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Unveiling the impact of deforestation on soil saprotrophic fungal community composition in Mau Forest ecosystem in rift valley, Kenya

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ABSTRACT

This study assessed how deforestation affected the diversity, richness, and community composition of soil saprotrophic fungus in Kenya's Mau Forest. Soil samples were collected from 60 plots across three disturbance levels (undisturbed, partially deforested, and deforested sites) during rainy and dry seasons. Fungal diversity was studied using colony-forming units (CFUs) and Shannon diversity indices, while soil physicochemical properties (pH, organic matter, nitrogen, and phosphorus) were assessed. Non-metric multidimensional scaling (NMDS), ANOVA, and Tukey's post hoc tests were used to evaluate differences and correlations. Fungal diversity and abundance significantly decreased with increasing disturbance. Diversity (Shannon index: 3.8 ± 0.3) and abundance (5.6×10^5 CFU/g) were highest at undisturbed sites, followed by partially deforested (2.9 ± 0.4 ; 3.1×10^5 CFU/g) and deforested (1.5 ± 0.2 ; 1.2×10^5 CFU/g) sites. Boxplots showed significant differences, with the highest richness at undisturbed sites. NMDS revealed distinct fungal communities: Rhizopus and Mucor occurred in deforested areas, whereas Trichoderma and Penicillium dominated undisturbed sites. Fungal diversity and abundance were higher during the wet season but lowest at deforested sites throughout both seasons. Nitrogen ($r = 0.78$, $p < 0.05$) and organic matter ($r = 0.84$, $p < 0.01$) showed positive associations, whereas phosphorus showed a negative association ($r = -0.65$, $p < 0.05$). Deforested soils had the lowest nitrogen ($2.1\% \pm 0.3$) and organic matter ($15.6\% \pm 1.2$) compared with undisturbed soils ($5.3\% \pm 0.9$; $0.8\% \pm 0.1$). The study emphasizes deforestation's negative consequences and the need for replanting and sustainable land-use practices.

Keywords: deforestation, fungal diversity, Mau Forest, saprotrophic fungi, soil biodiversity.

1. Introduction

From plants and animals to microbes like fungi, forests provide habitat for a wide variety of organisms, (Manoharachary et al., 2005; Chivian, 2003; Lladó et al., 2017) making them important to preserving biodiversity worldwide. Deforestation and other forestry disturbances, on the other hand, are serious risks to forest ecosystems, altering ecological processes and decreasing biodiversity (Rasiah et al., 2004). Forestry disturbances like clear-cutting and thinning (Zhou et al., 2020) have been shown to lower plant and microbial diversity in temperate regions, favoring generalist and stress-tolerant species over specialized taxa (Tomao et al., 2020). The effects of such disturbances are much more severe in tropical forests, which are hotspots for biodiversity, because of the great species richness and ecological complexity of the area (Mayer et al., 2022).

The impact of forestry disturbances on soil microbial communities such as saprotrophic fungi remain poorly understood in many tropical ecosystems, including sub-Saharan Africa, despite their crucial significance (Touré *et al.*, 2023).

Saprotrophic fungi are essential to forest ecosystems (Lindahl & Tunlid, 2015; Talbot *et al.*, 2013; Grinhut *et al.*, 2007; Bödeker *et al.*, 2016) because they are the main organic matter decomposers. These fungi help in the cycling of nutrients by converting complex organic materials like cellulose and lignin into simpler forms that may be used by plants and other microbes (Kubartová *et al.*, 2009). Their ecological function is directly influenced by their abundance, diversity, and community composition, which determine the rate and efficiency of decomposition (Ning *et al.*, 2021). High fungal diversity can enhance functional redundancy, ensure ecosystem stability, while shift in community composition may alter decomposition rates and soil nutrient availability. According to Lebreton *et al.* (2025). According to Ning *et al.*, (2021), saprotrophic fungi also improve carbon sequestration, contribute to soil fertility and structure, and work with other biota to preserve ecosystem balance. Assessing the resilience and health of forest ecosystems requires an understanding of the dynamics of saprotrophic fungal populations, which are important for their ecological significance (Lebreton *et al.*, 2025).

Changes in fungal community structure and soil characteristics result from forestry disturbances that affect the biological balance of forest ecosystems (Ning *et al.*, 2021). According to research conducted in North America, deforestation greatly decreases fungal diversity and abundance, favoring stress-tolerant, fast-growing genera like *Rhizopus* and *Mucor* while lowering the prevalence of specialized decomposers like *Trichoderma* and *Penicillium* (McGlone *et al.*, 2016). Similar trends have been noted in temperate and tropical forests, where disturbances have been connected to decreases in soil pH, organic matter, and nitrogen content all of which are important determinants of fungal populations (Cookson *et al.*, 2008).

In Kenya, despite its high biodiversity and dependence on forest ecosystems for ecological and economic sustainability, little research has examined the effects of deforestation on soil saprotrophic fungi. Research conducted in comparable ecosystems throughout Africa indicates that fungal community composition changes and substantial biodiversity loss results from forest degradation (Njuguini *et al.*, 2018). Comprehensive research on these processes in Kenyan forests, especially the Mau Forest, is, nevertheless, lacking.

An important natural resource that sustains biodiversity and controls East African hydrological cycles is the Mau Forest, one of Kenya's largest native forests. Unfortunately, this forest's ecological integrity is in danger due to widespread deforestation that has damaged vast areas of it. Although the broad impacts of deforestation on plant and animal biodiversity have been shown in earlier research, little is known about the specific impacts on soil saprotrophic fungi. The absence of information on the dynamics of fungal communities in these regions is a serious research and conservation planning concern.

By examining how soil saprotrophic fungus populations in the Mau Forest are affected by deforestation, this study seeks to close this gap. It specifically aims to: a) Examine how the diversity, abundance, and community composition of fungi have changed in undisturbed, partially deforested, and deforested areas; b) Investigate the seasonal fluctuations in fungal abundance and diversity to fully understand the temporal dynamics of fungal communities; and c) Examine how fungal diversity and the physicochemical characteristics of soil (such as organic matter, nitrogen, phosphorus, and pH) are interconnected.

In order to understand the intricate relationships between forest disturbance, soil characteristics, and fungal communities, the study takes a multidisciplinary approach, combining molecular techniques, soil physicochemical measurements, and statistical work. The idea behind the conceptual framework is that deforestation causes notable drops in soil organic matter, pH, and nitrogen content, all of which contribute to a decrease in fungal variety and abundance. Additionally, data suggests that deforestation reduces the predominance of specialized decomposers that are essential to ecosystem functioning while favoring the growth of opportunistic and generalist fungi.

This study adds to a growing body of knowledge that is crucial for forest management and conservation in Kenya and beyond by shedding light on the ecological effects of deforestation on soil fungus communities. The results will help guide policies like reforestation projects and sustainable land-use practices that aim to lessen the negative effects of deforestation. Furthermore, the approach and results of the study have wider

ramifications for comprehending how saprotrophic fungi contribute to ecosystem resilience and the global carbon cycle.

2. Materials and Methods

2.1. Study Area

The study site is located within Mau Forest in Kenya (Figure 1), one of the biggest native forests in East Africa. The Mau Forest Complex (MFC), which spans 455,000 hectares, is the nation's largest forest canopy. Between latitudes 2.210 and 2.330 North and longitudes 37.900 and 38.040 East is where it is located. It passes through seven counties: Baringo, Nandi, Narok, Uasin Gishu, and Kericho and Bomet to the west, Nakuru to the east, and Narok to the south (Figure 1). The region is characterized by an average temperature of 18.1°C and 1735 mm of precipitation each year. The distribution of rainfall is bimodal, peaking in April, July, and August. The wooded mountains, which range in elevation from 1,800 to 3,000 meters above sea level, serve as one of Kenya's primary water towers, serving as the headwaters for the Mara and Sondu catchments (Bewernick *et al.*, 2016). Maasai Mara National Park, Lake Nakuru National Park, South Turkana National Reserve, Kerio Valley/Kamnarok National Reserve, Lake Baringo, Lake Natron, Serengeti, and Kakamega Forest are among the important conservation sites supported by this ecosystem (Mau Taskforce Report., 2018).

