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Effect of Landscape Composition and Habitat Conditions on the Diversity of Predatory Insects (Spiders, Ants, and Ground Beetles) in Cabbage Fields

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KEYWORDS

Araneae;
Carabidae;
Formicidae;
Insect;
Population

Abstract In a landscape, various types of land use compositions and different habitat conditions can affect the diversity and abundance of living organisms, particularly predatory insects. The observed landscape is a cabbage plantation area located in the highlands, featuring diverse habitat conditions, vegetation variations, and surrounding land use compositions such as agriculture, natural habitats, industrial areas, and settlements. This study aims to determine the diversity and abundance of predators, particularly spiders, ants, and ground beetles, in cabbage farming, influenced by differences in landscape composition and habitat conditions in the Malang and Pasuruan districts. Landscape analysis was conducted through direct checking (ground survey), followed by digitization using QGIS software, and data analysis was performed using the RStudio application. Plant age did not affect the diversity and abundance of predatory insects in cabbage plants. Elevation was related to the abundance of ants, as well as the diversity and abundance of ground beetles. The use of insecticides had no relationship with the diversity and abundance of predatory insects. Almost all land use compositions around the study area significantly impacted the diversity and abundance of predators. Therefore, it can be concluded that certain habitat conditions and landscape compositions are related to the diversity and abundance of predatory insects in cabbage plants.

Introduction

Landscape is a vast area of land consisting of various heterogeneous land uses that encompass interacting ecosystems, such as rice fields, orchards, and others (Fahrig *et al.,* 2005). Agricultural landscape management is an approach aimed at conserving species, especially natural enemies like spiders, ants, and ground beetles, which play a crucial role in controlling pest populations. For instance, the diversity of predators in agricultural land increases with more complex or varied land use. Complex agricultural landscapes are characterized by the presence of trees, shrubs, wild weeds, and heterogeneous farming patterns. In contrast, simple landscapes have fewer non-agricultural plants and a more homogeneous farming structure (Plećaš *et al.,* 2014; Dainese *et al.,* 2019).

Tropical agricultural ecosystems in Indonesia, including food crops and horticulture in both lowland and highland areas, serve as habitats for various natural enemies effective in suppressing pest populations. These ecosystems, when managed sustainably, can enhance biodiversity and ecosystem services, including natural pest control, which directly supports

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agricultural productivity (Santoso *et al.,* 2020). Key components of landscape structure, such as patch size (fragments), matrix composition, and corridors, play significant roles in determining landscape complexity (Prasetyo, 2017). Agricultural landscape structure affects biodiversity and ecosystem services such as pollination and pest control (Susilawati *et al.,* 2018; Ulina *et al.,* 2019; Mongabay, 2024). Landscape structure relates to the type, distribution, dimensions, and forms of landscape components. Landscape functions include environmental goods and services provided, such as production functions (food, fiber, timber, energy), habitat functions (biodiversity habitats), regulatory functions (biosphere and atmospheric cycles), and cultural functions (aesthetic, recreational, and cultural values) (De Groot *et al.,* 2002).

The greater the diversity of land cover types within a landscape, the more species it can support (Duelli, 1997). In agricultural ecosystems, spatial structure, habitat diversity, and habitat composition vary widely from simple to complex. These factors influence local biodiversity and ecological functions on a landscape scale (Kruess, 2003). Recent studies highlight that biodiversity enhances ecosystem services such as pest control and pollination, directly improving crop yields (Dainese *et al.,* 2019; CABI, 2023). This study aims to determine the effects of landscape composition and habitat conditions on the diversity and abundance of spiders (Arachnida: Araneae), ants (Hymenoptera: Formicidae), and ground beetles (Coleoptera: Carabidae) in cabbage fields.

Material and methods

Study Area and Habitat Condition

The research was conducted from November to January 2023 using 12 cabbage farms located in Malang Regency and Pasuruan Regency, specifically in Pujon District, Tumpang District, Poncokusumo District, and Purwodadi District. To obtain more accurate regional data, coordinates were utilized through the Google Earth application. The distance between coordinate points was at least 1 km. The coordinates obtained through Google Earth are shown in (Figure 1).

The cabbage research fields are typically located in highlands, approximately > 600 meters above sea level. Determination of land characteristics and land use types in cabbage farming landscapes is assisted using satellite maps. From the 12 cabbage cultivation sites studied, a composition was derived consisting of various types of land use. Other variables measured include pesticide application, elevation, and landscape composition. pesticide application is known by calculating the intensity of pesticide use on those fields (Table 1).

