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The Effect of Organic Biomass Application to Diversity of Detritus Arthropods and Natural Enemies in Rice Field

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Abstract. The aims of this research are to describe the effect of adding organic biomass (which are Azolla, straw and organic fertilizer) to the diversity of detritus arthropods and natural enemies, and to analyze the dissimilarity of habitat in each treatment's field and to define the improvement of agro-ecosystem toward treatments. Fieldwork was conducted in Watugede of Singosari, Malang regency. Four area of rice field is chosen from an overlay as the site for each treatment. We used both direct sampling and baiting to collect arthropods. For baiting, pitfall trap was used. For direct sampling, we taken soil samples then placed in berlesse-tullgren funnel. Data converted to α and β diversity. Analysis of variance was used to ensure any improvement between habitats. The results show that adding certain biomass at the beginning of the agricultural system will enhance population and diversity of detritus arthropods. It's also enhancing natural enemy's diversity. Adding organic fertilizer has the biggest impact. There was an improvement of habitat in the treatments fields. The improvement comes from the higher possibility to gain ecological services. Adding biomass also enhances agro-ecosystem health according to the occurrence of richness-dominance covariance.

INTRODUCTION

Maintaining biodiversity is important to gain ecological services[1](Altieri & Nicholls, 2012). Ecological services in agricultural production system consist of pest control, pollination and nutrient cycle. The diversity contributes to the efficient use of natural resources[1] (Nicholls & Altieri, 2012). In the other hand, reduced diversity in agro-ecosystem caused an increasing need of human intervention. It means that the decreasing of biodiversity caused a huge dependency in external input and less efficient [1](Altieri & Nicholls, 2012).

In many cases, simplicity of arthropod's diversity in an agro-ecosystem tends to trigger pest outbreak[2] (Altieri, Nicholls, & Ponti, 2009). Monoculture allows the greater chance for the development of invasive species[3] (Garcia & Altieri, 2005). It has been happened frequently since the policy of agriculture intensification applied. Even now, the more intense of pesticide usage is needed, in order to anticipate the occurrence of pest resistance [4](Bottrell & Schoenly, 2012). The intensive pest control effort has been in-effective in minimizing crop loss[5](Maisyaroh, Yanuwiadi, Setyoleksono, & PG, 2014).

Monoculture is recommended by government policy in rice agricultural system. As the main food in Indonesia, plant rotation strategy has been discouraged. Then, there is a poor diversity either over space or time. The simplicity of agro-ecosystem leads to the lack of the ecological services. It makes rice agricultural system less efficient. It will be depend on more and more need of external input[6] (Barrett, Travis, & Dasgupta, 2011).

A good quality of agro-ecosystem could be adaptive from any challenge including pest problem. Indicator of a good quality agro-ecosystem is the higher diversity and the lower chemical input[7] (Luo, Fu, & Traore, 2014). The first step to gain a good quality of agro-ecosystem, is choosing farming methods that less favorable for pest invasion. The second is emphasizing the use of local resources and minimizing external inputs such as inorganic fertilizer and chemical pesticides. Also, the third step is enriching the soil by composting, mulching or adding animal manure[8] (Dreves, 1996). Enrich the soil with organic matter will generate micro-habitat supporting the life of various soil organism[9] (Zayadi, Hakim, & Setyoleksono, 2013).

Since there's limited option to increase diversity in a rice field, enhancing functional diversity from organic soil management aspect is the most reasonable way[1] (Altieri & Nicholls, 2012). It could be done by adding organic matter in to the field. Application of organic matter or biomass will manipulate detritus food web. As it will providing the energy source for the detritus species and so increasing diversity. The increasing of detritus diversity will boost the diversity of generalist predator[10] (Cahyana, Hakim, & Hindayana, 1996). Detritus will subsidize food for predator especially at the earlier of rice stage[11] (Zhang, Zheng, Jian, Qin, & Yuan, 2013). So, the diversity increases naturally based on nutrition flow from bottom to the top of the food web.

