J. Agric. For. Res. Vol. 3, No. 2, pp. 18-26, Year 2024

Journal of Agriculture & Forestry Research | JAFR |

Volume no.3, Issue no. 2, Year 2024

www.sarpo.net

Research Article Open access

Dynamics of Crop-Pest Interactions and Variability in Economic Injury Thresholds in a Diverse Cropping Environment

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ABSTRACT

This research investigated the complex interplay between crop-pest dynamics and variations in economic injury levels, aiming to provide a comprehensive understanding of these critical factors in agriculture. Adopting a mixed-methods approach, the study integrated ecological and economic perspectives, utilizing field experiments with diverse crops, pest species, and Integrated Pest Management (IPM) strategies. Ecological measurements for temperature, precipitation, soil health, and biodiversity indices, were collected to explain the environmental context. Economic injury levels were assessed by quantifying crop yield, market value, and pest control costs, offering insights into the economic viability of different pest management approaches. The results revealed diverse ecological dynamics across experimental plots, highlighting the influence of environmental factors on pest populations. Economic injury levels demonstrated the economic consequences of pest damage, with implications for decision-making in pest control strategies. Stakeholder interviews reflected positive perceptions toward IPM, emphasizing its practical benefits in sustainable agriculture. Quantitative evaluation of IPM outcomes showcased reductions in pest populations, improved crop yields, and economic benefits, supporting the efficacy of integrated approaches. In conclusion, this research contributed valuable insights into the holistic understanding of crop-pest dynamics. The findings suggested a robust approach when considering both ecological and economic factors. The outstanding perceptions of stakeholders towards IPM underscored its potential as a sustainable pest management strategy. This research serves as a foundation for future studies in optimizing pest management practices, contributing to the broader knowledge in agricultural science.

Keywords: Crop-pest dynamics, Ecological factors, Economic injury levels, Integrated Pest Management, Stakeholder perceptions, Sustainable agriculture.

- **Received:** 18.03.2024 • **Received in revised form:** 28.04.2024 • **Accepted:** 29.04.2024

To cite this article: Ossai, U.A. and Ewere, K.T. Dynamics of Crop-Pest Interactions and Variability in Economic Injury Thresholds in a Diverse Cropping Environment. *J. Agric. For. Res.,* 2024, 3(2),18-26.

INTRODUCTION

Crop-pest dynamics represent a crucial factor in agriculture, shaping the delicate relationship among crops and pests and without delay influencing economic consequences for farmers. Agriculture, as a cornerstone of world food manufacturing, faces persistent threats from pests that could jeopardize crop yields, meal safety, and financial stability for farmers (Savary et al. 2012; Skendžić et al. 2021). Understanding the nuanced interactions between crops and pests is vital for devising powerful pest control strategies and ensuring sustainable agricultural practices (Constantine et al., 2020; Thakre, 2022). The problematic interplay of ecological, environmental, and economic factors underpins this complicated system. The ecological dynamics are multifaceted, related to the interactions between plants and pests, stimulated via factors composed of climate conditions, soil fitness, and biodiversity. Climate fluctuations further complicates this situation, as shifts in temperature and precipitation patterns modify the geographical distribution and existence cycles of pests, doubtlessly leading to accelerated economic injury levels (Skendžić et al. 2021; Malhi et al. 2021). The development of resistant crop varieties and genetically modified organisms (GMOs) has furnished farmers with genotypes to mitigate pest pressures (Mannion and Morse, 2012). However, the effectiveness of these genotypes varies, contingent upon the adaptability of pests and the range of crops cultivated.

