MULTIVARIATE ANALYSIS OF MORELS HABITAT DIVERSITY ALONG WITH ASSOCIATED VEGETATION DYNAMICS IN DISTRICT SWAT, KHYBER PAKHTUNKHWA, PAKISTAN

Furqan Ali[1], Amjad Ur Rahman[2], Fazli Maula[2*], Huma Gul[2]

[1]*Department of Botany, Abdul Wali Khan University, Mardan23200, Khyber PukhtunkhwaPakistan*

[2]*Department of Plant sciences, Quaid-i-Azam, University, Islamabad 45320, Pakistan.*

furqanskhan@awkum.edu.pk

jadqau2009@gmail.com;

humagul@bs.qau.edu.pk

Corresponding author*:fazlimaul@bs.qau.edu.pk

Abstract

Morchella species are edible wild mushrooms growing under specific environmental conditions in temperate regions. The current study was designed to analyze morels diversity along with associated vegetation in addition to outline key eco-edaphic and environmental factors influencing distribution of mushrooms from three diverse forests of Swat, Pakistan. Randomized square plots were laid down along the transect line in 20 stands in the study area. Environmental factors were documented, and edaphic features were determined, analyzed, and compared. Four morels species Morchellaconica, Morchellaesculenta, Morchellasemilibera and Morchellaelata were reported from different elevation ranges. A higher canopy cover (88%) favors abundance of morels. Soil analysis showed that morel preferably appeared in loamy to sandy loam textured soil at pH (mean=7.4) and with high organic matter (2.5%) in the soil. The CCA analysis of associated plant species of morels whose relationship with various factors were carried out. Debregesiasaliciflorie, Ficusplamata, Alnusnitida, were associated dominant trees based on IVI whereas Pinuswallichiana, Cornusmacrophylla, Cedrusdeodara, Juniperuscommunis were rare trees. Jaminumofficinale, Jasminumpolyantum were dominant associated shrubs while Rubusfruiticosus, Rosa indica, were rare shrubs in morels habitat. Whilst Cynodondactylon, Poaannua, Artimesia vulgariswere the predominant herbs in morel habitat whereas Fragarianubicula, Galiumtricornutum, Remuxnepalensis, Berberis lyceum, were rare herbs. This study will help to understand the natural habitat of Morels along associated vegetation and to provide base line information for the future conservation and management planning of threatened and endangered Morels species.

Keywords:*Morchella, Habitat, Diversity, Vegetation, Floristic composition, Swat*

Introduction

Morels belong to the class Ascomycetes of Fungi of the family Helveliaceae. Generally, morels arise in a diversity of habitats, including mountain slopes, near plants that have been burned-out forests. They arise in mud, moist soil with abundant organic matter, and sand (Friedman, 1986).Morels are mostly found in northern temperate woods around the world, where they occupy a special ecological niche (Pilz et al., 2007). Several species have also been discovered in Pakistan's temperate forests, particularly in the Swat district (Hamayun et al., 2006). Environmental factors, e.g., soil type, vegetation, temperature, pH, light humidity, and the presence of moisture and nutrients in the substrates may limit mushroom growth and dispersal in

ISSN (Online): 3007-3898, ISSN (Print): 3007-388X, April to September 2025

space and time (Karrwa et al., 2014). A common substratum for the development of many ectomycorrhizal and saprotrophic mushrooms is humus-rich soil with coarse woody debris (CWD) (Harvey et al., 1980). An ideal soil type for mushrooms specifically morels, according to (Manikandan et al., 2011), is loamy, dark, fertile and rich, with organic matter soil. Many ecological studies have focused on the impact of environmental variables on sporocarp productivity (Vogt et al., 1992). *Morchella*species are used as both food and medicine in the local community. Morels are anti-inflammatory anti-tumor, and antibacterial agents, and are used to treat colds. Some of the traditional medicinal qualities of morels stated by many researchers were confirmed using cutting-edge technologies. The quality, processing, and collecting region all influence the price of morel mushrooms. Pakistani residents harvest about 55 to 65 tons of dried morel mushrooms each year. With 532,280 kg produced in 1997-98, KP produces more than 70% of all morels (Iqbal, 1991).Understanding community structure and plant distribution, as well as their comebacks to water rearrangement across the site, can help us better recognize how plant communities are organized and apply wise management practices or conservation (Xu et al.,2008). Depending on vegetation patterns, topography, and parent material, alongside provided water can be further vital than rainfall in certain areas (Meron et al., 2004). Watershed and stream network factors such as watershed slope and size, drainage density and stream length all contributes to the spatial outline in plant communities (Ali et al., 2000).

Materials and methods

Sampling Sites

Morels samples were collected from different areas in the province of Pakistan Khyber Pakhtunkhwa's Swat District. Swat valley is located between 34°-40′ and 35° N latitude and 72°-6′ and 74°-6′ E longitude. The famous Hindukush mountain range’s foothills surrounds it in the Khyber Pakhtunkhwa, the North West province of Pakistan (Fig 1).

