INTRODUCTION

Agriculture in India: The agricultural sector is one of the most crucial components of India's economy, contributing to the livelihoods of millions and significantly impacting macroeconomic stability.
Climate Change Impact: However, the sector is increasingly facing challenges due to the intensifying effects of climate change, including erratic weather patterns, such as droughts and floods, as well as shifting temperature and rainfall patterns. These disruptions are threatening the nation's food security and economic foundation.
Key Focus: Our research aims to explore how climate change is affecting agricultural productivity in India, particularly critical macroeconomic indicators like GDP, inflation, unemployment, and trade balances.
Objective: By using the Cobb-Douglas production function model, we seek to quantify the effects of temperature, precipitation, CO2 levels, and other climate variables on agricultural output. Our goal is to provide actionable insights to guide policymakers toward climate-smart agricultural practices and better adaptation strategies.

The figure depicts how climate change is impacting agriculture through four key mechanisms: Temperature and Precipitation Changes, Increased Carbon Dioxide (CO2) Levels, Reduced Water Availability, and Extreme Weather Events.

1. **Temperature and Precipitation Changes**:
    - Climate change is altering agro-climatic zones. Some higher latitude regions may benefit from extended growing seasons.
    - However, for regions already at optimal temperatures, further rises in temperature may negatively impact crop yields and growing cycles. This will affect key factors such as temperature, precipitation, and fertilizer use.
2. **Increased CO2 Levels**:
    - Increased carbon dioxide can improve water-use efficiency and photosynthesis in some crops like wheat, rice, and soybeans. This may lead to higher yields.
    - However, this benefit is offset by factors such as the increased prevalence of weeds and pests, as well as a reduction in the nutritional value of crops.
3. **Reduced Water Availability**:
    - Agriculture in rain-fed regions will suffer due to decreased water availability. This will increase reliance on irrigation, which could lead to overextraction of groundwater.
    - Additionally, increased competition for water among agriculture, industry, and urban populations will exacerbate water shortages.
4. **Extreme Weather Events**:
    - Extreme weather events such as floods and droughts are becoming more frequent. These events lead to greater crop losses, soil erosion, and reduced agricultural productivity.

- Droughts can stress water resources, while floods can cause soil degradation and contaminate water supplies with agricultural chemicals.

These four mechanisms — temperature changes, CO2 levels, water availability, and extreme weather events — are creating significant challenges for agricultural productivity, leading to long-term implications for food security and economic stability.

LITERATURE REVIEW:

Our literature review critically evaluates the intersection of economic impacts, climate change, agriculture, policy, and food security.

We begin by acknowledging the significant role climate change plays in influencing agricultural output.
Robert Mendelsohn (2014), demonstrated how climate variability threatens Asia's agricultural productivity—a region contributing to two-thirds of the global agriculture GDP. Mendelsohn's application of the Ricardian model predicts severe economic losses if adaptive measures are not undertaken.
Naveen Kumar Arora (2019) illuminates the human contribution to climatic extremes, forecasting a decline of 20-50% in cereal crops by 2100 if current practices persist. This underlines the critical necessity for sustainable agricultural methodologies and international policy coordination to mitigate these adverse effects effectively.

The review also delves into the macroeconomic implications, as detailed by Uvesh Husain and Sarfaraz Javed (2019). Their analysis links increased temperatures and erratic rainfall patterns directly to GDP fluctuations through impacts on agricultural output.

The core of mitigating these challenges lies in adaptive strategies and robust policy frameworks. Our review brings out three vital aspects:

1. Research highlights the lack of fairness in climate negotiations and that there needs to be centrally sound and socially equitable policies
2. Climate-smart solutions require heavy investments for them to be implemented on a wide scale
3. need for coordinated approaches evolving policies, international cooperation, and community involvement to address cli-
   mate change in the agricultural sector.

This approach is vital for crafting policies that address immediate impacts and prepare for long-term sustainability.

