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A Stationarity Analysis of Coarse Cereals Production in India

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Abstract

It is a very well known fact that Coarse cereals are a good source of nutrients and are resilient to climate change. Over that, they are drought tolerant and photo-insensitive. Coarse cereals have potential in the food processing industry and as an exportable commodity. Rajasthan, Maharashtra and Karnataka are among the largest producers of coarse cereals in India. Despite its benefits, the area under cultivation of coarse cereals is declining. Moreover, due to advancements in technology the yield rate has shown an increase. In this research paper the author has made an attempt to analyse the time series data of area under production of coarse cereals and its yield rate in India from 1967-68 to 2023-24. The data has been collected from RBI's Handbook of Statistics on Indian Economy. Further, it has been analysed in the context of its stationarity and structural break and forecasted. Multiple test have been done (to test whether production of coarse cereals is stationary) like ADF and Phillips-Perron Test. In the KPSS test, trend Stationarity is taken as Null Hypothesis and non-trend Stationarity is taken as Alternative Hypothesis. The estimated p-value of the test is 0.01 which is significant at 1% significance level. Thus, the Alternative Hypothesis (non-trend Stationarity) is rejected at 1% significance level. Further, by applying Multiple tests such as Recursive CUSUM test and Recursive MOSUM it has been discovered that there is definitely a structural break in the time series data. In this scenario, government intervention is needed to push the production of coarse cereals and to promote farmers to do so.

Keywords: *Coarse Cereals, Stationarity, Structural Break, Forecasting, Agriculture, Productivity, Sustainability, Food Security, Climate Resilience, Policy Support.*

1. INTRODUCTION

The analysis of coarse cereals production in India is a multifaceted topic that encompasses economic, environmental, and nutritional dimensions. While coarse cereals face significant challenges, their potential to contribute to food security and nutrition in India remains substantial. Addressing profitability and market support could revitalize their cultivation and consumption. A critical examination of the relevant literature reveals significant insights into the dynamics of coarse cereal markets, production trends, and the implications of water use in agriculture.

The foundational work by **(P Rao et al., 2004)** highlights the evolving role of sorghum and millet in Asia's agricultural landscape. The authors note a marked increase in the real price of sorghum straw, outpacing that of grain prices, which underscores a rising demand for livestock feed. This shift indicates a transition of sorghum from traditional food markets to non-food applications, particularly in industries that require consistent supply. The authors stress the necessity for strategic partnerships between research and industry to optimize marketing arrangements and enhance the utilization of sorghum, particularly in non-food sectors. This emphasis on innovation and collaboration is crucial for the future of coarse cereals in India.

Building on this foundation, **(Bhagavatula et al., 2013)** provide a broader context for coarse cereal economies in Asia, revealing that despite significant production increases, the region remains a net importer of coarse cereals. The authors highlight that India plays a crucial role as both an exporter and a major producer of sorghum, which is particularly well-suited for dry agro ecologies. They emphasize the economic value of sorghum, noting that its stover contributes substantially to the overall value of the crop and serves as an essential fodder resource. This economic perspective is vital for understanding the importance of coarse cereals in India's agricultural economy and food security

Further expanding the discussion, **(Kayatz et al., 2019)** delve into the implications of cereal production on water use in India, particularly in the context of the Green Revolution. The authors illustrate how the shift towards high-yielding cereals, particularly rice and wheat, has led to significant environmental impacts, including groundwater depletion. They highlight that cereals account for a substantial portion of water usage in agriculture and point out a concerning trend of declining consumption of coarse cereals. The authors argue for a renewed focus on these nutrient-dense crops to address public health issues related to micronutrient deficiencies, suggesting that increasing coarse cereal consumption could be a beneficial intervention for improving dietary quality in India.

Together, these articles provide a comprehensive overview of the challenges and opportunities facing coarse cereals production in India. They underscore the need for strategic innovations in marketing, production practices, and consumption patterns to enhance the role of coarse cereals in the agricultural and nutritional landscape of the country.

