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Abundance and Diversity of Insects and Arachnids in Organic and Conventional Rice fields of Davao Oriental

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Abstract

Rice ecosystems in Davao Oriental harbor diverse communities of insects and arachnids whose abundance, diversity, and ecological functions vary across farming systems and crop growth stages. These arthropod communities serve as important indicators of ecosystem health and agricultural sustainability, making their assessment essential for understanding the ecological impacts of organic and conventional rice production and for developing science-based strategies that support biodiversity conservation and sustainable crop management. Despite the ecological significance of arthropod communities in rice ecosystems, baseline information on the diversity and distribution of insects and arachnids across organic and conventional rice farming systems in Davao Oriental remains limited. This knowledge gap constrains efforts to evaluate ecosystem health, assess the effects of farming practices on biodiversity, and develop evidence-based strategies for sustainable rice production. Therefore, this study assessed the diversity and ecological roles of insect and arachnid communities in the rice agroecosystems of Davao Oriental to provide baseline ecological data and inform biodiversity-based pest management and sustainable rice production. Field surveys and collections were conducted using sweep nets, malaise traps, pitfall traps, and opportunistic sampling. Species diversity was measured using the Shannon diversity index (H'), where values below 1 indicate low diversity, 1–2 moderate, and above 2 high diversity. Results showed that organic rice fields supported greater taxonomic richness and abundance (46 insect and 8 arachnid families; 4,398 insect and 3,932 arachnid individuals) than inorganic fields (38 insect and 6 arachnid families; 3,809 insect and 3,482 arachnid individuals). Interestingly, inorganic fields had slightly higher Shannon index values (2.528 for insects; 0.9051 for arachnids), suggesting a more even species distribution. Temporal analysis across rice growth phases revealed that diversity peaked during the vegetative stage and declined toward ripening, indicating higher ecological activity early in crop development. These findings highlight the positive impact of organic farming on insect and arachnid diversity and underscore the ecological importance of insects and arachnids in rice systems. Moreover, the presence of pest-dominant taxa points to the need for enhanced biological control strategies. Monitoring arthropod diversity is essential for developing ecologically sound pest management approaches and reducing reliance on chemical inputs in rice agroecosystems.

Introduction

Rice (*Oryza sativa* L.) has been cultivated for over 6,000 years in South Asia. It was considered the most important food crop globally, feeding nearly half of the world's population (Swodesh & Yuvraj, 2020). Rice remains the most important staple food in the Philippines and is a cornerstone of the country's agricultural economy. It is the primary food source for most Filipino households and supports the livelihoods of millions of farmers and other stakeholders along the rice value chain, making it essential for national food security, rural employment, and economic development (Philippine Statistics Authority [PSA], 2024; Department of Agriculture [DA], 2024).

Rice fields not only served as sources of food but also as habitats that supported biodiversity in lowland areas worldwide. These fields functioned as substitute wetlands for many species (Bambaradeniya & Amerasinghe, 2004; Zhang et al., 2022). Furthermore, the role of insect biodiversity in rice farming had often been overlooked despite its importance (Sollai & Solari, 2022). Insects had a significant impact on rice cultivation, but their use as natural predators and parasitoids had little documentation (Gangurde, 2007). This critical gap in literature is even more pronounced when examining specific, highly effective generalist predator groups like spiders. As apex invertebrate predators in rice paddies, spiders offer immense value to biocontrol; they employ diverse hunting strategies, such as web-building in the canopy and active hunting on the water surface to suppress major pests like planthoppers and stem borers. By maintaining stable populations even during fallow periods and exhibiting overkilling behaviors, spiders provide year-round field management that significantly lowers reliance on costly chemical insecticides.

Yet, despite these clear ecological advantages, granular data on their specific impacts remains scarce. Compared to other arthropods, relatively little was known about the role of spiders in rice ecosystems, despite their value in field management and biocontrol (Saksongmuang et al., 2024). Historical field data established that diverse spider assemblies, often divided into distinct web-building and hunting guilds are highly effective at colonizing rice canopies early in the crop cycle. Existing research confirms their capacity to suppress multi-species pest outbreaks, but their exact conservation depends entirely on the stability of surrounding microhabitats and non-crop vegetation. Therefore, studying the species and abundance of spiders in different rice habitats is necessary to maximize their potential as biological control agents (Sinduja & Kendra, 2024).

This lack of ecological documentation directly mirrors historical challenges faced by agricultural practitioners in the field. Farmers heavily relied on synthetic pesticides to control pests, often unaware of the environmental consequences and the effects on beneficial insect and arachnid populations (Rola & Jamias, 2015). This heavy chemical reliance is exacerbated by a widespread knowledge deficit among growers; additionally, many farmers struggle to distinguish between beneficial insects and harmful pests, frequently misidentifying natural predators as crop threats due to a lack of ecological training (Dunn et al., 2023).

On a local scale, Davao Oriental, a province known for national rice production awards (DA Region XI, 2020), recognized this knowledge gap. Despite the province's celebrated agricultural output, particularly in prominent rice-producing hubs like Banaybanay, provincial frameworks have historically lacked baseline assessments detailing how intensive hybrid and conventional cropping styles alter macro-invertebrate communities. Without localized data mapping how general insect biodiversity, beneficial parasitoids, and predatory spiders fluctuate between shifting field borders and varying farming practices, the province lacks the precise ecological metrics required to sustain its high yields organically. Local agricultural planners and farmers remain largely blind to which beneficial insect orders and spider assemblies are active across distinct crop growth stages. Consequently, establishing this broader baseline is essential to bridge the disconnect between intensive, high-yield production and long-term, eco-friendly pest management.

Despite the ecological importance of insects and arachnids in maintaining the stability and functioning of rice agroecosystems, baseline information on their diversity, community composition, and ecological roles in Davao Oriental remains limited. This lack of localized ecological data hampers the assessment of ecosystem health, the evaluation of farming practices on arthropod biodiversity, and the development of biodiversity-based pest management strategies. To address this knowledge gap, this study provides the first extensive assessment of insect and arachnid diversity in rice agroecosystems of Davao Oriental, contributing valuable baseline information for sustainable rice production and future ecological research in the region. To address these knowledge gaps, this study aimed to characterize the diversity, abundance, community composition, and ecological roles of insect and arachnid communities in organic and conventional rice agroecosystems of Davao Oriental. It further compared arthropod diversity between farming systems, examined changes in their populations across rice growth phases, and determined the relationships between selected environmental variables and arthropod diversity to provide baseline ecological information for sustainable rice ecosystem management.

Materials and Methods

Study site

The study was conducted in Davao Oriental, Philippines, using purposive sampling to select research sites that represented the contrasting rice farming systems and ecological conditions relevant to the study objectives. Purposive sampling was considered appropriate because it enabled the deliberate selection of well-established rice fields with distinct management practices and comparable environmental conditions, thereby facilitating meaningful comparisons of insect and arachnid communities while minimizing the influence of confounding factors.

In Banaybanay, two one-hectare rice fields representing contrasting farming systems were selected. The organic rice field was located in Barangay Calubihan and was privately owned but managed by a local cooperative that has practiced certified organic rice farming for more than 15 years with technical and material support from Agro-Eco Philippines. The farm relied on compost, organic fertilizers, biological pest management, and the absence of synthetic pesticides, resulting in greater vegetation diversity and reduced chemical disturbance. These management practices were expected to provide more favorable habitats for insects and arachnids by increasing habitat complexity, food resources, and refugia for beneficial arthropods.

In contrast, the conventional rice field was located in Barangay Poblacion, where farmers practiced intensive rice production using synthetic fertilizers and chemical pesticides for nutrient and pest management. Compared with the organic field, the conventional farm had lower vegetation complexity and greater chemical inputs, conditions that may reduce arthropod diversity by affecting sensitive species while favoring taxa that are tolerant of agricultural disturbances. Both sites were identified with the assistance of the Municipal Agriculturist based on their long history of rice cultivation, accessibility for regular sampling, and comparable climatic and landscape conditions, allowing differences in arthropod communities to be primarily associated with farming practices rather than environmental variation.

Sampling and Data Collection

One-hectare plots were established in each study site. Sampling was conducted biweekly, beginning in January 2025, from the vegetative stage (nine days after transplanting) until the ripening stage of the rice crop. This sampling schedule enabled consistent monitoring of insect and arachnid communities throughout the crop growth cycle.

During each sampling event, field observations were recorded using a standardized field observation sheet to ensure consistency. The observation sheet documented rice growth phases, cultural practices observed during the visit, pest management activities, visible insect or pest damage, and general field conditions. Information on management practices was verified through direct observation and consultation with the farmer.

To comprehensively assess insect and arachnid diversity, multiple complementary sampling techniques were employed, including sweep netting, malaise trapping, pitfall trapping, and opportunistic sampling. The combined use of these methods enabled the collection of arthropods occupying different microhabitats and exhibiting different behaviors, thereby minimizing sampling bias and providing a more representative assessment of the arthropod community within the rice agroecosystem. Sweep netting was used primarily to collect flying and foliage-dwelling arthropods associated with the rice canopy. Sampling was conducted by walking in a standardized "U"-shaped transect across each one-hectare plot using a 38-cm-diameter sweep net following the procedure described by Sonico (2022). At each sampling event, a uniform number of sweeping strokes was performed at a consistent pace and height above the crop canopy to maximize sampling consistency among plots. After each transect, the contents of the sweep net were transferred into labeled collection containers for preservation and subsequent identification. Malaise traps were installed to sample actively flying insects that may not be efficiently collected by sweep netting. The traps consisted of tent-like structures with a central vertical fabric barrier based on the design of Campos et al. (2000), which intercepts flying insects and directs them upward into a collecting bottle containing 70% ethanol as a preservative. One malaise trap was strategically positioned near the center of each study plot in an open area to maximize insect interception and was operated continuously for three days before specimen retrieval. Ground-dwelling arthropods, particularly beetles, ants, crickets, and wandering spiders, were sampled using pitfall traps. Each trap consisted of a plastic cup (7 × 10 cm) buried flush with the soil surface and partially filled with a detergent solution to break surface tension and immobilize captured specimens. Fifteen pitfall traps were installed in each study site at approximately 2-m intervals to provide adequate spatial coverage of the field. The traps remained in place for 24 hours and were protected with banana bracts to minimize flooding, contamination by rainwater, and disturbance by birds or other animals.

