

IMPACT OF FALLOW ON SOIL HEALTH IN MOKOKCHUNG DISTRICT, NAGALAND, INDIA

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Highlights

- ▶ Study was conducted by selecting two sites i.e. Shifting Cultivation Site (SCS) and Forest Regeneration Site (FRS) at Mokokchung district, Nagaland, India.
- ▶ Soil pH, moisture, temperature, SOC, available nitrogen and fungal population were recorded.
- ▶ FRS site was found to have a greater soil quality as compared to the SCS.
- ▶ Study displays the detrimental effect of the Shifting Cultivation on the quality of soil.
- ▶ Highlights the need for monitoring and rectification at source to preserve the quality of the soil.

Abstract. Two sites were selected from the district of Mokokchung, Nagaland *viz.*, Forest Regeneration Site (FRS) and Shifting Cultivation Site (SCS). At FRS, soil pH ranged from 5.00 ± 0.13 – 5.50 ± 0.04 , soil moisture 35.44 ± 1.09 – $53.39\pm 0.84\%$, soil temperature 14.33 ± 0.47 – 23.83 ± 0.23 °C, soil organic carbon 2.20 ± 0.08 – $3.03\pm 0.02\%$ and available nitrogen 424.48 ± 6.73 – 547.46 ± 2.10 Kg/ha. At SCS, soil pH ranged from 5.94 ± 0.24 – 6.53 ± 0.02 , soil moisture 30.32 ± 2.64 – $45.72\pm 0.98\%$, soil temperature 17.83 ± 0.62 – 26.1 ± 0.08 °C, soil organic carbon 1.67 ± 0.29 – $2.34\pm 0.08\%$ and available nitrogen 324.16 ± 8.42 – 443.20 ± 1.06 Kg/ha. Significant correlation between soil temperature, pH, soil moisture and available nitrogen was observed at FRS, while correlation of soil moisture and pH was observed at SCS. A total of 21 fungal species belonging to 13 genera were identified from the two sites. FRS had more fungal diversity than SCS. The genus *Aspergillus* was dominant in both the studied sites. The study observed the detrimental effect of the shifting cultivation on soil health and highlights the need for monitoring and rectification to preserve soil health.

Keywords: land use, soil quality, shifting cultivation, Jhum fallow, landscape management, Nagaland.

Introduction

Shifting cultivation has its origins in the Mediterranean agriculture system (Karlen et al., 1994) and is one of the major forms of cropping system practised in north-east India. Shifting cultivation consists of three phases, namely, clearing a forest area by slashing vegetation and burning, cultivation of crops for a year or more and a variable fallow period (Mertz et al., 2009; Zodinpuui et al., 2016). Locally, this practise is called jhuming and the cultivators are known as the jhumias (Devi & Choudhury, 2013). However, with the increase in agricultural activity, there is a dramatic decrease in the fallow period. This reduced fallow cycle has been reported as a threat to biodiversity and soil conservation practises (Duguma et al., 2001; Van et al., 2008). Reports on the negative impact of shifting

cultivation consists of lowering of soil fertility, increased erosion, reduced crop yield and watershed siltation (Mertz, 2002; Maithani, 2005; Ziegler et al., 2009). Further, fallow frequency, tillage, and chemical weed control also affects soil quality (Nielsen & Calderón, 2011). Unsustainable farming practises lead to irreversible damage to the ecosystem, as such implementation of optimum fallow cycle is vital to improve soil health (Devi & Choudhury, 2013). Several workers have also suggested that forest restoration can improve the concentrations of carbon and nitrogen in the soil by accumulative organic matter input from aboveground litterfall and root turnover (Chang et al., 2011; Deng et al., 2013; Hume et al., 2016). Hence, this capacity of the soil to function in the current and the future reflects its quality (Doran & Parkin, 1994) and effort should be implemented on soil quality improvement and

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its conservation for its sustainable utilisation under varied uses and management (Unger et al., 1991).

