



## Foundations of Agronomy and Climate Science- An article

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### INTRODUCTION

Agronomy, the science of crop and soil management, has long been the cornerstone of agricultural productivity. In recent decades, however, it has evolved into a dynamic interdisciplinary field that integrates plant genetics, soil science, meteorology, and ecology. This evolution is driven by the pressing need to address global challenges such as climate change, food security, and environmental sustainability.

Climate change poses significant threats to agriculture, manifesting in altered precipitation patterns, increased frequency of extreme weather events, and shifting growing seasons. These changes affect crop yields, soil health, and water availability. Understanding the interplay between agronomy and climate science is crucial for developing adaptive strategies that ensure resilient and sustainable agricultural systems.

This chapter delves into the foundational principles of agronomy within the context of climate science. It explores the impact of climate change on crop production, soil health, and pest dynamics. Additionally, it examines integrated approaches such as climate-smart agriculture and precision farming that aim to mitigate adverse effects and enhance agricultural resilience.

By bridging the gap between traditional agronomic practices and emerging climate science, this chapter provides a comprehensive framework for understanding and addressing the challenges and opportunities in modern agriculture.

Agronomy is the science and technology of producing and using plants for food, fuel, fiber, chemicals, recreation, or land conservation. It encompasses a broad range of disciplines including plant genetics, plant physiology, meteorology, and soil science. Agronomy applies principles from biology, chemistry, economics, ecology, earth science, and genetics to optimize the production and use of crops and to manage natural resources sustainably.

The scope of agronomy extends from the molecular level, where plant breeding and genetics are studied, to the ecosystem level, where soil health, water management, and climate interactions are analyzed. Agronomists work to improve crop yields, enhance nutritional content, develop pest and disease-resistant varieties, and implement sustainable farming practices that conserve resources and protect the environment.

### **Importance of Agronomy in Sustainable Agriculture**

Agronomy plays a pivotal role in sustainable agriculture by integrating scientific knowledge with practical farming techniques to ensure long-term food security and environmental health. Key aspects include:

- **Food Security:** By optimizing crop production and implementing sustainable practices, agronomy contributes directly to global food security, addressing the challenge of feeding a growing population.
- **Economic Stability:** Agronomy enhances the economic stability of farming communities by improving crop yields, reducing production costs, and exploring market opportunities.
- **Sustainable Resource Management:** Agronomy promotes practices that conserve natural resources such as soil, water, and biodiversity, ensuring the longevity and resilience of agricultural systems.
- **Environmental Conservation:** Through soil conservation techniques, responsible pesticide use, and sustainable farming practices, agronomy contributes to environmental conservation.
- **Technological Advancements:** Agronomy drives technological innovations in agriculture, from precision farming technologies to genetically modified crops, contributing to increased efficiency and resilience against environmental challenges.

### **Emerging Global Climate Challenges Affecting Agriculture**

Climate change poses significant threats to agriculture, impacting crop production, water availability, and soil health. Emerging challenges include:

- **Temperature Extremes:** Increased temperatures can lead to heat stress, reducing crop yields. For instance, heat stress during reproductive stages can significantly lower yields in crops like rice and beans.

- **Water Scarcity:** Climate change exacerbates water scarcity, affecting irrigation and reducing crop yields. Droughts limit water availability, making it difficult for farmers to sustain production levels.
- **Soil Salinization:** Higher temperatures and lower precipitation increase the rate of evapotranspiration, leading to salt accumulation in the soil and reduced crop productivity.
- **Pest and Disease Proliferation:** Warmer temperatures and shifting weather patterns facilitate the spread of pests and diseases, posing a major threat to agriculture.
- **Yield Reductions:** Studies project significant yield losses in staple crops due to climate change. For example, wheat yields may decline by 6% to 25% by 2050, and rice yields by 3% to 15%.

### **Overview of Climate Change and Global Warming**

Climate change refers to significant alterations in global weather patterns over extended periods, primarily driven by human activities since the Industrial Revolution. The burning of fossil fuels, deforestation, and industrial processes have led to increased concentrations of greenhouse gases (GHGs) such as carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O) in the atmosphere. These GHGs trap heat, leading to a rise in Earth's average surface temperature—a phenomenon known as global warming. Consequently, regions are experiencing more frequent and intense weather events, including heatwaves, droughts, floods, and storms, disrupting ecosystems and human societies.