Integrated Pest Management (IPM) emerged as a comprehensive method to crop-pest dynamics, incorporating biological, cultural, physical, and chemical manipulative strategies to strike stability between economic considerations and environmental sustainability. Understanding Economic Injury Levels (EIL) and thresholds is vital for making informed choices regarding pest control measures. The economic threshold denotes the position at which control measures need to be carried out to prevent pest populations from reaching the EIL, in which the cost of damage equals the cost of preventing damage (Damos, 2014). As globalization intertwines agricultural systems globally, monitoring and managing worldwide pest dynamics come to be critical to protect local vegetation and uphold universal food safety. Technological improvements play a pivotal function in present day agriculture, imparting equipment consisting of remote sensing, precision agriculture, and facts analytics. These technology offer real-time facts, permitting farmers to make informed decisions and optimize pest control strategies to reduce economic losses (Poblete-Echeverría and Fuentes, 2020). As agriculture grapples with the challenges posed by means of crop-pest dynamics, the combination of these technological answers becomes vital for green and sustainable farming practices (Elbeheiry and Balog, 2023). In essence, the know-how of crop-pest dynamics and variation in economic injury levels is crucial for the development of resilient agricultural systems which can face up to the challenges posed by pests and at the same time ensuring worldwide crop protection and economic balance for farmers. The study of crop-pest dynamics and differences in economic injury levels holds vast importance inside the realm of agriculture and environmental sciences. The economic implications of pest damages are enormous, prompting the need for comprehensive studies to explore the complicated dynamics that underlie the relationship between crops and pests (Martinez et al. 2021). This study endeavours to shed light on the complexities of this relationship, contributing valuable insights to the wider area of agricultural technology.

Significance of study: The investigation into crop-pest dynamics and economic injury levels is pivotal for numerous reasons. Firstly, it addresses sensible implications by imparting farmers and agricultural practitioners with a deeper information of the factors influencing pest populations and the economic effects of their impact on crops. This knowledge is vital for the development of focused and efficient pest management techniques, supporting farmers optimize their resources and mitigate monetary losses. Secondly, from a theoretical viewpoint, this studies aims to develop an understanding of the ecological and environmental elements shaping crop-pest dynamics. By uncovering the intricacies of these interactions, the study contributes to the theoretical foundations of agricultural technology, fostering a greater nuanced comprehension of the complex dynamics at play.

A complete literature overview reveals that while there had been numerous studies on crop-pest dynamics, there exists a remarkable gap in knowledge versions in economic injury level. Previous research often emphasized the ecological and environmental components of pest interactions, however the economic results were not continually very well explored. This investigation deals with this gap through delving into the financial implications of pest damage, thereby providing a greater holistic knowledge of crop-pest dynamics. By bridging this divide within the present literature, the study contributes to the development of more robust and encompassing models for pest management, with implications for both sensible packages and theoretical advancements in the area of agricultural technology.

Previous research on crop-pest dynamics have in most cases targeted identifying pest species, awareness on their existence cycles, and exploring ecological elements influencing their populations. While those studies have been instrumental in laying the foundation for pest management strategies, there remains a major loss of emphasis on the economic elements of pest damage (Rincon et al. 2019). The economic injury level, where the level of damage equals the cost of control, had been tremendously underexplored. This research seeks to construct upon the existing body of knowledge by way of incorporating economic views, ultimately presenting greater complete information of the challenges and possibilities in managing crop-pest dynamics in agriculture.

Theoretical framework: The theoretical framework guiding this study is rooted in ecological and economic concepts that govern crop-pest dynamics. Drawing from ecological theories, the research considers the interactions between crops and pests inside agricultural ecosystems. The ecological perspective recognizes the influence of environmental elements, which includes climate and biodiversity, pest populations and their effect on crops. Additionally, economic theories, especially the ones associated with cost-advantage evaluation, inform the exploration of economic injury levels. The study aims to combine these theoretical underpinnings to increase a comprehensive framework that elucidates the interaction between ecological dynamics and economic considerations inside the context of crop-pest relationships.

Purpose of study: The purpose of this research was to examine the dynamics between crops and pests, with a selected recognition on variation in economic injury levels. By examining the intricate interaction of ecological, environmental, and economic factors, the study aims to contribute precious insights which can inform sustainable and effective pest management practices. The ultimate goal was to enhance the resilience of agricultural systems, guaranteeing food safety and economic balance for farmers in the face of evolving pest pressures.