2. REVIEW OF LITERATURE

Coarse cereals in India present both significant challenges and opportunities in the context of agricultural production and food security. Despite their nutritional advantages and climate resilience, coarse cereals have seen a decline in cultivation and profitability.

The production of Coarse cereals has experienced a decrease in area under cultivation, particularly in comparison to rice and wheat, which dominate Indian agriculture **(Oak, 2023)**. The net returns from coarse cereals vary significantly, with some states reporting losses, particularly for finger millet **(Ayalew & Sekar, 2015)**. The Minimum Support Price (MSP) for coarse cereals often does not cover production costs, leading to reduced farmer interest **(Ashok & Sasikala, 2011)**.

Coarse cereals are nutritionally superior to rice and wheat, containing essential micronutrients and functional components that can combat malnutrition **(Zou et al., 2023)**. These crops require less water and are more resilient to climate change, making them suitable for rainfed regions where water scarcity is a concern **(Oak, 2023)**. Government Initiatives: Increased focus on promoting coarse cereals through policy support and awareness can enhance their production and consumption **(Ashok & Sasikala, 2011)**.

Addressing the stagnation in coarse cereal production requires policy support and improved irrigation strategies to leverage their potential **(Jodha, 1973)**. Total Factor Productivity (TFP) growth for coarse cereals has been modest, averaging 1.4% per annum, primarily benefiting from irrigation and technological advancements during the Green Revolution **(Janaiah et al., 2005)**.

The GR introduced improved cultivars and crop management techniques, leading to a total factor productivity (TFP) growth of 1.4% per

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annum for sorghum in Maharashtra, where irrigation was prevalent **(Janaiah et al., 2005)**. The adoption of GR technologies has been linked to increased yields in maize and pearl millet, with productivity gains in the post-GR era being significantly higher than during the GR phase **(Yadav et al., 2019)**.

Expanding coarse cereals cultivation can enhance nutritional supply, increasing protein and iron levels by 1-5% and 5-49%, respectively **(Davis et al., 2019)**. Coarse cereals also contribute to climate resilience, reducing greenhouse gas emissions and irrigation demands, thus promoting sustainable agricultural practices **(Davis et al., 2019)**.

3. OBJECTIVES

- To Analyse the Stationarity of Coarse Cereals Production
- To Analyse the Structural break of Coarse Cereals Production
- To Forecast the Coarse Cereals Production

4. HYPOTHESIS

- The time series of Coarse Cereals Production is non-stationary
- There is no structural break in the time series of Coarse Cereals Production

5. METHODOLOGY OF THE STUDY

This is an analytical study based on secondary sources of data. Many of the previous studies have been reviewed and analysed thoroughly. Further explanation on the methodology of the study are as follows:

- **Time Period of Data:** 1967-68 to 2023-24
- **Source of Data:** Handbook of Statistics on Indian Economy and Ministry of Agriculture and Farmers Welfare (GoI)
- **Use of Software for data Analysis:** SPSS (R essentials)

6. DATA INTERPRETATION, RESULTS AND HYPOTHESIS TESTING

To accompany the objectives of this manuscript; the data about the production of Coarse Cereals have been taken from RBI's Hankook of statistics on Indian Economy.

The test of Stationary (Analysis of Results)

Table-1: Stationary test of Coarse Cereals production

	Values
Test(2)	Phillips-Perron
Alternative Hypothesis(2)	Stationary
P-Value(2)	0.01
Note(2)	p-value smaller than printed p-value
Truncation Lag(2)	3
Test(3)	Augmented Dickey-Fuller
Alternative Hypothesis(3)	Stationary
P-Value(3)	0.58522
Note(3)	None
Truncation Lag(3)	1
Test(4)	KPSS Test for Stationarity
Null Hypothesis(4)	Level
P-Value(4)	0.01
Note(4)	p-value smaller than printed p-value
Truncation Lag(4)	3

Source: **(Handbook of Statistics on Indian Economy & Ministry of Agriculture and Farmers Welfare (GoI) and computations using SPSS (R essentials) software)**

In the ADF test, Alternative Hypothesis is Stationarity and the Null Hypothesis is the Unit Root. The calculated p-value of the test is 0.58522 greater than 0.05 (Normal Critical Threshold of 5% significance level), which is not significant. Thus, the Alternative Hypothesis is rejected at 1% significance level. So, it can be concluded that the time series data that we have tested follows non-stationarity.

