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SOIL QUALITY EVALUATION OF ORGANIC AND CONVENTIONAL FARMING IN KARAKORAM LANDSCAPE, PAKISTAN

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ABSTRACT

In the rugged landscape of the Karakoram Range in lower Hunza Pakistan, we examined the agricultural soil quality under conventional and organic farming systems. Soil samples were collected from both farming practices using quadrates of $10^{*}10cm^{2}$ at a depth of 0-10cm for both physico-chemical and microarthropod extraction. The modified Berlese funnel method was used to extract soil microarthropod communities. The Soil Biological Quality Index (QBS-ar), Population Density (PD), and Taxa Richness (TR) were determined. Multivariate analysis of variance (MANOVA) showed a significant variation between conventional and organic farming systems for pH while most of the investigated parameters like bulk density (BD), moisture, soil temperature, Soil organic carbon (SOC), Soil organic matter (SOM), Nitrate nitrogen (NO_3-N), Available Phosphorus (Av. P), Exchangeable Potassium (Ex.K), QBS-ar, Population density, and Taxa richness did not show significant differences, however, the mean value of BD, PD, TR, and moisture were higher at organic farming while soil temperature, pH, Electrical conductivity (EC), SOM, SOC,NO_3-N, Ex.K and Av. P were higher in the conventional farming system. Pearson Correlation showed a significant negative relationship of EC with SOM, SOC, QBS-ar, and TR. In contrast, TR has shown a positive correlation with SOC, SOM, QBS-ar, and PD. Organic farming fields have a greater biological quality of soil, as evaluated by QBS-ar, TR, and PD, indicating improved soil quality/ conditions. In contrast, most of the physico-chemical and fertility parameters are higher in the conventional farming system.

Keywords: Mountain agriculture, QBS-ar, Soil organic carbon, Tillage.

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INTRODUCTION

Like other mountain areas, the soils of Karakoram and Himalaya ranges are susceptible to the impact of climate change and land use practices. The vulnerability to environmental change necessitates appropriate management of mountainous soils to balance agricultural productivity and agro-ecosystem health (Hussain *et al*., 2020). For millennia, the mountain people have adopted "Mixed Mountain Agriculture" and used their natural resources in a sustainable way without over-exploitation (Ali *et al*., 2017). In order to meet the increasing food demand due to rapidly growing population, our agriculture system has been shifted toward conventional farming. According to Singh and Singh (2017), the Green Revolution increased agricultural output by several orders of magnitude; it came at a significant environmental cost, including climate change. The extensive use of fossil fuels, natural resources, agrochemicals, and machinery compromised the ecological integrity of agroecosystems. In addition, it posed a danger to long-standing agricultural traditions. The conventional agriculture system relies highly on chemical fertilizer, with enhanced use of chemicals for weed and pest control, while tending to increase yield without employing organic natural manure (Altieri, 2002). Whereas the organic farming/cropping system can be defined as a production system that is sustainable in space and time, protecting and managing natural resources, avoiding the use of chemicals that are harmful to the environment and humans, and sustaining soil biological diversity and fertility (Bettiol *et al.,*2002). Organic crop production is one of the alternative farming approaches that has been pushed as a way of reducing pollution in the environment (Liliane and Charles, 2020).

