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# Research Article
# Reduced Fall Armyworm (*Spodoptera frugiperda* J.E. Smith) Infestation and Leaf Damage in Maize Fields Adjacent to Forested Margins in Two Districts of Malawi

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## Abstract

**Background and Objective:** Fall armyworm poses a major threat to maize production in Malawi. Forested field margins may influence pest incidence and crop damage, offering potential for sustainable pest management strategies. A study was conducted to assess the impact of forested field margins on fall armyworm incidence and leaf damage in maize in Lilongwe and Salima Districts in Malawi. **Materials and Methods:** A randomized block design involving maize fields adjacent to forested and non-forested margins was used. Nine plots per field were established for fall armyworm assessment, while vegetation diversity was evaluated using stratified plots for herbs, shrubs and trees. Data obtained was subjected to Analysis of Variance (ANOVA) at 5% significance level in GenStat, Odds ratio test in Statistical Package for Social Sciences (SPSS) and Renyi diversity profile in Biodiversity R. **Results:** The results revealed significantly fewer fall armyworms, infected plants and leaf damage in maize fields near forested margins compared to those farther away (p<0.001). Strong associations were observed between fall armyworm presence and plant infection/damage, with higher odds ratios in fields away from forests. Greater tree species richness (89 vs. 8 species) in forested margins likely contributed to reduced pest incidence and plant damage. **Conclusions:** The study demonstrated that proximity to diverse tree species significantly lowers pest infestations. This suggests that integrating forested field margins into agricultural landscapes can serve as a natural pest management strategy, reducing reliance on chemical pesticides and promoting sustainable farming.

**Key words:** Forested field margins, fall armyworm, maize, tree species richness and diversity, Agroecology, Biodiversity and Pest Management

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**Competing Interest:** The authors have declared that no competing interest exists.

**Data Availability:** All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Maize (*Zea mays*) is a staple crop cultivated extensively across the globe, serving as a primary source of food and income for millions of smallholder farmers[1]. However, its production is significantly threatened by the Fall armyworm (*Spodoptera frugiperda*), an invasive pest known for its voracious feeding habits and rapid spread[2-4]. Since its introduction to Africa in 2016, the fall armyworm has caused substantial yield losses, exacerbating food insecurity and reducing household income in many regions[5]. In Malawi, 6.5 million Malawians were proven food insecure due to *Spodoptera frugiperda* in 2016[6]. In Zimbabwe, severe infestation has been reported, causing 44% reduction in household income and 17% increased likelihood of food insecurity[7]. In Kenya, 30% yield losses countrywide, in some cases caused by *S. frugiperda* were reported[8]. Similarly, a 36% reduction in maize production nationwide was reported in Ethiopia[9]. Despite that these reports were based on people's perceptions; it can clearly be deduced that *S. frugiperda* is a significant threat to maize production in Africa. Other reports used reliable data on infestation; however, it is difficult to associate *S. frugiperda* infestation to yield loss. The rate of infestation alone may not accurately reflect the actual yield loss[10]. Despite this, research conducted in smallholder maize fields in Malawi and Zambia revealed that *Spodoptera frugiperda* caused minimal yield reductions. This limited impact could be attributed to maize's strong ability to recover from foliar damage[11]. Furthermore, the effect appears to have declined as natural predators have adapted to target the pest[12].

Despite *S. frugiperda* having less impact on crop yield, farmers might not feel comfortable having pests in their crop fields. The discomfort arises from the potential risks and uncertainties associated with the pest presence. Farmers are naturally inclined to keep their crops as healthy. Seeing pests even if harmless ones, can signal potential problems leading to discomfort and concern. Moreover, *S. frugiperda* is reported as a serious pest from the Americas, where it causes substantial damage to cereal crops, especially maize and rice. Its survival in the Old World threatens the food security and incomes of millions of smallholder farmers[12]. Even Malawi government after reports of *S. frugiperda* it needed to articulate a response to this invasive pest. The recommended initial response was pesticide-driven due to low capacity for Integrated Pest Management (IPM)[6]. The disadvantages of using synthetic pesticides cannot be overemphasized. It has serious consequences to human health and the environment[13-15]. This is exacerbated by lack of knowledge and

skill in use of pesticides by smallholder farmers. Pesticides are not target specific and can greatly impact on natural control agents, which can lead to increased pest attack due to resurgence of the target pest and other pests that were otherwise controlled by the disturbed natural control agents. As a result, farmers are compelled to apply pesticides repeatedly[16], which can further aggravate the problem. In addition, contact insecticides are often ineffective against *S. frugiperda* because the pest typically feeds and shelters within the maize whorl, where the chemicals have limited reach[12]. Smallholder farmers are again challenged with high cost of synthetic pesticides coupled with escalating pest management costs. There is an urgent need therefore to develop alternative pest management options that can be incorporated in sustainable IPM and that would be safe to humans and the environment. To accomplish the aforesaid, this study was carried out building on other studies that have been carried out contributing to development of alternative pest management options.

