

## Crop Adaptation in a Changing Climate: Trends in Soybean, Cotton, and Tur (Pigeon Pea) Production in Amravati Division

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### Abstract:

This paper investigates the impact of rainfall fluctuations on the production trends of major crops—cotton, soybean, and tur (pigeon pea)—in the Amravati Division of Maharashtra, India, from 2011 to 2023. Analysing annual production data across five districts (Akola, Amravati, Buldhana, Washim, and Yavatmal) in relation to rainfall patterns, the study reveals a significant correlation between climatic variability and crop yields. Soybean, cotton, and tur production exhibited considerable volatility, with sharp declines during low rainfall years and increases in periods of favourable precipitation. Buldhana and Amravati demonstrated better recovery trends, suggesting some level of crop adaptation, while Akola, Washim, and Yavatmal showed higher sensitivity to rainfall inconsistencies. The findings underscore the need for improved irrigation infrastructure, climate-resilient seed varieties, enhanced soil and water conservation techniques, and diversified cropping systems to foster long-term agricultural stability and mitigate the adverse effects of climate change in the region.

**Keywords:** *Crop Adaptation, Climate Change and Rainfall Variability*

### 1. Introduction:

Agriculture is the backbone of the economy in Amravati Division, playing a crucial role in the livelihoods of farmers and the overall development of the region. Over the years, the division has witnessed significant shifts in cropping patterns, largely influenced by climate change, market dynamics, and technological advancements.

Amravati Division, located in **Maharashtra**, consists of **five districts**: Amravati, Akola, Buldhana, Washim, and Yavatmal. The region is known for its **semi-arid climate**, with erratic rainfall and temperature fluctuations affecting agricultural productivity., is known for its

diverse agricultural practices. The region primarily cultivates cotton, soybean, and tur (pigeon pea), which are essential for both commercial and subsistence farming. The division's agricultural landscape is shaped by factors such as soil type, rainfall patterns, and irrigation facilities.

Cotton is a dominant cash crop, cotton cultivation supports thousands of farmers and contributes significantly to the textile industry. Soybean is Emerging as a key crop, soybean is valued for its oil and protein content, making it an essential component of the agricultural economy. Tur (Pigeon Pea) is a staple pulse crop, tur is crucial for food security and soil fertility, as it enhances nitrogen levels in the soil.

## 2. Objectives of the Study:

1. To analyse **annual trends** in Soybean, Cotton, and Tur production across Akola, Amravati, Buldhana, Washim, and Yavatmal.
2. To assess **the impact of rainfall fluctuations** on crop yields.
3. To determine **crop resilience and adaptation patterns** over time.
4. To propose **strategies for climate-resilient farming** in affected districts.

## 3. Research Methodology:

- ◆ **Data Collection:** Historical production, rainfall records, and percentage changes for each district.
- ◆ **Comparative Analysis:** Identifying production trends relative to rainfall patterns.
- ◆ **Statistical Methods:** Calculating growth rates, decline percentages, and stability measures.
- ◆ **Interpretation:** Assessing the correlation between weather variations and crop performance.

‘Since changes in rainfall have had a greater impact on crop production than other climatic factors like temperature, this paper focuses on rainfall pattern variations to assess their effect on crop adaptation.’

## 4. Climate Change Trends in Amravati Division:

Climate change has led to temperature fluctuations, erratic rainfall, and extreme weather events, affecting crop yields and farming practices. Farmers in Amravati Division have been forced to adopt climate-resilient crops, improved irrigation methods, and soil conservation techniques

to mitigate the adverse effects. Studies indicate that crop diversification and adaptation strategies are essential for sustaining agricultural productivity in the face of climate change

Amravati Division faces significant climate variability, with an average annual temperature of **26.7°C**, peaking at **40.9°C** in May. Rainfall, averaging **1052 mm**, is mostly concentrated in July, but shifting climate patterns have led to unpredictable monsoons and erratic temperature changes.

Extreme weather events such as **droughts, floods, and erratic monsoons** have disrupted agriculture, reducing crop yields—especially wheat—and worsening soil degradation. Rising temperatures have also increased **pest infestations**, making sustainable farming more challenging. Farmers are now adopting **irrigation improvements and climate-resilient crops** to counter these impacts.

Climate models predict that Amravati Division could experience a temperature rise of up to **3.7°C** by the end of the century, leading to more frequent heatwaves and extreme precipitation events. Rainfall patterns are expected to become more erratic, with an increase in heavy-precipitation events that could lead to flooding and soil erosion. These changes necessitate adaptive agricultural strategies, including climate-resilient crop varieties, improved irrigation techniques, and sustainable soil management

## 5. District wise land utilisation pattern:

The land utilization across districts in Amravati Division shows considerable

variation in cultivable and non-cultivable land distribution.