The conventional farming system has been practiced on a great scale around the globe; consequently, causing soil degradation creating a massive threat to the environment, and affecting sustainable agriculture production for future generations (Montgomery, 2007). It results in an increase in soil salinity, bulk density and the quantity of nitrogen which leads to the leaching of nitrogen and contaminating the groundwater (Logsdon *et al.,* 1993). Moreover, the prevalence of frequent droughts, attributed to current unstable practices of agriculture, plays a crucial role in contributing climate change (Reganold *et al.,* 1995; Pimentel *et al.,* 1995; Mader *et al.,* 2002a; Sullivan, 2002; Montgomery, 2007; Lal, 1994). Both farming practices greatly affect the soil's physico-chemical and biological properties. Soil enzyme activity in organic agricultural systems has been shown to be higher than that in conventional agriculture systems (Kobierski *et al*., 2020). Several studies showed a higher abundance of soil fauna in organic farming (Bokhorst, 1989; Brussaard *et al.* (1988, 1990); Swezey *et al*., 1994). According to Mantoni *et al.* (2021), organic management improves the quality of soil biology, which recommends the adoption of organic farming to maintain soil health. They also found that certain physical and chemical features of the soil have a significant impact on soil biology and microarthropod community structure, supporting the use of microarthropods as biological indicators.

The present study has been carried out in Hussainabad, a village situated in lower Hunza, Karakoram Range to evaluate the variations in soil properties that have undergone conventional and organic farming systems using selected physical, chemical and biological parameters. The sampling sites (agriculture field in Urdu called Khet) organic and conventional fields were identified with the help of local farmers and soil samples were taken for analysis.

MATERIALS AND METHODS

Study Area: Hussain Abad village, located in lower Hunza on N36°014.974, E74°023.218 at a height of 1863-2040m on the left bank of the Hunza River in the Karakoram mountain ranges of Northern Pakistan, features a rugged terrain. The valley is divided into five towns: Khizerabad, Seko, Centre Hussainabad, Shabaran, and Dolmani, where locals have followed organic and conventional farming practices for decades (Figure 1). Farmers use a sophisticated approach to manage their fields organically; they have a wealth of traditional knowledge about soil health, but most of them are unfamiliar with scientific vocabulary. The farmers use leaf litter from the forest and crop residues from cropping land as animal beds in cattle sheds where these litter and crop residues undergo the process of compositing in a certain period of time. In the month of November-January, the compost is put into agriculture fields prior to tillage to prepare the soil for cultivation.

Farmers have been shifting their practices from organic to conventional farming in Gilgit Baltistan for the last few decades when fertilizers made their way into the world of agriculture. This shifting is due to the construction of the Karakoram Highway and the high availability of chemical fertilizers in the market. Farmers use fertilizers (nitrates, urea, and phosphate) along with animal manure to get maximum yield in one go in the conventional fields. Whereas, the organic fields are treated with cattle manure. The chemical fertilizers mostly used by the farmers in Gilgit Baltistan are Nitrophos, Phosphate (NP), P_2O_5(20%), Nitrogen (22%), Urea, and Nitrogen (46%).

Research Design: The entire village was divided into three clusters i.e. Seko, Centre Hussainabad and Shabaran for soil sampling from both organic and conventional fields (Figure 1). All three clusters of farmers practice both organic and conventional farming. In all three clusters, organic and conventional fields in Urdu called a Khet were identified with the help of local farmers residing in the area involved in farming. A total 54 soil samples were collected from organic and conventional fields (3 (clusters)*9 (soil replicates) *2 (two farming practices: organic and conventional) = 54). Samples were taken from the topsoil using 10x10x10cm^{2}quadrate sizes. Bulk samples were taken from each site by using a bulk core ring and sealed in airtight polythene bags. During the sample collection, the temperature of the soil was recorded using a temperature probe. Samples taken from each site were sealed, labeled, and transported to the laboratory for further analysis.

Laboratory analysis: Soil microarthropods extraction was done by using modified Berlese-Tullgren funnel method (Phillipson, 1971; Coleman *et al.,* 2004) in the laboratory. The gravimeter method was used for the determination of soil moisture whereas Bulk density was measured through the core method (Blake and Harte, 1986). Prior to any physico-chemical analysis, the soil was sieved through 2mm mesh size. Soil pH was determined by a glass-calomel electrode (WTW Series, inoLab 720) using standard methods of 1:1 of soil and distilled water mixture and EC was determined by an electrical conductivity meter (4510 Conductivity meter JENWAY). Soil carbon was measured using the combustion method (Nelson and Sommers, 1983).