Voyage Journal of Scientific Research and Exploration (VJSRE) Vol 2. Issue 1
ISSN (Online): 3007-3898, ISSN (Print): 3007-388X, April to September 2025

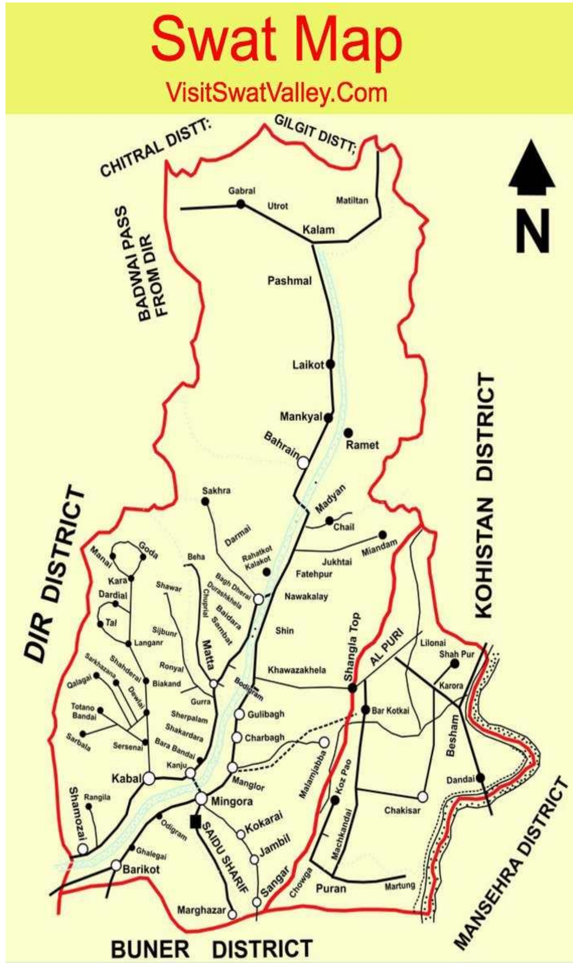

Figure 1. Map of the study area

Samples Collection

The present investigation was carried out during the year 2020-2021. The research area was extensively visited from March-July as Morchella species are collected during this period. The samples were collected from Malam Jabba, Gabbin Jabba, and Kalam in the Swat district of Khyber Pakhtunkhwa, Pakistan.Morels samples were collected in the rainy seasons of July-August, winter (December-January), spring (March-April), and summer (May-June) of 2020-2021 in Pakistan's District Swat, Khyber Pakhtunkhwa.During the survey, the physical and ecological features of the observed specimens were accurately documented. Mushrooms were gathered, photographed in their natural environment from all angles and stored in card boxes. Each specimen had a collection number, a date, and the name of the location attached. Using a sharp digger, fruiting bodies of mushrooms were gathered (Sarwar, 2013).

Sampling of vegetation

Quadrat quantitative methods were used for the collection of ecological data. A total of 20 quadrats were done in the study area. Each quadrat was further consisting of replicates, i-e (M1Q1a, M1Q1b, M1Q1c). The area of the quadrat was, 1×1m² 5×5m² 10×10m²and for shrubs, herbs and trees, respectively (Khan et al., 2013). The specimens of Morchella and other associated plant species were also collected during field surveys. The nearest trees, shrubs, and herbs data were also recorded. The whole research area was visited on a regular basis in order to identify native plants and collect data on floristic diversity. The nearest trees, bushes, and herbs were measured independently from the plot center to determine related plant distance (by considering Morchella as plot center). Henderson et al., 1989) calculated frequency, relative frequency, closeness and relative proximity, and IVI, respectively (ranging from 1 to 100). Based on the physical factors under consideration, standard identification techniques were used.

Sample Processing and Preservation

Samples of Morchella and other closely related plant species were collected during several field surveys in 2020 and 2021 in different geographic regions including hilly, lowland and irrigated areas of Pakistan. After collection, the samples were shade dried, labeled and stored at 4°C.

Identification

The collected specimens were carried to the laboratory. With the help of the existing literature and using the characteristics of mature morels species, the characters were recorded for identification and up to species level (Kishwar et al., 2007). For the identification of morels species, morphological characterization was done in Plant Mycology Laboratory Quaid-e-Azam university Islamabad. With the help of the Flora of Pakistan, an expert taxonomist, and other literature that was available, related plant species were identified.

Interviews

Interviews were conducted with local people to get to know the local population and people with knowledge of the plants (judges, Pansaris, women and shepherds). Interviews documented local plant names, habit, age, flower color, flowering/fruiting season and other relevant information.

Data Analysis

Two-way cluster analysis reveals the deep links between three different plant associations or groupings, showing the cryptic fabric of nature's hidden patterns in the field of ecological inquiry. A data attribute map further reveals the fascinating relationships between these related species and

ISSN (Online): 3007-3898, ISSN (Print): 3007-388X, April to September 2025

the environmental factors, offering priceless information about the fragile ecological balance. The dynamic dynamics of vegetation spanning the spectrum of Morels variety are lastly graphically captured by a Comprehensive Canonical Correspondence Analysis (CCA) biplot, illuminating the intricate interactions between species and their environmental niches. The complex dance of life within our natural landscapes and the mysterious realm of ecological interactions are both profoundly illuminated by this analysis many facets.

Results

Floristic composition

A total of 76 different associated plant species (belongs to 40 different families) were recorded from western Himalayas Pakistan. Habitatwise they consisted of 15 trees (20%), 09 shrubs (12%) and 52 herb (68%) species (Fig 3). In addition, 4 Morels i.e. *Morchellaconica*, *Morchellaesculenta*, *Morchellasemilibera* and *Morchellaelata* species were reported from the study area (Fig2).

