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Grasshopper diversity in several agricultural areas and savannas in Dompu, Sumbawa Island, Indonesia

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Abstract. *Leksono AS, Yanuwiadi B, Khotimah A, Zairina A. 2021. Grasshopper diversity in several agricultural areas and savannas in Dompu, Sumbawa Island, Indonesia. Biodiversitas 23: 75-80.* In Sumbawa Island, the conversion of forests and savannahs into agricultural land has increased rapidly since 2010. This research aims to compare grasshopper species' abundance, richness, and diversity between several farmland and savannas in Dompu, Sumbawa Island. It was conducted at ten locations in Dompu, Sumbawa Island, and included an ecotone, two post-harvested rice farms, two post-harvested corn farms, a mixed farm, a vegetable farm, and three savannas. Furthermore, samples were taken four times from four plots at each location in the post-harvest period from August to September 2021. Grasshopper sampling was carried out using the sweeping method with an insect net with each plot size of 2 x 10 m^2. A total of 2264 individual grasshoppers belonging to 26 species and four families were collected from all research sites. The dominant species were *Alloteratura* sp., *Trilophidia annulata*, *Atractomorpha crenulata*, *Phlaeoba fumosa*, *Oxya japonica* and, *Phlaeoba infumata*. The greatest grasshopper species richness and diversity were found in post-harvest rice farms, while the lowest was in the vegetable farm, and most of these species are considered pests. This research shows that the composition of grasshoppers on agricultural land is very similar to that of the adjacent savannah. Hence, monitoring and controlling their presence is necessary by paying attention to savannas as refuge land.

Keywords: Agricultural land, *Alloteratura*, *Atractomorpha crenulata*, Orthoptera, *Trilophidia annulata*

INTRODUCTION

Indonesia is one of the megadiverse countries with diverse animal and plant species. Three out of the seventeen world's mega-diversity countries, Indonesia, Malaysia, and the Philippines, are characterized by high biodiversity and endemism (Kier et al. 2009). The great species richness and diversity in Indonesia is due to its geographical position, located in the border of two important geographical zones in the world, namely the Orientalia zone and the Australian zone, and a large number of islands (Lohman et al. 2011).

Arthropoda contributes to great species diversity. Indonesia is estimated to have over 150,000 species of arthropods, but the actual number of species remains unknown. Arthropods are biotic components that play an important role in the ecosystem (Culliney 2013). Moreover, they contribute to pivotal life processes because these animals are part of most terrestrial food webs. Therefore, the performance of a healthy community is strongly supported by the preservation of arthropods (Mattson 2012).

Southeast Asia is also rich in orthopterans such as grasshoppers (Tan et al. 2017a). Apart from the incomplete understanding of the diversity of orthopedics in Southeast Asia (Tan et al. 2017a), there is a pressing need to examine the ecology of orthoptera in Southeast Asia. Orthoptera (grasshoppers, crickets, and katydids) belong to the largest terrestrial insects group, comprising more than 27,000 described species (Cigliano et al. 2017). Grasshoppers are also important bioindicators among herbivores due to their specific habitat preferences and their sensitivity to changes in their habitat (Cigliano et al. 2011). They play an important role in maintaining the balance of the agroforestry ecosystem. However, some grasshopper species are agricultural pests, leaf eaters, and a small part act as the predators of other insects.

In Indonesia, the group of this species is widespread and widely recognized as pests. In the city of Lampung and Sumba, the Migratory locust (*Locusta migratoria manilensis*) is known in the local community for destroying crops (Lassa 2017). Grasshoppers, as potential pests, can destroy many types of crops, hence it is necessary to record their biodiversity and activities. Several studies on aspects of grasshopper diversity and abundance have been conducted. Sirin et al. (2010) examined the diversity and abundance of grasshopper species concerning altitude. The result showed the greatest species diversity and abundance at medium and low, high and low altitudes. Meanwhile, Prakoso (2017) examined grasshoppers in agroecosystems of corn and forest stand ecosystems. The research found seven grasshopper species belonging to Tetrigidae, Acrididae, and Pyrgomorphidae consisting of *Gesonula mundata* (Small Lao rice grasshopper), *Oxya hyla* (Rice grasshopper), *Valanga nigricornis* (the Javanese grasshopper), *Criotettix robustus* (ground-hoppers), *Miramella alpina* (Green mountain grasshopper), *Hesperotettix viridis* (The snakeweed grasshopper) and *Atractomorpha crenulata* (The tobacco grasshopper).