Data Analysis: To determine the significant difference between the two farming systems, we have applied the General linear model, MANOVA (Multivariate analysis). To determine the further relationship between various investigated soil variables we have applied Pearson's correlation using SPSS-20.

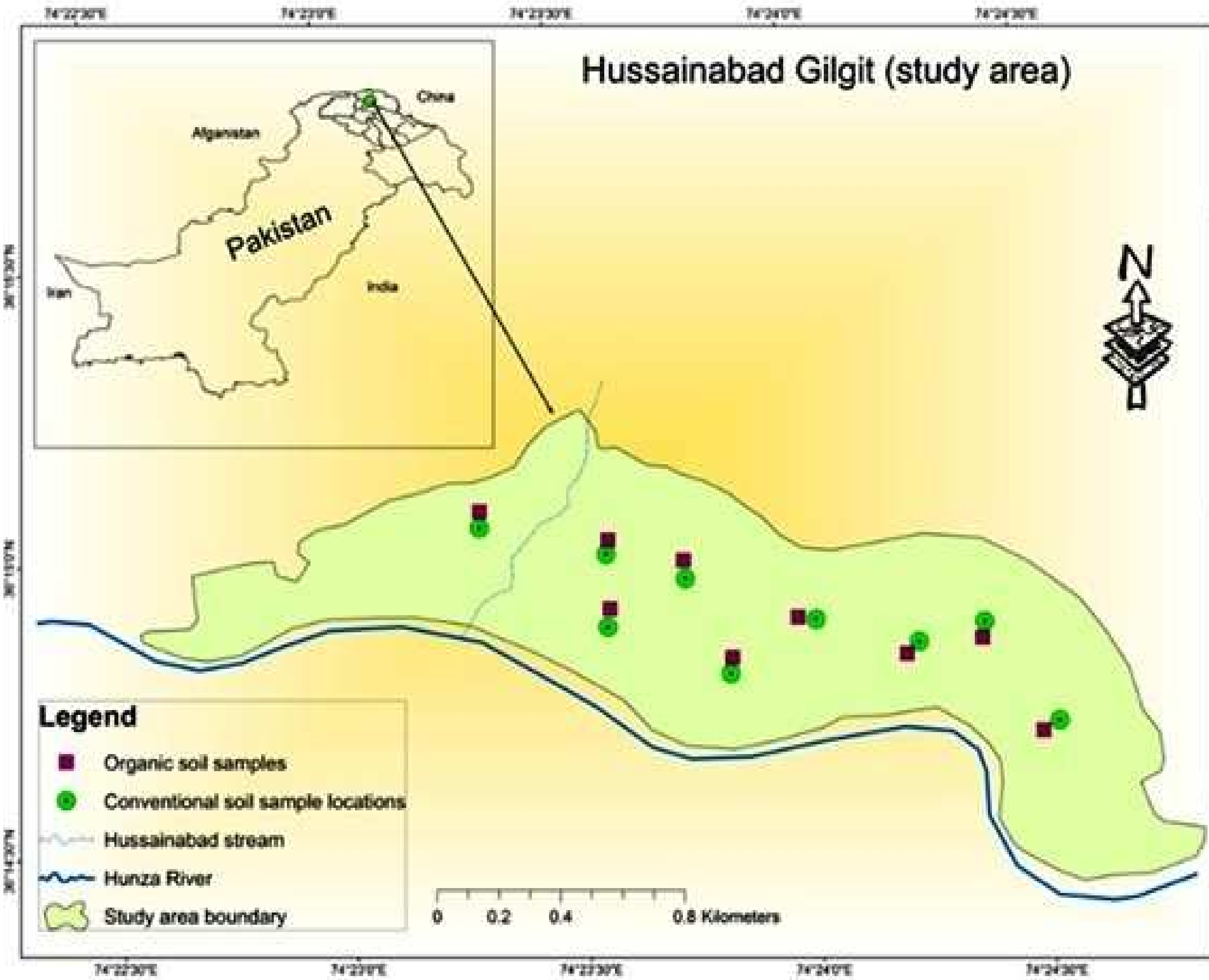

Figure 1: Map of study area indicating sampling locations

RESULTS AND DISCUSSION

Physico-chemical properties across conventional and organic farming systems: MANOVA showed significant variations between conventional and organic farming systems for soil pH while most of the investigated parameters like soil bulk density, moisture, temperature, SOC, SOM, were not significantly different (Table 1,2,3). The mean value of soil moisture was higher in organic farming systems while soil temperature, pH, EC, SOM, and SOC values are observed to be higher in conventional farming systems (Table 1). Overall poor SOC (< 1 %) was reported at both the farming practices but slightly higher under organic farming sites compared to conventional sites. Similarly, the results of Mader *et al.* (1999) reported high microbial biomass C, enzyme activity, and earthworms in organically treated soils as compared to conventional farms. Moreover, Gerhardt (1997) reported similar results in the organic farming system. Soil pH is significantly higher at conventional sites (alkaline: 7.8) compared to organic farming (slightly alkaline 7.3) as shown in Table 1. Soil pH is one of the most important chemical properties influencing reactions in soil. Soil fertility is greatly influenced by pH due to its impact on the solubility of various nutrients. Optimum soil fertility is typically observed within a pH range of 6-7.2. The agricultural soils of Haramosh valley, located in central Karakoram, an alkaline pH (7.8) was recorded (Begum *et al.*, 2019).

