Fragmentation of Woody Patches: Mitigation and Future Conservation Strategies in Kalam Valley, Swat District, Pakistan

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Abstract.

Background Kalam Valley situated in the Hindu Kush range of District Swat, contains important woody vegetation that is threatened by habitat fragmentation. This study explores the spatial distribution, ecological position, and conservation requirements of woody patches, Field observations showing severe anthropogenic pressures, including illegal timber extraction, fuel wood necessity, tourism infrastructure, and agricultural development, *Cedrus deodara*, *Pinus wallichiana*, and *Quercus baloot* are among the most affected species.Density andbasalarea assessments recognized *Salix tetrasperma* as ecologically dominantspeicie, whilespecies like Populus *alba* and *Pinus gerardiana* showed controlled distributions.

Methods To assess woody vegetation, 42 transects were established across the study area using a systematic sampling approach. Within each transect, tree diameter at breast height (DBH) was measured with calipers and measuring tape and tree height was determined using a hypsometer. Disturbance intensity was estimated from basal cover measurements. Forest fragments were delineated through interpretation of Google Earth imagery and confirmed by repeated field visits. All woody individuals within plots were identified, measured, and counted, with seedlings and saplings recorded separately. Signs of human disturbance—particularly tree felling and cutting—were documented, and both old and fresh stumps were tallied and measured to calculate basal area loss. The number of plots per transect varied according to site accessibility and transect length. Fieldwork employed a 100-m measuring tape, altimeter, and standardized data sheets.

Results .the forest area which is closer to the villages were subject to extreme pressure from fuel wood collection, timber extraction, and land clearance for agriculture and housing. Long-lived woody species, which require centuries to reach peak community status, were excessively targeted for multiple uses including fencing, poles, and construction. Local accounts showed that approximately half of the valley's forests have been removed—through both legal and illegal means—leading to unsustainable rates of deforestation.

Conclusion prevention of forest fragmentation is critical for conservation of biodiversity in Kalam Valley. Restoration of forest should be prioritizing on large-scale through plantation programs involving local communities, environmental education is mandatory to raise awareness among the community to protect the forest. Minimizing the infrastructure building such as road and housing within forested zones,will be essential to prevent further habitat degradation.

Background

Woody plants comprising trees, shrubs, and lianas are predominantly perennial species whose roots and stems contain wood produced through secondary growth (Luchi et al., 2020). They are distributed globally, with the majority occurring in subtropical and tropical regions, where they are often evergreen (Zhang et al., 2020). Woody plants are considered pioneers of ecosystems (Rawlik et al., 2021), contributing to the formation of climax communities (Deng et al., 2023) and sustaining ecosystem functioning (Meunier et al., 2021). They act as ecosystem engineers, shaping landscapes while providing fuel, shelter, and protection for both fauna and flora (Zhang et al., 2020).

In addition, woody plants serve as renewable energy sources and carbon sinks (Ghanbari et al., 2021), thereby reducing anthropogenic carbon emissions and contributing to climate change mitigation (Larionov et al., 2020). They also play a vital role in water purification, soil stabilization, and the creation and protection of wildlife habitats (Machida et al., 2021).

Forest fragmentation is the process by which large, homogeneous forest tracts are transformed into smaller, heterogeneous, and isolated patches. This transformation occurs gradually and renders the resulting patches more vulnerable to degradation from both natural and anthropogenic pressures (Deng et al., 2023).Forest fragmentation can occur due to either anthropogenic (human-induced) or natural causes. Human-induced drivers include land conversion for agriculture, construction of roads, and other infrastructure development. Natural causes of fragmentation include wildfires, floods, and other natural disasters.Fragmentation can be mitigated through various measures, such as the establishment of protected areas, promotion of sustainable transportation, and development of eco-friendly tourism initiatives.

Kalam Valley is located in the northern part of Swat District, Pakistan, and is surrounded by green mountains containing diverse coniferous and broad-leaved forests. The study area is geographically positioned at 35°26′39.7″ N, 72°44′29.0″ E. The valley has a dry temperate climate, with winters that are exceptionally cold and prolonged, and summers that are warm but cooler than those in the lower parts of Swat District. According to the local office of the Pakistan Meteorological Department (Kalam Station, 2020), the annual average temperature is 13.4 °C, and the mean annual rainfall is approximately 639 mm. November is the driest month, with an average of 15 mm of rainfall, while April is the wettest month, with 93 mm of precipitation. July is the warmest month, with an average temperature of 24.1 °C, and January is the coldest, averaging 1.5 °C.