Recent studies have explored the relationship between agricultural landscapes and pest dynamics, particularly focusing on how proximity to natural habitats influences pest incidence and crop damage. For instance, in Ghana, crop damage from fall armyworm increased significantly with distance from semi-natural habitats, suggesting that these areas harbor natural enemies that help suppress pest populations[17].

Similarly, in Southern Africa, forest proximity positively affects natural enemy-mediated control of fall armyworm (FAW). These studies highlight the potential benefits of integrating natural habitats into agricultural landscapes to harbor natural enemies[18].

While these studies have provided valuable insights into the role of natural habitats in pest management, such studies have not been carried out in Malawi. The need to validate previous research and confirm robustness of the findings in different areas cannot be overemphasized as it will help to establish stronger evidence for the conclusions drawn in the existing literature. Additionally, the influence of tree species richness and diversity within these forested margins on pest dynamics has not been thoroughly investigated[19-23]. Understanding the interactions between forested field margins and fall armyworm dynamics is crucial for developing sustainable pest management strategies[21,24].

The main objective of this study therefore was to assess the effect of forested field margins on fall armyworm incidence and leaf damage on maize. The specific objectives were: (1) To determine the effects of proximity of maize fields to forested field margins on the number of fall armyworm, the number of infected plants and the extent of leaf damage,

(2) To establish the association between the presence of fall armyworm and the occurrence of infected plants, as well as the severity of leaf damage and (3) To assess tree species richness and diversity in the forested field margins in maize fields. Therefore, this study provides insights that can inform the design of agroecological practices, such as the conservation or establishment of forested margins, to enhance natural pest control mechanisms and reduce reliance on chemical pesticides. By elucidating these relationships, the research seeks to contribute to more resilient and sustainable maize production systems, ultimately supporting food security and the livelihoods of smallholder farmers.

## MATERIALS AND METHODS

**Study area:** The study was carried out in the central region of Malawi in Lilongwe and Salima Districts. (Fig. 1) during 2022/2023 and 2023/2024 growing seasons. Two Extension Planning Areas (EPA), Mpingu and Chinguluwe in Lilongwe and Salima districts, respectively, were selected. The two EPAs were selected based on the evidence of the existence of the FAW. The two EPAs are in different agroecological zones, which entail different edaphic, weather and climatic conditions. Farming is the major livelihood activity for majority of households in Lilongwe and Salima Districts[25]. The two districts are significant maize producers making them more vulnerable to *S. frugiperda* attack.

Mpingu EPA is in Lilongwe District in the Central Region of Malawi. The EPA is to the west of Lilongwe, the Capital City of Malawi. Lilongwe district is found in the Lilongwe - Kasungu plain, located on the mid altitude plateau of Central Africa and represents one of the most fertile agro-ecological zones in Malawi that stretches to Dedza, Mchinji, Dowa and Kasungu Districts. Lilongwe District has generally dark red clay or sandy clay soils. Crops suitable for this include maize, tobacco, groundnuts, beans, Irish potato, sweet potato, soya beans and cassava[25]. The geographical coordinates for Lilongwe are 13°58'00.9"S 33°47'14.1"E. The area has a flat terrain at an elevation of 1,050 meters above mean sea level. Temperatures in this area range between 18-24°C. The area receives an average annual rainfall of about 825.9 mm with minimum annual totals of 517 mm and maximum annual total of 1269.4 mm. Higher amounts of rainfall are received in the months of January and February. Generally, the area receives rainfall between the months of November and April. Mostly the area has sandy loam soils, which are good for maize production[26].