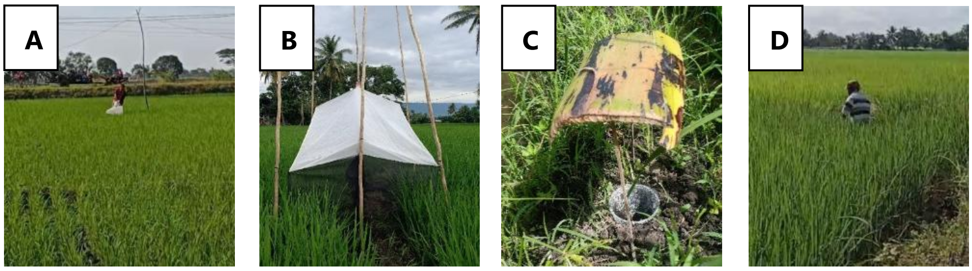


Figure 1. The Different Sampling Methods. **A.** Sweep Net Sampling, **B.** Malaise Trap, **C.** Pitfall Trap, **D.** Opportunistic Sampling

Opportunistic sampling was conducted simultaneously during field surveys to collect arthropod species that were not effectively captured by the standardized sampling methods. Researchers manually collected insects and arachnids observed on rice plants, weeds, field bunds, irrigation canals, and other microhabitats using forceps, aspirators, or collection vials. This approach increased the likelihood of recording cryptic, sedentary, nocturnal, or low-density species, thereby improving the completeness of the species inventory.

All collected specimens were properly labeled with the date, sampling site, collection method, and plot number immediately after collection. Specimens were then transferred into properly labeled collection vials containing 95% ethanol for preservation and transported to the laboratory for processing. In the laboratory, the specimens were sorted according to collection method and morphotype, cleaned when necessary to remove debris, and examined under a stereoscopic dissecting microscope to observe their external morphological characteristics, including body segmentation, wing venation, antennae, mouthparts, leg morphology, and other diagnostic features necessary for taxonomic identification. Representative specimens were photographed and documented after identification and returned to fresh 95% ethanol and stored in properly labeled, airtight specimen vials at room temperature for future reference and verification.

Specimen Identification

Specimens were identified to the lowest possible taxonomic level using the identification keys of Shepard et al. (1987), the entomological reference by Triplehorn and Johnson (2012), relevant taxonomic literature, and authoritative online databases, including the Integrated Taxonomic Information System (ITIS; https://www.itis.gov), the Global Biodiversity Information Facility (GBIF; https://www.gbif.org), iNaturalist (https://www.inaturalist.org), and the World Spider Catalog (https://wsc.nmbe.ch) for arachnid identification. Previous studies on rice arthropods in the Philippines and Southeast Asia were also consulted to verify taxonomic classifications. Furthermore, the identified specimens were verified by Dr. Elorde Jr. Crispolon to confirm their taxonomic identification. The specimens were subsequently classified into functional groups as either harmful (pests) or beneficial (predators, parasitoids, pollinators, and decomposers) based on their documented ecological functions.

Data Analysis

Biodiversity indices (Shannon, Evenness, Dominance, Menhinick) were computed using PAST software.

Results and Discussion

Relative Abundance

This study revealed clear differences in the abundance and composition of insect and arachnid families between organic and inorganic selected rice fields in Davao Oriental as shown in Table 1. Organic fields supported a higher overall richness, with 4,398 insect individuals across 45 families, compared to 3,809 individuals across 38 families in inorganic fields. This supports earlier findings that organic systems generally foster greater arthropod diversity due to reduced chemical inputs and more heterogeneous habitats (Bengtsson et al., 2005; Tuck et al., 2014).

Table 1. Relative Abundance

Class	Family	Organic		Inorganic	
		Population	% Relative Abundance	Population	% Relative Abundance
1.Arachnida	✓Araneidae	1203	30.61%	1198	34.51%
2.Arachnida	✓Linyphiidae	3	0.08%	1	0.03%
3.Arachnida	✓Lycosidae	84	2.14%	80	2.30%
4.Arachnida	✓Oxyopidae	98	2.49%	138	3.97%
5.Arachnida	✓Salticidae	5	0.13%	5	0.14%
6.Arachnida	✓Tetragnathidae	2536	64.50%	2050	59.05%
7.Arachnida	✓Theridiidae	1	0.03%	0	0.00%
8.Arachnida	✓Thomisidae	2	0.05%	0	0.00%
9.Insecta	☒Acrididae	58	1.31%	23	0.60%
10. Insecta	☒Alylidae	1146	25.97%	42	1.09%
11. Insecta	✓Anisolabididae	2	0.05%	0	0.00%
12. Insecta	☑Apidae	1	0.02%	0	0.00%
13. Insecta	✓Braconidae	30	0.68%	35	0.91%
14. Insecta	☑Calliphoridae	5	0.11%	3	0.08%
15. Insecta	✓Carabidae	12	0.27%	9	0.23%
16. Insecta	✓Chalcididae	133	3.02%	216	5.60%
17. Insecta	☒Chironomidae	115	2.61%	159	4.12%
18.Insecta	☒Chrysomelidae	19	0.43%	2	0.05%
19.Insecta	☒Cicadellidae	801	18.17%	396	10.26%
20.Insecta	✓Coccinellidae	29	0.66%	55	1.42%
21.Insecta	✓Coenagrionidae	385	8.73%	564	14.62%
22.Insecta	☒Coreidae	2	0.05%	0	0.00%
23.Insecta	✓Corixidae	1	0.02%	0	0.00%
24.Insecta	☒Crambidae	531	12.04%	786	20.37%
25.Insecta	☒Curculionidae	0	0.00%	1	0.03%
26.Insecta	☒Delphacidae	72	1.63%	272	7.05%
27.Insecta	✓Dolichopodidae	6	0.14%	3	0.08%
28.Insecta	☒Drosophilidae	12	0.27%	1	0.00%
29.Insecta	✓Formicidae	16	0.36%	54	1.40%
30.Insecta	✓Gerridae	8	0.18%	0	0.00%
31.Insecta	✓Gryllidae	12	0.27%	3	0.08%
32.Insecta	☒Gryllotalpidae	2	0.05%	0	0.00%
33.Insecta	☑Hydrophilidae	6	0.14%	5	0.13%
34.Insecta	✓Ichneumonidae	4	0.09%	108	2.80%
35.Insecta	✓Libellulidae	67	1.52%	179	4.64%
36.Insecta	☒Lygaeidae	2	0.05%	1	0.03%

Table 1. *Cotinued…*

Class	Family	Organic		Inorganic	
		Population	% Relative Abundance	Population	% Relative Abundance
37.Insecta	✓Miridae	1	0.02%	2	0.05%
38.Insecta	☑Muscidae	16	0.36%	79	2.05%
39.Insecta	⊠Nuctuidae	1	0.02%	0	0.00%
40.Insecta	⊠Nymphalidae	72	1.63%	17	0.44%
41.Insecta	⊠Pentatomidae	42	0.95%	11	0.28%
42.Insecta	✓Pipunculidae	22	0.50%	2	0.05%
43.Insecta	✓Reduviidae	1	0.02%	2	0.05%
44.Insecta	✓Sciomyzidae	57	1.29%	16	0.41%
45.Insecta	✓Scoliidae	5	0.11%	0	0.00%
46.Insecta	☑Stratiomyidae	22	0.50%	32	0.83%
47.Insecta	☑Syrphidae	9	0.20%	47	1.22%
48.Insecta	✓Tabanidae	7	0.16%	3	0.08%
49.Insecta	✓Tachinidae	46	1.04%	33	0.86%
50.Insecta	✓Tettigoniidae	219	4.97%	3	0.08%
51.Insecta	⊠Tetrigidae	17	0.39%	5	0.13%
52.Insecta	⊠Tipulidae	368	8.34%	631	16.35%
53.Insecta	⊠Ulidiidae	12	0.27%	4	0.10%
54.Insecta	✓Veliidae	0	0.00%	3	0.08%
55.Insecta	✓Vespidae	1	0.02%	0	0.00%
Number of Insect Family		45		38	
Number of Arachnid Family		8		6	
Total Arachnids		3,932		3482	
Total Insects		4,398		3809	

Legend: ✓ - natural enemies
☑ - other beneficial insects (decomposers, pollinators)
⊠ - pests

In organic fields, pest families such as Alydidae (25.97%), Cicadellidae (18.17%), and Crambidae (12.04%) were dominant, but notable was the strong representation of predatory and parasitic groups including Coenagrionidae (8.73%), Tettigoniidae (4.97%), and Chalcididae (3.02%), which enhance natural pest suppression (Gurr et al., 2003). Several families rarely noted by rice farmers were also recorded, such as Pipunculidae, Stratiomyidae, Syrphidae, Sciomyzidae, and Dolichopodidae, although in low abundance. These taxa, while uncommon in local farmer knowledge, are ecologically significant, pipunculidae are parasitoids of leafhoppers, syrphidae function as pollinators and predators, sciomyzidae prey on snails, and dolichopodidae act as generalist predators. Their presence, even at low densities, signals a broader ecological web that could be harnessed for pest regulation in organic rice systems.

Arachnid populations were also richer in organic fields, with 3,932 individuals dominated by Tetragnathidae (64.49%) and Araneidae (30.60%). Though less abundant, families such as Salticidae and Linyphiidae further contribute to predation pressure, underscoring the central role of spiders in rice agroecosystems (Schmidt et al., 2005).

