Resilience of Soil Fungal Communities Following a Forest Fire

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Introduction

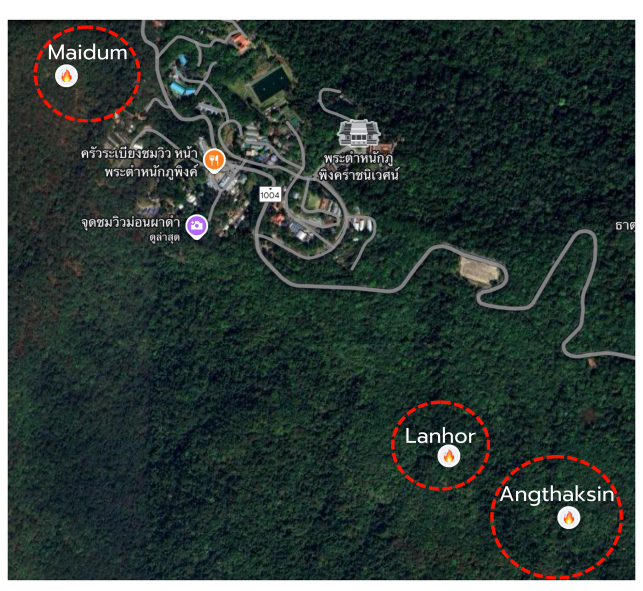
Wildfires are natural disturbances that play a crucial role in shaping forest ecosystems, influencing soil properties, nutrient cycling, and microbial communities *(D. Alem et al., 2020; A. Orumaa et al., 2022)*. Among these, soil fungi are essential for organic matter decomposition, plant nutrient uptake, and ecosystem resilience. However, fire can disrupt fungal communities by altering their diversity and composition, potentially affecting their ecological functions.

Previous studies suggest that fungal communities exhibit varying degrees of resilience to fire, depending on fire intensity, soil conditions, and post-fire succession *(D. Alem et al., 2020; A. Orumaa et al., 2022)*. Some fungal taxa, particularly those involved in organic matter decomposition, may increase in abundance, while mycorrhizal fungi that depend on host plants may decline. Understanding the long-term effects of fire on fungal communities is critical for assessing forest recovery and developing effective post-fire restoration strategies.

This study investigates the impact of fire on soil fungal communities by comparing burned and unburned forest plots. Using high-throughput sequencing of fungal ITS regions, we assess fungal diversity, composition, and potential functional shifts following fire disturbance.

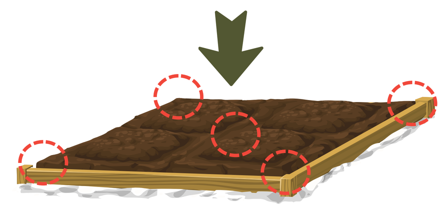
Methods

1. Soil Sample Collection

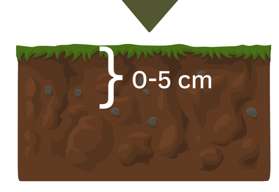


Samples collected from three main sites.
(Doi Suthep-Pui National Park, Chiang Mai, Thailand)
- Angthaksin: 18°47'47.38"N, 98°54'20.70"E
- Lanhor: 18°47'52.67"N, 98°54'9.83"E
- Maidum: 18°48'25.39"N, 98°53'34.97"E

Each site includes burned and unburned plots for comparison.



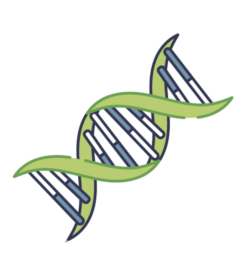
Soil samples were taken from 5 points per plot (4 corners + center).