Soil factors such as soil pH, moisture, temperature, organic carbon and nitrogen influence the distribution of fungi (Kumar et al., 2015). The role of soil fungi is vital in the soil for nutrient cycling, disease suppression and water dynamics, which ultimately creates plants that become healthier and more vigorous (Jenkins, 2005). There are reports of lowered microbial population in shifting cultivation land as compared to forest lands (Gupta et al., 1986). This practise of shifting cultivation has been carried out since times immemorial in the state of Nagaland, a state in the north-east corner of India bordering Myanmar. The study aims to work out on some selected soil physico-chemical parameters and also to estimate the difference in fungal population from two selected sites located in the district of Mokokchung, Nagaland viz., Forest Regeneration Site (FRS) with a fallow period of 10 years and a Shifting Cultivation Site (SCS), which after undergoing its fallow period of 10 years, is currently in its 3rd year of crop cultivation.

1. Materials and methods

Site selection: Two sites were selected in Longsa village under Mokokchung District, Nagaland. The first site is a Forest Regeneration Site (FRS) located at Latitude 26° 14' 31" N and Longitude 94° 31' 44" E with an altitude of 813 m above msl. This site was a site of shifting cultivation (2008–2011) before being converted into a fallow land. Site FRS remained undisturbed for a period of 10 years (2011–2020). The villagers have reported that no agricultural activity has been carried out during the fallow period. Plants like *Ageratum conyzoides*, *Albizzia chinensis*, *Amaranthus* sp., *Angiopteris* sp., *Artemisia vulagris*, *Azadirachta indica*, *Bambusa pallida*, *Eupatorium adenophorum*, *Macaranga denticulate*, *Pueraria*, *Mikania cordata*, *Schima wallichii*, *Sonchus wightianus*, *Thysanolaena maxima* and *Terminalia myriocarpa* are dominant at FRS. The second site is a Shifting Cultivation Site (SCS) with a geographical coordinate of Latitude 26° 13' 38" N and Longitude 94° 32' 24" E with an altitude of 1024 m above msl. This site was kept abandoned for 10 years (2007–2017) with no agricultural activities after which cultivation has been carried out continuously at SCS for the last 3 consecutive years (2017–2020). Crops like *Manihot esculenta*, *Oryza sativa*, and *Zea mays* are cultivated at this site. FRS and SCS are separated by a distance of 1.9 km.

Physico-chemical parameters of soil sample: Preliminary site selection started from January 2019–February 2019. Seasonally, soil samples were collected randomly from both sites during March 2019 to February 2020. Further, samples were collected from both the sites on the same day owing to the short distance between the two sites. Samples were collected for spring (March–May 2019), summer (June–August 2019), autumn (September–November 2019) and winter (December 2019–February 2020). Samples were collected from 0–15 cm layer depth.

Soil samples were combined to form a composite sample. For soil pH, 5 g of soil were mixed with distilled water at a ratio 1:2.5 ml and kept in rotary shaker for 15 minutes. The suspension was then allowed to settle for 5 minutes and pH was measured using digital systronic pH meter 361. Soil moisture was measured by Gravimetric method. For soil nutrients and physio-chemical analysis, air-dried samples were sieved to pass through <2 mm screen. Soil temperatures were recorded during sampling with a soil thermometer. Soil organic carbon was determined following the wet digestion of (Walkley & Black, 1934). Available Nitrogen was determined using KEL PLUS Nitrogen analyser. All the samples were analysed in triplicates and values are give in mean±S.D.

