IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 18, April 2026
Impact Factor: 8.2

A Survey on Pest Attack Early Risk Indicator Systems Using Environmental Data

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Abstract: *Crop pest attacks are one of the major causes of agricultural losses worldwide, leading to reduced yield and economic instability for farmers. Traditional pest detection methods rely on visual observation, which often identifies the problem only after significant damage has already occurred. Early detection and prediction of pest attacks can help farmers take preventive measures and minimize losses [10]. Recent research focuses on developing intelligent pest monitoring and early warning systems using environmental parameters such as temperature, humidity, and rainfall [1], [2].*

This survey paper reviews recent advancements in pest prediction and early warning systems in agriculture. Various approaches such as Artificial Intelligence, Machine Learning, climate-based models, and integrated pest management techniques are analyzed [3], [11]. The study compares different methods based on their accuracy, efficiency, and practical usability. From the analysis, it is observed that early risk indicator systems can significantly reduce crop damage by providing timely alerts. However, challenges such as data dependency, system complexity, and lack of accessibility for farmers still exist [5], [15]. Future research can focus on developing simple, cost-effective, and user-friendly systems suitable for real-world agricultural applications.

Keywords: Pest Prediction, Agriculture, Early Warning System, Machine Learning, Climate Data, Smart Farming

I. INTRODUCTION

Agriculture plays a vital role in the global economy, especially in developing countries where a large portion of the population depends on farming for their livelihood. One of the major challenges faced by farmers is crop damage caused by pests and diseases. According to studies, a significant percentage of crop losses occur due to pest infestations, which directly affects food production and farmer income [10].

Traditional pest control methods rely on manual inspection and pesticide application after the infestation becomes visible. However, by the time pests are detected, considerable damage has already occurred. This highlights the need for early warning systems that can predict pest attacks before they become severe.

With the advancement of technologies such as Artificial Intelligence, Machine Learning, and data analytics, it has become possible to develop intelligent systems that can predict pest attacks using environmental parameters [1]. Factors such as temperature, humidity, rainfall, and crop type play a crucial role in pest growth and spread.

In addition, smart agriculture techniques and big data analysis have enabled researchers to design systems that provide timely alerts and recommendations to farmers [11]. These systems aim to improve productivity, reduce pesticide usage, and support sustainable farming practices.

DOI: 10.48175/IJARSCT-34375

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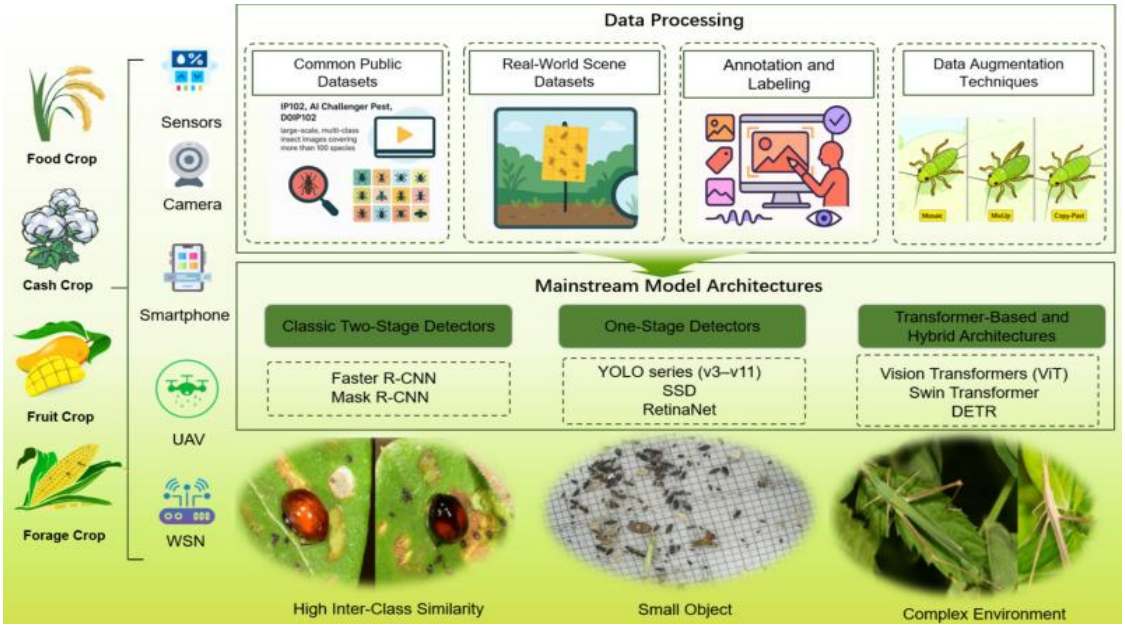