In the Phillips-Perron Test, Alternative Hypothesis is Stationarity. The calculated p-value of the test is 0.01 which is significant at 1% significance level. Thus, the Alternative Hypothesis cannot be rejected at 1% significance level.

In the KPSS test, trend Stationarity is taken as Null Hypothesis and non-trend Stationarity is taken as Alternative Hypothesis. The estimated p-value of the test is 0.01 which is significant at 1% significance level.

Thus, the Alternative Hypothesis (non-trend Stationarity) is rejected at 1% significance level. It means that there is a trend in the time series, which implies that there is a difference in the Stationarity series of Coarse Cereals Production.

7. STRUCTURAL BREAK TEST (ANALYSIS OF RESULTS)

The result of Structural Break Test is given in the table below.

Table-2: Structural Change Tests of oilseeds production's time series

	Test Statistic	P-Value
Recursive CUSUM test	1.9557	0
OLS-based CUSUM test	2.9156	0
Recursive MOSUM test	2.7635	0.01
OLS-based MOSUM test	1.9892	0.01
RE test (recursive estimates test)	2.9156	0
ME test (moving estimates test)	1.9892	0.01

Source: **(Handbook of Statistics on Indian Economy & Ministry of Agriculture and Farmers Welfare (GoI) and computations using SPSS (R essentials) software)**

The structural break test has been done to check if there is significant change in key parameters, such as means or coefficients at certain points. It is intended to determine whether there is evidence of one or more points in time where the data's behavior or structure has shifted significantly.

The null hypothesis is taken as there is no structural break, meaning that the relationship between variables remains consistent over time. And the alternative Hypothesis is taken as that there are one or more structural breaks.

The Recursive CUSUM test shows that the test statistic is 1.9557 which is significant at 0.01 level. The OLS-based CUSUM test shows that the test statistic is 2.9156 with p-value of 0, which is significant at 0.01 level. The Recursive MOSUM test indicates that the p-value is significant at 0.01 level. Again the OLS-based MOSUM test shows a p-value significant at 0.01 level. Moreover, the RE test (recursive estimates test) and ME test (moving estimates test) are also significant at 0.01 level. Thus the null hypothesis that there is no significant structural break is rejected. It means that there is a significant structural break in the time series.

The data which has been tested and analysed for structural changes are shown in the figures below.

Figure 1 to 6: Structural Change in the time series of Oilseeds production. The source of data and the method of analysis is the same as for stationary tests.

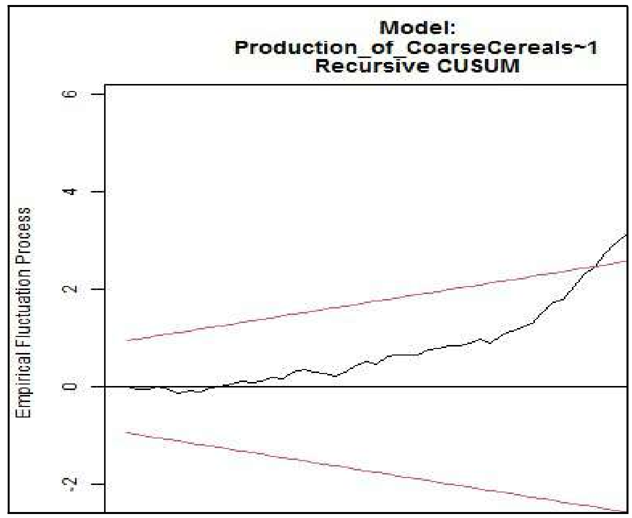

Fig-1: Recursive CUSUM test
Source: **(Computations using SPSS (R essentials) software)**