Numerous native trees can be found in the forest, including the African olive (*Olea africana*), the red cedar (*Juniperus procera*), the bamboo (*Bambusa vulgaris*), the soccer ball fruit (*Tabernaemontana stapfiana*), the parasol tree (*Polyscias kikuyuensis*), the woodland waterberry (*Syzygium guineense*), the black ironwood (*Olea capensis*), the red stinkwood (*Prunus africana*), the *Albizia gummifera*, the *Dombeya goetzenii*, *Grevillea robusta*, and the East African yellow-wood (*Podocarpus latifolius*), among many others. The Kenya Forest Service mostly plants these exotic trees for commercial purposes, such as *Eucalyptus grandis*, *Pinus patula*, and *Cupressus lusitanica* (Jebiwott *et al.*, 2023).

Table 1: 2001 excision in Mau Forest Complex

Forest Block	Area excised in 2001 (Ha)	% of forest area excised in 2001
South West Mau	22,797	27
Eastern Mau	35,301	54
Molo	902	100
Western Mau	1035	5
Mount Londiani	125	0
Nabkoi	74	2
Mount Tinderet	788	3

Source: UNEP, 2008

The forest's rich biodiversity and varied degrees of disturbance from human destruction are its defining features (Table 1). Cropland made for 59% of the land cover in the Mau Forest buffer zone, making it the predominant land cover. Cropland area increased by 17,376 hectares between 1990 and 2019, whereas forest cover and grassland decreased by 13,551 hectares and 4,432 hectares, respectively. This change demonstrates the growing strain on the forest ecology brought on by a number of dangers and difficulties. Forest elimination, unchecked agriculture growth beyond excision lines, overgrazing, illegal logging, charcoal manufacture, and forest fires are all significant contributing factors. In addition, poor management of the Plantation Establishment and Livelihood Improvement Scheme (PELIS), the planting of water-intensive *Eucalyptus* trees in crucial catchment areas, and infrastructure development all contribute to the degradation of forest resources, endangering ecosystem functions and biodiversity.

Three types of sampling sites were chosen to reflect the following: fully deforested areas, moderately deforested areas, and undisturbed forest. Each site's geographic coordinates were noted to guarantee reproducibility.

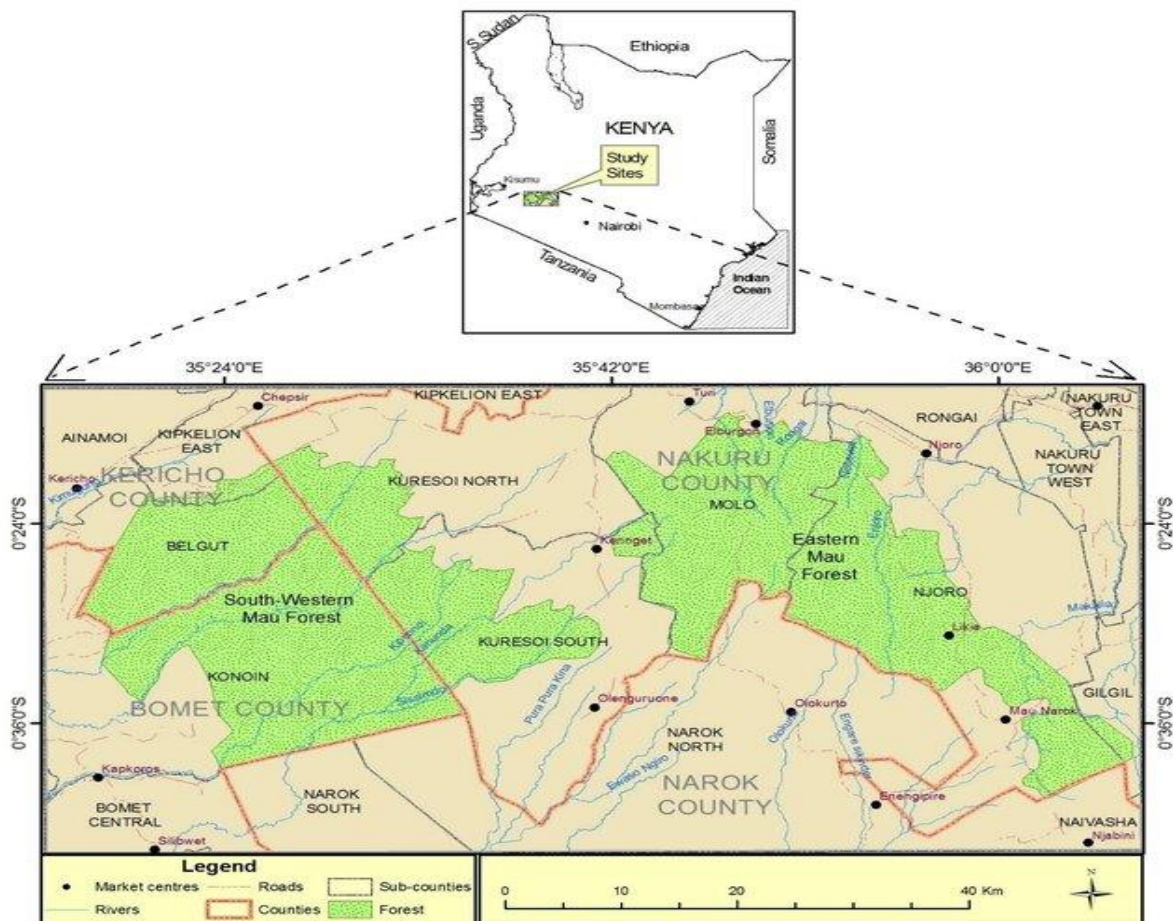


Figure 1. Map of Mau Forest Complex showing the study areas in the Eastern and South-Western Mau forests, which are dispersed throughout the Kenyan counties of Nakuru, Kericho, Bomet, and Narok.

2.2. Research Design

Three treatments were replicated across twenty blocks each containing three plots representing the three treatments generated using a Complete Block Design (CBD). Since the treatments already existed in the landscape at the time of sampling, we first identified suitable areas with based on key ecological characteristic in this case vegetation structure (canopy cover and dominant tree species such as *Podocarpus latifolius* and *Olea capensis*). Within each block, plots were then randomly selected to minimize selection bias while ensuring comparability across treatments. Interventions included:

- I. Undisturbed Forest (U): These plots were used as a control since they depicted intact forest settings with little human intervention. A closed canopy, a variety of plants, and undisturbed soil conditions were their defining characteristics.
- II. Partially Deforested (PD): The locations of these plots were in regions with some remaining vegetation and moderate deforestation. They displayed evidence of human activity, including selective logging or grazing, fragmented vegetation, and partial canopy loss.
- III. Deforested (D): Usually transformed into open spaces or agricultural fields, these plots represented regions entirely free of forest cover. They revealed an extreme amount of soil exposure, no vegetation and no canopy cover.

We organized the interventions dimensions and implementations during the rainy and dry seasons to closely reflect Kenya's standard forest management methods. Samples were collected fourteen years post-human activities in Mau Forest.

2.3. Sample Collection

Each treatment was randomly assigned to 20 plots, with blocks serving as replicates to account for spatial variations within the forest landscape. The 20 m × 20 m plots were equally distributed throughout the Eastern and South-Western Mau Forest Complex study sites. To guarantee consistent sampling setting, soil samples were collected during the wet and dry seasons. A composite sample was created by pooling five randomly selected soil cores (10 cm in diameter and 15 cm in depth) from each site. Samples of the litter layer were also

gathered in order to include fungi that are involved in the breakdown of organic matter on the surface. After being carried on ice and kept in sterile plastic bags, all samples were processed in less than 48 hours.