The enhancement of detritus species richness will also amplify its role on soil physic regulation. Detritus activity will improve soil porosity and so provide aeration. The activities also boost the mixing between organic and mineral fraction of the soil, and make mineral available for the plant. Even its feces contribute in humus formation, which is physically stabilize the soil and increase its capacity to store nutrient[12] (Culliney, 2013)

It seems important to provide any cultural option in order to enhance detritus population in the soil. The option must be based on the resources availability and also economically reasonable[13](Crowder, Northfield, Strand, & Snyder, 2010). Straw is a potential local resource. It's available in every agricultural cycle. In fact, local farmers used to burn the straw. This treatment is contra-productive towards soil arthropods diversity[14] (Eni, Andem, Oku, Umoh, & Ajah, 2014). The next local resource is *Azolla pinata*, a plant species which spread rapidly in the wet rice field. Also, its debris has a high nitrogen compound. The other option is animal manure fermented into organic fertilizer. It provides not only rich nutrient but at the same time it will fix the soil physic.

Here we compare the effect of three kinds of biomass to the occurrence of detritus and natural enemy. We'll see if any changes in their diversity. We assumed that enrich the soil will make a favorable environment for detritus organism. Since detritus play the role as substitution energy source for predator's[11] (Zhang et al., 2013), it's interesting to figure out the effect on population and diversity of predators species. The study of diversity effect to the preparation of ecological services in agro-ecosystem also presented. Hopefully, it will encourage the application of detritus conservation at farmer's level.

The objectives of research are to define (1) Effect of adding certain biomass (Azolla, straw and organic fertilizer) to detritus and natural enemies diversity, (2) Dissimilarity of habitat toward each treatment and (3)The improvement of agro-ecosystem in treatment field compared by farmer's field

EXPERIMENTAL DETAILS

Study sites

Fieldwork was conducted in rice field overlay in Watugede of Singosari district, Malang regency. This overlay was 58 acres at 450 m above sea level. The research was done in the rainy season in January until April 2016. Four area of rice fields are chosen from an overlay as the site for each treatment. Each site has the similar size, range from 130 m^2 up to 150 m^2. Each site was disconnected in water irrigation. It's also separated each other, either by a pathway or another field area.

Biomass application

Straw applied shortly after harvesting process. It's already chopped by harvest machine then spread in the whole treatment area. We used all straw from the area itself. Azolla added after the first tillage. Two week period is taken before the second tillage, so Azolla could spread over the field. Even though some population will be destructed as long as the second tillage activities, but some more is still remain in the field. For the early infestation, there was 5 kg Azolla starter applied.

The next treatment is the application of organic fertilizer for an amount of 200 kg. It also applied after the first tillage. All the treatments field named as +Azolla, +Straw and +OF (organic fertilizer). All of it will be compares to non-treatment fields named as farmer's way.

Agricultural Techniques

All the techniques used by local farmer applied in the treatment field, including choosing varieties, day old transplanting, watering and fertilizing. We avoid the using of pesticide to maximize data of arthropods population.

Sample Collection and Identification

We used both direct sampling and baiting to collect arthropods. For baiting, pitfall trap was used. Pitfall trap placed in five plots on every site. The plots are 30 cm x 30 cm area in the field takes along the diagonal line across the site. Pitfall traps was a 15 cm in diameter and 20 cm height plastic's tube. Almost 1/3 of the tube filled with soap solution as arthropod's trap. There was no water intake to the field at the day the pitfall placed. The trap is placed 24 hours before it will be taken for observation.

For direct sampling, five plots (30 x 30cm) were taken randomly at least 5m from the edge in order to reduce edge effects. In each plot, there are three sub-plots where the soil sample taken with soil corer (15 cm depth and 10 cm in diameter). The three soil samples represent 1 plot placed in berlesse tullgren funnel for 2 x 24 hours in 15 watt bulb lamp.

Sampling was begun at 7 days after transplanting (DAT) in two weeks intervals. During plant session, there were 8 observations. All specimens were stored in 70% ethanol and were identified to morpho-species using a stereo microscope and using an introduction to the study of insect (Borror, Triplehorn, & Johnson, 1992) as identification guidance.

