

Impact of Better Management Practices on Farmland Biodiversity Associated with Sugarcane Crop

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Abstract: Over the course of time, intensification in agriculture and degradation of natural habitats have posed a serious concern for biodiversity, ecosystem functioning and food security across the globe. Sugarcane is one of the notorious crops in this regard. Keeping in view these sustainability challenges in sugar sector, certain multi stakeholder worldwide initiatives have been set up. These initiatives promote sustainable sugarcane production by promoting environmental friendly Better Management Practices (BMPs); leading to socio-economic prosperity. However, the empirical evidences of impact of BMPs on farmland biodiversity and ecosystem functions are rare. Current study aimed to evaluate the impact of four major BMPs related to fertilizers (i.e. use of farm yard manure and avoiding synthetic fertilizers), insecticides (i.e. need based application of botanical insecticides and avoiding synthetic insecticides), irrigation (i.e. need base application of irrigation after careful crop ecosystem analysis) and trash management (i.e. trash mulching after each harvest and avoiding trash burning) on biodiversity of soil macro-invertebrates, mammals and birds. After three consecutive years of BMPs application, BMP plots were more taxa rich (38) than that of non-BMP plots (33). The abundance was also higher in BMP plots (4107 individuals) than that of non-BMP plots (2718). The comparison of Shannon-Wiener and Simpson diversity indices by using bootstrapping and permutation methods revealed BMP plots as species more diverse than that of non-BMP plots. Comparison of diversity profiles by using exponential of the Ryani index further confirmed this finding. It was concluded that continuous adoption of environmental friendly BMPs can significantly improve farmland biodiversity and ecosystem functions in sugarcane crop.

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1. Introduction

Sugarcane has been cultivating in Pakistan on commercial scale since independence (i.e. 1947). It has now gained the status of an important cash crop and plays a pivotal role in the agricultural and industrial economy of the country. Pakistan is the 5th largest sugar producer country of the world with an estimated annual production of 63920 metric tons; where sugarcane is grown on 1241 thousand hectares with average productivity of 51 tons per hectares (FAO, 2009).

The land under sugarcane cultivation is often associated with loss of natural habitat and cropland. It undermines the food security status of the given place by acting as a major contributor of biodiversity loss (Srikanth et al., 1997; Netondo et al., 2010).

Species diversity which is also known as biodiversity in sociological and political perspectives

(Hamilton, 2005) is one of the basis of agriculture. Agricultural biodiversity thereby refers to all components of biodiversity –at genetic, species and ecosystem levels that are relevant to food security and ecosystem services in an agro-ecosystem (Upreti and Ghale, 2002). Besides promoting ecosystem productivity, biodiversity also contributes to ecosystem resilience and stability as it performs important ecosystem functions of nutrient recycling, maintenance of local climate, regulation of local hydrological processes, detoxification of noxious chemicals, pollution regulation of undesirable organisms etc. (Boef, 2000; Altieri, 1994).

During last two decades, the development and use of pesticides to control annual pests, weeds and diseases has been increased steadily which now has become the integral part of farming system in Pakistan (Haq et al., 2008). Besides pesticides, other

common practices like tillage, fertilizer application, irrigation and harvest and post harvest operations (e.g. trash burning) can impose temporary to long lasting impacts on average environmental conditions which leads to some change in ecosystem functions (Altier et al., 1994; Sajjad et al., 2012).

With the intensification in agriculture, the air, water and land is being contaminated. Indiscriminate and imbalanced use of synthetic fertilizers, especially urea along with synthetic pesticides coupled with unavailability of organic manures has led to considerable reduction in soil health and biodiversity (Singh et al. 2013). Heavy tillage operations and trash burning on the other hand, lead to depletion of soil and foliage-dwelling beneficial arthropods and may not impact on pest populations (Pimentel et al., 1993; Sajjad et al. 2012). Irrigation practices however have not shown very clear cut relationship with farmland macro-invertebrates but birds have been reported to be higher in abundance in medium and low intensity irrigation areas than that of high intensity irrigations areas (McIntyre et al. 2011).