Figure 2. Photographs of mushrooms were collected from the Swat district.

A)*Morchellaconica*B)*Morchellaesculenta*C)*Morchellasemilibera* D) *Morchellaelata*

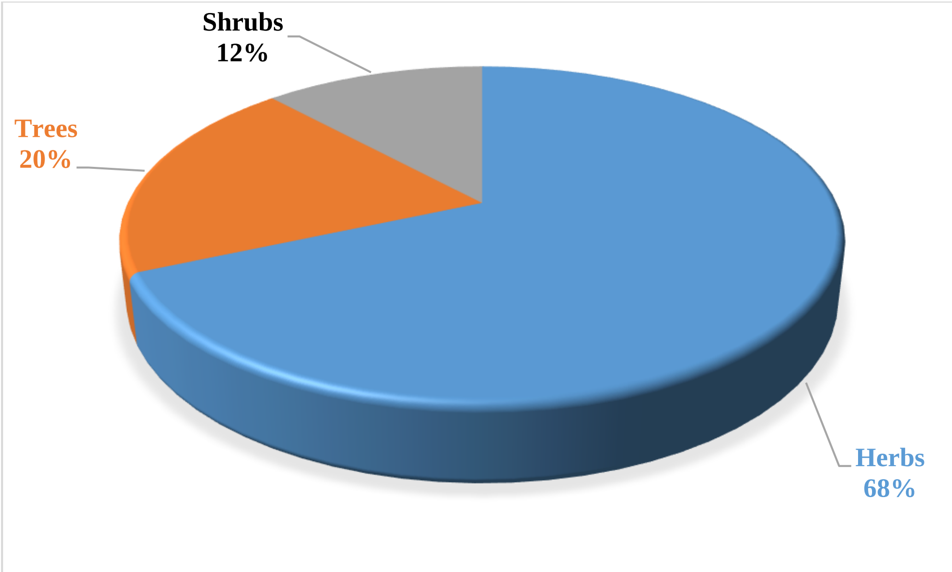

Figure 3. Exploring plant habit diversity of the percentage breakdown of associated plants.

Family wise composition

Majority of the associated species were represented by Rosaceae (12%) with 7 species, second dominant family is Fabaceae is (11%) with 6 species, were the third dominant family is Caryophyllaceae with 5 species, Asteraceae (7%), Pinaceae (7%) were the fourth dominant families with 5 species each, although Oleaceae (4%), Sapindaceae (4%), Urticaceae(4%), Amaranthaceae (4%), Berberidaceae (4%), Lamiaceae (4%), Plantaginaceae(4%), Berberidaceae (4%), Polygonaceae (4%), with 2 species each, While Viburnaceae (2%), Amaryllidaceae (2%), Primulaceae (2%), Pteridaceae (2%), were with 1 species each (Fig4).

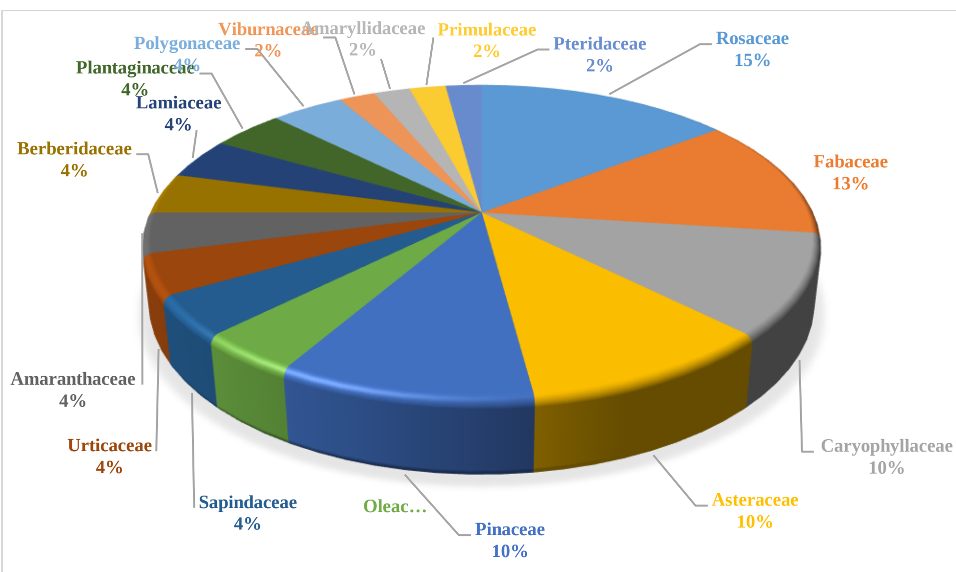

Figure 4. Understanding diversity percentage distribution by families.

Dominant and rare plant species

All the associated plant species were classified in to dominant and rare plant species based on highest and lowest Importance Value Index (IVI).

Dominant Tree layer

Debregesiasalicifloria, Ficuspalmata, Alnusnitida, Pinusroxburghii, Aesculusindica, Juglansregia are dominant plants (Fig5).