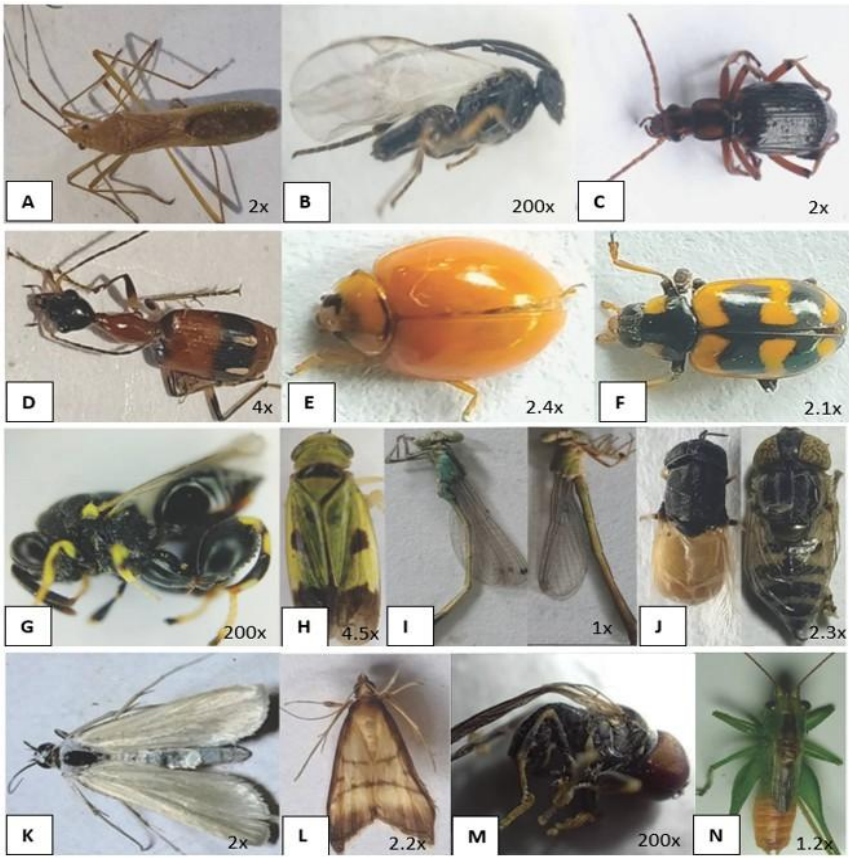


Figure 2a. Some of the insect families collected.
(A) Alydidae (dorsal view), (B) Braconidae (lateral view),
(C) & (D) Carabidae (dorsal view), (E) & (F) Coccinellidae (dorsal view),
(G) Chalcididae (lateral view), (H) Cicadellidae (dorsal view),
(I) Coenagrionidae (lateral view, (J) Syrphidae (dorsal view),
(K) & (L) Crambidae (dorsal view), (M) Pipunculidae (lateral view),
(N) Tettigoniidae (dorsal view)

In inorganic fields, insect richness and abundance were lower, reflecting the suppressive effects of pesticides and habitat simplification (Hole et al., 2005). Crambidae (20.37%), Tipulidae (16.35%), and Cicadellidae (10.26%) were dominant, while beneficial groups such as Chalcididae (5.60%), Libellulidae (4.64%), and Ichneumonidae (2.80%) persisted but in reduced numbers. Families like Pipunculidae, Reduviidae, Curculionidae, and Veliidae appeared only in trace amounts, illustrating their vulnerability to chemical disturbance.

Interestingly, beneficial insects were numerically higher in the inorganic fields (1,241 individuals) than in the organic (994), likely due to pest resurgence effects attracting generalist predators and parasitoids (Rusch et al., 2010). However, such abundance may be temporary and less stable compared to the more resilient communities in organic systems.

Figure 2b. Some of the insect families collected.
(A) Cerambycidae (dorsal view), (B) Chironomidae (lateral view),
(C) Chrysomelidae (dorsal view), (D) Coreidae (dorsal view),
(E) Libellulidae (dorsal view) & (F) Libellulidae (lateral view),
(G) Eulophidae (lateral view), (H) Evaniidae (lateral view),
(I) Formicidae (lateral view), (J) Gryllidae (dorsal view),
(K) Gryllotalpidae (dorsal view, (L) Pentatomidae (dorsal view),
(M) (N) & (O) Ichneumonidae (lateral view)

Overall, the findings highlight that while pest families dominate both systems, organic fields harbor a wider range of uncommon but ecologically valuable insect families that are often overlooked by farmers. These groups including parasitoids like Pipunculidae and Braconidae, predators like Dolichopodidae and Sciomyzidae, and pollinators which play important roles in sustaining ecological balance. Strengthening farmer awareness of these uncommon taxa is critical for promoting conservation practices and integrated pest management strategies that enhance long-term sustainability in rice production.

Diversity

Table 2 shows notable differences in insect and arachnid diversity between organic and inorganic rice fields. The organic field supported more insect families (42 vs. 38) and individuals (4,398 vs. 3,860), with higher richness reflected by the Menhinick index (0.6926 vs. 0.6116). Similarly, arachnids were more numerous in the organic field (3,932 individuals, 8 families) than in the inorganic (3,472 individuals, 6 families), suggesting reduced chemical disturbance and favorable habitats promote greater richness and abundance. These patterns underscore the role of organic management in supporting more complex arthropod communities that enhance ecosystem services such as pest regulation and nutrient cycling (Gurr et al., 2003).Net Present Value, Benefit-Cost Ratio and Internal Rate of Return are presented in Table 1. The results that integrated rice-duck farming system show higher viability highlighting an NPV of PHP 81,331.44 per hectare for 10 years. Moreover, the benefit-cost ratio showed an acceptable value given the decision criterion of greater than 1. The internal rate of return (IRR) for IRDFS has a value greater than 10%, the discount factor. This result also conformed with those studies of Khan et al. (2005.) and Barroga et al. (2007) revealing that IRDFS has positive and higher returns.

However, diversity indices integrating richness and evenness show a different trend. Insects in inorganic fields had slightly higher Shannon (2.528 vs. 2.477) and Simpson's 1-D (0.8856 vs. 0.8648) values, with a significant difference (p = 0.0494). This was due to higher evenness (0.397 vs. 0.2589) and lower dominance, indicating a more balanced insect community structure despite lower richness. Similarly, arachnid diversity was higher in inorganic fields (Shannon H' = 0.9051 vs. 0.8393; p = 0.00026745), with more even distributions across families (Evenness 0.412 vs. 0.2893). In contrast, the organic fields, while richer, showed higher dominance, suggesting communities driven by a few abundant taxa.

Table 2. Diversity, evenness, dominance and richness of insects and arachnids in organic and inorganic rice field.

Indices	**Organic**		**Inorganic**	
	Insects	Arachnids	Insects	Arachnids
Shannon index	2.477*	0.8393**	2.528*	0.9051**
Evenness	0.2589	0.2893	0.3297	0.412
Dominance	0.1352	0.5107	0.1144	0.4698
Menhinick	0.6926	0.1276	0.6116	0.1018

*means significant

**means highly significant

In total, the organic rice fields foster greater taxonomic richness in both insects and arachnids, while inorganic fields exhibit higher evenness and community balance. This highlights the trade-off between richness and evenness, with organic systems favoring biodiversity and inorganic systems shaping more evenly distributed populations. Such patterns suggest that organic fields contribute to resilience through taxonomic variety, whereas inorganic fields create stability through balanced community structures.

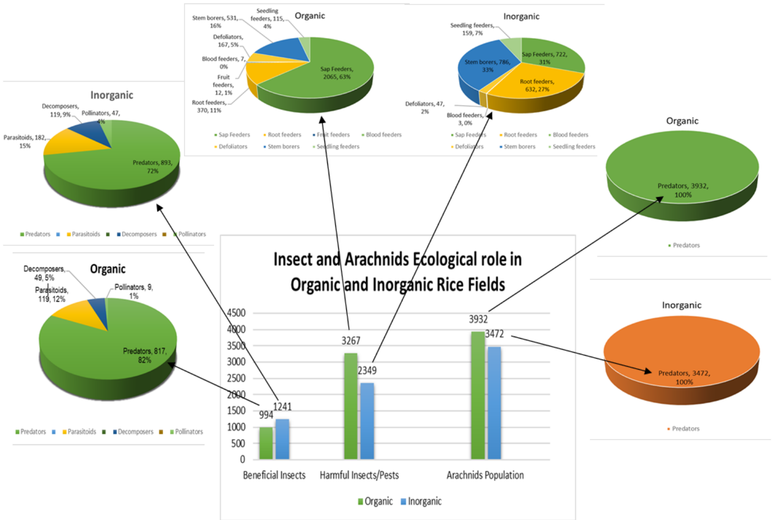


Figure 3. Ecological functions

Co-occurrence

Figure 3 presents a Venn diagram illustrating the distribution of insect and arachnid families recorded in organic and inorganic rice farming systems in Davao Oriental. The diagram shows that 45 insect families were identified, of which 37 families (82.2%) occurred in both farming systems, 8 families (17.8%) were exclusive to the organic fields, and 3 families (6.7%) were found only in the inorganic fields. Among arachnids, eight families were recorded, with six families (75%) shared by both farming systems, two families (25%) occurring exclusively in the organic fields, and no arachnid families found exclusively in the inorganic fields.