Keeping in view these sustainability challenges in sugar sector, certain multi-stakeholder worldwide initiatives have been introduced like BONSUCRO (Anonymous, 2014). These initiatives promote sustainable sugarcane production by promoting environmental friendly Better Management Practices (BMPs); leading to socio-economic prosperity (WWF, 2005; IUCN, 2013). The term BMP has been used in many commodity based multi-stakeholder initiatives and is defined as 'approaches that protect the environment by helping to reduce impacts of growing commodities, also help producers to make profit in a more sustainable way'

The use of organic manure, green manuring and management of pests and diseases through the use of non-synthetic pesticides and other integrated approaches are the common feature of BMPs and organic sugarcane farming as well. The beneficial effect of sustainable sugarcane production on human health, wildlife, domestic animals, net profit and business are impressive (Kshirsagar, 2006). However, the empirical evidences in this regard are rare especially in Pakistan where less attention has been paid by stakeholders on environmental sustainability in sugar supply chain.

Current study was planned to evaluate the impact of some environmental friendly BMPs i.e. use of organic manure, use of botanical insecticides and trash mulching (avoiding trash burning) on

biodiversity of soil crawling arthropods and birds in district Jhang, Pakistan.

2. Materials and Methods

2.1 Study sites and focal plots

The study was conducted in three villages i.e. Ashaba, Lakhbadar and Madoki of district Jhang (Punjab), Pakistan (31.306°N and 72.328°E) during June to November, 2014. In each village, two types of sugarcane plots (1.2 hectares) were selected in their 2nd ratoon i.e. the 'BMPs plots' where farmers applied a set of four BMPs and 'non-BMP plots' where farmers applied their routine management practices. Each plot was surrounded by seasonal crops other than sugarcane (i.e. wheat, white clover and maize) at least up to one hectare. There was at least a distance of half kilometer between two types of plots.

Four main practices which made BMP plots distinct from non-BMP plots included the i) use of farm yard manure and avoidance of synthetic fertilizers, ii) need based application of botanical insecticides and avoidance of chemical insecticides, iii) trash mulching after each harvest and avoiding trash burning iv) need base application of irrigation after careful crop ecosystem analysis.

2.2. Data collection

Fortnightly data was recorded from 1st week of April to 4th week of September. Two types of biodiversity observations were made i.e. i) above soil inhibiting/crawling animals which could be visually observed from and ii) the visiting birds. To record above inhibiting animals, we placed 10 pitfall traps randomly in each focal plot for 24 hours in such way that each pitfall trap should be away from the other by at least 15.24 meters of distance. Each plastic pitfall trap was 0.46 meter in depth and 0.30 meter in diameter. Birds were counted by following the perimeter count method as proposed by Atkinson et al. (2006). Fortnightly data of all the three plots of each treatment (BMP and non-BMP plots) was pooled separately before final analysis.

2.3 Identification of animals:

For the convenience in work and avoiding taxonomic constraints, the arthropods were categorized into morphologically similar groups (morphogroups) and closely related species or morpho-species were clustered into their respective morpho-group i.e., ants, spiders, ladybird beetles, ground beetles (predators), sow bugs, cockroaches (scavengers), hairy caterpillars and field crickets (phytophagous). Birds were identified in field using a standard pictorial key.

2.4 Data analysis:

We assessed diversity by using Shannon-Wiener index and Simpson Index (1-D) and used rank-abundance curve plots as a way to visualize the structure of the animal communities (Magurran, 2004). To measure our sampling efforts, individual based rarefaction curves were used to estimate the number of species (S) expected in a random samples of 'n' individuals taken from a larger collection made up of 'N' individuals and 'S' species (Gotelli and Entsminger, 2005). Diversity was compared by using a module which computes a number of diversity indices for two samples, and then compares the diversities using two different randomization procedures as follows:

Bootstrapping: In this method, the two samples i.e. A and B are pooled first and then 1000 random pairs are taken of samples (Ai, Bi) from this pool, with the same numbers of individuals as in the original two samples. For each replicate pair, the diversity indices $\text{div}(A_i)$ and $\text{div}(B_i)$ are computed. The number of times $|\text{div}(A_i) - \text{div}(B_i)|$ exceeds or equals $|\text{div}(A) - \text{div}(B)|$ indicates the probability that the observed difference could have occurred by random sampling from one parent population as estimated by the pooled sample.

Permutation: In this method, 1000 random matrices with two columns (samples) are generated, each with the same row and column totals as in the original data matrix. The p value is computed as for the bootstrap test.

The validity of the results was further confirmed by using the exponential of the Renyi index (Renyi, 1961), which depends upon a parameter 'alpha'. For $\alpha=0$, this function gives the total species number, $\alpha=1$ gives an index proportional to the Shannon index, while $\alpha=2$ gives an index which behaves like the Simpson index. The analysis was performed by using computer software 'PAST' (Hammer et al., 2001).