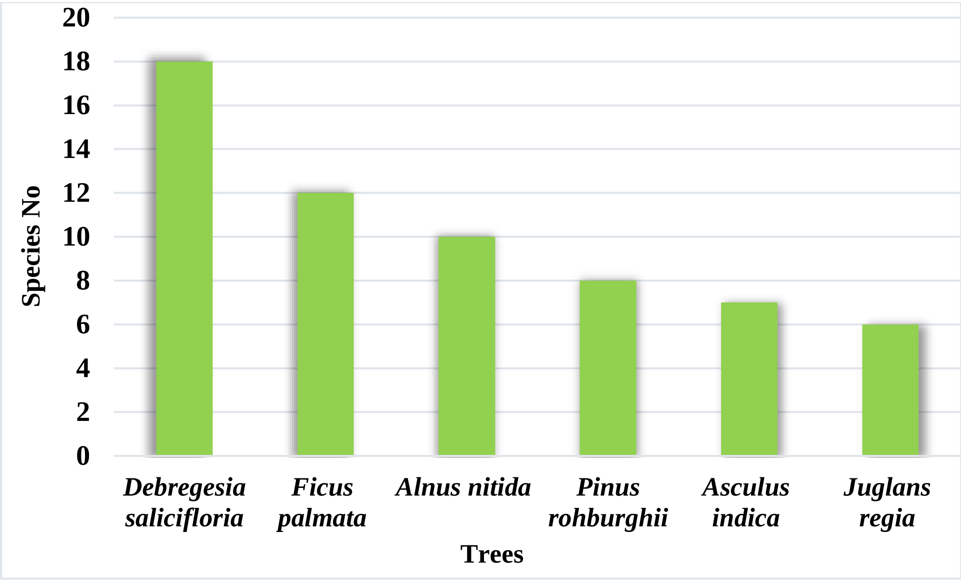

Figure 5. The dominant tree species of the forest.

Rare Tree layer

Pinuswallichiana, Cornusmacrophylla, Cedrusdeodara, Juniperuscommunis, Quercusincana, Acer caesium, Abiespindrow, Quercussemecarpifolia, Rhododendron arboreum are rare trees (Fig6).

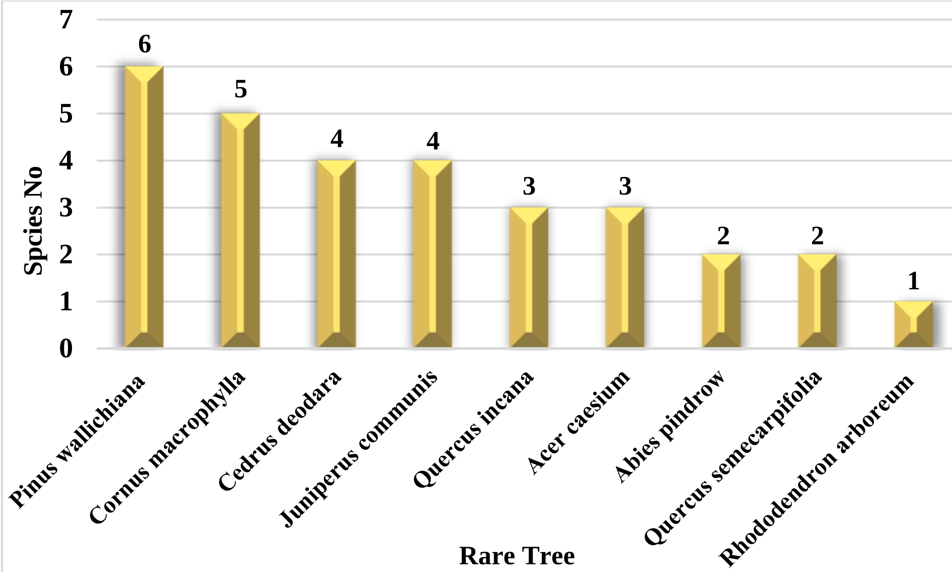

Figure 6. Guardians of biodiversity of discovering rare tree species.

Dominant Shrub layer

*Jaminumofficinale, Jasminumpolyantum, Medicagodenticulata*are dominant shrubs (Fig7).

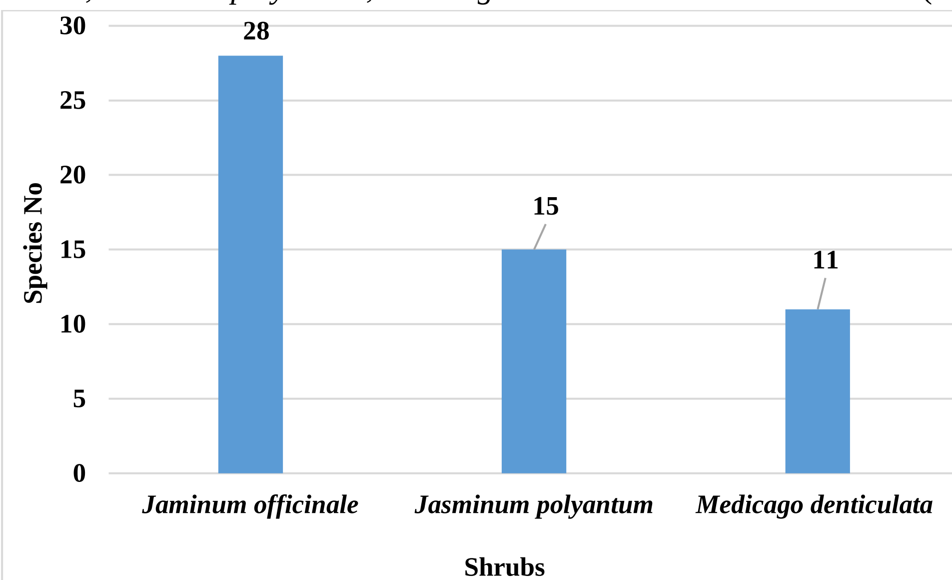

Figure 7. Thriving in dominance meet the leading shrubs of the ecosystem.