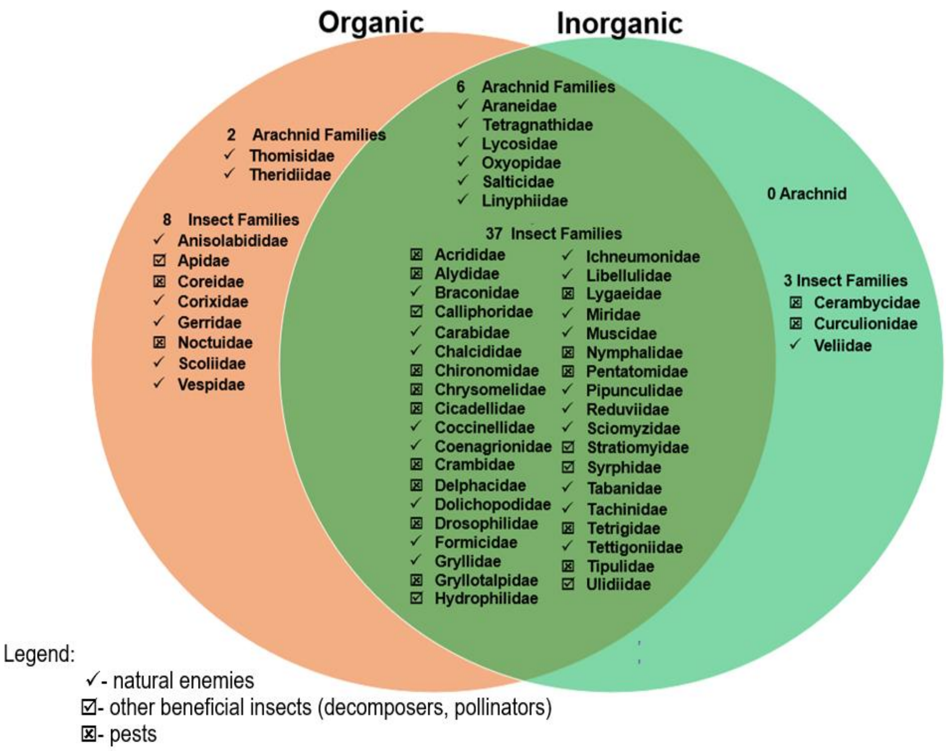


Figure 4. Co-occurrence

The occurrence of eight insect families (Anisolabididae, Apidae, Coreidae, Corixidae, Gerridae, Noctuidae, Scoliidae, and Vespidae) and two arachnid families (Thomisidae and Theridiidae) exclusively in the organic fields indicates that organically managed rice ecosystems supported a greater number of unique arthropod taxa than the inorganic fields. Many of these families include pollinators, predators, parasitoids, and other beneficial organisms that are commonly associated with structurally diverse habitats and reduced pesticide inputs. Organic farming practices generally promote greater habitat heterogeneity and minimize chemical disturbances, thereby providing favorable conditions for sensitive arthropod taxa (Hole et al., 2005; Bengtsson et al., 2005).

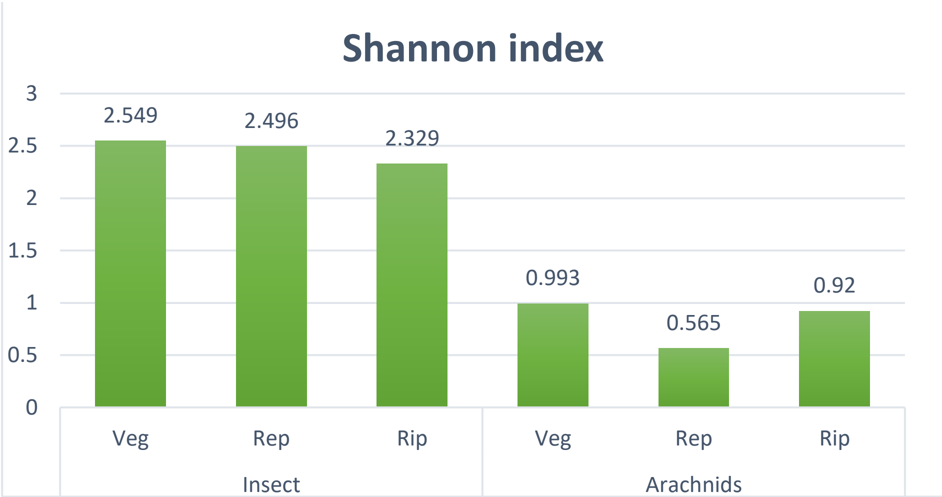
In contrast, only three insect families, Cerambycidae, Curculionidae, and Veliidae, were recorded exclusively in the inorganic fields, while no arachnid families were unique to this farming system. This relatively low number of exclusive taxa suggests that conventional management practices may support fewer specialized arthropod groups. The application of synthetic pesticides and simplified vegetation structure in conventionally managed fields may reduce habitat suitability for some arthropod families, resulting in lower taxonomic uniqueness (Geiger et al., 2010).

Most insect and arachnid families were shared between the two farming systems, indicating that many taxa possess broad ecological tolerances and are capable of persisting under different management regimes. Shared insect families included Acrididae, Alydidae, Braconidae, Carabidae, Cicadellidae, Formicidae, Syrphidae, Tettigoniidae, and several others, whereas the shared arachnid families comprised Araneidae, Tetragnathidae, Lycosidae, Oxyopidae, Salticidae, and Linyphiidae. These widespread families likely represent generalist species that are adaptable to varying environmental conditions and farming practices, making them important components of rice agroecosystems (Gabriel et al., 2010).

The greater number of unique insect and arachnid families observed in the organic fields suggests that organic farming may provide more suitable habitats for a wider range of arthropod taxa than inorganic farming. However, because this analysis is based on the presence or absence of families rather than their abundance or species richness, these results should be interpreted as evidence of differences in taxonomic occurrence rather than overall biodiversity. Nevertheless, the findings highlight the importance of conserving habitat diversity within rice agroecosystems to maintain arthropod communities that contribute to ecosystem functioning and provide baseline information for future biodiversity assessments in Davao Oriental.

Variations in Insect and Arachnid Communities Across Rice Growth Phases

The graphical presentation of the Shannon diversity index for insects and arachnids across the vegetative, reproductive, and ripening stages of rice showed in Figure 4 reveals a clear pattern of the variations in insect and arachnid diversity. Insects exhibited the highest diversity during the vegetative phase (2.549), followed by a slight decline in the reproductive phase (2.496), and a more notable decrease in the ripening phase (2.329). This trend suggests that insect communities are more diverse during the early stages of rice growth, likely due to favorable environmental conditions such as abundant foliage, moderate microclimate, and available resources.



Veg-means Vegetative phase

Rep-means Reproductive phase

Rip-means Ripening phase

Figure 5. Diversity of insect and arachnid succession across different growth phases of rice.

Similarly, arachnid diversity was highest during the vegetative phase (0.993), sharply declined in the reproductive phase (0.565), and partially recovered in the ripening phase (0.920). These changes indicate that arachnids, many of which are predatory, may be influenced by both habitat structure and the availability of prey such as insects.

The observed successional patterns highlight the dynamic nature of arthropod communities in rice agroecosystems. The high diversity during the vegetative stage emphasizes the importance of early crop phases for supporting beneficial arthropods, which play vital roles in natural pest control. The decline in diversity as the rice matures could reduce the effectiveness of biological regulation, potentially increasing the crop's vulnerability to pest outbreaks. Understanding these successional trends can inform integrated pest management (IPM) practices by identifying critical periods for conservation or targeted intervention (Altieri, 1999; Gurr et al., 2003). Therefore, monitoring diversity through the crop growth stages not only enhances ecological knowledge but also supports more sustainable agricultural management strategies.

Diversity in the different growth phases

The Table 3 shows the diversity indices of insects and arachnids in the different growth phases of rice. The Shannon index (H'), a measure combining species richness and abundance evenness, is highest in the vegetative phase (2.549) and gradually declines to 2.329 by the ripening phase. This suggests a richer and more evenly distributed insect community early in crop development, likely due to favorable habitat conditions and greater food availability during vegetative phase. At this phase, softer plant tissues, such as tender leaves and shoots, are more abundant, which attract herbivorous insects and subsequently their natural enemies (Settle et al., 1996). These tender plant parts offer both a suitable microhabitat and nutritional resources for a variety of phytophagous insects, enhancing overall insect and arachnid diversity (Heong et al., 1995). This vegetative-stage richness plays a crucial role in shaping early-season food webs and natural enemy colonization, which are important for later pest suppression (Way & Heong, 1994).

Table 3. Diversity indices of insects and arachnids into different growth phases of rice

Indices	Insect			Arachnids		
	Veg	Rep	Rip	Veg	Rep	Rip
Shannon index	2.549	2.496	2.329	0.993	0.565	0.920
Evenness	0.2843	0.2757	0.2283	0.4497	0.2933	0.3135
Dominance	0.111	0.1252	0.197	0.4243	0.7194	0.5262
Menhinick	0.5395	0.5799	0.8138	0.0949	0.086	0.2047

Veg-Vegetative stage
Rep-Reproductive stage
Rip-Ripening stage

In arachnids, the Shannon Index drops sharply from 0.993 to 0.565 during the reproductive phase, likely due to a surge in the population of Tetragnathidae, which come to dominate the community. This temporary decline in diversity reflects a reduction in evenness, as a single family becomes numerically dominant. Tetragnatha, being web-building spiders, tend to proliferate in habitats with increased prey availability, especially in dense crop canopies during flowering stages (Nyffeler & Sunderland, 2003). However, diversity partially recovers to 0.920 during the ripening phase, corresponding with an increase in ground-active predators such as Lycosidae (wolf spiders), which are known to respond to structural habitat changes and increased prey mobility on the soil surface (Langellotto & Denno, 2004).

The Evenness index declines across the different rice growth phases in the insect community, indicating that a few dominant species increasingly outcompete others, particularly as the crop approaches the ripening stage. This trend suggests that habitat or resource conditions during later crop stages may favor certain taxa over others (Altieri, 1999). Similarly, the arachnid population mirrors this trend, reaching its lowest Evenness at the reproductive phase (0.293), suggesting a temporary loss of community balance likely due to the massive increase in Tetragnathidae, which can dominate in periods of high prey availability and optimal canopy structure for web-building (Nyffeler & Sunderland, 2003). Modest recovery in the ripening phase may be attributed to the resurgence of ground-dwelling predators like Lycosidae (Langellotto & Denno, 2004).

Correspondingly, the Dominance index in insects increases from 0.111 to 0.197, reflecting a progressively uneven distribution of individuals, possibly due to the proliferation of families such as Alydidae, Coccinellidae, or Cicadellidae, which tend to peak in abundance during the later stages of rice development (Settle et al., 1996). In arachnids, Dominance sharply peaks at 0.719 during the reproductive phase, confirming the overwhelming presence of Tetragnathidae, which can drastically reduce community diversity due to their numerical superiority and competitive web space monopolization (Uetz, 1991).

Interestingly, the Menhinick index which measures species richness relative to sample size increases over time, from 0.5395 to 0.8138. This suggests that although diversity and evenness decline, rare or occasional species might enter the rice field ecosystem as crop structure changes (Barrion & Litsinger, 1995). The Menhinick index in the arachnid community is consistently lower than in insects, reflecting lower species richness overall in the arachnid community, though it increases in ripening (0.2047) as different families appeared or become more active when the rice matures and vegetation structure opens up (Barrion & Litsinger, 1995).