3. Results and Discussion

A total of 6486 individuals were recorded in 4 phyla, 8 classes and 22 orders in both BMP and non-BMP plots. Insects comprised of the highest proportion (61.47%) of the total abundance followed by woodlouse (18.32%), birds (12.92%) and spiders (5.97%). Centipedes, snails, earthworms and rodents constituted only a smaller proportion of total abundance (Table 1). Being yearlong crop, sugarcane provides an ideal micro-climate for flourishing a variety of arthropods (Ahmed et al., 2004). Previously, few attempts have been made regarding documenting macro invertebrate biodiversity of sugarcane crop in Punjab, Pakistan i.e. Mohsin et al. (2011) reported 24 species in 10 orders and 2 classes while Ahmed et al. (2004) reported 117 insect species in 12 orders. As our main focus was to assess the impact of some BMPs on farmland biodiversity associated with sugarcane crop, we broadly categorized animals into groups, so our findings are more generalized rather than being species specific.

Table 1. Comparison of taxa richness, abundance and diversity indices among BMP and non-BMP plots by using Bootstrapping (Boot) and Permutation (Perm) at alpha 0.05 level.

		BMP	Non-BMP	Boot p(eq)	Perm p(eq)
Richness	Ashaba	34.00	18.00	0.00	0.00
	Lakhabadar	22.00	15.00	0.00	0.00
	Madoki	23.00	18.00	0.01	0.01
	Cumulative	39.00	30.00	0.00	0.00
Individuals	Ashaba	1116.00	701.00	0.00	0.00
	Lakhabadar	1018.00	1166.00	0.00	0.00
	Madoki	1660.00	825.00	0.00	0.00
	Cumulative	3794.00	2692.00	0.00	0.00
Shannon-Wiener	Ashaba	2.75	1.89	0.00	0.00
	Lakhabadar	2.28	1.74	0.00	0.00
	Madoki	2.13	2.04	0.09	0.10
	Cumulative	2.51	2.18	0.00	0.00
Simpson index	Ashaba	0.90	0.77	0.00	0.00
	Lakhabadar	0.85	0.77	0.00	0.00
	Madoki	0.81	0.82	0.35	0.36
	Cumulative	0.86	0.84	0.00	0.00

Table 2. Comparison of population of animals in eight different Classes among BMP and non-BMP plots. Percent population is given in parenthesis.

Group	Class	BMP	Non-BMP	Total
Insects	Insecta	2239 (59.01)	1748 (64.93)	3987(61.47)
Woodlouse	Isopoda	749 (19.74)	439 (16.31)	1188 (18.32)
Spiders	Arachnida	215 (5.67)	172 (6.39)	387(5.97)
Centipedes	Chilopoda	3 (0.08)	-	3 (0.05)
Snails	Gastropoda	40 (1.05)	9 (0.33)	49 (0.76)
Earthworms	Oligochaeta	4 (0.11)	-	4 (0.06)
Rodents	Mammalia	24 (0.63)	6 (0.22)	30 (0.46)
Birds	Aves	520 (13.71)	318 (11.81)	838 (12.92)

The individual based rarefaction curves (using expected number of taxa as function of sample size) of both the plot types reached at an asymptotic level (taxa richness did not increase with increasing sampling efforts at certain point) showing that our sampling efforts were enough to represent the maximum number of taxa (Fig. 1).

The taxa assemblage structure visualized through rank-abundance curves, exhibited similarity among the two plots i.e. few abundant species and large number of scarce species. Moreover, the five most abundant taxa were also common in taxa assemblage structure of both the plots i.e. woodlouse, ants, chinch bugs, termites and spiders, respectively (Fig. 2).

