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# DISTRIBUTION OF AGRICULTURAL CROP PESTS UNDER CLIMATE CHANGE AND STRATEGIES FOR THEIR CONTROL

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**Abstrac:** This article examines, from a scientific and analytical perspective, the effects of global climate change on the biological development, geographic distribution, and pest activity of agricultural crop pests. The relevance of the problem is substantiated with concrete figures drawn from recent research published by the FAO, the IPCC, and international scientific journals (*Science*, *Nature Communications*, *Scientific Reports*), as well as from statistical data collected for the Republic of Uzbekistan. It is shown that changes in the temperature regime increase the number of pest generations, expand their ranges, and improve overwintering conditions. The modern agrotechnical, biological, chemical, and digital-monitoring components of the integrated pest management (IPM) system are also analyzed, and practical recommendations are developed for agriculture in Uzbekistan.

**Keywords:** climate change, pests, integrated pest management (IPM), agroecosystem, cotton, cereals, biological control, phytosanitary monitoring, Uzbekistan.

## 1. Introduction: Relevance of the Problem

In recent decades, global climate change has become one of the most important factors affecting agricultural production. According to the World Meteorological Organization and the Intergovernmental Panel on Climate Change (IPCC), the average global surface temperature has already risen by 1.1–1.3 °C relative to the pre-industrial period, and this process directly affects every component of agroecosystems, including the biological activity of harmful insects, mites, molds, and weeds. According to estimates by the Food and Agriculture Organization of the United Nations (FAO), between 20 and 40 percent of the world's agricultural harvest is lost every year to various pests and diseases, which amounts to economic losses of approximately USD 220 billion per year, while invasive pests alone cause an additional USD 70 billion in damage annually.

The relevance of the problem lies in the fact that climate change not only affects pests directly but also fundamentally alters their geographic ranges. According to a large-scale study by researchers from the universities of Washington and Colorado (Deutsch et al., 2018, *Science*), each 1 °C rise in global mean temperature increases insect-driven losses of the three major cereal crops — wheat, rice, and maize — by 10 to 25 percent. If warming reaches 2 °C, pest-related yield losses are projected to increase by 46 percent for wheat, 19 percent for rice, and 31 percent for maize (Figure 1), equivalent to an additional loss of up to 213 million tonnes of grain per year. This trend poses a serious threat to food security,

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especially in regions with rapidly growing populations; in 2022, 783 million people worldwide experienced hunger.

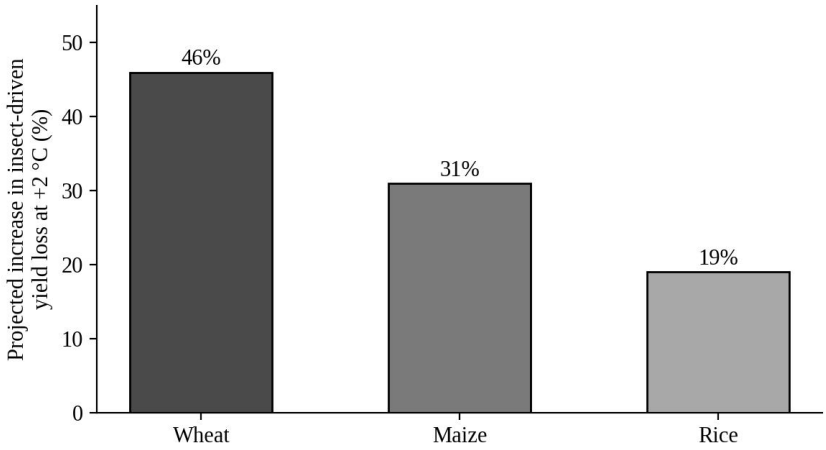



**Figure 1.** Projected increase in insect-driven yield losses under 2 °C of warming for the three major cereal crops (data from Deutsch et al., 2018).