Composition of Insects and Arachnids

The composition of beneficial insects, insect pests, and arachnids varied considerably across the different growth phases of rice, vegetative, reproductive, and ripening, reflecting dynamic ecological interactions within the rice agroecosystem (Figures 5–7). These patterns highlight the shifting balance between pest populations and their natural enemies, providing insights into ecosystem functioning and the potential for biologically based pest management strategies.

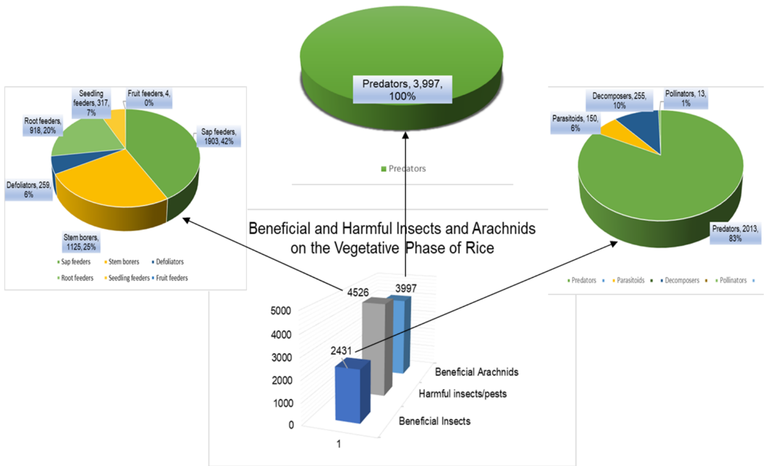


Figure 6. The beneficial and harmful insects and arachnids on the vegetative phase of rice.

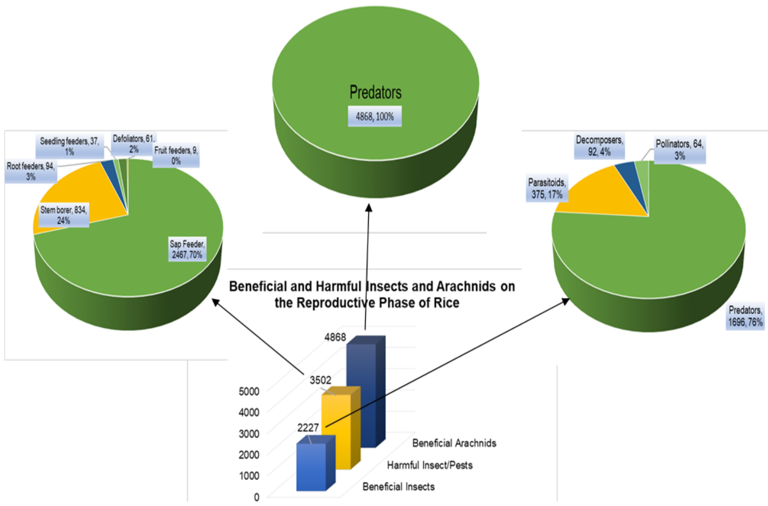


Figure 7. The beneficial and harmful insects and arachnids on the reproductive phase of rice.

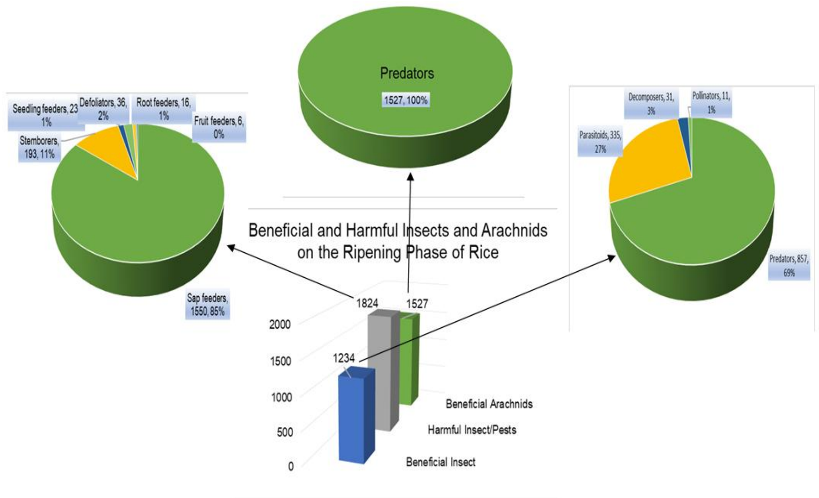


Figure 8. The beneficial and harmful insects and arachnids on the ripening phase of rice.

Vegetable Phase

During the vegetative phase, a rich assemblage of arthropods was observed, revealing an active and complex ecological network. A total of 2,431 beneficial insects were recorded, dominated by predators (2,013 individuals), followed by decomposers (255), parasitoids (150), and a small number of pollinators (13). The predominance of predatory insects indicates a robust natural control mechanism during this stage, as these organisms, particularly beetles and other generalist predators, play a key role in suppressing early pest outbreaks (Gurr et al., 2016).

Conversely, the population of insect pests was significantly higher, totaling 4,526 individuals. Sap feeders accounted for the majority (1,903), followed by stem borers (1,125), root feeders (918), defoliators (259), seedling feeders (317), and fruit feeders (4). The dominance of sap feeders is alarming since many species in this group, such as green leafhoppers, are vectors of serious viral diseases like rice tungro virus (Heong et al., 1995). Stem borers, which damage the internal tissues of rice plants, were also abundant, often causing “deadheart” and “whitehead” symptoms that lead to yield losses (Bandong & Litsinger, 2005).

A total of 3,997 beneficial arachnids, all functioning as predators, were also documented during the vegetative phase. Spiders, especially those belonging to Lycosidae (wolf spiders) and Salticidae (jumping spiders), play a vital role in pest regulation by feeding on insect eggs, larvae, and soft-bodied adults (Riechert & Lockley, 1984). Their abundance during the vegetative stage is particularly crucial, as pest populations—especially Delphacidae and Cicadellidae—are often at their peak (Settle et al., 1996; Heong et al., 1991). These findings emphasize the need to protect natural predators through habitat management and reduced pesticide use to sustain biological control services (Gurr et al., 2003; Letourneau et al., 2011).

Reproductive Phase

The reproductive phase exhibited continued ecological complexity, with fluctuations in both beneficial and pest populations. A total of 2,227 beneficial insects were collected, again dominated by predators (1,696 individuals), followed by parasitoids (375), decomposers (92), and pollinators (64). The high abundance of predators and parasitoids underscores their role in maintaining ecological balance and providing natural pest suppression (Gurr et al., 2016; Letourneau et al., 2011).

However, pest populations remained dominant, totaling 3,502 individuals, with sap feeders (2,467) constituting the majority. This group, including green and brown planthoppers, not only causes direct feeding damage but also acts as vectors for viral diseases such as rice tungro virus and grassy stunt virus (Heong et al., 1995; Cabunagan et al., 2000; Horgan et al., 2021). Stem borers (834) continued to pose significant threats, capable of causing yield losses of up to 80% if uncontrolled (Pathak & Khan, 1994; Litsinger et al., 2006). Root feeders (94), defoliators (61), seedling feeders (37), and fruit feeders (9) were also present in lower but still ecologically relevant numbers.

The beneficial arachnid population was remarkably high during this stage, with 4,868 individuals, indicating a strong predatory presence. Their abundance suggests that rice fields provide favorable conditions for spider communities, especially under systems with reduced chemical inputs or increased vegetation complexity (Schmidt & Tscharntke, 2005). The coexistence of high predator density alongside elevated pest numbers implies a tightly linked predator–prey dynamic characteristic of balanced but responsive agroecosystems.

Ripening Phase

By the ripening phase, notable shifts in community composition were recorded. The total number of beneficial insects decreased to 1,234 individuals, yet predators (857) and parasitoids (335) remained the dominant functional groups, followed by decomposers (31) and pollinators (11). This persistence of natural enemies during late crop stages highlights their continuing ecological importance in mitigating pest resurgence even near harvest (Gurr et al., 2016).

Harmful insect populations declined compared to earlier phases but still reached 1,824 individuals, dominated by sap feeders (1,550). Among these, members of the Alydidae family became particularly prevalent. Although traditionally considered secondary pests, Alydids are increasingly recognized for causing “pecky rice,” grain shriveling, and discoloration by piercing developing grains and sucking plant sap, leading to reduced grain quality and market value (Srinivas et al., 2014; Chougule et al., 2020). Their rise in abundance underscores the importance of sustained monitoring up to the ripening phase, as late-season pest activity can inflict substantial economic losses (Savary et al., 2012).

Meanwhile, 1,527 beneficial arachnids were recorded, indicating that predator populations remained stable through the crop’s maturity. Their sustained presence reflects the availability of prey and suitable microhabitats, which support continuous pest suppression (Schmidt & Tscharntke, 2005).

Conclusions and Recommendations

This study demonstrated that rice agroecosystems in Davao Oriental harbor diverse insect and arachnid communities whose abundance, diversity, and composition are influenced by landscape context, farming practices, rice growth stages, and environmental conditions. Organic rice fields generally supported greater abundance, diversity, and more unique insect and arachnid families than conventional fields, although they also harbored higher pest populations. In contrast, conventional fields maintained fewer arthropod taxa but retained substantial populations of beneficial insects. Arthropod communities also varied across rice growth stages and were significantly influenced by temperature and relative humidity. Overall, the findings provide valuable baseline information for biodiversity conservation and support the integration of ecological approaches into sustainable rice production in Davao Oriental.

The adoption of biodiversity-friendly farming practices, particularly Integrated Pest Management (IPM), is recommended to conserve beneficial insects and arachnids while reducing reliance on synthetic pesticides. Pest management programs should also consider crop growth stages and prevailing weather conditions to improve their effectiveness. Finally, long-term monitoring and further studies on the ecological roles of insects and arachnids are recommended to strengthen biodiversity-based pest management and sustainable rice production in Davao Oriental.