On the other hand, Chinguluwe EPA is found in Salima District in the Central Region of Malawi. Salima District lies in the shores of Lake Malawi to the East of Lilongwe, the capital city of Malawi. Salima District geographical coordinates are 13°47 S 34°26 E[27]. Chinguluwe EPA has a flat terrain with an elevation of 512 meters above the mean sea level. Average
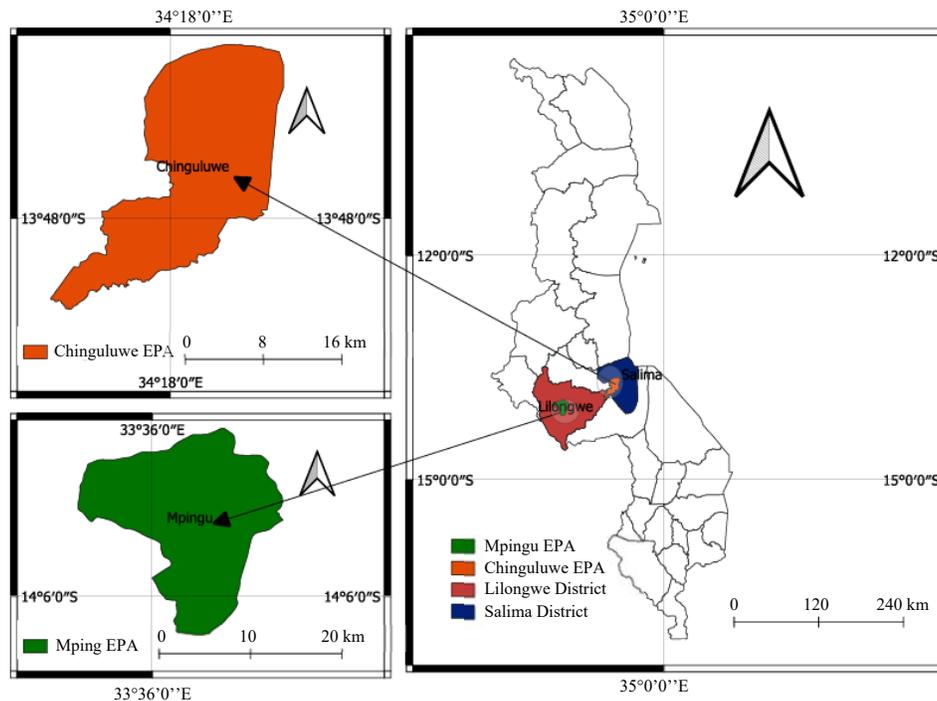


Fig. 1: Location of Chinguluwe and Mpingu extension planning areas (EPAs) in Salima and Lilongwe Districts, respectively. Pangapanga-Phiri *et al.*[28]

temperatures range between 19.2-32.4°C. The average annual rainfall in the area is 834 mm with annual minimum of 568.7 mm and 1103.6 mm annual maximum. Rainfall is between the months of November and April. Generally, Chinguluwe has sandy loam soils with some areas having clayey soils[26].

**Experimental design and data collection:** Twenty-four farmers were selected based on the location of their farms. Twelve farmers (six from each of the EPAs) had their maize fields sharing boundaries with forested areas while the other twelve had their maize fields sharing boundaries with other crop fields. Blocks of nine, 16.2×16.2 m plots were laid in all the 24 identified fields. Maize, variety SC 649-Mkango was planted in all blocks under conventional tillage. Scouting was used to determine sample points on each maize plot. A total of 216 maize plots were scouted using the method described by other researchers[29]. Scouting was done in a semi systematic manner following a "W" shaped pattern approach. To determine damage category, the CIMMYT pictorial guide and the Davis scale, which rates damage from 1 to 9 was used[30]. Observations and data collection were made on ten plants at each of the five sampling points per plot. A total of 10800 plants were assessed to determine number of FAW, number of infected plants, number of egg masses and damage category.

To determine plant species diversity in field margins, plots of different sizes were laid considering different strata of vegetation (herb, shrub and tree). Small plots of 1×1 m were used to assess the herbaceous layer, as herbs have the ability to intensively occupy a small area and are more sensitive to micro-environmental changes. To assess the shrub layer, which has a larger structure and more complex distribution compared to herbs, 5 m x 5 m plots were used. The tree layer was assessed using 10 m x10 m plots[31]. A total of 72 plots (three plots for each maize field) for each category were laid in the study area.

All plant species found within the selected plots were identified to the lowest taxonomic level (species and genus). Field guides, botanical keys and expert consultations were used to ensure accuracy in species identification. The abundance of herbaceous species was determined by counting the number of individuals per species. For dense populations, cover estimations was conducted using a scale, where cover was categorized based on the percentage of the plot occupied by a particular species. In shrub and tree plots, the number of individual shrubs and trees per species was counted and recorded. The study was conducted in the months of November to April in the 2022/2023 and 2023/2024 growing seasons.

**Statistical data analysis:** Analysis of Variance (ANOVA) for number of fall armyworm present, number of infected plants and damage category of plants was performed according to the model presented in Table 1 to test the significance of year, E.P.A., proximity and crop age effects. Year was considered as a random effect and the other sources of variation as fixed effects. Statistical analysis was performed using SPSS software version 25. Differences between treatment means were separated using Fischer's least significant difference (LSD) at the α = 0.05 level.

The association between presence of fall armyworm and presence of infected plants as well as the association between presence of fall armyworm and damage of plants for both fields closer and away from forested areas were evaluated by calculating the Chi-square ($\chi^2$) test for association and the Mantel-Haenszel common odds ratio (OR) at a confidence level of 95% using SPSS software version 25.

