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HUMAN INDUCED THREATS TO PTERIDOPHYTES IN SONEBHADRA DISTRICT AND THEIR CONSERVATION THROUGH SUSTAINABLE MANAGEMENT APPROACHES

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ABSTRACT

Pteridophytes are among the oldest and ecologically important groups of plants that play a significant role in maintaining ecological balance and biodiversity within forest ecosystems. These plants help in soil conservation, moisture retention, nutrient cycling, and prevention of soil erosion, thereby supporting environmental stability and healthy habitats. Sonebhadra District, known for its rich forests, mineral resources, and diverse vegetation, has witnessed rapid environmental changes due to increasing population pressure, mining, industrialization, deforestation, agricultural expansion, and urban development. Such continuous human activities have adversely affected the natural habitats of pteridophytes, resulting in habitat degradation, fragmentation, and decline in species diversity across the region. The present study examines the diversity and ecological significance of pteridophytes in Sonebhadra District while analyzing the impact of anthropogenic disturbances on their survival and habitat sustainability. The findings reveal that uncontrolled exploitation of natural resources, environmental pollution, and ecological degradation have significantly reduced suitable habitats for many pteridophyte species. The study further emphasizes the urgent need for ecological awareness, sustainable environmental management, and effective conservation strategies to protect pteridophytic diversity and preserve the ecological stability and natural heritage of the region for future generations.

KEYWORDS: Pteridophytes, Conservation, Anthropogenic Activities, Vegetation, Threats, Mining Activities, Infrastructure, Environment

Pteridophytes, generally recognized as ferns and their allied groups, are among the most ancient vascular plants existing on Earth and occupy a significant position in the evolutionary development of terrestrial vegetation. Unlike flowering plants, these plants reproduce through spores and possess specialized vascular tissues for the conduction of water and nutrients. They are commonly found in humid, shaded, and undisturbed natural habitats where environmental conditions favor their growth and survival.

Pteridophytes participate actively in nutrient recycling and ecological succession, thereby contributing to the regeneration and continuity of natural habitats. Because they are highly sensitive to environmental fluctuations such as changes in humidity, temperature, and habitat quality, pteridophytes are often regarded as effective indicators of ecological disturbances and environmental degradation.

Despite their important ecological role, pteridophytes are increasingly facing serious threats due to rapid population growth and continuous human interference in natural ecosystems. Sonebhadra District, known for its rich forests, mineral wealth, and diverse vegetation, has undergone major environmental changes over the years because of mining activities, industrialization, thermal power projects, deforestation, agricultural expansion, urban growth, and infrastructural development. These activities have gradually disturbed natural habitats, fragmented forest ecosystems, degraded soil quality, and altered local environmental conditions. As a result, the diversity, distribution, and survival of many pteridophyte species in the district have been adversely affected. Since pteridophytes grow best in moist, shaded, and undisturbed habitats, they are highly sensitive to ecological disturbances and environmental imbalance. Many species are now becoming restricted to isolated habitats, while others are gradually declining because suitable ecological conditions are continuously shrinking under increasing human pressure. Unfortunately, despite their ecological significance, pteridophytes often remain neglected in conservation programs because they lack immediate economic value and public awareness regarding their importance remains limited.

The present study attempts to understand the diversity, distribution, and ecological significance of pteridophytes in Sonebhadra District while examining the impact of human population growth and anthropogenic activities on their natural habitats. The study also focuses on identifying the major causes of habitat degradation and species decline and explores suitable conservation and

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sustainable management approaches for protecting pteridophyte diversity. Based on field observations, ecological studies, biodiversity records, and published literature, the findings reveal the urgent need for habitat protection, sustainable environmental management, ecological awareness, and active participation of local communities in conservation efforts. The study ultimately emphasizes that conservation of pteridophytes is important not only for preserving plant diversity but also for maintaining ecological balance, environmental sustainability, and the natural heritage of Sonebhadra District for future generations.

SONEBHADRA: GEOGRAPHICAL, ECOLOGICAL AND ENVIRONMENTAL OVERVIEW

Sonebhadra District is regarded as one of the most environmentally and geographically important districts of Uttar Pradesh. Located in the southeastern region of the state, the district is well known for its extensive mineral reserves, forest resources, industrial development, tribal communities, and rich biodiversity. Because of the concentration of thermal power stations and mining-based industries, Sonebhadra is frequently described as the "Energy Capital of India." Alongside its industrial significance, the district also possesses considerable ecological importance due to its forests, hills, rivers, plateaus, and varied natural landscapes that support diverse forms of plant and animal life.