Isolation of fungi: Soil samples were collected from 0–15 cm layer depth from the two sites. Fungal species were isolated in Potato Dextrose Agar (Himedia) plates supplemented with streptomycin sulphate. For soil dilution (Waksman, 1921), 1 gm of soil sample was diluted in 10 ml of sterilized distilled water to make microbial suspension 10⁻¹ to 10⁻⁵. Dilution of 10⁻² to 10⁻⁵ were used to isolate fungi. One ml of dilution was taken from each serial dilution sample in triplicate form and transferred to plates of Potato Dextrose Agar (PDA). PDA medias were supplemented with 0.03 g/L streptomycin sulphate for inhibiting any bacterial growth and allowed to solidify. Plates were incubated at 25±1 °C for 5–7 days in dark. Colonies were inoculated in PDA plates and incubated at 25±1 °C for 5–7 days. Microscopical examination consisted of preparing temporary lacto-phenol cotton blue slides and observation under compound microscope. The fungi were identified with the help of literatures (Gillman, 1957; Nagmani et al., 2006; Webster & Weber, 2007).

Statistical analysis: SPSS version 16.0 was used for the calculation of Pearson's correlation. The data obtained were also subjected to analysis of variance (ANOVA) and the means were compared with Duncan's multiple range test to determine the effect of seasons on soil parameters (DMRT).

2. Results and discussion

2.1. Soil physico-chemical parameters at FRS and SCS

Table 1 shows the physico-chemical parameters of soil at FRS. Soil pH value ranged from minimum 5.00±0.13 during winter and maximum 5.50±0.04 during autumn. The lowest value of soil moisture content of 35.44±1.09% was recorded during winter while the highest of 53.39±0.84% was recorded during autumn. Soil temperature, varied from 14.33±0.47–23.83±0.23 °C. The lowest temperature was recorded during winter while highest temperature was recorded during autumn. Highest SOC was reported during summer (3.03±0.02%) while lowest value of 2.20±0.08% was reported during winter. Lower value of available nitrogen 424.48±6.73 Kg/ha was recorded during winter, while highest value of 547.46±2.10 Kg/ha was

observed during autumn. Table 2 display the physico-chemical parameters of soil at SCS. Autumn displayed the highest pH value (6.53 ± 0.02), while winter season had the lowest pH value (5.94 ± 0.24). Lowest soil moisture content of $30.32 \pm 2.64\%$ was observed during winter, while highest value of $45.72 \pm 0.98\%$ was observed during autumn. Soil temperature was minimum during winter (17.83 ± 0.62 °C) while maximum value was observed during summer (26.1 ± 0.08 °C). The lowest value of SOC was observed during winter ($1.67 \pm 0.029\%$) while maximum value of $2.34 \pm 0.08\%$ was observed during summer. The highest value of available nitrogen was observed during summer with a value of 443.20 ± 1.06 Kg/ha, while lowest value of 324.16 ± 8.4 Kg/ha was reported during winter.

The soil samples were found to be moderately acidic in both sites. The pH range of most productive agricultural soils is between 5.5 and 7.5 (Wubie, 2013). pH was found

to be lower at FRS compared to SCS in all the seasons (Figure 1). One factor for the increased pH at SCS might be the practise of burning of soils, which supplies ashes to the soil and subsequently raised pH at SCS (Devi & Choudhury, 2013). A positive correlation of pH was observed with soil moisture in both the sites (Table 3 and Table 4). This correlation may be attributed to the reports of soil water content increasing the soil pH, making it more alkaline (Smyth, 2012). Soil moisture has a profound effect on soil microbial activity (Liu et al., 2009). FRS had higher soil moisture than SCS (Figure 2). Several workers have reported that soil moisture increased in agricultural systems that employ fallow (Jones & Popham, 1997; Nielsen et al., 2002). The presence of higher soil moisture at FRS may be attributed to higher water retention and surface water entry in the soil due to the presence of denser vegetation (Devi & Choudhury, 2013). Among soil properties,