Rare Shrub layer

Rubusfruiticosus, Rosa indica, Contoneastermicrophylla, Indigoferaheterantha, Sorbariatomentosa, Viburnum mullaha are rare shrubs (Fig8).

Voyage Journal of Scientific Research and Exploration (VJSRE) Vol 2. Issue 1
ISSN (Online): 3007-3898, ISSN (Print): 3007-388X, April to September 2025

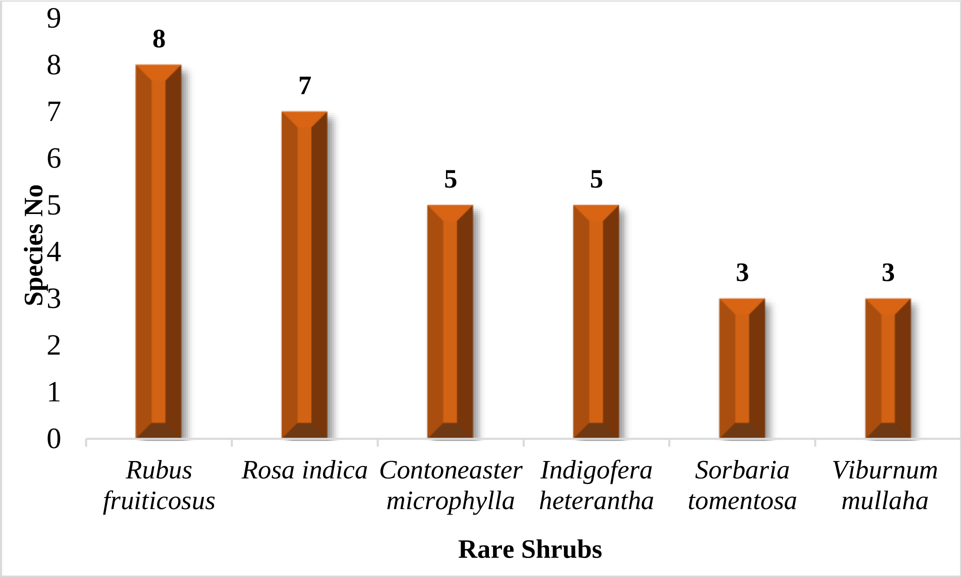

Figure 8. Rare and enigmatic shrub species.

Dominant herbs

Cynodondactylon, Lathyrusaphaca, Vicia sativa, Stellariauliginosa, Ruxemdantatus, Rumexhastatus, Galiumapairne, Poaannua, Artimesia vulgaris, Hedranepalensis, Medicagopolymorpha are dominant herbs (Fig9).

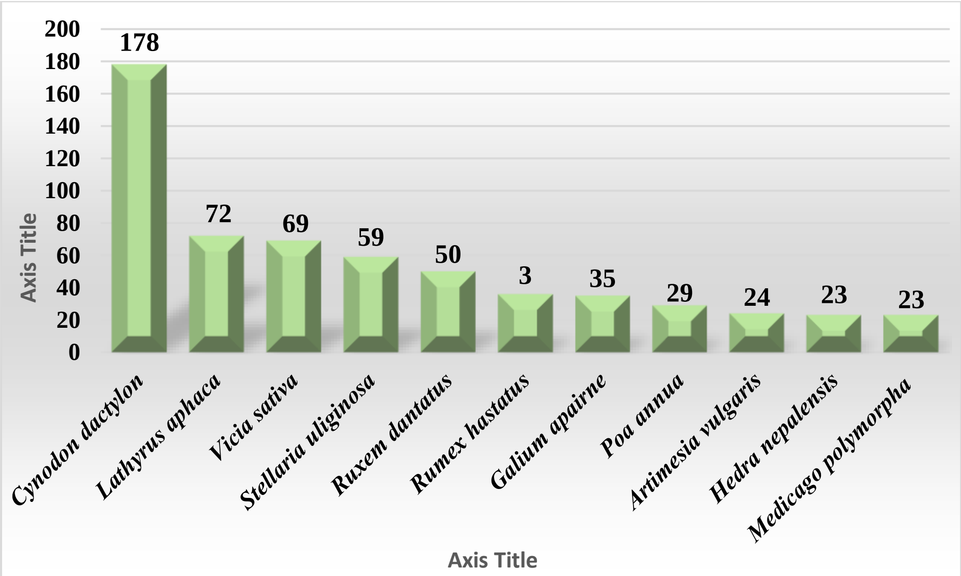

Figure 9. Exploring the dominant herbs species.

Rare herbs

*Fragarianubicula, Galiumtricornutum, Remuxnepalensis, Geranium ocellatum, Phodophyllumpettatum, Astemisia vulgaris, Stellariamonosperma,Berberis lyceum, Cerastiumfontana, Rumexcrispellus, Artemisia Vulgaris, Brassica campestris*are rare herbs (Fig10).