In Sumbawa Island, the conversion of forests and savannahs into agricultural land has increased rapidly since 2010 due to the high demand for corn. Research conducted in savannah and extensive cultivation areas shows the importance of agricultural landscape management. A mosaic-like agricultural landscape with savannah areas and extensively managed ruderal areas may preserve the high biodiversity of grasshoppers. However, such mosaic effectiveness strongly depends on extensive agricultural management practices that retain significant amounts of herbaceous growth throughout the year (Kuppler 2015). Research on grasshopper potential as a pest in several post-harvest agricultural lands and savanna may provide an overview of the potential of the area around agricultural land as a refuge area, consequently, control measures can be carried out wisely. However, none of these studies were specifically conducted in several spots in Dompu Sumbawa Island. This research aims to analyze variations in the abundance, richness, and diversity of grasshopper species among several farmland and savannas in Dompu Sumbawa Island.

MATERIALS AND METHODS

This research was conducted in ten locations in Dompu, West Nusa Tenggara, Sumbawa Island, consisted of Note: ECT (Ecotone), MIX (Mixed farm of *Carica papaya* (papaya) and *Zingiber officinale* (ginger)), PCF1 (Post-harvest corn farm 1), PCF2 (Post-harvest corn farm 2), PRF1 (Post-harvest rice farm 1), PRF2 (Post-harvest rice farm 2), SAV1 (Savana location 1), SAV2 (Savana location 2), SAV3 (Savana location 3), VEG (Vegetable farm) (Figure 1). A more detailed description of the locations is portrayed in Table 1. In each location, samples were taken four times from four plots at each location during a post-harvest season from August to September 2021.

The grasshopper sampling was carried out using the sweeping method with an insect flying net with a diameter of 25 cm. The quadrat method, which consists of a predefined sampling surface, was adopted to collect grasshoppers each with a size of 2 x 10 m^2. The samplings were conducted in the morning from 8 a.m. to 11 a.m. under sunny skies and light winds. At each plot, the sampling period took 30-40 minutes. Three groups of field collectors consisted of two persons in each location involved in the sampling to ensure the collection on the same day.

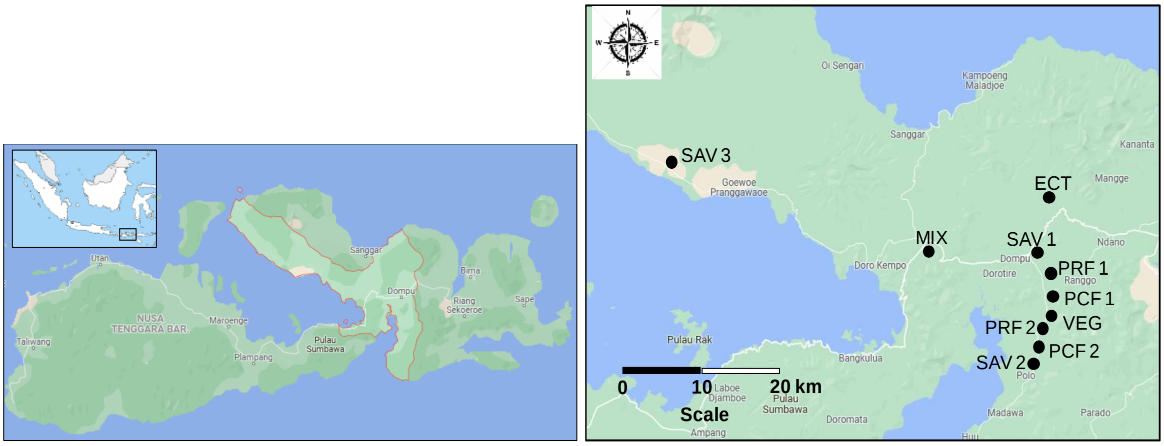

Figure 1. Location of ten research sites in Dompu (Sumbawa Island), West Nusa Tengara, Indonesia. Note: ECT: Ecotone; MIX: Mixed farm of *Carica papaya* (papaya) and *Zingiber officinale* (ginger); PCF1: Post-harvest corn farm 1; PCF2: Post-harvest corn farm 2; PRF1: Post-harvest rice farm 1; PRF2: Post-harvest rice farm 2; SAV1: Savana location 1; SAV2: Savana location 2; SAV3: Savana location 3; VEG: Vegetable farm

