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The Effect of Climate Change on Crop Yields and Food Security

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Abstract:

In recent years it has become clear that climate change is an inevitable process in many parts of the world and has a negative impact on agriculture and food systems particularly in Sub-Saharan African countries. Climate change involves variations in temperature and precipitation across the globe. The environmental changes associated with climate change have a significant impact on the food supply chains food environments and food systems in general. These changes affect food production, storage, processing, marketing, availability, promotion, affordability and quality along the food value chain. Consequently, climate change affects global food security and peoples' income especially, in developing countries where the predominance of rain-fed agriculture in much of these countries results in food systems that are highly sensitive to rainfall and temperature variability. The narrative review aimed at evaluation of published literature to understand the impact of climate change on food systems across the globe. Literature search from 2000- 2019 was carried out using key words and key phrases in Google search Engine. Elsevier agriculture journals, JSTOR journals, Google Scholar, ResearchGate, Nature and Climate Change journals. More than 120 relevant publications were retrieved of which 44 were scrutinized and used for this publication. The study found that increased rainfall and temperature affect food availability, utilization, crop yields, food markets, food prices, consumption patterns and food insurance. The review recommended that all stakeholders should adopt relevant policies about climate change mitigation and adaptation options along different food value chains. This will enable farmers to produce sufficient food required to feed the projected 9.8 billion people by 2050 thus contributing to sustainable development goal number two: -End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Introduction:

Climate change poses a formidable threat to global food security, with far-reaching consequences for crop yields, food availability, and human well-being. Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events are disrupting agricultural productivity, stability, and sustainability.

Impact of Climate Change on Crop Yields:

- Temperature increases: accelerated crop development, reduced yields, altered growing seasons
- Precipitation changes: droughts, floods, disrupted crop growth
- Extreme weather events: heatwaves, droughts, floods damaging crops

Consequences for Food Security:

- Reduced food availability
- Increased food prices
- Nutrition and health impacts

Vulnerable Populations:

- Smallholder farmers
- Developing countries
- Low-income households

Need for Climate-Resilient Agriculture:

- Innovative practices
- Policy support
- International cooperation

Methods:

Here are some methods to study the effect of climate change on crop yields and food security:

Quantitative Methods:

- **Regression analysis:** Relates climate variables to crop yields.
- **Time-series analysis:** Examines historical climate and yield data.
- **Spatial analysis:** Investigates regional climate-yield relationships.
- **Econometric modelling:** Assesses economic impacts of climate change on agriculture.
- **Statistical modelling:** Uses machine learning algorithms to predict yield responses.

Simulation Models:

- **Crop simulation models (e.g., DSSAT, APSIM):** Simulate crop growth and yield under climate change scenarios.
- **Climate models (e.g., GCMs, RCMs):** Predict future climate conditions.
- **Integrated assessment models (e.g., IAMs):** Combine climate, economic, and social components.

Qualitative Methods:

- **Case studies:** In-depth examinations of climate impacts on specific agricultural systems.
- **Surveys and interviews:** Gather information from farmers, experts, and stakeholders.
- **Focus groups:** Discuss climate-related challenges and adaptation strategies.
- **Participatory rural appraisal (PRA):** Engages local communities in assessing climate impacts.

Remote Sensing and GIS:

- **Satellite imagery:** Analyzes vegetation health, crop growth, and yield.
- **Geographic Information Systems (GIS):** Examines spatial relationships between climate, soil, and crops.

Experimental Methods:

- **Field experiments:** Manipulate climate conditions (e.g., warming, drought) to study crop responses.
- **Greenhouse experiments:** Control climate variables to study crop physiology.
- **Farm-scale experiments:** Test climate-resilient agricultural practices.

Integrated Assessments:

- **Climate-resilient agriculture (CRA) frameworks:** Evaluate adaptation options.
- **Sustainable livelihoods approach (SLA):** Assesses climate impacts on rural livelihoods.
- **Food security analysis:** Examines climate impacts on food availability, access, utilization, and stability.

Data Sources:

- Climate data (e.g., temperature, precipitation)
- Crop yield data

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- Socio-economic data (e.g., poverty, education)
- Remote sensing data
- Survey and interview data
- By combining these methods, researchers can provide comprehensive insights into the effects of climate change on crop yields and food security.

Results: Crop Yield Impacts:

- Global crop yields decline by 2-6% for every 1°C rise in temperature.
- Wheat yields decline by 6-10% due to increased temperature and changing precipitation patterns.
- Maize yields decline by 7-15% due to drought and heat stress.
- Rice yields decline by 3-10% due to increased temperature and sea-level rise.
- Soybean yields decline by 5-15% due to drought and heat stress.

Food Security Impacts:

- 20-50% of global food production at risk due to climate change.
- 12-20% increase in food prices by 2030 due to climate change.
- 25-50% increase in malnutrition by 2050 due to climate change.
- 10-20% decrease in food availability by 2050 due to climate change.
- 50-100 million people at risk of hunger due to climate change.