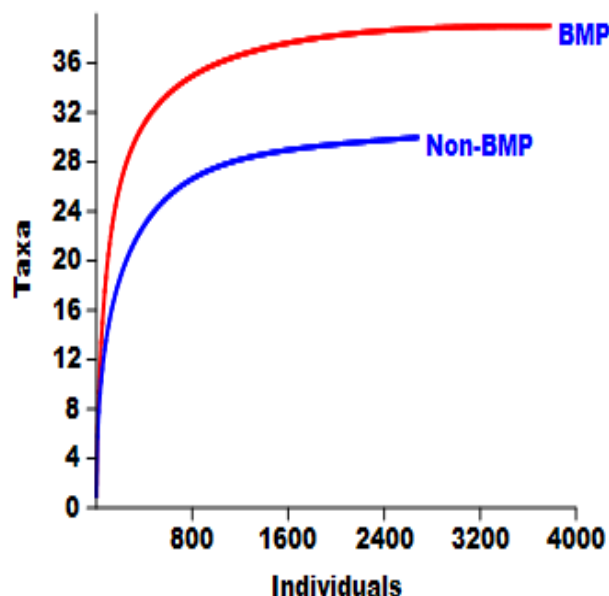


Fig. 1. Rarefaction curves of BMP and non-BMP plots based on individual rarefaction method showing the expected number of taxa as a function of sample size.

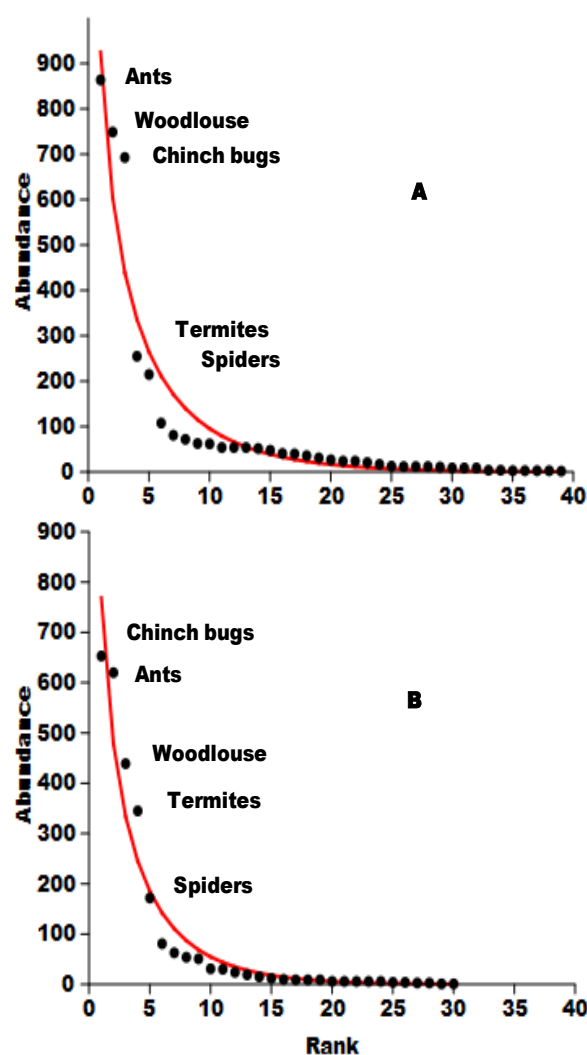


Fig. 2. Rank-abundance curves of animals among BMP-plots (A) and non-BMP plots (B). Names of taxa with the highest abundance are mentioned.

BMP plots were significantly more taxa rich at all the three locations than that of non-BMP plots i.e. 34, 22 and 23 species (or groups of species) in BMP plots against 18, 15 and 18 species (or groups of species) in non-BMP plots at Ashaba, Lakhbadar and Madoki, respectively (Table 2 and 3).

Centipedes and earthworms were the sole feature of BMPs plots indicating the positive impact of BMPs on soil macro-arthropods. Singh et al. (2013) in the similar study also emphasized on an adequate assessment of soil macro-fauna in terms of their diversity and multiple biological interactions, with the ultimate objective of reducing the use of chemicals (herbicides, insecticides, fertilizers), thus ensuring the long-term sustainability in agricultural systems.

As we applied botanical insecticides, avoided trash burning, applied irrigations only when needed and avoided synthetic fertilizers in BMP plots, these practices are also regarded as sustainable agriculture practices and also a necessary part of organic farming. Certain explanations have been given by researchers regarding the negative impacts of synthetic insecticides and fertilizers on soil biodiversity. For example urea after adding in soil is converted into (excrete) anhydrous ammonia, ammonium hydroxide and carbon dioxide which are toxic or harmful to organisms (Singh et al. 2013). Similarly, contrary to synthetic insecticides, botanical insecticides with few exceptions, act quickly, degrade rapidly and have low mammalian toxicity. Resistance to these compounds is not developed quickly as unlike conventional pesticides that are based on a single active ingredient. They affect only target pest and closely related organisms, are effective in very small quantities and provide the residue free food and a safe environment to live (Ware 1983).

