

Book Chapter: Spatial Distribution and Damage Dynamics of Major Insect Pests in Rice Field across Three Agroecological Zone in Sierra Leone

Alie Hindolo Dembeh Mansaray¹, Alusaine Edward Samura², Vandi Amara^{2*}, Dan David Quee², Alimu Mansaray³, James Kargbo¹

¹Ministry of Agriculture and Food Security, Freetown, Sierra Leone

²Department of Crop Protection, School of Agriculture and Food Science, Njala University, Njala Campus, Njala, Sierra Leone

³Sierra Leone Agricultural Research Institute/Njala Agricultural Research Center, Njala, Sierra Leone

Email: *vandiamara66@gmail.com

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Abstract

Rice production in Sierra Leone is critically affected by insect pest infestations, leading to significant yield losses and food insecurity. This study assessed the prevalence, spatial distribution, and damage caused by major insect pests across three major rice-producing districts (Kambia, Kenema, and Moyamba) representing diverse agroecological zones. A total of 90 rice fields were surveyed using standard sweep net sampling and GPS-enabled data collection. Five key insect pest species were identified: leafhoppers, stem borers, rice ear bugs, and rice gall midges, with leafhoppers being the most dominant. Results revealed notable regional variation, with Kambia exhibiting the highest pest density and damage levels. The panicle initiation and heading stages of rice were the most vulnerable, with pest density peaking at 5.1 pests/m² and associated damage exceeding 50%. Waterlogged soil significantly increased the likelihood of high pest infestation (OR = 2.01), underscoring the influence of soil moisture on pest proliferation. Logistic regression and generalized linear models identified pest density, crop growth stage, and environmental conditions as significant predictors of infestation severity. Kenema also demonstrated elevated pest pressures, likely due to unique microclimatic and agronomic factors. In contrast, Moyamba showed relatively lower pest incidence. The findings emphasize the need for stage-specific pest control, improved water management, and the promotion of Integrated Pest Management (IPM) strategies tailored to local conditions. Strengthening farmer knowledge and access to IPM tools is essential to reduce pest-induced losses and enhance sustainable rice production in Sierra Leone.

Keywords

Rice, Major Insect Pest, Spatial, Distribution, Agroecological, Sierra Leone

1. Introduction

Rice is the main staple crop in Sierra Leone and provides 80% of its caloric intake [1]. Rice cultivation in Sierra Leone is primarily undertaken by smallholder farmers who produce barely enough for home consumption with little or none for the market across both upland and diverse lowland ecologies. The smallholder farmers in Sierra Leone are generally resource-poor with only the hoe, axe, and cutlass as the main implements, while labour is mainly supplied by family members, thereby severely limiting their scale of production [2]. According to FAO [3], of the total global rice production of 499.6 million tonnes in 2020, SSA contributed about 3%. Of the rice produced in SSA, more than 80% was from eight countries (Nigeria, Madagascar, Ivory Coast, Tanzania, Mali, Guinea, Sierra Leone, and Senegal; with Nigeria and Madagascar accounting for one third of the rice production in the subregion [3]. A steady increase in rice cultivation has occurred over the years, but not sufficient to meet basic requirement of demand, hence a deficit in the country's rice supply chain. Consumption of rice, however, exceeds production in the country. Sierra Leone produces 712,092 metric tonnes of rice while it consumes 1094 million metric tonnes of rice annually [4]. Moreover, the country has long struggled to meet its local rice consumption demands. In Sierra Leone, pest and disease attacks are among the major factors limiting the production and high yield. Insect pests attack has become a major challenge limiting rice production couple with other challenging factors such as climate change, poor irrigation, poor soil fertility and diseases infection (*Ripersia oryzae*), Plant hoppers (*Nephotettix apicalis*, *Sogatella fercifera* and *Ceeadela spectra*), Yellow stem borer, striped borer, and Armyworm (*Mythimna seprata*) to be found invasive in the rice field and is responsible for about 80% yield loss. However, in Sierra Leone little is known about the status and distribution of insect pests of rice in farmers' fields as well the damage they cause to our rice crop. Therefore, the aim of the study was to assess the prevalence and distribution of major insect pests of rice as well as their damage to rice in Sierra Leone.