Further analysis was conducted to determine tree species richness and diversity for the close to forest and away proximity. This was done by using Renyi diversity profile in Biodiversity R[32]. Biodiversity R. is software that does all the biodiversity analyses, while Renyi diversity profiles are curves that provide information on richness and evenness. The shape of the profile is an indication of the evenness. A horizontal profile indicates that all species have the same evenness. The starting position at the left-hand side of the profile is an indication of the species richness. Profile that starts at a higher level has higher richness. The major advantage of Renyi diversity profiles is that sites can easily be ordered from high to low diversity. If the profile for one site is everywhere above the profile for another site, then this means that the site with the highest profile is more diverse than the other[33].

Table 1: Model used in the analysis of variance

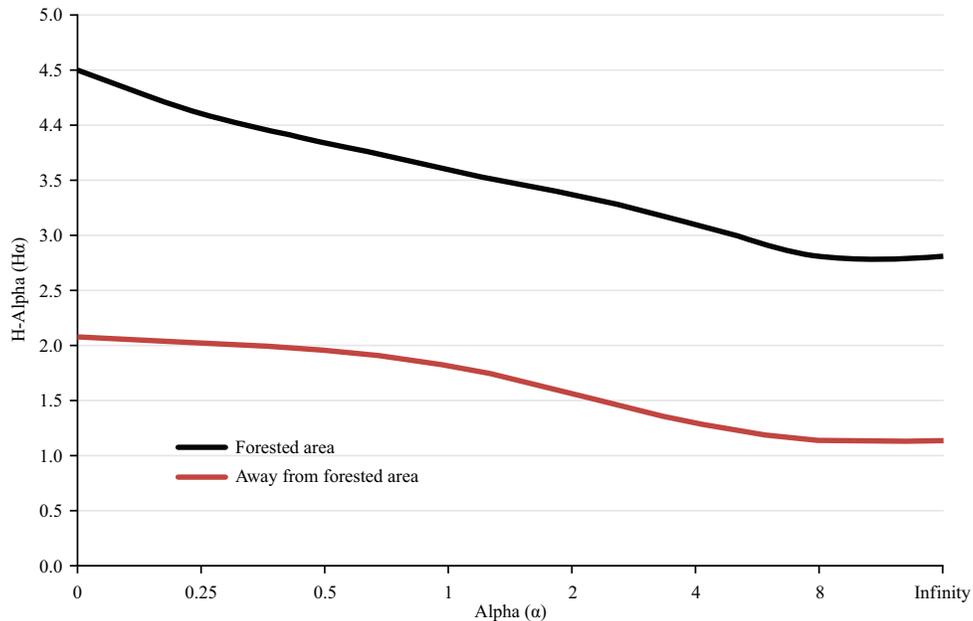| No. | Source of variation |
| --- | --- |
| 1 | Year (Y) |
| 2 | EPA (E) |
| 3 | Proximity (P) |
| 4 | Age in weeks (A) |
| 5 | E×P |
| 6 | E×A |
| 7 | P×A |
| 8 | E×P×A |
| 9 | Residual |

Fig. 2: Renyi diversity profile for tree species in forested area and away from forested area

## RESULTS

**Effects of proximity on number of fall army worm, number of infected plants and damage:** Results on the effect of proximity to forested field margins on number of fall armyworm, number of infected plants and damage for different EPAs and year are presented in Table 2 and 3. The results indicate that there were significant (p<0.001) differences on mean number of fall armyworm, mean number of infected plants and damage on plants between the closer proximity and away proximity. There was reduction of number of fall armyworms, number of infected plants and damage levels for maize fields closer to forested field margins as compared to those maize fields at an increased distance from forested field margins.

**Association between presence of fall armyworm and (a) Presence of infected plants and (b) Damage:** Summary on the association between presence of fall armyworm and presence of infected plants as well as the association between presence of fall armyworm and damage of plants for both fields closer and away from forested areas are presented in Table 4-7. The results indicate that there is a significant association between presence of fall armyworm and presence of infected plants for both fields closer ($\chi^2 = 5.045$; p<0.001) and away ($\chi^2 = 37.284$; p<0.001) from forested areas. The plants closer to forested areas were three times (Odds ratio = 2.94) likely to be infected, while

those plants away from forested areas were sixteen times (Odds ratio = 16.04) likely to be infected.

Furthermore, the results indicate that there is a significant association between presence of fall armyworm and damage of infected plants for both fields closer ($\chi^2 = 6.292$; p<0.001) and away ($\chi^2 = 46.282$; p<0.001) from forested areas. The plants closer to forested areas were four times (Odds ratio = 3.61) likely to be damaged while those plants away from forested areas were nineteen times (Odds ratio = 19.23) likely to be damaged.

