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Effect of Shifting Cultivation on Soil health and Microbial Diversity in Junnar Taluka of Pune District

P. Vasudevan [a], R. G. Jaybhaye [b] and S. Panicker [a*]

[a] Dr. D. Y. Patil Arts, Commerce, Science College, Sant Tukaram Nagar, Pimpri, Pune-411018, India.
[b] Department of Geography, Savitribai Phule Pune University, Pune-411007, India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors PV and RGJ designed the study. Author PV conducted data gathering. Authors PV and SP wrote the article. All authors read and approved the final manuscript

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ABSTRACT

Background: Swidden cultivation, slash and burn cultivation, and bush-fallow agriculture are other names for shifting cultivation. Around the world, its name is different. Crop type and farming methods have an impact on the physico-chemical properties of the soil. Soil health is also influenced by the quantity and biomass of microorganisms present.
Aims: The goal of the current study was to determine how soil bacterial communities and soil quality in Pune district's western ghat region were affected by shifting farming.
Study Design: 18 soil samples from 4 villages of the Junnar tehsil were collected after harvesting the cultivated crop.
Place and Duration of Study: The sample was collected within the 2 to 4 acres of the shifting cultivation plots identified in the villages in the western ghat region of Pune district.
Methodology: The soil samples were collected after harvesting every crop and from the fallow land. Analysis of Physico–Chemical properties of soil samples was performed. Bacteria were isolated and identified from the soil samples. Statistical analysis was done to interpret the obtained results.

**Corresponding author: Email: suneetapanicker@gmail.com;*

Results: The fallow land and crop (Varai, Khursani, Sawa, Nachani, and Hulga) harvested soils were among the soil samples. Different numbers of ten distinct bacterial genuses were isolated from each soil. When compared to fallow soil, the Total Viable Count (TVC) of the crop harvest soil was shown to have significantly dropped. It was also discovered that certain soil characteristics improved throughout the fallow period.
Conclusion: The results pointing out the importance of the length of the fallowing on the soil health and thus on the crop yield.

Keywords: Shifting cultivation; physico-chemical characters; fallow period; TVC; soil health.

1. INTRODUCTION

Shifting cultivation has a long history that dates back to the beginning of agriculture [1]. The term "Shifting Cultivation" is used differently throughout the world, however it is commonly associated with "Slash and Burn" and "bush fallow" farming. In the hilly regions of northeastern India, Podu in Orissa, Kumari in the Western Ghats, watra in Rajasthan, Penda, Bewar, or Dahia in the Madhya Pradesh district of Bastar, it is referred to as "Jhum."

In addition to the hilly Eastern Ghats region of Andhra Pradesh, Madhya Pradesh, and portions of the Western Ghats, where it survives in a modified form, shifting agriculture is highly prevalent in the North Eastern hilly region of India as well as Orissa. In the Western Ghats, shifting farming was commonplace and extended northward along its forested peaks to the south-west Aravalis extension in the district of Dungarpur.

1.1 Changes in Soil Fertility during Shifting Cultivation

There are many reports on potential use of microbial properties as measure of soil productivity or microbial activity [2]. Soil enzyme activity which is one of the biochemical properties of soil plays a crucial role in regulating soil nutrient cycling. Soil enzyme activities of the soil are due to the enzymes that are piled up and also from the enzyme activities of proliferating microorganisms. These are very reactive and can give accurate and fast information about the minute changes occurring in soil [3]. Microbial activities directly affect the stability and fertility of the ecosystems and can serve as sensitive indicators of ecology stress suffered by soil. Microorganisms are involved in decomposing soil organic matter nutrient cycling and stabilization of plant ecosystems [4] and thus regulate the soil processes. Moreover, the changes in the microbiota are highly coupled with the soil carbon (C) and Nitrogen (N) processing through their enzyme activities [5]. Unfortunately, not much is known about these factors or how they affect shifting cultivation in terms of the accumulation of biomass in the forest, the cycling of nutrients, and the involvement of microbes that changes with the length of the fallow period. Thus, it is imperative that we look for sustainable farming methods that can change the shifting agricultural system and have less negative effects on the ecosystem. Thus, knowing how plants, soil, and microbes interact can aid in developing a transformational shifting agriculture system. Studying how changing farming practices affect microbial diversity and, in turn, soil fertility was the primary goal of this research project.