Figure 1: Illustration of Pest Detection and Early Risk Prediction System Using Environmental Data

II. LITERATURE SURVEY

In paper [1], the authors proposed a deep learning model to predict risks of crop pests and diseases using sequential environmental data such as temperature, humidity, and carbon dioxide levels. The model achieves high prediction accuracy; however, it requires large datasets and high computational resources, which limits its use for small-scale farmers. In paper [2], a crop pest monitoring and early warning system is developed in China using modern agricultural technologies. The system improves pest control efficiency, but its dependency on infrastructure and sensor networks makes large-scale deployment challenging.

In paper [3], early warning systems are discussed as an important component of integrated pest management. These systems help prevent the introduction and spread of exotic pests by providing timely alerts. However, their effectiveness depends on continuous monitoring and accurate data collection. In paper [5], an early warning analysis

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system for crop diseases and insect pests is presented using computational techniques. The system provides effective predictions, but requires continuous data input and system maintenance.

In paper [6], pest risk analysis is conducted to evaluate the risk of introducing harmful pests through crop seeds. The study provides theoretical insights but lacks real-time implementation capabilities. In paper [7], a multipest damage indicator system is proposed for assessing crop protection strategies. While the system improves decision-making, it is complex and requires detailed agricultural data.

In paper [8], an ecological approach to pest control is discussed, focusing on sustainable and environmentally friendly methods. Although effective in reducing pesticide usage, these methods do not provide immediate prediction or early warning capabilities. In paper [9], recent innovations in pest detection and control strategies in the era of smart agriculture are explored. The study highlights the role of digital technologies but also points out challenges such as adoption and cost.

In paper [10], the authors analyze crop losses caused by pests and highlight the importance of early detection systems. The study shows that a significant portion of crop damage can be prevented with timely intervention. In paper [11], a big data-based pest prediction system is proposed for horticulture crops. The system improves prediction accuracy using large datasets, but requires advanced infrastructure and computational power.

In paper [12], eco-smart pest management techniques in rice farming are discussed. These methods focus on sustainable pest control but require proper knowledge and training for implementation. In paper [13], the risks associated with pesticide exposure are analyzed, emphasizing the need for controlled and preventive pest management strategies.

In paper [14], biological control methods using natural predators are studied for pest management. While environmentally friendly, these methods may not provide immediate results and depend on ecological balance. In paper [15], multiple agricultural risks, including pest-related risks, are analyzed with a focus on risk management and mitigation strategies. The study highlights the importance of predictive systems but also identifies challenges such as uncertainty and data variability.

Further studies indicate that most modern pest prediction systems rely on Artificial Intelligence, Machine Learning, and environmental data analysis. These systems are capable of providing early warnings and improving agricultural productivity. However, they often require complex models, high computational power, and continuous data collection.

From the overall analysis, it can be observed that existing systems focus more on accuracy and advanced technologies rather than simplicity and usability. Many systems are not easily accessible to farmers due to technical complexity and infrastructure requirements. Therefore, there is a need for a simple, cost-effective, and user-friendly pest attack early risk indicator system that can provide timely alerts and assist farmers in taking preventive actions.