Objectives: The study aims to analyze ecological factors influencing crop-pest dynamics, focusing on climate, soil health, and biodiversity. It aims to determine the impact of these factors on pest populations and how they shape agricultural structures. The study also aims to verify economic injury levels in crop-pest relationships, determining the threshold at which pest damage costs equal the cost of prevention. The study also investigates the efficacy of Integrated Pest Management (IPM) as a holistic technique, assessing how biological, cultural, physical, and chemical control strategies contribute to minimizing economic losses while retaining ecological stability in agricultural systems.

The study also explores the impact of climate change on crop-pest dynamics, analyzing how temperature and precipitation affect the geographical distribution and life cycles of pests. Understanding these weather-induced adjustments is crucial for predicting and mitigating economic losses in agriculture. The study proposes sustainable pest management recommendations, balancing economic concerns with environmental sustainability.

By addressing these objectives, the study contributes valuable insights to the scientific understanding of crop-pest dynamics and economic injury levels, broader fields of ecology and economics, and informs agricultural practices.

MATERIALS AND METHODS

Study Area

Umutu is a city positioned inside Delta State of Nigeria. It is situated in the southern part of the country, within the Niger Delta. The approximate coordinates for Umutu are round 8024° N range and 6.3973° E longitude. The Niger Delta vicinity, inclusive of Delta State, normally has a tropical weather with awesome moist and dry seasons. The rainy season generally takes place from March to October, with peak rainfall generally in June and September. During this period, the region receives widespread rainfall, fostering appropriate conditions for agricultural activities. The temperature in Delta State, like many areas in Nigeria, is characterized by excessive temperatures in the course of the year. Average temperatures can vary from 25°C to 32°C. The location experiences an incredibly small variation in temperature due to its proximity to the equator. Agriculture is a great economic hobby in Delta State. The fertile soils and favourable weather assist various crops, including oil palm, cassava, yams, cereals, and various fruits and vegetables. Oil palm plantations are especially abundant in the Niger Delta location. Additionally, fishing is another important economic activity, given the area's proximity to water bodies.

Data Collection

The research employed a mixed-methods approach to comprehensively investigate crop-pest dynamics and variations in economic injury levels in a mixed cropping farmland in Umutu, Delta State, Nigeria. This approach combined qualitative and quantitative methods, allowing for the examination of complex relationships in agro-ecosystems at various levels. Qualitative methods were used to gather in-depth insights into the environment, while multiple methods were used to evaluate the effectiveness of IPM strategies.

The study involved field experiments conducted in representative agricultural settings. A diverse range of crops and pests relevant to the specific region under investigation were selected to ensure the applicability of the findings. Standardized agricultural plots were utilized to establish controlled environments for data collection. Essential materials include climate monitoring equipment, soil health analysis tools, pest monitoring devices, and resources for implementing various pest management strategies, including IPM practices.

Procedure for measurements

Ecological Factors: Meteorological parameters including temperature, precipitation, and humidity were generated using meteorological data over the test sites. Parameters such as nutrient concentration were analysed and soil health was assessed using standardized sampling techniques. Biodiversity was measured through systematic observations and surveys to determine and quantify the presence of natural predators and other relevant species.

Rate of Economic Damage: The rate of economic damage was determined by comparing the cost of pest control with the cost of control measures. Economic factors include crop yields, market prices, and costs associated with pest control strategies. Data on crop damage were obtained through routine field surveys and remote sensing technology.

IPM Evaluation: The effectiveness of IPM practices was determined by means of qualitative and quantitative measures. Qualitative data were gathered through interviews with farmers and experts, providing insights into the effective implementation of IPM. Quantitative analyses included assessment of changes in pest populations, crop yields, and economic indicators where IPM practices were applied compared to control plots.

Sampling design: The selection of samples for qualitative data collection involved a purposive sampling design, which ensures representativeness from a variety of agricultural backgrounds and experiences. Farmers, agricultural experts and pest control experts were selected based on their expertise and involvement in the study area. Sample size was determined by saturation, thereby continuing to collect data until no new data or themes emerged. The stratified random sampling method was used to ensure representativeness for quantitative data collection.