Sampling depth: 0-5 cm

2. DNA Extraction and Fungal Community Analysis

DNA extraction using ZymoBIOMICS® kits



NGS (Illumina MiSeq) for fungal community profiling

Taxonomic classification using UNITE and NCBI databases

Data analysis with QIIME2 and Phyloseq

Statistical tests

Conclusion

- **Alpha Diversity Analysis** Fire does not drastically reduce fungal diversity but may shift the community balance, favoring certain species over others.
- **Beta Diversity Analysis** Wildfire alters fungal community structure by changing species composition rather than overall abundance.
- **Environmental Variables Influencing Microbial Composition** Ammonium is the primary factor influencing fungal composition, but other unmeasured environmental or biological interactions may contribute to community changes.
- **Differential Abundance Analysis** Wildfire alters fungal communities by increasing fire-resistant species like Ascomycota while reducing others like Basidiomycota. Interestingly, *Penicillium* increased in abundance in fire-affected areas.
- **Ecological Functional Prediction** Overall fungal diversity remains relatively stable, their ecological role shifts toward greater organic matter decomposition, which may affect long-term forest recovery.

Acknowledgement

- Assoc. Prof. Dr. Prasit Wangphakapanawong, Dr. Nattaluk Khamyong, and Dr. Kittiyut Panchai for their guidance on research planning and soil sample collection.

References

- D. Alem, T. Dejene, J. A. Oria-de-Rueda, J. Geml, C. Castaño, J. E. Smith, & P. Martín-Pinto. (2020). Soil fungal communities and succession following wildfire in Ethiopian dry Afromontane forests, a highly diverse underexplored ecosystem. Forest Ecology and Management. (474). doi: org/10.1016/j.foreco.2020.118328
- A. Orumaa, A. Agan, S. Anslan, T. Drenkhan, R. Drenkhan, K. Kauer, K. Köster, L. Tedersoo, & M. Metslaid. (2022). Long-term effects of forest res on fungal community and soil properties along a hemiboreal Scots pine forest fire chronosequence. Science of the Total Environment. DOI: 10.1016/j.scitotenv.2022.158173

Results

Alpha Diversity Analysis

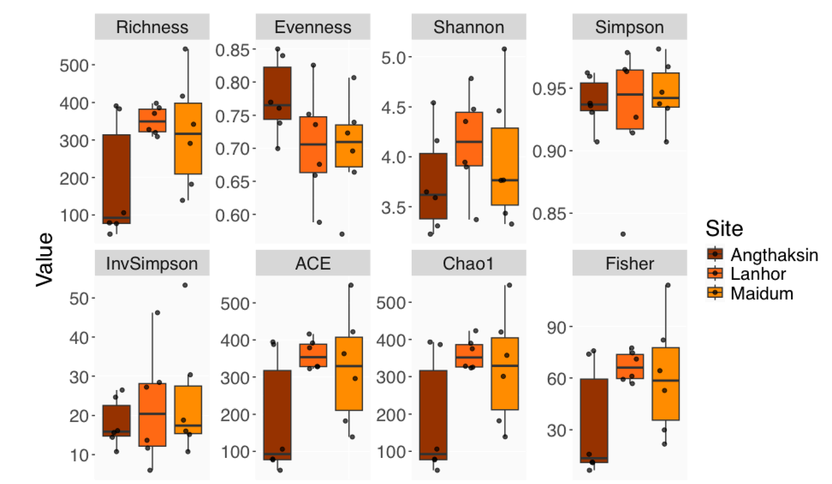


Figure 1: Alpha Diversity Metrics of Fungal Communities Across Three Sites (Angthaksin, Lanhor, Maidum) at amplicon sequence variants (ASVs) level, highlighting similar community composition among sites. The boxplot shows differences in species richness, evenness, and diversity indices, highlighting community composition trends.