2. MATERIALS AND METHODS

2.1 Soil Sample Collection

The Junnar taluka (19.2048° N, 73.8732° E) which is gently sloping land with moderate erosion has shallow well drained, clayey soil. 18 soil samples from 4 villages of the Junnar tehsil were collected after harvesting the cultivated crop. The sample was collected by laying 5 quadrants of 1m by 1m, within the 2 to 4 acres of the shifting cultivation plots identified in the villages. The soil sample was collected after harvesting every crop and from the fallow land. 200g soil per quadrant was collected from 1cm to 9cm depth, and was pooled together in a 5kg sterile polythene bags and transported at room temperature to the laboratory within 24hours. On arrival at the lab the soil samples were stored at 4°C, the soil samples were processed within 3 to 4 days. To determine all the parameters for each soil sample, portion of soil was air-dried and sieved through a 2 mm sieve and then was diluted in water.

2.2 Analysis of Physico–Chemical Properties of Soil

Physico–Chemical Properties of Soil like pH, Electrical Conductivity (EC), organic carbon,

available phosphorus and available potash [6], soil $CaCO_3$ [7], total cation (Ca + Mg) available sodium [8,9], soil moisture [10], soil texture [11], Water Holding Capacity (WHC) [12] were determined as described earlier.

2.3 Isolation and Identification of Bacteria

By serially diluting the soil, the total viable count of soil bacteria was used to analyze the microbial community. After dissolving 1g of soil in 10ml of saline and serially diluting it up to 10^{-10}, 0.1ml of each dilution was applied in triplicate on a sterile nutrient agar plate. These plates were incubated for 24 to 72 hours at room temperature. Colony forming units (cfu) per milliliter of soil sample were calculated by counting the bacterial colonies that continued to grow on the plates. It is the number of cfu multiplied by the volume of dilution multiplied by the dilution factor. The isolated bacterial colonies growing on these plates were visualised and picked up every day. The colony morphology was noted, Gram, spore, and capsule staining was performed and then subjected to biochemical tests to achieve identification up to the genus level according to Bergey's manual of Determinative Bacteriology, ninth edition.

2.4 Statistical Analysis

SPSS software version 21 was used to conduct statistical analyses. A correlation was generated between all the soil parameters tested in this study. Heat maps were created using R software version 3.6.1, for the correlation analysis data taken from SPSS. The richness of the collected data was used to compute the Simpson's diversity and evenness indices. Principal component analysis (PCA) was applied to the data to find common correlations between the parameters.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Analysis

A physico-chemical examination was carried out on each soil sample, which was gathered from different villages within each tehsil. Eighteen soil samples were taken from the shifting agriculture plots in four communities among the Junnar. After statistical calculations, the average and standard deviation of every parameter were taken into consideration for additional investigation.