Data Analysis

To understand whether any change in agro-ecosystem toward biomass added, we used α and β diversity approach. Diversity within habitat measurement consists of the heterogeneity index by Shannon-wiener, index of dominance by Simpson, species richness by Margalef and evenness from Shannon. To ensure any improvement between habitats, we used analysis of variance (ANOVA) and further tested by least significance differences (LSD). Meanwhile, in describing β diversity, we use Whittaker formula. We also use one of agro-ecosystem health assessment method declared by Magurran (2003), which is called dominance shifts analysis. All data analysis was performed using SPSS 20.

RESULT AND DISCUSSION

Abundance of Arthropods

A total of 4,518 individuals were identified as belonging to 89 morpho-species of arthropods in 6 class-es, 10 orders, and 47 families. All individuals collected then determined each of its roles, whether if it's phytophagous, detritus or predator/parasitoid using an Introduction to the study of Insect by Borror (1992) as guidance. The list of families and species of arthropods is shown in Table 1.

Table 1. The Taxa of Detritus and Natural Enemies Found in Each Treatment Field

Class/ Order	+ Azolla		+ Straw		+ OF		Farmer's way	
	Fam	sps	Fam	sps	Fam	sps	Fam	sps

Detritus								
Clitellata								
Haplotaxida	1	1	1	1	1	1	1	1
Collembolla								
Entomobryomorpha	2	2	1	1	2	3	1	1
Poduromorpha	2	2	1	1	2	2	1	1
Symphypleona	1	1	1	1	1	1	1	1
Gastropode								
Ampullarioidea	1	1	1	1	1	1	1	1
Insecta								
Coleopteran	5	6	4	4	5	6	3	3
Diplura	1	1	-	-	1	1	-	-
Diptera	3	3	3	3	4	4	3	3
Hymenoptera	1	1	1	1	1	1	1	1
Isoptera	-	-	1	1	-	-	1	1
Sub total	17	18	14	14	18	20	13	13
Predator								
Arachnida								
Araneae	4	4	4	4	4	4	4	4
Araneida	1	1	2	2	1	1	1	1
Opiliones	1	1	1	1	2	2	1	1
Chilopoda								
Geophilomorpha	1	1	1	1	1	1	1	1
Insecta								
Coleopteran	4	4	3	3	4	4	2	2
Dermaptera	1	1	1	1	1	1	1	1
Hemiptera	2	2	4	4	4	4	3	3
Hymenoptera	1	3	1	3	1	4	1	3
Odonata	1	1	1	1	1	1	1	1
Orthoptera	2	3	3	4	1	3	2	3
Sub total	18	21	21	24	20	25	17	20
Parasitoid								
Insecta								
Diptera	1	1	-	-	-	-	-	-
Hymenoptera	6	8	9	11	7	9	7	9
Sub total	7	9	9	11	7	9	7	9

The most suitable habitat for the abundance of detrivore family is in +OF field. Coleopteran has the highest number of family. The six families found are Carabidae, Curculionidae, Hydrophilidae, Staphylinidae , and Tenebrionoidae. All the families were known as debris feeder. Meanwhile in the predator sides, +O.F. also got the most number of families. The Coleopteran, Hemipteran, and Araneae share the same number of family. Coleopteran order consists of Carabicae, Coccinelidae, Scidmaenidae and Staphylinidae families. Families of Hemipteran order are Geriidae, Mesoviilidae, Miridae, and Veliidae. The Araneae order contains families like Araneidae, Lyniphiidae, Oxyopidae, Salticidae and Tetragnathidae. The most common parasitoid is from Hymenopteran order. The highest number families identified in +Straw. Nine families are identified as Braconidae, Bethylidae, Chalcidae, Elasmidae, Eulophidae, Ichneumonidae, Sceleonidae, Trichogrammatidae, and Vespiidae.

Total individual detritus species collected from all tools are vary from 634 in farmer's way to 985 in +Azolla (Fig. 1). It looks like biomass could enhance the detrivore population. As it's known that organic matter will boost detritus population (Cahyana et al., 1996). But, we found that is in the predator side, there's no obvious evidence. Despite showing the higher number of predator compares to farmer field, +Azolla becomes the lowest.