2. Methodology

2.1. Description of the Study Area

The survey was conducted in Kambia, Kenema and Mayamba districts of Sierra Leone. Kambia district is in the Northwest region and is known for its fertile lowland and high cultivation of rice. The district is ranked first in terms of rice cultivation and there are a lot of bulli land and mangrow swamps which support rice production. Kenema district is the eastern region which is a major agricultural

hub of the eastern region especially for cash crops such as cocoa, coffee and palm oil. The district is regarded as one of the highest rice producing districts in the eastern region and it's known for its vibrant market activities and relatively high rainfall which also support diverse agricultural activities. Moymaba district is in the southern region and predominantly the rural population are engaged mainly in rice, cassava and groundnut farming. The district is one of the best rice producing districts in the southern region. These districts were selected based on the variation in agroecological conditions farming system and socio-economic characteristic allowing for a comprehensive assessment.

2.2. Research Design

This study uses survey research design to determine the prevalence and distribution of major insect pests of rice in three districts.

2.3. Data Collection

A survey was conducted in September 2024 in three major rice growing districts (Kambia, Kenema and Moyamba) of the country to assess major diseases of rice on farmers' fields. The survey was carried out on the main axes of three districts. The survey was conducted by three trained enumerators that are knowledgeable enough in diseases assessment. The fields surveyed were separated on average by 10 km, the diagonal (×) method was used in this study to assess the plants and a total of 30 plants were evaluated in each field, with 15 plants randomly selected along each diagonal. A tablet which has Kobo application and GPS facility that made it possible to identify the geographical coordinates (longitude, latitude, altitude) in each field was used to collect in each field.

Firstly, to assess the incidence of the pest damage at the plant level, 30 plants per field were evaluated by selecting plants along each diagonal and the portion of infested plants was recorded and expressed as incidence.

$$\text{Mean incidence}(\%) = \frac{\sum \text{Number of pest caught by the net}}{\sum \text{Number of plant population within sample area}} \times 100$$

Secondly, to assess the pest population density, a sweeping net, an essential tool for capturing adult insects in a field, providing a straightforward and efficient way to monitor pest populations, was used to determine the type and number of insect pests found in each field. The insect pests were systematically swept by the net through the crop canopy at a consistent angle and speed, covering a defined area. This action dislodges insects from the plants and traps them in the net. After completing the sweeps, the contents of the net were examined carefully to identify and count the captured insects. The number of insects was recorded, and the pest density was calculated as the number of insects per unit area swept.

$$\text{Pest Density} = \frac{\text{Number of insects caught}}{\text{Area swept or number of sweeps}}$$

2.4. Data Analysis

An analysis of variance with one classification criterion (ANOVA) was carried out to determine the distribution of the incidence and severity of symptoms. The differences between the means were compared by using Fisher's LSD test to distinguish homogeneous groups at the significance level $P = 0.05$. The distribution maps were drawn using Geomfunction in R studio. To determine the factors that affect the likelihood of high pests' population in farmers field, logistic regression and generalized linear model (GLM) with a passion or negative binomial distribution analysis was done according to Cameron and Trivedi (2013).

The formula for logistic regression was computed as:

$$\log\left(\frac{P}{1-p}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n + \epsilon$$

where:

$\frac{P}{1-p}$ = is the odd of high infestation occurring

β_0 = intercept

$\beta_1 + \beta_1, \beta_2, \dots, \beta_n$ = The coefficients of the predicator variable

ϵ = the model's error term (also known as the residuals).

x_1, x_2, \dots, x_n = are the predicotors baibales (pests density, rice growth stage and soil moisture)

The general linear model equation is computed as follows

$$\log(E(Y)) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n$$

where:

$E(Y)$ = the expeted pest density

β_0 = intercept

$\beta_1 + \beta_1, \beta_2, \dots, \beta_n$ = The coefficients of the predicator variable

x_1, x_2, \dots, x_n = are the predicotors baibales (pests density, rice growth stage, region and soil moisture)