Geographically, Sonebhadra occupies a unique position as it shares boundaries with Madhya Pradesh, Chhattisgarh, Jharkhand, and Bihar.[2] The district extends over a vast geographical area of approximately 6,788 square kilometers, making it one of the largest districts in Uttar Pradesh.[3] The physical landscape is characterized by rocky terrains, forested hills, plateaus, valleys, and uneven topography that form part of the Vindhyan and Kaimur hill systems. These geographical features influence the district's climatic conditions, vegetation patterns, and ecological diversity. Numerous streams, waterfalls, caves, and river systems further enhance the environmental richness of the region and create favorable habitats for various plant groups, including pteridophytes. (Figure 1, 2 & 3)

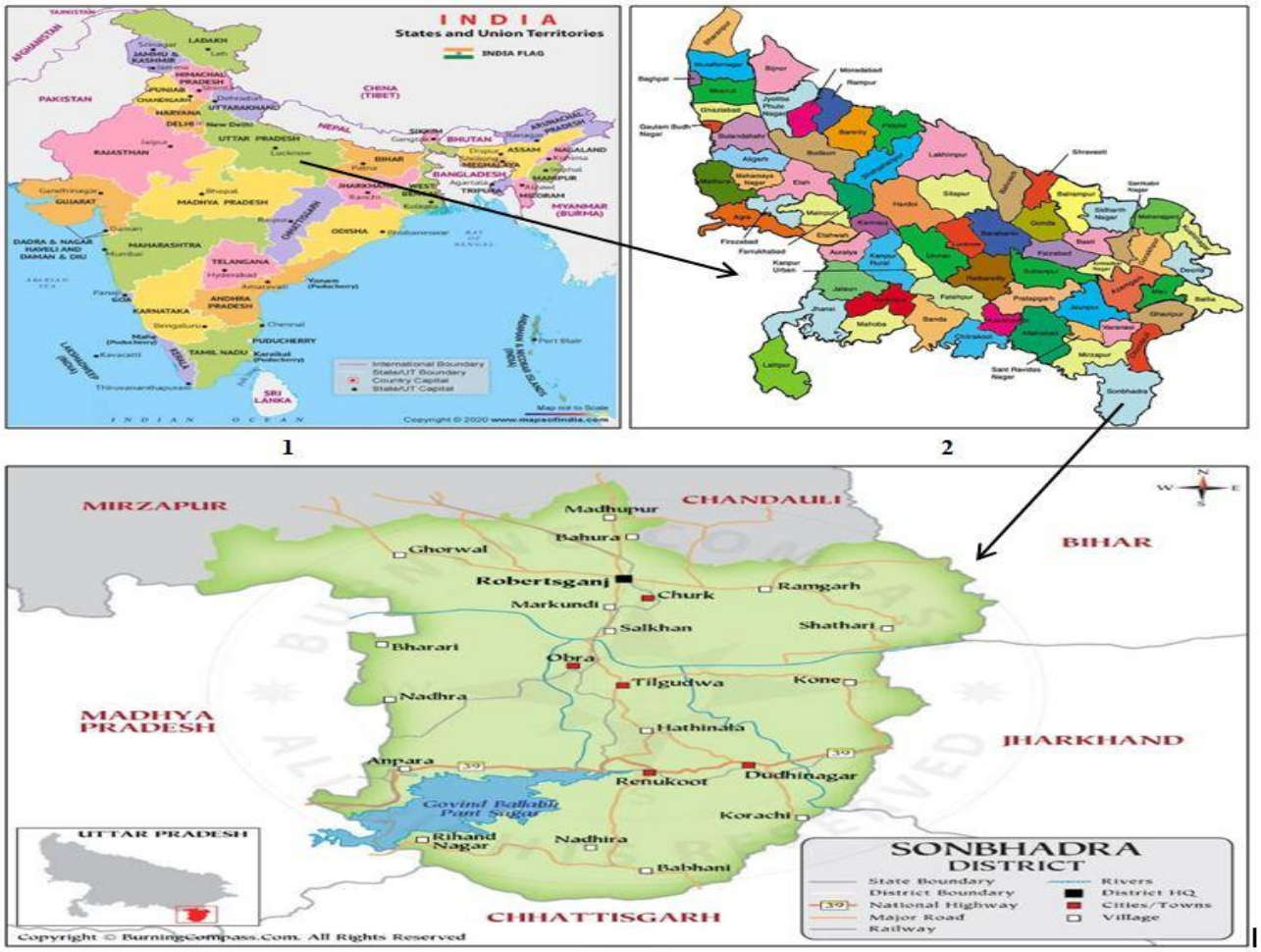

Figure: 1) : Map of India showing U.P., 2) Map of U.P. showing District Sonebhadra, 3) Study area showing collection sites.

Several important rivers flow through Sonebhadra and contribute significantly to its ecological and economic life. Major rivers such as the Son, Rihand, Kanhar, Karmanasha, and Belan support irrigation, fisheries, water storage, hydroelectric generation, and biodiversity conservation.[5] River valleys and surrounding forest ecosystems also create suitable ecological niches for numerous pteridophyte species by maintaining soil moisture and humidity levels..

Economically, the district is highly important because of its rich mineral deposits, including coal, limestone, bauxite, silica, and dolomite. Availability of these resources has encouraged the development of extensive mining activities and industrial establishments in areas such as Obra, Renukoot, Anpara, Shaktinagar, and Dala. Thermal power plants and mining industries operating in the district contribute significantly to regional and national energy production.

Despite its industrial contribution, rapid developmental activities have generated serious environmental challenges in Sonebhadra. Mining operations, industrial emissions, deforestation, urbanization, and infrastructural expansion have caused extensive ecological degradation. Problems such as soil erosion, air pollution, water contamination, habitat fragmentation, and biodiversity loss have increasingly affected the district's natural ecosystems.[9] Sensitive plant groups like pteridophytes have become particularly vulnerable because they depend on stable, humid, and undisturbed habitats for survival.