Table 1. Seasonal variation in physico-chemical characteristics of soil at FRS

Seasons \ Parameters	pH	Soil moisture (%)	Soil temperature (°C)	Soil organic carbon (%)	Available nitrogen (Kg/ha)
Spring	5.31 ± 0.94	42.97 ± 0.66	21.83 ± 0.23	2.33 ± 0.04	523.88 ± 1.36
Summer	5.46 ± 0.23	50.96 ± 0.61	23.66 ± 0.47	3.03 ± 0.02	511.39 ± 0.87
Autumn	5.50 ± 0.04	53.39 ± 0.84	23.83 ± 0.23	2.87 ± 0.04	547.46 ± 2.10
Winter	5.00 ± 0.13	35.44 ± 1.09	14.33 ± 0.47	2.20 ± 0.08	424.48 ± 6.73

Table 2. Seasonal variation in physico-chemical characteristics of soil at SCS

Seasons \ Parameters	pH	Soil moisture (%)	Soil temperature (°C)	Soil organic carbon (%)	Available nitrogen (Kg/ha)
Spring	6.30 ± 0.09	39.01 ± 1.10	24.83 ± 0.23	1.95 ± 0.04	417.64 ± 0.81
Summer	6.41 ± 0.08	40.13 ± 0.89	26.1 ± 0.08	2.34 ± 0.08	443.20 ± 1.06
Autumn	6.53 ± 0.02	45.72 ± 0.98	25.16 ± 0.23	1.98 ± 0.18	381.22 ± 0.80
Winter	5.94 ± 0.24	30.32 ± 2.64	17.83 ± 0.62	1.67 ± 0.29	324.16 ± 8.42

Table 3. Correlation matrix among the soil parameters at FRS

	pH	Soil moisture	Soil temperature	Soil organic carbon	Available nitrogen
pH	1				
Soil moisture	.978*	1			
Soil temperature	.986*	.930	1		
Soil organic carbon	.870	.928	.801	1	
Available nitrogen	.933	.864	.955*	.636	1

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

Table 4. Correlation matrix among the soil parameters at SCS

	pH	Soil moisture	Soil temperature	Soil organic carbon	Available nitrogen
pH	1				
Soil moisture	.985*	1			
Soil temperature	.932	.871	1		
Soil organic carbon	.721	.591	.846	1	
Available nitrogen	.699	.582	.906	.909	1

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

temperature is considered as the most important factor when it comes to mineralization process of organic matter (Arevalo et al., 2012). Temperature was found to be moderately higher at SCS compared to FRS. Although temperature decreases with altitude, an increase in temperature was observed during the study (Figure 3). This may be attributed to the direct exposure of the surface soil to sunlight in absence of dense vegetation at SCS. A positive correlation of temperature with pH and available nitrogen was found at FRS (Table 3). This correlation may be attributed to increased soil temperature stimulating microbial activity, thereby increasing the availability of plant nutrients in the soil (Onwuka & Mang, 2018). As a result, higher nitrogen levels were recorded during the warmer seasons. pH value meanwhile decreased during the colder season and increased during warmer season. This may be attributed to hydrogen ions being diluted by water during the rainy season (Lalmuansangi et al., 2019). SOC was higher at FRS than SCS in all the seasons during the study period (Figure 4). Similar reports of increased organic carbon in forest soils as compared to agricultural land was reported by Dadhwal et al. (2011) and Singh and Munth (2013). SOC has been reported to be a key control with regards to soil fertility and agricultural (Tiessen et al., 1994). The increased SOC in FRS may be attributed to the lack of disturbance to the natural vegetation, leading to higher litterfall. Another factor effecting SOC may be the difference in altitude between the two studied sites. Altitude may affect the plant species richness which in turn effects the plant community. Shiek et al. (2009) reported on lower input of organic carbon in the soil of higher altitude due to decreased vegetation. Lowered SOC in SCS may also be due to continues tillage and subsequent runoff from the land (Tasung & Ahmed, 2017). There is also a significant alarm that the practise of shifting cultivation could exhaust the soil carbon stock, which could lead to a rise of carbon dioxide percentage in the atmosphere (Bruce et al., 1999). No significant correlation was observed in both the sites. The values of available nitrogen showed a trend of increase in its concentrations at FRS as compared to SCS (Figure 5). Similar trends were reported by Xu et al. (2018). Temperature is the most important climatic factor controlling soil nitrogen. Increased temperature leads to an increase in soil available nutrients because of accelerated decomposition of soil organic matter. The positive correlation of available nitrogen with temperature at FRS was observed (Table 3). The increase in temperature may lead to an increase in nitrogen levels during the warmer season as compared to the colder season. No correlation was observed at SCS. Increased fallow periods have been reported to enhance the accumulation of nitrate through mineralization of organic matter (Campbell et al., 1990). Singh and Jamir (2017) also reported that continuous cropping removes enormous amounts of nutrients from the soil. It is observed that soil quality was better at FRS than SCS in all the seasons. The effect of seasons on soil parameters at FRS and SCS are also highlighted in Table 5 and Table 6. DMRT test revealed that changes in the soil