**Tree species richness and diversity for the forested area and away proximity:** Renyi diversity profiles for the two treatments are presented in Fig. 2. The results show that the profile for the forested field margins was everywhere above the profile for the away proximity area. This means that the forested field margins were more diverse than the away proximity area. Further analysis of tree species richness indicates that the forested field margins had a higher tree species richness than the away proximity. A total of 89 tree species were recorded in forested area and only eight tree species were recorded in away proximity area (Appendix A). This further indicates that the tree species richness and diversity might have contributed to the number of fall armyworm, number of plants infected, as well as damage of maize plants. The higher tree species richness and more tree species diversity in forested area resulted in reduction of number of fall armyworm, number of plants infected and damage of maize plants in the near proximity area.

Appendix A: Tree species richness in forested and non-forested crop margins

| No. | Tree species | Forested area | Away proximity area |
|---|---|---|---|
| 1 | *Acacia galpinii* | Present | Absent |
| 2 | *Acacia nigrescens* | Present | Absent |
| 3 | *Acacia nilotica* | Present | Absent |
| 4 | *Acacia polyacantha* | Present | Absent |
| 5 | *Adansonia digitata* | Absent | Present |
| 6 | *Ageratum houstoniana* | Present | Absent |
| 7 | *Albizia anthelmintica* | Present | Absent |
| 8 | *Albizia harveyi* | Present | Absent |
| 9 | *Albizia versicolor* | Absent | Present |
| 10 | *Bauhinia petersiana* | Present | Absent |
| 11 | *Bidens pilosa* | Present | Absent |
| 12 | *Brachystegia spiciformis* | Present | Absent |
| 13 | *Brachiaria brizantha* | Present | Absent |
| 14 | *Bridelia micrantha* | Present | Absent |
| 15 | *Brillantaisia subulugurica* | Present | Absent |
| 16 | *Burkea africana* | Present | Absent |
| 17 | *Calotropis procera* | Present | Absent |
| 18 | *Capparis erythrocarpus* | Present | Absent |
| 19 | *Chloris gayana* | Present | Absent |
| 20 | *Cissampelos mucronata* | Present | Absent |
| 21 | *Combretum apiculatum* | Present | Absent |
| 22 | *Combretum collinum* | Present | Absent |
| 23 | *Combretum fragrans* | Present | Absent |
| 24 | *Combretum paniculatum* | Present | Absent |
| 25 | *Combretum zeyheri* | Present | Absent |
| 26 | *Commiphora africana* | Present | Absent |
| 27 | *Corchorus olitorius* | Present | Absent |
| 28 | *Cordyla africana* | Absent | Present |
| 29 | *Cussonia arborea* | Present | Absent |
| 30 | *Dichrostachys cinerea* | Present | Absent |
| 31 | *Digitaria milanjiana* | Present | Absent |
| 32 | *Diospyros lycioides* | Present | Absent |
| 33 | *Eragrostis ciliaris* | Present | Absent |
| 34 | *Eucalyptus saligna* | Absent | Present |
| 35 | *Euphorbia tirucalli* | Present | Absent |
| 36 | *Faidherbia albida* | Absent | Present |
| 37 | *Flueggea virosa* | Present | Absent |
| 38 | *Friesodielsia obovata* | Present | Absent |
| 39 | *Grewia bicolor* | Present | Absent |
| 40 | *Hippocratea parviflora* | Present | Absent |
| 41 | *Holarrhena pubescens* | Present | Absent |
| 42 | *Hygrophila auriculata* | Present | Absent |
| 43 | *Hyparrhenia rufa* | Present | Absent |
| 44 | *Hyperthelia dissoluta* | Present | Absent |
| 45 | *Hypoestes forskaolii* | Present | Absent |
| 46 | *Julbernardia globiflora* | Present | Absent |
| 47 | *Julbernardia paniculata* | Present | Absent |
| 48 | *Kohautia longifolia* | Present | Absent |
| 49 | *Lannea discolor* | Present | Absent |
| 50 | *Lannea stuhlmannii* | Present | Absent |
| 51 | *Lantana camara* | Present | Absent |
| 52 | *Leonotis leonurus* | Present | Absent |
| 53 | *Mangifera indica* | Present | Present |
| 54 | *Markhamia obtusifolia* | Present | Absent |
| 55 | *Maytenus heterophylla* | Present | Absent |
| 56 | *Melinis repens* | Present | Absent |
| 57 | *Mucuna stans* | Present | Absent |
| 58 | *Ocimum canum* | Present | Absent |
| 59 | *Ocimum canum* | Present | Absent |
| 60 | *Ozoroa reticulata* | Present | Absent |
| 61 | *Panicum maximum* | Present | Absent |