Table 1. Description of research site

Location	Abbr.	Description
Ecotone	ECT	Ecotone located between a ricefield land and a stream, dominated by small grass
Mixed farm of papaya and ginger	MIX	A mixed land composed of *Carica papaya* (papaya) and *Zingiber officinale* (ginger)
Post-harvest corn farm 1	PCF1	A post corn farm is dominated by medium grass
Post-harvest corn farm 2	PCF2	A post corn farm is dominated by medium grass
Post-harvest rice farm 1	PRF1	A post rice farm is dominated by medium grass
Post-harvest rice farm 2	PRF2	A post rice farm is dominated by medium grass
Savana location 1	SAV1	A savanna is dominated by cogon grass
Savana location 2	SAV2	A savanna is dominated by cogon grass
Savana location 3	SAV3	A savanna is dominated by cogon grass
Vegetable farm	VEG	A vegetable farm is composed of Brassicaceae (cabbage and mustard)

The obtained grasshopper specimens were put in bottles filled with 70% ethanol. The specimens identification was carried out at the Laboratory of Animal Diversity, Department of Biology, Faculty of Mathematics and Natural Sciences, Brawijaya University. The specimens were sorted, dried, and then pinned before being identified at the species level. Small specimens were kept in alcohol, while the large ones were stored in an insectarium. The grasshopper specimens were identified based on several identification books (Johnson 2008; Tan 2012; Tan 2017).

The abundance, species richness, and diversity data were analyzed descriptively. Species diversity was analyzed using the Shannon Wiener index (diversity analysis). Similarities in composition between the research site were analyzed using the Bray-Curtis index. Differences between locations were tested by one-way analysis of variance. The results of the data normality test using the Kolmogorov-Smirnov analysis showed that the abundance and diversity data were normally distributed, hence the ANOVA tests were performed, while the species richness data were not normally distributed. After the transformation of the species richness data, further tests indicated the data remained abnormally distributed. Therefore, the test for species richness differences between locations was carried out using a non-parametric test with the Kruskal-Wallis analysis. The posthoc test for parametric analysis by ANOVA was carried out by LSD tests, while that for non-parametric tests was carried out by the Mann-Whitney test. Statistical tests were performed using Excel and SPSS® version 20 (SPSS Inc. Chicago, IL, USA).

RESULTS AND DISCUSSION

A total of 2264 individual grasshoppers of 26 species and four families were collected from all research sites. The dominant species were *Alloteratura* sp. (Bush crickets) (16.48%), *Trilophidia annulata* (band-winged grasshopper) (15.55%), *Atractomorpha crenulata* (Tobacco grasshopper) (10.07%), *Phlaeoba fumosa* (Brown grasshopper) (9.14%), *Oxya japonica* (the Japanese grasshopper) (8.16%) and *Phlaeoba infumata* (silent slant-faced grasshopper) (7.60%) (Table 1). All dominant species demonstrated a significant abundance between different sites. *Alloteratura* sp. was found abundantly in a mixed farm, post-harvested corn farm 1 and savanna 3. *T. annulata* was found abundantly in post-harvest corn farm 1 and savanna 3. The *A. crenulata*, *P. fumosa*, and *P. infumata* were also found abundantly in post-harvest corn farms 1.