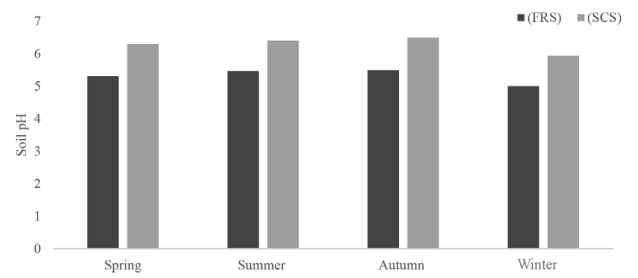


Figure 1. Seasonal variation in soil pH at FRS and SCS

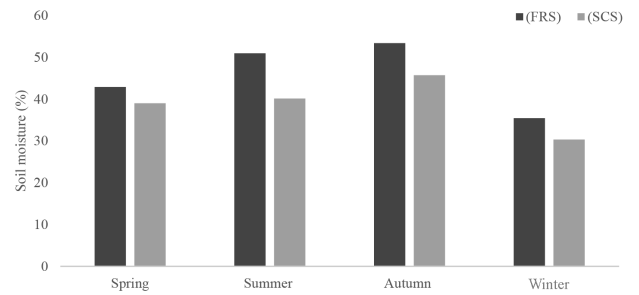


Figure 2. Seasonal variation in soil moisture at FRS and SCS

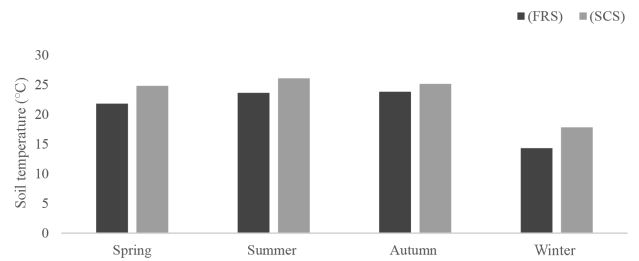


Figure 3. Seasonal variation in soil temperature at FRS and SCS

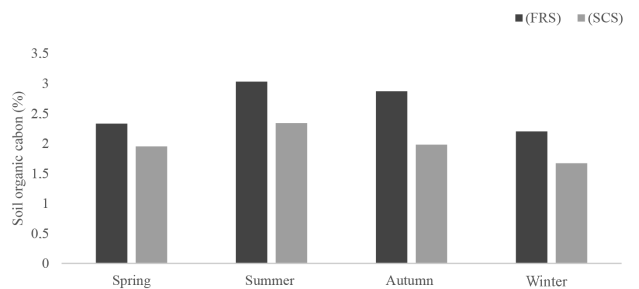


Figure 4. Seasonal variation in soil organic carbon at FRS and SCS

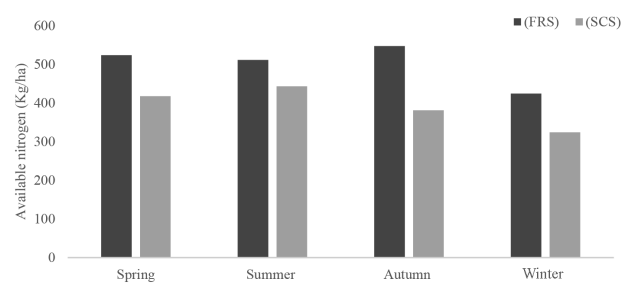


Figure 5. Seasonal variation in soil available nitrogen at FRS and SCS

physico-chemical parameters were also affected seasonally. Mizra and Patil (2020) reported on the effect of season on physico-chemical properties of soil collected from Gautala reserve forest, Jalgaon, Maharashtra. Soil property is reliant on both biotic and abiotic components that vary spatially and seasonally (Dar et al., 2018). During the study, FRS and SCS had an altitudinal difference of 211 m. With variation in altitude, climatic factor changes. Such changes correspond to change in soil biota impacting soil quantity and quality (Dar et al., 2012).

2.2. Fungal population at FRS and SCS

FRS had a total of 18 fungal populations belonging to 11 genera (Table 7). Maximum diversity was observed in summer followed by spring, autumn and winter respectively. It was observed that the genus *Aspergillus* was the dominant genus with 5 species at FRS, followed by *Penicillium* with 3 species. Whereas, at SCS, a total of 14 fungal populations belonging to 9 genera were recorded (Table 8). Maximum diversity was recorded during summer,

Table 5. Effect of season on soil parameters at FRS

Parameters Seasons	Soil pH	Soil moisture (%)	Soil temperature (°C)	Soil organic carbon (%)	Available nitrogen (Kg/ha)