In Central Asia, and in Uzbekistan in particular, the problem is especially acute. Cotton and cereal production, key sectors of the national economy, are located in a warm and dry climatic zone, and such conditions favor the rapid development and multivoltine reproduction of most pest species. Therefore, studying the patterns of pest distribution under climate change on a scientific basis and developing effective, ecologically sustainable control strategies are among the priority tasks of agrarian science and practice in Uzbekistan.

## 2. Mechanisms by Which Climate Change Affects Pest Biology and Distribution

Insects are poikilothermic (cold-blooded) organisms, and their body temperature, metabolic rate, developmental rate, and reproductive output depend directly on ambient temperature. The scientific literature indicates that the effects of climate change on pests manifest through the following main mechanisms:

- **Accelerated metabolism.** As temperature rises, insects' digestion and energy expenditure accelerate, so the mass of plant material consumed per insect increases.
- **Increased number of generations (polyvoltinism).** A longer warm period allows insects to complete several additional generations within a single season; for example, the cotton bollworm (*Helicoverpa armigera*) may produce 6–7 generations per season in warmer regions instead of 4–5.
- **Higher overwintering survival.** Mild winters reduce mortality during the winter diapause of pests, which markedly increases spring population density.
- **Range (distributional limit) expansion.** Pests typical of warmer regions are shifting northward and to higher mountain elevations; in particular, it has been scientifically confirmed

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that the overwintering range of the diamondback moth (*Plutella xylostella*) has expanded by approximately 2.4 million square kilometers worldwide over the past 50 years.

- **Formation of phytosanitary vulnerability.** Heat and water-deficit stress reduce plants' natural resistance to pests, which lowers the economic threshold.

In addition, several studies have noted that rising atmospheric carbon dioxide ($CO_2$) concentrations reduce the nitrogen and protein content of plant tissues, forcing herbivorous insects to consume more foliage. Changes in the precipitation regime, particularly prolonged droughts, create conditions for mass outbreaks of pests that thrive in hot, dry environments, such as spider mites.

The relationships among these mechanisms are summarized in Figure 2.

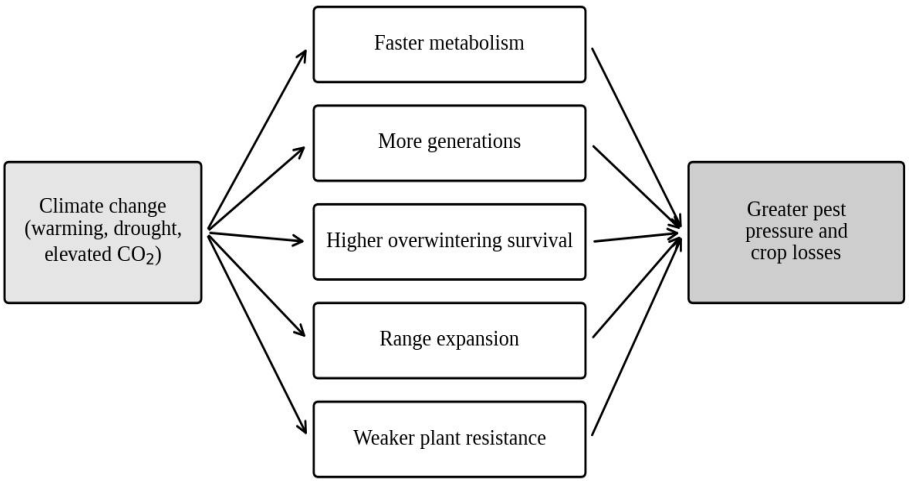



**Figure 2.** Conceptual scheme of the main mechanisms by which climate change increases pest pressure on crops.

## 3. Practical Examples of Pest Distribution Worldwide

### *3.1. Fall armyworm (Spodoptera frugiperda)*

Native to the Americas, this pest has spread since 2016 first to Africa and then to Asia, reaching more than 100 countries within a few years against the background of climate warming, and it causes serious damage to crops such as maize, sorghum, and millet. According to the FAO, in some parts of Africa alone, the share of crop lost to insects reaches 30–60 percent, which poses a direct threat to food security.