Appendix A: Continue

| No. | Tree species | Forested area | Away proximity area |
|---|---|---|---|
| 61 | *Panicum maximum* | Present | Absent |
| 62 | *Parinari curatellifolia* | Present | Absent |
| 63 | *Peltophorum africanum* | Present | Absent |
| 64 | *Pericopsis angolensis* | Present | Absent |
| 65 | *Philenoptera violacea* | Present | Absent |
| 66 | *Piliostigma thonningii* | Present | Absent |
| 67 | *Pogonarthria squarrosa* | Present | Absent |
| 68 | *Rauvolfia caffra* | Present | Absent |
| 69 | *Sclerocarya birrea* | Present | Absent |
| 70 | *Senna occidentalis* | Present | Absent |
| 71 | *Senna petersiana* | Present | Absent |
| 72 | *Senna siamea* | Present | Absent |
| 73 | *Sesamum angolense* | Present | Absent |
| 74 | *Setaria sphacelata* | Present | Absent |
| 75 | *Sida acuta* | Present | Absent |
| 76 | *Solanum incanum* | Present | Absent |
| 77 | *Spermacoce princeae* | Present | Absent |
| 78 | *Stereospermum kunthianum* | Present | Present |
| 79 | *Strychnos spinosa* | Present | Absent |
| 80 | *Tacca leontopetaloides* | Present | Absent |
| 81 | *Themeda triandra* | Present | Absent |
| 82 | *Thespesia garckeana* | Present | Absent |
| 83 | *Tithonia diversifolia* | Present | Absent |
| 84 | *Trichodesma zeylanicum* | Present | Absent |
| 85 | *Tridax procumbens* | Present | Absent |
| 86 | *Triumfetta rhomboidea* | Present | Absent |
| 87 | *Turraea nilotica* | Present | Absent |
| 88 | *Vangueria infausta* | Present | Absent |
| 89 | *Vernonia glabra* | Present | Absent |
| 90 | *Vernonia petersii* | Present | Absent |
| 91 | *Vernonia poskeana* | Present | Absent |
| 92 | *Xanthium strumarium* | Present | Absent |
| 93 | *Ximenia caffra* | Present | Absent |
| 94 | *Zanha africana* | Present | Absent |
| 95 | *Ziziphus mauritiana* | Absent | Present |

Table 2: Effect of proximity on mean number of fall armyworm, number infected plants and damage categories at Mpingu EPA, Lilongwe

| | 2023 | | | 2024 | | |
|---|---|---|---|---|---|---|
| Proximity | Mean number of fall armyworm | Mean number of infected plants | Mean damage category | Mean number of fall armyworm | Mean number of infected plants | Mean damage category |
| Closer to forested field margins | 2.7±0.3[b] | 9.2±0.5[b] | 3.3±0.1[b] | 4.8±0.4[b] | 16.9±0.8[b] | 3.5±0.1[b] |
| Away from forested field margins | 4.5±0.5[a] | 11.9±0.6[a] | 4.1±0.1[a] | 8.8±0.6[a] | 25.5±1.1[a] | 4.5±0.1[a] |

Mean numbers are followed by standard errors. Means with different superscripts within a column significantly differ (p<0.001)

Table 3: Effect of proximity on mean number of fall armyworm, number infected plants and damage categories at Chinguluwe EPA, Salima

| | 2023 | | | 2024 | | |
|---|---|---|---|---|---|---|
| Proximity | Mean number of fall armyworm | Mean number of infected plants | Mean damage category | Mean number of fall armyworm | Mean number of infected plants | Mean damage category |
| Closer to forested field margins | 4.7±0.7[b] | 8.5±0.8[b] | 2.7±0.2[b] | 1.3±0.2[b] | 3.8±0.2[b] | 2.7±0.1[b] |
| Away from forested field margins | 8.4±0.8[a] | 10.9±0.7[a] | 3.6±0.2[a] | 3.2±0.5[a] | 5.3±0.6[a] | 3.5±0.2[a] |

Mean numbers are followed by standard errors. Means with different superscripts within a column significantly differ (p<0.001)

Table 4: Association between presence of fall armyworm and presence of infected plants for closer proximity

| Outcome description | | Presence of fall armyworm (%) | | |
|---|---|---|---|---|
| | | Yes | No | Total (%) |
| Presence of infected plants (%) | Yes | 10.1 | 49.2 | 59.3 |
| | No | 2.6 | 38.1 | 40.7 |
| Total | | 12.7 | 87.3 | 100.0 |

$\chi^2 = 5.045$, df = 1, p<0.001 and Odds ratio = 2.94

Table 5: Association between presence of fall armyworm and damage of plants for closer proximity

| Outcome description | | Presence of fall armyworm (%) | | |
| --- | --- | --- | --- | --- |
| | | Yes | No | Total (%) |
| Damage (%) | Yes | 23.7 | 38.8 | 62.5 |
| | No | 5.4 | 32.1 | 37.5 |
| Total | | 29.1 | 70.9 | 100.0 |