**Table: 1**  
**Land Utilization Pattern by District (00' ha)**

District	Total Geographical Area (sq. km)	Total Cultivable Land (sq. km) (Percentage)	Non-Cultivable Land (sq. km) (Percentage)
Amravati	12,235	6,729 (55%)	5,506 (45%)
Akola	5,427	3,256 (60%)	2,171 (40%)
Buldhana	9,661	5,603 (58%)	4,058 (42%)
Washim	5,150	3,193 (62%)	1,957 (38%)
Yavatmal	13,582	6,791 (50%)	6,791 (50%)

**Source:** Land Utilization Statistics (2018), Mahaagri, Department of Agriculture, Govt. of Maharashtra

**Washim** leads with the highest cultivable land percentage (62%), followed closely by **Akola** (60%) and **Buldhana** (58%). These districts rely heavily on agriculture, supporting both staple and cash crops. **Amravati**, while still highly agricultural (55%), has a significant share of non-cultivable land, reflecting a mix of urban expansion, forested areas, and barren land. **Yavatmal**, in contrast, has the lowest cultivable land (50%), largely due to its extensive forest cover, making it ecologically significant within the division.

The non-cultivable land percentage further highlights differences in land use patterns. **Yavatmal** tops this category, with 50% of its land being non-cultivable, reinforcing its role in biodiversity conservation. **Amravati** follows with 45%, likely influenced by urban development and semi-arid zones. **Buldhana** and **Akola** maintain similar shares (42% and 40%,

respectively), reflecting a balance between agriculture and other land uses. **Washim**, with the lowest non-cultivable land (38%), remains predominantly agricultural. These variations illustrate how geography, climate, and economic priorities influence district-wise land utilization across Amravati Division.

**6. Annual Trends in Soybean Production and Rainfall Across Districts in Amravati Division (2011-2023):**

The table-2 presents annual soybean production trends across Akola, Amravati, Buldhana, Washim, and Yavatmal, along with variations in rainfall over the years. The percentage changes in parentheses indicate year-on-year growth or decline in production, helping identify patterns influenced by climatic conditions.

**Table: 2**  
**Annual Trends in Soybean Production and Rainfall (2011-2023)**

("00" tonnes) (%)

Year	Akola	Amravati	Buldhana	Washim	Yavatmal	Rainfall (mm)
2011-12	1,677 (-)	3,731 (-)	3,742 (-)	2,906 (-)	2,981 (-)	846
2012-13	2,904 (+73.16%)	4,718 (+26.45%)	4,303 (+14.99%)	3,382 (+16.37%)	3,891 (+30.52%)	875
2013-14	1,919 (-33.91%)	3,527 (-25.24%)	4,790 (+11.31%)	2,323 (-31.31%)	1,566 (-59.75%)	1019
2014-15	696 (-63.73%)	1,283 (-63.62%)	1,891 (-60.52%)	1,213 (-47.78%)	976 (-37.67%)	598
2015-16	1,021 (+46.69%)	1,267 (-1.24%)	1,604 (-15.17%)	1,682 (+35.71%)	1,409 (+44.36%)	661
2016-17	3,057 (+199.41%)	4,834 (+281.53%)	7,036 (+338.65%)	4,461 (+165.21%)	2,824 (+100.24%)	792
2017-18	1,440 (-52.89%)	2,652 (-45.13%)	4,396 (-37.52%)	2,271 (-49.09%)	2,063 (-26.94%)	552
2018-19	2,988 (+107.50%)	3,516 (+32.57%)	4,484 (+2.00%)	4,143 (+82.43%)	3,272 (+58.60%)	701
2019-20	1,902 (-36.34%)	1,986 (-43.51%)	5,358 (+19.49%)	3,237 (-21.86%)	2,344 (- 28.36%)	816
2020-21	2,656 (+39.34%)	2,003 (+0.85%)	6,951 (+29.73%)	5,253 (+62.27%)	2,851 (+21.62%)	612
2021-22	2,506 (-3.38%)	2,601 (+29.85%)	7,477 (+7.56%)	5,024 (-4.35%)	2,866 (+0.52%)	756
2022-23	3,876 (+51.05%)	1,810 (-30.41%)	7,916 (+5.87%)	9,227 (+83.66%)	2,300 (-19.74%)	677
<b>Total</b>	<b>31,662</b>	<b>46,096</b>	<b>65,517</b>	<b>52,602</b>	<b>29,162</b>	<b>9,983</b>
<b>Average</b>	<b>2,638</b>	<b>3,841</b>	<b>5,460</b>	<b>4,384</b>	<b>2,430</b>	<b>832</b>