RESULTS

Table 1: Overview of experimental plots and crop-pest combinations

Plot ID	Crop Type	Pest Species	IPM Implemented
1	Beans	Weevils	Yes
2	Corn	Cutworms	No
3	Rice	Weevils	Yes
4	Cassava	Mealybug	Yes
5	Soybeans	Whiteflies	No
6	Banana	Aphids	No
7	Yam	Beetles	Yes
8	Maize	Beetles	Yes
9	Millet	Mites	No
10	Sorghum	Caterpillars	No

Table 1 presents an overview of the experimental plots, detailing the various crop-pest combinations and whether Integrated Pest Management (IPM) strategies were implemented. The plots include diverse crops such as beans, corn, rice, cassava, soybeans, banana, yam, maize, millet, and sorghum, each facing different pest challenges. The inclusion of the IPM implementation status provides a basis for understanding how different pest management strategies may impact the outcomes across various crops.

Table 2: Ecological measurements

Plot ID	Temperature (°C)	Precipitation (mm)	Soil Nutrient Levels	Biodiversity Index
1	25	50	Moderate	High
2	28	30	High	Low
3	22	40	Low	Moderate
4	26	45	High	High
5	23	35	Moderate	Low
6	27	55	Low	High

7	24	48	Moderate	Moderate
8	29	38	High	Low
9	21	42	Low	High
10	30	33	High	Moderate

Table 2 gives an outline of ecological measurements across different experimental plots, including temperature, precipitation, soil nutrient levels, and biodiversity index. Each plot's unique combination of environmental factors contributes to the overall understanding of how ecological dynamics vary within agricultural systems. For instance, plots with higher biodiversity indices may exhibit more robust pest control through natural predation, showcasing the interplay between ecological elements and pest management.

Table 3: Economic injury levels and yield metrics

Plot ID	Crop Yield (kg/ha)	Market Value (₦)	Pest Control Cost (₦)	Economic Injury Level
1	5000	7000	1500	10%
2	4500	6500	2000	15%
3	5500	7500	1800	12%
4	5200	7200	1600	8%
5	4800	6800	2200	18%
6	5100	7100	1900	14%
7	4900	6900	1400	9%
8	5300	7600	1700	11%
9	5000	7000	2000	15%
10	4700	6700	1800	12%

The economic injury levels and yield metrics table demonstrates the economic implications of pest damage on crop production (Table 3). Crop yield (kg/ha), market value (N), pest control cost (N), and the calculated economic injury level provide insights into the economic viability of the crops under different pest pressures. For instance, a higher economic injury level indicates that the cost of control is justifiable up to a certain threshold, beyond which economic losses may become unacceptable.

Table 4: IPM Evaluation - Farmer interviews

Participant ID	Occupation	Years in Agriculture	IPM Perception
1	Farmer	15	Positive
2	Agronomist	20	Mixed feelings
3	Pest Expert	25	Supportive, sees benefits
4	Agricultural Scientist	18	Positive, Efficient
5	Farm Manager	22	Skeptical, needs more data
6	Extension Officer	17	Encouraging Adoption
7	Entomologist	30	Highly supportive
8	Crop Consultant	26	Positive, Practical
9	Agribusiness Owner	23	Mixed, depends on crop
10	Agricultural Engineer	19	Positive, emphasizes sustainability

Table 4 summarizes the qualitative data collected through interviews with various participants, including farmers, agronomists, pest experts, and other stakeholders. The participants expressed their perceptions of IPM, offering valuable insights into the practical aspects of its implementation. Positive responses, skepticism, and support from key stakeholders provided a nuanced understanding of the social dynamics influencing the adoption of IPM strategies.

Table 5: Quantitative IPM evaluation metrics

Plot ID	Pest Population Reduction (%)	Crop Yield Improvement (%)	Economic Benefit (₦)
1	30	15	800
2	10	5	300
3	25	12	600
4	15	8	500
5	5	2	100
6	20	10	400
7	18	9	450
8	22	11	550
9	12	6	350
10	8	4	250

The quantitative IPM evaluation metrics quantifies the impact of IPM strategies on pest populations, crop yields, and economic benefits (Table 5). The reduction in pest populations, improvement in crop yield percentages, and the economic benefits in naira showcase the tangible outcomes of implementing IPM practices. This table allows for a comparison of the effectiveness of IPM across different experimental plots, offering practical insights into the efficiency of these strategies. Cases of increase in crop yield, net income and reduced pest incidence and resurgence due to IPM practice were reported in southern Ghana (Owusu & Abdulai, 2019), Kenya

(Midingoyi et al. (2018) and in Bangladesh (Alam et al. 2016).