3. Results

3.1. Pest Species Density across the three Districts

The findings in **Figure 1** revealed that across the three districts, stem borer, rice ear bug, leafhopper, and rice gall midge were the insect pest species in farmers field though with different density per unit area across the three districts (Kambia, Kenema and Kailahun) From the result it was revealed that the number/density of stemborer was highest in Kambia district (4.2 per unit area) and lowest in Moyamba district (2.8). The variation indicates that the stem borer population might be because of the environmental condition or crop management practice which may favor stem borer population due to temperature, humidity or vegetation that enhance the survival and reproduction. The condition in Moyamba district may not proliferate. Similarly, Notable variation was observed in rice ear bug popula-

tion across the districts. The findings however observed the highest population in Kambia district (2.5) followed by Moyamba district (1.8) and the least was observed in Kenema district (1.2). The relatively high population in Kambia district might be because of the environmental factors that influenced and facilitated the establishment and survival of the rice ear bugs.

Rice leaf hopper was the most prevalent insect pest species found across the districts. The finding revealed that Kambia district had the highest number of leafhopper (6.3) followed by Kenema district (5.6) and Moyamba district recorded moderately low density (4.7). The high density of leafhoppers in Kambia district can also be attributed to the presence of high favored environment conditions for the Lifecycle of the Pest. The result also showed that rice gall midge population was moderately higher in Kamba (2.5) but was low in Moyamba (1.2) and Kenema (1.8) which suggest that rice gall midge was relatively low in farmers field across the three districts.

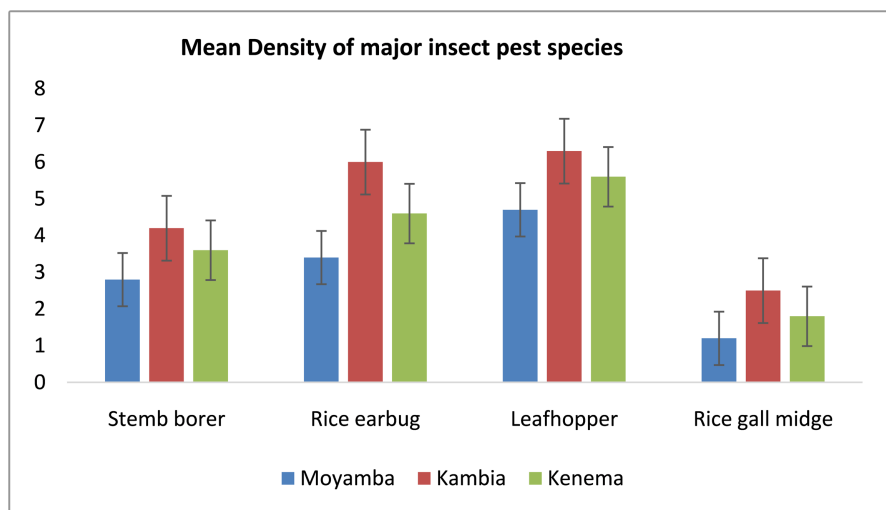


Figure 1. Mean density of major insect pest species across three rice-growing districts in Sierra Leone.

The distribution and the extent of damage of rice leafhopper across the three rice growing districts in **Figure 2(a)** and **Figure 2(b)** showed varied level of infestation and distribution. The distribution maps revealed that leafhoppers were found in all the farms visited with a population ranging from 1 - 6 and most of the farms have leafhopper population ranging from (3 - 4) which is classified as moderately low with the highest concentration observed in Kambia district, followed by Moyamba district. A few farm in Kenema district also recorded high Leafhopper numbers, but the highest concentration was in Kambia district. A similar trend was also observed in the percentage damage of the with farms in Kambia district experiencing the highest percentage damage of leafhopper ranging from 41% - 55%. In Kenema district, some farms recorded high damage levels, while in Moyamba district only few farms experienced severe damage. However, most rice farms in Moyamba reported moderate damage levels ranging from 20% - 30%.