### **Greenhouse Gas Emissions and Their Role**

Agriculture is both a contributor to and a victim of climate change. It accounts for approximately 25% of global GHG emissions, primarily through enteric fermentation in livestock (producing methane), rice paddies (methane emissions), and the use of synthetic fertilizers (nitrous oxide emissions). Conversely, agriculture is affected by climate change through altered precipitation patterns, increased temperatures, and more frequent extreme weather events. These changes can lead to reduced crop yields, soil degradation, and increased pest and disease pressures, thereby threatening food security and rural livelihoods.

## Changing Weather Patterns and Climate Variability

Climate change is leading to significant shifts in weather patterns. In many regions, there is a trend toward increased temperatures and altered precipitation regimes. Some areas are experiencing more intense and frequent droughts, while others face heavier rainfall and flooding. These changes disrupt traditional farming calendars, making it challenging for farmers to predict planting and harvesting times. For instance, in Madhya Pradesh, India, an increase in Compound Dry and Hot Events (CDHEs)—simultaneous occurrences of heatwaves and droughts—has been observed, posing severe threats to agriculture and rural livelihoods.

## Impacts of Climate Change on Crop Yields

Climate change is projected to have varying impacts on different crops. For example, maize yields are expected to decline by 24% by 2030 under high greenhouse gas emissions scenarios. Wheat, on the other hand, may experience a potential growth of about 17% under similar conditions. These changes are due to shifts in temperature, rainfall patterns, and elevated carbon dioxide concentrations. In India, a 1°C increase in temperature has been

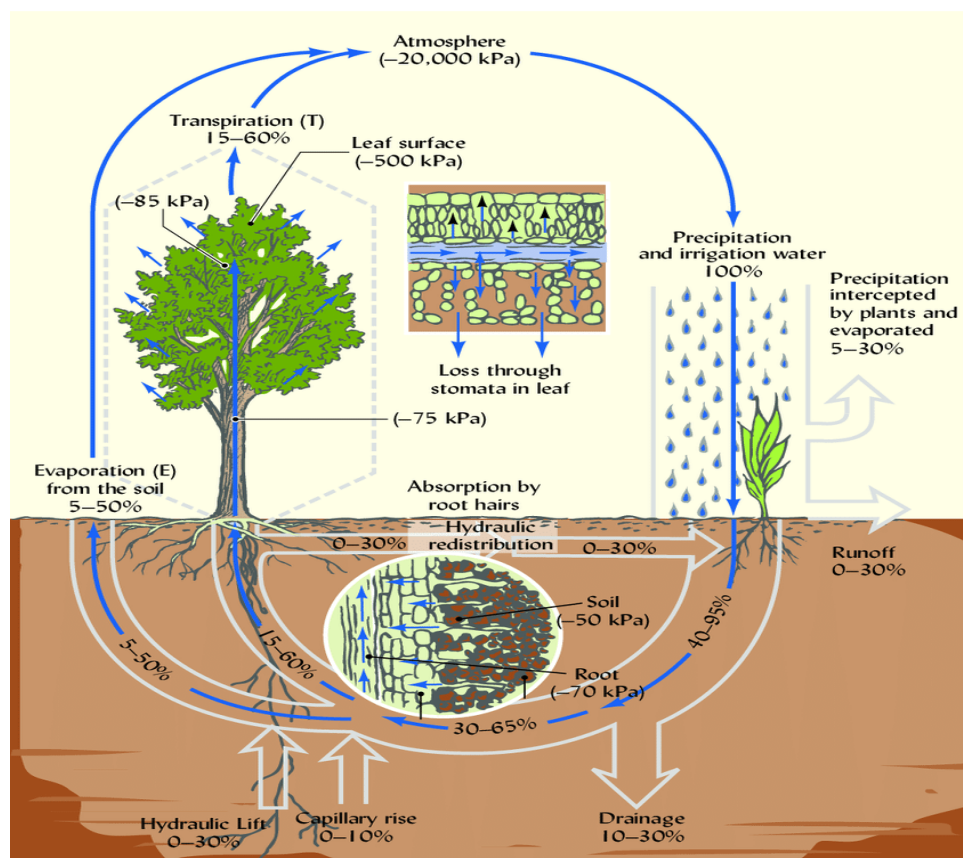
associated with a 6% decline in rice yields in the short term and a 4% decline in the long term.