It happened also in parasitoid individual number. There was a huge population of the parasitoid in farmers field mostly contains *Opius* sp., *Cotesia* sp. and *Goniozus* sp. It found mostly in 7 and 35 DAT, or during vegetative phase of the plant. It happened again in 77 DAT during generative phase (Fig. 2). *Cotesia* sp. and *Goniozus* sp. were known as parasitoids of rice leaf-roller (*Cnapalocrosis medinalis*), meanwhile *Opius* sp. play role as rice flies (*Orseolia oryzae*) larvae parasitoid.

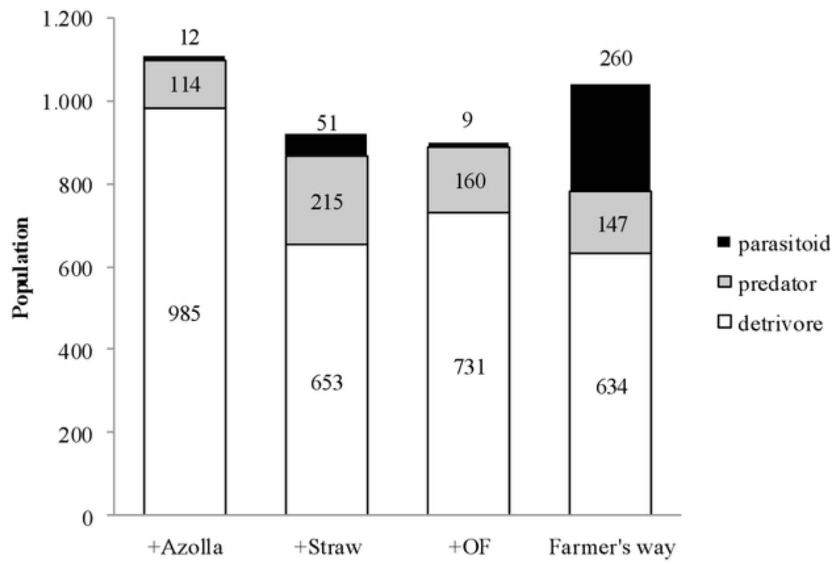


Figure 1. Comparison of Total Individuals of Detrivore, Predator, and Parasitoid in Each Field

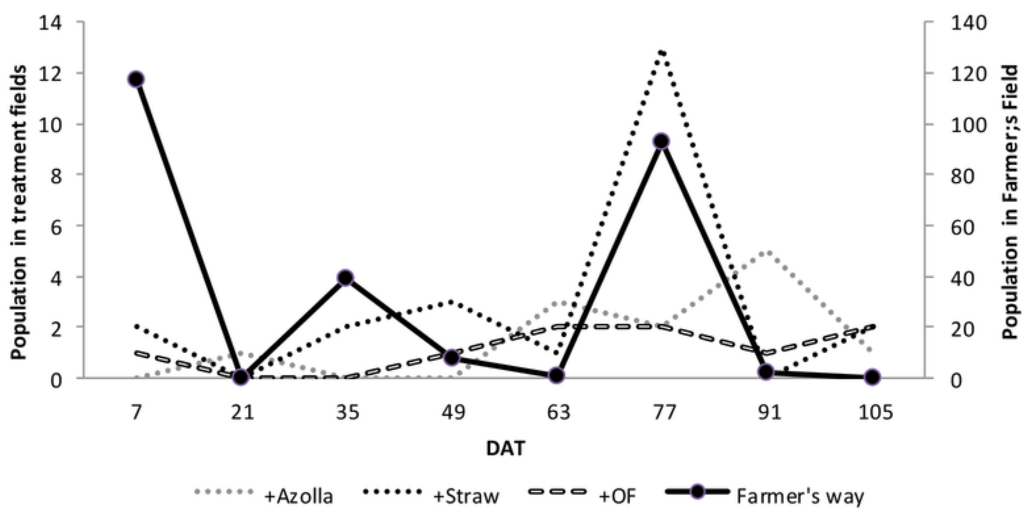


Figure 2. Population Dynamic of *Opius* Sp., *Cotesia* sp. and *Goniozus* sp. during Observation

Result of Analysis of Variance on α Diversity Component

We compare the variance of each α diversity measurement in every observation. The measurement contains four components, which are heterogeneity index, dominance index, richness, and evenness. There are fluctuations of each component in every observation, but in the average, they all showed a significant difference (Table 2).