### *3.2. Brown planthopper (Nilaparvata lugens)*

According to a study published in *Scientific Reports* in 2024, under a high-warming climate scenario (RCP8.5), the marginal distribution zones of this long-distance migratory pest are projected to expand from the current 27.2 percent to 38.8 percent by the 2080s, while the most favorable ("very favorable")

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zones are projected to shrink from 27.5 percent to only 3.6 percent. This indicates a qualitative and fundamental redistribution of the pest's range (Figure 3).

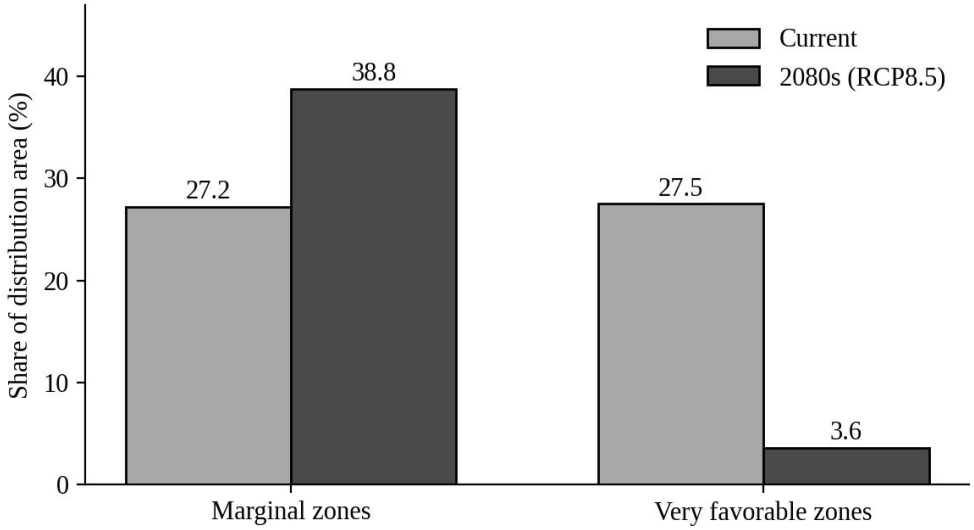



**Figure 3.** Projected change in the distribution zones of *Nilaparvata lugens* by the 2080s under the RCP8.5 scenario (Hong et al., 2024).

### *3.3. Desert locust (Schistocerca gregaria)*

A scientific review prepared by the FAO emphasizes that the desert locust, the most destructive migratory pest in the world, is expected to change its traditional migration routes and geographic distribution limits because of climate change, as unusual precipitation and temperature regimes coincide with locust breeding periods.

### *3.4. Wheat rust diseases and other phytopathogens*

Alongside insect pests, climate change also affects the spread rate and the frequency of epiphytotics (mass disease outbreaks) of fungal diseases (for example, yellow rust, *Puccinia striiformis*), because the spores of these pathogens spread faster in humid and cool air, and the infection stage accelerates during warm, rainy periods.

The main examples discussed in this section are summarized in Table 1.

**Table 1.** Summary of the pest and pathogen examples discussed in Section 3.

| Organism | Type / host | Key finding |
|---|---|---|
| Fall armyworm (*Spodoptera frugiperda*) | Insect; maize, sorghum, millet | Spread to more than 100 countries since 2016; crop losses reach 30–60% in some parts of Africa |

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| Organism | Type / host | Key finding |
|---|---|---|
| Brown planthopper (*Nilaparvata lugens*) | Insect; rice | Marginal zones projected to grow from 27.2% to 38.8%, while very favorable zones shrink from 27.5% to 3.6% by the 2080s (RCP8.5) |
| Desert locust (*Schistocerca gregaria*) | Migratory insect | Traditional migration routes and distribution limits expected to shift |
| Yellow rust (*Puccinia striiformis*) | Fungal disease; wheat | Spread rate and epiphytotic frequency affected by humidity and temperature |