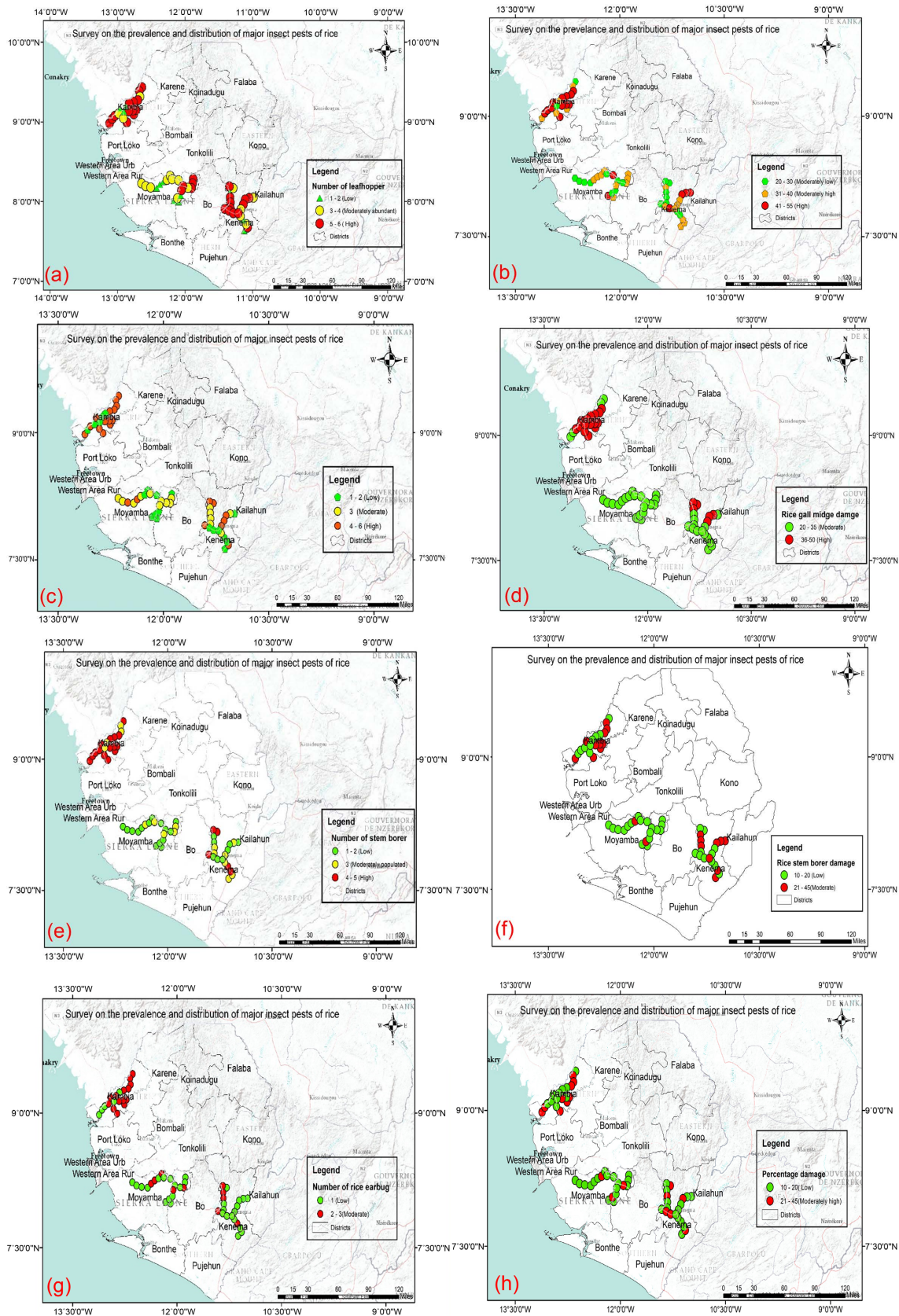


Figure 2. Number of leafhoppers and damage of rice leafhopper in three major rice growing districts of Sierra Leone.