At present, Sonebhadra faces multiple conservation challenges arising from population growth, unsustainable resource extraction, industrial pollution, illegal deforestation, agricultural expansion, and climate-related environmental changes. These factors continue to increase pressure on forest ecosystems and threaten the survival of several sensitive species. Consequently, there is an urgent need for sustainable environmental management and biodiversity conservation within the district.

MATERIALS AND METHODS

The present research was undertaken to examine the diversity, ecological importance, and conservation condition of pteridophytes in Sonebhadra District while evaluating the effects of increasing human population and various anthropogenic activities on their natural habitats.The methodology adopted for the study involved field observations, collection of secondary data, ecological assessment, and review of relevant scientific literature related to pteridophyte diversity and environmental conservation.

Study Area

The study was carried out in different forested and ecologically significant regions of Sonebhadra District, Uttar Pradesh. The district was selected because of its rich forest cover, varied topography, mineral resources, and ecological diversity. Various habitats such as forest floors, rocky crevices, hill slopes, stream banks, moist shaded areas were surveyed, as these environments provide favorable conditions for the growth of pteridophytes

Following are the study area across the district Sonebhadra:

Robertsganj

Robertsganj serves as the headquarters of Sonebhadra District and is surrounded by hilly terrains, rocky landscapes, forest patches, seasonal streams, and moist ecological habitats.The climatic conditions, especially during and after the monsoon season, create favorable moisture conditions for the growth of pteridophytes.

Salkhan Fossil Park

Salkhan Fossil Park is one of the most scientifically important geological sites in India and is recognized for its ancient fossil deposits believed to be several hundred million years old. The region consists of rocky hill formations, sedimentary rock surfaces, dry deciduous vegetation, and scattered forest patches.

The ecological importance of Salkhan Fossil Park lies not only in its geological heritage but also in its role in supporting unique microhabitats associated with lower plant groups and primitive vegetation forms.

Hathinala Biodiversity Park

Hathinala Biodiversity Park is one of the ecologically significant biodiversity-rich regions of Sonebhadra District. The area is characterized by forest vegetation, moist valleys, rocky hill slopes, seasonal streams, and relatively undisturbed natural habitats. Due to comparatively higher humidity and vegetation density, the region supports diverse floral components, including pteridophytes.

