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Biodiversity Comparison between Paired Organic and Conventional Fields in Puducherry, India

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Abstract: Modern intensive chemical agriculture and its expansion have caused a dramatic decline in the agro-biodiversity throughout the world. Recently, accumulating evidences indicate that organic farming is a sustainable farming system that can potentially reduce the biodiversity loss and conserve biodiversity. This chapter investigates the impacts on biodiversity in paired organic and conventional agricultural plots, to determine whether organic agriculture can deliver biodiversity benefits including enhanced ecosystem services. The study assessed a wide range of taxa through different methods-plants by quadrates; soil microbes; earthworms by counting; butterflies and dragonflies by pollard walk method; other arthropods by visual searching and pitfall traps; reptiles by hand capture method; molluscs by hand picking and dredging; amphibians-frogs by direct sighted/visual encountered and birds by direct sighting, calls and variable width line-transect method. Habitat area, composition and management on organic fields were likely to favor higher levels of biodiversity by supporting more numbers of species, dominance and abundance across most taxa. Overall organic hedgerows harbored larger biodiversity during both pre-harvest and post harvest period. Species richness, dominance and abundance of most taxa are lost after harvest in both conventional and organic fields due lack of habit, habitat and microclimate. However, the magnitude of the response varied among the taxa. Organic fields are the systems less dependent on external inputs restore and rejuvenate environment resulting in higher biodiversity that promotes higher sustainable production on a long-term basis.

Key words: Organic farming, conventional farming, biodiversity, restoration, puducherry

INTRODUCTION

Agriculture has been the basic source of subsistence for human survival. Introduction of Green revolution agriculture-chemical intensive and high tech/bio-tech agriculture, during the last quarter of the 20th century culminated in the dramatic declines in density and diversity of many beneficial species associated with agricultural fields (Hole *et al*., 2005; FIBL, 2012). Loss of ecosystem services and biodiversity on this scale has fuelled the debate over the sustainability of current intensive farming practices that includes fears over water contamination and pollution, soil erosion/quality degradation, landscape quality and food safety (Ericksen *et al*., 2009; Pandey and Singh, 2012).

Increasing human population is predicted to convert further one billion hectares of natural habitat into agricultural fields, predominantly in the developing world, which in turn will double or triple inorganic fertilizers usage, resulting in threefold demand for water/pesticide usage, thus ultimately threaten global biodiversity, food security and human health (Gabriel *et al*., 2010; CLI-Crop Life International, 2010; OFRF, 2011). All these facts ultimately demand alternative support systems that are eco-friendly, socio-culturally compatible, sustainable and with less intensive practices that are ecologically and economically beneficial for the overall health of environment, flora, fauna and human race. However, there are relatively few studies that demonstrate that organic farming practices positively influence species richness and abundance of various taxa like plants, predatory invertebrates and birds, globally (Araujo *et al*., 2009; FIBL, 2012) and especially rarely in India (Goh, 2011; Mehmood *et al*., 2011; Pandey and Singh, 2012).

To a certain extent, weed population in the agricultural field margins are reported to be beneficial in terms of ecological and economic values i.e., medicinal plants (Ponce *et al*., 2011; Nascimbene *et al*., 2012). A fertile soil is characterized by the presence of diverse group of active biotic community which enhance/supports undisturbed decomposition and it provides essential nutrients for the crop growth

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(Stockdale and Watson, 2009; Grantina *et al*., 2011). Soil organisms are crucial for the sustainability of agro-ecosystems. Soil biological properties such as microbial biomass or activity, as well as earthworm abundance or diversity, were reported to be major soil quality bio-indicators (Fonte *et al*., 2009; Simonsen *et al*., 2010). High level of soil biological activity enhances the nutrient supply to crops reduces nutrient leaching and helps to control soil pests (Snapp *et al*., 2010; Jeffords, 2012).

Worldwide invertebrates are essential for biodiversity enhancement; as they are being the diet for many birds and young birds and also as biological pest control and their abundance are drastically reduced due to the wide usage of agro-chemicals (Thomas *et al*., 2011; Batary *et al*., 2012). Spiders have been shown to be useful in controlling aphid numbers (Crowder *et al*., 2010; Krauss *et al*., 2011) and several other economic pests. Butterflies and dragonflies are ecologically important as agents of pollination and bio indicators; they also serve as food sources for birds and other beneficial faunal communities (Diekotter *et al*., 2010; Jonason *et al*., 2011).

Several invertebrate species like carabids and spiders feed on key agricultural pests i.e., aphids and slugs and epigaeic arthropods like earthworms are considered sensitive indicators of soil fertility (Simonsen *et al*., 2010; Nakhro and Dkhar, 2010). Other arthropods, like Acari (mites), Formicidae (ants), Heteroptera (true bugs), Millipedes, Centipedes, Collembola, Diptera (flies) and Hymenoptera are sensitive indicators and they all play important role in soil nutrient cycling, in aid weed control through seed-eating (Zehnder *et al*., 2007; Thomas *et al*., 2011) and the average activity/density of arthropods in the fields determines the soil fertility and productive capacity of that field (Maeder *et al*., 2002; Krauss *et al*., 2011). Molluscs serve as important prey/predator as bio-control agent, bio indicator and it can also accumulate heavy metals and used as decontaminator (by harvesting the snails) in agricultural fields polluted with heavy metals (Kurihara *et al*., 1987). Amphibians, reptiles and birds serve as important predators on harmful insects/pests and acts as bio-control agents (Gabriel *et al*., 2010; Batary *et al*., 2012; Thomas *et al*., 2011). Globally, populations of birds and pollinators have drastically declined due to the effects on chemicals used in conventional fields and thus demanding a shift towards organic farming, where the density and diversity birds can be conserved and enhanced (Batary *et al*., 2012; Kirk *et al*., 2011; Krauss *et al*., 2011; FIBL, 2012).