2.4. Isolation and Culturing of Saprotrophic Fungi

The dilution plating method was used to isolate the fungus. After homogenizing the soil samples, 90 mL of sterile distilled water were used to suspend a 10g subsample. To inhibit bacterial growth, serial dilutions were made and applied to potato dextrose agar (PDA) treated with antibiotics. Plates were incubated at 25°C for five days. For identification, newly formed fungal colonies were sub cultured onto new PDA plates.

2.5. Molecular Identification

The CTAB technique was used to extract DNA from pure fungal cultures. ITS1 and ITS4 primers were used to amplify the ribosomal DNA's internal transcribed spacer (ITS) region. Purified and sequenced PCR products were obtained. Using BLAST, sequences were compared to those in the NCBI GenBank database to identify fungal species.

2.6. Physicochemical Analysis of Soils

Important physicochemical characteristics, such as pH, organic matter content, nitrogen (N), and phosphorus (P), were examined in soil samples taken from each location. Standard procedures were used to measure these parameters: phosphorus by the Olsen technique, nitrogen by Kjeldahl digestion, organic matter by loss on ignition, and pH with a pH meter.

2.7. Fungal Diversity and Abundance Analysis

Fungal diversity indices (Shannon and Simpson) and species richness were determined for each site using the fungal composition data. Colony-forming units (CFU) per gram of soil were determined to assess fungal abundance. Comparisons were made across the three disturbance categories using one-way ANOVA.

2.8. Statistical Analysis

To assess the impact of deforestation on soil fungus populations and their relationship with soil physiochemical properties, statistical studies were conducted using both multivariate and univariate methods. The community composition differences between sites were visualized using non-metric multidimensional scaling (NMDS). To evaluate the connections between fungal diversity and soil variables, Pearson correlation coefficients were computed. Additionally, General Linear Mixed Models (GLMMs) were used to assess the effects of treatments (Undisturbed [U], Partially Disturbed [PD], and Disturbed [D]) on fungal community metrics and soil chemical properties in order to account for the hierarchical structure of the experimental design (with blocks as random factors). To account for variation across sampling sites, blocks were added as a random effect even though the treatment was modelled as a fixed effect.

The model was formulated as:

$$Y_{ijk} = \mu + \text{Treatment } i + \text{Block } j + (\text{Treatment } i \times \text{Block } j) + \epsilon_{ijk}$$

Where:

Y_{ijk}	= response variable (e.g., fungal diversity, soil phosphorus) for the i-th treatment, j-th block, and k-th observation.
μ	= overall mean.
Treatment I	= fixed effect of the i-th treatment (U, PD, D).
Block j	= random effect of the j-th block.
Treatment i × Block j	= interaction term between treatment and block (if relevant).
$\epsilon \{ijk\}$	= residual error term.

Post-hoc Tukey tests were conducted to evaluate pairwise differences among treatments and R software was used to perform statistical tests, with a significance level of $p < 0.05$.

3. Results

3.1. Physicochemical Properties of Soil

Significant differences between the three levels of treatment groups (undisturbed, partially deforested, and deforested areas) are depicted in Figure 2. The lowest amounts of organic matter (5.3%), nitrogen (0.8%), and

pH (5.2) are found in deforested areas, which is in keeping with the documented reduction brought on by less plant cover and nutrient cycling. On the other hand, undisturbed areas exhibit the highest levels of pH (6.8), nitrogen (2.1%), and organic matter (15.6%), indicating good soil conditions. Because of decreased plant absorption and increased nutrient runoff, phosphorus levels are much greater in deforested sites (26.4 mg/kg) than in undisturbed sites (14.7 mg/kg).

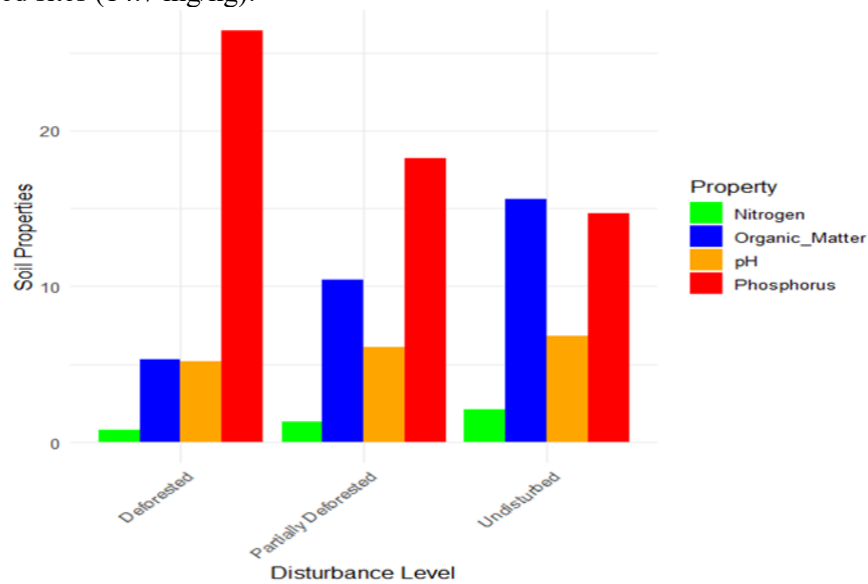


Figure 2. A bar chat that shows how the amounts of organic matter, nitrogen, phosphorus, and pH are spread out across the treatment levels levels.

3.2. Diversity and Abundance of Fungi

Treatment levels significantly affect saprotroph richness, according to the one-way ANOVA results ($F = 706.2$, $p < 2e-16$). All treatment groups (deforested, partially deforested, and undisturbed) exhibit substantial differences in their saprotroph richness as demonstrated by post-hoc analysis (Figure 3). Richness was highest at undisturbed sites (U), then partially deforested sites (PD), and lowest at deforested sites (D).

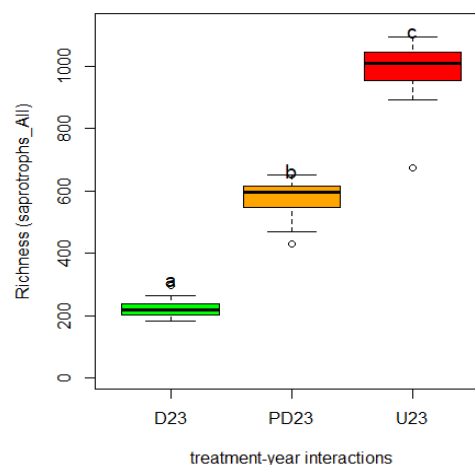


Figure 3. The impact of treatment on saprotroph richness for three different disturbance levels: partially deforested (PD), deforested (D), and undisturbed (U).

The results show that the richness of saprotroph taxa varied significantly among the three treatments (Figure 4). The genera species all show clear trends in their richness. The highest richness is consistently found in U23 (Undisturbed) sites, followed by PD23 (Partially Deforested) sites, and the lowest in D23 (Deforested) sites. *Rhizopus stolonifer*, *Aspergillus niger*, *Penicillium chrysogenum*, *Fusarium oxysporum*, *Trichoderma harzianum*, *Alternaria alternata*, *Botrytis cinerea*, *Cladosporium spp.*, and *Bipolaris sorokiniana* all showed statistically significant increases in richness from D23 to U23, with statistically significant differences across

all treatments (Table 2). The highest variability (Std. Error) was observed in *Trichoderma harzianum* and *Penicillium chrysogenum*, suggesting higher sensitivity to deforestation impacts (Table 2). These results are supported by the ANOVA and Tukey's post hoc tests, which show that intact forest ecosystems have the highest diversity and that forest disturbance dramatically lowers saprotrophic fungus richness.