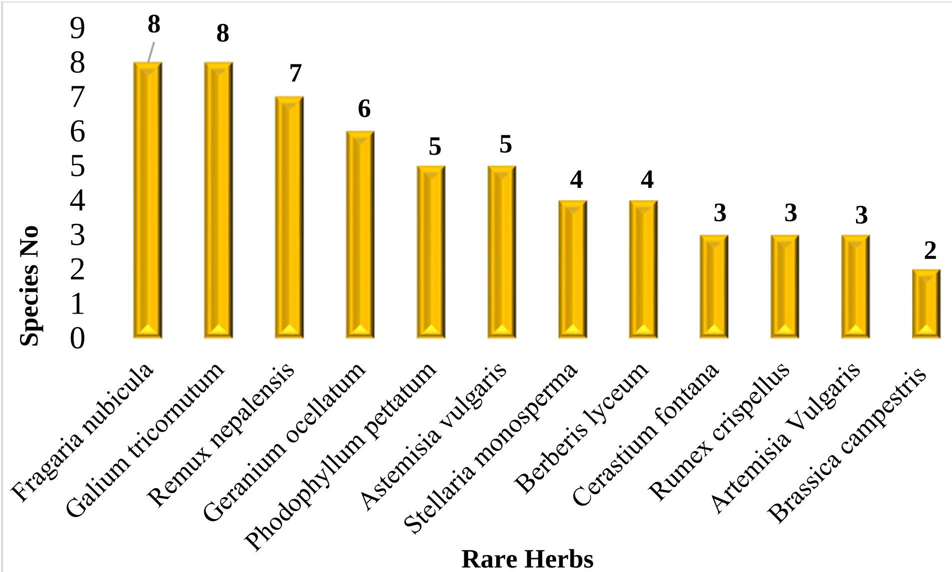

Figure 10. Unveiling the enigmatic world of rare herb species.

Species distribution and abundance

Two-way Cluster Analysis elucidated with the help of absence and presence of the plant species. It showed the distribution of plant species at each station. The black dots in the given dendrogram showed the presence of plant species, whereas white dots showed the absence of plants (Fig11).

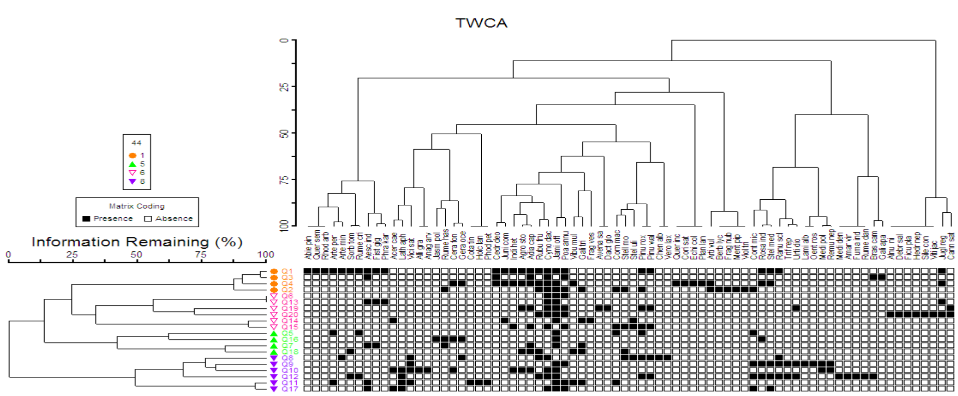

Figure 11. Two-way cluster analysis reveals nature's hidden ecological patterns.

Classifying plants into various associations/ groups

Cluster analyses of PCORD version 5 classifies all the plant species (76) into three plant associations/ groups based on Sorenson Distance Measurements (Fig 12).

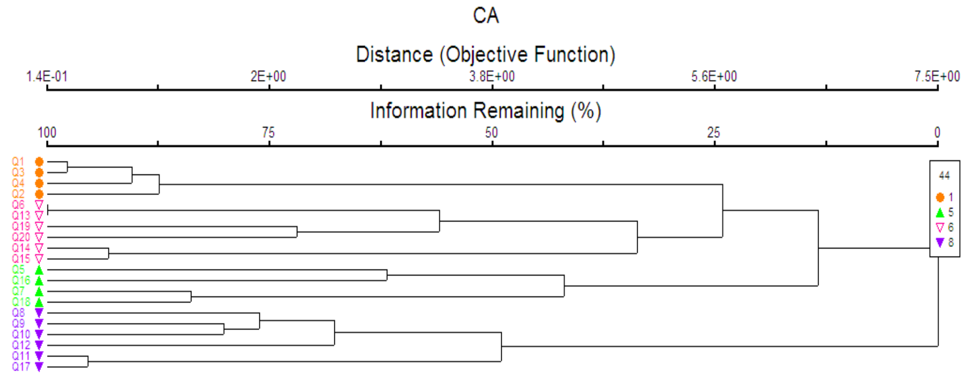

Figure 12. The intricate relationships with cluster analyses of three plant associations/groups.

Vegetation dynamics along the environmental gradient

This CCA bi-plot consisted of key factors of morels along relationship with various gradients was shown (Fig13). The first quadrant showed that most of the plant species were under the effect of canopy and regeneration. Similarly, the second quadrant was affected by the gradients like soil texture (silt and clay), PH, Electrical conductivity and Organic matter. Whereas moving to the third quadrant most of the associated species of morels were affected by grazing pressure. The fourth quadrant was influenced by gradients corresponding to sand, anthropogenic pressure and elevation.