This study aims to study the biodiversity in plants, vertebrates (frogs, snakes and birds), invertebrates (earthworms, carabid beetles, spiders, butterflies, dragonflies and other arthropods) and soil microbes in hedgerows and in fields of organic and conventional farming systems in order to analyze two hypotheses, whether responses to organic farming in terms of species number, diversity and abundance are taxon specific and whether organic fields differ from conventional fields in habitat diversity, species composition and management. The present study is a pioneering attempt on comparing floral and faunal biodiversity in organic and conventional farming systems from South India.

MATERIALS AND METHODS

Experimental site and design: Puducherry is located on the Coramandal coast 11°52' N, 79°45' E and 11°59' N and between 79°52' E covers an area of 480 sq.km. The study area experiences mean annual temperature of 30.0°C and mean annual rainfall about 1311-1172 mm. The mean number of annual rainy days is 55, the mean monthly temperature ranges from 21.3-30.2°C. The climate is tropical dissymmetric with the bulk of the rainfall during northeast monsoon October- December (Indian Meteorological Department - Chennai). The present study is based on the field work carried out by us at Kuruvinatham and Soriankuppam villages (Fig. 1), 24 km South on the way to Cuddalore from the Puducherry main town. These villages come under Bahour commune. These regions are once highly fertile area before the introduction of conventional farming. Conventional farming (GRA) technologies (early 1970s) have caused rapid decline of ground water table and increased the salinization of aquifers, polluted/degraded the soil and water quality, reduced the diversity of beneficial biota and has caused eutrophication of water bodies. This has culminated in the decline in growth and yield of production (personal communications from local traditional organic farmers and Kalanjiyam NGO). This has motivated some innovative farmers to rediscover their past traditional organic farming methods in 2004, with the help of their fathers/grandfathers and encouragement/support from local NGOs. The innovative traditional organic farming methods (Padmavathy and Poyyamoli, 2011a, b) include the usage of Panchagavya, Amuthakaraisal, Meein amilam, Vanamudham, Thayingaipal Pulitharmor karaisal, Puchuviraty etc. and these practices rectify the ill effects caused by conventional farming.

Study sites are located on the river bank/basin of Ponnaiyar River, has a clayey soil texture with major proportion of clay (55%) and fine sand (35.5%), that are more suitable and convenient (soil texture) for groundnut and vegetable cultivation. Conventional and organic agriculture fields were chosen on the basis of the

Fig. 1: Location of the study site

homogeneity of inherent soil characteristics. A 125 farming informants were reduced to two sets of 15 organic fields (with a history of organic farming practice for the last 6 years) and 15 Inorganic/Green Revolution Agriculture fields (with a history of inorganic farming practice for more than 6 years) based on their organic farming experience and they also possesses a uniform crop sequence pattern as Paddy/Groundnut/Ladys finger (per year) were selected (Padmavathy and Poyyamoli, 2011a). The fields sizes varied between <1 to >5 ha. A comprehensive description of inorganic fertilizers and organic amendments application in conventional and organic farming during the survey are described here in Table 1. Both organic and conventional farms were mostly rain fed and in the absence of rain, water was distributed via canals (using motor pumps in the fields) at annual rates from 280 to 620 mm, i.e., mean daily water input for paddy is 11.3 -14.4 mm d^{-1} and for other crops- 9-11.5 mm d^{-1} (Department of Economics and Statistics 08-12).

Flora and fauna: Various taxa like plants, frogs, snakes, birds and invertebrates i.e., earthworms, other arthropods, beetles, spiders, butterflies, dragonflies and soil microbes were sampled. Habitat data were collected at field levels once during the project period. Ground-based surveys on the habitat were undertaken for the bird survey. Hedge height and width were measured at 10 evenly spaced points around the boundary of each target field; tree/shrub composition, numbers of trees and gaps were recorded within 5 m of these points (Smart *et al*., 2003). Plant species biodiversity was monitored once every month for 3 years in selected agricultural fields (2008, 2009 and 2010). The method recommended by Smart *et al.* (2003) was adopted in the present study (1) Field boundary plots recorded presence and abundance (% cover) of species in line-transect, the plots extending 10 m parallel to the boundary and 1 m along the sides of uncultivated field (2) Percent plant cover of non crop plants within the cultivated portion of the field was recorded in 10 quadrates of 0.5×0.5 m each placed at distances of 2, 4, 8, 16 and 32 m from the ploughed margins on 6-12 transects per field, depending upon field size; <1 ha (6 transects), small farmers - 1-2 ha (6-8 transects), semi-medium farmers - 2-4 ha (8 -10 transects), medium farmers - 4-10 ha (10-12 transects) and large farmers >10 ha (12 transects).