Table 1. Number of individual grasshopper species among ten research sites

Species	ECT	MIX	PCF1	PCF2	PRF1	PRF2	SAV1	SAV2	SAV3	VEG	Total	%
Alloteratura sp.	0	60	235	15	0	10	0	53	0	0	373	16.48
Trilophidia annulata	17	0	117	15	23	9	41	9	113	8	352	15.55
Atractomorpha crenulata	20	42	50	21	24	24	26	21	0	0	228	10.07
Phlaeoba fumosa	16	0	78	25	21	17	24	21	0	5	207	9.14
Oxya japonica	0	0	54	7	38	26	24	10	0	14	173	7.64
Phlaeoba infumata	0	60	67	23	0	15	0	0	0	7	172	7.60
Conocephalus maculatus	38	0	0	10	0	0	0	0	76	0	124	5.48
Valanga nigricornis	2	10	0	10	0	3	29	0	12	42	108	4.77
Eritettix sp.	0	0	0	7	0	0	0	0	79	0	86	3.80
Tetrix japonica	0	81	0	0	0	0	0	0	0	0	81	3.58
Oxya chinensis	3	45	0	0	0	0	0	0	0	0	48	2.12
Tettigidea lateralis	0	0	0	0	0	0	0	0	45	0	45	1.99
Locusta migratoria	0	0	18	5	0	3	0	0	0	15	41	1.81
Phaesticus insularis	0	0	34	0	0	0	0	0	0	0	34	1.50
Phlaeoba antenna	0	0	30	0	0	0	0	0	0	0	30	1.33
Oxya hyla	0	0	0	14	0	12	0	0	0	0	26	1.15
Achurum carinatum	0	0	0	0	10	0	15	0	0	0	25	1.10
Gesonula mudata	4	0	0	1	0	0	0	17	0	1	23	1.02
Stenocatantops splendens	0	0	0	12	0	1	0	7	0	0	20	0.88
Atractomorpha similis	6	0	0	0	0	5	0	4	0	0	15	0.66
Acrida turrita	2	0	0	0	7	0	2	0	0	0	11	0.49
Apalacris varicornis	0	0	0	0	0	0	0	7	0	0	7	0.31
Euparatettix sp.	0	0	0	0	0	0	7	0	0	0	7	0.31
Euconocephalus sp.	0	0	0	3	0	0	0	3	0	0	6	0.27
Phaneroptera elongata	0	0	0	4	0	0	0	2	0	0	6	0.27
Pseudorhynchus lessonii	0	0	0	6	0	0	0	0	0	0	6	0.27
Grand Total	108	298	683	179	123	127	168	161	325	92	2264	100.00

Note: ECT: Ecotone; MIX: Mixed farm of *Carica papaya* (papaya) and *Zingiber officinale* (ginger); PCF1: Post-harvest corn farm 1; PCF2: Post-harvest corn farm 2; PRF1: Post-harvest rice farm 1, PRF2: Post-harvest rice farm 2; SAV1: Savana location 1; SAV2: Savana location 2; SAV3: Savana location 3; VEG: Vegetable farm

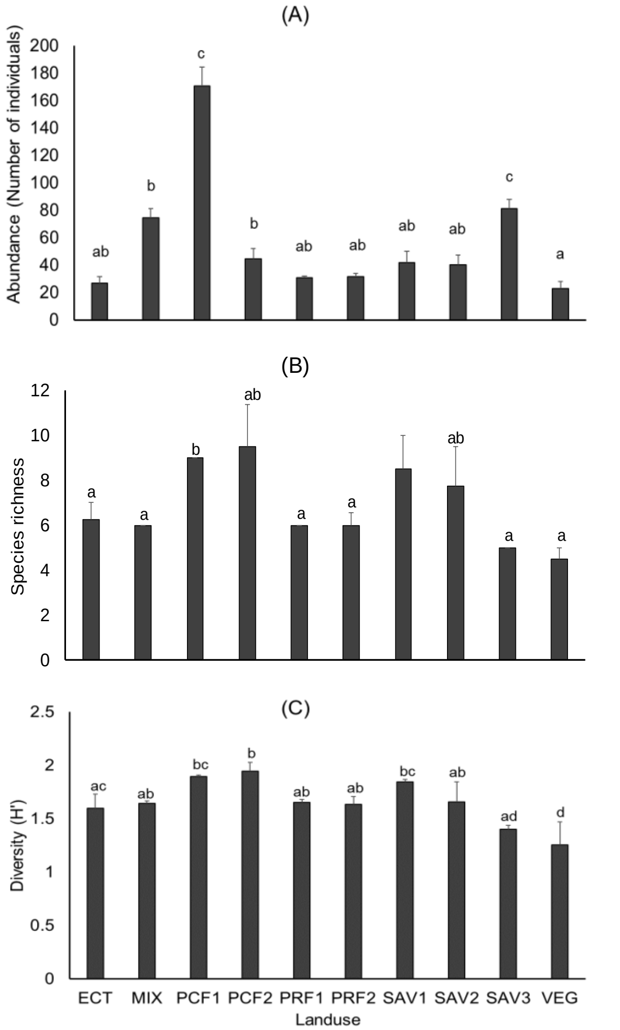

Figure 2. The grasshopper abundance (A), species richness (B), and diversity (C) variation of; among ten research sites in Dompu Sumbawa; the different alphabet above the error bars indicate the significant difference in the mean