Sr. No.	Author & Year (Citation)	Title	Journal	Advantages	Disadvantages
1	Lee et al. (2023) [1]	Deep Learning Pest Prediction Model	Plant Methods	High accuracy, uses environmental data	Requires large dataset and high computation
2	Wu et al. (2022) [2]	Pest Monitoring & Early Warning System	Engineering Agriculture	Real-time monitoring, early alerts	Needs infrastructure and sensors
3	Noar et al. (2021) [3]	Early Warning System in IPM	Journal of Integrated Pest Management	Prevents pest outbreaks	Depends on accurate data collection
4	Noar et al. (2021) [4]	Integrated Pest Management System	Journal of Integrated Pest Management	Improves pest control efficiency	Limited real-time prediction
5	Wang et al. (2013) [5]	Pest Early Warning Analysis System	Springer Conference (CCTA)	Effective prediction model	Requires continuous monitoring
6	Pataky & Ikin (2013) [6]	Pest Risk Analysis	International Seed	Helps in risk	Theoretical, not real-

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			Federation	evaluation	time
7	Fermaud et al. (2016) [7]	Multipest Damage Indicator	Australian Journal of Grape and Wine Research	Better decision-making	Complex implementation
8	Ekström & Ekbom (2011) [8]	Ecological Pest Control Approach	Critical Reviews in Plant Sciences	Environment-friendly	No early prediction capability
9	Nurdianawati (2026) [9]	Smart Agriculture Pest Detection	Jurnal Pengabdian Masyarakat dan Riset Pendidikan	Uses modern technologies	High cost and adoption issues
10	Oerke (2006) [10]	Crop Loss Analysis due to Pests	Journal of Agricultural Science	Highlights importance of early detection	Does not provide solution system
11	Lubis (2025) [11]	Big Data Pest Prediction System	Digital Agriculture and Innovation Journal	High accuracy with large data	Requires big data infrastructure
12	Mohapatra et al. (2019) [12]	Eco-Smart Pest Management	Oryza Journal	Sustainable approach	Needs expert knowledge
13	Landrigan et al. (1999) [13]	Pesticide Risk Study	Environmental Health Perspectives	Focus on safety and prevention	Not a prediction system
14	Frank (2010) [14]	Biological Pest Control System	Biological Control Journal	Eco-friendly pest control	Slow response time
15	Aubert et al. (2024) [15]	Agricultural Risk Analysis System	Review of Agricultural, Food and Environmental Studies	Covers multiple risks	Uncertainty and complexity

The analysis of the reviewed research papers shows that most existing pest prediction and early warning systems are based on advanced technologies such as Artificial Intelligence, Machine Learning, and big data analytics. These systems utilize environmental parameters like temperature, humidity, and rainfall to predict pest occurrences and provide early alerts to farmers. Several studies also focus on integrated pest management and sustainable agricultural practices to reduce crop damage and improve productivity.

However, despite these advancements, many systems face challenges such as high implementation cost, dependency on large datasets, complex computational models, and the need for advanced infrastructure. Additionally, most systems are not easily accessible to farmers due to their complexity and lack of user-friendly interfaces.

Based on these observations, there is a need to develop a simple, cost-effective, and efficient pest attack early risk indicator system that can provide timely alerts using minimal data and computational resources. Such a system can help farmers take preventive actions and reduce crop losses, making it more suitable for real-world agricultural applications.

III. FUTURE SCOPE

Future research in pest prediction systems should focus on developing user-friendly and cost-effective solutions that can be easily adopted by farmers. Integration of mobile applications, real-time weather APIs, and simplified machine learning models can improve system usability.

Additionally, combining early risk prediction with recommendation systems can help farmers take preventive actions effectively. The use of local language interfaces and voice-based systems can further enhance accessibility for rural users.

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IV. CONCLUSION

This survey paper analyzes recent research on pest prediction and early warning systems aimed at overcoming the limitations of traditional pest detection methods. The study highlights the use of advanced technologies such as Artificial Intelligence, Machine Learning, and environmental data analysis for early risk prediction of pest attacks. It is observed that these systems can significantly reduce crop damage, improve agricultural productivity, and support better decision-making for farmers. However, challenges such as high implementation cost, system complexity, and dependency on large datasets still limit their practical adoption. Overall, pest attack early risk indicator systems offer a promising solution for modern agriculture, and with further improvements in simplicity, scalability, and cost-effectiveness, they can play an important role in promoting sustainable and smart farming practices.

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