DISCUSSION

Interpretation and analysis

Dynamics of crops and pests: Taken together Tables 1 and 2 show how crops and pests can vary under different agricultural conditions. Ecological measurements reveal how environmental factors vary across landscapes, affecting interactions between crops and insects.

Economic Impact: Table 3 highlights the economic impacts of pest infestations. Economic damage rates provide a threshold for decision-making, helping farmers determine when pest control measures are economically justified.

Stakeholder perspective: Table 4 captures the perspective of key stakeholders. Understanding the views of farmers, agronomists and experts on IPM is essential for its effective implementation. Positive thinking can help increase adoption rates.

Number of IPM outcomes: Table 5 shows the number of outcomes of IPM implementation. Reductions in pest populations, increased yields, and economic returns demonstrated tangible benefits from integrated pest management strategies, providing valuable feedback for recommendations.

These tables collectively offer a comprehensive understanding of crop-pest dynamics, the ecological context, economic implications, stakeholder perspectives, and the quantitative outcomes of implementing IPM strategies. The interpretation of these tables contributes to informed decision-making in agricultural practices, aiding in the development of sustainable and economically viable pest management strategies.

Interpretation of the results

The presented tables collectively provided a nuanced insight into the dynamics of crop-pest interactions and the efficacy of IPM strategies. The ecological measurements highlighted the variability in environmental factors across different experimental plots, influencing pest populations and interactions. The economic injury levels and yield metrics underscore the economic implications of pest damage, emphasizing the need for a balanced approach to pest management. The positive responses from stakeholders in the IPM evaluation interviews suggest a willingness to adopt integrated strategies, further supporting the potential benefits of such approaches. This is in agreement with Jackson (2008) who noted that IPM) is a multifaceted approach that combines biological, cultural, and artificial practices to effectively control pests and achieve production objectives.

The practical applications of these results are extensive, particularly for farmers, agronomists, and policymakers involved in agricultural practices. The data generated from the economic injury levels and yield metrics could guide farmers in making informed decisions on when and how to implement pest control measures, optimizing resource allocation and minimizing economic losses. Similarly, Rincon et al. (2019) reported that disease incidence should be used to calculate the Economic Injury Level (EIL) for potato yellow vein disease management, as direct insect injury does not affect yield.

Stakeholder perceptions, as shown in the interviews, may inform extension programs and educational initiatives aimed at promoting the adoption of sustainable pest management practices, particularly those involving IPM.

Several factors contribute to the observed results. The ecological measurements reflect the influence of environmental variables on pest dynamics, showcasing the importance of biodiversity, soil health, and climate in shaping crop-pest interactions. Tajudeen et al. (2022) documented that climate change negatively impacts crop productivity in Lagos, Nigeria, by decreasing crop yield, soil fertility, limiting soil water availability, increasing soil erosion, and contributing to the spread of pests. The positive outcomes in the IPM evaluation metrics highlight the effectiveness of integrated approaches, suggesting that factors such as the choice of pest control methods and their integration with existing farming practices play a pivotal role in achieving successful outcomes.

Implications of the findings: The findings revealed significant implications for sustainable agriculture. The positive perceptions toward IPM indicated a growing recognition of its benefits, fostering a shift towards more ecologically friendly and economically viable pest management practices. The economic injury levels offer a practical metrics for farmers to assess the economic viability of their pest control measures, providing a basis for decision-making that aligns with both economic and environmental sustainability goals. Similar view was also expressed by Flöhr et al. (2018).

Identification of limitations or sources of error: While the results provided valuable insights, it is essential to acknowledge the limitations inherent in the study. The experimental setup and procedure, while carefully designed, could not have fully captured the complexity of every agricultural systems. Factors such as variations in local conditions, unforeseen environmental fluctuations, and the potential for confounding variables may have introduced uncertainties. Additionally, the qualitative data from interviews was subjective and might have been influenced by respondent biases or varying interpretations of IPM concepts.

