

In-Depth Analysis: CH₄ Emissions from Agriculture

1. Full-Series Trend (1970–2024): India's Largest Methane Source

Methane from agriculture, primarily from livestock (enteric fermentation) and rice cultivation, is India's largest single source of CH₄ emissions. The overall trend is one of significant but steady growth, rising from ~348 Mt CO₂eq in 1970 to ~572 Mt CO₂eq in 2024. Unlike the explosive, exponential growth of CO₂ sectors, agricultural methane has followed a more linear, "heavy-tanker" trajectory—massive in scale but slower to change course. Its growth has been persistent, but not runaway.

2. Breakpoint Detection: The Green Revolution and a Long Slowdown

The analysis identifies key breakpoints at **1976, 1989, and 2019**. These dates correspond to major shifts in India's agricultural development. The slopes [3.9, 6.7, 2.8, 5.8] tell a story of a boom, a long moderation, and a recent, concerning re-acceleration.

Regime 1 & 2: 1970–1988 (The Green Revolution Boom)

- **Slopes: 3.9 and 6.7**
- The break in 1976 marks the onset of the "Green Revolution" taking full effect. The subsequent doubling of the emissions growth rate to **6.7** reflects the rapid intensification of agriculture during this period—including a significant expansion of livestock populations and increased rice cultivation—which drove a boom in methane output.

Regime 3: 1989–2018 (The Long Moderation)

- **Slope: 2.8**
- This is the most defining period for the sector. For three decades, the rate of emissions growth **slowed by more than half**. This "long moderation" is a crucial insight. It suggests that after the initial revolutionary boom, the agricultural system entered a phase of saturation or consolidation. The explosive growth in livestock numbers and rice paddies tempered, leading to a much more manageable, slower rate of emissions increase.

Regime 4: 2019–2024 (The Re-Acceleration)

- **Slope: 5.8**
- The 2019 break marks a concerning reversal. The growth rate has **doubled again**, returning to levels not seen since the 1980s. This suggests a recent

re-intensification of the agricultural sector.

- The COVID-19 pandemic had no structural impact on this trend (p-value *approx* 0.28), as agricultural activity continued, confirming the sector's resilience to economic shocks.

3. Piecewise & ARIMA Insights: A Return to a High-Growth State

The shift in slopes clearly shows the transition from a high-growth to a low-growth and back to a high-growth state. The forecast, based on an **ARIMA(3, 2, 0)** model for the final regime, projects emissions will reach **~629 Mt CO₂eq by 2034**. This represents a **~10% increase** over the decade—a significant absolute increase, but a modest growth *rate* compared to CO₂ sectors.

4. Core Data-Backed Conclusions

- **A Story of Moderation and Reversal:** The key narrative for agricultural methane is not one of runaway growth, but of a boom (Green Revolution), followed by a long and successful (if perhaps unintentional) period of moderation.
- **The Recent Re-acceleration is a Warning:** The post-2019 return to a high-growth trajectory is a major concern. It suggests that the factors that drove the 30-year slowdown may have run their course, and the sector could be entering a new phase of accelerated emissions.
- **Immune to Economic Shocks:** This sector's trajectory is driven by agricultural policy and practices, not the general economy, as shown by its indifference to the 2020 pandemic shock.
- **A Massive but Manageable Challenge:** While the scale of these emissions is immense, their historically slower growth rate and the proven potential for moderation (as seen from 1989-2018) suggest that targeted policies on livestock management and rice cultivation could be highly effective in controlling this crucial emissions source.