Soil organic carbon is vital for the soil fertility as it plays an important role in retaining water, improving soil structure and acting as a chemical buffer. Fertility parameters such as NO_3-N, Av. P and Av. K didn't vary significantly between organic and conventional farming sites. However, the mean values were slightly higher at conventional sites compared to organically treated soil (Table 4). This may be due to input of chemical fertilizer along with the cattle manure applied once a year while preparing the field for cultivation. Our findings contradict the findings of other researchers who found that soil treated with organic manure had improved soil chemical characteristics (Herencia *et al.,* 2008: Pelosi *et al.,* 2015: Wortman *et al*., 2011: Sheoran *et al*., 2018). Studies by Herencia (2008), reported that organic farming practices resulted in higher soil organic carbon (OC), N, and available P, K, Fe, and Zn further maintaining SOM level is the fundamental and key component to increase the soil fertility.

Table 1: Mean values of Physico-chemical and biological properties.

Treatment	SOM (%)	SOC (%)	ST (ºC)	pH	EC (µS/cm)	QBS-ar	PD (individuals/m²)	TR
Organic	1.599	0.7038	23.948	7.355	560.4	44.07	3513.7	5.63
conventional	1.619	0.7124	25.259	7.771	563.1	38.18	2977.7	5.48

BD= Bulk density, SOM= Soil organic matter, ST= Soil Temperature, SOC= Soil Organic matter, EC= electrical Conductivity, QBS-ar = Soil Biological quality index, PD= Population density, TR= Taxa Richness

Table 2: General Linear Model (Multivariate) MANOVA.

	BD	Moisture	Temp	pH	EC	SOM	SOC
Treatment	0.23^{ns}	1.64^{ns}	1.86^{ns}	43.24^{***}	0.00^{ns}	0.01	0.01
Location	17.3^{***}	2.54^{ns}	13.745^{***}	15.03^{***}	0.68^{ns}	0.06^{ns}	0.06^{ns}

NOTE: $P<0.05=^{*}$, $P<0.01=^{**}$, $P<0.001=^{***}$, non-significant=ns

BD= Bulk density, SOM= Soil organic matter, ST= Soil Temperature, SOC= Soil Organic carbon, EC= Electrical Conductivity.