$\chi^2 = 6.292$, df = 1, p<0.001 and Odds ratio = 3.61

Table 6: Association between presence of fall armyworm and presence of infected plants for away proximity

| Outcome description | | Presence of fall armyworm (%) | | |
| --- | --- | --- | --- | --- |
| | | Yes | No | Total (%) |
| Presence of infected plants (%) | Yes | 27.5 | 41.5 | 69.0 |
| | No | 1.2 | 29.7 | 31.0 |
| Total | | 28.7 | 71.3 | 100.0 |

$\chi^2 = 37.284$, df = 1, p<0.001 and Odds ratio = 16.04

Table 7: Association between presence of fall armyworm and damage of plants for away proximity

| Outcome description | | Presence of fall armyworm (%) | | |
| --- | --- | --- | --- | --- |
| | | Yes | No | Total (%) |
| Damage (%) | Yes | 23.1 | 17.2 | 40.3 |
| | No | 3.9 | 55.8 | 59.7 |
| Total | | 26.9 | 73.1 | 100.0 |

$\chi^2 = 46.282$, df = 1, p<0.001 and Odds ratio = 19.23

## DISCUSSION

The present study conducted in Lilongwe and Salima Districts, Malawi, investigated the impact of forested field margins on fall armyworm (*Spodoptera frugiperda*) incidence and leaf damage in maize. The study revealed significant differences in the mean number of fall armyworms, infected plants and plant damage between maize fields located near forested margins and those situated further away. Specifically, fields closer to forested areas exhibited reduced pest numbers, fewer infected plants and less damage compared to more distant fields. These results align with previous research emphasizing the beneficial role of semi-natural habitats in pest management. A study in Abdel-Rahman *et al.*[5] reported that crop damage from Fall armyworm increased significantly with distance from the field edge, suggesting that proximity to semi-natural habitats may enhance natural enemy activity and reduce pest damage.

Likewise, a study conducted in Zambia[34] documented more than eleven species of natural enemies of the fall armyworm, including parasitoids that target eggs, egg-larval and larval stages, as well as various predators. This finding underscores the crucial role of biodiversity in regulating pest populations. Additionally, the significant association between the presence of fall armyworm and the occurrence of infected and damaged plants observed in the Malawian study further corroborates with these

findings[5,34]. Plants closer to forested areas were three times more likely to be infected (Odds ratio = 2.94) and four times more likely to be damaged (Odds ratio = 3.61), while those farther away were sixteen times (Odds ratio = 16.04) and nineteen times (Odds ratio = 19.23) more likely to be infected and damaged, respectively. This suggests that forested margins may serve as reservoirs for natural enemies, thereby mitigating pest impact on adjacent maize fields[7,35].

Furthermore, the present study also highlighted the higher tree species richness and diversity in forested field margins, with 95 tree species recorded compared to only eight in areas further away. This increased biodiversity is likely to contribute to the suppression of fall armyworm populations, as diverse plant communities can support a wider array of natural enemies[36]. This is consistent with findings from other regions[5,34], where landscapes with higher tree covers have been associated with lower pest incidence and damage severity[37].

The present findings align with previous research that emphasizes the role of biodiversity and habitat complexity in pest regulation. For instance, a study from Zimbabwe[18] demonstrated that maize fields closer to forests had lower FAW incidence, highlighting the significance of forest proximity in natural pest control mechanisms. Besides, the present research indicates that higher plant diversity leads to a 44% reduction in herbivore pest feeding rates, underscoring

the benefits of diverse vegetation in mitigating pest populations. Similarly, polyculture systems, which involve growing multiple crop species together, have been shown to reduce pest prevalence due to increased plant diversity, thereby disrupting pest host-finding and supporting natural enemy populations[35]. Thus, the push-pull agricultural pest management strategy leverages plant diversity to repel pests and attract them to trap crops, effectively reducing pest infestations in main crops. Other studies also have found that increased arthropod species diversity within maize farms is negatively correlated with pest abundance, suggesting that biodiversity can suppress pest populations[38].

The agreement between the current study's findings and previous research can be attributed to several ecological mechanisms. For instance, forested margins and diverse plant species provide habitats and resources for natural enemies of pests, such as predators and parasitoids, leading to increased biological control of pests like FAW[39]. Additionally, increased vegetation diversity can interfere with the ability of pests to locate their host plants, thereby reducing infestation rates[40]. Lastly, diverse plant communities enhance ecosystem services, including pollination and nutrient cycling, which contribute to overall plant health and resilience against pest attacks[41].

The consistent findings across different studies and regions emphasize the significance of integrating forested field margins and maintaining landscape heterogeneity as one of the sustainable pest management strategies[12]. Therefore, by fostering environments that support natural enemy populations, farmers can reduce reliance on chemical pesticides, promote biodiversity conservation and enhance agricultural productivity. These agroecological practices no only contribute to effective FAW management but also align with broader goals of sustainable agriculture and food security[42-47].