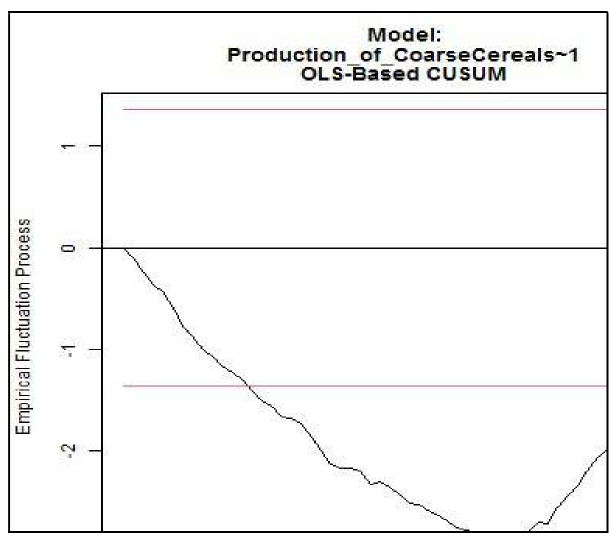

Fig-2: OLS-based CUSUM test
Source: **(Computations using SPSS (R essentials) software)**

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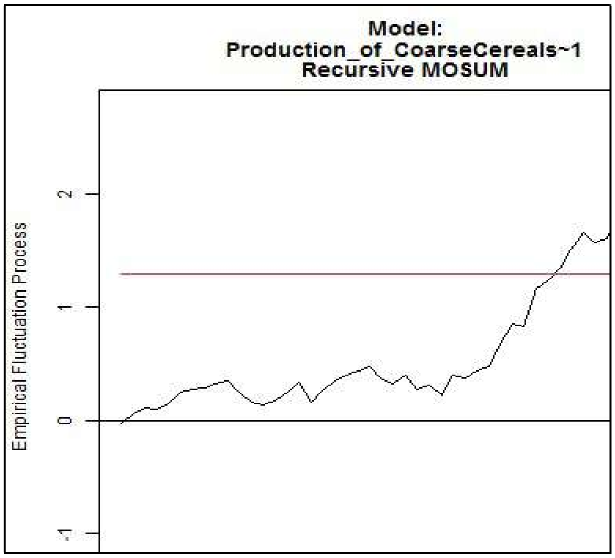

Fig-3: Recursive MOSUM test
Source: **(Computations using SPSS (R essentials) software)**

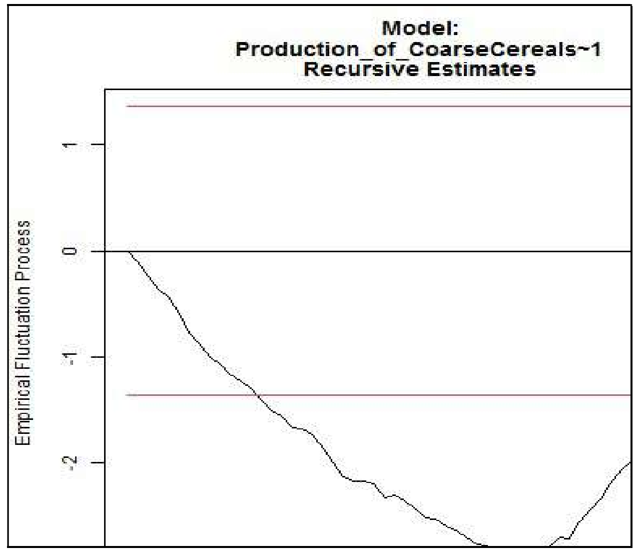

Fig-5: RE test (recursive estimates test)
Source: **(Computations using SPSS (R essentials) software)**