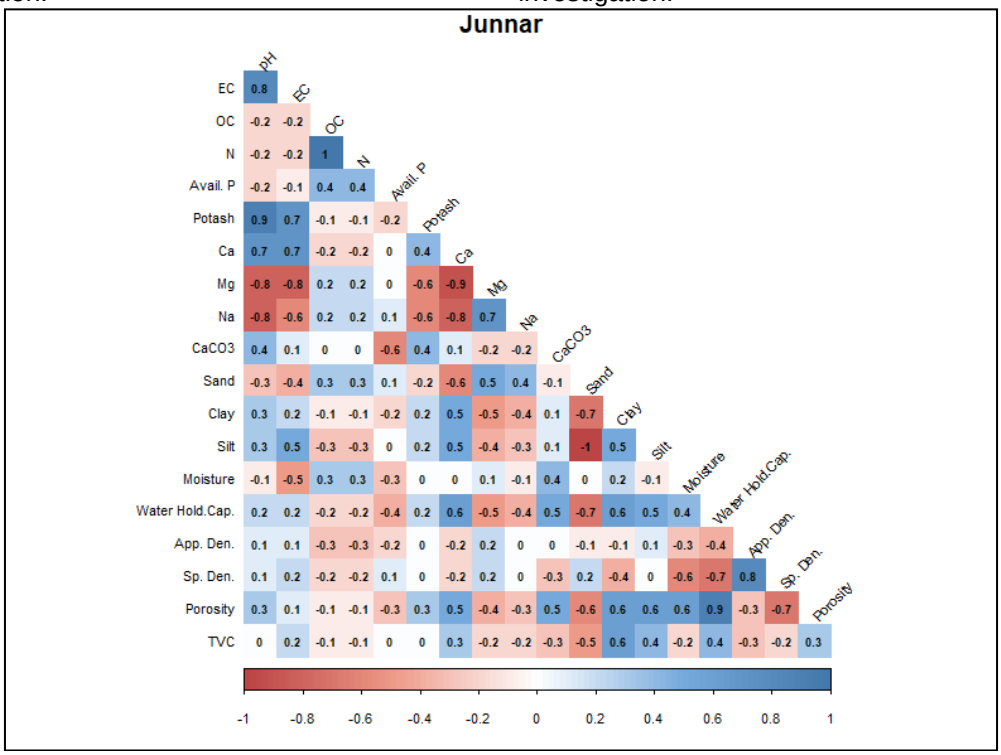

Fig. 1. Pearson Correlation correlation between Junnar soil properties; the values in red indicate a negative correlation, and those in blue indicate a positive correlation; the number of degrees of freedom (df) = 1, Strong positive correlation (above +0.6), strong negative correlation (above -0.6) and neutral relation (zero)

According to the soil analysis, there is a high positive correlation between the pH of Junnar tehsil and EC, and a strong negative correlation with Mg and Na. Electric conductivity was shown to be positively related to potash and Ca and negatively related to Mg. Carbon was strongly positively related to the nitrogen and clay and neutral to; similarly nitrogen was neutral to $CaCO_3$. Available phosphorus was strongly negatively related to $CaCO_3$ and neutral to Ca and Mg. Also, potash was neutral to moisture and both densities and negatively related to Mg and Na. In the same way, calcium was strongly negatively related to Mg and Na and neutral to moisture. Sodium showed neutral relation with both densities. Magnesium was positively related to Na whereas $CaCO_3$ was also neutral to both densities. Sand had a neutral relation with moisture and negatively related to silt, WH and clay. Silt was also neutral to both densities. Apparent density was positively related to specific density. WH was positively related to porosity and negatively related to specific density. Lastly moisture showed positive relation to porosity while negative to both densities. TVC of this soil showed a strong positive correlation with clay and a neutral relation with pH, phosphorus and potash. This correlation can be visualized in Fig. 1.

3.2 Microbial Analysis

Each of the examined samples included a variety of bacteria in differing quantities, indicating their dominance in the soil. These appear to be unevenly distributed in the soil samples under study. Any kind of soil will have bacteria, although the quantity of these organisms varies according on the soil's organic substrate and structure. Some of the bacteria can survive in unfavourable ecosystem due to their endospore forming ability. Few are also known to withstand extreme conditions. pH, temperature, humidity, agricultural practices, fertilizers, pesticides, and the addition of organic materials all have a significant impact on the number of bacteria (Rao, 1994).

TVC of 634 X 10^6 cfu/ml was determined for the 18 samples collected from 4 villages of Junnar Tehsil. Total ten different bacterial genuses isolated from all the 18 soil samples were *Brocothrix, Bacteroidetes, Staphylococcus, Frankia, Kurthia, Streptomyces, Nocardia, Actinobacter, Amphibacillus* and *Bacillus* in the increasing order of the number of each genus isolated (Fig. 2).