Table 2. Analysis of Variance on Detrivore Data

Anova f0.05 (4,8) 2.94	indicator of α diversity			
	Heterogeneity index	Domination index	Richness	Evennes
Detritus	12.59*	3.96*	5.37*	6.16*
Natural enemy	8.28*	10.08*	3.43*	2.44

Remark: The mark (*) showed a significant differences as the value of F criteria is higher than F statistic

Heterogeneity index, richness, and evenness in farmer's field is the lowest (Table 3). Higher heterogeneity index explains that a habitat contains a wider variety of species which all species has equal abundance. Heterogeneity index will show the highest value if only two factors accomplished. The first factor is the higher number of species which is indices by species richness. The second is the higher evenness. Meanwhile, evenness measure observed the pattern in a hypothetical assemblage (Magurran, 2003). Its value varies from 0 to 1. If the value approaches 1 then all species are equally abundant. On the contrary, the lower value shows a "broken stick" distribution. It happens when certain species has a high population, and the other species rare. In the other words, there was a dominant species within the habitat. In so, the value of dominance index will inversely compare to the three others.

It showed in Table 3 that added biomass has increased α diversity of detritus population data. +OF has the highest improvement to value of heterogeneity index

Table 3. Differences of α Diversity Indicator on Detrivore Population Between Fields

Treatment Field	average							
	heterogeinity		dominance		richness		evenness	
+ Azolla	1.53±0.11	bc	0.31± 0.01	a	1.83±0.12	b	0.70±0.02	b
+ Straw	1.26±0.06	b	0.42 ±0.007	a	1.62±0.22	ab	0.62±0.005	b
+ OF	1.66±0.01	c	0.27±0.003	ab	1.99±0.16	b	0.75±0.01	b
farmer's way	0.80±0.20	a	0.50±0.06	b	1.20±0.19	a	0.45±0.05	a

Remark : *) the notation showed a significant differences based on LSD's test

There is clear evidence that adding biomass could enhance detritus species. Not only its population, but also its heterogeneity index, richness, and evenness. Collembolan found as the most common order of detritus. Its densities vary from 8.14 x102.m^{-3} in +Straw, 16.63 x102.m^{-3} in +Azolla to 19.1 x102.m^{-3} in +OF. Meanwhile in Farmer's way were 6.72 x102.m^{-3}. Collembolan feed from decaying matters and associated micro-flora. We found that micro-flora especially fungi (*Trichoderma* sp. and *Aspergillus* sp.) in treatment fields has increased also (Table 4). It could be determined that a sufficient food source is present. Without availability of organic matter collembolan potentially become pest (Neher & Barbercheck, 1999)

Table 4. Population of Dominant Fungi in Propagul.gramm^{-1}

Soil dominant microflora	+Straw	+Azolla	+OF	Farmer's way
Tricogramma sp.	52 x10^3	2.3 x10^3	43 x10^3	1.1x10^3
Aspergillus sp.	91 x10^3	3.6 x10^3	88 x10^3	1.2 x10^3

In fact, adding biomass not only provides more fungus propaguls as micro-flora but also enhance protozoa. In soil community, protozoa has role as a major predator of bacteria. So it could regulate plant diseases that caused by bacteria (Kennedy, 1999). Since we have limited source in protozoa observation, we use an indicator species. *Lumbricus* sp. could be an indicator for the presence of protozoa (Bamforth, 1999). It was found that *Lumbricus* sp. population increase more three times in +straw and +o.f compare to those in farmer's site (1.77 x102 m^{-3}). The highest population is in +Azolla field (7.08 x102 m^{-3}).

Even though, added biomass did not showed a clear effect in the individual number of the natural enemy but a contrast occurred if the data converse to α diversity component. There was a significant effect of added biomass to heterogeneity index, dominance index, and species richness. All the treatments field has a higher index, especially in +OF field (Table 5).