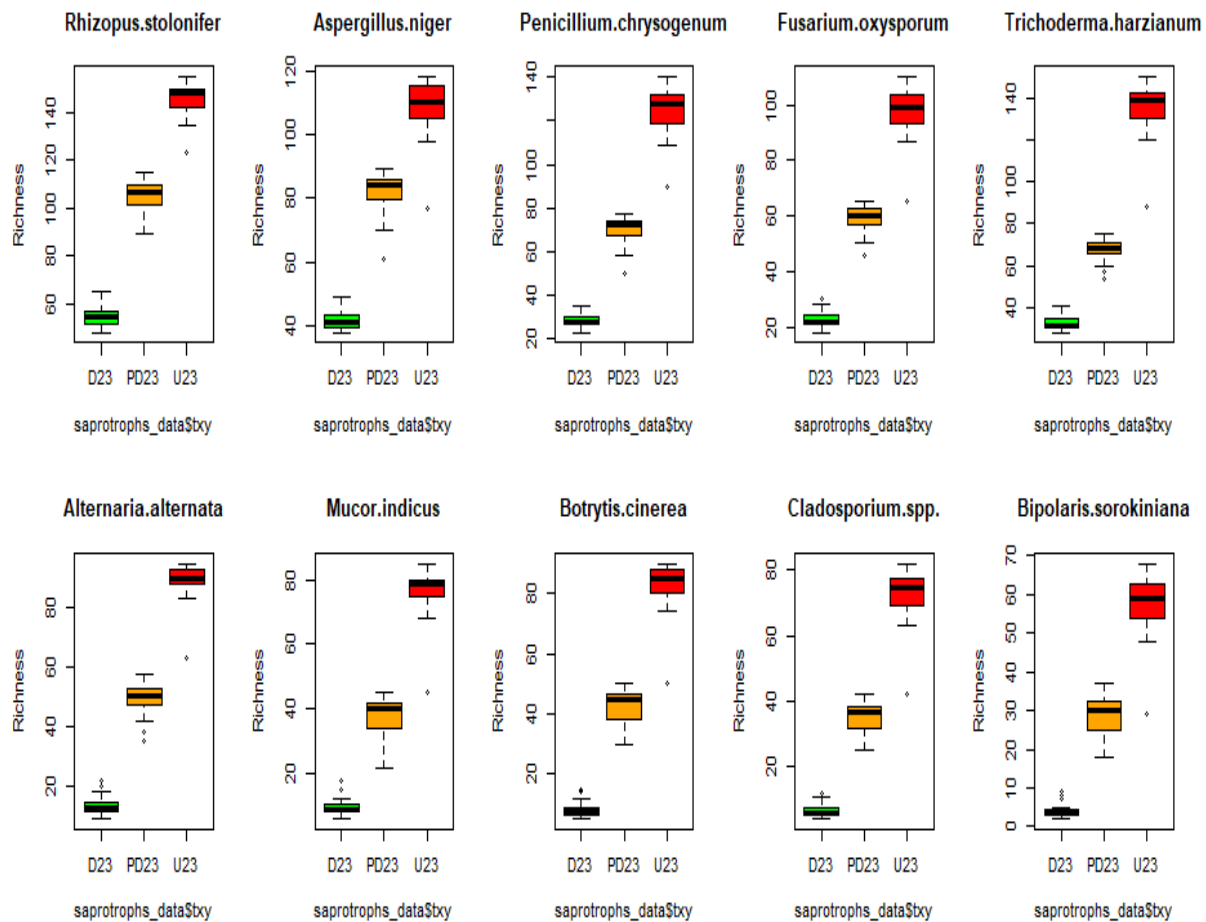


Figure 4. Boxplots of species richness across the treatment levels showing how Kenyan Mau Forest disturbance levels dramatically alters saprotrophic fungal richness, with undisturbed sites showing the highest diversity across all genera

Table 2. GLMM Analysis of Saprotroph Genera Richness Across Disturbance Levels

Genus	Treatment	Estimate	Std. Error	df	F-value	p-value	Tukey Post-Hoc Differences (p < 0.001)
<i>Rhizopus stolonifer</i>	D23	54.45	3.12	57	1086	< 2e-16	U23 > PD23 > D23
	PD23	105.5	4.21				
	U23	146	5.03				
<i>Aspergillus niger</i>	D23	41.65	2.87	57	468.7	< 2e-16	U23 > PD23 > D23
	PD23	82	3.85				
	U23	108.2	4.56				
<i>Penicillium chrysogenum</i>	D23	28.3	2.45	57	711	< 2e-16	U23 > PD23 > D23
	PD23	70.05	3.72				
	U23	124.7	5.12				
<i>Fusarium oxysporum</i>	D23	22.6	2.21	57	650.6	< 2e-16	U23 > PD23 > D23
	PD23						
	U23						

Genus	Treatment	Estimate	Std. Error	df	F-value	p-value	Tukey Post-Hoc Differences (p < 0.001)
<i>Trichoderma harzianum</i>	PD23	59.05	3.45	57	721.7	< 2e-16	U23 > PD23 > D23
	U23	97.45	4.78				
	D23	32.45	2.67				
<i>Alternaria alternata</i>	PD23	67.55	3.92	57	907.8	< 2e-16	U23 > PD23 > D23
	U23	135.15	5.32				
	D23	13.4	2.02				
<i>Mucor indicus</i>	PD23	49.55	3.25	57	522.3	< 2e-16	U23 > PD23 > D23
	U23	89.25	4.93				
	D23	9.9	1.87				
<i>Botrytis cinerea</i>	PD23	37.15	3.05	57	664.4	< 2e-16	U23 > PD23 > D23
	U23	76.45	4.72				
	D23	8.2	1.75				
<i>Cladosporium spp.</i>	PD23	42.35	3.15	57	603.8	< 2e-16	U23 > PD23 > D23
	U23	82.75	4.89				
	D23	6.7	1.6				
<i>Bipolaris sorokiniana</i>	PD23	35.2	2.98	57	390.9	< 2e-16	U23 > PD23 > D23
	U23	71.9	4.67				
	D23	4.05	1.42				
	PD23	28.6	2.75	57			
	U23	57	4.23				

In terms of CFU per gram of soil, site-specific differences in soil saprotrophic fungal abundance were measured in CFU per gram of soil (Figure 5). The areas with the largest fungal abundances were moderately deforested (3.1×10^5 CFU/g) and undisturbed forest sites (5.6×10^5 CFU/g). In completely cleared regions, fungal abundance decreased significantly (1.2×10^5 CFU/g).

The Shannon Diversity Index (H') was applied to assess fungal community diversity across different treatments, integrating species richness and evenness. In this study, undisturbed areas exhibited the highest diversity ($H' = 3.4 \pm 0.2$), with 42 species observed, reflecting a well-balanced fungal community. Partially disturbed areas showed a moderate reduction in diversity ($H' = 2.6 \pm 0.3$) with 28 species, likely due to community shifts and dominance by certain species. Deforested areas had the lowest diversity ($H' = 1.8 \pm 0.3$), with only 18 species observed, indicating significant biodiversity loss and dominance by resilient, opportunistic fungi. These results demonstrate a clear gradient in fungal diversity, declining from undisturbed to deforested areas, highlighting the impact of anthropogenic disturbances on ecosystem health and underscoring the importance of conservation to sustain biodiversity and ecosystem resilience.