Figure 1. Geographic Location of Cabbage Research Fields

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Plot Design and Data Collection

Insect sampling was conducted when the cabbage plants were 2, 4, 6, and 8 weeks after planting (WAP) using pitfall traps and pan traps, which are widely recognized as effective methods for capturing ground-dwelling and flying insects in agricultural and natural ecosystems (Skvarla *et al.,* 2021). The observation plots were 10 × 10 meters in size. Within one plot, there were 5 sub-plots arranged diagonally. Each trap was placed 1 meter apart from the others. The traps were alternately installed between pitfall traps and pan traps (Figure 2).

Table 1. Pesticide Intensity, Elevation and Research Site Coordinates

Landscape Code	Insecticides Intensity	District	Elevation (m asl)	Coordinates
Gesingan	9	Pujon	1181	7°51'06.1"S; 112°28'29.5"E
Madiredo	10	Pujon	1121	7°49'27.8"S; 112°27'54.6"E
Wiyurejo	9	Pujon	1099	7°50'03.9"S; 112°28'16.5"E
Ngabab 1	10	Pujon	1077	7°50'07.1"S; 112°26'44.6"E
Ngabab 2	10	Pujon	1179	7°49'44.3"S; 112°26'03.2"E
Tawangsari	9	Pujon	1156	7°49'00.6"S; 112°26'50.4"E
Duwet Krajan 1	11	Tumpang	787	8°01'32.4"S 112°47'59.3"E
Duwet Krajan 2	10	Tumpang	1055	8°00'51.8"S 112°49'53.3"E
Belung Dua 1	11	Poncokusumo	639	8°01'40.6"S 112°46'02.5"E
Belung Dua 2	11	Poncokusumo	602	8°01'43.8"S 112°45'26.1"E
Gerbo	9	Purwodadi	643	7°50'14.0"S 112°46'23.7"E
Dawuhan Sengon	10	Purwodadi	584	7°49'38.8"S 112°46'19.5"E

Figure 2. Plot design of the research

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Sampling was conducted after Pitfall traps and Pan traps had been set up for 24 hours filled with detergent water. Sampling took place during the vegetative and generative phases. For cabbage plants, sampling was conducted at 2 and 4 weeks after transplanting (vegetative phase) and at 6 and 8 weeks after transplanting (generative phase). Specimens collected were then placed into vials filled with alcohol to preserve them and prevent damage, followed by sorting of the samples.

Landscape Characteritation and Landscape Composition

At the landscape level, a ground survey within a 500-meter radius was conducted using satellite maps as the base map to determine coordinates of observation locations. Direct surveys were performed to identify land use types, which were then delineated on a provisional map for easier digitization. Subsequently,a 500-meter radius measurement was taken at each observation site and georeferenced using QGIS software. Georeferencing was essential to align and adjust scanned map coordinates with actual map coordinates. After georeferencing, the next step involved digitizing the landscape in each research area. All patches within the landscape were identified and their habitat types recorded, serving as the basis for landscape digitization. Finally, the Number of Patches (NP) and Class Area (CA) were determined based on the digitized areas in each research site using LecoS (Landscape Ecology Statistics) (Table 2). CA is the area of land use in hectares (ha).

Data analysis that will be used to examine the various factors influencing the diversity and abundance of predatory insects.

The analyses employed in this study were Regression Analysis, ANOSIM (Analysis of Similarities) and Generalized Linear Model (GLM), which are commonly used in ecological studies to explore the relationships between environmental variables and biodiversity (Zuur *et al.,* 2018; Bolker, 2022; Hilbe, 2023). Prior to analysis, Shapiro-Wilk normality tests were conducted on each response variable. If the data did not follow a normal distribution, logarithmic transformation (log(x)) was applied. Regression analysis was used to assess the relationship between insecticide application intensity, elevation, and plant age on predator diversity and abundance.

Table 2. Number of Patch (NP) and Class Area (CA) Values of Agricultural Land, Natural Habitat, Settlements, and Industry.