The 120 samples were randomly collected from 30 study sites (organic-15 vs. conventional-15) agricultural fields (60 samples) and boundaries (60 samples) every month from August 2008 to October 2010 for the analysis of soil microbes. Estimation of earthworm population was done by counting (m^{-2}) based on the method suggested by Chhonkar *et al.* (2007). Serial dilution plate count technique (Pramer and Schmidt, 1966) was used by transferring 1 mL of appropriate dilutions of 10^6, 10^3 and 10^4 for the enumeration of soil bacteria, fungi and actinomycetes on soil extract agar, martins rose

Table 1: Fertilizer/Manures/Insecticides/Bio-pesticides application in organic and conventional fields

	Organic farming (ha^{-1})	Conventional farming (ha^{-1})
Paddy	50 mg Cow dung compost	120-130 kg N (Urea)
	11 mg Green manure	80-20 kg P_2O_5 (Superphosphate)
	1.2 mg Vermi compost	40-50 kg K_2O (KCl)
	100 l Panchakavya	250-500 L Insecticides
	100 l Amirthakaraisal	
	80 l Meein amilam	
	50 l Thayingaipal and pulithamoor karaisal	
	55 l Vanamutham	
	90 l Bio-pesticides	
Ladys finger	40 mg Cow dung compost	100-115 kg N (Urea)
	9 mg Green manure	60-75 kg P_2O_5 (Superphosphate)
	0.8 mg Vermi compost	35-45 kg K_2O (KCl)
	65 l Panchakavya	220-230 L Insecticides
	65 l Amirthakaraisal	
	50 l Meein amilam	
	40 l Thayingaipal and pulithamoor karaisal	
	35 l Vanamutham	
	75 l Bio-pesticides	
Groundnut	50 mg Cow dung compost	100-110 kg N (Urea)
	11 mg Green manure	50-60 kg P_2O_5 (Superphosphate)
	1.2 mg Vermi compost	30-38 kg K_2O (KCl)
	50 l Panchakavya	200-210 L Insecticides ha^{-1}
	50 l Amirthakaraisal	
	35 l Meein amilam	
	35 l Thayingaipal and pulithamoor karaisal	
	25 l Vanamutham	
	65 l Bio-pesticides	

bengal agar and Kusters agar. The agars are used as nutrient media for microbial growth.

For arthropods, years of sampling and fields used were similar to that for plants but they were sampled twice a month. They were estimated by visual searching method (Latif *et al*., 2009) and pitfall trap method (Schmidt *et al*., 2006). A grid of 18 pitfall traps ha^{-1} was set in each target field, comprising nine within the crop and nine within the uncropped boundary. Traps were set for 48 h before emptying. Paired target fields were always sampled at the same time. Because of seasonal variation in animal activity and trapping efficiency, separate samples were collected before and after harvest. All the arthropods were identified to family/morphospecies level by the Soil Ecologists from Puducherry Science Forum and Pondicherry University, who were familiar in identifying different important soil arthropods.

Butterflies were systematically surveyed during August 2008 to October 2010-observed, caught with standard entomological net, identified using field guides by Gunathilagaraj *et al*. (1998) and recorded in the field book. Pollard walk method (Pollard, 1977; Pollard and Yates, 1993) was followed for observing butterflies, i.e., walking along the fixed paths while recording and counting the species. The observation width was limited to about 5 m. Butterflies were observed (n = 24) from 6.30 h to 11:00 h twice in a week. The years of sampling and fields used were similar for dragonflies and damselflies and butterflies were observed by searching and direct observation method as suggested by Sutherland (2006), were identified using the field guide of Subramanian (2005) and then counted.

Quantitative estimation of the molluscs was done by hand picking and dredging throughout in and along the agricultural fields (crop and hedgerows), by belt transects- 10×100 m and 5 quadrate of 30× 30 cm size were randomly selected for collection within each transect; it was sampled once a month in each field. The hand digging is reported to be more preferable technique, as it causes minimum damage to the area. The species were identified using the Ramakrishna (2003).

Reptiles-snakes and lizards were enumerated by hand capture method (Sutherland, 2006) and identified with the help of the key characters given by Smith (1935, 1943), Murthy (1977, 1992, 1995) and Murthy and Rama Rao (1988), frogs were direct sighted/visual encountered, counted and identified using the Smith (1935, 1943) manuals; rodents were sampled using nesting or resting structures method (Sutherland, 2006) and identified using Prater (1971) manual. During each visit, the observer walked the perimeter of each field and once across the centre of each field and fauna were sampled once a month in each field. Abundance values for individual fields were based on mean counts across visits.

Direct sighting, calls and variable width line-transect method (Sutherland, 2006; Padmavathy *et al*., 2010) were used for bird sampling at a larger spatial scale extending over several fields. Surveys were done on the target field

Table 2: Effects of farming system on number of species (species density), dominance and abundance. (Dominance is measured as the Berger-Parker dominance index (May, 1975). *Significance of system effect (shown in bold) was based on z-tests (birds) or GLM models taking account of year (all other taxa). **Mean difference between organic (O) and inorganic/conventional (N) log-scale attribute (positive values indicate O>N)