The distribution and the extent of damage of rice gall midge across the three rice growing districts in **Figure 2(c)** and **Figure 2(d)** showed varied level of infestation and distribution. The distribution maps revealed that rice gall midge were found in all the farms visited with a population ranging from 1 - 6 and most of the farms have leafhopper population ranging from (1 - 2) which is classified as low with the highest concentration observed in Kambia district (4 - 6), followed by Kenema district. Though few farms in Moyamba district also recorded high numbers, the highest concentration was in Kambia district. A similar trend was also observed in the percentage damage with farms in Kambia district experiencing severe damage (30% - 50%). In Kenema district, some farms recorded high damage levels, while in Moyamba district only few farms experienced severe damage. However, most rice farms in Moyamba reported moderate damage levels ranging from 20% - 36%.

The distribution and the extent of damage of rice stem borer across the three rice growing districts in **Figure 2(e)** and **Figure 2(f)** showed varied level of infestation and distribution. The distribution maps revealed that rice stem borer were found in all the farms visited with a population ranging from 1 - 5 and most of the farms have stemborer population ranging from (4 - 5) which is classified as high with the highest concentration observed in Kambia district, followed by Kenema district. Few farms in Moyamba district also recorded moderate numbers, the highest concentration was in Kambia district. Similar trend was also observed in the percentage damage with farms in Kambia district experiencing severe damage (21% - 45%). In Kenema district, some farms recorded moderate damage levels, while in Moyamba district only few farms experienced damage. Overall, the damage of stemborer in all the farms visited was moderate.

The distribution and the extent of damage of rice ear bug across the three rice growing districts in **Figure 2(g)** and **Figure 2(h)** showed varied level of infestation and distribution. The distribution maps revealed that rice ear bugs were found in all the farms visited with a population ranging from 1 - 3 and most of the farms have earbug population ranging from (1 - 2) which is classified as low with the highest concentration observed in Kambia district (4 - 6), followed by Kenema district. Though few farms in Moyamba district also recorded moderately low numbers (2 - 3 plant⁻¹), the highest concentration was in Kambia district. A similar trend was also observed in the percentage damage with farms in Kambia district experiencing moderate damage (21% - 45%). In Kenema district, some farms recorded moderate damage levels, while in Moyamba district only few farms experienced moderate damage. Overall, the rice ear bug damage across the three districts was moderate.

Pest density in **Table 1** has a pronounced positive association with the likelihood of severe infestations, as shown by an odds ratio of 1.57 ($p < 0.001$). This value signifies that each incremental rise in pest density elevates the odds of high infestation by 57%. This strong relationship underscores the role of pest density as a key predictor of infestation severity, reinforcing the importance of systematic

pest monitoring to identify and address potential outbreaks early in their development. Such measures could preemptively mitigate infestation levels before they reach damaging thresholds, thereby safeguarding rice yield and quality.

Table 1. Logistic regression results for factors affecting the likelihood of high pest infestation in rice fields.

Variable	Coefficient (B)	Odds Ratio	95% Confidence interval	p-value
Pest Density	0.45	1.57	1.30 - 1.89	<0.001
Growth Stage				
Tillering	0.25	1.28	0.98 - 1.67	0.07
Heading	0.62	1.86	1.42 - 2.44	<0.001
Ripening	0.32	1.38	1.10 - 1.72	0.01
Soil Condition				
Moist	0.15	1.16	0.92 - 1.46	0.2
Waterlogged	0.70	2.01	1.45 - 2.77	<0.001

Examining the rice plant's growth stages, the **heading stage** emerges as the most vulnerable period, with an odds ratio of 1.86 ($p < 0.001$), indicating that plants at this stage are 86% more likely to experience high pest infestation compared to those at the ripening stage (the reference category). This increased susceptibility may relate to the structural and nutritional changes in the rice plant during heading, as panicle development typically exposes nutrient-rich tissues that attract pests. Given this heightened risk, intensifying pest control interventions during the heading stage could effectively reduce pest-induced damage and contribute to more resilient rice crops.

The **ripening stage** also shows a statistically significant association with high infestation (OR = 1.38, $p = 0.01$). This finding suggests that, even at later stages, rice plants remain somewhat susceptible to pest damage, albeit at a lower risk than during heading. Effective pest management during ripening could therefore help reduce post-heading infestations, ensuring that the crop reaches full maturity with minimal pest-related losses.