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Ethical Considerations

This study involved the collection, observation, and identification of insects and other arthropods in agricultural ecosystems. No human participants or vertebrate animals were involved in the study; therefore, approval from an Institutional Research Ethics Committee was not required. Permission from the concerned landowners was obtained prior to field sampling, where applicable. The collection, handling, preservation, and identification of specimens were conducted responsibly and with minimal disturbance to the study sites and surrounding ecosystems.

CRediT Authorship Statement

Felix U. Sansaet Jr.: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft, Writing – Review & Editing, Project Administration. **Elorde Jr. Crispolon:** Methodology, Supervision, Investigation, Data Curation, Formal Analysis, Visualization, Writing – Review & Editing, Validation, Project Administration. **Nancy Evangelista-Duque:** Formal Analysis, Editing, Validation, Project Administration.

Declaration on Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

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Declaration on Generative AI use

During the preparation of this manuscript, the authors used (OpenAI) solely for language improvement and grammar checking. The authors reviewed and edited all AI-assisted outputs and take full responsibility for the content, accuracy, interpretation, and originality of the manuscript. Generative AI was not used to generate, analyze, or interpret the research data or to make scientific conclusions.

Data Availability Statement

The data generated and analyzed during this study are available from the corresponding author upon reasonable request. The dataset includes the recorded insect abundance, taxonomic identification, sampling information, and biodiversity indices generated from the study.

References

Amarillo-S, A., & Montañez, M. (2014). Impact of organic crops on the diversity of insects: A review of recent research. Revista Colombiana De Entomología, 40, 131.

Amoroso, V. B., & Aspiras, R. A. (2011). Hamiguitan range: A sanctuary for native flora. Saudi Journal of Biological Sciences, 18(1), 7-15.

Ane, N., & Hussain, M. (2015). Diversity of insect pests in major rice growing areas of the world. Journal of Entomology and Zoology Studies, 4(2), 36-41.

Ates, Fritzie & Relox, Richel & Leaño, Emmanuel. (2011). Avifaunal assemblage in Mt. Hamiguitan, Davao Oriental, Mindanao Island, Philippines. Journal of Environmental Science and Management. 14.

Attwood, S. J., Maron, M., House, A. P., & Zammit, C. (2008). Do arthropod assemblages display globally consistent responses to intensified agricultural land use and management? Global Ecology and Biogeography, 17(5), 585–599. https://doi.org/10.1111/j.1466-8238.2008.00397.x

Bambaradeniya, C. N. B., & Amerasinghe, F. P. (2004). Biodiversity associated with the rice field agroecosystem in Asian countries: A brief review. IWMI Working Papers, 63, 1-24.

Bandong, Jovito & Litsinger, James. (2005). Rice crop stage susceptibility to the rice yellow stemborer *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae). International Journal of Pest Management. 51. 37-43. 10.1080/09670870400028276.

Barganska, Z., Slebioda, M., & Namiessnik, J. (2016). Honey bees and their products bioindicators of environmental contamination .Critical Reviews in Environmental Science and Technology, 46(3), 235-248. doi: 10.1080/10643389.2015.1078220

Barnes, A. D., Scherber, C., Brose, U., Borer, E. T., & Ebeling, A. (2020). Biodiversity enhances the multitrophic control of arthropod herbivory. Science Advances, 6(45), eabb6603. https://doi.org/10.1126/sciadv.abb6603

Barrion, A. T., & Litsinger, J. A. (1995). Riceland spiders of South and Southeast Asia. CAB International.

Bengtsson, J., Ahnström, J., & Weibull, A. C. (2005). The effects of organic agriculture on biodiversity and abundance: A meta-analysis. Journal of Applied Ecology, 42(2), 261–269. https://doi.org/10.1111/j.1365-2664.2005.01005.x

Bernardes, M., Pazin, M., Pereira, L., & Dorta, D. (2015). Impact of pesticides on environmental and human health. DOI: 10.5772/59710

Bianchi, F. J. J. A., Goedhart, P. W., & Baveco, J. M. (2008). Enhanced pest control in cabbage crops near forest in The Netherlands. Landscape Ecology, 23(5), 595–602. https://doi.org/10.1007/s10980- 008-9219-6

Bommarco, R., Kleijn, D., & Potts, S. G. (2013). Ecological intensification: Harnessing ecosystem services for food security. Trends in Ecology & Evolution, 28(4), 230–238. https://doi.org/10.1016/j.tree.2012.10.012

Bottrell, D. G., & Schoenly, K. G. (2012). Resurrecting the ghost of green revolutions past: The brown planthopper as a recurring threat to high- yielding rice production in tropical Asia. Journal of Asia-Pacific Entomology, 15(1), 122– 140. https://doi.org/10.1016/j.aspen.2011.09.004

Brookes, G. (2022). Genetically modified (GM) crop use 1996-2020: Environmental impacts associated with pesticide use change. doi: 10.1080/21645698.2022.2118497

Cabras, A., Buenavente, P. A., & Villegas, J. (2024). Two new species of Metapocyrtus Heller from Mindanao Island, Philippines (Coleoptera, Curculionidae, Entiminae, Pachyrhynchini). Ecologica Montenegrina, 73, 125-137. doi:10.37828/em.2024.73.13

Campos, W., Pereira, D., & Schoereder, J. (2000). Comparison of the efficiency of flight interception trap models for sampling Hymenoptera and other insects. Anais da SociedadeEntomológica do Brasil, 29(2), 381-389.

Chandini, R., Kumar, R., & Prakash. (2019). The impact of chemical fertilizers on our environment and ecosystem.

Coddington, J. A., & Levi, H. W. (1991). Systematics and evolution of spiders (Araneae). Annual Review of Ecology and Systematics, 22(1), 565–592.https://doi.org/10.1146/annurev.es.22.110191.003025

Crowder, D. W., Northfield, T. D., Strand, M. R., & Snyder, W. E. (2010). Organic agriculture promotes evenness and natural pest control. Nature, 466(7302), 109–112.https://doi.org/10.1038/nature09183

Culliney, T. (2013). Role of arthropods in maintaining soil fertility. Agriculture, 3(4), 629-659. doi: 10.3390/agriculture3040629

Dainese M., Martin E. A., Aizen M. A., Albrect M., Bartomeus I., Bommarco R, et al. (2019). A global synthesis reveals biodiversity-mediated benefits for crop production. Sci. Adv. 5, eaax0121. doi: 10.1126/sciadv.aax0121

Department of Agriculture (DA) Region XI. (2020). Davao Oriental: Rice production champion. Retrieved from https://davaooriental.gov.ph/news/agriculture/davao-oriental awarded-as-national-rice-achiever-2/

Department of Environment and Natural Resources. (2014). Mount Hamiguitan Range Wildlife Sanctuary. Retrieved from https://www.denr.gov.ph/

Department of Environment and Natural Resources. (2002). Mount Hamiguitan Range Protected Landscape: Management Plan. Retrieved from https://www.denr.gov.ph/

Dietrich, C. H. (2005). Keys to the families of Cicadomorpha and subfamilies and tribes of Cicadellidae (Hemiptera: Auchenorrhyncha). Florida Entomologist, 88(4), 502–517. https://doi.org/10.1653/0015-4040(2005)88[502:KTTFOC]2.0.CO;2

Dunn, Lucinda & Latty, Tanya & Van Ogtrop, Floris & Tan, Daniel. (2023). Cambodian rice farmers' knowledge, attitudes, and practices (KAPs) regarding insect pest management and pesticide use. International Journal of Agricultural Sustainability. 21. 10.1080/14735903.2023.2178804.

Elisha, Otekenari & Jebbin, Felix,. (2020). The Loss of Biodiversity and Ecosystems: A Threat to the Functioning of our Planet, Economy and Human Society.

Entling, Martin & Tscharntke, Teja. (2005). The role of perennial habitats for Central European farmland spiders. Agriculture Ecosystems & Environment. 105. 235-242. 10.1016/j.agee.2004.03.009.

Evans, Edward. (2009). Lady beetles as predators of insects other than Hemiptera. Biological Control. 51. 255-267. 10.1016/j.biocontrol.2009.05.011.

Finke, Deborah & Denno, Robert. (2003). Intra - guild predation relaxes natural enemy impacts on herbivore populations. Ecological Entomology. 28. 67 - 73. 10.1046/j.1365-2311.2003.00475.x.

Foelix, R. F. (2011). Biology of spiders. Oxford University Press.

Food and Agriculture Organization of the United Nations. (2017). The future of food and agriculture: Trends and challenges.

Food and Agriculture Organization of the United Nations. (2019). The state of the world's plant genetic resources for food and agriculture.

Foottit, R. G., & Adler, P. (2009). Insect biodiversity: Science and society (2nd ed.).Wiley. doi: 10.1002/9780470690954

Gagic V, Hulthen AD, Marcora A, Wang X, Jones L, Schellhorn NA. Biocontrol in insecticide sprayed crops does not benefit from semi - natural habitats and recovers slowly after spraying. J Appl Ecol. 2019;56:2176 – 2185. https://doi.org/10.1111/1365-2664.13452

Galindo, V., Giraldo, C., Lavelle, Armbrecht, I., Fonte, S. (2022). Land use conversion to agriculture impacts biodiversity, erosion control, and key soil properties in an Andean watershed. https://doi.org/10.1002/ecs2.3979

Gallai, Nicola & Salles, Jean-Michel & Settele, Josef & Vaissière, Bernard. (2009). Economic valuation of the vulnerability of world agriculture confronted to pollinator decline. Ecological Economics. 68. 810-821. 10.1016/j.ecolecon.2008.06.014.

Gangurde, Sarwshri. (2007). Aboveground arthropod pest and predator diversity in irrigated rice (Oryza sativa L.) production systems of the Philippines. J. Trop. Agr.. 45.

Geiger, F., Bengtsson, J., Berendse, F., Weisser, W. W., Emmerson, M., Morales, M. B., ... & Inchausti, P. (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. Basic and Applied Ecology, 11(2), 97–105. https://doi.org/10.1016/j.baae.2009.12.001

Giribet, Gonzalo & Edgecombe, Gregory. (2013). The Arthropoda: A Phylogenetic Framework. 10.1007/978-3-642-36160-9_2.