## Effects on Soil Fertility and Nutrient Cycling

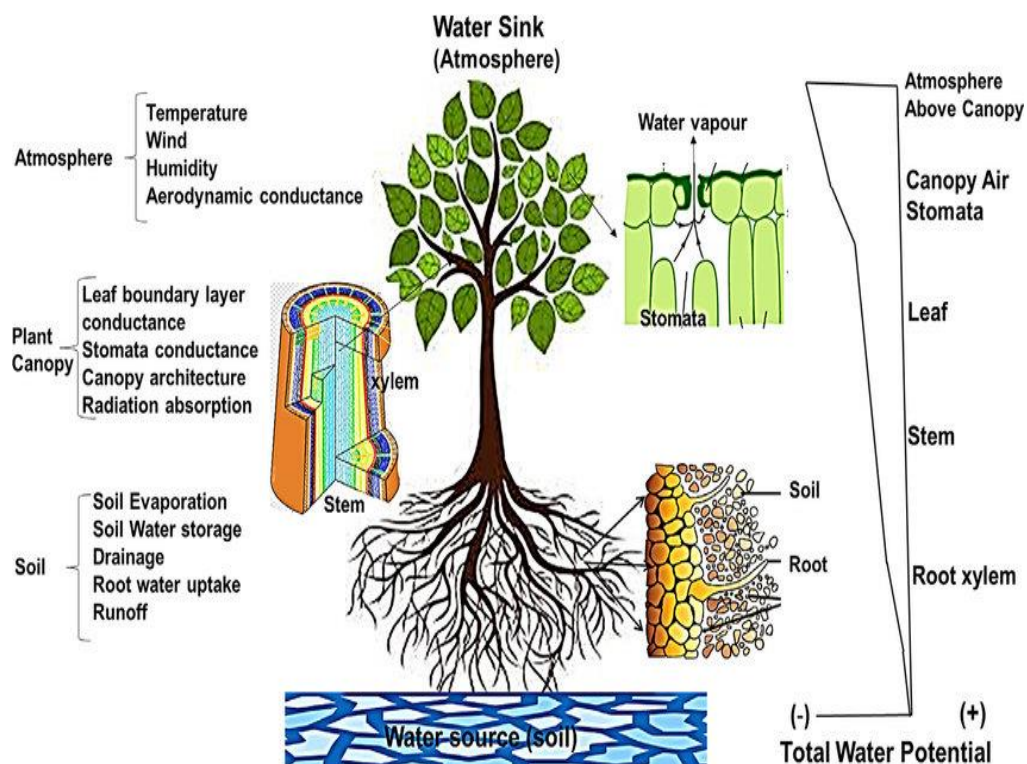
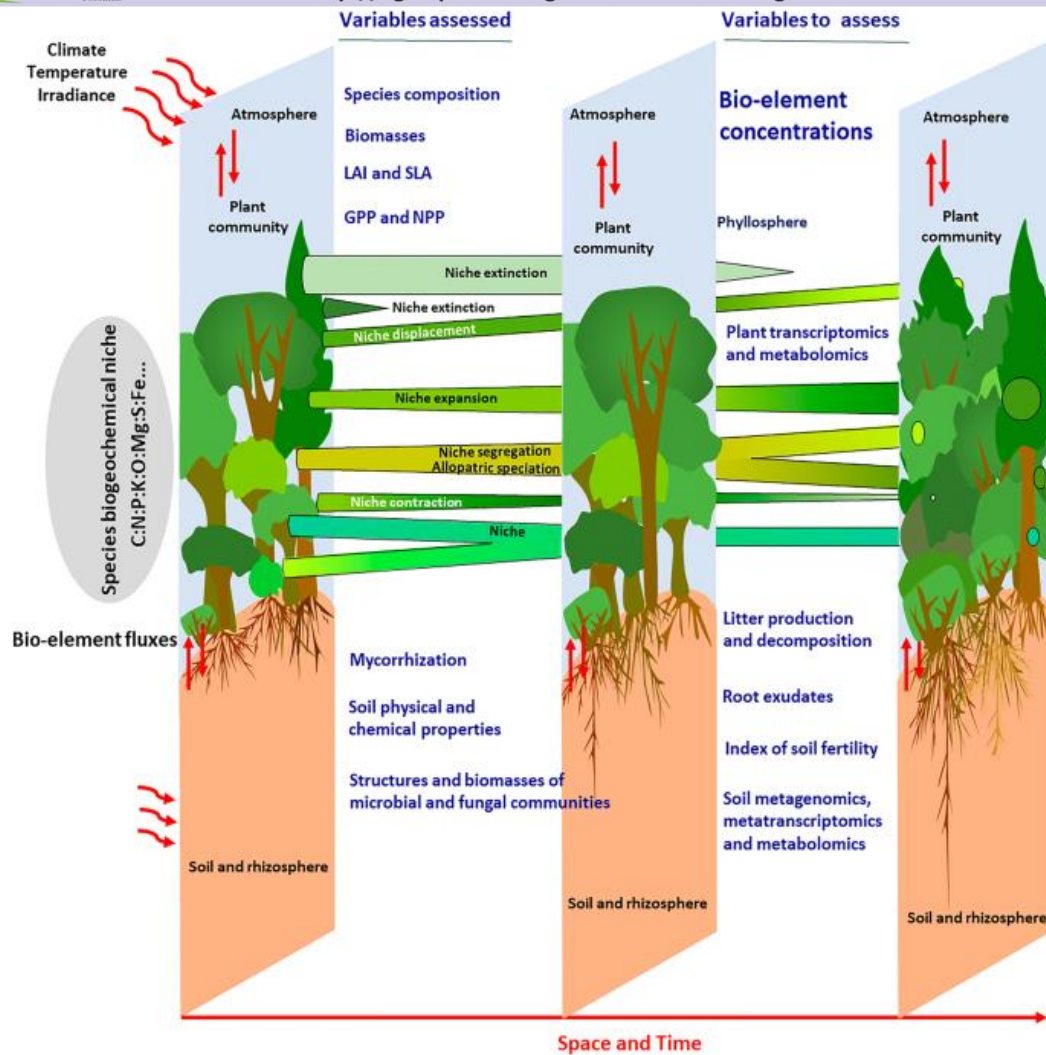
Climate change exacerbates soil degradation through increased temperatures, altered precipitation, and extreme weather events. Higher temperatures can lead to increased evaporation, reducing soil moisture and affecting nutrient availability. Changes in precipitation patterns can result in soil erosion, leaching of nutrients, and salinization, particularly in irrigated areas. These factors compromise soil fertility, necessitating increased use of fertilizers, which can further degrade soil health and lead to environmental pollution.