The concept of "fragmentation" has been elaborated in various means in the literature. Deniz *et al.* described fragmentation as; the procedure of conversion of natural forest into smaller and isolated patches, Goparaju *et al.* (2021) define that fragmentation is the procedure of the change in land structure, and bigger forest s are separated into smaller and complex units in the process. According to Coşkun Hepcan (2024) fragmentation occur due to human intervention, especially when they want more land for crop production, construction of houses and building roads for transportation. Snyder defined forest fragmentation as the separation of vast and adjacent, woody areas into smaller unit of forest, especially when they are detached by human intervention for road construction, agriculture land and for other purposes. Concluding from these definitions of different authors it can assume that fragmentation has two key points: it occurs over a specific period and mostly due to human activities.

There are two different arguments about the influence of fragment on vegetation. Macarthur and Wilson (1967) stated that fragments that have more area likely to have more plant variety than smaller patch while Debinski and

Holt (2000) Demonstrated that connecting multiple smaller fragments can safeguard a greater number of plant species across a wider area than a single large fragment. Therefore, these studies revealed a confirmative association among forest area with plant population in the tropical forests the effects of human disorders and forest fragmentation could change the ecosystem type of an area. Therefore, the human interruption may have either positive or negative effects on the leftover forest and can play a significant role in defining its composition (Debinski and Holt, 2000).

Many plants species are only found in fragmented vegetation and it is critical to know the consequence of fragmentation on forest population, structure and diversity and also essential for forest environment protection and conservation of forest , most of the studies on forest fragmentation display negative impact of forest fragmentation however some studies also report positive effect of fragmentation on tree structure and diversity(Hill and Curran 2003, Ranta *et al*, 1998, Page *et al*, 2010). Healthy forests play a essential role in cooling the landscape, particularly during warming days and extreme heat events (Gohr *et al*, 2021).Fragmentation also influences the flora of an area and therefore can reduce the availability of food sources for many species living in that area. Forests play a main role in carbon sequestration, mitigation of climate change, and safety of soil and water resources. They cover 31% of the global land area, and they contained half of the earth biodiversity. However, deforestation and other anthropogenic activities led to extensive forest loss worldwide, resulting in the form of large, forest patches and reduced connection between them. Recently, forest fragmentation has been found to widely, causing shocking habitat loss, climate change. Therefore, it is important to present a proper way to calculate the degree of forest fragmentation and understand its causing agents. Forests are susceptible to anthropogenic pressure such as deforestation, overexploitation, habitat loss, and fragmentation, Fragmentation can reduce habitat connectivity, which in turn may negatively impact populations. Connectivity of population can affect ecology and is also co relate to the power of a plant species to continue and retrieve from ecological distresses that Is habitat destruction and climate change. A loss of connectivity, combined with climate change, poses a serious threat to biodiversity. Climate change is likely to alter ecosystems. Deforestation can affect the fragmentation as well as forest connectivity habitat due to limited gene flow, dispersion, and population interactions, which may finally result in the loss of endangered species, especially those species that have small number or controlled distributions (Jaramillo *etal; (*2023), Fragmented habitats exhibit increased susceptibility to invasions by non-native species and certain native colonizers (Primack and Morrison, 2013).

In degraded landscapes, invasive exotics species often compete with native species struggling to cope with extreme environmental changes. This invasion process, contingent on the exotic species' adaptability, leads to diminished native species richness and diversity, posing a risk of local extinctions for specific ecological groups (Rahman, 2023). Carbon loss resulting from edge effects is a recently recognized consequence fragmentation of forest (silva-Junior *et al.,* 2020). Even small forest fragments and patches of green canopy near heavily altered human landscapes provide substantial benefits for regulating local microclimates (Aalto *et al.,* 2021). However, these microclimatic regulation effects are more significant in large, intact forest ecosystems (Gohr *et al*., 2021). Climate change has increased the vulnerability of both forest ecosystems and the communities that rely on them. Managing these impacts through an integrated approach is crucial to enhance forest ecosystem services and reduce climate-related risks (Roshani *et al.,* 2022) Due to growing concerns over the widespread negative impacts of forest fragmentation; researchers have investigated spatial forest patterns across diverse geographic regions (Taubert *et al*., 2018).

In rural areas of Pakistan, the absence of reliable energy sources such as electricity and natural gas has made fuel wood a major part of daily life, meeting 53% total annual domestic energy requirements of the country which

Estimates that 70–79% of households depends on fuel wood for cooking and heating, mostly in regions where gas supplies are unavailable (Hafeez 2000 and Siddiqui 2004). This dependence is probable to continue in the near future, due to the poor Pakistan's economic development (Raza & Cucculelli, 2024).The major cause of forest depletion is the high demand for fuel wood in the country; Pakistan is ranked as second high deforestation rate in the world According to the International Union for Conservation of Nature (IUCN), due to population growth the consumption rate of wood is increased by 3%annualy. If the current deforestation fashion continues, IUCN warns that Pakistan's forests could disappear within the next 10–15 years.