**Sources:** Maha-Agri, Department of Agriculture, Govt. of Maharashtra, Report 2011-23.

**Akola:** Soybean production showed extreme volatility, with sharp declines in 2014-15 (-63.73%) during low rainfall (598 mm) and peaks in 2016-17 (+199.41%) and 2018-19 (+107.50%), aligning with moderate rainfall (792 mm, 701 mm). Production is highly dependent on rainfall consistency.

**Amravati:** Soybean in Amravati experienced major fluctuations, with steep drops in 2014-15 (-63.62%) due to low rainfall (715 mm), while the highest recovery occurred in 2016-17 (+281.53%), during 878 mm rainfall. Consistency in rainfall plays a crucial role in stabilizing production.

**Buldhana:** The highest producer, with less volatility compared to other districts. Despite major drops in 2014-15 (-60.52%), the strongest recovery in 2016-17 (+338.65%) and steady performance in 2018-19 (+2.00%) suggest good resilience to climatic variations.

**Washim:** Production peaked in 2016-17 (+165.21%), coinciding with 902 mm rainfall, while major drops occurred in 2014-15 (-47.78%), with low rainfall (564 mm). The district remains highly sensitive to rainfall inconsistencies.

**Yavatmal:** Production fluctuated with sharp declines in dry years (2013-14: -59.75%), 2014-15 (-37.67%), and 2022-23 (-19.74%), while moderate rainfall years

boosted yields. This district has less stability compared to Buldhana and Amravati.

Soybean production across districts shows high sensitivity to rainfall fluctuations, with sharp declines in drought years (2014-15, 2017-18) and peak yields in moderate rainfall periods (2016-17, 2018-19). Buldhana and Amravati demonstrate strong resilience, while Akola and Yavatmal struggle with stability, highlighting the need for better climate adaptation strategies.

### 7. Annual Trends in Cotton Production and Rainfall Across Districts in Amravati Division (2011-2023):

**Table: 3**  
**Annual Trends in Cotton Production and Rainfall (2011-2023)**  
(“00” tonnes) (%)

Year	Akola	Amravati	Buldhana	Washim	Yavatmal	Rainfall (mm)
2011-12	2593 (--)	2702 (--)	3217 (--)	1039 (--)	7135 (--)	846
2012-13	3240 (+24.95%)	6115 (+126.31%)	3461 (+7.58%)	880 (-15.30%)	9814 (+37.54%)	875
2013-14	3436 (+3.54%)	6332 (+3.54%)	6396 (+84.80%)	373 (-57.61%)	7004 (-28.63%)	1019
2014-15	1226 (-64.31%)	1962 (-69.01%)	1325 (-79.28%)	168 (-54.95%)	2874 (-59.44%)	695
2015-16	1949 (+58.97%)	4170 (+112.53%)	1658 (+25.13%)	196 (+16.66%)	4834 (+68.19%)	707
2016-17	4427 (+127.14%)	8040 (+92.80%)	5166 (+211.18%)	375 (+91.32%)	10979 (+127.12%)	792
2017-18	2404 (-45.69%)	3803 (-52.69%)	1809 (-64.98%)	177 (-52.80%)	4775 (-56.50%)	552
2018-19	4195 (+74.50%)	6260 (+64.60%)	3089 (+70.75%)	356 (+101.12%)	8440 (+76.75%)	701
2019-20	3806 (-9.27%)	4602 (-26.48%)	1571 (-49.14%)	360 (+1.12%)	5527 (-34.51%)	816
2020-21	3355	7404	4751	818	7620	612

	(-11.84%)	(+60.88%)	(+262.41%)	(+127.72%)	(+37.86%)	
<b>2021-22</b>	3055 (-8.94%)	6189 (-16.41%)	5472 (+15.17%)	604 (-26.16%)	7208 (-5.40%)	756
<b>2022-23</b>	3624 (+18.62%)	3874 (-37.40%)	5425 (-0.85%)	413 (-31.62%)	5698 (-20.94%)	677
<b>Total</b>	<b>42,685</b>	<b>68,863</b>	<b>50,839</b>	<b>6,878</b>	<b>91,152</b>	<b>9,983</b>
<b>Average</b>	<b>3,557</b>	<b>5,738</b>	<b>4,236</b>	<b>573</b>	<b>7,596</b>	<b>832</b>

**Sources:** Maha-Agri, Department of Agriculture, Govt. of Maharashtra, Report 2011-23.

The above table presents annual soybean production trends across Akola, Amravati, Buldhana, Washim, and Yavatmal, along with variations in rainfall over the years. The percentage changes in parentheses indicate year-on-year growth or decline in production, helping identify patterns influenced by climatic conditions.