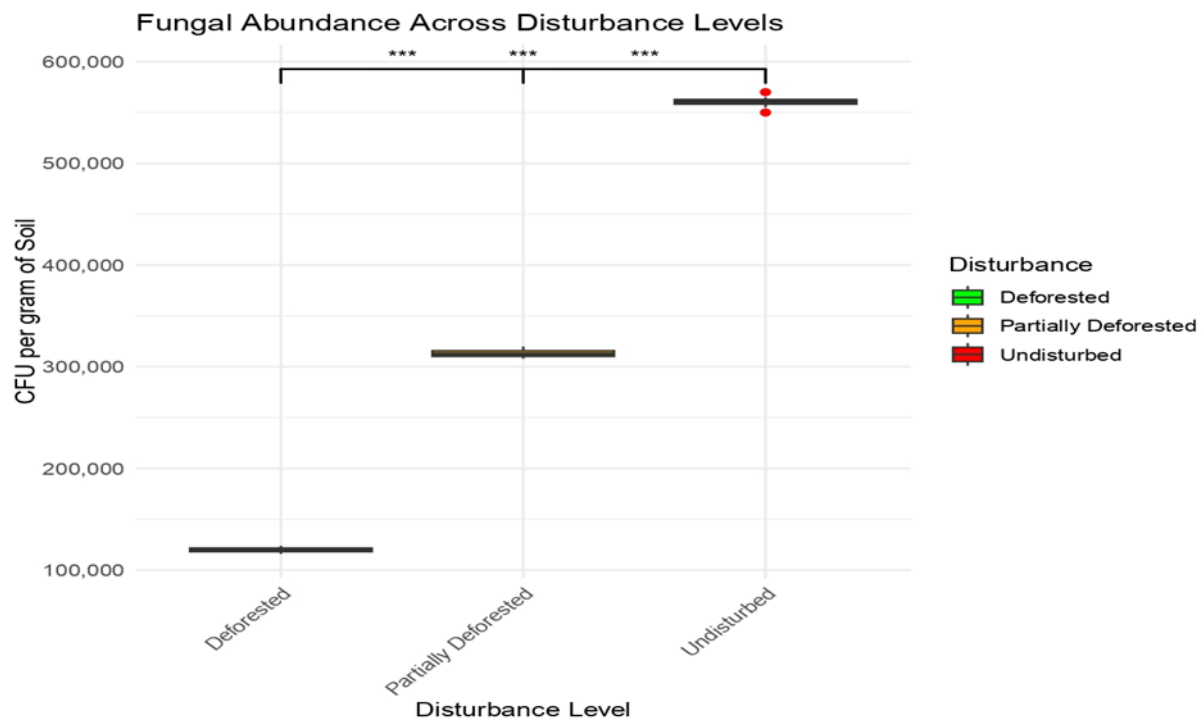


Figure 5. Fungal CFUs sharply fall over disturbance gradients, as shown in the boxplot of fungal abundance by disturbance levels.

Table 3. Generalized Linear Mixed Model (GLMM) analysis showing highly significant differences ($p < 0.001$) in fungal abundance across disturbance levels, with deforested sites (D) having the lowest abundance (1.2×10^5 CFU/g), followed by partially deforested (PD, 3.1×10^5 CFU/g), and undisturbed sites (U) exhibiting the highest abundance (5.6×10^5 CFU/g); Tukey's post-hoc test confirmed all pairwise differences ($p < 0.001$) following the trend $U > PD > D$.

Source	Estimate	Std. Error	df	F-value	p-value	Tukey Post-Hoc Differences ($p < 0.001$)
Disturbance Level			27	27,980	$< 2e-16$	Undisturbed > Partially Deforested > Deforested
Deforested (D)	1.2×10^5	9,520				
Partially Deforested (PD)	3.1×10^5	12,340				PD > D ($193,150 \pm 4,626.8$)
Undisturbed (U)	5.6×10^5	14,875				U > D ($440,250 \pm 5,625.9$), U > PD ($247,100 \pm 4,526.3$)
Residuals			27			

3.3. Fungal Community Composition

Based on the degree of disturbance, the fungal communities were clearly clustered in the non-metric multidimensional scaling (NMDS) plot (refer figure 6). U and D absolutely separated, while PD has a considerable overlap (intermediate position) between them. Unique fungal communities dominated by taxa including *Trichoderma*, *Penicillium*, and *Aspergillus* were observed in undisturbed forest settings. While some species were similar between partially deforested and undisturbed areas, opportunistic fungus like *Fusarium* were more prevalent in the former. There were very few specialized decomposers in deforested environments, which were dominated by fast-growing, stress-tolerant plants like *Rhizopus* and *Mucor*. The analysis, performed using Bray-Curtis distances, resulted in a two-dimensional solution with a final stress value of 0.1909, indicating a reliable representation of community dissimilarities in reduced dimensions. The best solution was achieved after 20 iterations, with repeated convergence validating its robustness.

Confidence ellipses (95% level) highlighted clear separation between the groups, signifying significant compositional differences among the disturbance categories. Undisturbed areas formed tight clusters, suggesting consistent and diverse fungal communities. In contrast, partially disturbed and deforested areas

exhibited more dispersed clusters, reflecting reduced diversity and dominance of opportunistic species. Species richness and community composition shifted progressively along the NMDS axes, with NMDS1 capturing variation associated with disturbance gradients (Figure 6).

NMDS Plot of Saptrophs Community Composition in Mau forest ecosystems

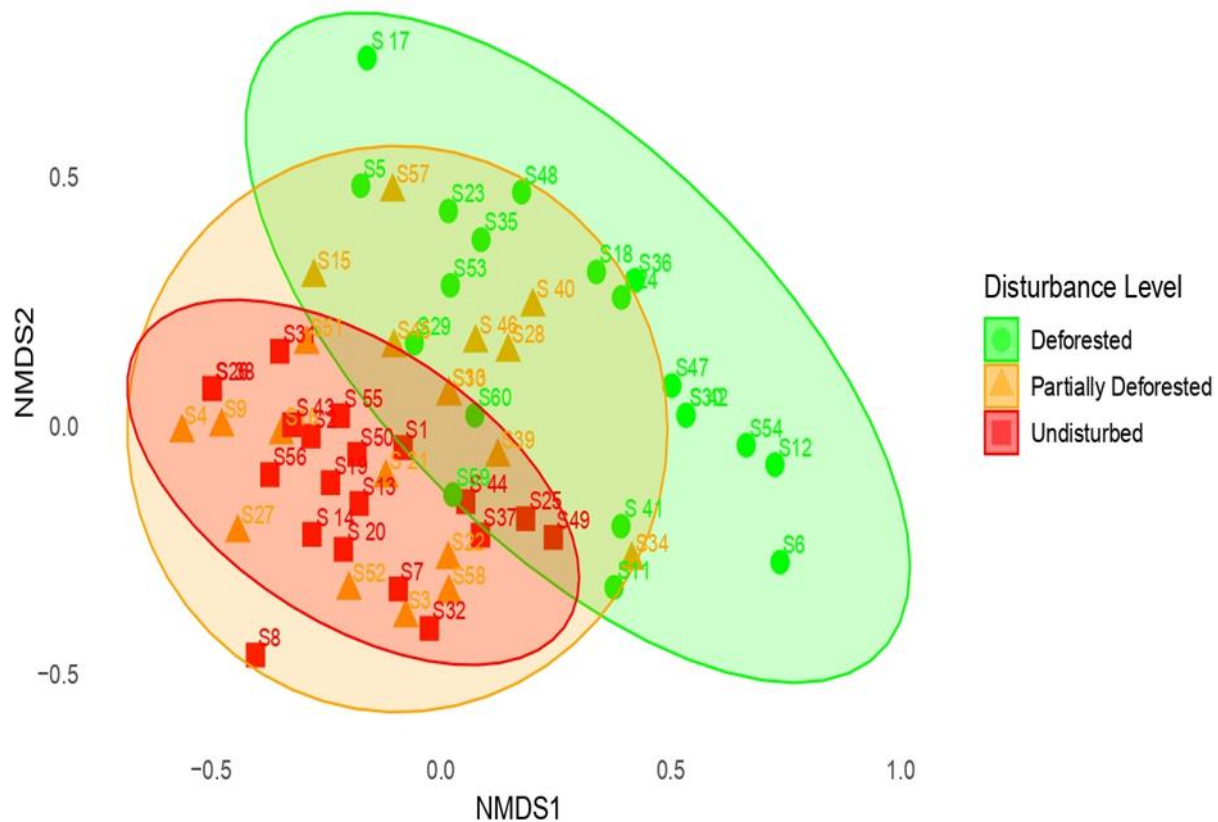


Figure 6. NMDS Plot demonstrating the use of NMDS based on Bray-Curtis dissimilarity to cluster fungal communities. The plot also included individual sample points labelled with unique identifiers, enhancing interpretability. The use of colour and shape to represent disturbance levels (green for undisturbed, orange for partially disturbed, and red for deforested) visually emphasized the impact of deforestation on fungal community structure.