Deforestation changes climate system by disturbing water cycles and increasing biodiversity loss at local and international scales. Climate change, in turn, increase deforestation. Draught causing tree mortality, reduced growth, and intensified vulnerability to forest fires and windstorms drought not only accelerates deforestation but also reduces forest productivity worldwide. Agricultural lands are being transformed rapidly into urban infrastructure, which not only reduces food production capacity but also reduces livelihood opportunities in the field of agriculture. Being an agricultural country, Pakistan holds immense areas of fertile land. Agriculture adds over 20% to the national GDP and employs more than half of the total labour force, playing a key role in generating foreign exchange (Rehman and Khan, 2022).

Pakistan, an arid to semi-arid country with an economy mostly depend on agriculture, is home to northern forests that assist as key biodiversity hotspots. However, these forests face threats from environmental dangers such as droughts, windstorms, floods, and forest fires. In the Northern Hemisphere, forests are particularly disposed to natural disturbances, including insect infestations, flooding, wildfires, and soil erosion, these threats already caused widespread damage across Pakistan. Despite these challenges, forest policy in the country has largely prioritized timber production, with limited consideration given to emerging issues such as global warming and rising tree mortality (Ullah *et al.*, 2022).In modern technological and human population explosion perspective woody forests are at the verge of extinction. Disturbance of forests disturb global environment (Kumi *et al.*, 2020). The world forests are declining rapidly; consequently, balance of the ecosystem is disturbed. The rich biodiversity is prone to extinction (Calbi *et al.,* 2021). Habitat fragmentation is one of the primary drivers of biodiversity loss worldwide and has emerged as an important interest in the field of conservation biology (Ramírez-Delgado *et al.,* 2022). Researchers have examined forest spatial patterns across various geographic areas due to concerns about the far-flung negative effects of fragmentation. High levels of fragmentation can significantly reduce habitat connectivity, which in turn impacts species populations. Connectivity plays a crucial role in functional ecology, as it affects a species' capacity to survive, adapt, and regain from environmental disturbances such as habitat decomposition and climate change (Grantham *et al.*, 2020).

In general, the majority of the less developed countries have experienced rapid population growth and are heavily dependent on the use of biomass to meet domestic energy requirements (Ngwira. and Watanabe, 2019).During past 300 years the global forest has been reduce by almost 20% and this reduction might affect many species, the decreases in forest area may change the size of the forest and convert these forest area into small patches and thus the forest become fragmented, Fragmentation include the habitat loss and the remaining forest will be change into smaller parts or patches (Kouki *et al*) Natural calamities are disturbing woody forests by reducing their habitat, altering biotic and abiotic factors, isolation of associated species and fragmentation of connected habitats (Rosti *et al.,* 2022). Fragmentation abruptly effect composition of species, diversity, abundance, and distribution and life phases of species (Calbi *et al.,* 2021). The fragmented wood patches also induce climate change as they are the controllers of nature. The climate changes in return unsympathetically affect the woody population. Fragmentation is also responsible for the extinction of many organisms and also causes the rise in global temperature (Mann *et al.*, 2023).

Population size and specie richness are critically decreased due to habitat loss they further revealed that small size population are more vulnerable to fragmentation and they are near to extinction, the migration and genetic drift of the species are also much effected due to the fragmentation due to the isolation of these species their gene flow was also affected (Rahman *et al.*, 2023). The ecological amplitude of the low land woody species is broad whereas the woody flora at the top of high altitudes has narrow amplitude that is badly affected by natural events (Assefa and Gobezie, 2022). Though all plant scientists are focusing on the conservation, protection and regeneration of woody species across the globe still large number of forests is declining in all parts of the world. Mitigating efforts are required to recover the plant cover especially the woody canopy that are always umbrella for the rest of plant, animals, insects and even soil biota (Liu *et al.,* 2019).

In Pakistan the total area covered by forests is 4%. Among them 5% of the forests are declared as protected. The coniferous forests cover 4% of the total vegetation. These forests provide better most of the timber and fuel wood for domestic usage to the local population. 90% of the woody vegetation in Pakistan is used as fuel wood (Ilyas, 2006). 40 % of the entire forest land is covered by the coniferous forest located mostly in the hilly area of North alpine vegetation (Ali *et al.,* 2023). Pakistan has tropical (dry deciduous, thorn), subtropical (broad leaves, Pine) and temperate (dry, moist) type of forests. The littoral and swamp forest are located at coastal areas whereas the temperate and Alpine forests occupy the high altitudes of Himalayan and Hindukush (Ali *et al;* 2025).