Table 5. Differences of α Diversity Indicator on Natural Enemies Population Between Fields

Field	Average							
	Heterogeinity		Dominance		Richness		Eveness	
+ Azolla	1.99±0.11	b	0.17± 0.003	a	2.93±0.59	ab	0.92±0.001	a
+ Straw	2.00±0.07	b	0.17 ±0.002	a	2.73±0.60	ab	0.89±0.002	a
+ OF	2.11±0.07	b	0.15±0.002	a	3.18±0.55	b	0.91±0.003	a
Farmer's way	1.30±0.28	a	0.46±0.06	b	2.09±0.25	a	0.68±0.16	a

Remarks: *) the notation showed significant differences based on LSD test

Opius sp. population outbreak may lead to the abundance of rice flies as the main host in farmer's field. Or there was a temporary niche because of its sporadic pattern. But unfortunately, we don't have sufficient data to back up the argumentation.

In spite, the natural enemy diversity components improve in treatments fields. We could show that proportion between detritus and natural enemies are better in each treatment field. That is the lower layer of food web has the bigger population. It will decrease the opportunity of intra-guild predation or intra-guild parasite occurred (Gagnon, Heimpel, & Brodeur, 2011)

Results of β diversity

The dissimilarity between habitat, that is tested by ANOVA (Table 2 and 3), showed the rising of heterogeneity index as results of the more abundance equality. Other way, there is evidence that some habitat has a shared species with other. Measurement of β diversity index is needed to ensure whether two habitats have more or fewer species overlap. β diversity becomes a reflection that a biotic change has occurred.

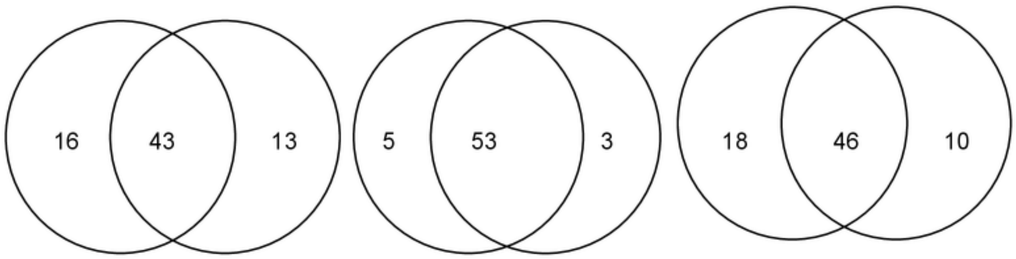
There are some methods to determine β diversity, one of them is Whittaker formula (Magurran, 2003). It extent the difference between habitat by comparing the number of species found in each site relatively into a total number of species that is occurs in both area or named as shared species. The similarity comes if a more of shared species found on both sites.

Table 6. Result of β Diversity Measures according to Whittaker's Formula (1960)

	+ Azolla	+Straw	+OF
Farmer ways	0.65	0.42	0.61
+ Azolla	-----	0.56	0.50
+ Straw	-----	------	0.55

Remarks: the lower β diversity indicates similarity between 2 sites according to the larger number of its complementary species.

According to Whitaker measurement (Table 6), the straw application has the most similarity habitat with farmer's way. It shows that straw has the lower effect to the species diversity. It also means that straw and farmer's way have the highest complementary species. Meanwhile, Azolla application brings the biggest impact on species changing if it compare to farmer's way. The numbers of complementary species between sites are drawn below in Fig. 3.



+Azolla vs Farmer's way   +Straw vs Farmer's way   +OF vs Farmer's way

Figure 3. Complementary species between 2 sites

β diversity measurement shows that differences between site also determined by the magnitude of faunal turnover observed (Missa et al., 2009). The more size of magnitude means the less number of shared species. It only 33 shared species of 89 morpho-species in all four habitats (37%).

We compared in a pair every site according to species richness sequence (Fig. 4), to explain turnover occurred between treatment sites. It shows that each biomass has a different effect on species turnover. For example, we see that in +straw vs +azolla the number of species has a slight difference. In the same time, it has the highest value of β. It means there were a less shared species between two sites. It also defines that some dominant morpho-species are specialized to particular habitats.