3.2.1Simpson's diversity index (SDI)

The SDI was found to be very near to 1, indicating that all of the soil under study has a high level of variety. The diversity of soil microbial communities and, consequently, the soil quality, have an impact on the range of biogeochemical processes, the complexity of interactions, multifunctionality, and sustainability of the soil ecosystem [13]. Our results for soil bacterial composition coincide with those of a study [14], who gave a Global Atlas of the Dominant Bacteria Found in Soil.

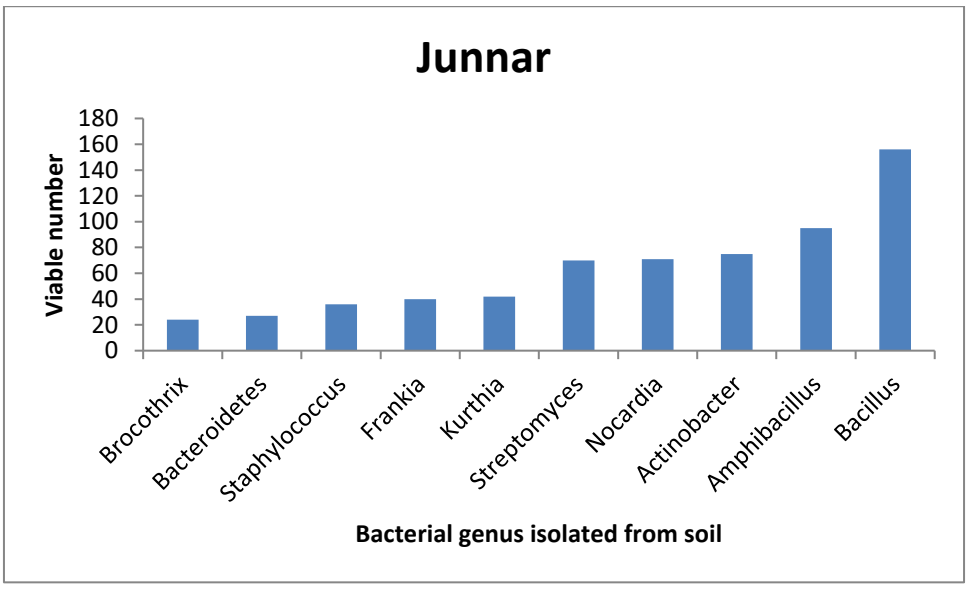

Fig. 2. Count of individual bacteria isolated from all the samples

Table 1. Simpson's diversity index

Bacterial Isolates	Total Number	Bacterial Isolates
Brocothrix	24	Brocothrix
Bacteroidetes	27	Bacteroidetes
Staphylococcus	36	Staphylococcus
Frankia	40	Frankia
Kurthia	42	Kurthia