Sites	Agriculture		Natural Habitat	
	NP	CA	NP	CA
Gesingan	30	42.82 ha	5	13.27 ha
Madiredo	4	50.24 ha	8	3.13 ha
Wiyurejo	4	63.29 ha	19	11.44 ha
Ngabab 1	4	53.47 ha	6	19.09 ha
Ngabab 2	2	67.18 ha	25	11.27 ha
Tawangsari	7	41.16 ha	13	19.86 ha
Duwet Krajan 1	6	20.19 ha	2	52.40 ha
Duwet Krajan 2	2	47.18 ha	8	24.48 ha
Belung Dua 1	9	37.10 ha	3	28.38 ha
Belung Dua 2	5	45.70 ha	3	19.03 ha
Gerbo	2	64.94 ha	8	12.19 ha
Dawuhan Sengon	2	37.69 ha	2	25.68 ha

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ANOSIM was utilized in this study to assess differences in community composition across groups, providing a robust non-parametric approach to evaluating ecological dissimilarities based on ranked distance matrices (Clarke et al., 2018; Anderson & Walsh, 2022). ANOSIM analysis was also used to examine predator insect composition based on plant age. Meanwhile, GLM analysis was used to determine the influence of landscape composition on predator biodiversity and abundance within a landscape. All analyses were performed using Rstudio version 4.2.1. This allows us to understand the influence and relationship of habitat conditions and landscape composition on the diversity and abundance of predator insects within a landscape.

Results and Discussion

Diversity of Predatory Insects in Cabbage Fields

The identification results indicate the presence of three predators found in the research area: spiders, ants, and ground beetles. According to the findings, there were 542 spider individuals consisting of 9 families and 58 morphospecies (Table 3). For ants, a total of 4,053 individuals from 5 subfamilies were classified into 52 morphospecies (Table 3). Meanwhile, for ground beetles, there were 41 individuals representing 10 morphospecies (Table 3). The Lycosidae morphospecies were the most dominant with 113 spider individuals. Lycosidae, known as wolf spiders, act as predators of arthropods such as caterpillars, moths, and flies (Figure 3). Among ants, the genus Lophomyrmex had the highest number and dominated the research area (Figure 3). Lophomyrmex, a genus widely distributed and commonly found on Earth's surface, is described by Rigato (1994) as ants with extensive distribution in the Indo-Australian region. Some species within this genus, such as *Lophomyrmex bedoti* and *Lophomyrmex birmanus*, are known scavengers. Meanwhile, ground beetles belonging to the Staphylinidae family exhibited the highest morphospecies diversity in the research area, with 16 morphospecies and 115 individuals (Figure 3). Staphylinidae functions as generalist predator insects targeting collembolans, nematodes, larvae, and other small insects.

Table 3. Diversity and Abundance of Spiders, Ants and Gruond Beetles on Cabbage Fields

No	Fields	Spiders		Ants		Ground Beetles	
		S	N	S	N	S	N
1	Gesingan	9	13	17	163	2	2
2	Madiredo	12	50	14	39	1	1
3	Wiyurejo	12	69	16	372	1	1
4	Ngabab1	13	67	5	42	2	16
5	Ngabab2	10	17	5	29	3	7
6	Tawangsari	16	17	8	57	1	1
7	Duwet Krajan1	8	23	26	648	1	1
8	Duwet Krajan2	13	32	4	7	4	9
9	Belung Dua1	21	51	11	232	4	93
10	Belung Dua2	22	124	12	72	5	8
11	Gerbo	16	49	25	1214	3	26
12	Dawuhan Sengon	12	30	17	1178	4	41

Note: Species richness (S) and abundance (N) of the spiders, ants and ground beetles in each location

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The effect of Plant age on Predator Communities

Based on regression analysis, plant age does not correlate with the diversity of spiders, ants, and ground beetles (Table 4). The ANOSIM analysis results indicate that plant age also does not affect the composition differences of spiders (R_{ANOSIM} = 0.001; p = 0.447), ants (R_{ANOSIM}= -0.061; p = 0.994), and ground beetles (R_{ANOSIM} = -0.069; p = 0.99). The overlapping lines shown by the ANOSIM graph suggest that species composition is similar across different plant ages (Figure 3). Although the plant canopy becomes denser as the plant ages, affecting the microclimate, plant age does not influence spiders, ants, or ground beetles. This is because spider species that live on the ground surface, such as Lycosidae and Salticidae, do not depend on the plant canopy. Ground-dwelling hunting spiders do not make webs on the plant canopy, so their survival is not reliant on the canopy for creating webs as a place to live (Diniyati, 2021).