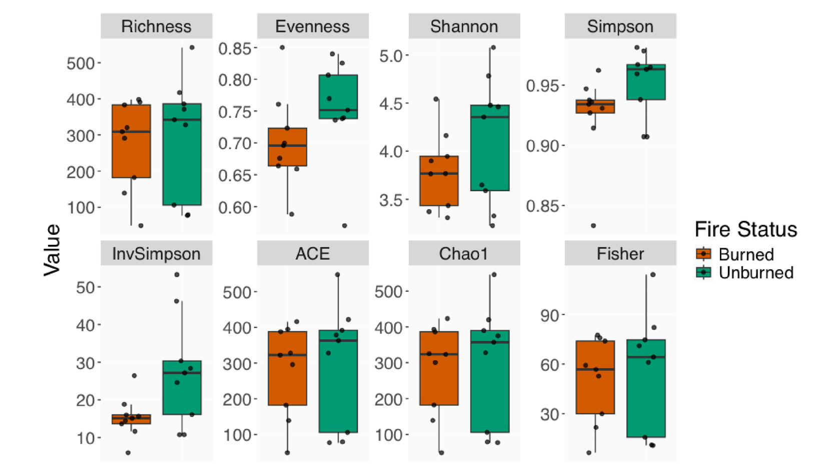


Figure 2: Alpha Diversity Metrics of Fungal Communities in Burned vs. Unburned Areas at ASVs level, highlighting similar community composition among sites. The boxplot shows differences in species richness, evenness, and diversity indices, highlighting similar community composition trends.

Beta Diversity Analysis

Test	Dissimilarity	Df	SumOfSqs	R2	F	p-value	Significance
~Fire	Bray-Curtis	1	0.4956	0.07993	1.39	0.056	.
	Jaccard	1	0.5223	0.07293	1.2586	0.038	*
~Fire+Site_name	Bray-Curtis	3	1.6931	0.27305	1.7529	0.001	***
	Jaccard	3	1.6885	0.23576	1.4397	0.001	***
~Fire, strata = Site	Bray-Curtis	1	0.4956	0.07993	1.39	0.005	**
	Jaccard	1	0.5223	0.07293	1.2586	0.004	***

Table 1: PERMANOVA Analysis of Fire Impact on Microbial Beta Diversity Using Bray-Curtis and Jaccard Dissimilarity. Three models were tested: 1. (~Fire): Examines fire effects without considering site influence. 2. (~Fire + Site_name): Evaluates combined effects of fire and site. 3. (~Fire, strata = Site_name): Controls for site variation by restricting permutations within each site. A significant p-value ($p < 0.05$) indicates fire impacts microbial composition, with stronger effects when site differences are controlled. Bray-Curtis assesses abundance-based differences, while Jaccard measures species presence/absence changes.

Environmental Variables Influencing Microbial Composition

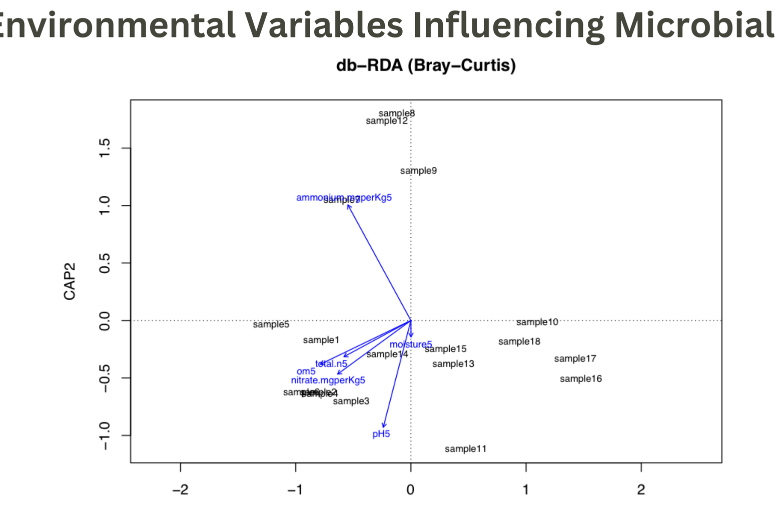


Figure 3: db-RDA Plot Showing Environmental Influences on Microbial Community Composition (Bray-Curtis Dissimilarity). Each point represents a sample, with arrows indicating the strength and direction of environmental effects. Ammonium concentration is the most significant factor, while pH, organic matter, nitrogen, nitrate, and moisture have lesser impacts.