Table 2. Analysis of Physico-chemical parameters of each soil sample

Sample No.	Village	pH	EC	OC	N	Avail. P	Potash	Ca	Mg	Na	CaCO3	Sand	Clay	Silt	Moisture	Water Hold.Cap.	App. Den.	Sp. Den.	Porosity	TVC
			(Mc/cm)	(%)	(kg/ha)	(kg/hc)	(kg/hc)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(gm/cc)	(gm/cc)	(%)	($x10^6$cfu/ml)
JK 1 Hulga(1st yr)	Khireshwar	5.9	0.15	0.76	532	13.57	188	55.48	35.56	8.21	2	55.25	21.32	23.33	12.2	56.49	2.14	1.15	57.67	23
JK 2 Varai(2nd yr)	Khireshwar	6.32	0.17	2.21	1547	14.01	872.39	60.74	31.94	3.83	2.5	50.41	25.62	23.9	17.77	53.9	2.14	1.13	62.55	7
JK 3 Khurasni 3rd yr)	Khireshwar	6.19	0.08	0.73	511	13.79	653.76	64.36	31.84	0.96	2.13	56.9	23.33	19.63	15.22	57.47	2.09	1.09	58.36	4
JK 4 Nachani(4th yr)	Khireshwar	5.82	0.08	1.06	742	14.24	356.98	54.16	39.27	5.07	1.88	67.01	18.34	14.5	11.17	52.86	2.1	1.16	55.52	3
JK 5 Fallow)	Khireshwar	5.59	0.13	1.82	1274	14.24	126.74	48.81	41.71	8.82	1.5	67.19	18.24	14.47	8.9	46.69	2	1.17	54.92	35
JA 1 Varai	Ambe	6.54	0.51	0.38	266	14.01	1158.61	70.21	20	2.59	1.8	37.89	23.19	38.78	9.11	52	2.18	1.2	57.5	4
JA 2 Nachani	Ambe	6.48	0.44	0.91	637	14.24	653.76	64.27	27.95	2.1	1.38	70.74	12.51	16.54	6.43	43.46	2.42	1.48	50.33	4
JA 3 Sawa	Ambe	6.55	0.42	0.13	91	13.57	1302.25	70.12	22.91	1.52	2	56.37	22.31	21.26	10.19	56.64	2.17	1.2	59.69	3
JA 4 Khurasani	Ambe	6.32	0.4	0.75	525	14.24	650.59	74.57	18.48	2.8	1.8	38.07	27.1	34.73	8.38	57.85	2.14	1.15	59.76	63
JA 5 Fallow	Ambe	6.56	0.43	0.91	637	14.01	1168.11	67.43	24.14	1.69	1.38	22.62	33.18	44.1	8.78	55.79	2.26	1.27	58.2	119
JH 1 Varai	Hatweez	6.33	0.36	2.59	1813	14.24	739.31	72.89	20.7	2.09	1.5	59.72	20.2	19.97	13.86	55.33	1.82	1.07	57.95	41
JH 2 Khurasani	Hatweez	6.74	0.48	1.66	1162	13.57	1417.37	67.73	24.73	1.81	3.88	42.62	21.21	36.05	11.66	59.56	2.07	1.14	60.23	7
JH 3 Sawa	Hatweez	6.18	0.36	1.34	938	13.79	203.84	74.96	22.23	1.8	2	37.56	32.11	30.2	11.68	59.69	2.13	1.13	59.97	38
JH 4 Fallow	Hatweez	6.02	0.32	1.2	840	14.24	321.07	73.78	22.46	2.13	2	26.26	25.18	48.46	11.93	60.6	2.11	1.12	60.44	41
JP 1 Varai	Pimparwadi	6.3	0.35	0.13	91	13.12	766.77	70.94	23.09	1.74	2.88	43.88	26.7	29.3	13.6	61.41	2.12	1.12	61.24	84
JP 2 Khurasani	Pimparwadi	6.77	0.45	1.38	966	14.01	1396.24	76.06	7.9	1.14	2.63	54.27	28.3	17.25	10.98	57.18	1.96	1.07	59.52	19
JP 3 Sawa	Pimparwadi	6.39	0.39	0.75	525	14.24	847.04	74.58	20.06	1.59	1.63	43.17	25.4	31.24	10.42	60.6	1.66	1.05	61.15	114
JP 4 Fallow	**Pimparwadi**	**6.41**	**0.36**	**0.13**	**91**	**14.01**	**861.83**	**74.87**	**17.91**	**2.87**	**2.13**	**27.76**	**22.41**	**49.63**	**12.06**	**60.83**	**2.14**	**1.16**	**63.67**	**25**