The plant ages observed in this study were monitored four times at 2 WAP (weeks after planting), 4 WAP, 6 WAP, and 8 WAP. As seen in (Figure 4a), the overlapping NMDS plots for each plant age indicate that the diversity of spiders at each observation week is highly similar, as is the case for ants (Figure 4b) and ground beetles (Figure 4c). This suggests that the diversity in each plot is very similar, leading to the conclusion that each plot has similar habitat conditions. According to Tawakkal *et al.* (2019), not only the overlapping plots but also the proximity of points on the NMDS plot indicates a similarity in species composition; conversely, if the points are farther apart, it indicates a difference in species composition. The age of the cabbage plants is also not correlated with the diversity or abundance of ants and ground beetles. This is because ants have a high adaptive ability, so the canopy does not significantly affect ants, particularly in terms of foraging. Similarly, for ground beetles, aside from plant age, the diversity and abundance of ground beetles can be influenced by the high availability of prey.

Table 4. Regression And ANOSIM Analysis Results: The Relations Between Plant Age and The Diversity and Abundance of Predators

Variables	**Spiders**		**Ants**		**Ground Beetles**	
	R^2 Value	**P Value**	**R^2 Value**	**P Value**	**R^2 Value**	**P Value**
Species Diversity						
Plant Age	<0.001	0.819	<0.001	0.992	0.012	0.444
Individual Abundance						
Plant Age	0.013	0.432	0.007	0.573	0.024	0.293

Note: P values below 0.05 are considered significant

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Figure 3. Predators found in the research area: (a) Spider (Lycosidae), (b) Ant (Lophomyrmex), (c) Ground Beetle

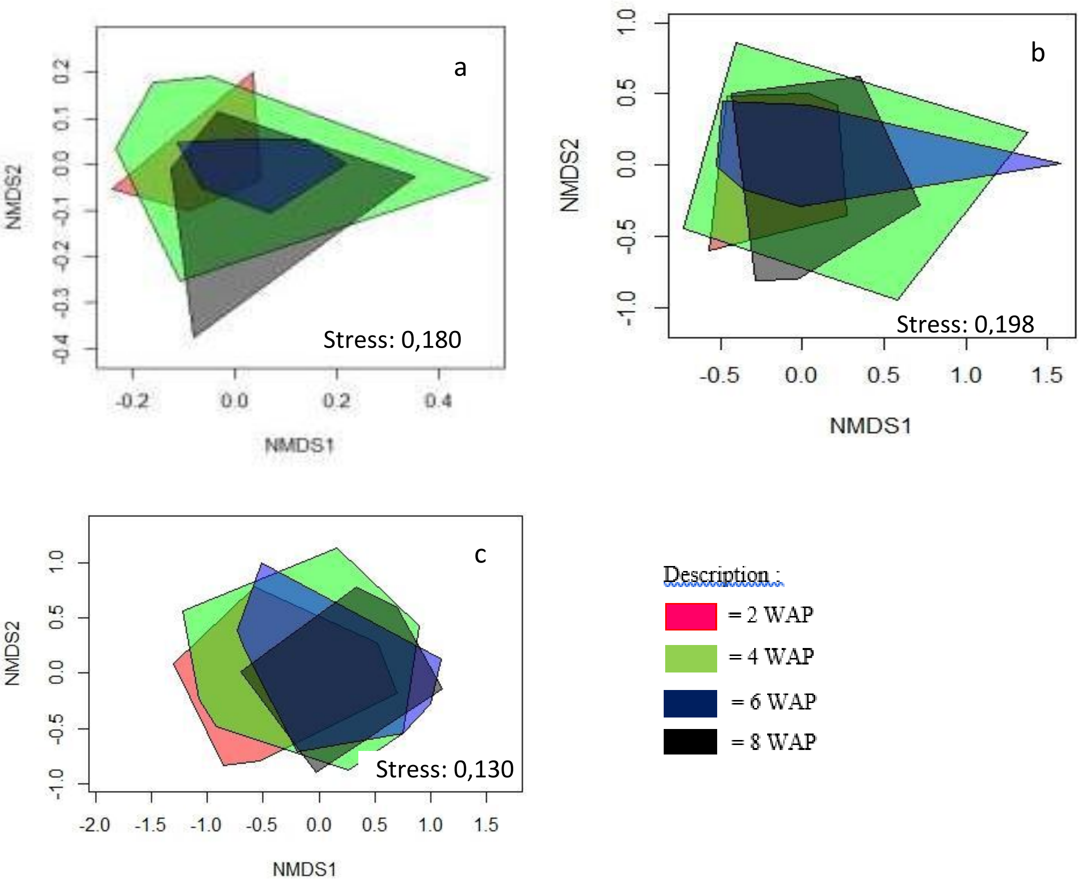

Figure 4. NMDS plot showing differences in the composition of (a) spiders, (b) ants, and (c) ground beetles based on plant age