General linear model or multivariate analysis indicated that BD, soil temperature, pH, QBS-ar and TR differ significantly with respect to different locations (Tables 2 and 3). The significant values observed between treatment and location for the parameters are BD (P<0.05), Moisture (P<0.05), Soil Temperature (P<0.05), pH (P<0.05) SOM, and SOC (P<0.05) respectively (Table 1). The results of the Pearson Correlation matrix showed a significant negative correlation between BD and moisture, a positive relationship between soil moisture with temperature and pH as expected (Table 6).

Soil Biological Quality Index (QBS-ar) between conventional and organic farming: Six different groups of soil microarthropods were recorded comprising Acari, Collembola, Chilopoda, Diptera (Adult and Larvae), Coleopteran (Adult and Larva), and Formacidae in both organic and conventional farming system except Symphyla found only at organic fields. Between conventional and organic agricultural systems, MANOVA revealed non-significant variations in biological parameters such as QBS-ar index, population density, and taxonomic richness (Table 3). However, as compared to conventional farming, the mean value of Population Density, Taxa Richness, Bulk Density, and Soil biological quality index, QBS-ar was found to be higher in organic farming, indicating improved soil conditions for soil fauna (Tables 3, 4 and 5). Population density at organic forming was slightly higher (3513 ind./m²) compared to conventional (2977 ind./m²). Higher richness and diversity of fauna reflects more fertile soil and favorable condition for the development of diverse plant communities and greater phytomass (Khaziev, 2011). Organic farming enhances the abundance and species richness of soil organisms as compared to conventional field farming, (Ghiglieno *et al.,* 2019, 2020).The soil biological quality index was not statistically significant between the two farming systems, but mean values were observed slightly higher in the organic field (Table 3, and Figure 2). Much research showed higher QBS-ar in organic farming as compared to conventional (Parisi *et al*., 2005; Rüdisser *et al.,*2015).

Table 3: General Linear Model Biological parameters

	QBS-ar	PD	TR
Treatment	1.91^{ns}	0.24^{ns}	0.77^{ns}
Location	2.99^{*}	1.46^{ns}	3.62^{*}
TT Vs Location	0.43^{ns}	0.23^{ns}	1.66^{ns}

PD, Population density, QBS-ar, Soil biological Quality, TR Taxa Richness

Table 4: Mean values of soil fertility parameters.

Treatments	$N-NO_3$(ppm)	Av. P (ppm)	Av.K(ppm)
Organic	4.77	2.71	60.37
Conventional	7.39	3.23	71.0

$N-NO_3$ = Nitrate Nitrogen, Av.P = Available phosphorus, Av. K= Available Potassium

Table 5: QBS-ar values under conventional and Organic farming systems

Soil fauna	Site 1		Site 2		Site 3	
	Organic	Conventional	Organic	Conventional	Organic	Conventional
Acari	20	20	20	20	20	20
Chilopoda	20	20	-	20		-
Diptera larva	10	10	10	10	10	10
Diptera adult	-	1	1	-	1	1
Collembola	28	18	39	38	8	8
Coleoptera Adult	-	-	5	5	-	5
Coleoptera larva	-	5	5	5	-	5
Formacidae	5	5	5	-	-	-
Symphyla	-	-	20	-	-	-
QBS-ar	**83**	**59**	**105**	**98**	**39**	**49**

Table 6: Correlation Matrix (Bivariate correlation) among various soil properties.