	Species density			Dominance			Abundance		
Categories	p*	D**	R(CI)[a]	p*	D**	R(CI)[a]	p*	D**	R(CI)[a]
Plants(field boundary)[b]	<0.001	0.41	1.49 (1.35-1.64)	0.511	-0.1	0.97 (0.94-1.00)	0.612	0.22	1.25 (1.05-1.48)
Plants (within-crop)[b]	0.003	0.62	1.85 (1.68-2.05)	0.003	-0.1	0.64(0.56-0.74)	0.551	0.74	2.09 (1.74-2.53)
Soil microbes (boundary pre-harvest)	0.003	0.11	1.99 (0.898-1.04)	0.003	-0.2	0.93 (0.91-1.12)	0.031	0.19	1.12 (1.05-1.42)
Soil microbes (boundary post-harvest)	0.005	0.09	1.92 (0.75-1.02)	0.561	-0.2	1.02 (0.95-1.11)	0.002	0.14	1.85 (0.64-1.19)
Soil microbes (crop pre-harvest)	0.001	0.58	1.05 (0.98-1.12)	0.652	-0.1	1.03 (0.89-1.16)	0.001	0.27	1.39 (1.16-1.62)
Soil microbes (crop post-harvest)	0.232	0.39	1.03 (0.92-1.17)	0.611	-0.3	0.99 (0.95-1.03)	0.321	0.15	1.10 (0.92-1.32)
Earthworms (boundary pre-harvest)	0.002	0.39	1.01(0.93-1)	0.421	-0.3	0.92(0.81-1.3)	0.002	0.21	1.14(1-1.33)
Earthworms (boundary post-harvest)	0.203	0.53	1.53 (0.61-0.98)	0.762	-0.1	0.95 (0.82-1.00)	0.812	0.31	1 (0.97-1.13)
Earthworms (crop pre-harvest)	0.005	0.99	1.09 (0.99-1.20)	0.482	-0.2	1.02 (0.96-1.09)	0.443	0.26	1.30 (1.02-1.66)
Earthworms (crop post-harvest)	0.295	0.89	1.01(0.93-1.00)	0.431	-0.1	0.98(0.95-1.1)	0.391	0.21	1.21 (1.00-1.43)
Butterflies (boundary pre-harvest)	0.002	0.92	1.11 (0.79-1.06)	0.921	-0.2	1.05 (0.99-1.12)	0.871	0.41	1.04 (0.98-1.37)
Butterflies (boundary post-harvest)	0.001	0.73	1.83 (0.71-0.98)	0.862	-0.3	0.95 (0.82-1.00)	0.812	0.31	1 (0.97-1.13)
Butterflies (crop pre-harvest)	0.002	0.51	1.53 (0.46-0.60)	0.413	-0.2	0.85 (0.79-0.92)	0.442	0.21	1.01 (0.93-1.27)
Butterflies (crop post-harvest)	0.433	0.32	0.93 (0.31-0.58)	0.531	-0.2	0.73 (0.70-83.00)	0.813	0.32	1 (0.97-1.13)
Dragonflies/damseflies (boundary pre-harvest)	0.512	0.42	1.51 (1.37-1.67)	0.521	-0.3	0.97 (0.87-1.07)	0.003	0.11	1.04 (0.97-1.23)
Dragonflies/damseflies (boundary post-harvest)	0.531	0.39	1.41 (1.32-1.59)	0.430	-0.4	0.97 (0.94-1.00)	0.611	0.22	1.25 (1.05-1.48)
Dragonflies/damseflies (crop pre-harvest)	0.511	0.38	1.31 (1.29-1.39)	n.a	n.a	n.a	n.a	n.a	n.a
Dragonflies/damseflies (crop post-harvest)	0.521	0.32	1.21 (1.27-1.47)	n.a	n.a	n.a	n.a	n.a	n.a
Spiders/opiliones (boundary pre-harvest)	0.002	0.39	1.03 (0.92-1.17)	0.611	-0.3	0.99 (0.95-1.03)	0.321	0.15	1.10 (0.92-1.32)
Spiders/opiliones (boundary post-harvest)	0.003	0.51	1.11 (0.92-1.34)	0.461	0.3	1.03 (0.96-1.12)	0.002	0.16	1.22 (1.05-1.42)
Spiders/opiliones (crop pre-harvest)	0.004	0.16	1.17 (1.06-1.30)	0.972	-0.4	0.96 (0.93-1.00)	0.003	0.22	1.25 (1.05-1.48)
Spiders/opiliones (crop post-harvest)	0.425	0.12	1.17 (0.97-1.41)	0.853	-0.4	0.93 (0.86-1.01)	0.691	0.42	1.06 (0.83-1.36)
Carabids (boundary pre-harvest)	0.211	-0.9	0.91 (0.79-1.06)	0.921	0.5	1.05 (0.99-1.12)	0.872	0.31	1.04 (0.78-1.37)
Carabids (boundary post-harvest)	0.463	-0.11	0.83 (0.66-1.03)	0.782	-0.1	0.99 (0.93-1.05)	0.002	-0.12	0.83 (0.69-1.06)
Carabids (crop pre-harvest)	0.038	0.10	0.99 (0.89-1.20)	0.481	0.2	1.02 (0.96-1.09)	0.441	0.26	1.30 (1.02-1.66)
Carabids (crop post-harvest)	0.325	0.11	0.92 (0.75-1.02)	0.561	-0.2	1.02 (0.95-1.11)	0.571	0.14	0.85 (0.64-1.19)
Other arthopods (boundary pre-harvest)	0.002	0.31	1.97(1.83-2.06)	0.021	0.1	1.51(0.85-1.3)	0.311	0.18	1.17 (1.05-1.25)
Other arthopods(boundary post-harvest)	0.002	0.52	1.91(0.79-1.01)	0.002	-0.1	0.91(0.89-1.1)	0.001	0.16	1.13 (1.00-1.29)
Other arthopods (crop pre-harvest)	0.001	0.43	1.01(0.73-0.96)	0.001	0.1	1.61(0.79-1.1)	0.312	0.21	1.25 (1.00-1.43)
Other arthopods (crop post-harvest)	0.232	0.89	1.01(0.93-1.00)	0.432	-0.1	0.98(0.95-1.1)	0.003	0.21	1.21 (1.00-1.41)
Molluscs (boundary pre-harvest)	0.003	0.38	1.53 (1.29-1.39)	n.a	n.a	n.a	n.a	n.a	n.a
Molluscs (boundary post-harvest)	0.004	0.32	1.13(1.27-1.47)	n.a	n.a	n.a	n.a	n.a	n.a
Frogs (boundary pre-harvest)	0.001	0.13	1.11 (0.92-1.34)	0.461	-0.3	1.03 (0.96-1.12)	0.001	0.21	1.22 (1.05-1.42)
Frogs (boundary post-harvest)	0.002	0.11	1.02 (0.89-1.10)	0.412	-0.2	1.01 (0.92-1.10)	0.002	0.22	1.19 (0.99-1.26)
Snakes (boundary pre-harvest)	0.004	0.13	1.01 (0.92-1.14)	0.035	0.3	1.03 (0.91-1.12)	0.003	0.25	1.22 (1.05-1.42)
Snakes (boundary post-harvest)	0.004	0.11	1.09 (0.898-1.04)	0.003	-0.2	1.43 (0.91-1.12)	0.001	0.19	1.12 (1.05-1.42)
Lizards (boundary pre-harvest)	0.002	0.18	1.22 (1.09-1.70)	0.612	0.4	1.01 (0.95-1.30)	0.003	0.20	1.29 (0.99-1.36)
Lizards (boundary post-harvest)	0.002	0.13	1.32 (0.69-1.10)	0.712	0.5	1.37 (0.92-1.10)	0.002	0.19	1.19 (0.69-1.16)
Rodents (boundary pre-harvest)	0.621	0.38	1.53 (1.29-1.39)	n.a	n.a	n.a	n.a	n.a	n.a
Rodents (boundary post-harvest)	0.411	0.32	1.13(1.27-1.47)	n.a	n.a	n.a	n.a	n.a	n.a
Birds (2008/09)	0.002	0.17	1.03 (0.99-1.06)	0.661	-0.3	0.98 (0.89-1.07)	0.002	0.41	1.26 (1.08-1.44)
Birds (2009/10)	0.021	0.13	1.01(0.91-1.01)	0.611	-0.2	0.91 (0.81-0.96)	0.001	0.37	1.13(1.03-1.25)