**Fallow samples are highlighted yellow*

Table 3. Count of bacterial genera found in individual soil sample

Sample No	Village	Bacillus	Amphibacillus	Staph.	Actinobacter	Nocardia	Streptomyces	Frankia	Kurthia	Bronchothrix	Bacteriodes	Viable count(in triplicate)	TVC ($x10^6$ cfu/ml)
JK1(Hulga)	Khireshwar	6	3	1	1	3	3	2	2	1	1	30+15+24	23
JK2(Varai)	Khireshwar	2	1	1	1	1	0	0	1	0	0	5+8+7	7
JK3(Khursani)	Khireshwar	1	1	0	1	0	1	0	0	0	0	1+6+4	4
JK4(Nachani)	Khireshwar)	1	1	0	0	0	1	0	0	0	0	3+1+5	3
JK5(Fallow)	Khireshwar)	11	6	3	3	3	2	2	2	2	1	42+40+23	35
JA1(Varai)	Ambe	3	1	0	0	0	1	0	0	0	0	7+1+4	4
JA2(Nachani)	Ambe	1	0	1	0	1	1	0	0	0	0	10+1+1	4
JA3Sawa	Ambe	1	0	0	0	1	1	0	0	0	0	5+3+0	3
JA4Khurasani	Ambe	22	5	5	4	6	6	3	4	4	4	78+75+36	63
JA5Fallow	Ambe	44	16	3	12	16	9	6	8	1	4	145+75+137	119
JH1Varai	Hatweez	3	11	4	6	4	4	4	3	1	1	58+32+33	41
JH2Khurasani	Hatweez	2	1	0	1	2	1	0	0	0	0	9+8+4	7
JH3Sawa	Hatweez	5	8	3	2	6	5	4	2	2	1	49+21+44	38
JH4Fallow	Hatweez	3	6	1	6	9	8	4	1	2	2	26+31+66	41
JP1Varai	Pimparwadi	19	9	6	12	10	9	8	4	3	4	59+82+112	84
JP2Khurasani	Pimparwadi	4	4	1	3	3	2	1	1	0	0	12+23+22	19
JP3Sawa	Pimparwadi	22	19	6	16	6	14	4	13	6	8	109+75+160	114
JP4Fallow	Pimparwadi	6	3	1	7	0	2	2	1	2	1	32+12+31	25

**Fallow samples are highlighted yellow*

3.2.2 Richness

A measure of richness is the number of species in each sample. A sample is considered "richer" if it contains a greater number of species. As a result, there were just ten distinct isolates in the soil Junnar, indicating a decreased richness (Fig. 2).

3.2.3 Evenness

An area's richness can be measured using evenness, which is a measure of the relative abundance of its various species. Comparatively speaking, a community with a similar abundance of multiple species is thought to be more diversified than one dominated by one or two species. Because the overall sample population is highly unevenly distributed among the various isolates, with Bacillus isolate predominating, all samples thus displayed unevenness.

Diversity rises in tandem with improvements in species richness and evenness. Richness and evenness are two factors that Simpson's Diversity Index considers when calculating diversity. The likelihood that two randomly chosen individuals from a sample will come from different species is represented by this compliment (1-D). As a result, great diversity is seen in every soil.

Soils can be naturally acidic due to processes such as removal of base cations, microbial respiration, and production of organic acids. pH range of 5.5 to 7 is suitable for almost all crops. Fallowing of the land tends to reduce the soil pH and make it suitable for good yield. Same is observed from the Table 2. In contrast, increasing soil pH with fallow period was reported by study [15]. In another study it was shown that the pH of the rhizosphere soil decrease with increase fallow length which may be due large root exudates of annual plants in different fallow land [16]. The cultivation of khursani and varai makes the soil more alkaline as compared to sawa, nachani and hulga. It would therefore be possible to return the pH of the soil to normal by allowing such lands to remain uncultivated for longer than seven or eight years.

Almost similar pattern was observed for all the crop harvested soil parameters when compared with the fallow soil. The results of the TVC and the fallow soil characteristics in Pimparwadi village indicated slight variance. Fallow soil has lower TVC than soil that had been harvested for crops. The land's perhaps shorter than two-year fallowing time could be the cause.