The **tillering stage** displays a marginally positive association with high infestation likelihood (OR = 1.28, $p = 0.07$). Although this relationship is not statistically significant, the trend indicates some vulnerability at this stage, implying that vigilant pest monitoring during tillering might be beneficial, particularly in fields or regions with historically high pest activity. Environmental factors, specifically **soil moisture conditions**, also play a substantial role in pest infestation levels. **Waterlogged soil conditions** are strongly associated with a high likelihood of pest infestation (OR = 2.01, $p < 0.001$), effectively doubling the risk compared to non-waterlogged conditions. Waterlogged environments may create favorable microhabitats that facilitate pest reproduction and survival, possibly by increasing hu-

midity levels that pests thrive in. Furthermore, waterlogged conditions can impair rice plant health, potentially lowering the plants' resilience against pest damage. Implementing strategic drainage and soil moisture management practices may therefore be instrumental in reducing pest risks under such conditions. In contrast, **moist soil conditions** show a non-significant association with pest infestation (OR = 1.16, $p = 0.2$), suggesting that moderate moisture does not substantially elevate pest incidence. While pests may find moist conditions somewhat favorable, they do not confer the same high risk as waterlogged conditions. This implies that while adequate moisture should be maintained for plant health, excessive moisture should be avoided to limit pest proliferation risks. Consequently, fine-tuning soil moisture to optimal, non-waterlogged levels could serve as a feasible pest control strategy, minimizing severe infestations while promoting plant health and resilience.

3.2. Factors Affecting Pest Density in Rice Fields

The analysis in **Table 2** reveals that the panicle initiation stage exhibits the strongest positive association with pest density (IRR = 1.42, $p < 0.001$), indicating a 42% increase in pest incidence relative to the reference ripening stage. This suggests that the panicle initiation phase, a critical stage in rice development marked by high nutrient demand and tissue changes, may be particularly susceptible to pest attacks. The heightened pest activity at this stage likely aligns with pests' preference for nutrient-rich, vulnerable plant tissues, which provide essential resources for their development and reproduction. This observation underscores the need for heightened pest management during panicle initiation, as protecting rice at this stage is critical for reducing pest-related yield losses. Additionally, the tillering and heading stages also show significant positive associations with pest density (IRR = 1.22, $p = 0.01$; IRR = 1.16, $p = 0.04$, respectively), though to a lesser extent than panicle initiation. These findings indicate that pests are particularly active and likely to inflict damage during early to mid-reproductive stages, emphasizing that pest control interventions during these periods can significantly reduce infestation levels. Conversely, the seedling stage shows a weak negative association with pest density (IRR = 0.90, $p = 0.25$), implying that pests are less attracted to or successful in infesting rice at this early growth phase. This reduced pest susceptibility may be attributed to the physical and biochemical characteristics of seedlings, which might deter pest colonization. Regionally, Kenema displays a significantly higher pest density (IRR = 1.35, $p = 0.003$) compared to other districts, pointing to distinct environmental or agroecological factors in this area that may enhance pest survival, reproduction, or infestation success. Such factors may include variations in microclimate, crop management practices, or landscape features, which collectively increase pest pressure in Kenema. In contrast, Kambia does not demonstrate a statistically significant increase in pest density (IRR = 1.13, $p = 0.22$), suggesting that pest proliferation may be less affected by the conditions or practices in this district, leaving Kenema as the more vulnerable location for

pest outbreaks. Soil conditions also play a notable role, with waterlogged fields associated with significantly higher pest densities (IRR = 1.32, $p = 0.01$). This supports the hypothesis that saturated soils provide favorable conditions for pests by creating a humid microenvironment conducive to pest development and potentially affecting the plant's defense mechanisms. High soil moisture might facilitate the establishment and spread of pests by weakening rice plants' resilience and increasing stress susceptibility. In contrast, moist soil conditions do not demonstrate a significant impact on pest incidence (IRR = 1.05, $p = 0.55$), indicating that moderate moisture levels are less likely to exacerbate pest pressure compared to waterlogged conditions.

Table 2. Generalized linear model (GLM) results—factors affecting pest density in rice fields.