However, it is important to note that not all predatory insects are directly affected by changes in cabbage plant age. Other factors such as environmental conditions, food availability, and interactions with other species also play a role in determining the diversity and abundance of predatory insects in cabbage feild. Although the plant canopy becomes denser as the plant age increases, affecting the microclimate, plant age does not impact spiders, ants, or ground beetles. The age of cabbage plants is also not correlated with the diversity or abundance of ants and ground beetles. This is because ants have a high

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adaptive ability, so the canopy does not significantly affect them, particularly in terms of foraging. Similarly, for ground beetles, aside from plant age, their diversity and abundance can be influenced by the high availability of prey. Additionally, vegetation diversity at each location can affect the number of predators (Najmi *et al.,* 2018). Coleoptera are among insects commonly found both in plant canopies and on the surface or in the crevices of the soil (Toly, 2019).

Relations Between Elevation and Insecticide Application on Species Diversity and Predator Individual Abundance

Based on the results of regression analysis, elevation does not correlate with species diversity and individual abundance of spiders, but it does correlate with individual abundance of ants, as well as with diversity and abundance of ground beetles. Conversely, pesticide application shows no correlation with the diversity and abundance of all observed predators (Table 5). According to Baldissera *et al.* (2008), the abundance of Araneidae is higher inside compared to the forest edge. At the forest edge, where trees are sparse and small in size, ranging from 4–7 meters tall, there are more orb-weaving spiders found at higher tree heights or their nest locations, making landscape elevation less influential on these spider species. According to Foelix (2011), the location for web-building not only requires specific microclimates but also space. Orb-weaving spiders can be found in areas with higher altitudes as they support passive hunting strategies relying on prey carried by the wind (Måsviken *et al.,* 2023).

At higher altitudes, there is a decrease in ant diversity due to changes in their ecological roles replaced by other arthropods. Temperature and air humidity can affect the distribution and development of ants in secondary forest areas. The average microclimate temperature and air humidity of 27°C and 85%, respectively, are considered suitable for ant development (Shattuck, 2000). Differences in temperature, humidity, feeding patterns, and activities significantly affect species diversity of ants. For example, climate and feeding patterns can alter the size and appearance of ants' bodies (Shattuck, 2000).

Table 5. Regression Results: Relation of Elevation and Insecticide Intensity with Species Diversity and Abundance of Predators

Variables	Spiders		Ants		Ground Beetles	
	R^2 Value	P Value	R^2 Value	P Value	R^2 Value	P Value
Species Diversity						
Elevation	0.164	0.190	0.219	0.124	0.388	0.031
Insecticide Intensity	0.042	0.521	0.061	0.880	0.197	0.147
Individual Abundance						
Elevation	0.288	0.071	0.418	0.022	0.361	0.038
Insecticide Intensity	0.107	0.297	0.019	0.668	0.145	0.222

Note: P values below 0.05 are considered significant

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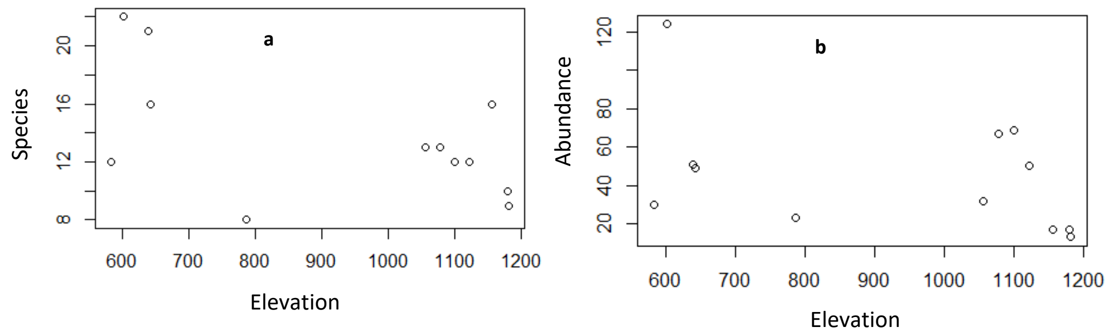