Objectives.

1. Identification of fragmented site that contain vulnerable woody species that needs protection and conservation on priority bases.
2. Population assessment of the intact woody forests and fragmented patches and analysis of major root causes of forests fragmentation.
3. Analyzing level of anthropogenic pressure on the woody species.

Materials and Methods

Study Area

This study was conducted in Kalam Valley, located in the upper part of Swat District, Khyber Pakhtunkhwa (KPK) Province, Pakistan. The research focused on identifying fragmented sites containing vulnerable woody species requiring priority conservation, assessing populations in both intact forests and fragmented patches, analyzing the root causes of forest fragmentation, and evaluating the level of anthropogenic pressure on woody vegetation.

Regional Context: Swat Valle

Swat Valley is a natural region in the Malakand Division of KPK Province, surrounded by green mountains with diverse vegetation. The valley has an average elevation of 980 m (3,220 ft) and a climate that is considerably cooler and wetter than much of Pakistan. It features lush green landscapes, snow-capped alpine meadows, and is one of the country's most popular tourist destinations.

The annual temperature varies considerably. June and July are the warmest months, with mean maximum summer temperatures of about 32.5 °C and average minimums of 15.7 °C. December and January are the coldest months, with mean maximum winter temperatures around 8.8 °C and average minimums near −7 °C. Annual rainfall averages approximately 270 mm, with the highest recorded rainfall of 467 mm in 2010 and the lowest—less than 50 mm—in 2017. In Upper Swat, temperatures are lower, winters are freezing, and annual precipitation can reach up to 1,200 mm (Pakistan Meteorological Department, Saidu Sharif Station).

Kalam Valley Location

Kalam is situated in the upper part of Swat and is bounded by thick forests and mountains. Its geographic coordinates are 34°45′0″ N and 72°21′0″ E. At the center of Kalam Valley, the Ushu and Gabral rivers converge to form the Swat River. To the northwest lies Gabral Valley, bordering Dir District; to the north is Matiltan Village; and to the northeast are Indus Kohistan and the Gilgit region.

Edaphology

Soils in the study area vary considerably. Villages such as Jalband, Kass, Paler, and Bahan have predominantly sandy soils, while Boyon, Ashoran, and Kokonil have clay-loam textures. Shaho and Gorkin feature sandy-loam soils. The upper and hilly areas possess rich, humus-containing soils of blackish color, composed of clay, loam, and organic matter. These fertile soils support dense vegetation, including herbs, shrubs, and evergreen trees.

Vegetation

Kalam Valley hosts a rich and diverse flora, ranging from herbs and shrubs to large trees. Dominant tree species include *Pinus wallichiana*, *Cedrus deodara*, *Quercus incana*, *Taxus fuana*, *Abies pindrow*, *Betula utilis*, and *Picea smithiana*. Common shrubs include *Indigofera heterantha*, *Peretiopsis jaquemontii*, and *Berberis lycium*. Notable herbaceous species include *Caltha alba*, *Paeonia emodi*, *Podophyllum* spp., *Valeriana wallichii*, *Aconitum heterophyllum*, *Aconitum chasmanthum*, *Artemisia* spp., *Bergenia ciliata*, and *Delphinium roylei*.

Ethnic Groups and Languages

Kalam Valley is predominantly rural, inhabited by indigenous communities. The majority speak the Gawri language, though other ethnic groups are present. In Jalband, Pashto is common, while in Anakar and Palogah, Gujjar communities speak their own language. In central Kalam, some families speak Torwali. Ushu and Matiltan villages are home to Qasqari (Chitrali) speakers.

Socioeconomic Conditions

Kalam Valley is remote and lacks many basic facilities. Most residents are economically disadvantaged and migrate to lower areas during winter in search of livelihoods, returning in summer. Tourism is a major source of income, but the devastating 2022 floods severely damaged infrastructure, leaving roads only partially restored and impacting local livelihoods. Farming is widespread, and Gujjar communities rely heavily on livestock rearing, selling dairy products in local markets. Many residents collect wild edible plants and mushrooms for income. Some are involved in livestock trading, government service, or work abroad. Tourism and hospitality remain key economic activities.