Global Biodiversity Information Facility. (2025). GBIF.org. https://www.gbif.org

Gollapelly Ravi, L.N. Mohapatra, Shaik Moizur Rahman, Prateek Kumar Charati and Revanth T. (2022). Diversity of Spider Fauna (Arachnida: Araneae) in Rice Agro Ecosystem. Biological Forum– An International Journal, 14(2): 940-943.

Gotelli, Nicholas J. et al. (2012). Environmental proteomics, biodiversity statistics and food-web structure. Trends in Ecology & Evolution, Volume 27, Issue 8, 436 - 442

Gomiero, T., Pimentel, D., & Paoletti, M. G. (2011). Environmental impact of different agricultural management practices: Conventional vs. organic agriculture. Critical Reviews in Plant Sciences, 30(1-2), 95-124.

Grimaldi, D. and Engel, M. (2005). Evolution of the Insects. Cambridge University Press. ISBN0-521-82149-5

Gurr, G. M., Lu, Z., Zheng, X., Xu, H., Zhu, P., Chen, G., ... & Heong, K. L. (2016). Multi-country evidence that crop diversification promotes ecological intensification of agriculture. Nature Plants, 2(3), 16014. https://doi.org/10.1038/nplants.2016.14

Gurr, G. M., Wratten, S. D., & Luna, J. M. (2003). Multi-function agricultural biodiversity: Pest management and other benefits. Basic and Applied Ecology, 4(2), 107–116. https://doi.org/10.1078/1439-1791-00122

Gurr, G. M., Wratten, S. D., & Altieri, M. A. (2003). Ecological engineering for pest management: Advances in habitat manipulation for arthropods. CSIRO Publishing.

Gurr, G. M., Lu, Z., Zheng, X., Xu, H., Zhu, P., Chen, G., ... & Heong, K. L. (2016). Multi-country evidence that crop diversification promotes ecological intensification of agriculture. Nature Plants, 2(3), 16014. https://doi.org/10.1038/nplants.2016.14

Haddad, C. R., Dippenaar-Schoeman, A. S., & Wesolowska, W. (2015). The influence of land use on spider assemblages in South African grasslands. African Zoology, 50(2), 145–162. https://doi.org/10.1080/15627020.2015.1041179

Hassall, C., & Thompson, D. J. (2008). The effects of environmental warming on Odonata: A review. International Journal of Odonatology, 11(2), 131– 153. https://doi.org/10.1080/13887890.2008.9748319

Heinrichs, E. A. (1994). Biology and management of rice insects. Wiley Eastern Ltd.

Heong, K. L., & Hardy, B. (Eds.). (2009). Planthoppers: New threats to the sustainability of intensive rice production systems in Asia. International Rice Research Institute.

Heong, K.-L., Lu, Z.-X., Chien, H.-V., Escalada, M., Settele, J., Zhu, Z.-R., & Cheng, J.-A. (2021). Ecological Engineering for Rice Insect Pest Management: The Need to Communicate Widely, Improve Farmers' Ecological Literacy and Policy Reforms to Sustain Adoption. Agronomy, 11(11), 2208. https://doi.org/10.3390/agronomy11112208

Heong, K. L., Wong, L., & Delos Reyes, M. (2018). Insect pests of rice in Asia: A review. Journal of Insect Science, 18(3), 537-555.

Heong, K. L., & Schoenly, K. G. (1998). Impact of insecticides on herbivore-natural enemy communities in tropical rice ecosystems. Ecological Applications, 8(4), 831-847.

Heong, K. L., Aquino, G. B., & Barrion, A. T. (1991). Arthropod community structures of rice ecosystems in the Philippines. Bulletin of Entomological Research, 81(4), 407–416. https://doi.org/10.1017/S0007485300031925

Hibino, H. (1996). Biology and epidemiology of rice viruses. Annual Review of Phytopathology, 34, 249–274. https://doi.org/10.1146/annurev.phyto.34.1.249

Hillstrom, M. L., & Lindroth, R. (2008). Elevated atmospheric carbon dioxide and ozone alter forest insect abundance and community composition. Insect Conservation and Diversity. Retrieved from http://aspenface.mtu.edu/pdfs/Hillstrom%20and%20Lindroth%202008.pdf

HLPE (2017). Sustainable agricultural development for food security and nutrition: What roles for livestock? Committee on World Food Security.

Hooper, D. U., et al. (2005). Effects of biodiversity loss on ecosystem functioning: Implications for ecosystem services. Ecology Letters, 8(10), 1051-1064.

IFOAM Organics International. (2020). The IFOAM organic principles. Retrieved from https://www.ifoam.bio/en/organic-principles

iNaturalist. (2025). iNaturalist. https://www.inaturalist.org

Integrated Taxonomic Information System. (2025). ITIS. https://www.itis.gov

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019). Global Assessment Report on Biodiversity and Ecosystem Services.

Intergovernmental Panel on Climate Change (IPCC). (2019). Climate Change and Land: An IPCC special report.

John, Matthew & Bankole, Ibukunoluwa & Ajayi-Moses, Oluwatayo & Ijila, Tofunmi & Jeje, Timilehin & Patil, Lalit. (2023). Relevance of Advanced Plant Disease Detection Techniques in Disease and Pest Management for Ensuring Food Security and Their Implication: A Review. American Journal of Plant Sciences. 14. 10.4236/ajps.2023.1411086.

Kapos, Valerie & Kurz, Werner & Gardner, Toby & FERREIRA, J. & Guariguata, Manuel & Koh, Lian & Mansourian, Stephanie & Parrotta, John & Sasaki, Nophea & Schmitt, Christine. (2012). Impacts on forest and land management on biodiversity and carbon.

Karp, D. S., Gennet, S., Kilonzo, C., Partyka, M., Chaumont, N., & Kremen, C. (2018). Crop pests and predators exhibit inconsistent responses to surrounding landscape composition. Proceedings of the National Academy of Sciences, 115(33), E7863–E7870. https://doi.org/10.1073/pnas.1800042115

Kremen, C., & Miles, A. (2012). Ecosystem services in biologically diversified versus conventional farming systems: Benefits, externalities, and trade-offs. Ecology and Society, 17(4), 40. https://doi.org/10.5751/ES-05035- 170440

Kumari, Reeta & A, Deepali & Bhatnagar, Sonal. (2021). Biodiversity Loss: Threats and Conservation Strategies. International Journal of Pharmaceutical Sciences Review and Research. 68. 10.47583/ijpsrr.2021.v68i01.037.

Lach, L., Parr, C. L., & Abbott, K. L. (Eds.). (2010). Ant ecology. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199544639.001.0001

Landis, D. A., Wratten, S. D., & Gurr, G. M. (2000). Habitat management to conserve natural enemies of arthropod pests in agriculture. Annual Review of Entomology, 45, 175–201. https://doi.org/10.1146/annurev.ento.45.1.175

Lavelle, P., et al. (2006). Soil invertebrates and ecosystem services. European Journal of Soil Biology, 42(Supplement 1), S3-S15.

Letourneau, D. K., Armbrecht, I., Salguero Rivera, B., Montoya Lerma, J., Jiménez Carmona, E., Daza, M. C., ... & Trujillo, A. R. (2011). Does plant diversity benefit agroecosystems? A synthetic review. Ecological Applications, 21(1), 9–21. https://doi.org/10.1890/09- 2026.1

López, R., & Potter, D. A. (2000). Ant predation on eggs and larvae of the black cutworm (Lepidoptera: Noctuidae) and Japanese beetle (Coleoptera: Scarabaeidae) in turfgrass. Environmental Entomology, 29(1), 116–125. https://doi.org/10.1603/0046-225X-29.1.116

Madesh, K.. (2024). Exploring the Secrets of Insect Biodiversity. 10.13140/RG.2.2.26667.45604.

Maggi, Tara & Pardo, L. (2024). Insect Pollinators: A Key to Ecosystem Resilience and Food Security.

Magurran, A. E. (2004). Measuring biological diversity. Blackwell Publishing.

Marc, P., Canard, A., & Ysnel, F. (1999). Spiders (Araneae) useful for pest limitation and bioindication. Agriculture, Ecosystems & Environment, 74(1–3), 229–273. https://doi.org/10.1016/S0167-8809(99)00038-9

McGeoch, M. A. (2007). The selection, testing, and application of terrestrial insects as bioindicators. Biological Reviews, 73(2), 181-201.

Mohagan, A. B. (2010). Mount Hamiguitan Range Protected Landscape: A review of its natural resources.

Mohagan, Alma & Treadaway, Colin. (2010). Diversity and Status of Butterflies across Vegetation Types of Mt. Hamiguitan, Davao Oriental, Philippines. Asian Journal of Biodiversity. 1. 10.7828/ajob.v1i1.99.

Mokam, D. G., Djiéto-Lordon, C., & Bilong Bilong, C.-F. (2014). Patterns of species richness and diversity of insects associated with cucurbit fruits in the southern part of Cameroon. Journal of Insect Science, 14(1), 248. https://doi.org/10.1093/jisesa/ieu110

Mostafalou, S., & Abdollahi, M. (2017). Pesticides and human health: A review of evidence. Toxicology and Applied Pharmacology, 325, 41-53.

Natural History Museum Bern. (2025). World Spider Catalog (Version 26.0). https://wsc.nmbe.ch

Nyffeler, M., & Birkhofer, K. (2017). An estimated 400–800 million tons of prey are annually killed by the global spider community. The Science of Nature, 104(3–4), 30. https://doi.org/10.1007/s00114-017-1440-1

Nyffeler, Martin & Sunderland, Keith. (2003). Composition, abundance and pest control potential of spider communities in agroecosystems: A comparison of European and US studies. Agriculture, Ecosystems & Environment. 95. 579-612. 10.1016/S0167-8809(02)00181-0.