Variable	Coefficient (B)	Incidence Rate Ratio (IRR)	95% Confidence interval (IRR)	p-value
Growth stage				
Seedling	-0.10	0.90	0.76 - 1.07	0.25
Tillering	0.20	1.22	1.05 - 1.42	0.01
Panicle Initiation	0.35	1.42	1.19 - 1.69	<0.001
Heading	0.15	1.16	1.01 - 1.34	0.04
Ripening	Reference			
Location (District)				
Kenema	0.30	1.35	1.10 - 1.65	0.003
Kambia	0.12	1.13	0.92 - 1.40	0.22
Environmental factor				
Soil condition (Moist)	0.05	1.05	0.89 - 1.23	0.55
Waterlogged	0.28	1.32	1.07 - 1.63	0.01

In this study, Kenema consistently exhibited the highest pest density (4.5 pests per square meter) alongside the most substantial crop damage (45%) and a larger field area affected (35.2%) compared to Moyamba and Kambia. The observed differences in pest density and severity among districts were statistically significant ($p < 0.05$), suggesting that location-specific environmental or geographical conditions in Kenema might enhance pest habitat suitability or impede effective pest management practices. This finding could reflect variations in microclimatic factors such as humidity, rainfall, and temperature patterns, which are known to influence pest behavior, reproduction rates, and survival. Additionally, the agricultural practices prevalent in Kenema, as well as soil type and moisture conditions, may contribute to heightened pest presence and activity in this region, warranting further investigation to identify and mitigate contributing factors.

Pest density in **Table 3** peaked notably during the panicle initiation stage of rice

growth, reaching 5.1 pests per square meter, with an associated damage rate of 50% and the largest impacted field area (39.2%). The vulnerability of the panicle initiation stage could be attributed to the fact that the reproductive structures, which are critical for yield, are actively forming during this period and may attract more pests or exacerbate pest-related damage. In contrast, the seedling and ripening stages recorded the lowest pest density and damage rates, indicating that these stages are comparatively less susceptible to pest infestation. This differential vulnerability across growth stages aligns with existing research on pest life cycles and host preferences, highlighting the importance of stage-specific pest management interventions. Specifically, intensified monitoring and control measures should be prioritized around the panicle initiation stage to mitigate yield loss effectively.

Table 3. Analysis of pest density, damage, and field area affected across districts, growth stages, and soil conditions.

Variable	Pest Density (Mean ± SE)	Damage (%)	Field Area Affected (Mean ± SE)	p-value
Kenema	4.5 ± 0.3	45.0	35.2 ± 2.4	<0.001
Moyamba	3.8 ± 0.2	30.0	28.5 ± 2.1	0.03
Kambia	4.1 ± 0.3	40.0	33.0 ± 2.0	0.02
Growth Stage				
Seedling	3.2 ± 0.4	20.0	18.0 ± 1.5	<0.001
Tillering	4.8 ± 0.4	35.0	31.5 ± 2.2	0.004
Panicle Initiation	5.1 ± 0.5	50.0 ± 3.6	39.2 ± 2.3	<0.001
Heading	4.0 ± 0.2	25.0 ± 1.6	30.0 ± 1.8	0.02
Ripening	3.7 ± 0.3	15.0	22.5 ± 1.7	0.01
Soil Condition				
Dry	3.6 ± 0.4	25.0 ± 2.0	27.0 ± 1.8	0.03
Moist	4.5 ± 0.3	40.0 ± 3.6	33.5 ± 2.1	<0.001
Waterlogged	5.2 ± 0.4	55.0 ± 4.3	41.0 ± 2.4	<0.001

Soil moisture emerged as another critical factor influencing pest density and severity. Fields with waterlogged conditions recorded the highest pest density (5.2 pests per square meter), with damage levels peaking at 55% and an affected field area of 41%. Waterlogged soil creates a humid microenvironment favorable for pest proliferation and activity, potentially increasing the prevalence of pests such as stemborers and leafhoppers that thrive in high-moisture conditions. In contrast, fields with moist or dry soil conditions exhibited lower pest densities and reduced damage, which may reflect less hospitable conditions for pest survival or movement. These findings underline the need for adaptive pest management strategies that consider soil moisture levels, with targeted interventions in waterlogged fields to curtail pest incidence and crop damage. Understanding the interplay be-

tween soil conditions and pest dynamics is critical, as it can inform field preparation, drainage practices, and site-specific pest control approaches.