The abundance was also significantly higher in BMP plots than that of non-BMP plots at Ashaba and Madoki while it was lower in Lakhbadar. However the overall experimental abundance was higher in BMP plots. Similarly, diversity indices including Simpson and Shannon-Wiener indices also had statistically stronger values in BMP plots than that of non-BMP plots at Ashaba and Lakhbadar while they were statistically similar in both the plots at Madoki (Table 2). Diversity profile of both the BMP and non-BMP plots (as analyzed by using exponential of Rany index) also revealed significantly higher alpha values in BMP plots than that of non-BMP plots (Fig. 3).

Intensification in agriculture coupled with fragmentation and loss of farmland habitat qualities

have resulted in reduced biodiversity values at farmlands. In Europe for example, from 1961 to 1999, the agricultural land under irrigation was nearly doubled; the use of nitrogenous and phosphate fertilizers was increased by 638% and 203%, respectively, while the production of pesticides was increased by 854% (Green et al., 2005). As a result, average breeding populations of Europe's common farmland in 2006 was about 50% lower than in 1980, which remained irreversible (PECBM, 2006). Similarly, sugarcane farming has led to the reduction of *Melaleuca* ssp. and the eucalyptus tree species in Australia (Johnson, 2000) on account of intense subsistence farming and agricultural diversification.

On the other hand, organic farming which is characterized by lower farming intestines and higher proportion of semi-natural areas has shown clear benefits of biodiversity and ecosystem functions over conventional farming. Depending on altitude, organic farms have reported to have 46 to 72 percent more semi-natural habitats, 30 percent more number of species and 50 percent more individuals than non-organic farms (Ocak and Ogun, 2012). Organic farming however is not possible at a large scale especially in developing countries like Pakistan, however, adoption of some BMPs related to pest management, soil management and irrigation methodologies can greatly support useful farmland biodiversity and ultimately their ecosystem functions.

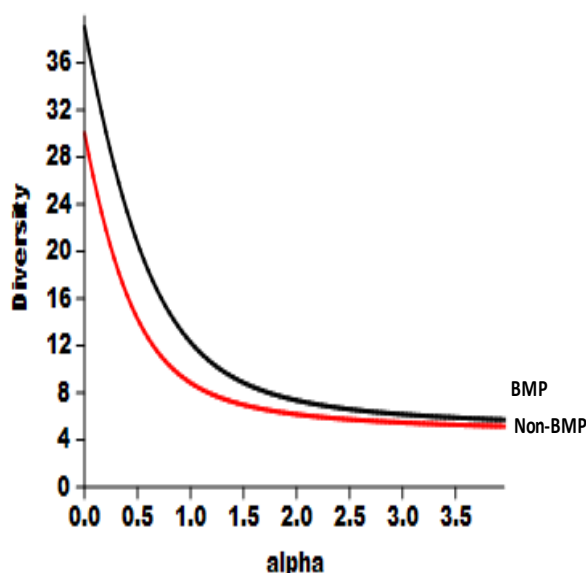


Fig. 3. Comparison of diversity profiles of BMP and non-BMP plots by using the exponential of the Renyi index.

Studying the functional group diversity (i.e. groups of species sharing the same function) is the more useful idea when studying the impact of agriculture on biodiversity (Souza et al., 2013) as it ultimately involves ecosystem functions. For example in current study, arthropod biological control agents (i.e. may be regarded as a functional group) -included coccinellids, rove beetles, assassin bugs, chrysopa, mantis and ants- were more abundant in BMP plots than that of non-BMP plots. Similarly, soil builders and scavengers (i.e. may be regarded as another functional group) in this study -included earthworms, ants, ground beetles, termites, earwigs, woodlouse, centipedes and snails- were also higher in abundance in BMP plots than that of non-BMP plots.

4. Conclusion

It was concluded that adoption of four BMPs i.e. i) use of farm yard manure and avoidance of synthetic fertilizers, ii) need based application of botanical insecticides and avoidance of chemical insecticides, iii) trash mulching after each harvest and avoiding trash burning iv) need base application of irrigation after careful crop ecosystem analysis, can significantly improved species richness and functional diversity in sugarcane agro-ecosystem.

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Competing Interests: The authors declare that there is no potential conflict of interest.

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