The study underscores the importance of maintaining and integrating forested field margins within agricultural landscapes. Farmers may apply findings from this study by adopting agroforestry practices that incorporate tree diversity around maize fields. By increasing tree species richness near farmlands, natural enemies of FAW such as birds, parasitoids and predatory insects, can thrive, enhancing biological pest control. This approach reduces reliance on synthetic pesticides, which can have environmental and economic drawbacks[40].

Again, findings from this study suggest that landscape heterogeneity plays a crucial role in pest regulation. Agricultural planners and extension services can use this information to promote conservation agriculture, where maintaining patches of forests and natural vegetation around farms can create a buffer zone against FAW infestations. Such an approach aligns with ecological intensification, where ecosystem services are harnessed for sustainable farming[35].

Policymakers can use the study's outcomes to develop policies that encourage the protection and restoration of natural habitats within agricultural areas. Incentivizing farmers to retain or plant trees around their fields can enhance biodiversity and contribute to long-term pest control. Additionally, regulations can promote the use of Integrated Pest Management (IPM) strategies that combine cultural, biological and ecological approaches to control FAW infestations[39].

Agricultural extension officers can apply these findings by educating farmers on the benefits of maintaining tree diversity around their maize fields. Training programs and field demonstrations can illustrate how proximity to diverse tree species lowers pest infestations and contributes to healthier crops. This knowledge can empower farmers to adopt more sustainable and cost-effective pest control methods[41].

One of the most significant practical implications of this study is the potential reduction in pesticide use. Chemical pesticides, while effective, they pose risks such as pest resistance, soil degradation and human health concerns. By integrating forested field margins as a natural pest control strategy, farmers can minimize pesticide application, lowering production costs and environmental harm[7].

With FAW causing extensive crop damage and yield losses in many parts of Africa, the study's findings offer a sustainable solution to improving maize production. Reduced FAW infestations translate into healthier crops, higher yields and enhanced food security, which is particularly critical for smallholder farmers who rely on maize as a staple food[12,45]. The study highlights the role of tree species richness in mitigating pest outbreaks. This underscores the need to conserve and restore natural habitats, which not only support pest control but also promote biodiversity. Maintaining ecological balance within agricultural landscapes ensures resilience against other environmental stresses such as climate change and soil degradation. Farmers who implement forested field margins can benefit economically in multiple ways. First, by reducing FAW damage, they can secure better yields and marketable produce. Second, minimizing pesticide use lowers input costs. Third, promoting agroforestry can provide additional income streams, such as timber, fuelwood and non-timber forest products[42]. Forested field margins not only help control pests but also contribute to climate change adaptation. Trees improve soil health, regulate microclimates and enhance water retention, all of which support sustainable agricultural productivity. As climate change increases the frequency and intensity of pest outbreaks, leveraging biodiversity for natural pest control will be increasingly vital[40].

Based on these insights, the study recommends the following:

• Farmers and land managers should prioritize the preservation of existing forested areas adjacent to agricultural fields to maintain biodiversity and natural pest control mechanisms
• Where feasible, the creation of new forested buffers with diverse tree species can be implemented to enhance habitat complexity and support natural enemy populations
• Integrating trees into farming systems through agroforestry can provide multiple benefits, including pest regulation, improved soil health and increased farm resilience
• Engaging local communities in the management and benefits of forested field margins can foster collective action and sustainable landscape management

## CONCLUSION

Forested field margins play a significant role in mitigating the incidence and severity of fall armyworm (*Spodoptera frugiperda*) infestations in maize fields in Malawi. By comparing fields near forested areas with those located farther away, the results of this study clearly show that proximity to forested margins is associated with reduced pest presence, fewer infected plants and lower levels of crop damage. These findings align with regional and global research emphasizing the ecological benefits of semi-natural habitats in pest suppression. The study offers compelling evidence that biodiversity can serve as a natural pest control strategy. Its application in agroforestry, pest management and sustainable agriculture presents multiple benefits, including reduced reliance on pesticide, increased maize yields, biodiversity conservation and economic gains for farmers. Policymakers, agricultural extension officers and farmers should collaborate to implement these findings, promoting ecological farming practices that enhance food security and environmental sustainability.

## SIGNIFICANCE STATEMENT

This study discovered the potential role of forested field margins in suppressing fall armyworm infestation and leaf damage in maize fields. By comparing maize plots near forested and non-forested areas, the research revealed that proximity to diverse tree species substantially reduces pest incidence and crop damage, demonstrating the ecological benefits of maintaining biodiversity around agricultural fields.

These findings are beneficial for developing sustainable pest management practices that minimize chemical pesticide dependence and enhance ecosystem resilience. This study will help researchers to uncover the critical areas of biodiversity-pestz–pest interaction that many were not able to explore. Thus, a new theory on ecological pest regulation through landscape diversity may be arrived at.

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