	BD	Moisture	ST	pH	EC	SOM	SOC	QBS-ar	PD	TR
BD	1									
Moisture	-.55**	1								
ST	-.23	.29*	1							
pH	-.31*	.33*	.14	1						
EC	-.22	.15	.10	-.09	1					
SOM	.19	-.15	-.14	.05	-.89**	1				
SOC	.19	-.15	-.14	.05	-.89**	1**	1			
QBS-ar	-.02	.12	.17	-.14	-.28*	.25	.25	1		
PD	-.05	.08	.16	-.17	-.17	.22	.22	.66**	1	
TR	.10	.01	.12	-.09	-.36**	.32*	.32*	.85**	.56**	1

Note: **. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

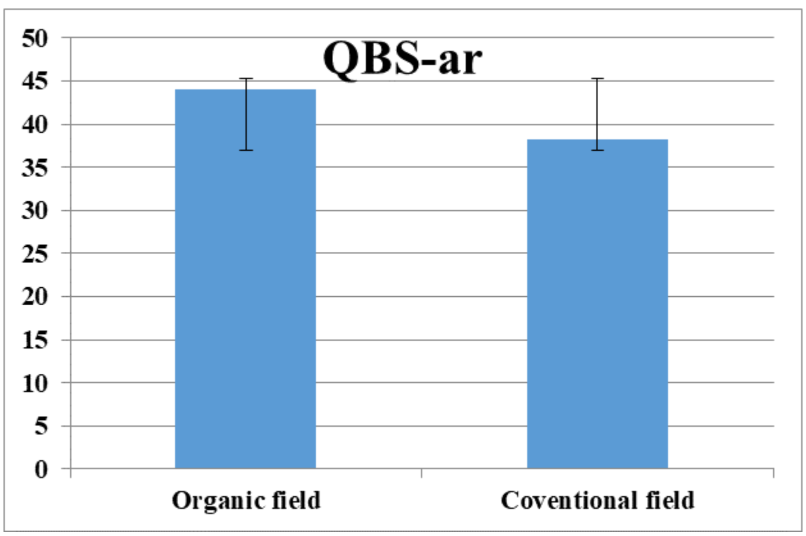

Figure 2. Comparison of QBS-ar between organic and conventional field

Pearson's correlation showed a positive correlation of QBS-ar with PD and TR (Table 6). As explained by Howard & Howard (1990), higher QBS-ar and PD are extremely related to high SOC values and showed a positive relationship with each other. Soils with high porosity and organic matter are observed with high levels of population density and diversity of mesofauna (Anderen & Lagerlof, 1983). Higher Shannon diversity index, microarthropods abundance, soil total respiratory activity and earthworm at the organic plots were reported by Bettiol *et al.* (2002). Soil pH has a negative correlation with QBS-ar, PD and TR (Table 6), similar findings were reported by Begum *et al.* (2010) and Begum *et al*. (2011) in the Nepal Himalayas. Moreover, moisture has a positive correlation with QBS-ar, PD and TR as expected, soil moisture is one of the factors that support microbial growth and performance in the soil. Soil biological quality index QBS-ar were found to be higher at all the sites except site 1, Acari was the most dominant group at all the sites. Acari, Collembola, and Diptera were found at all the sites while Symphyla was found only at one site (Table 5). Higher QBS-ar was reported in organic than conventional soils reported by Simoni *et al.* (2013). According to Gagnarli *et al*. (2015) higher abundance of mesofauna is associated with organic vineyards. A significant negative relationship of EC with SOM, SOC, QBS-ar, and TR has been indicated whereas TR has shown a positive correlation with SOC, SOM, QBS-ar and PD as expected (Table 6). The higher the soil organic carbon higher the diversity and population of soil micro arthropods leading to higher QBS-ar.

Conclusions: This research shows that organically treated fields have higher soil biological quality, as determined by QBS-ar, than conventionally treated fields, which have somewhat superior soil ecological characteristics. Most of the investigated soil physico-chemical properties were found slightly higher in conventional farming fields due to the input of chemical fertilizers. According to the findings of this study, local people should practice organic farming so that they can use soil in a sustainable manner. Soil is not only a source of food, but it also plays an important part in maintaining our ecosystem by providing a habitat for a broad collection of soil organisms. Further intensive research is required to cover data from different seasons and controlled plots for more accurate results.

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