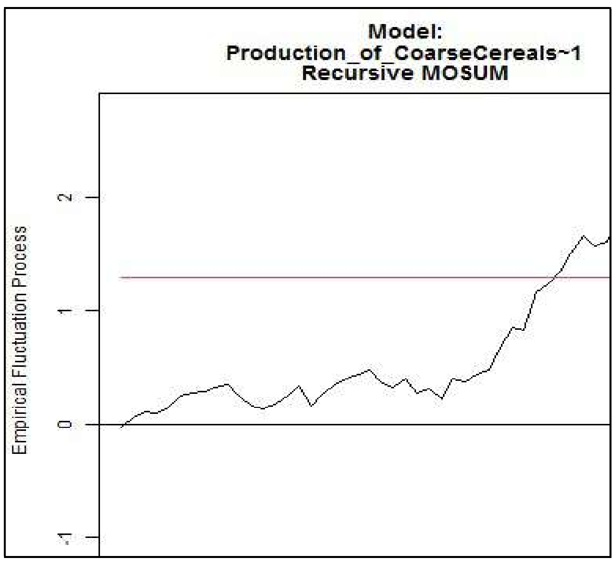

Fig-4: OLS-based MOSUM test
Source: **(Computations using SPSS (R essentials) software)**

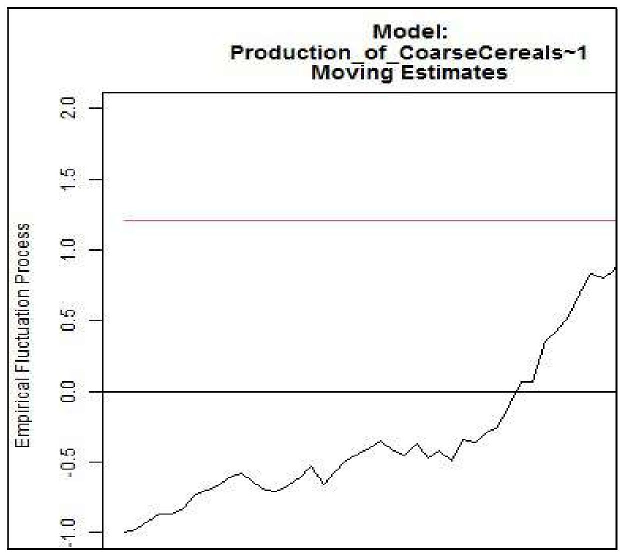

Fig-6: ME test (moving estimates test)
Source: **(Computations using SPSS (R essentials) software)**

Figure 1 to 6, shows the line graphs of time series and structural changes (if any) for oilseeds production. In each diagram the straight red line is the threshold line, whereas the curve in black indicates the production line. Any departure of the curve above or below the threshold lines is a sign of structural changes. It can be seen from the figures, that there is structural change in the time series of oilseeds production (the same is confirmed by Table 2 of structural changes tests). However, the point of time for structural break is different in different tests.

8. FORECASTING OF DATA

The data for next 17 years has been forecasted on the basis of data available for 1967-68 to 2023-24. However, due to the requirements of the software, the years in the table have been mentioned as calendar years and not as financial years. For example, the year 2024-25 is written as 2024. In Table 3, UCL shows the upper class limit and LCL shows the lower class limit of the forecasted data series. The value of exact forecasted data is somewhere between them.

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Table-3: Forecast of Coarse Cereals Production

Model		Forecast																
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Production_of_CoarseCereals-Model_1	Forecast	548.67	563.41	578.15	592.89	607.63	622.38	637.12	651.86	666.60	681.35	696.09	710.83	725.57	740.31	755.06	769.80	784.54
	UCL	615.62	630.79	646.33	662.36	678.97	696.22	714.16	732.82	752.19	772.25	792.98	814.34	836.29	858.80	881.83	905.34	929.31
	LCL	481.71	496.03	509.97	523.42	536.30	548.53	560.07	570.90	581.02	590.44	599.20	607.32	614.86	621.83	628.29	634.26	639.77

For each model, forecasts start after the last non-missing in the range of the requested estimation period, and end at the last period for which non-missing values of all the predictors are available or at the end date of the requested forecast period, whichever is earlier.