Agriculture and Livestock Farming

Agriculture is the primary livelihood for most households. While the lower valley contains some plains, upper areas have terraced slopes for cultivation. Springs and small streams provide drinking water and irrigation. Major crops include potato, cabbage, turnip, and pea. Native fruits such as plum, apple, and walnut are produced and transported to markets across Pakistan. Livestock—particularly cows and goats—are kept for daily dairy needs, while larger herds of cows, sheep, and goats are grazed in high pastures from May to October. Horses are also kept, and livestock trading contributes to household income

Methodology

Fragmentation

Narrative literature review

For the contextual and theoretical dimension traditional narrative review methodology were adopted. This approach involves systematically gathering, evaluating, and synthesizing existing literature (textbooks and journal articles) to derive insights and identify knowledge gaps. As defined by Grant and Booth (2009), it requires a thorough, independent, and critical examination of current scholarship. Properly accomplished, such reviews considerably contribute to academic discourse (Ferrari, 2015; Green et al., 2006), guide research development, and stimulate innovative viewpoints on emerging issues (Snyder, 2019).

Fragment were selected by the use of Google earth and frequent survey during the field visit, the area coverage of the fragments was obtained from forest department,

Organized sampling method were used for the sampling of woody vegetation in all fragment, transect line were systematically laid in each fragment at a distance of about 300 meters from the next transect,

In each transect diameter at breast and height (DBH) were calculated by the use of caliper and measuring tape, the height of the tree were measured using hypsometer, all woody plants were collected, measured and counted within the plot, in each transect the seedling and sapling were also counted, felling and cutting were also noted because they are considered the important human activities.

in the region in order to investigate the disturbance level of fragments old and new cut stumps were noted and measured to estimate the basal area of tree stump in each transect, disturbance level for each fragment were calculated on the basis of basal cover by the formula of DI

$$DI = \frac{\text{TBC of cut stumps /hactare}}{\text{TBC of all standing stem/hactare}} x100$$

Where DI stand for disturbance index, and TBC for total basal cover.

Shannons`s diversity index and species abundance were calculated in order to know the basal area, density and species richness for each fragment.

Community Analysis

Sampling designing survey was made throughout the valley forest for the proposed sites for sampling. Sampling method was used for vegetation data.100-meter measuring tape, Altimeter, Data sheets were used during the sampling of vegetation. Sampling sites were ordered along transects in NW AND SW directions from the base of the forest towards the top. Depending upon the length and accessibility of the plot the number of transect varies .42 plots measuring 30 meter each were used to calculate the plants species. The space between two successive plots along the transect was 50 m and the transects were 100 m apart.

Analysis of the vegetation of the community was calculated by the formula for each term I.e. IVI value, coverage and density Hussain, s.s (1984), IVI value were used to estimate the dominant species in each community.

$$Frequency = \frac{\textit{Total Number of of a Specie in a plot}}{\text{Total Number of plots}} x100$$

$$Density = \frac{\textit{Total Number of Individual of a Specie}}{\text{Total Number of plots}} x100$$

$$Relative\ Density \frac{\textit{Density of a Given Specie}}{\text{Total Densities of all the Species}} x100$$

$$Cover = \frac{\text{Diametert of Individual of a Specie}}{3.14} x100$$

$$Relative\ Cover = \frac{\text{Cover of Individual of a Specie}}{\text{Total Cover of all Species}} x100$$

$$Relative\ Frequency = \frac{Total\ Frequency\ of\ a\ Specie}{Total\ Frequency\ of\ all\ Species}$$

IVI=RFxRDxRC

Results

Disturbance Levels in Forest Fragments

The disturbance level in each level is different during field visit it was observed that different species were illegally cut down for different purpose such as fuel wood, timber, fencing and furniture. it was also known to us during transect walk and discussion with local community, forest guard and the count of stumps *Cedrus deodara* tree is easily cut and have high valued as it is easy to cut for fuel purpose and also used for furniture making as it is so good looking. *Abies pendro* is also frequently cut for house making and fuel purpose.*Pinus wallichiana* is also cut down for house making as they are termite resistant and due to its soft wood local people use its wood for the fencing of their agriculture land.

During the field visit it was also observed that *Pinus gerardiana* is very limited in the area and been endangered as the tree is cut down for its cone that bear the most expensive seed called chilghoza, while the tree is standing in a steep and difficult place the people cannot pick the cone easily so they cut down the tree,

According to the local community lack of alternate fuel sources they are cutting the forest; beside fuel wood consumption land encroachment for agriculture, road construction and construction have a great role in forest disturbance as seen in many fragments.