4. Discussion

The study reveals significant variation in pest densities across districts, with the highest stem borer density observed in Kambia (4.2 pests per unit area) and the lowest in Moyamba (2.8 pests per unit area). These differences suggest that Kambia's environmental factors, such as temperature, humidity, and vegetation, may create favorable conditions for pest proliferation, corroborating findings by Singh *et al.* [5], who demonstrated the influence of these factors on pest survival and reproduction. In contrast, the lower density observed in Moyamba may reflect more effective local agronomic practices such as regular crop rotation, improved drainage or the use of pest-resistant rice varieties. These practices can disrupt pest life cycles and reduce the availability of suitable habitats; this aligns with Kumar *et al.* [6] who reported that habitat management and crop diversification significantly suppress pest proliferation. Elevated temperatures increase pest feeding rates and reproduction cycle while high humidity enhances egg viability and larvae survival. The study highlights that frequent and moderate rainfall can boost per population by supporting lush vegetation which provides both food and shelter. For instance, it was observed that leaf hoppers were most abundant in Kambia, this pattern mirrors Ahmed *et al.* [7] who linked consistent rainfall and nitrogen rich conditions to increase leaf hopper activity. The rice growth stage significantly influences pest damage. The heading stage emerged as the most vulnerable, likely because soft tissues are more easily penetrated by pests. This finding confirms Zhu *et al.* [8], who reported the need for heightened pest monitoring during sensitive crop stage. The finding indicates that waterlogged conditions nearly double the infestation risk. It was evident that saturated soils moisture creates humid microclimates within the canopy which is ideal for pests such as stem borers and leaf hoppers, consistent with Reddy *et al.* [9], who found that high soil moisture promotes pest outbreak. The study consistently emphasized the high pest densities in Kambia which necessitate robust integrated pest management that includes synchronizing planting dates to disrupt pest life cycles, practicing timely weeding and removing alternative hosts, and introducing pest-resistant rice varieties. Biological controls, such as the conservation of natural enemies, should be encouraged, while judicious and timely pesticide applications may be necessary, particularly during the heading stage when crops are most vulnerable. With lower pest densities, efforts should focus on maintaining and strengthening existing good practices. Continued crop rotation, improved field drainage to reduce excess moisture, and periodic field scouting should be prioritized. The introduction of pheromone traps or light traps could further support early detection, and promoting farmer knowledge about natural predators will help maintain low pest pressures. The clear positive correlation between pest density and infestation severity further demonstrates that pest density is a reliable predictor for crop damage and this emphasizes

the need for systematic pest monitoring and early intervention to prevent economic yield loss. The study suggests that across all surveyed districts, community-based pest surveillance systems would enable rapid reporting and coordinated responses to pest outbreaks is important. Training programs on the benefits of proper water management such as maintaining optimal soil moisture to avoid waterlogging can also reduce pest habitat suitability. Increased access to certified insect-resistant rice varieties, particularly for smallholder farmers, and farmer field schools to demonstrate IPM techniques and the timing of interventions would further strengthen control efforts.

5. Conclusion

This study concluded that there is a spatial and ecological variation in pest densities across rice-growing districts, driven by agroecological and agronomic factors. Kambia consistently recorded the highest pest densities and damage level highlighting the influence of favorable environmental factors such as high humidity and waterlogged soils on pest proliferation which underscore the need for targeted pest management strategies, including cultural practices, pest-resistant varieties, and timely interventions, particularly during the vulnerable heading stage. Pest pressure peaked during the panicle initiation and heading stages which confirms these are the most vulnerable period for rice crops. Soil moisture management emerged as a critical factor, with improved drainage shown to reduce infestation risks. Site-specific integrated pest management strategies including cultural practices, timely planting, improved drainage, and the use of pest-resistant varieties are critical to reducing pest-induced yield losses. Strengthening farmers' knowledge and access to adaptive pest management tools will support sustainable rice production and contribute to improved food security in Sierra Leone.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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