Source: **(Handbook of Statistics on Indian Economy & Ministry of Agriculture and Farmers Welfare (GoI) and computations using SPSS (R essentials) software)**

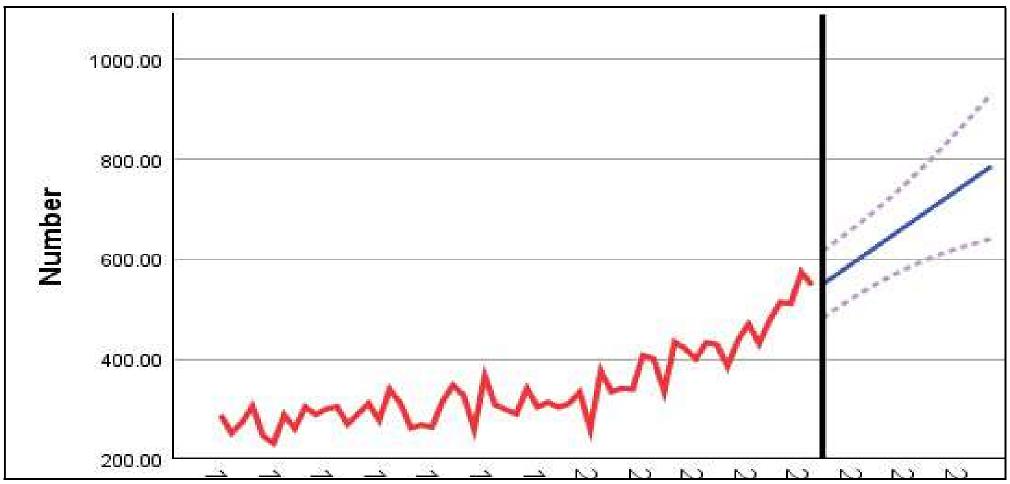

Fig-7: Forecast of the Oilseeds Production from 2024-25 to 2040-41

The above figure has been plotted on the basis of past data and forecasted data (given in table 3). In the figure the red curve shows the line graph for past data. The line in blue (running upward) is the line graph for forecasted data series. The forecasted data line is between the two dotted lines, which are the lines of upper class limit and lower class limit.

9. CONCLUSION AND RECOMMENDATIONS

9.1 Reasons for decreasing area under cultivation of Coarse Cereals

The decreasing area under cultivation of coarse cereals can be attributed to several interrelated factors, including economic viability, changing agricultural policies, and environmental challenges. These elements collectively contribute to a decline in the cultivation of coarse cereals, despite their nutritional and climate resilience benefits. The following sections outline the key reasons for this trend.

- **Profitability:** Coarse cereals often yield lower net incomes compared to other crops like rice and wheat. For instance, the net income from mash crops was significantly lower than that from bajra and rice, leading farmers to favor more profitable options **(Sher et al., 2015)**.
- **Market Demand:** The demand for rice and wheat has historically overshadowed that for coarse cereals, resulting in reduced cultivation areas as farmers respond to market signals **(Oak, 2023)**.
- **Decoupling of Payments:** The introduction of policies like the Single Payment Scheme (SPS) has incentivized farmers to reduce cereal production, including coarse cereals, as they are less

competitive in the current market environment(Severini & Valle, 2008).

- **Lack of Support:** There is insufficient government support and Minimum Support Prices (MSP) for coarse cereals, which discourages farmers from cultivating them(Oak, 2023).
- **Climate Change:** Global warming poses a significant threat to suitable regions for cereal cultivation, with predictions indicating a potential decrease in suitable areas by 46% under increased CO_2 conditions(Okamoto et al., 1997). This impacts coarse cereals, which are often more resilient but still face challenges from changing weather patterns.