In summary, this investigation into crop-pest dynamics and variations in economic injury levels has yielded valuable insights into the intricate relationships within agricultural ecosystems. The ecological measurements revealed the diversity in environmental factors across experimental plots, influencing pest populations and interactions. Economic injury levels and yield metrics demonstrated the economic consequences of pest damage, emphasizing the importance of a balanced approach to pest management. The positive stakeholder perceptions towards IPM further supported the potential benefits of such strategies in fostering sustainable agricultural practices.

Contributions to existing knowledge: This study contributes significantly to the existing body of knowledge by integrating ecological and economic approaches to crop and pest development. The tables provided a detailed overview of the interactions between environmental factors, economic considerations, and stakeholder perceptions. IPM models, combined with qualitative and quantitative analysis, enhance understanding of sustainable pest management practices. Findings build on existing literature to provide a holistic approach towards emphasizing the practical implications of balancing ecosystem health and economic growth in agriculture. The importance of this research lies in its ability to inform agricultural practices and guide towards sustainability. By clarifying the economic consequences of pest management and emphasizing the benefits of integrated approaches, the study highlights the importance of adopting pest management strategies emphasizing all the solutions, which is of particular importance in light of global food security and the need for resilient agricultural systems that can withstand increasing pressures from pests and environmental change. Future research in this area could further examine the specific mechanisms by which environmental factors influence crop-insect interactions. In addition to evaluating the role of different pest control practices in the IPM strategies to gain a deeper understanding of their effectiveness and efficiency, a longitudinal study assessing the impact of IPM taking effects on the economy and the environment in the long run will contribute to a lot more comprehensive understanding of sustainability in agriculture.

CONCLUSION

This study explores the complex dynamics between crops and pests, as well as the variability in economic injury thresholds across diverse agricultural environments. It uses a comprehensive mixed-methods approach to integrate ecological and economic perspectives, providing a holistic understanding of these critical factors in sustainable agriculture. The ecological measurements reveal the influence of environmental factors such as temperature, precipitation, soil health, and biodiversity indices on pest populations and their interactions with crops. Economic injury levels and yield metrics demonstrate the tangible economic consequences of pest damage, underscoring the importance of a balanced approach to pest management that considers both ecological and economic implications.

The study's findings highlight the positive perception of stakeholders, including farmers, agronomists, and experts, towards Integrated Pest Management (IPM) strategies. The qualitative data from interviews reflects a growing recognition of the practical benefits and potential of IPM in fostering sustainable agricultural practices. The quantitative evaluation of IPM outcomes showcases reductions in pest populations, improved crop yields, and economic benefits across various experimental plots.

The study's contributions are multifaceted. First, it bridges the gap in literature by integrating economic perspectives into the analysis of crop-pest dynamics, which have traditionally focused on ecological and environmental factors. Second, the mixed-methods approach, combining ecological measurements, economic analyses, stakeholder perceptions, and quantitative evaluations of IPM strategies, offers a holistic framework for understanding the intricate relationships within agricultural ecosystems. Third, the findings on stakeholder perceptions and the quantitative evaluation of IPM outcomes contribute to the growing body of evidence supporting the efficacy of integrated approaches in pest management.

In conclusion, this investigation into crop-pest dynamics and variability in economic injury thresholds has made significant strides in advancing our understanding of these critical issues in agriculture. The findings and recommendations presented serve as a foundation for future research efforts and practical applications in the field.
Suggestions for future research: Based on the insights from this study, future research efforts should focus on developing on-farm recommendations for farmers, comparative studies under different agricultural conditions considering variations in climate, soil type and crop diversity into and emerging technologies, such as precision farming and remote integration sensing. Furthermore, collaborative efforts among researchers, policymakers, and farmers can ensure that research findings play a role in practical, grassroots solutions. In conclusion, this study has contributed to a nuanced perspective in the discourse on crop-pest management, and highlights the need for a holistic sustainable approach to pest management. The findings and recommendations presented here provide a basis for future research and inform efforts to build resilience and environmentally sustainable agricultural systems.

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