## Water Availability and Irrigation Challenges

Water is a critical resource for agriculture, and climate change is affecting its availability. In many regions, changing precipitation patterns and increased evaporation rates are leading to water scarcity. For instance, in Maharashtra, India, despite having large dams, the state faces water imbalance due to inefficient irrigation infrastructure and poor water management practices. This scarcity challenges irrigation-dependent agriculture, leading to reduced crop yields and increased competition for water resources.







## **Soil-Plant-Atmosphere Continuum Under Climate Stress**

The Soil-Plant-Atmosphere Continuum (SPAC) is a critical framework for understanding water movement in terrestrial ecosystems, encompassing the continuous flow from soil through plants to the atmosphere. Climate change introduces significant stressors that disrupt this continuum, leading to a cascade of effects on agricultural productivity and ecosystem stability. Elevated soil temperatures, for instance, can increase evaporation rates, reducing soil moisture and impairing plant hydration. This disruption hampers nutrient uptake and photosynthesis, essential processes for plant growth. Moreover, changes in precipitation patterns and increased frequency of extreme weather events exacerbate soil erosion and degradation, further compromising soil health. These alterations in the SPAC not only affect plant physiology but also influence atmospheric conditions, creating feedback loops that intensify climate impacts. Understanding and mitigating these disruptions require integrated approaches that consider the interconnectedness of soil, plant, and atmospheric systems.