9.2 Measures to increase the production of Coarse Cereals

The following measures can significantly boost their production:

- Drought Resistance: Coarse cereals exhibit adaptive mechanisms to drought, which can be leveraged to improve yields under changing climate conditions (Zou et al., 2023).
- Sustainable Practices: Utilizing less water compared to rice and wheat, coarse cereals can be promoted in water-scarce regions (Oak, 2023).
- Molecular Breeding: Advanced techniques like CRISPR and speed breeding can enhance desirable traits in coarse cereals, potentially increasing yield and reducing the time to market (M et al., 2020).
- Genetic Diversity: Emphasizing the importance of genetic variability can help develop more resilient crop varieties (M et al., 2020).
- Value Chain Enhancement: Creating a robust value chain for millets through processing innovations and marketing strategies can increase consumer demand (Rao et al., 2021).
- Nutritional Awareness: Promoting the health benefits of coarse cereals can attract health-conscious consumers, thereby increasing market demand (Rao et al., 2021).

9.3 Reasons for Structural Break in the production of Coarse Cereals

The production of coarse cereals in India has experienced significant structural breaks due to various interrelated factors. These breaks have led to a decline in the growth rates and yields of coarse cereals, despite their potential benefits. Understanding these reasons is crucial for addressing the challenges faced by this sector.

- **Historical Context of Structural Breaks**
  - Structural breaks in coarse cereals production were notably observed around 1967-68 and 1988-89, coinciding with broader agricultural reforms and shifts in policy focus towards rice and wheat(Ghosh, 2013)(Ghosh, 2013).
  - The post-reform period has seen increased interstate variations in growth rates, with many states experiencing a deceleration in coarse cereals production(Ghosh, 2013).

- **Changing Agricultural Practices**
  - A significant shift in cropping patterns has occurred, with farmers increasingly favoring high-yielding varieties of rice and wheat over coarse cereals, which are perceived as less profitable(Meenal, 2018).
  - The introduction of modern agricultural practices and inputs has not been equally applied to coarse cereals, leading to lower yields and reduced area under cultivation(Oak, 2023).

- **Climate Resilience and Nutritional Aspects**
  - Coarse cereals are more climate-resilient, requiring less water than rice and wheat, yet their production has not been prioritized in agricultural policies(Oak, 2023).
  - Despite their nutritional superiority, coarse cereals have not gained the same market traction, leading to a decline in their production(Oak, 2023).

Conversely, while the decline in coarse cereals production is evident, some argue that the focus on rice and wheat has been necessary to ensure food security for a growing population. This perspective highlights the complex trade-offs in agricultural policy and production priorities in India.

9.4 Significance of Structural Break

The significance of structural breaks in the production of coarse cereals is multifaceted, impacting both agricultural practices and nutritional outcomes. Structural breaks refer to significant shifts in production trends, which can influence the efficiency and sustainability of coarse cereal cultivation. Understanding these breaks is crucial for optimizing production strategies and enhancing food security. The following sections elaborate on key aspects of this significance.

- **Impact on Production Trends**
  - Structural breaks in coarse cereal production can indicate shifts in agricultural practices, such as the introduction of new technologies or changes in crop management strategies **(Ghosh, 2013)**.
  - Historical data shows that production growth rates have decelerated post-1988, highlighting the need for adaptive strategies in response to these breaks **(Ghosh, 2013)**.

- **Nutritional Benefits**
  - Coarse cereals are rich in phytochemicals and antioxidants, contributing to improved health outcomes and reduced chronic disease risks **(Kaur et al., 2014)**.
  - Their incorporation into diets can enhance nutritional diversity, especially when combined with staple cereals like rice and wheat **(Kaur et al., 2014)**.

- **Economic Implications**
  - The processing of coarse cereals, such as broken rice, can lead to value-added products, improving economic returns for farmers and processors **(Jianshu, 2015)**.
  - Structural breaks can also affect market dynamics, influencing supply chains and pricing strategies for coarse cereals **(Ghosh, 2013)**.

Conversely, while structural breaks can present challenges, they also offer opportunities for innovation in agricultural practices and product development, potentially leading to more resilient food systems.

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