[a]Sample mean ratio of the O/N attribute with 95% confidence intervals in parenthese (values greater than 1 indicate O>N); [b]Excluding cropped plants. The presence of molluscs, frogs, snakes, lizards and rodents in crop fields (OF/Con.) were not witnessed/non applicable/not significant and hence they are not included in the table

and up to five adjacent fields once per month at each site from August 2008 to October 2010. During each visit, the observer walked the perimeter of each field and once across the centre of each field. Identification was done using Kathiresan (2000) manual. Abundance values for individual fields were based on mean counts across visits. Comparisons of habitat and management attributes are based on Wilcoxon matched-pair tests. Analyses in Table 2 follow the format of Perry *et al.* (2003). Regression using SPSS 16 Windows version packages were used.

RESULTS AND DISCUSSION

There were significant differences in width, height and length of the hedgerows between organic and conventional fields (means of 0.21±0.02 and 0.17±0.01, n = 15, p<0.05; 0.15±0.02 and 0.10±0.01, n = 15, p<0.05, respectively. Figure 2 represents that hedgerows in organic fields was greater in their height (p<0.05), base width (p<0.05) and top width (p<0.01) than hedgerows in conventional fields (Padmavathy and Poyyamoli, 2011a). Organic fields had a larger land proportion for grass/fodder near cropped land and it was much higher than conventional agricultural fields (respective percentage means of 35.7±1.5 and 15.2±1.5, n = 26, p<0.01). Most of the organic fields were smaller than conventional fields (0.7±0.2 and 8.02±0.4 ha, n = 15 and 1.2±0.5 and 10.02±0.5 ha, n = 15 p<0.01), thus, because majority of the organic farmers were small and medium scale framers (Poyyamoli and Padmavathy, 2011). Shrub and herb species recorded in hedges/hedgerows differed significantly, organic fields had mean average of 12±6 (n = 15) and conventional fields 7±3 (n = 15), p<0.05).

