



Climate Change Impacts on Crop Yield and Phenology

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INTRODUCTION

Climate change is profoundly altering global agricultural systems, impacting crop yields and phenology. Phenology the study of the timing of biological events plays a crucial role in determining agricultural productivity. Shifts in temperature, precipitation patterns, and the frequency of extreme weather events are influencing the growth cycles of crops, leading to significant implications for food security. This essay explores the multifaceted impacts of climate change on crop yield and phenology, highlighting regional variations and adaptation strategies.

1. Understanding Crop Phenology and Yield

- **Crop Phenology:** Refers to the stages of development in a crop's life cycle, including germination, flowering and maturity.
- **Crop Yield:** The total production of a crop per unit area, influenced by factors such as temperature, water availability and soil fertility.

The synchronization of phenological stages with favourable climatic conditions is essential for optimal yield. Disruptions due to climate change can lead to mismatches, adversely affecting productivity.

2. Impacts of Climate Change on Crop Phenology

- **Temperature Increases:** Rising temperatures can accelerate crop development, leading to shortened growing seasons. For instance, in northern China, maize anthesis and maturity dates have advanced by 0.2-5.5 and 0.6-11.1 days per decade, respectively, due to climate warming.
- **Altered Rainfall Patterns:** Changing precipitation patterns, including shifts in timing and intensity, can disrupt planting and harvesting schedules. In the Rift Valley of Kenya, a decrease in rain days during the peak growing season has led to a shortening of the growing season by approximately three weeks since 1976.
- **Extreme Weather Events:** Increased frequency of extreme events like droughts and floods can cause significant delays or failures in crop development. For example, in 2024, unprecedented rainfall in France resulted in a 3-40% reduction in winter crop production.

3. Effects on Crop Yield

- **Reduced Grain Filling Period:** Shortened growing seasons can lead to insufficient time for grain filling, resulting in lower yields. In central Asia, every 1°C increase in minimum temperature during the growing season could decrease rice yields by 10%.
- **Pollen Sterility:** High temperatures during the reproductive phase can cause pollen sterility, leading to reduced grain number and weight. Studies have shown that temperature extremes during the reproductive phase could reduce maize grain yield by up to 90%.
- **Increased Pest and Disease Pressure:** Warmer temperatures can expand the range of pests and diseases, further compromising yields. In Argentina, reduced frost occurrences have led to increased leafhopper infestations in corn fields, resulting in significant yield losses.

4. Regional Case Studies

- **Indus Basin, Pakistan:** Climate change has significantly impacted wheat phenology, with earlier anthesis and maturity dates observed under both RCP4.5 and RCP8.5 scenarios. Adaptation strategies, such as adjusted sowing dates and irrigation practices, have shown potential in mitigating yield losses.
- **Huang-Huai-Hai Plain, China:** Rising temperatures have advanced the flowering and maturity dates of wheat, leading to a reduction in the reproductive growth period. This has implications for both yield and water usage efficiency.
- **North China Plain:** The development of new wheat cultivars has helped mitigate some negative effects of climate change, with yield increases observed under certain scenarios. However, climate warming remains a significant challenge.

5. Adaptation Strategies

- **Crop Calendar Optimization:** Adjusting planting and harvesting dates to align with changing climatic conditions can help maintain productivity. In India and Bangladesh, shifting crop calendars has been identified as a feasible adaptation strategy.
- **Development of Heat-Resistant Varieties:** Breeding crops with enhanced heat tolerance

can improve resilience to temperature extremes. Studies on wheat varieties have shown yield increases ranging from 7% to 12% with improved heat resistance.

- **Integrated Crop Management:** Implementing practices such as optimized irrigation, soil fertility management, and pest control can enhance crop resilience. In Pakistan, combining adjusted sowing dates with improved irrigation practices has led to increased wheat biomass and yield.

6. Challenges and Future Directions

- **Uncertainty in Climate Projections:** Variability in climate models poses challenges in predicting precise impacts on crop phenology and yield. For instance, different rice phenology models exhibit varying biases under warmer climates.
- **Socio-economic Factors:** Access to resources, technology and information influences the ability of farmers to implement adaptation strategies. Smallholder farmers, particularly in developing regions, face significant barriers.
- **Need for Integrated Approaches:** Combining crop modelling, breeding and management practices is essential for developing sustainable solutions. An integrated eco-physiological framework can guide future research efforts to mitigate yield declines.

CONCLUSION

Climate change significantly affects crop phenology and yield, with rising temperatures, altered precipitation patterns and increased frequency of extreme weather events disrupting agricultural productivity. These changes lead to shorter growing seasons, reduced grain filling periods, and increased susceptibility to pests and diseases. Adaptation strategies, such as optimizing sowing dates, developing heat-tolerant cultivars and implementing integrated crop management practices, are essential to mitigate these impacts. However, challenges persist, particularly in regions with limited resources. Continued research, investment in agricultural innovation and supportive policies are crucial to ensure food security in the face of a changing climate.