Pimparwadi village showed maximum presence of all the isolates in the soils collected after harvesting Varai and Sawa, while Ambe village soil collected after harvesting Khursani exhibited maximum presence of all isolates as seen in Table 3. This shows that the crop cultivation did not influence the number and diversity of the bacteria in that soil.

3.3. Correlation Analysis

A Pearson correlation coefficient was computed to assess the relationship between the various soil parameters and bacterial genus isolated from these soils.

In Junnar tehsil, there is a significant negative correlation between sand, soil apparent density and the bacterial viable count, whereas, a positive correlation exists between clay and the total bacterial count, along with dominance of Bacillus, Actinobacter, Amphibacillus, Nocardia and Streptomyces, during this period the crops cultivated are Hulga (Macrotyloma uniflorum, or horse gram) in the first year, followed by Varai (Panicummiliaceum, or proso millet) in the second year, Khurasani (Hyocyamus niger, Niger seed) in the third year, Nachani (Eleusine corocana or African millet) in the fourth year, followed by fallow period.

All isolates showed a positive correlation with EC, Ca, clay, water holding capacity and porosity. They all exhibited a negative correlation with Mg, Na, apparent density, $CaCO_3$ and sand. Frankia was only bacterial isolate that had a positive relation with moisture and in the same way Bacillus solely showed a positive relation with specific density of soil.

The development of nutrients in the soil is mainly due to the biological transformations which are caused by soil microorganisms [17]. They have a significant influence on the soil function and thus can be used as soil quality indicators. The current research revealed that the bacterial populations in study area were significantly influenced by fallow age. According to a different study, bacteria are less susceptible to changes in the environment and soil than fungi, which can be easily controlled by variations in the pH, nutrients, and harshness of the environment [18].

Bacterial isolates / Soil parameters	*Bacillus*	*Amphibacillus*	*Staph.*	*Actinobacter*	*Nocardia*	*Streptomyces*	*Frankia*	*Kurthia*	*Bronchothrix*	*Bacteriodes*
pH	0.104	0.016	-0.079	0.112	0.047	0.001	-0.083	0.07	-0.169	0.015
EC	0.221	0.197	0.155	0.23	0.252	0.234	0.169	0.181	0.107	0.197
OC	-0.201	0.089	0.021	-0.17	-0.035	-0.184	-0.099	-0.072	-0.2	-0.235
N	-0.201	0.089	0.021	-0.17	-0.035	-0.184	-0.099	-0.072	-0.2	-0.235
Avail. P	0.021	0.157	0.021	0.006	-0.088	0.037	-0.202	0.153	0.139	0.085
Potash	0.11	-0.042	-0.183	0.084	-0.025	-0.096	-0.186	0.034	-0.265	-0.042
Ca	0.139	0.315	0.294	0.396	0.276	0.416	0.343	0.252	0.337	0.33
Mg	-0.143	-0.247	-0.216	-0.329	-0.217	-0.298	-0.241	-0.201	-0.216	-0.237
Na	-0.08	-0.172	-0.075	-0.262	-0.202	-0.246	-0.146	-0.131	-0.018	-0.161
CaCO3	-0.271	-0.326	-0.215	-0.14	-0.145	-0.208	-0.126	-0.304	-0.205	-0.225
Sand	-.492*	-0.385	-0.19	-.489*	-.570*	-.498*	-.484*	-0.332	-0.353	-0.418
Clay	.559*	.498*	0.348	0.441	.648**	.499*	.541*	0.424	0.299	0.411
Silt	0.377	0.268	0.088	0.425	0.438	0.411	0.375	0.234	0.315	0.348
Moisture	-0.31	-0.092	-0.082	-0.016	-0.152	-0.134	0.013	-0.152	-0.152	-0.177
Water Hold.Cap.	0.186	0.329	0.26	0.466	0.334	.482*	0.449	0.297	0.417	0.403
App. Den.	-0.041	-.541*	-0.444	-0.455	-0.011	-0.418	-0.201	-.517*	-.504*	-0.444
Sp. Den.	0.058	-0.279	-0.25	-0.265	-0.023	-0.254	-0.209	-0.218	-0.33	-0.228
Porosity	0.13	0.213	0.194	0.39	0.17	0.291	0.288	0.226	0.342	0.292