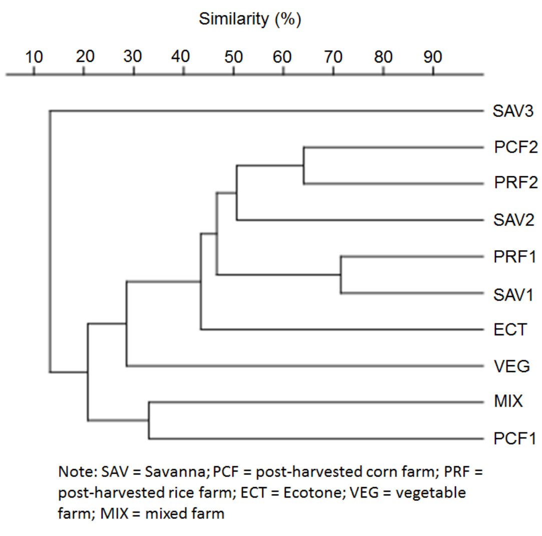

Figure 3. The similarity of grasshopper compositions among research sites

Out of the ten research sites, the abundance of grasshoppers in post-harvest rice farms 1 (170.75 ± 13.63) was the highest, while that in the vegetable farm was the lowest (23 ± 4.90). The results of statistical analysis showed that the differences in grasshopper abundance between locations were significant (F = 40.43; P < 0.001), the posthoc test results are shown in the graph (Figure 2A). The greatest grasshopper species richness was found in post-harvest rice farm 1 (9.50 ± 1.89), while the lowest was found in vegetable fam (4.50 ± 0.50). The results of statistical analysis showed that the differences in the grasshopper richness species among locations were significant (Chi-square = 30.11; P < 0.001), the results of the posthoc test were shown in the graph (Figure 2B). The same result was obtained in terms of species diversity. The greatest grasshopper species diversity was found in post-harvest rice farm 1 (1.95 ± 0.08), while the lowest was in vegetable fam (H' = 1.25 ± 0.22). The results of statistical analysis showed that the differences in grasshopper species diversity between locations were significant (F = 40.43 .91; P < 0.01), posthoc test results were shown in the graph (Figure 2.C).

The results of the locust composition similarity test between research areas showed that the degree of similarity in composition between communities ranged in the medium to low range of 20-75 percent. The highest similarity of composition was found in the grasshopper community in PRF 1, savanna 1, which was 71.5%. The ten communities formed two main clusters. The first cluster comprises grasshoppers from PCF2, PRF2, savanna 2, PRF1, savanna 1, ecotone, and vegetable land. The second cluster comprises only two communities in mixed land and PCF1. The composition in savanna three was considered as an outgroup. Internally, group one can be further divided into two sub-groups consisting of the first sub-group consisting of PCF2, PRF2, and savanna 2, while sub-group 2 consists of PRF1 and savanna 1.

Discussion

Alloteratura sp., *T. annulata*, *A. crenulata*, *P. fumosa*, *O. japonica* and, *P. infumata* were among the most abundant species in this research. Most of these grasshoppers are widespread and highly adapted to environmental changes. Dominant grasshopper species are characterized by highly mobile generalists that tolerate changed landscapes and are mostly geographically widespread (Adu-Acheampong and Samways 2019). Among the species, *O. japonica*, *A. crenulata*, and *Phlaeoba infumata* are common in Asia. Adults and their nymphs are serious pests of economically important grasses, and various crops include rice, millet, sugarcane, maize, wheat, and cabbage (Hassan 2014; Singh 2015). Previous research conducted in Malang East Java showed a similar result due to the great abundance of several species, including *Alloteratura* sp., *P. fumosa*, *A. crenulata*, and *O. japonica*. These species were dominant in several land uses, including agricultural land (Leksono et al. 2020). Research in Baturaden, Central Java, showed that three dominant species, *Hesperotettix viridis*, *G. mundata*, and *O. hyla* were included. The other species such as *G.*

mundata, *O. hyla*, and *V. nigricornis* are common in the corn agroecosystems (*Zea mays*), while *Criotettix robustus*, *M. alpina*, *H. viridis pratensis*, and *A. crenulata* are species in plantation forest ecosystems (Prakoso 2017). Another study in Mount Ciremai National Park reported that the dominant species include *Gesonia* sp., *P. rustica* and *Caryanda spuria* (short-horned grasshopper), while *O. cinensis* (Chinese rice grasshopper) and *Oxya* sp. were found in a few individuals.