**4. Climate Change and the Pest Problem in Uzbekistan**

According to scientists at the Institute of Genetics and Plant Experimental Biology of the Academy of Sciences of the Republic of Uzbekistan, against the background of the global warming trend, glaciers in the country are melting intensively and water scarcity is intensifying, which increases stress in agricultural crops and reduces their resistance to pests. Scientific studies conducted in Khorezm Region show that the mean annual air temperature has risen by 0.8 °C over the past several decades, with the strongest warming occurring in the summer months — precisely the period when the main pests of cotton and other crops are actively developing.

According to the results of an agroclimatic study conducted in 2023 by UNDP in cooperation with the Hydrometeorological Service in Fergana, Namangan, and Andijan regions, the sum of effective temperatures accumulated during the growing season (1 April to 1 October) over the last five years exceeded the long-term climatic norm. On the one hand, this is a positive factor for cotton yield; on the other hand, it accelerates the development cycle of heat-demanding pests (for example, the cotton bollworm, spider mites, and aphids) and increases the likelihood of additional generations.

In Uzbekistan, the main pests of cotton have been identified as the autumn cutworm (root-feeding larvae), aphids, thrips, the common spider mite, the alfalfa bug and the cotton bug, and the cotton bollworm. According to specialists' observations, in some years unfavorable heat conditions during the growing season delayed cotton development while, at the same time, causing mass outbreaks of insects and other pests. This shows that Uzbekistan's warm climate, while favorable for agriculture, also creates a good environment for pests.

The situation is even more pressing for cereal crops. According to an analysis of long-term observations across the republic, the years 1999, 2004, 2009, 2010, 2016, and 2024 were epiphytotic years for yellow rust, during which the disease reduced yields by 50–60 percent, and by as much as 100 percent in Surkhandarya Region in 1999 (Table 2). For the 2026 harvest, winter cereals were sown on more than 1 million hectares of irrigated land in Uzbekistan, and specialists forecast wider

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spread of rust precisely in unfertilized and poorly developed fields, which once again confirms the importance of preventive and agrotechnical measures.

**Table 2.** Yellow rust epiphytotic years in Uzbekistan and associated yield losses.

| Year | Yield loss |
|---|---|
| 1999 | 50–60% nationally; up to 100% in Surkhandarya Region |
| 2004, 2009, 2010, 2016, 2024 | 50–60% (epiphytotic years) |

At the same time, thanks to science-based management, Uzbekistan is also achieving positive results in cotton production: between 2021 and 2025, yield per hectare rose from 3.2 to 4.55 tonnes, which shows that high and stable yields can be obtained even under unfavorable climatic conditions when modern variety replacement, precision agrotechnology, and scientific monitoring measures are applied effectively.

## 5. Modern Pest Control Strategies (Integrated Pest Management, IPM)

Under climate change, relying on a single chemical control method is not only ecologically hazardous but also economically ineffective, because the continuous use of pesticides with the same mode of action accelerates the development of resistance in pests. Therefore, in global practice, the Integrated Pest Management (IPM) system is recognized as the priority approach; it involves the coordinated application of several methods based on the economic threshold.

### *5.1. Agrotechnical (cultural) methods*

- Planting climate-resilient and pest-tolerant varieties and introducing crop rotation systems;
- Adjusting sowing and harvesting dates to coincide with the most vulnerable developmental stage of the pest;
- Increasing agrolandscape diversity to create a favorable environment for beneficial insects (parasitoids and predators);
- Reducing plant stress by optimizing soil and irrigation regimes, thereby increasing natural resistance.

Figure 4 shows how the IPM components fit together, and Appendix A summarizes the measures in each component.