Chopan

Chopan is an important industrial and transport region of Sonebhadra District situated near forested and mineral-rich landscapes. The topography of the area consists of rocky terrains, low hill ranges, forest patches, and river-associated habitats. Chopan experiences significant anthropogenic pressure due to mining, transportation activities, industrial development, and urban expansion.

Renukoot

Renukoot is one of the major industrial towns of the district and is known for mining, aluminum industries, thermal power activities, and forest-associated landscapes. The region is surrounded by hills, rocky plateaus, forest patches, and riverine ecosystems that support diverse vegetation under favorable ecological conditions.

Markundi

Markundi is an ecologically important hilly region located within the Vindhyan landscape of Sonebhadra District. The area is characterized by steep rocky hill slopes, forest vegetation, moist valleys, seasonal streams, and natural caves.

The moist and shaded environments present within forest interiors, rocky crevices, and stream-associated habitats support the occurrence of several fern species and allied plants. During the monsoon and post-monsoon seasons, pteridophyte growth becomes more prominent because of increased humidity and moisture availability. The ecological conditions of Markundi are comparatively more favorable for pteridophyte diversity than heavily industrialized regions of the district.

Figure 4: Showing Collection site (Salkhan Park)

Figure 5: Showing Collection Site (Hathinala biodiversity park)

Figure 6: Hathinala biodiversity park

Collection of Data

The study was based on both primary and secondary sources of data.

Primary data for the present study were collected through field surveys and direct observations conducted in selected areas and ecological regions of Sonebhadra District. Various localities were visited to observe the occurrence, distribution, and habitat conditions of pteridophyte species. During the surveys, special attention was given to habitat characteristics, moisture conditions, shade availability, soil nature, associated vegetation, and human disturbances in surrounding areas. Observations regarding the abundance, ecological conditions, and habitat status of pteridophytes were carefully recorded at different sites.

In our primary data collection, we found a varieties of pteridophytes, which are as follows: *Lygodium flexuosum,Pteris vittata.Adiantum caudatum,Selaginella bryopteris,Cheilanthes farinose, Adiantum lunulatum.*

During the field survey, some varieties of pteridophytes were found in greater numbers, while others were comparatively less abundant for example, Pteris vittata was commonly observed, whereas the variety of Cheilanthes farinosa was found in smaller numbers.

Secondary data were collected from published research papers, floristic surveys, botanical records, forest department reports, biodiversity databases, ecological studies, government publications, books, and scientific journals related to pteridophytes and environmental conservation. Relevant literature was reviewed to understand the taxonomy, ecological significance, distribution, and conservation status of pteridophytes in India, particularly in Sonebhadra District. (Figure 4 to 20)

Figure 7: Collection of plants

Figure 8: *Cheilanthes farinosa*

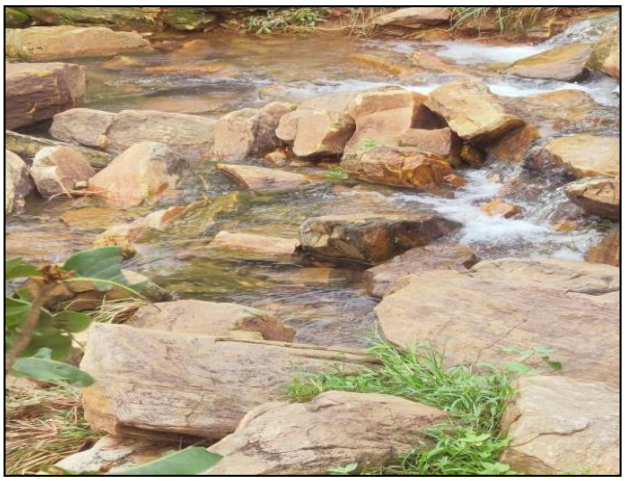

Figure 9: Collection site Ecopoint

Figure 10: Collection site Eco point (*Riparian vegetation)*

Figure 11: Varieties of *Adiantum*

Figure 12: Varieties of *Adiantum lunulatum*

Figure 13: Varieties of *Adiantum caudatum*

Figure 14: Varieties of *Adiantum capillus-veneris*

Figure 15: *Cheilanthes farinose* (Dorsal view)

Figure 16: *Lygodium flexuosum*

Figure 17: *Cheilanthes farinose* (Natural view)

Figure 18: *Selaginella bryopteris*

Figure 19: *Pteris vittata*

Figure 20: Collection Site (along roadside)

RESULTS AND DISCUSSION

The present study revealed that Sonebhadra District possesses rich and ecologically significant pteridophytic diversity supported by its varied landscapes, forest ecosystems, rocky terrains, river valleys, moist hill slopes, and shaded habitats.