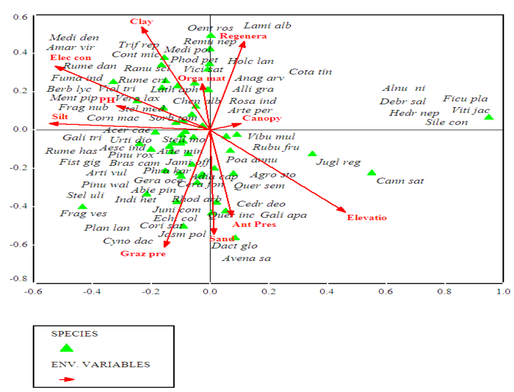

Figure 13. A data attribute plot revealing the fascinating correlations between associated species and environmental variables in CCA analysis.

Vegetation dynamics along the Morels diversity

This CCA bi-plot consisted of associated plant species of morels whose relationship with various gradients was shown (Fig 14). The first quadrant showed that most of the plant species (*Alnusnitida*, *Rosa indica*, *Hedranepalensis*,) were associated/ grouped around *Morchellaelata*. Similarly, in the second quadrant the associated vegetation of *Morchellaconica*includes; (*Amaranthusviridis*, *Trifoliumrepenes*, *Fragarianubicula*,). Whereas moving to the third quadrant

Voyage Journal of Scientific Research and Exploration (VJSRE) *Vol 2. Issue 1*
ISSN (Online): 3007-3898, ISSN (Print): 3007-388X, April to September 2025

most of the associated species (*Pinuswallichiana*, *Vicia sativa*, *Medicago denticulate*,) were grouped *Morchellaesculenta* around this morel. The fourth quadrant associated vegetation (*Viola tricolor*, *Galiumapairne*, *Poaannua*,) of *Morchellasemilibera*includes.

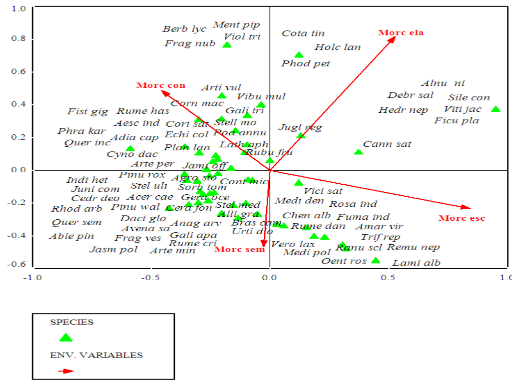

Figure 14. CCA biplot showing vegetation dynamics along the Morels diversity.

Discussion

Morel (*Morchella*spp, Ascomycetes) are a diverse group of mushrooms that grow in temperate climates all over the world. Commercial quantities of these delicate mushrooms are harvested in diverse areas for worldwide supply due to increased market demand. Mushroom overharvesting has raised concerns about forest health and the decrease of morels in general (Emery, 2010). Morel mushrooms can be found in a wide range of natural ecosystems around the world, and various studies have linked them to environmental changes including deforestation, soil drying, heavy rainfall, pesticide use, and so on. Morel patterns in nature must be understood for conservation and to enhance the benefits of non-timber forests. According to recent research from tropical forest (Suryanarayanan et al., 2003), fungi diversity in the tropical regions is larger than in moderate regions. The current study of mushrooms in the northern Pakistan is the first study of its nature to describe the whole vegetation along morels. Our research site is surrounded to a plethora of mushrooms, and the current study uncovers fresh information about the diversity of mushrooms. Morels have been found to be vegetative associates in other studies (Buscot and Roux, 1987). The studies described previously were most likely conducted in phytogeographical dissimilar places, resulting in different plant species being connected with them. (Latif et al., 2005) from Pakistan. *Abiesspindrow*, *Taxusbaccata*, *Pinuswallichiana* and *Juglansregia*, were identified as vegetative indications in the study. In our study, a more objective technique was used to identify the indicator species of morel habitat in the area, the discovery of which was in clear agreement with local harvester observations in Pakistan. Mushrooms are more common in forests during certain seasons, when the canopy is heavier, allowing for more moisture in the atmosphere and soil on the ground, which helps the underground mycelium's conversion into mushrooms. Our results indicated that most morels were observed in close canopy and winter season. Morels were found to be growing beneath thick canopy cover, especially on the N and NW slopes, which kept the right moisture conditions for morel production. In the study, a higher range of relative humidity (67 to 86 percent) was also discovered (Singh et al., 2004). Fruiting sprouts sprouted under a variety of soil conditions, from sandy to heavier textured soil, usually favored growth. The studies also show a similar pattern (Singh et al., 2004) also found that pH 5.8 to 7 is ideal for morel development. Morel species were detected at lower soil temperatures, which were met in natural conditions during the spring or early summer season, according to temperature data. The temperature factor is important for fructification in mushrooms, according to (Mihail et al., 2007). Our results were identical to those provided in the work of in terms of electric conductivity, organic content, and temperature range (Singh *et al.*, 2004). Morchella species distribution patternwere in complete agreement with past research work (Karwa et al., 2014). *Morchellaelata* mushrooms appeared on undisturbed soil near healthy oak trees. While morels grown in open spaces 2 to 5 m from tree trunks in all *M. elata*cases, they grow in shady places the majority of the time. Results of previous work showed that *Morchellaconica* morels that fruited in disrupted soil lacked nutrient reserves to support fruiting in a second or third season at the disturbed site. They are opportunistic and only show up for one season. The *Morchellaelata* ecotype, on the other hand, is likely to have some sort of interaction with the surrounding live vegetation, which provides it with a steady supply of nutrients and allows it to fruit at the same location for many years.