Spring	5.31 ^b	42.97 ^b	21.83 ^b	2.33 ^b	523.88 ^c
Summer	5.46 ^c	50.96 ^c	23.66 ^c	3.03 ^d	511.39 ^b
Autumn	5.50 ^c	53.39 ^d	23.83 ^c	2.87 ^c	547.47 ^d
Winter	5.00 ^a	35.44 ^a	14.33 ^a	2.20 ^a	424.48 ^a

Note: Values in the same column with different superscript are significantly different at 5% level by Duncan's multiple range test.

Table 6. Effect of season on soil parameters at SCS

Parameters Seasons	Soil pH	Soil moisture (%)	Soil temperature (°C)	Soil organic carbon (%)	Available nitrogen (Kg/ha)
Spring	6.30 ^b	39.01 ^b	24.83 ^b	1.95 ^b	417.652 ^c
Summer	6.41 ^c	40.13 ^b	26.10 ^c	2.34 ^d	443.21 ^d
Autumn	6.53 ^d	45.72 ^c	25.16 ^b	1.98 ^c	381.22 ^b
Winter	5.94 ^a	30.32 ^a	17.83 ^a	1.67 ^a	324.16 ^a

Note: Values in the same column with different superscript are significantly different at 5% level by Duncan's multiple range test.

Table 7. Fungal diversity at FRS

Fungal population	Spring	Summer	Autumn	Winter
1. <i>Acremonium falciforme</i>	+	+	+	-
2. <i>Aspergillus candidus</i>	+	+	+	-
3. <i>Aspergillus flavus</i>	+	+	+	+
4. <i>Aspergillus fumigatus</i>	+	+	-	+
5. <i>Aspergillus niger</i>	+	+	+	+
6. <i>Aspergillus versicolor</i>	-	+	-	-
7. <i>Chaetomium sp.</i>	+	+	-	-
8. <i>Cladosporium chaldosporioides</i>	+	+	+	+
9. <i>Geotrichum candidum</i>	+	+	+	+
10. <i>Humicola sp.</i>	-	+	+	+
11. <i>Mortierella sp.</i>	+	+	-	-
12. <i>Mucor circinelloides</i>	+	+	-	+
13. <i>Paecilomyces carneus</i>	-	+	+	-
14. <i>Penicillium chrysogenum</i>	+	+	+	+
15. <i>Penicillium sp. 1</i>	+	+	-	-
16. <i>Penicillium sp. 2</i>	-	-	+	-
17. <i>Trichoderma harzianum</i>	+	+	-	-
18. <i>Trichoderma viride</i>	+	+	-	-

Note: - indicate absent; + indicate present.