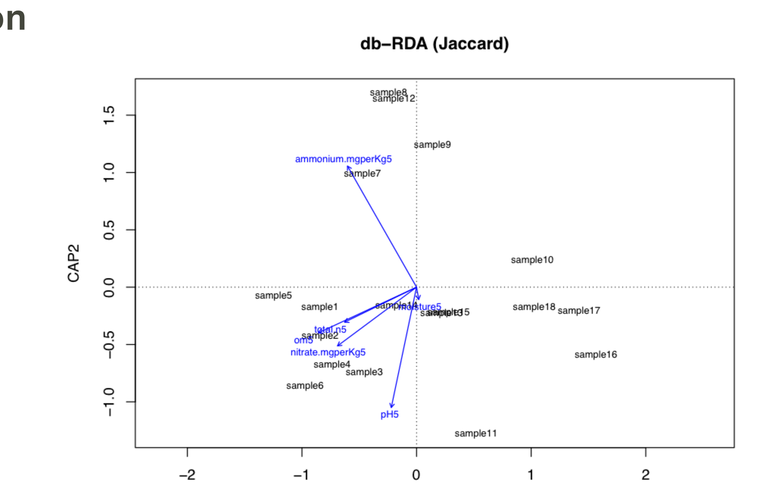


Figure 4: db-RDA Plot Showing Environmental Influences on Microbial Community Composition (Jaccard Dissimilarity). Each point represents a sample, with arrows indicating the strength and direction of environmental effects. Ammonium concentration is the most significant factor, while pH, organic matter, nitrogen, nitrate, and moisture have lesser impacts.

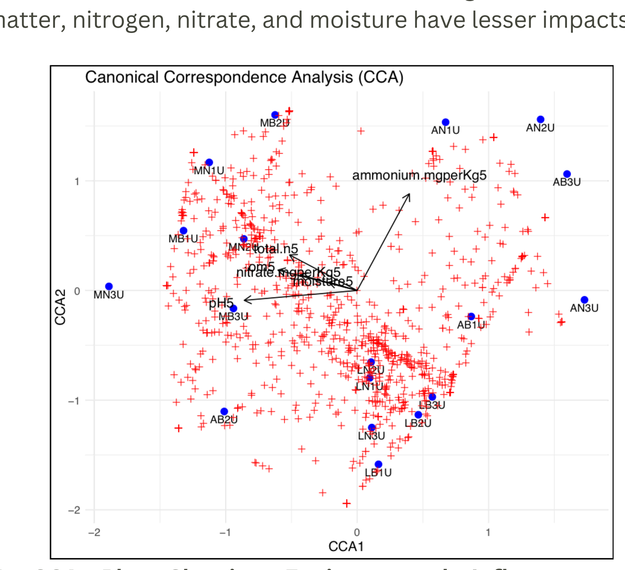


Figure 5: CCA Plot Showing Environmental Influences on Microbial Community Composition. Each point represents a sample, with arrows indicating the strength and direction of pH, organic matter, nitrogen, nitrate, ammonium, and moisture on community distribution.

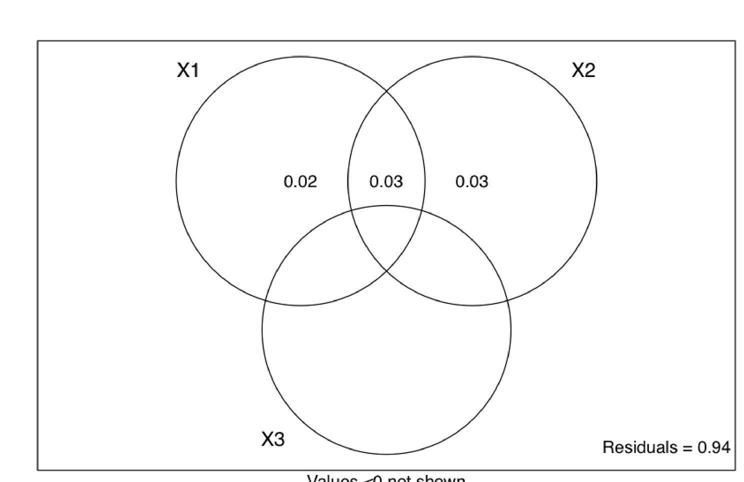


Figure 6: VPA Showing Environmental Contributions to Beta Diversity in Microbial Communities. Variables are grouped into soil chemistry: pH, organic matter (X1), nitrogen factors: total nitrogen, nitrate, ammonium (X2), and moisture (X3). Residuals (0.94) indicate 94% of variation remains unexplained, suggesting other influencing factors.