**Akola:** Cotton production declined sharply in 2014-15 (-64.31%) due to low rainfall (598 mm) but rebounded in 2016-17 (+127.14%), aligning with 792 mm rainfall. Production struggles to recover quickly after drought periods.

**Amravati:** Similar trends to Akola, with the worst drop in 2014-15 (-69.01%), followed by a strong recovery in 2016-17 (+92.80%), highlighting its rainfall dependency. Stability remains a challenge.

**Buldhana:** Demonstrated the best recovery trends, with major declines in 2014-15 (-79.28%) but an exceptional rebound in 2016-17 (+211.18%), showing strong resilience in post-drought conditions.

**Washim:** The weakest district for cotton production, highly sensitive to rainfall variations. Declines in 2014-15 (-54.95%) aligned with low rainfall (564 mm), while major increases in 2020-21 (+127.72%) were seen during high rainfall (892 mm).

**Yavatmal:** The highest cotton producer, but highly volatile. The worst declines

were in 2014-15 (-59.44%), while peak recovery in 2016-17 (+127.12%) proves its heavy dependence on climatic stability.

Cotton yields are directly influenced by rainfall, with major losses in dry years (2014-15, 2017-18) and strong recoveries in wet years (2016-17, 2018-19). Yavatmal leads in total production but faces extreme volatility, while Buldhana exhibits the best recovery patterns, showing higher adaptability. Akola and Washim remain highly vulnerable, necessitating improved irrigation and soil conservation techniques.

### 8. Annual Trends in Tur Production and Rainfall Across Districts in Amravati Division (2011-2023):

The table- 4 presents annual soybean production trends across Akola, Amravati, Buldhana, Washim, and Yavatmal, along with variations in rainfall over the years.

**Akola:** Akola shows significant fluctuations in production, with the highest increase occurring in **2012-13 (+323%)** and **2019-20 (+325%)**. A sharp decline was observed in **2014-15 (-77%)** and **2022-23 (-73%)**. The total production across the years is **10,139**, with an average of **845** per year. Rainfall trends generally

**Table: 4**  
**Annual Trends in Tur Production and Rainfall (2011-2023)**

("00" tonnes) (%)

Year	Akola	Amravati	Buldhana	Washim	Yavatmal	Rainfall (mm)
2011-12	220 (-)	1089 (-)	441 (-)	296 (-)	1089 (-)	846
2012-13	931 (+323%)	1331 (+22%)	439 (-0%)	356 (+21%)	1201 (+10%)	875
2013-14	838 (-10%)	1339 (+1%)	148 (-66%)	223 (-38%)	804 (-33%)	1019
2014-15	196 (-77%)	368 (-73%)	185 (+25%)	162 (-27%)	255 (-66%)	695
2015-16	451 (+130%)	576 (+57%)	242 (+31%)	230 (+42%)	626 (+145%)	707
2016-17	1420 (+215%)	1469 (+155%)	644 (+166%)	356 (+55%)	2309 (+269%)	792
2017-18	597 (-58%)	1111 (-24%)	477 (-27%)	190 (-47%)	1308 (-43%)	552
2018-19	345 (-42%)	1255 (+13%)	454 (-4%)	344 (+81%)	1449 (+11%)	701
2019-20	1155 (+325%)	901 (-28%)	1112 (+145%)	390 (+13%)	433 (-70%)	816
2020-21	504 (-56%)	1011 (+12%)	1426 (+28%)	535 (+37%)	799 (+85%)	612
2021-22	1580 (+213%)	1133 (+12%)	3716 (+161%)	368 (-31%)	1390 (+74%)	756
2022-23	422 (-73%)	396 (-65%)	689 (-82%)	396 (+8%)	542 (-61%)	677
<b>Total</b>	<b>10,139</b>	<b>13,678</b>	<b>11,975</b>	<b>4,986</b>	<b>12,831</b>	<b>9,983</b>
<b>Average</b>	<b>845</b>	<b>1,140</b>	<b>998</b>	<b>415</b>	<b>1,069</b>	<b>832</b>

**Sources:** Maha-Agri, Department of Agriculture, Govt. of Maharashtra, Report 2011-23.

**Akola:** Akola shows significant fluctuations in production, with the highest increase occurring in **2012-13 (+323%)** and **2019-20 (+325%)**. A sharp decline was observed in **2014-15 (-77%)** and **2022-23 (-73%)**. The total production across the years is **10,139**, with an average of **845** per year. Rainfall trends generally correlate with production, but large

variations suggest external factors affecting yield.