Conclusion

This study will help to understand the natural habitat of Morels along associated vegetation and to provide base line information for the future conservation and management planning of threatened and endangered Morels species. More work is needed to explain the temporal and spatial patterns of different Morels species along diverse associated vegetation and ecotypes in order to have a better understanding of the morel's intricate life cycle.

Acknowledgements

The first author is thankful to anonymous reviewers for their comments on the manuscript.

References

Ali, M. M., Dickinson, G., & Murphy, K. J. (2000). Predictors of plant diversity in a hyper arid desert wadi ecosystem. *Journal of Arid Environments, 45*(3), 215–230.

Buscot, F. and J. Roux. 1987. Association between living roots and fruit bodies of Morchella rotunda. Transactions of the British Mycological Society 89: 249-252.

Emery, M. R., & Barron, E. S. (2010). Using local ecological knowledge to assess morel decline in the U.S. mid-Atlantic region. *Economic Botany, 64*, 205–216.

Friedman, S. A. (1986). Morels, may apples and the meaning of life. *Mushroom: The Journal of Wild Mushrooming, 4,* 5–9.

Hamayun, M., Khan, S. A., Ahmad, H., Shin, D. H., & Lee, I. J. (2006). Morel collection and marketing: A case study from the Hindu-Kush mountain region of Swat, Pakistan. *Lyonia, 11*(2), 7–13.

Harvey, A. E., Larsen, M. J., & Jurgensen, M. F. (1980). Partial cut harvesting and ectomycorrhizae: Early effects in Douglas-fir-larch forests of western Montana. *Canadian Journal of Forest Research, 10*(3), 436–440.

Henderson, J. A., Peter, D. H., Lesher, R. D., & Shaw, D. C. (1989). *Forested plant associations of the Olympic National Forest*.

Iqbal, M. (1991). *Non-timber forest products: Their income-generation potential for rural women in North West Frontier Province (Pakistan)*. International Labour Organization and Government of NWFP.

Karwa, M. K., & Rai. (2004). Tapping into the edible fungi biodiversity of Central India. *Biodiversitas: Journal of Biological Diversity, 11*(2), 97–101.

Khan, S. M., Page, S., Ahmad, H., & Harper, D. M. (2013). Identifying plant species and communities across environmental gradients in the Western Himalayas: Method development and conservation use. *Ecological Informatics, 14*, 99–103.

Kishwar, S., Gul, M., Firdous, S. S., & Asghar. (2007). Hymenomycetes from Multan District. *Pakistan Journal of Botany, 39*(2), 651–657.

Latif, A., Shinwari, Z. K., & Begum, S. (2005). Potential and market status of mushrooms as non-timber forest products in Pakistan. *Ethnobotanical Leaflets, 2005*(1), 41.

Manikandan, K., Sharma, V. P., Kumar, S., Kamal, S., &Shirur, M. (2011). Edaphic conditions of natural sites of *Morchella* and *Phellorinia*. *Mushroom Research, 20*(2), 117–120. Meron, E., Gilad, E., von Hardenberg, J., Shachak, M., &Zarmi, Y. (2004). Vegetation patterns along a rainfall gradient. *Chaos, Solitons & Fractals, 19*(2), 367–376.

Mihail, J. D., Bruhn, J. N., & Bonello, P. (2007). Spatial and temporal patterns of morel fruiting. *Mycological Research, 111*(3), 339–346.

Pilz, D. (2007). *Ecology and management of morels harvested from the forests of western North America* (Vol. 710). U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Sarwar, S. (2013). *Boletes and their ectomycorrhizal morphotypes from some coniferous forests of Pakistan* [PhD dissertation, University of the Punjab, Lahore, Pakistan].

Singh, S. K., Kamal, S., Tiwari, M., Rai, R. D., & Upadhyay, R. C. (2004). Myco-ecological studies of natural morel bearing sites in Shivalik hills of Himachal Pradesh, India. *MicologíaAplicada International, 16*(1), 1–6.

Su, C. A., Xu, X. Y., Liu, D. Y., Wu, M., Zeng, F. Q., Zeng, M. Y., & Luo, X. (2013). Isolation and characterization of exopolysaccharide with immunomodulatory activity from fermentation broth of *Morchella conica*. *DARU Journal of Pharmaceutical Sciences*, *21*(1), 1–6.

Suryanarayanan, T. S., Govindan, V and Murali, T. S. (2003). Endophytic fungal communities in leaves of tropical forest trees: Diversity and distribution patterns. Journal of Current Science, Vol: 85 (04), 489-493.

Vogt, K. A. (1992). Sporocarp production by basidiomycetes, with emphasis on forest ecosystems. In G. C. Carroll & D. T. Wicklow (Eds.), *The fungal community: Its organization and role in the ecosystem* (pp. 563–581).

Xu, X. L., Ma, K. M., Fu, B. J., Song, C. J., & Liu, W. (2008). Relationships between vegetation, soil, and topography in a dry warm river valley, SW China. *Catena*, *75*(2), 138–145.