong growth.

In analyzing the dynamics of instability and growth rate a consistent trend has emerged where the growth rate is low then the instability also tends to be low and conversely, when the growth rate is high then instability also rises. This correlation indicates the intrinsic connection between these factors, as they move in same direction. High growth rates coincide with high rate of instability, suggesting a symbiotic relationship between the two factors. Therefore, out of five periods, not even a single period was well placed with low risk and high growth in India and Uttar Pradesh state.

Sustainability Index of sugarcane yield

Sustainability index measures for sugarcane yield are essential to ensure the long-term viability of the sugar industry while minimizing its environmental impact. The sugar industry is facing numerous challenges, including climate change, labour rights infringements, deforestation, biodiversity loss, water depletion, land degradation, and greenhouse gas emissions.

The sustainability index measures the overall performance of sugarcane production in terms of environmental, social, and economic sustainability. It assesses various indicators, including soil condition, climate, commercial acceptability, energy security, investment security, soil sustainability, climate change, efficiency, profitability, social development, water resources, air quality, and human well-being, impacts on health, impacts

Table 5: Sustainability index of sugarcane yield.

PERIODS	INDIA	UTTAR PRADESH
Period I(1950 to 1967)	0.230	0.166
Period II(1968 to 1985)	0.228	0.134
Period III(1986 to 2003)	0.133	0.127
Period IV(2004 to 2022)	0.164	0.236
Period V(1950 to 2022)	0.474	0.595

on farmers' income, labour conditions, and biodiversity.

Therefore, sustainability in yield of sugarcane in India and Uttar Pradesh has been measured with the help of sustainability indices as described in material and methods section in which the study period was divided into five periods: period I from 1950 to 1967, period II from 1968 to 1985, period III from 1986 to 2003, period IV from 2004 to 2022 and period V from 1950 to 2022 (entire period). The study found that lower sustainability index values closer to zero are the most desirable, indicating a more sustainable yield of sugarcane.

From Table 5 revealed that in India, the sustainability index values were as follows: 0.230 in period I, 0.232 in period II, 0.133 in period III, 0.164 in period IV, and 0.474 in period V. For Uttar Pradesh, the sustainability index values were: 0.116 in period I, 0.134 in period II, 0.147 in period III, 0.236 in period IV, and 0.595 in period V.

Therefore, it was observed that the sustainability index for India and Uttar Pradesh was decreased majorly which is lower value of sustainability index means lower will be the environmental balance and natural sustainability but in recent there is increase in sustainability because of increase in labour and input cost. Overall, the sustainability index was maximum for Uttar Pradesh *i.e.* 0.595 and India (0.474).

Conclusion

From above discussion, highlight that the analysis of sugarcane growth trends in India and Uttar Pradesh for the last 72 year from 1950 to 2022 revealed that positive and significant patterns. The Compound Annual Growth Rate (CAGR) indicates a significant increase in the spread of sugarcane cultivation in both India as a whole and Uttar Pradesh throughout all time periods. Production growth rates in India had significant fluctuations over specific periods. Notably, there were production decline in Period III (1986-2003) and Period IV (2004-2022). Similarly, Uttar Pradesh also experienced a downtrend in Period I (1950-1967) and Period III. Yield growth in Uttar Pradesh was significant during all periods, except for Period I (1950-1967). The analysis of production changes highlights the significant influence of yield enhancement during earlier times, which then transitions to an emphasis on expanding the cultivated area during later decades, namely in Period IV. An analysis of instability reveals a decline in area, output, and yield instability throughout time. However, in recent years, there has been an increase in volatility, mostly due to factors such as water scarcity and market price fluctuations. The association between growth rate and instability implies that periods of fast expansion are linked with more instability, whereas periods of slow growth are associated with reduced instability, demonstrating a strong link between both aspects. Sustainability indices for sugarcane production, which are critical for long-term sustainability, show a variety of patterns. Lower indices in the past indicate more sustainability, while recent eras show increased problems due to growing labor and input costs.

In order to mitigate the potential hazards associated with sugarcane farming, there has been a rise in the cultivation area dedicated to sugarcane. However, the crop's productivity has remained relatively unchanged. Therefore, it is imperative to exert efforts towards improving production. Hence, this study proposes enhancing the sugarcane output by employing high-yielding varieties of sugarcane, implementing enhanced cultivation techniques, and enhancing water and soil management. This will result in less volatility in productivity and overall improvement in sugarcane production. The drought crisis is a contributing reason to instability. Therefore, it is imperative to address this problem by implementing sustainable solutions such as micro-irrigation equipment and mulching. Efforts must be made at the government level and by extension agents to embrace recommended sustainable practices or sustainable sugar initiatives. This would help improve sugarcane production levels while keeping production costs low.