Research in Punjab, Pakistan showed the abundance of three grasshopper species, including *O. hyla*, *O. japonica*, and *Hieroglyphus banian* (Bluish-green rice grasshopper) (Hussain et al. 2017). Highly abundant *O. hyla*, *Tetrix* sp., *Calliptamus* sp., *Trilophidia* sp. and *H. banian* were also reported in South Gujarat, India (Thakkar et al. 2015). These species are common in rice fields and are regularly observed eating rice leaves; hence these grasshoppers are severe rice pests (Akhtar et al. 2012; Ane and Hussain 2015). Species of the subfamily Oxyinae and Hieroglyphinae such as *Acrida exaltata* (*Belalang menara*), *O. hyla,* and *Acrida gigantea* (*Belalang menara besar*) were reported as significant pests of the paddy crop. Meanwhile, the large-sized grasshoppers such as *Hieroglyphus* sp. *Choreodocus* sp., *L. migratoria*, and *Gastrimargus africanus* (The common yellow-winged grasshopper chidyamamina) are usually found in large grasses or in bushes near agricultural and non-agricultural areas, which were less disturbed by humans. They mainly damage leaves by chewing angular holes with their mandibles (Sultana et al. 2019). The *O. nitidula* and *Acrida* sp. are reported to be pests of vegetables in East Uttar Prades, India (Yadaf et al. 2015).

The *T. annulata* is geographically widespread over a steep climate gradient from the cold and temperate north region to the tropical climate of southern China. These distributions provide the opportunity to examine the influence of the environmental clines on intraspecific morphological variation. The genus *Trilophidia* comprises five species, whose habitats include saturated grasslands, grassland savannas, irrigated areas, and sparse vegetation areas, which are largely restricted to the Ethiopian and Oriental Regions. Out of these five species, *T. annulata* is the only widespread species distributed over the Oriental Region from West Pakistan to North Borneo and the Palearctic Region of Mongolia, China, Korea, and Japan (Bai et al. 2016).

In this research, *V. nigricornis* were found in several locations, including savannas and a vegetable farm where Brassicaceae was cultivated. During the investigation of the insect diversity on watermelon (*Citrullus lanatus*) conducted in Cilacap, Central Java, a high abundance of *A. crenulata* and *V. nigricornis* was found. In India and Malaysia, these species were identified as pests (Lee 2013; Singh 2015).

This research showed that there was a relationship between cultivated land and savanna, as shown by the level of community similarity between locations. During the post-harvest, the grasshopper community of the savannah belongs to the same group as that of the rice or maize farms. The similarity analysis shows that all species in post-harvested rice field one are found in savanna 1, nine out of the 11 species in post-harvested rice field two are found in savanna 2. In contrast, eight of 17 species from post-harvested corn farms two are found in savanna 2. This indicates the role of the savanna as a refuge area when their main food is unavailable. Therefore, this research suggests that farmers must pay attention to species that act as pests, attacking crops.

Several recommendations can be made to farmers. First, the manipulation of the soil environment by increasing the Nitrogen content of the soil. This is supported by previous research in the agricultural region of West-Central Senegal. Land use is influenced by the abundance and distribution of grasshoppers, especially *Oedaleus senegalensis*, likely through soil-plant interactions. The *O. senegalensis* abundance was negatively correlated with plant Nitrogen (Word et al. 2019) because this species prefers low Nitrogen environments (Cease et al. 2015). Second, increasing crop diversity through a mixed planting system. This research shows the low similarity in the composition of a grasshopper on soils of mixed plants with their compositions in other locations. Subsequently, the abundance and diversity of mixed planting grasshoppers are low. Another research reported that high crop diversity could significantly suppress damage of oligophagous pests such as cereal aphids, rice stem borers, and corn borers while having no effects on polyphagous pests such as cotton bollworms and armyworms (Sheng et al. 2017). Third, maintain the presence of natural enemies such as praying mantis. This research reported the presence of *Hierodula patellifera* and *H. vitrea* (praying mantis) in a small population in the savanna (SAV 3). Efforts to preserve the natural enemies of grasshoppers are pivotal activities.

The abundance and species diversity of grasshoppers varied depending on land use. The abundance of grasshoppers in post-harvest rice farm 1 was the highest, while it was lowest in the vegetable farm. The highest grasshopper species richness and diversity were found in post-harvest rice farm 1, while the lowest was found in the vegetable farm. Subsequently, there was a moderate similarity between the grasshopper compositions in post-harvested rice and corn farmlands with those in savannas, indicating the role of the savanna as the refuge area.

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