3.4. Seasonal Variations

Fungal diversity and abundance varied with the season, with all sites recording greater values during the rainy season. In undisturbed forests, for example, fungal CFUs were 40% higher during the rainy season than during the dry. Nonetheless, the effects of deforestation were constant across the seasons, with the least amount of fungal diversity and abundance being seen in deforested areas (Figure 7).

3.5. Connections between Soil Properties and Fungal Diversity

Fungal diversity indices showed high positive associations with soil organic matter ($r = 0.96$, $p = 7e-11$) and nitrogen content ($r = 0.91$, $p = 1.7e-08$), according to Pearson correlation analysis. Fungal diversity and soil phosphorus levels were shown to be positively correlated ($r = 0.97$, $p = 1.4e-12$) while pH content ($r = 0.97$, $p = 2.6e-12$). These results imply that the structure of fungal communities is greatly impacted by changes in soil characteristics brought on by deforestation (Figure 8).

Both the diversity and abundance of soil saprotrophic fungus significantly decreased as a result of deforestation. There were noticeable changes in the makeup of the fungal communities, with stress-tolerant species predominating in deforested areas. While phosphorus levels were inversely correlated with fungal richness, soil organic matter and nitrogen concentration were found to be important regulators of fungal diversity.

seasonal variations on abundance and diversity of saprotrophs

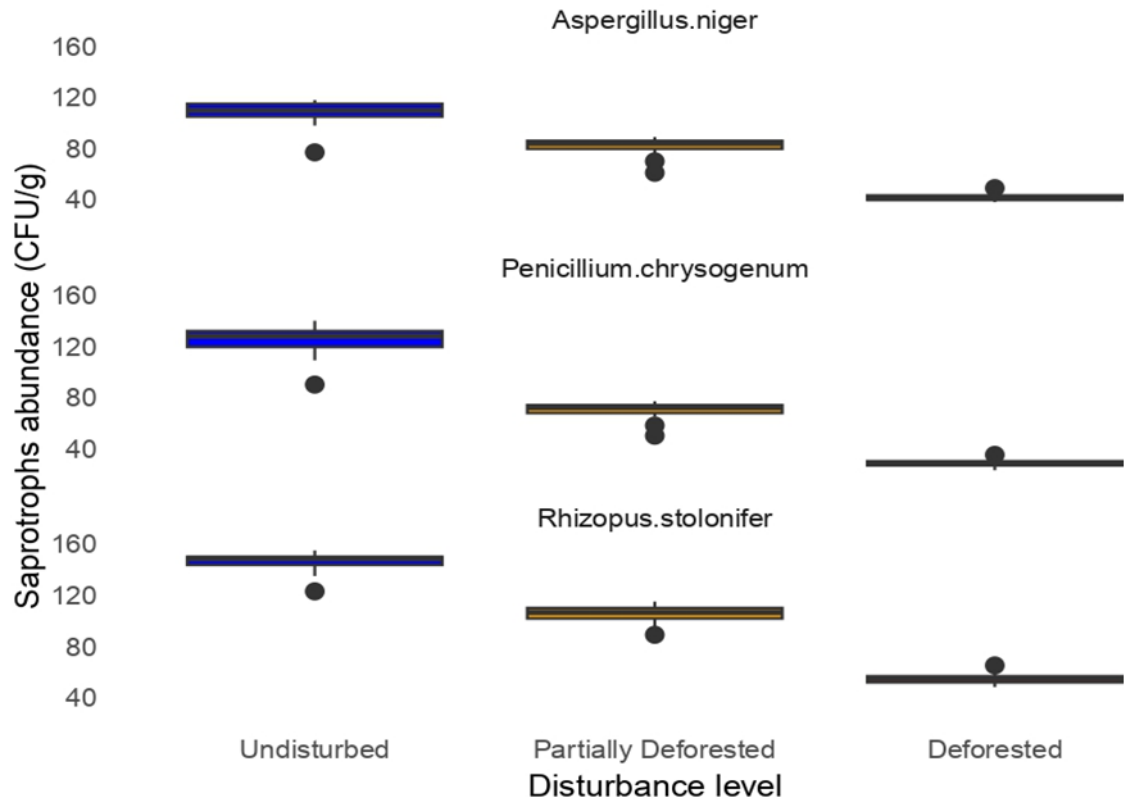


Figure 7. The seasonal variation box plot illustrates how fungal abundance varies with the seasons and degree of disturbance.

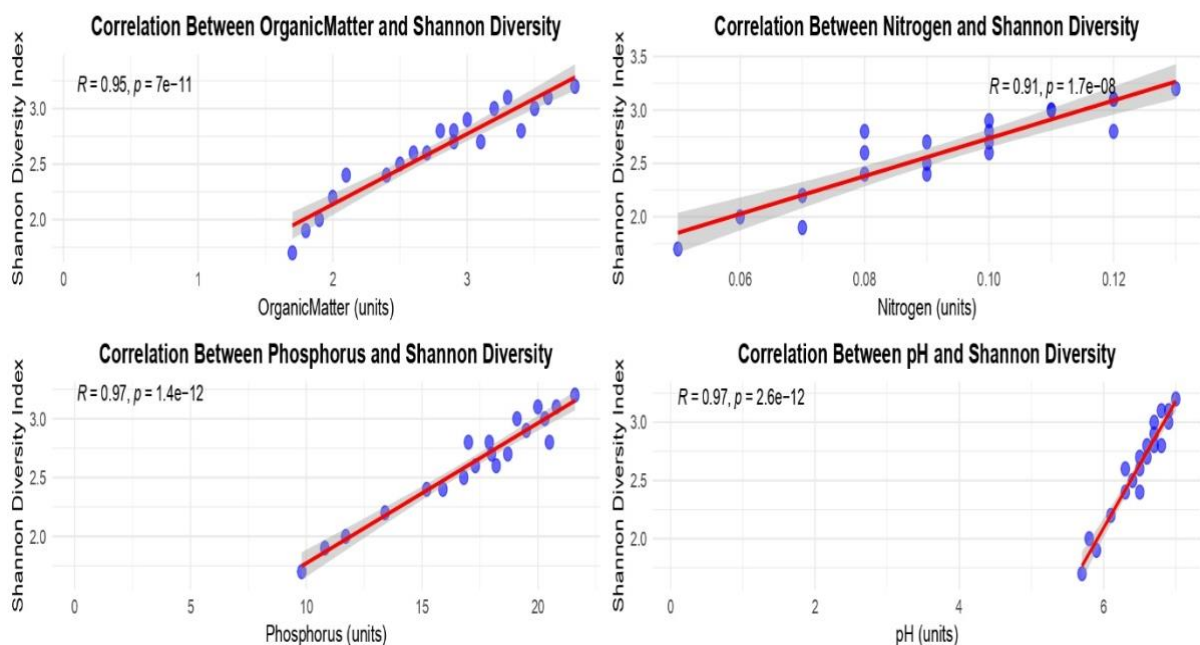


Figure 8. Scatter plots showing the correlation between soil properties (organic matter, nitrogen, phosphorus, and pH) and fungal diversity (Shannon index). Each plot includes a regression line and Pearson correlation coefficient

4. Discussion

This study emphasises how deforestation by human significantly affects the diversity, richness, and community composition of soil saprotrophic fungi in Kenya's Mau Forest ecosystem. Therefore, developing management

strategies of fungal communities in this forest requires an understanding of how the human interventions impact their survival. A comparison of undisturbed, partially deforested, and deforested areas (Appendix 1) highlights the complex interrelationships among forest disturbance, fungus populations, and soil health.