## **Soil Health and Its Vulnerability to Climate Change**

Soil health is a dynamic state of soil that enables it to function as a vital living system, supporting plant and animal productivity, maintaining or enhancing water and air quality, and promoting plant, animal, and human health. Climate change exacerbates soil degradation through increased temperatures, altered precipitation patterns, and extreme weather events. These changes can lead to reduced soil organic matter, loss of soil structure, and increased erosion, compromising soil fertility and its capacity to support healthy plant growth.

## **Soil Erosion, Degradation, and Carbon Sequestration**

Climate-induced factors such as intense rainfall and droughts accelerate soil erosion and degradation, leading to the loss of topsoil and essential nutrients. This degradation diminishes the soil's ability to sequester carbon, releasing stored carbon dioxide into the atmosphere and contributing to the greenhouse effect. Implementing sustainable land management practices, such as reduced tillage, cover cropping, and agroforestry, can mitigate these effects by enhancing soil structure and promoting carbon sequestration.

## **Plant Physiological Responses to Elevated Temperature**

Elevated temperatures can disrupt plant physiological processes, leading to heat stress. This stress impairs photosynthesis, reduces chlorophyll content, and increases the production of reactive oxygen species (ROS), which can damage cellular structures. Plants respond by activating heat shock proteins and antioxidant systems to protect cellular integrity. However, prolonged exposure to high temperatures can lead to irreversible damage and reduced crop yields.

## **Effects of Increased CO<sub>2</sub> Concentration on Plant Growth**

Increased atmospheric CO<sub>2</sub> concentrations can enhance photosynthetic rates in plants, a phenomenon known as the CO<sub>2</sub> fertilization effect. This effect can lead to increased plant biomass and improved water-use efficiency. However, the benefits are often tempered by other climate stressors such as elevated temperatures and water scarcity. Additionally, changes in plant chemical composition under elevated CO<sub>2</sub> may affect nutritional quality and plant-pest interactions.

## **Plant Responses to Water Stress and Drought Conditions**

Water stress and drought conditions trigger a series of plant responses aimed at conserving water and maintaining cellular function. These include stomatal closure to reduce transpiration, accumulation of osmotic regulators to maintain cell turgor, and activation of drought-responsive genes. While these mechanisms help plants survive short-term water deficits, prolonged drought can lead to reduced growth, yield loss, and in severe cases, plant death.

## **Weed, Pest, and Disease Management in a Changing Climate**

### **Overview of Pest, Weed, and Disease Challenges under Climate Change**

Climate change is significantly altering the dynamics of agricultural ecosystems, leading to shifts in the prevalence and distribution of pests, weeds, and diseases. Warmer temperatures, altered precipitation patterns, and increased atmospheric CO<sub>2</sub> levels are contributing to:

- **Increased Pest Populations:** Warmer climates can accelerate the life cycles of pests, leading to more generations per year and potentially greater crop damage.
- **Weed Proliferation:** Elevated CO<sub>2</sub> levels can enhance weed growth, making them

more competitive with crops and harder to control.

- **Disease Spread:** Changes in weather patterns can expand the range of plant diseases, introducing new challenges for crop protection.

These changes necessitate adaptive management strategies to mitigate their impact on agriculture.

### **Integrated Pest Management (IPM) Approaches**

Integrated Pest Management (IPM) is a sustainable approach that combines biological, cultural, physical, and chemical tools to manage pest populations. Key components include:

- **Monitoring and Early Detection:** Regular surveillance to identify pest populations and potential outbreaks.
- **Biological Control:** Utilizing natural predators, parasitoids, and pathogens to suppress pest numbers.
- **Cultural Practices:** Crop rotation, intercropping, and resistant varieties to reduce pest establishment.
- **Chemical Control:** Judicious use of pesticides, focusing on targeted applications to minimize environmental impact.