Organic farming is clearly a complex and well-integrated system approach. Habitat heterogeneity within the system is linked to rotational and cropping practices (usually including livestock) as are the extent and quality of habitat components. Cover of weeds in organic fields was higher in field edges at 2 m (FE2 55%) and it gradually decreased as the distances from the Fields Edges (FE) increased, FE 32 recorded the lower (25%) weed cover in organic fields; in conventional fields the weed cover was almost constant (25-22%) throughout FE 2 to FE 32 whereas as in case of crop cover a gradual increase was observed in both organic fields (FE 2 (70%); FE 32 (90%)) and conventional fields (FE 2-75% and FE 32 (80%) from the field edge towards the center (Fig. 3).The weed species mostly belonged to the families Fabaceae, Brassicaceae, Polygonaceae and Poaceae (grasses) (Hald and Reddersen, 1990; Hole *et al.*, 2005; Armengot *et al.*, 2012). Broad-leaved species are less able

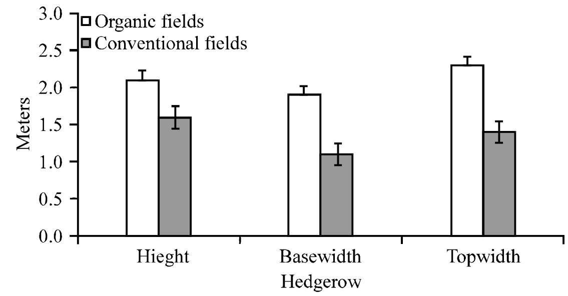

Fig. 2: Hedge parameters (m) of target fields on organic and conventional systems

to tolerate the intensive weed control measures and denser crop swards of herbicide-treated, heavily fertilized conventional fields (Hyvonen *et al.*, 2003; Hole *et al.*, 2005; Ponce *et al.*, 2011). Flora abundance/non-crop trees and weeds were higher in field margins than in the mid-field under both organic and conventional systems (Gabriel *et al.*, 2010; Thomas *et al.*, 2011). Organic systems supported the hypothesis of an improved efficiency in soil microbes and soil fauna in utilizing energy and organic resources. Hence, organically managed soils establish ecological systems that are able to sustain biological productivity as well as agricultural productivity on a long term basis (Nakhro and Dkhar, 2010; Gabriel *et al.*, 2010; OFRF, 2011; Pandey and Singh, 2012; FIBL, 2012).

Organically managed fields exhibited a significant variation (p = 0.003) in microbial population in comparison to conventional fields both in pre/post harvest period and in general there was a significant positive correlation between soil quality and soil microbial population (r = 0.56, p = 0.01). Organically managed fields had significantly more microbial and earthworm population than GRA fields (Maeder *et al.*, 2002; Fonte *et al.*, 2009; Simonsen *et al.*, 2010; Grantina *et al.*, 2011) who found that microbes and earthworms populations were twice or thrice greater in organic fields than that of conventional fields. Organic inputs were cited as the principal factor, providing a significantly greater input of organic carbon in the form of animal (and green) manures, thereby bolstering (in particular) beneficial microbial populations (Araujo *et al.*, 2009; Snapp *et al.*, 2010; OFRF, 2011). In the case of conventional (GRA) fields, the evidence indicates that microbial and earthworm communities are likely to be affected by edaphic factors such as soil type and crop type, excessive tillage and extensive use of chemical fertilizers (Nakhro and Dkhar, 2010; OFRF, 2011; FIBL, 2012).

Organic fields were significantly different in total diversity and abundance of butterflies and dragonflies in

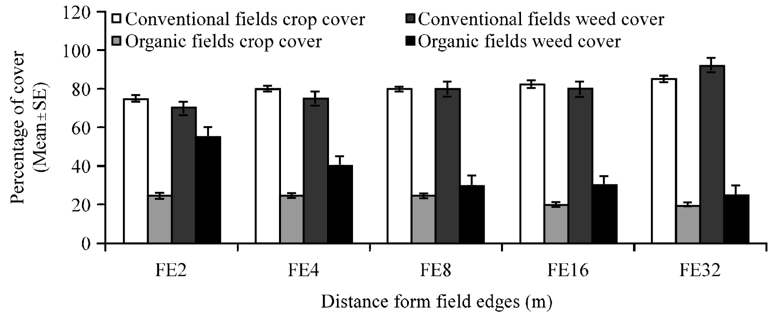

Fig. 3: Crop and weed cover (Mean±SE) along transects into the crop on non-organic/conventional fields (N) and organic fields (O). Hatched bars show cover values for crop plants and black bars show values for weeds at 2, 4, 8, 16 and 32 m from the field edge

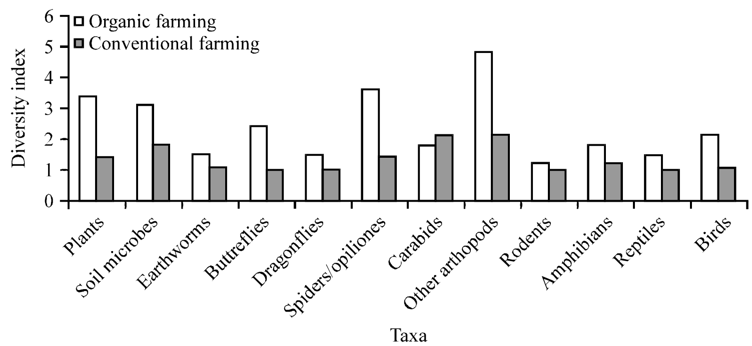

Fig. 4: Comparison of diversity index among various taxa in organic and conventional agricultural fields

both crop-edges (p = 0.002/0.001) and field boundaries (p = 0.002) during pre/post harvest period. It was a direct result of a greater abundance of non-pest species, insects, arthropods, invertebrate species and absence of toxic chemicals in organic fields. A greater abundance and diversity of food plants and habitat in organic field boundaries and a lack of spray drift/chemicals were also cited as potentially beneficial factors (Hole *et al*., 2005; Gabriel *et al*., 2010; Jonason *et al*., 2011) for the presence/diversity/abundance of various pollinators like birds, butterflies/dragonflies.