Fig. 3. Pearson Correlation coefficient among the bacterial isolates and soil parameters; the red values indicate a negative correlation, and those in green indicate a positive correlation; the number of degrees of freedom (df) = 1, strong negative correlation (above -0.5), Strong positive correlation (above +0.5) and neutral relation (near zero)

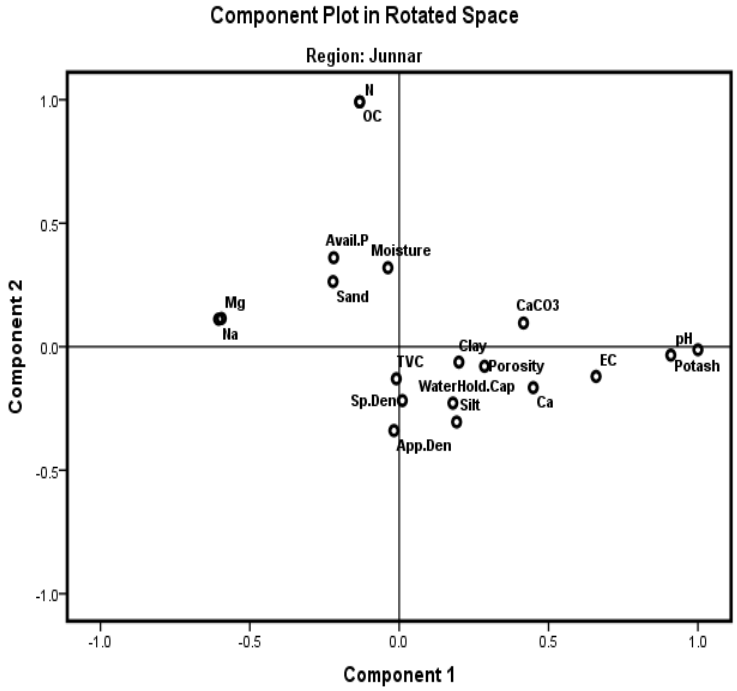

Fig. 4. PCA for Junnar Taluka

A related study [19] compared soil enzymatic activity (dehydrogenase, acid phosphatase, alkaline phosphatase, urease, protease) and chemical soil quality parameters (soil pH, available P and K, organic carbon, and total nitrogen content) in organic and conventional farming systems. It found that the organic system was positively correlated (statistically significantly) with favorable soil pH, a higher content of organic C, total N, and C/N ratio.

3.4 Principal Component Analysis

Principal component analysis (PCA) was used to analyze agricultural data from several villages in order to identify shared general patterns in the condensed multivariate data space without sacrificing information owing to dimensionality reduction. Using SPSS version 21, every statistical analysis was completed.

From the Factor matrix of Varimax rotation from the PA extraction method shows that Na and Mg has the similar pattern with factor component of -0.496 and -0.505 in component 2 as shown in 2 dimensional figure of Junnar; Whereas, N and OC also showing similar Varimax rotation component of 0.287 and PH (0.815) and Potash 0.907 (Fig. 4).

4. CONCLUSION

The findings show notable distinctions amongst the investigated soils in terms of both biological and physico-chemical characteristics. It may be inferred from these two metrics that the duration of the fallow season affects the condition of the soil. The TVC found in fallow soils was notably greater than that found in soils used for crop harvesting. As a result, land management systems ought to provide a range of sustainable solutions to farmers in order to meet their needs. A few corrective actions that are recommended at the end may be taken to enhance and safeguard the environment.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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