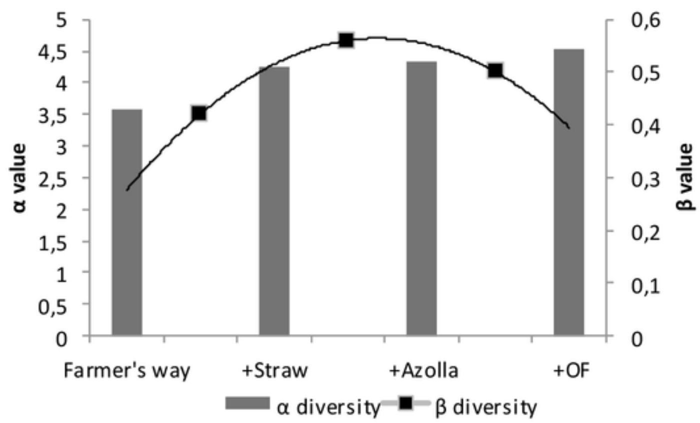
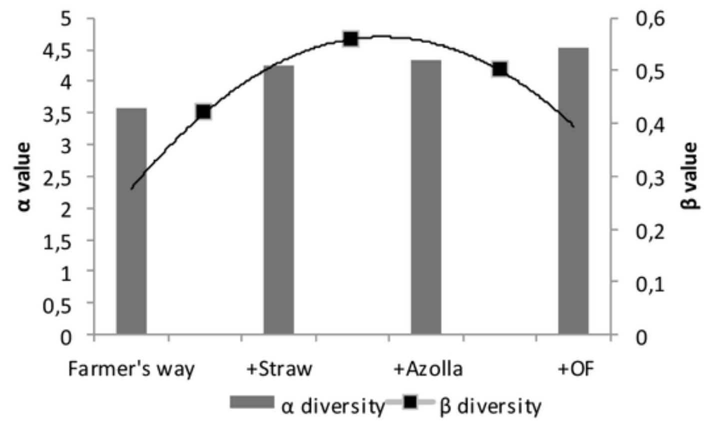


Figure 4. Changes in α and β Diversity with Biomass Added

Assessment of Environment Health

Adding biomass is either azolla, straw or organic fertilizer tends to increase species richness by providing a niche conservation (Entling *et al.*, 2012). An improvement in species richness followed decreasing dominance promising a better agro-ecosystem. It could be used as an indicator of sufficient population of natural enemies occurred. And so the pest control mechanism available as ecological services.

A better diversity of soil fauna in treatment field will enhance carbon-nitrogen cycling and decomposition of a various compound into nutrient (Kennedy, 1999). There is also an improvement of soil chemical compound (shown in Table 7). It proves that a promising nutrient cycle also occur, as one of ecological services.



Remarks: Solid regression depict farmers site data series, broken line for treatment

Figure 5. The Diversity Comparison between 8 observations in farmer's sites (open diamond) with the 24 observation on treatments sites. We found that farmer's site could be distinguished from treatment site of equivalent richness (ANCOVA F8,24 =8.273 P=0.001).

Table 7. Comparison of Soil Chemical Compound between Treatment and Farmer's Way

Soil chemical compound	+Straw	+Azolla	+OF	Farmer's way
C-organic	2.26	2.29	2.16	1.37
N-total	0.26	0.3	0.24	0.16
P	51.43	12.83	12.1	18.13
K	0.83	15.93	0.55	0.26
Organic matter	3.9	3.96	3.73	2.37

SUMMARY

Adding certain biomass in an early stage of the agricultural system will enhance both of detrivore's population and diversity. It also enhances natural enemy's diversity and so, increases the possibility to gain pest control services from agro-ecosystem. It shows that adding organic fertilizer has the biggest impact. Furthermore Adding biomass could enhance agro-ecosystem health according to richness-dominance covariance.

Biomass application regularly in every agricultural cycle will provide ecological services that it is important for sustainability of the rice field productivity.

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