Organic fields had more spider populations (p = 0.002-0.004) than conventional fields during both pre/post harvest period. Richer understory vegetation/weeds in hedges due to the abundance organic matter and complete absence of chemical fertilizers, insecticides/pesticides provide greater structural complexity, a more suitable microclimate/habitat. This supplies the prey species with a greater abundance of plant food. Hence, the abundance (and in some instances diversity) of spiders/harvestments in organic arable fields is mainly found in these smaller areas, adjacent to the botanically diverse margins. All these principal factors are not always applicable in conventional farming fields, ultimately resulting in decline in predatory spiders/opiliones in terms of their density and diversity (Hole *et al*., 2005; Stockdale and Watson, 2009; Jia *et al*., 2010; Batary *et al*., 2012).The presence of more carabides (p = 0.038) in the conventional fields (Table 2) is a bio-indicator of various anthropogenic activities such as urbanization, crop and forest management, overgrazing and soil pollution (Oehl *et al*., 2004; Ponce *et al*., 2011), thus supporting the findings of the present study. In organic field significantly ($p<0.005$) more beneficial species were distributed throughout the fields and hedgerows, whereas in conventional fields, the non-sprayed hedges provide a refuge for few beneficial species.

Organically managed fields contain a greater abundance (p = 0.002-0.001) and diversity (p = 0.002) of other arthropods like Centipedes, Heteroptera (true bugs), Formicidae (ants), Collembola, Hymenoptera (sawflies, wasps, bees), Diptera (flies) Acari (mites) and Staphylinids, than conventionally managed fields. It is mainly due to improved soil quality, nutrient content in soils, high organic, no or low level of soil disturbance/pollution, absence of chemicals and eco-friendly management techniques in organic fields, which are completely or partially absent in conventionally managed fields (Maeder *et al*., 2002; Raupp *et al*., 2006; Nakhro and Dkhar, 2010; Pandey and Singh, 2012). Diversity, dominance and abundance of rodents in both fields did not show any significant differences ($p>0.811$) among the fields and it is similar to the findings of Navntoft *et al*., (2006) and Daedlow *et al*., (2012).

Diversity, dominance and abundance of other beneficial arthropods, snakes, lizards, frogs and birds in organic fields were more ($p = 0.002$-0.004) in number than conventional fields. The presence of more suitable/appropriate hedgerows, habit, habitat and absence of chemicals in organic fields than in conventional fields, decisively influence the diversity of biota as reported by several earlier workers (Thomas *et al*. 2011; FIBL, 2012). The beneficial fauna are mostly present during evening and early morning in fields (source: farmers' responses and field visits/observations. A greater abundance and diversity of plant groups and many invertebrate, resulting from organic management was highlighted by several workers as the principal reason for the significant differences in the avian community between the contrasting farming systems (Kirk *et al*., 2011; Krauss *et al*., 2011; FIBL, 2012). Intensification/specialization of agricultural systems and higher pesticide/ fertilizer inputs have reduced the availability of key invertebrate like bees, bumble bees and foods for many farmland birds like sparrows, bats, lapwings, vultures etc., within conventional systems (Batary *et al*., 2012; Thomas *et al*., 2011; FIBL, 2012) thus, reducing the diversity/density of birds.

The numbers of species, measured as species density (Gotelli and Colwell, 2001) and abundance were typically higher on organic fields (71 out of 84 D values in Table 2 were positive). However, the pattern was less clear for dominance as measured by the Berger-Parker dominance index (May, 1975). There were significant differences ($p<0.05$) related to higher species density, higher diversity (i.e., lower dominance) or higher abundance in organic compared to conventional fields (Table 2). The exception was in carabids abundance in the boundary, with fewer individuals recorded on organic fields. Significant differences between systems were evident in all taxa comparisons (42), whereas highly significant differences between systems in different taxa were evident in 51 out of 114 comparisons and were more frequent for species density (27/42), overall abundance (17/36) than for dominance (7/36). Cover of weeds was consistently higher at all distances into the crop. Evidence for system differences was merely evenly distributed across taxa and based on the confidence intervals given in Table 2 organic fields supported 48-155% more species density among various taxa and examination of the D and R values (Table 2) show that estimated all taxa were relatively higher and efficient in organic fields.

Overall the organic hedgerows harbored greater ($p = 0.002$-0.004) taxa biodiversity (density, dominance and abundance) in plants, earthworms, soil microbes, butterflies, spiders/opiliones, frogs, snakes than in crop fields during pre/post harvest (Table 2). Soil microbes, earthworms, other arthropods, carabids, butterflies, spiders/opiliones were more in organic crop fields than in boundary and organic agriculture have promoted biodiversity in general, especially in terms of soil microbes and beneficial predatory arthropods (Oehl *et al*., 2004; Reganold *et al*., 2010; Grantina *et al*., 2011). Stockdale and Watson (2009), Boutin *et al*. (2008) and Ponce *et al*. (2011) found that organic fields had higher abundance of weeds and beneficial arthropods. Kirk *et al*. (2011) stated that bird abundance were significantly ($p<0.05$) higher on organic sites (mean 43.1 individuals per site) than nonorganic sites (35.8 individuals per site). Krauss *et al*. (2011), Thomas *et al*. (2011), Armengot *et al*. (2012) and FIBL (2012) reported organic fields were 5 times higher in plant species richness, about 25 times higher pollinator species richness and 100 times higher abundance as compared to conventional fields; the of abundance of cereal aphids was 5 times lower in organic fields, while predator abundances were 3 times higher and predator-prey ratios 25 times higher in organic fields indicating higher potential for biological pest control in organic fields.