Figure 5. Regression Plot of The Relationship Between Elevation and Species Diversity (A) and Individual Abundance (B) of Spiders on Cabbage fields

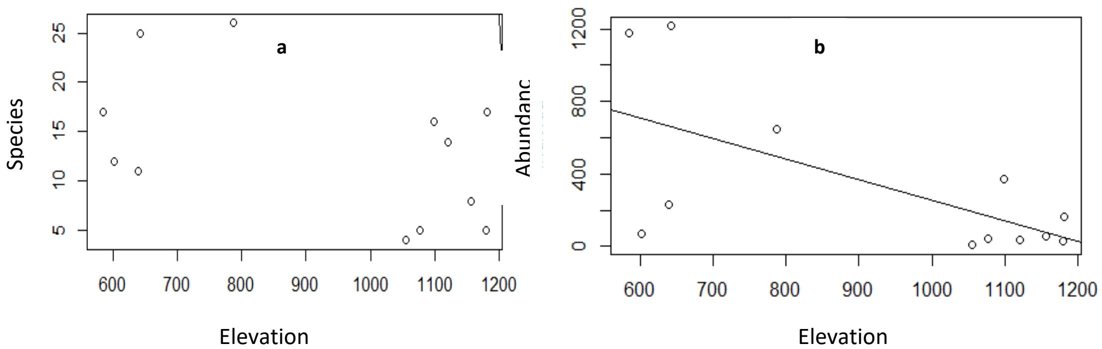

Figure 6. Regression Plot of the Relationship Between Elevation and Species Diversity (A) and Individual Abundance (B) of Ants on Cabbage Fields

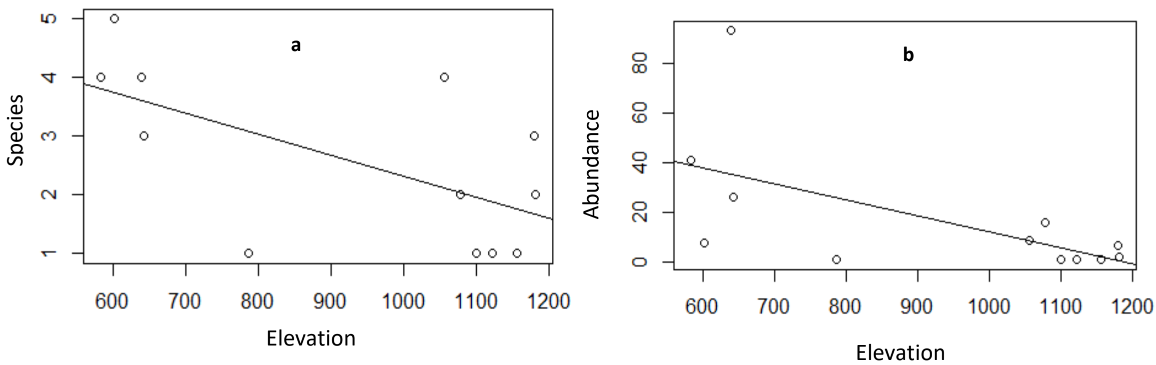

Figure 7. Regression Plot of The Relationship Between Elevation and Species Diversity (a) and Individual Abundance (b) of Ground Beetles on Cabbage Fields

As altitude increases, beetle abundance tends to decrease. The influence of elevation on beetle abundance is closely related to temperature and air humidity, which affect beetle metabolism. Higher altitudes typically have lower temperatures, higher humidity, and lower air pressure. This statement is supported by Syarkawi et al. (2015), stating that air humidity affects insect body water content, insect distribution, foraging activities, and insect life cycles. Insect life cycles tend to slow down in environments with lower temperatures, resulting in a decrease in insect populations.