Research Methodology

3.1 Cobb – Douglas Production Function Model

Climate change impact estimates primarily rely on empirical and cross-sectional research results. Earlier methods used agro-economic simulation models and agroecological zone analysis to predict agricultural impacts. However, these models struggle to account for pricing effects at the domestic level and data limitations in developing countries. The Ricardian approach, which incorporates farmers' responses to climate change, is preferred but has limitations in regulating key factors and predicting domestic price changes.

The current study uses Cobb-Douglas Production function to overcome the above-mentioned limitations, with an aim to quantify how climate variables influence agricultural outputs in India and project potential future impacts under different climate scenarios. The Cobb-Douglas Production function is used to determine or represent the relationship between the amount of two or more inputs (in our case, 5 inputs) and the amount of output that can be produced.

1. **GDP**:
    - Agriculture is a cornerstone of India's economy, employing around 60% of the population, especially in rural areas.
    - Despite this, the Gross Value Added (GVA) of agriculture has declined from 20.3% to 18.3% in recent years, now accounting for just 14% of the Indian economy.
    - **Key Concern**: In northern India, rising temperatures and erratic rainfall are particularly damaging to wheat production. The long-term impacts of climate change, including water scarcity and soil degradation, are driving down agricultural productivity and GDP.
2. **Unemployment**:
    - Employment in the agricultural sector has significantly declined, from 64% in 1991 to 42.86% in 2022. This leaves a growing number of rural workers without stable employment.
    - **Climate vulnerability**: Seasonal unemployment is worsened by changes in crop cycles, leading to inconsistent agricultural productivity. Migrants from rural areas face limited employment opportunities, especially as the industrial and service sectors have not grown sufficiently to absorb these workers.
3. **Inflation**:
    - Climate variability directly influences food price inflation. For example, in 2020, inflation surged to 8% due to extreme weather events and disruptions caused by COVID-19.
    - Historical data shows that droughts, floods, and hurricanes have severely reduced agricultural yield, driving up food prices. Events like the **2010/2011 La Niña** confirm that global climate shocks can lead to sharp inflation in food markets.
4. **Trade**:

- Climate change is contributing to volatility in agricultural exports and imports, particularly for key crops like rice. In the fiscal year 2021-22, rice exports reached a peak, but production and future trade are under threat.
- **Example**: Floods in South India, notably in Tamil Nadu and Karnataka, have led to waterlogging in rice fields, hampering exports.
- The COVID-19 pandemic further disrupted global trade, increasing logistical costs and delays, exacerbating supply chain challenges for agricultural commodities.

22. Contribution of the Agricultural Sector in GDP (n.d.)
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Suggestions

1. **Promote Climate-Smart Agriculture (CSA)**:
   - Practices like crop diversification and water management increase resilience. The **NAPCC** prioritizes CSA, and regions practicing it in southern India have seen improved yields.
   - **Example**: **Kenya** saw significant food security improvements using drought-resistant crops and efficient irrigation.
2. **Invest in Research and Development (R&D)**:
   - R&D is vital for developing climate-resilient crop varieties and farming techniques.
   - **Example**: The **Sharbati wheat variety** in northern India is a drought-tolerant crop developed through R&D efforts.
3. **Expand Access to Financial Services**:
   - Loans and insurance help farmers invest in climate-resilient technologies.
   - **Example**: **Bangladesh's** microfinance programs helped farmers invest in irrigation and crop diversification, increasing resilience.
4. **Weather Index Insurance**:
   - Insurance that pays based on weather conditions helps farmers manage climate risks.
   - **Example**: In **Maharashtra**, the **PMFBY** provided payouts to farmers during droughts, aiding recovery.
5. **Improve Access to Climate Data**:
   - Real-time data allows farmers to make better decisions.

- **Example**: In **Tamil Nadu**, weather advisories helped reduce crop losses by allowing farmers to adjust schedules.