Organic hedgerows harbored more biodiversity/ species richness during both pre-harvest and post harvest period, due to convenient availability of niches all the time. In crop fields interestingly species density, dominance and abundance of most taxa are lost/altered after harvest in both conventional and organic fields. It is due to the lack/availability of habit, habitat and microclimate; lack of organic matters after harvest in organic fields result in exclusion of some species and the absence of chemical applications in conventional fields invite some species. There was a positive correlation ($r = 0.39$, $p<0.05$) between organic farms with biodiversity (density, dominance and abundance) and there was a negative correlation ($r = 0.22$, $p<0.05$) with biodiversity (density, dominance and abundance) in conventional farming due to extensive use of conventional fertilizers, pesticides/insecticides resulting in the loss of biodiversity. Organic farming supported more weed species/trees and the liquid organic amendments used in organic farming provides comfortable habit and habitat for soil microbes and various beneficial arthropod family, thus supporting more amphibians, reptiles and avian species. This is how organic fields support a wider series of species density, diversity and abundance than conventional fields. Agro-biodiversity especially in terms of density/diversity/abundance is strongly influenced by nature of inputs into the agro-ecosystems and from this study it is proved that if the farms are fully organic in its inputs it will enhance the biodiversity and a series valuable ecosystem services, whereas if the inputs are fully inorganic we are able to observe a series of serious negative impacts in the ecosystems and its services. If it is 100% organic biodiversity and ecosystem services are to be enhanced, while contrary is to when the inputs are 100% inorganic/chemical.

In summary, results of the present study indicated that organic farming supported higher levels of plant and animal biodiversity, density and abundance. Figure 4 indicates that in organic fields had greater diversity (ranging 4.5 to 1.5) than conventional fields (ranging 2.5 to 1) in all taxa except in carbides where diversity was slightly higher in conventional fields (2.3) than organic fields (2). This is similar to the previous findings from Hole *et al.* (2005), Thomas *et al.* (2011), FIBL (2012) and Pandey and Singh (2012). Organic fields are more diverse than conventional fields, but the density and abundance of carbides were higher on conventional fields thus, an indicator of disturbed and contaminated soils (Oehl *et al.*, 2004; Ponce *et al.*, 2011). The exclusion of synthetic pesticides and fertilizers from organic farming is a fundamental difference between the contrasting farming systems. The present study also revealed that organic agricultural fields differ from conventional agricultural fields in the extent, composition and management of habitats. These differences between farming systems are key to understanding biodiversity differences between agricultural fields and their roles.

CONCLUSION

Healthy ecosystems are characterized by higher species diversity. Organic farming benefit agricultural biodiversity by prohibiting the use of chemical pesticides/insecticides and conventional fertilizers in fields which in turn have a positive impact on environment, flora, fauna and human communities by avoiding both direct and indirect negative effects of conventional chemicals, while enhancing ecosystem services. Organic farming supports much greater levels of abundance and diversity than conventional farming systems. This includes those plant and animal groups that are known to have significantly declined on conventional farmland in recent years. The total in-field benefits are greater than the field boundary differences, indicating that the total biodiversity supported by organically farmed areas is substantial. Organic farming also reintroduces the benefits of mixed farming to predominantly arable areas, addressing a fundamental problem in the current agricultural situation that cannot easily be addressed. The biodiversity benefits are delivered by the whole system of organic farming, not simply by the collection of practices required by the organic standards. Establishment/careful management of non-crop habitats and field margins can greatly enhance diversity and abundance of arable plants, invertebrates, birds and mammals. The practice of organic farming positively impact agricultural biodiversity and soil quality through the provision of greater habitat heterogeneity, niche diversity that promote higher sustainable production on a long-term basis at a variety of temporal and spatial scales within the agricultural landscape.

Apart from this following policy measures must be initiated to protect/encourage biodiversity/organic farming:

- Synergies and close cooperation among different sectors (Government, NGO, universities and other research and extension services concerned) have to be fostered with the aim to support and encourage the progressive creation of an integrated organic farming knowledge net work; this will ensure the capacities and scientific activities of the concerned stake holders are oriented to be problem solving and as effective responses to the felt needs of organic farmers and biophysical nature of the concerned agro-ecosystem
- Specific priority research areas in organic agriculture need to be identified and targeted to facilitate raising of adequate fund and subsidies for wider adoption of organic farming
- A regional multidisciplinary action research network on sustainable organic agriculture may be set up in the future for Tamil Nadu-Puducherry
- A regional sustainable supply chain approach have to be established to ensure a steady supply of quality inputs (traditional seeds, biofertilizers/ pesticides, etc for organic farming), opportunities for value addition, certification, marketing and integration into community based Agro-ecotourism
- Organic agriculture courses have to be included in academic curricula, professional training opportunities on organic farming and processing practices have to be promoted

- Organic agriculture have to be integrated in the extension services plans, programmers and activities in the Govt/NGOs, with the aim to promote the effective transfer and diffusion of organic farming know among local/regional/national farmers/producers

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