IPM emphasizes the use of multiple strategies in combination, reducing reliance on any single method and promoting long-term sustainability.

### **Strategies for Resistance Management**

The overuse of herbicides and pesticides has led to the development of resistance in many pest and weed species. Strategies to manage and delay resistance include:

- **Rotating Herbicide Modes of Action:** Alternating between herbicides with different mechanisms to prevent resistance buildup.
- **Tank Mixing:** Combining herbicides with different modes of action to reduce the likelihood of resistance.
- **Non-Chemical Control Methods:** Incorporating mechanical, cultural, and biological controls to reduce chemical dependence.
- **Monitoring Resistance Levels:** Regular testing of pest populations to detect early signs of resistance.

Implementing these strategies can help maintain the efficacy of control measures and prolong the usefulness of existing herbicides and pesticides.

### **Role of Biological Control and Sustainable Practices**

Biological control involves the use of natural enemies—such as predators, parasitoids, and

pathogens—to manage pest populations. Benefits include:

- **Targeted Action:** Natural enemies typically affect specific pests, reducing non-target impacts.
- **Sustainability:** Reduces the need for chemical inputs, promoting environmental health.
- **Long-Term Control:** Some biological agents can establish populations that provide ongoing pest suppression.

Sustainable practices, such as organic farming, agroecology, and conservation tillage, complement biological control by enhancing biodiversity and ecosystem resilience.

### **Future Perspectives on Pest and Disease Control**

The future of pest and disease management in agriculture will likely involve:

- **Precision Agriculture:** Utilizing technologies like AI, drones, and sensors to monitor pest populations and apply control measures more efficiently.
- **Genetic Innovations:** Developing pest-resistant crop varieties through genetic engineering and gene editing techniques.
- **Climate-Resilient Practices:** Adapting farming practices to cope with changing climatic conditions, ensuring food security.
- **Policy and Education:** Implementing policies that support sustainable pest management and providing education to farmers on best practices.

### **Multiple-Choice Questions (MCQs)**

1. What does agronomy mainly study?
  - a) Oceans and fish
  - b) Soil, crops, and farming practices
  - c) Stars and planets
  - d) Insects and animals

☒ Correct answer: b
2. Which of the following is a major cause of climate change?
  - a) Planting trees
  - b) Using solar energy
  - c) Burning fossil fuels
  - d) Recycling waste

☒ Correct answer: c
3. Why is soil important in agriculture?
  - a) It keeps animals warm
  - b) It holds water for rivers
  - c) It provides nutrients for plants
  - d) It reflects sunlight

☒ Correct answer: c



4. What happens to crops when temperatures become too high?
  - a) They grow faster
  - b) They become tastier
  - c) They may stop growing or die
  - d) They need less water

☒ Correct answer: c
5. Which practice helps protect soil from erosion?
  - a) Deforestation
  - b) Overgrazing
  - c) Cover cropping
  - d) Burning fields

☒ Correct answer: c
6. What is one way farmers can adapt to climate change?
  - a) Stop growing food
  - b) Use more water
  - c) Grow climate-resilient crops
  - d) Farm only in winter

☒ Correct answer: c
7. Which gas is a major greenhouse gas?
  - a) Oxygen
  - b) Nitrogen
  - c) Carbon dioxide (CO<sub>2</sub>)
  - d) Helium

☒ Correct answer: c
8. What is a benefit of crop rotation?
  - a) Increases soil nutrients
  - b) Makes soil dry
  - c) Reduces plant growth
  - d) Decreases rainfall

☒ Correct answer: a
9. What is meant by “sustainable agriculture”?
  - a) Farming that only grows one crop
  - b) Farming that protects the environment and uses resources wisely
  - c) Farming that uses lots of chemicals
  - d) Farming that cuts down all forests

☒ Correct answer: b
10. Which of these helps reduce the impact of climate change?
  - a) Cutting down trees
  - b) Using plastic bags
  - c) Composting and organic farming
  - d) Burning garbage

☒ Correct answer: c

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