The study clearly demonstrated that pteridophytes thrive best in ecologically stable habitats where forest cover and humidity are maintained naturally. Areas rich in vegetation and less affected by human interference showed comparatively higher species diversity and healthier populations of ferns and allied plants.

The findings of the study also emphasized the important ecological role played by pteridophytes within forest ecosystems. These plants contribute significantly to soil conservation by protecting exposed surfaces from erosion and stabilizing slopes through their rhizomatous growth and root systems. Their presence helps in retaining soil moisture and maintaining humid microclimatic conditions necessary for sustaining forest biodiversity. In addition, pteridophytes participate in nutrient cycling and ecological succession, thereby supporting ecological balance and environmental sustainability. The study observed that habitats supporting healthy pteridophyte growth generally exhibited better ecological conditions and comparatively lower levels of environmental degradation.

During the field survey, different collection sites in Sonebhadra District revealed that some varieties of pteridophytes were abundant, while certain varieties were found in very limited numbers. For instance, the variety of *Cheilanthes farinose, Lygodium flexuosum, Selaginella bryopteris* were restricted to only a few areas, particularly in Hathinala Biodiversity Park. Similarly, varieties of *Adiantum lunulatum* were also observed only in such restricted ecological areas. In certain industrial regions of Sonebhadra, particularly around Obra, the occurrence of *Pteris vittata* has shown a noticeable increase, raising ecological concerns. This species is now being observed more commonly near drainage areas.

However, despite their ecological importance, the study revealed that pteridophyte diversity in Sonebhadra District is increasingly threatened by rapid human population growth and continuous anthropogenic disturbances. Activities such as deforestation, mining, industrialization, urban expansion, agricultural encroachment, road construction, and excessive exploitation of forest resources have caused severe ecological imbalance and habitat degradation across many parts of the district. Continuous destruction and fragmentation of forests have reduced the availability of suitable habitats essential for the survival of many pteridophyte species.

Mining and industrial activities emerged as some of the most significant threats affecting pteridophyte habitats in the study area. Open-cast mining, excavation, removal of vegetation cover, and industrial pollution have disturbed natural ecosystems and altered local environmental conditions. In many localities, natural habitats that previously supported pteridophyte growth were found to be degraded due to continuous developmental activities. Dust deposition, reduction in soil fertility, pollution of water resources, and changes in moisture conditions were observed to negatively influence the occurrence and regeneration of sensitive pteridophyte species.

Not only industrialization and mining, but also the increasing human population has led to a decline in the varieties of pteridophytes. Previous records and research papers indicate that this region once possessed a rich diversity of pteridophytes, which has now considerably decreased.

The study further revealed that increasing dependence of local populations on forest resources has intensified ecological pressure on natural ecosystems. Fuelwood collection, grazing activities, agricultural expansion, and illegal tree cutting have accelerated habitat destruction and environmental degradation in several forest areas. Since pteridophytes require moist, shaded, and relatively undisturbed habitats, even small ecological disturbances were found to affect their distribution and regeneration capacity. Several species appeared restricted to isolated and comparatively protected habitats, indicating the gradual decline of favorable ecological niches within the district.

Another important observation of the study was the limited awareness regarding the ecological value and conservation importance of pteridophytes. Compared to flowering plants and economically important vegetation, pteridophytes often remain neglected in conservation planning and biodiversity management programs. Lack of proper documentation, scientific monitoring, and conservation-oriented research has further increased the vulnerability of these plants in ecologically disturbed regions such as Sonebhadra.

Overall, the findings of the present investigation indicate that continuous environmental degradation and anthropogenic pressure are posing serious threats to pteridophyte diversity and habitat stability in the district. The reduction of forest cover, ecological disturbances, and changing environmental conditions have collectively

contributed to the decline of suitable habitats for many species. The study therefore highlights the urgent need for immediate conservation attention and sustainable environmental management practices to protect these ecologically valuable plants and preserve regional biodiversity.

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