Despite these factors tourism is also a threat for the forest as the people are constructing new roads in the forest for the sake of new tourist spot. The forest become vulnerable for cutting because the mafias have easy access to the forest due to the construction of roads and they start smuggling of the timber, beside this people also start constructing hotel and lodges thus they also cut down the trees for timber

Basal Area and Species Density

Specie density increase in small fragments due to the excessive growth of population. In most cases, the effects of habitat fragmentation on species density can be related to the particular species to deteriorate both the fragmented patch and the adjacent habitat. Such species are not firmly restricted to a single habitat type and can consume resources from different landscape. Their ability to move between patches and nearby areas allows them to use limited resources, escape competition, and maintain population densities despite habitat division., when the surrounding environment is relatively absorbent containing mix vegetation, and other functional cover it can work as an corridor for habitat rather than a complete barrier, In some cases, the unexpected effects of habitat fragmentation on species density can be described by the ability of certain species to consume both the fragmented habitat and the surrounding environment. Such species are capable of exploiting resources across different landscape, allowing them to keep or even increase population densities despite habitat subdivision. Their movement allows them to supplement resources, escape competition, and keep on in a different conditions on the other hand habitat specialists confined to specific ecological places are more susceptible to fragmentation because of narrow resource requirements and limited dispersal ability. Environmental permeability also plays a critical role.it may functions as a habitat rather than a barrier for the adjacent landscape including semi-natural vegetation, low-intensity farmland, or other usable cover, this phenomenon has been written in many articles. For example, certain bird species such as the American robin (*Turdus migratorius*) and Eurasian blackbird (*Turdus merula*) flourish in both forest patches and suburban areas, showing stable in fragmented landscapes. Likewise, some insect pollinators and weedy plant species exploit edge habitats and agricultural lands, benefiting from increased resource availability in the matrix. On the other hand, forest inside specialists like the wood thrush (*Hylocichla mustelina*) or shade-tolerant underwood plants show severe declines under the same conditions.

These findings show that species reactions to fragmentation are not identical but are strongly affected by life-history characters, dispersal schemes, and landscape situation. Subsequently, the negative effects expected by classical island biogeography or metapopulation models may be less prominent or even reversed for dominant species in permeable landscapes.

The whole mean density for the total of 541 individual trees is 0.31(table 4.1). Total numbers of woody plants are, according to the study the highest density is that of *Salix tetrasperma* Roxb. which is 6.85,This density show that the Salix plants are remain undisturbed and dominating the area where the climate is suitable for their growth, Salix are the mostly found near the water, while the lowest density is that of *Populous alba* which is 0.138,The leaves and wood of the populous are frequently used by the inhabitants and due to the slow growth there number decreasing ,the populous species is present in subalpine pastures in a limited area and they are cut down by the community for furniture and fuel wood while the leaves are used for the livestock as fodder, the study showed that *Salix* is a pioneer specie and has no importance for the local inhabitant therefore it is present in high number.

Table 4.1 Species with their mean density

S/NO	Specie name	MEAN DENSITY
1	Cedrus deodara (Roxb.) G. Don	2.168
2	*Pinus wallichiana* A.B.Jacks	1.069
3	*Abies pindrow* (Royle ex D.Don) Royle	0.889
4	*Parrotiopsis jacquemontiana* (Decne.) Rehder	0.308

5	*Populus alba* L.	0.138
6	Quercus baloot Griffith	0.26
7	*Juniperus communis* L.	0.095
8	*Betula utilis* D.Don	0.067
9	*Picea smithiana* (Wall.) Boiss.	0.189
10	*Acer caesium* Wall. ex Brandis	0.161
11	*Corylus colurna* L.	0.071
12	*Fraxinus xanthoxyloides* (G.Don) Wall. ex A.DC.	0.071
13	*Quercus baloot* Griff.	0.14
14	*Salix tetrasperma* Roxb.	6.85
15	*Pinus gerardiana* Wall. ex D.Don	0.047
16	*Quercus semecarpifolia* Sm.	0.14