Nyffeler, M., & Benz, G. (1987). Spiders in natural pest control: A review. Journal of Applied Entomology, 103(1–5), 321–339. https://doi.org/10.1111/j.1439-0418.1987.tb00992.x

Obrycki, J. J., & Kring, T. J. (1998). Predaceous Coccinellidae in biological control. Annual Review of Entomology, 43, 295–321. https://doi.org/10.1146/annurev.ento.43.1.295

Ovawanda, E., Witjaksono, & Trisyono A. (2016). Insect Biodiversity in organic and non-organic rice ecosystem in the district of Bantul. Jurnal Perlindungan Tanaman Indonesia, Vol. 20, No. 1, 2016: 15–21

Pal, S., & Satpathi, S. K. (2016). Species richness and relative abundance of pest faunal complex infesting okra under mid-hill conditions of Eastern Himalayas. Journal of Agriculture and Technology, 3(1), 74–78.

Perfecto, I., & Vandermeer, J. (2008). Biodiversity conservation in tropical agroecosystems: A new conservation paradigm. Annals of the New York Academy of Sciences, 1134(1), 173–200. https://doi.org/10.1196/annals.1439.011

Perry, Jitka & Lojka, Bohdan & Quiñones, Lourdes & Van Damme, Patrick & Houška, Jakub & Fernández, Eloy. (2016). How natural Forest Conversion Affects Insect Biodiversity in the Peruvian Amazon: Can Agroforestry Help?. Forests. 7. 82. 10.3390/f7040082.

PNS/BAFS (2021). Philippine National Standard for Organic Agriculture.

Potts, S. G., et al. (2010). Global pollinator declines. Trends in Ecology & Evolution, 25(7), 345-353.

Potts, S., et al. (2020). Insect pollination services: A review. Journal of Pollination Ecology, 20(1), 1-12.

Pretty, J. N., & Bharucha, Z. P. (2015). Integrated pest management for sustainable intensification of agriculture in Asia. Insects, 6(1), 152-196.

Prokopy, Ronald & Kogan, Marcos. (2009). Integrated Pest Management. Encyclopedia of Insects. 523-528. 10.1016/B978-0-12-374144-8.00148-X.

Protected Areas and Wildlife Bureau (PAWB). (2020). Mount Hamiguitan Range Wildlife Sanctuary.

Puech, C., Baudry, J., Joannon, A., Poggi, S., & Aviron, S. (2014). Organic farming and landscape structure: Effects on insect-pollinated plant diversity in intensive agricultural landscapes. Agriculture, Ecosystems & Environment, 185, 133–141. https://doi.org/10.1016/j.agee.2013.12.013

Quicke, D. L. J. (2015). The Braconid and Ichneumonid parasitoid wasps: Biology, systematics, evolution and ecology. Wiley Blackwell.

Rao, Kritika & Kanaujia, Amita. (2023). Spiders' Impact on Controlling Insect Pests in the Agricultural Ecosystem. 4. 2389-2392.

Riechert, S. E., & Lawrence, K. (1997). Test of hypotheses about spider sociality. Journal of Insect Behavior, 10(5), 687-703.

Riechert, S. E., & Lockley, T. (1984). Spiders as biological control agents. Annual Review of Entomology, 29(1), 299–320. https://doi.org/10.1146/annurev.en.29.010184.001503

Rola, A. C., & Jamias, S. B. (2015). Sustainable agriculture and rural development in the Philippines: A review. Journal of Environmental Science and Management, 18(1), 1-14.

Rusch, A., Valantin - Morison, M., Sarthou, J. P., & Roger - Estrade, J. (2010). Biological control of insect pests in agroecosystems: Effects of crop management, farming systems, and seminatural habitats at the landscape scale: A review. Advances in Agronomy, 109, 219–259. https://doi.org/10.1016/S0065-2113(10)09006-1

Saksongmuang, V., Michalko, R.,Petcharad, B., and Bumrungsri, S. (2024). Changes in community composition and prey capture of web-building spiders during rice field development. Basic and Applied Ecology,Volume 79, Pages 29-37, ISSN 1439-1791, https://doi.org/10.1016/j.baae.2024.05.003.

Saminathan, Karthikeyan & Kaithamalai, Bhuvaneswari & Kennedy, John & Gopinathan, Suganthi. (2024). Biodiversity of pests and natural enemies in different production environments of rice and cabbage: impacts of insecticide application. Organic Agriculture. 14. 1-11. 10.1007/s13165-024-00454-9.

Sanchez, P. A., et al. (2003). Soil fertility replenishment in Africa: An investment in natural resource capital. African Crop Science Conference Proceedings, 5, 343-356.

Sánchez-Bayo F. (2021). Indirect Effect of Pesticides on Insects and Other Arthropods. Toxics. 2021 Jul 30;9(8):177. doi: 10.3390/toxics9080177. PMID: 34437495; PMCID: PMC8402326.

Schutze, & Aketarawong, Nidchaya & AMORNSAK, & Armstrong, Karen & Augustinos, Antonios & BARR, & BO, & Bourtzis, Kostas & Boykin Okalebo, Laura & ÁCERES, & CAMERON, & Chapman, Toni & CHINVINIJKUL, & CHOMIČ, & Meyer, Marc & Drosopoulou, Elena & Englezou, Anna & EKESI, & Gariou-Papalexiou, Angeliki & CLARKE, A. (2014). Synonymization of key pest species within the Bactrocera dorsalis species complex (Diptera: Tephritidae): taxonomic changes based on a review of 20 years of integrative morphological, molecular, cytogenetic, behavioural and chemoecological data. Systematic Entomology.

Schmidt, M. H., Roschewitz, I., Thies, C., & Tscharntke, T. (2005). Differential effects of landscape and management on diversity and density of ground-dwelling farmland spiders. Journal of Applied Ecology, 42(2), 281–287. https://doi.org/10.1111/j.1365- 2664.2005.01013.x

Schowalter, T. D. (2011). Insect ecology: An ecosystem approach. Academic Press.

Settle, W. H., Ariawan, H., Astuti, E. T., Cahyana, W., Hakim, A. L., Hindayana, D., & Lestari, A. S. (1996). Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. Ecology, 77(7), 1975–1988. https://doi.org/10.2307/2265694

Shannon, D., & Fitter, A. H. (2004). Biodiversity and ecosystem function in agricultural systems: A review. Agriculture, Ecosystems & Environment, 104(1), 3–16. https://doi.org/10.1016/j.agee.2004.01.020

Simpson, E. H. (1949). Measurement of diversity. Nature, 163, 688. http://dx.doi.org/10.1038/163688a0

Sina, I., & Zulkarnaen, I. (2019). Margalef Index, Simpson Index, and Shannon-Weaver Index calculation for diversity and abundance of beetle in tropical forest. STATMAT: Jurnal Statistika dan Matematika, 1(2), 83–93.

Sinduja, Murugaiyan & Kendra, Vigyan. (2024). Spiders as Natural Pest Controllers: Insights into Their Distribution, Diversity, and Ecological Impact in Agriculture.1-9.

Sollai, G., & Solari, P. (2022). An overview of "insect biodiversity." Diversity, 14(2), 134. https://doi.org/10.3390/d14020134

Solórzano Kraemer, M. M., Kraemer, A. S., & Stebner, F. (2013). Variations of arthropod biodiversity due to human intervention and climatic variations: Study of a protected and a non-protected area in a tropical forest. arXiv preprint arXiv:1312.6522.

Sonico, M. G. (2022). Insect diversity in an organic rice farm in Brgy. Langkong, M'lang, North Cotabato, Philippines. Southeastern Philippines Journal of Research and Development, 27(1), 45-56. https://doi.org/10.53899/spjrd.v27i1.189

Swodesh Rijal & Yuvraj Devkota, 2020. "Rice (Oryza sativa) is native to Asia and grown worldwide," Malaysian Journal of Sustainable Agriculture (MJSA), Zibeline International Publishing, vol. 4(1), pages 29-33, February.

Tilman, D., et al. (2001). Forecasting agriculturally driven global environmental change. Science, 292(5515), 281-284. https://doi.org/10.1126/science.1057544

Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto,I., ... & Whitbread, A. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. Biological Conservation, 151(1), 53–59. https://doi.org/10.1016/j.biocon.2012.01.068

Tscharntke, T., Klein, A. M., Kruess, A., Steffan - Dewenter, I., & Thies, C. (2005). Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management. Ecology Letters, 8(8), 857 – 874. https://doi.org/10.1111/j.1461-0248.2005.00782.x

Underwood, Teri & McCullum-Gomez, Christine & Harmon, Alison & Roberts, Susan. (2011). Organic Agriculture Supports Biodiversity and Sustainable Food Production. Journal of Hunger & Environmental Nutrition. 6. 398-423. 10.1080/19320248.2011.627301.

Vitousek, P. M., et al. (2009). Nutrient imbalances in agricultural development. Science, 324(5934), 1519-1520. https://doi.org/10.1126/science.1166367

Wagner, D.L. (2017). Trends in Biodiversity: Insects. 10.1016/B978-0-12-409548-9.09819-5.

Wilson, E. O. (2001). The diversity of life. W.W. Norton & Company.

Wheeler, Q. D. (2004). Taxonomic triage and the poverty of phyphony. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 359(1444), 571-583. https://doi.org/10.1098/rstb.2003.1446

Wheeler, W. C. (2020). Phylogenetics: Theory and practice. Systematic Biology, 69(2),221-236.

World Heritage Data Sheet (2015). http://world-heritage-datasheets.unep-wcmc.org/datasheet/output/site/mount-hamiguitan-range-wildlife-sanctuary/

Zemed WB. (2024). Insects Importance in Contemporary Agriculture and the Natural Environment. medtigo J Pharmacol. ;1(1):e14160207. doi:10.5281/zenodo.14160207

Zhang, Y., Li, M., & Feng, Y. (2022). Biodiversity conservation in rice ecosystems: A review. Sustainability, 14(11), 6638.

Zhang, W., Ricketts, T. H., Kremen, C., Carney, K., & Swinton, S. M. (2007). Ecosystem services and dis-services to agriculture. Ecological Economics, 64(2), 253–260. https://doi.org/10.1016/j.ecolecon.2007.02.024

Zovko,M, Sandra, S., Lešić, Z., & Lemić, D., Vinko, L. (2021). The Impact of Climate Change on Agricultural Insect Pests. Insects, 12(5), 440. https://doi.org/10.3390/insects12050440