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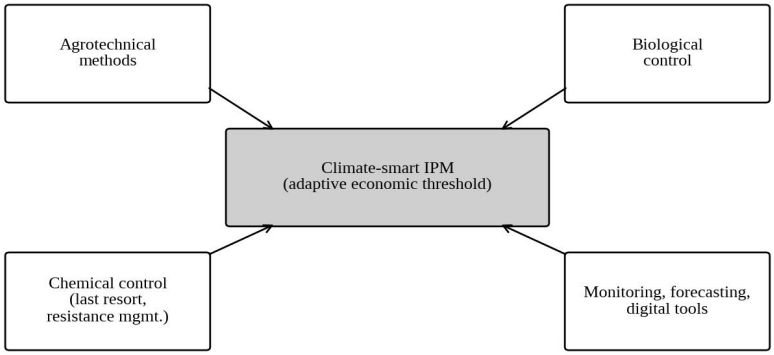



**Figure 4.** Components of a climate-smart integrated pest management (IPM) system.

### *5.2. Biological control methods*

Biological control is a method of keeping pest numbers below the economic threshold by means of natural enemies (parasitoids, predatory insects, entomopathogenic fungi, and bacteria), and it markedly reduces the need for broad-spectrum chemical preparations. The use of egg parasitoids of the genus *Trichogramma* against the cotton bollworm, as well as entomopathogenic fungi (*Beauveria bassiana*, *Metarhizium anisopliae*) and bacterial preparations (based on *Bacillus thuringiensis*), is among the tested and effective methods in cotton production in Uzbekistan and other Central Asian countries.

### *5.3. Chemical control and resistance management*

In the IPM system, the chemical method is applied only as a last resort, when the economic threshold has been exceeded. To prevent the development of resistance, it is recommended to rotate preparations with different modes of action, to prefer selective products that do not harm beneficial insects, and to limit the number of treatments applied in a single season.

### *5.4. Phytosanitary monitoring, forecasting, and digital technologies*

Under climate change, establishing a long-term monitoring system is one of the most important components of IPM, because it makes it possible to track climate-dependent dynamics of pest populations and to prevent the establishment of invasive species in new areas. In recent years, real-time tracking of temperature and precipitation data through remote sensing, artificial-intelligence-based image analysis, and agro-bulletin systems has helped to forecast pest spread in advance; this is also reflected in the agro-bulletin project introduced in the Fergana Valley regions of Uzbekistan in 2023.

### *5.5. Adapting the economic threshold to climate*

Studies show that plants subjected to drought stress are considerably more vulnerable to pest attack; therefore, under such conditions it is recommended to set a lower economic threshold, that is, to take preventive measures even when pest numbers are below the conventional norm. This approach requires that the IPM system be not static but adaptive to climatic conditions (climate-smart).

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## 6. Conclusions and Recommendations

The analysis shows that climate change significantly affects the biological activity, number of generations, and geographic distribution limits of agricultural crop pests, as a result of which traditional protection measures are progressively losing their effectiveness. Concrete indicators — a 10–25 percent increase in insect-driven grain losses per 1 °C of warming globally, the 0.8 °C temperature rise recorded in Khorezm Region, and the above-normal sum of effective temperatures in the Fergana Valley in Uzbekistan — confirm how acute the problem is. The fact that wheat yellow rust caused yield losses of 50–100 percent in some years likewise demonstrates that climate-related risks are real.

Based on the above, the following recommendations are put forward:

- Expand a unified, long-term monitoring and early-warning system that tracks the climate-dependent dynamics of pests and diseases at the national scale;
- Develop climate-resilient and pest-tolerant local varieties and hybrids and accelerate their introduction into production;
- Expand the production of biological control agents (parasitoids, entomopathogenic preparations) and the infrastructure for their use;
- Strengthen advisory and training services on IPM principles for farmers and smallholders;
- Introduce agro-bulletin and digital forecasting systems gradually in all agricultural regions.

In conclusion, under climate change, effective pest control is possible only through the consistent application of a scientifically grounded, multicomponent, and adaptive integrated pest management (IPM) system, which is of strategic importance for ensuring Uzbekistan's food security and the sustainable development of its agriculture.

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