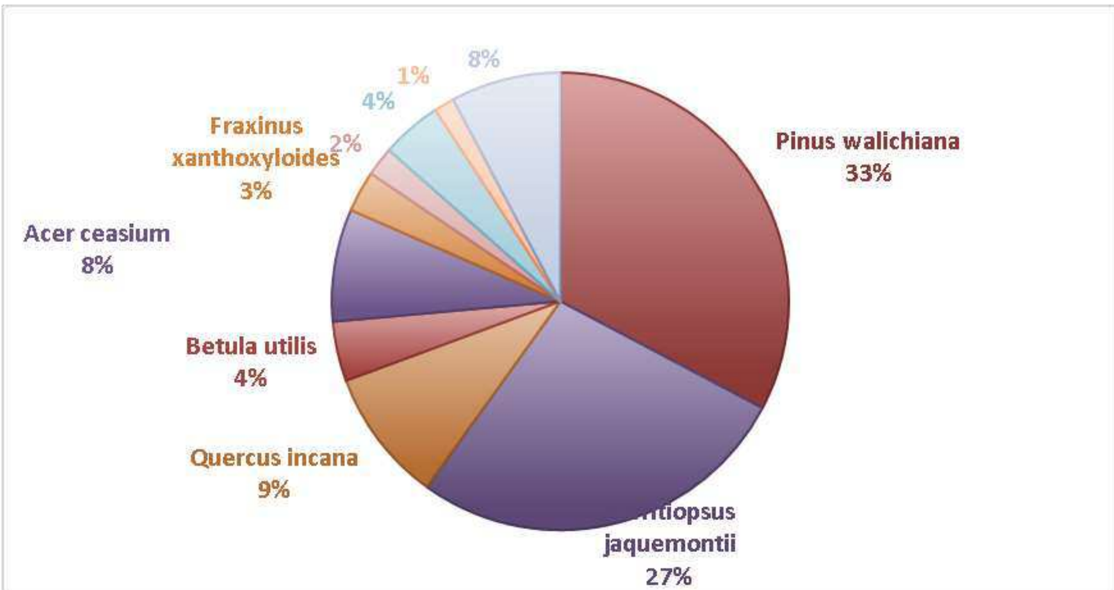

Fig 4.1. Mean density of woody specie

Woody Species Population Structure

It is the techniques through which the plants are distributed in the forest. It helps the forester to categorize the plants for further management.it also provides evidence of disturbance and the history of forest and their future tendency.

The population structure can be selected on the basis of their IVI

4.1.5. Frequency of Woody Species

A change in frequency for all woody plant species were recorded in each fragment during the study, accordingly woody species that have low frequency value are either restricted to only a single fragment or location and they are rarely distributed or these species need conservation. There are so many reason of their low frequency distribution that includes specie characteristics, there regeneration potential, anthropogenic and natural disturbance and so on. The specie with high frequency shows their wider distribution in the fragment and forest.

S .no	***SPECIE***	Frequency
1	*Cedrus deodara (Roxb.) G. Don*	59.5
2	*Pinus wallichiana A.B.Jacks.*	28.57
3	*Abies pindrow (Royle ex D.Don) Royle*	33.33
4	*Parrotiopsis jacquemontiana (Decne.) Rehder*	9.5
5	*Populus alba L.*	4.7
6	*Quercus baloot Griffith*	4.7
7	*Juniperus communis L.*	7.14
8	*Betula utilis*	7.14
9	*Picea smithiana (Wall.) Boiss.*	14.28
10	*Acer caesium Wall. ex Brandis*	9.52
11	*Corylus colurna L.*	4.7
12	*Fraxinus xanthoxyloides (G.Don) Wall. ex A.DC.*	4.7
13	*Salix tetrasperma Roxb*	7.14
14	*Quercus baloot Griff.*	4.7
15	*Pinus gerardiana Wall. ex D.Don*	7.14
16	*Quercus semecarpifolia Sm.*	7.1

Important Value Index (IVI)

The Importance Value Index (IVI) analysis revealed that *Salix tetrasperma* holds ecological dominance in the study area, with the highest IVI value of 226, indicating its widespread presence and structural significance in Kalam Valley's Forest composition. (Table 4.2) followed by *Quercus baloot, Cedrus deodara* and *Pinus wallichiana*, showing their dominance in high elevation zone and their role in canopy formation. *Parrotiopsis jacquemontiana (Decne.) Rehder*, *Picea smithiana*, and *Corylus colurna*, signifying adequate ecological effect and distribution. On the otherside, species like *Pinus gerardiana*, *Fraxinus xanthoxyloides*, and *Acer caesium* displayed lower IVI scores, indicating to partial dominance or restricted habitat roles. These findings provide a quantitative basis for identifying keystone species for conservation efforts, especially in the area whiuch experiencing anthropogenic pressure.

Table 4.2 important value index (IVI) of species

S/NO	*SPECIE*	IVI
1	*Cedrus deodara (Roxb.) G. Don*	155.82
2	*Pinus wallichiana A.B.Jacks.*	145.2
3	*Abies pindrow (Royle ex D.Don) Royle*	82.93
4	*Parrotiopsis jacquemontiana (Decne.) Rehder*	112.3
5	*Populus alba L.*	56.8
6	*Quercus baloot Griffith*	90.8
7	*Juniperus communis L.*	71.2
8	*Betula utilis*	67.63
9	*Picea smithiana (Wall.) Boiss.*	102.6
10	*Acer caesium Wall. ex Brandis*	39.75
11	*Corylus colurna L.*	99.8
12	*Fraxinus xanthoxyloides (G.Don) Wall. ex A.DC.*	39.5
13	*Salix tetrasperma Roxb*	226
14	*Quercus baloot Griff.*	176.2
15	*Pinus gerardiana Wall. ex D.Don*	36.15
16	*Quercus semecarpifolia Sm.*	60.7