Table 8. Fungal diversity at SCS

Fungal population	Spring	Summer	Autumn	Winter
1. <i>Aspergillus fumigatus</i>	+	+	+	+
2. <i>Aspergillus lentulus</i>	–	+	–	–
3. <i>Aspergillus niger</i>	+	+	+	+
4. <i>Aspergillus versicolor</i>	+	+	–	–
5. <i>Cladosporium chaldosporiodes</i>	+	+	+	–
6. <i>Humicola sp.</i>	–	–	–	+
7. <i>Mucor circinelloides</i>	+	–	+	–
8. <i>Paecilomyces carneus</i>	+	+	–	+
9. <i>Penicillium chrysogenum</i>	+	+	+	–
10. <i>Penicillium sp. 1</i>	+	+	+	+
11. <i>Rhizopus sp.</i>	+	+	–	–
12. <i>Trichoderma harzianum</i>	+	–	–	+
13. <i>Trichoderma viride</i>	–	+	+	+
14. <i>Trychophyton sp.</i>	–	+	+	–

Note: – indicate absent; + indicate present.

followed by spring, autumn and winter respectively. The genus *Aspergillus* was found to be dominant at SCS with 4 species, followed by the genus *Penicillium* and *Trichoderma* with two species each respectively. The total fungal population recorded from the two sites were *Acremonium falciforme*, *Aspergillus candidus*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus lentulus*, *Aspergillus niger*, *Aspergillus versicolor*, *Chaetomium sp.*, *Cladosporium chaldosporiodes*, *Geotrichum candidum*, *Humicola sp.*, *Mortierella sp.*, *Mucor circinelloides*, *Paecilomyces carneus*, *Penicillium chrysogenum*, *Penicillium sp. 1*, *Penicillium sp. 2*, *Rhizopus sp.*, *Trichoderma harzianum*, *Trichoderma viride* and *Trychophyton sp.* FRS had more fungal population than SCS. Similar results were observed by Miah et al. (2010) who reported lowered fungal population in shifting cultivation sites as compared to forest areas. The difference in altitude among the two sites may also play a factor with regards to the difference in fungal population. Siles et al. (2016) reported on the impact of altitude on the microbial community. They concluded that altitude together with season and site specific-effects determine the microbial community structure. During the study, the two sites also had varying moisture content, which has also been reported to affect the composition of soil microbial community due to differences in drought tolerance (Gray et al., 2011). In the present study, it was observed that the genus *Aspergillus* was dominant in both the studied sites. Perrone et al. (2011) reported that species that produce spore-bearing structures can be easier to discover. Therefore the reason for the dominance of the *Aspergillus* can be attributed to the better sporulating features of the genus. Further fungal colony with good sporulating features has also been reported to colonize better on the culture plates (Jena et al., 2015). The genus *Aspergillus* in particular has been reported for its impact on plant growth and induced resistance against phytopathogens (Kaushal et al., 2020).

Conclusions

The forest regeneration site (FRS) was found to have a greater improved soil quality and also more fungal population as compared to the shifting cultivation site (SCS). We can conclude that the various edaphic factors such as pH, moisture, temperature, SOC and available nitrogen and altitude have impact on the soil fungal population, thereby effecting soil health in both the site of different land use practises. Thus mitigating soil quality deterioration can be achieved by maintaining the fallow period and implementing a shorter cultivation cycle. A sustainable method of shifting cultivation must be implemented in order to prevent further deterioration of soil quality.

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Conflict of interest

The authors declares no conflict of interest.

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