References

Abnave, V.B. (2019) Sustainability Concerns on Sugarcane Production in Maharashtra, India: A Decomposition and Instability Analysis. *The Institute for Social and Economic Change*, Bangalore.

Abnave, V.B. (2015) Growth pattern and profitability of sugarcane cultivation in India: an analysis of Maharashtra, Karnataka and Uttar Pradesh states. *Agricultural Situation in India*, **72(8)**, 16-24.

Agricultural Statistics at a Glance, Directorate of Economics & Statistics. Government of India, Last accessed (2023).

Chand, R. and Raju, S.S. (2009) Instability in Indian Agriculture during different phases of technology and policy. *Indian Journal of Agricultural Economics*, **64(2)**, 283-288.

Cuddy, J.D.A. and Della P.A. (1978). Measuring the instability of time series data. *Oxford Bulletin of Economics Statistics*. **40(1)**, 79-85.

Gaware, U.P., Mishra R.R., Baviskar P.P., Pavithra S., Patibandla L., Kumari K. and Ahmad N. (2022). Growth and decomposition analysis of sugarcane in India. *The Pharma Innovation Journal*, **11(1)**, 232-235.

Kumar, S. and Singh S. (2014). Trends in Growth Rates in Area, Production and Productivity of Sugarcane in Haryana, *International Journal of Advanced Research in Management and Social Sciences*, **4(4)**.

Maurya, O.P., Verma O.P., Kumar H. and Singh J. (2020). Growth and Decomposition Analysis of Sugarcane Production in India. *International Journal of Current Microbiology and Applied Sciences*. **11**, 585-588.

Mishra, P., Sahu P.K., Dhekale B.S. and Vishwajith K.P. (2015). Modeling and forecasting of wheat in India and their yield sustainability. *Indian Journal of Economics and Development*, **11(3)**, 637-647.

Nivetha, T. and Uma K. (2021). Growth, Instability and Decomposition Analysis of Nutri Cereals in Tamil Nadu. *Asian Journal of Agricultural Extension Economics & Sociology*. **39**, 86-90.

Ojha, G.P. and Bhatt K.N. (2018). Instability and Decomposition Analysis of Sugarcane Production in all India, Uttar Pradesh and Maharashtra. *Journal of Agriculture and Allied Sciences*, **7(2)**.

Pattnaik, I. and Shah A. (2015). Trends and decomposition of agricultural growth and crop output in Gujarat: Recent evidence. *Indian Journal of Agricultural Economics*, **70(2)**, 182-197.

Sahu, P.K., Kundu A.L., Mani P.K. and Pramanick M. (2005). Sustainability of different nutrient combination in a long term rice-wheat cropping system. *Journal New Seeds*. **7**, 91-101.

Singh, B., Sharma P., Arya C.K., Singh A. and Kumar J. (2021). Spatial growth and instability analysis of area, production and yield of sugarcane in India. *Economic affair*, **66(2)**, 245-252.

Srivastava, A.B., Supriya Mishra P., Singh K.K. and Choudhary H.P.S. (2022). Instability and production scenario of wheat production in Uttar Pradesh using ARIMA model and it's role in food security. *Indian Journal of Economic Development*, **18(1)**, 181-188.

Supriya Srivastava A.B., Kumari B., Yadav S., Shrivastava A. and Neerugatti M.P. (2023). Comparative Analysis of Sugarcane Production for South East Asia Region. *Sugar Tech.*, 1-10.

Vishawajith, K.P., Sahu P.K., Dhekale B.S. and Mishra P. (2016). Modeling and forecasting sugarcane and sugar production in India. *Indian Journal of Economics and Development*, **12(1)**, 71-80.

Vishwajith, K.P., Sahu P.K., Mishra P., Dhekale B.S. and Upadhyay N. (2018). Crop yield sustainability: A few measures. *Journal of Pharmacognosy and Phytochemistry*, **7(2S)**, 247-253.

Wadghane, R. (2022). Sustainability management status of agro-ecosystems: A case study of sugarcane farmers in Shevgaon and Paithan (Sub-districts) of Maharashtra, India. *Agricultural Research*, **11(4)**, 737-746.