**Amravati:** Amravati's production remained relatively stable, with notable growth in **2016-17 (+155%)** and **2012-13 (+22%)**. However, there was a sharp drop in **2014-15 (-73%)** and **2022-23 (-65%)**. The total production stands at **13,678**, averaging **1,140** annually. Rainfall trends

exhibit moderate fluctuations, influencing production patterns.

**Buldhana:** Buldhana's production saw its largest increase in **2016-17 (+166%)** and **2021-22 (+161%)**. The most severe decline occurred in **2013-14 (-66%)** and **2022-23 (-82%)**. The total production over the years is **11,975**, with an annual average of **998**. Production is heavily influenced by rainfall, with years of high precipitation leading to significant growth.

**Washim:** Washim exhibited extreme variations, with production surging in **2018-19 (+81%)** and **2020-21 (+37%)**, but major declines in **2017-18 (-47%)** and **2021-22 (-31%)**. The total production over the years is **4,986**, averaging **415** annually. With its relatively lower total yield compared to other districts, production appears highly sensitive to rainfall changes.

**Yavatmal:** Yavatmal showed considerable swings in production, peaking in **2016-17 (+269%)** and **2021-22 (+74%)**. However, production fell sharply in **2014-15 (-66%)** and **2019-20 (-70%)**. The total production is **12,831**, with an average of **1,069** annually. Despite high rainfall variations, production patterns reflect adaptability across different conditions.

Tur production is the most volatile among the three crops, with dramatic declines in low-rainfall years (2014-15, 2022-23) and massive spikes in wet periods (2016-17, 2021-22). Yavatmal and Amravati dominate production but experience extreme instability, while Buldhana shows better recovery ability. Washim struggles the most, emphasizing the need for more sustainable farming practices to mitigate climate risks

## 9. Conclusion:

The annual trends in Soybean, Cotton, and Tur production across Akola, Amravati, Buldhana, Washim, and Yavatmal reveal a strong correlation with rainfall fluctuations, making climatic stability a critical factor for agricultural sustainability.

- **Soybean:** Production fluctuates significantly across all districts, with peak years (2016-17, 2018-19) aligning with moderate rainfall (700-800 mm). Buldhana and Amravati show the best recovery trends, while Akola and Yavatmal struggle with stability.
- **Cotton:** This crop exhibits severe drops during drought years (2014-15, 2017-18) and strong recoveries in favorable rainfall periods. Yavatmal remains the top producer, but Buldhana displays the best resilience, bouncing back faster than other districts. Washim remains the weakest producer with extreme sensitivity to rainfall changes.
- **Tur:** Tur exhibits the most volatility, with sharp declines in low rainfall years (2014-15, 2017-18, 2022-23) and massive spikes in wet years (2016-17, 2021-22). Yavatmal and Amravati lead in production, but Washim remains highly unstable compared to the other districts.

## Crop Adaptation – Has It Happened?

Crop adaptation appears partially implemented but not fully effective, as extreme yield fluctuations persist despite varying rainfall conditions.

- ◆ Districts with better adaptation: Buldhana and Amravati show strong recovery trends, suggesting some level of adaptation, possibly through better irrigation, resilient seed varieties, or improved farming techniques.
- ◆ Districts struggling with adaptation: Akola, Washim, and Yavatmal display high sensitivity to rainfall fluctuations, with significant losses in drought years. This indicates that adaptation strategies may be inadequate or inconsistently applied across these regions.

### Recommendations for Better Crop Adaptation

1. Improve irrigation infrastructure to mitigate losses during low rainfall years.
2. Introduce climate-resilient seed varieties to stabilize production across all districts.
3. Enhance soil and water conservation techniques to retain moisture and reduce reliance on unpredictable rainfall cycles.
4. Encourage diversified cropping systems to minimize risks associated with extreme climate fluctuations.

While some adaptation has occurred, production trends still indicate high vulnerability to rainfall changes, meaning more robust climate strategies are necessary to achieve long-term stability.

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