Our study demonstrated that deforestation negatively affects soil physiochemical properties, with deforested areas showing a considerable decline in organic matter, nitrogen, and pH as compared to undisturbed sites. These shifts align with earlier research that links these decreases to the depletion of vegetation and related litter input, which are essential for preserving soil fertility and biological survival (Assefa *et al.*, 2017; Rasiah *et al.*, 2004). According to Jones *et al.* (2020), the higher phosphorus levels seen in deforested areas are probably caused by increased fertiliser runoff and decreased plant uptake (Otero *et al.*, 2011). The findings highlight the vulnerability of saprophytic fungi to human activities, like in this study, saprotrophs may diminish completely in completely deforested areas but their abundance and species richness are closely dependent on the number of trees retained. The presence and composition of genera species were still maintained even in clear cuts, although at a very low relative abundance out of the total fungal community. However, key genera such as *Trichoderma*, *Penicillium*, and *Aspergillus* were gradually eliminated with the increasing level of tree cutting.

The results are in agreement with the previous studies that have highlighted saprotrophs as highly sensitive to thinning (e.g., Zhou *et al.*, 2020; Kim *et al.*, 2021; Tinya *et al.*, 2020; Ódor *et al.*, 2013) and confirm some other earlier studies showing increased survival of saprotrophs fungi close to retained trees in the undisturbed areas of the forest (e.g., Mayer *et al.*, 2022; Jones *et al.*, 2003; Tomao *et al.*, 2020). According to the reviewed studies, stand structure characteristics as canopy cover, stand basal area, and tree species variety especially for saprophytic species, have a favourable correlation with fungal diversity (Tomao *et al.*, 2020).

4.1. Fungal Diversity and Abundance Along Disturbance Gradients

The dramatic fall in CFU counts and Shannon diversity index values in deforested areas indicates that fungal diversity and abundance are significantly reduced by deforestation. Undisturbed locations exhibit the highest levels of richness and abundance, highlighting the importance of unaltered forests in sustaining a variety of functional fungal communities. The results of Ong *et al.*, (2013), who showed that forest disturbance upsets fungal ecosystems and favours opportunistic species over specialised decomposers, are consistent with these findings. The findings highlight the significance of forest conservation in maintaining soil biodiversity, which is essential for the resilience and well-being of ecosystems.

4.2. Shifts in Fungal Community Composition

Different fungal community patterns across disturbance levels were identified by the NMDS study. *Aspergillus*, *Trichoderma*, and *Penicillium* taxa recognised for their functions in organic matter breakdown and nutrient cycling dominated undisturbed environments (Treseder and Lennon, 2015). On the other hand, *Rhizopus* and *Mucor*, which are fast-growing and stress-tolerant taxa that flourish in disturbed habitats, were shown to be more common in deforested areas (Vandegrift *et al.*, 2023; Rosa *et al.*, 2023). These results demonstrate that whereas specialised decomposers are less common, generalist and opportunistic fungi are favoured by deforestation. Long-term effects on nutrient dynamics and soil health may result from such changes.

4.3. Seasonal Variations in Fungal Diversity and Abundance

Across all disturbance levels, seasonal variations were noted, with the rainy season showing greater fungal diversity and abundance. This pattern is a result of more moisture being available, which encourages fungal activity and growth. But despite of seasonal variations, the steady reduction in diversity and richness in deforested areas throughout the year highlights the long-lasting effects of deforestation. Similar tendencies in tropical forest ecosystems were described by Marques *et al.*, (2022), and these findings are consistent with their findings.

4.4. Correlation between Soil Properties and Fungal Diversity

The important role that pH, nitrogen, and soil organic matter play in forming fungal communities is highlighted by the substantial positive correlations found between fungal diversity and these soil characteristics. Wang *et al.*, (2018) found that organic matter and nitrogen were important factors in microbial diversity, and these findings are in line with their earlier studies. Contrary to several previous results, this study found a positive

correlation between phosphorus levels and fungus diversity. The dynamics of phosphorus availability and its interactions with other soil variables are examples of site-specific processes that may be responsible for this.

4.5. Implications for Conservation and Management

The results demonstrate the adverse effects that deforestation causes to soil fungus populations and related ecological processes. The substantial decline in diversity and abundance in deforested areas emphasises how urgently conservation measures are needed to protect forest ecosystems. Reforestation and the encouragement of sustainable land-use practices could lessen these effects and improve soil biodiversity in deforested areas. Furthermore, it appears that preserving soil health is essential to developing resilient fungal communities in forest environments, given the substantial correlations found between fungal diversity and soil characteristics.

5. Conclusion

This study emphasises how deforestation in Kenya's Mau Forest has a significant effect on soil saprotrophic fungi. Together with changes in community composition, the notable decrease in variety and abundance illustrates the severe ecological disturbances brought on by forest loss. Preserving intact forest ecosystems and repairing degraded regions must be the top priorities of conservation efforts in order to protect soil biodiversity and ecosystem processes. Long-term monitoring and an investigation of the mechanisms behind the observed trends should be the main goals of future study in order to guide specific conservation measures.

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Declaration of generative AI use

The authors declare that no generative AI or AI-assisted technologies were used in the preparation of this manuscript.

References

- Assefa, D., Rewald, B., Sandén, H., Rosinger, C., Abiyu, A., Yitaferu, B., & Godbold, D. L. (2017). Deforestation and land use strongly effect soil organic carbon and nitrogen stock in Northwest Ethiopia. *Catena*, 153, 89–99. <https://doi.org/10.1016/j.catena.2017.02.003>
- Bewernick, T., Rufino, M., Mora, B., & Ur, W. (2016). Mapping Forest Degradation in the Mau Forest Complex Using NDFI Time Series.
- Bödeker, I. T. M., Lindahl, B. D., Olson, Å., & Clemmensen, K. E. (2016). Mycorrhizal and saprotrophic fungal guilds compete for the same organic substrates but affect decomposition differently. *Functional Ecology*, 30(12), 1967–1978. <https://doi.org/10.1111/1365-2435.12677>
- Chivian, E. (n.d.). Biodiversity: Its Importance to Human Health A Project of the Center for Health and the Global Environment Harvard Medical School under the auspices of the World Health Organization, the United Nations Development Programme, and the United Nations Environment Programme. www.med.harvard.edu/chge
- Cookson, W. R., Murphy, D. V., & Roper, M. M. (2008). Characterizing the relationships between soil organic matter components and microbial function and composition along a tillage disturbance gradient. *Soil Biology and Biochemistry*, 40(3), 763–777. <https://doi.org/10.1016/j.soilbio.2007.10.011>
- Duguid, M. C., & Ashton, M. S. (2013). A meta-analysis of the effect of forest management for timber on understory plant species diversity in temperate forests. In *Forest Ecology and Management* (Vol. 303, pp. 81–90). <https://doi.org/10.1016/j.foreco.2013.04.009>
- Forest, M., Jebiwott, A., Morara Ogendi, G., Kaseya Kazaba, P., & Akintunde Alo, A. (n.d.). An Assessment of the Process and Impacts of Evictions on Livelihoods in.
- Grinhut, T., Hadar, Y., & Chen, Y. (2007). Degradation and transformation of humic substances by saprotrophic fungi: processes and mechanisms. In *Fungal Biology Reviews* (Vol. 21, Issue 4, pp. 179–189). <https://doi.org/10.1016/j.fbr.2007.09.003>
- Jones, M. D., Durall, D. M., & Cairney, J. W. G. (2003). Ectomycorrhizal fungal communities in young forest stands regenerating after clearcut logging. In *New Phytologist* (Vol. 157, Issue 3, pp. 399–422). <https://doi.org/10.1046/j.1469-8137.2003.00698.x>