Differential Abundance Analysis

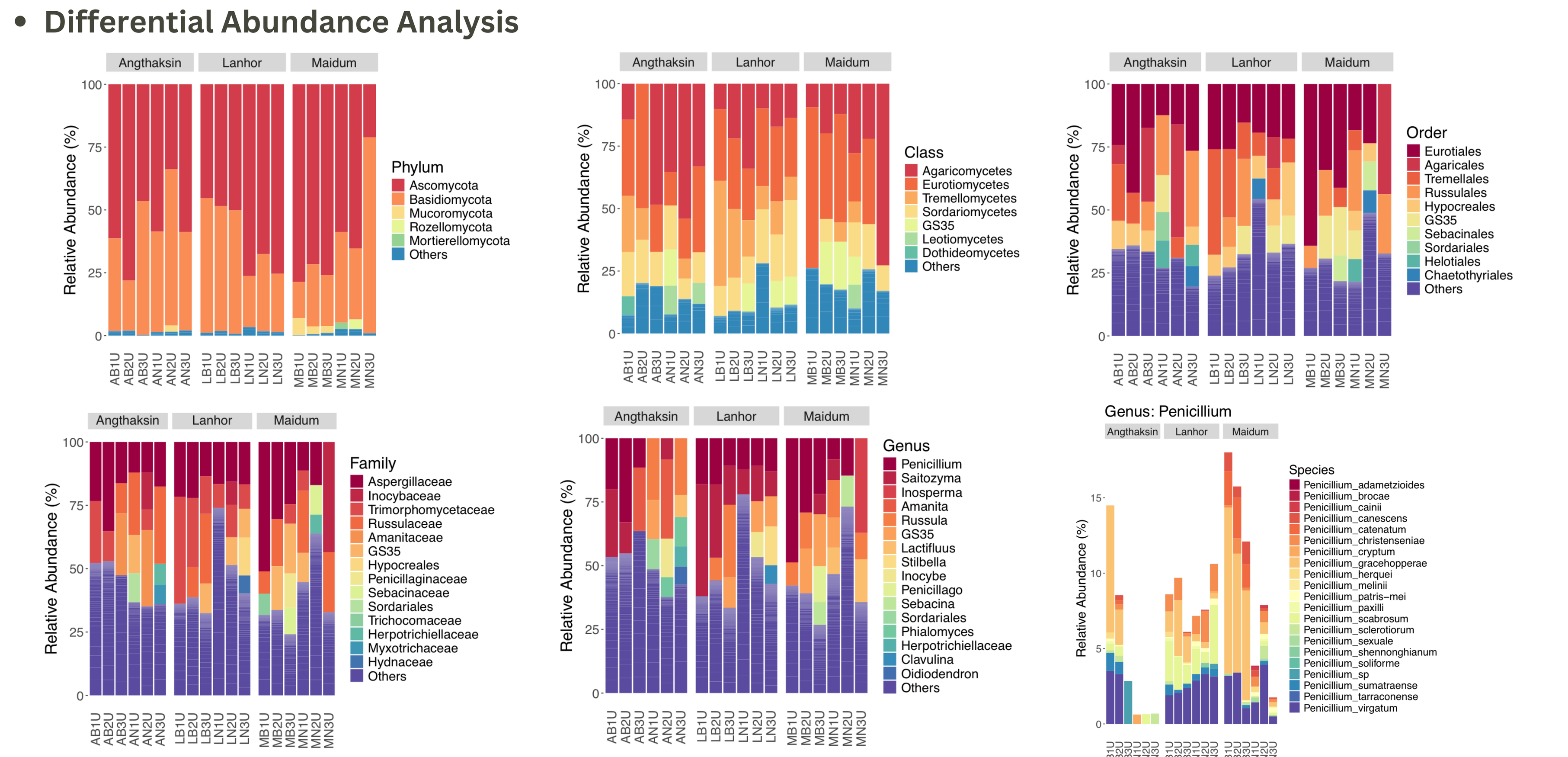


Figure 7: Proportional Prevalence of Fungi Across Sites and Fire Conditions. The bar chart shows fungal community composition across Angthaksin (A), Lanhor (L), Maidum (M), burned (B), and unburned (U) areas.

Ecological Functional Prediction

Figure 8: Average prevalence of the six most common fungal lifestyles under burned and unburned conditions. Bars indicate the standard error of the mean (SEM).