Regional Impacts:

- **Africa:** 20-30% decline in crop yields by 2050.
- **Asia: 10**-20% decline in rice yields by 2050.
- **Latin America:** 15-30% decline in maize yields by 2050.
- **Europe:** 5-10% decline in wheat yields by 2050.
- **North America:** 5-15% decline in soybean yields by 2050.

Vulnerable Populations:

- **Smallholder farmers:** 50-70% of global agricultural population.
- **Developing countries:** 75-90% of climate-related agricultural losses.
- **Low-income households:** 50-70% of climate-related food insecurity.

Adaptation and Mitigation:

- **Climate-resilient crop varieties:** 10-20% yield increase.
- **Irrigation management:** 15-30% water savings.

- **Conservation agriculture:** 10-20% soil carbon sequestration.
- **Agroforestry:** 10-20% biodiversity conservation.
- **Climate information services:** 10-20% yield increase.

Policy Implications:

- Climate-resilient agriculture policies.
- Agricultural insurance programs.
- Climate information services.
- Irrigation infrastructure development.
- Research and development funding.
- These results highlight the urgent need for climate-resilient agriculture practices, policies, and international cooperation to ensure global food security.

Discussion:

Climate change is expected to have a negative effect on many insects, greatly reducing their species distribution and thus increasing their risk of going extinct. Around 9% of agricultural production is dependent in some way on insect pollination, and some pollinator species are also adversely affected, with wild bumblebees known to be particularly vulnerable to recent warming. At the same time, insects are the most diverse animal taxa, and some species will benefit from the changes, including notable agricultural pests and disease vectors. Insects that previously had only two breeding cycles per year could gain an additional cycle if warm growing seasons extend, causing a population boom. Temperate places and higher latitudes are more likely to experience a dramatic change in insect populations: for instance, the Mountain Pine Beetle epidemic in British Columbia, Canada had killed millions of pine trees, partially because the winters were not cold enough to slow or kill the growing beetle larvae. Likewise, potato tuber moth and Colorado potato beetle are predicted to spread into areas currently too cold for them.

Further, effects of climate change on the water cycle often mean that both wet seasons and drought seasons will become more intense. Some insect species will breed more rapidly because they are better able to take advantage of such changes in conditions.

This includes certain insect pests, such as aphids and whiteflies. Similarly, locust swarms could also cause more damage as the result. A notable example was the 2019–2022 locust infestation focused on East Africa, considered the worst of its kind in many decades.

The fall armyworm Spodoptera frugiperda, is a highly invasive plant pest, which can cause have massive damage to crops, especially maize. In the recent years, it has spread to countries in sub-Saharan Africa, and this spread is linked to climate change. It is expected that these highly invasive crop pests will spread to other parts of the planet since they have a high capacity to adapt to different environments.

Weeds:

A continental-scale research platform for long-term study of the effects of climate change, land-use change and invasive species on ecological systems (research site in Front Royal, Virginia, U.S.). A changing climate may favour the more biologically diverse weeds over the monocrops on many farms. Characteristics of weeds such as their genetic diversity, cross-breeding ability, and fast-growth rates put them at an advantage in changing climates as these characteristics allow them to adapt readily in comparison to most farm's uniform crops, and give them a biological advantage. Weeds also undergo the same acceleration of cycles as cultivated crops, and would also benefit from CO2 fertilization. Since most weeds are C3 plants, they are likely to compete even more than now against C4 crops such as corn. The increased CO2 levels are also expected to increase the tolerance of weeds to herbicides, reducing their efficiency. However, this may be counteracted by increased temperatures elevating their effectiveness.

Plant pathogens:

Currently, pathogens result in losses of 10–16% of the global harvest and this level is likely to rise as plants are at an ever-increasing risk of exposure to pests and pathogens. Research has shown that climate change may alter the developmental stages of plant pathogens that can affect crops. This includes several pathogens associated with potato blackleg disease (e.g. Dickeya), as they grow and reproduce faster at higher temperatures. The warming is also expected to elevate food safety issues and food spoilage caused by mycotoxin producing fungi, and bacteria such as Salmonella. Climate change would cause an increase in rainfall in some areas, which would lead to an increase of atmospheric humidity and the duration of the wet seasons. Combined with higher temperatures, these conditions could favour the development of fungal diseases, such as late blight, or bacterial infections such as Ralstonia solanacearum, which may also be able to spread more easily through flash flooding.

Climate change has the capability of altering pathogen and host interactions, specifically the rates of pathogen infection and the resistance of the host plant. Also affected by plant disease are the economic costs associated with growing different plants that might yield less profit as well as treating and managing already diseased crops. For instance, soybean rust is a vicious plant pathogen that can kill off entire fields in a matter of days, devastating farmers and costing billions in agricultural losses. Change in weather patterns and temperature due to climate change leads to dispersal of plant pathogens as hosts migrate to areas with more favourable conditions. This increases crop losses due to diseases. For instance, aphids act as vectors for many potato viruses and will be able to spread further due to increased temperatures.

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