- Kim, S., Axelsson, E. P., Girona, M. M., & Senior, J. K. (2021). Continuous-cover forestry maintains soil fungal communities in Norway spruce dominated boreal forests. *Forest Ecology and Management*, 480. <https://doi.org/10.1016/j.foreco.2020.118659>
- Kubartová, A., Ranger, J., Berthelin, J., & Beguiristain, T. (2009). Diversity and decomposing ability of saprophytic fungi from temperate forest litter. *Microbial Ecology*, 58(1), 98–107. <https://doi.org/10.1007/s00248-008-9458-8>
- Lebreton, A., Zeng, Q., Miyauchi, S., Kohler, A., Dai, Y.-C., & Martin, F. M. (2025). Evolution of the Mode of Nutrition in Symbiotic and Saprotrophic Fungi in Forest Ecosystems. 26. <https://doi.org/10.1146/annurev-ecolsys-012021>
- Lindahl, B. D., & Tunlid, A. (2015). Ectomycorrhizal fungi - potential organic matter decomposers, yet not saprotrophs. In *New Phytologist* (Vol. 205, Issue 4, pp. 1443–1447). Blackwell Publishing Ltd. <https://doi.org/10.1111/nph.13201>
- Lladó, S., López-Mondéjar, R., & Baldrian, P. (2017). Forest Soil Bacteria: Diversity, Involvement in Ecosystem Processes, and Response to Global Change. *Microbiology and Molecular Biology Reviews*, 81(2). <https://doi.org/10.1128/mmb.00063-16>
- Manoharachary, C., Sridhar, K., Singh, R., Adholeya, A., Suryanarayanan, T. S., Rawat, S., & Johri, B. N. (2005). Fungal biodiversity: Distribution, conservation and prospecting of fungi from India. In *Current Science* (Vol. 89, Issue 1). <https://about.jstor.org/terms>
- Marques, N. C. S., Machado, R. B., Aguiar, L. M. S., Mendonça-Galvão, L., Tidon, R., Vieira, E. M., Marini-Filho, O. J., & Bustamante, M. (2022). Drivers of change in tropical protected areas: Long-term monitoring of a Brazilian biodiversity hotspot. In *Perspectives in Ecology and Conservation* (Vol. 20, Issue 2, pp. 69–78). Associacao Brasileira de Ciencia Ecologica e Conservacao. <https://doi.org/10.1016/j.pecon.2022.02.001>
- Mau, W. (2018). Coordinated Water Towers Conservation (2 nd Quarter).
- Mayer, M., Rosinger, C., Gorfer, M., Berger, H., Deltedesco, E., Bässler, C., Müller, J., Seifert, L., Rewald, B., & Godbold, D. L. (2022). Surviving trees and deadwood moderate changes in soil fungal communities and associated functioning after natural forest disturbance and salvage logging. *Soil Biology and Biochemistry*, 166. <https://doi.org/10.1016/j.soilbio.2022.108558>
- McGlone, M. S., Buitenwerf, R., & Richardson, S. J. (2016). The formation of the oceanic temperate forests of New Zealand. In *New Zealand Journal of Botany* (Vol. 54, Issue 2, pp. 128–155). Taylor and Francis Ltd. <https://doi.org/10.1080/0028825X.2016.1158196>
- Ning, Q., Chen, L., Zhang, C., Ma, D., Li, D., Han, X., Cai, Z., Huang, S., & Zhang, J. (2021). Saprotrophic fungal communities in arable soils are strongly associated with soil fertility and stoichiometry. *Applied Soil Ecology*, 159. <https://doi.org/10.1016/j.apsoil.2020.103843>
- Njuguni, S. K. M., Nyawira, M. M., Wachira, P. M., Okoth, S., Muchai, S. M., & Saado, A. H. (2018). Effects of land use on the diversity of Macrofungi in Kereita Forest Kikuyu Escarpment, Kenya. *Current Research in Environmental and Applied Mycology*, 8(2), 254–281. <https://doi.org/10.5943/cream/8/2/10>
- Ódor, P., Király, I., Tinya, F., Bortignon, F., & Nascimbene, J. (2013). Patterns and drivers of species composition of epiphytic bryophytes and lichens in managed temperate forests. *Forest Ecology and Management*, 306, 256–265. <https://doi.org/10.1016/j.foreco.2013.07.001>
- Ong, J. E., Wooi, & Gong, K. (2013). STRUCTURE, FUNCTION STRUCTURE, FUNCTION AND MANAGEMENT OF AND MANAGEMENT OF MANGROVE ECOSYSTEMS MANGROVE ECOSYSTEMS.
- Otero, J. D., Figueroa, A., Muñoz, F. A., & Peña, M. R. (2011). Loss of soil and nutrients by surface runoff in two agro-ecosystems within an Andean paramo area. *Ecological Engineering*, 37(12), 2035–2043. <https://doi.org/10.1016/j.ecoleng.2011.08.001>
- Rasiah, V., Florentine, S. K., Williams, B. L., & Westbrooke, M. E. (2004). The impact of deforestation and pasture abandonment on soil properties in the wet tropics of Australia. *Geoderma*, 120(1–2), 35–45. <https://doi.org/10.1016/j.geoderma.2003.08.008>
- Rosa, C. A., Lachance, M. A., Limtong, S., Santos, A. R. O., Landell, M. F., Gombert, A. K., Morais, P. B., Sampaio, J. P., Gonçalves, C., Gonçalves, P., Góes-Neto, A., Santa-Brígida, R., Martins, M. B., Janzen, D. H., & Hallwachs, W. (2023). Yeasts from tropical forests: Biodiversity, ecological interactions, and as sources of bioinnovation. In *Yeast* (Vol. 40, Issue 11, pp. 511–539). John Wiley and Sons Ltd. <https://doi.org/10.1002/yea.3903>
- Talbot, J. M., Bruns, T. D., Smith, D. P., Branco, S., Glassman, S. I., Erlandson, S., Vilgalys, R., & Peay, K. G. (2013). Independent roles of ectomycorrhizal and saprotrophic communities in soil organic matter

- decomposition. *Soil Biology and Biochemistry*, 57, 282–291. <https://doi.org/10.1016/j.soilbio.2012.10.004>
- Tinya, F., Kovács, B., Aszalós, R., Tóth, B., Csépanyi, P., Németh, C., & Ódor, P. (2020). Initial regeneration success of tree species after different forestry treatments in a sessile oak-hornbeam forest. *Forest Ecology and Management*, 459. <https://doi.org/10.1016/j.foreco.2019.117810>
- Tomao, A., Antonio Bonet, J., Castaño, C., & de-Miguel, S. (2020). How does forest management affect fungal diversity and community composition? Current knowledge and future perspectives for the conservation of forest fungi. In *Forest Ecology and Management* (Vol. 457). Elsevier B.V. <https://doi.org/10.1016/j.foreco.2019.117678>
- Touré, G. P. T., Koné, A. W., Nandjui, J., Ebou, A. E. T., Otinga, A. N., Maïga, A. A., Kouadjo, C. G. Z., Tiho, S., & Zézé, A. (2023). Changes in arbuscular mycorrhizal fungal communities, mycorrhizal soil infectivity, and phosphorus availability under *Chromolaena odorata* (Asteraceae) invasions in a West-African forest-savanna ecotone. *Mycorrhiza*, 33(4), 257–275. <https://doi.org/10.1007/s00572-023-01113-9>
- Treseder, K. K., & Lennon, J. T. (2015). Fungal Traits That Drive Ecosystem Dynamics on Land. *Microbiology and Molecular Biology Reviews*, 79(2), 243–262. <https://doi.org/10.1128/mmbr.00001-15>
- Vandegrift, R., Newman, D. S., Dentinger, B. T. M., Batallas-Molina, R., Dueñas, N., Flores, J., Goyes, P., Jenkinson, T. S., McAlpine, J., Navas, D., Policha, T., Thomas, D. C., & Roy, B. A. (2023). Richer than Gold: the fungal biodiversity of Reserva Los Cedros, a threatened Andean cloud forest. *Botanical Studies*, 64(1). <https://doi.org/10.1186/s40529-023-00390-z>
- Wang, C., Liu, D., & Bai, E. (2018). Decreasing soil microbial diversity is associated with decreasing microbial biomass under nitrogen addition. In *Soil Biology and Biochemistry* (Vol. 120, pp. 126–133). Elsevier Ltd. <https://doi.org/10.1016/j.soilbio.2018.02.003>
- Zhou, Z., Wang, C., Ren, C., & Sun, Z. (2020). Effects of thinning on soil saprotrophic and ectomycorrhizal fungi in a Korean larch plantation. *Forest Ecology and Management*, 461. <https://doi.org/10.1016/j.foreco.2020.117920>