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Relations of Landscape Composition at Study Locations to Ant Diversity and Abundance

Based on the results of the GLM analysis of the relationship between landscape and diversity (Table 6) and abundance of predator individuals (Table 7), it was found that NP (Number of Patches) of agricultural land correlated with the abundance of spider individuals. CA (Class Area) of agricultural land and natural habitats affected the diversity of ant species. In addition, NP of agricultural land affected the diversity and abundance of spider and ant individuals, while CA of agricultural land affected the abundance of spider and ground beetle individuals. CA of natural habitats affected all three predators studied. Habitats disturbed by human intervention, such as agricultural lands near settlements (close to human activity), like household tools and stored food, create suitable habitats for nesting and foraging for tramp ants (Rizali *et al.* 2008). The higher the level of habitat disturbance, the more likely it is to find increased ant diversity and abundance. Habitats with high disturbance intensity, such as residential areas, beaches, and parks, can only facilitate the presence of ant species that can adapt to human disturbances (Gibb & Hochuli 2003).

Table 6. Generalized Linear Model (GLM) Relating Landscape Variables and the Species Richness of Insect Predators

Variables	Spiders			Ants			Ground Beetles		
	Estimate	SE	P	Estimate	SE	P	Estimate	SE	P
Species									
NP. Agricultural Land	-0.042	0.025	0.092	-0.063	0.030	0.035	0.031	0.069	0.656
CA. Agricultural Land	0.223	0.148	0.133	-0.539	0.178	0.002	0.319	0.396	0.420
NP. Natural Habitat	-0.009	0.076	0.895	0.098	0.122	0.422	-0.159	0.176	0.365
CA. Natural Habitat	0.187	0.131	0.155	0.442	0.166	0.007	0.195	0.396	0.596

Note: P values below 0.05 are considered significant

Table 7. Generalized Linear Model (GLM) Relating Landscape Variables and the Abundance of Insect Predators

Variables	Spiders			Ants			Ground Beetles		
	Estimate	SE	P	Estimate	SE	P	Estimate	SE	P
Abundance									
NP. Agricultural Land	-0.044	0.019	0.022	-0.064	0.011	<0.001	-0.018	0.030	0.544
CA. Agricultural Land	-0.117	0.087	0.177	-0.395	0.057	<0.001	0.492	0.134	<0.001
NP. Natural Habitat	0.041	0.051	0.412	0.324	0.082	<0.001	-0.363	0.067	<0.001
CA. Natural Habitat	0,133	0,078	0,089	-0,207	0,057	<0,001	0,382	0,115	<0.001

Note: P values below 0.05 are considered significant

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CA in agricultural land has a positive correlation with the abundance of ground beetles, as the cabbage cultivation area is surrounded by other agricultural land with different vegetation such as red chili, mustard greens, corn, and carrots, where the surrounding vegetation diversity increases insect abundance. According to Duelli (2007), the greater the diversity of land cover types within a landscape, the more species are found in that landscape. Natural habitats also influence the abundance of ground beetles, as these habitats are rich in various types of vegetation that provide food and shelter. Azima et al. (2017) stated that the diversity of predatory insect species in a habitat is influenced by the complex structure of plant vegetation.

Thus, it can be concluded that most natural habitats influence the diversity and abundance of predators because natural habitats around cabbage fields play a crucial role in maintaining the balance of the local ecosystem. These areas serve as refuges for various types of wildlife, including a wide range of insects that act as pests, predators, or pollinators, contributing to environmental sustainability. The natural vegetation surrounding the cabbage fields helps reduce soil erosion, increase soil fertility through organic matter decomposition, and provide food and water sources for local fauna. Furthermore, the presence of these natural habitats can act as buffers, protecting cabbage crops from pest attacks by attracting natural predators that control pest populations. Therefore, maintaining natural habitats around cabbage fields not only supports biodiversity but also enhances sustainable agricultural productivity.

Conclusion and suggestion

Habitat conditions, particularly plant age, do not significantly influence the diversity and abundance of predatory insects, and cultivation methods, such as the application of insecticides, appear to have no effect on the three predator types observed. However, altitude is positively correlated with ant abundance as well as the diversity and abundance of ground beetles. Regarding landscape factors, the NP of agricultural land is associated with spider diversity. Meanwhile, the CA of both agricultural land and natural habitats significantly impacts ant species diversity and correlates with ground beetle abundance. Furthermore, the abundance of ants, spiders, and ground beetles is linked to all studied landscapes, indicating that both agricultural lands and natural habitats play a crucial role in shaping predator populations. This suggests that landscape composition and elevation are critical factors in maintaining the ecological balance and predator biodiversity in these environments.

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