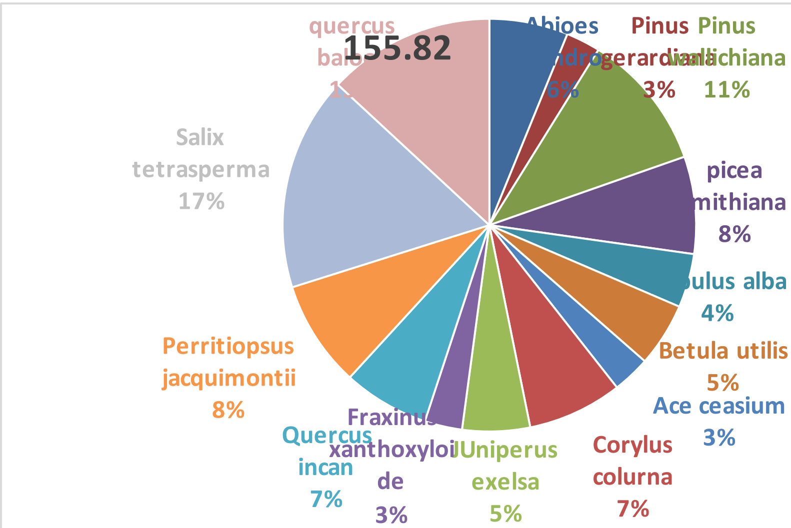

Fig4.2 species and their IVI value

Vegetation Communities of Kalam Valley

1. Quercusedrus–Pinus Community (Gaheel)

In this community three woody species were recorded that are *Quercus baloot* dominant (IVI = 176.2), *Pinus wallichiana* (40.1), *Cedrus deodara* (36.2). Density 0.141, frequency 14.28%. Forest are cut down for hotels and houses construction the leftover fwoody plants at risk from ongoing construction.

2. **Pure Cedrus Community (Jalband)**

3. In this community Only *Cedrus deodara was* present with (IVI = 207). Density 0.071, frequency 7.14%. This area is a tourist Centre the remaining woody plants are much lower in number that indicate severe anthropogenic pressure.

3. Perritiopsus–Acer–Pinus–Quercus Community (Anakar)

In this community Fourwoody plants species: *Perritiopsus jaquemontii* dominant (100.9), *Acer caesium* (53.8), *Pinus gerardiana* (29.5), and *Quercus semicarpifolia* (31.8). Density 0.164, frequency 16.66%, coverage 2.19%.were present, the forest was fragmented by road; fuelwood consumption is higer in this area..

4. Cedrus–Perritiopsus–Pinus–Acer–Quercus Community (Anakar)

In this community only Two species: *Cedrus deodara* (145.3) dominant, *Picea smithiana* (68.7) were present, Density 0.142, frequency 14.28%, coverage 33.78%. Fragmentation occurs due to road construction; presence of stump indicates logging.

5. Cedrus–Picea Community (Anakar)

In this co0mmunity Five species: *Cedrus deodara* (75.2), *Perritiopsus jaquemontii* (44.7), *Pinus gerardiana* (42.8), *Acer caesium* (37.7), *Quercus baloot* (17.7). Density 0.211, frequency 21.42%, coverage 9.2%.were present, Fragmented was caused by glacier glacier and road; high fuel wood consumption causing deforestation.

6. Cedrus–Picea Community (Anakar)

In this community only Two speciesarte present: *Picea smithiana* (123) dominant, *Cedrus deodara* (93.4) less abundant. Density 0.166, frequency 17.66%, coverage 40.12%.fragmentation is due to Road and farmland expansion; fresh stumps present.

7. Cedrus–Pinus–Abies Community (Anakar)

In this community Three specieswere present: *Cedrus deodara* (110.4) dominant, *Pinus wallichiana* (54.4), *Abies pindrow* (54.4). Density 0.06, frequency 19.04%, coverage 41.11%. Forest was converted to agriculture land; presence of stump counts indicates highfuelwood pressure.

8. Cedrus–Abies Community (Anakar)

In this community only Two species were present Cedrus *deodara* (167.7) dominant, *Abies pindrow* (43.9) less abundant. Density 0.118, frequency 11.9%, coverage 25.79%. Fragmentation is due to Road and farmland expansion; fresh stumps present.

9. Cedrus–Pinus–Abies Community (Anakar)

In this community Three specieswere present: *Cedrus deodara* (145.5) dominant, *Pinus wallichiana* (32.7), *Abies pindrow* (32.7). Density 0.141, frequency 14.28%, coverage 210.9%,. Forestarea was converted to agriculture.

10. Cedrus–Abies–Pinus roxburghii Community (Ushu)

In this community Three specieswere present : *Pinus roxburghii* (242.9) dominant, *Abies pindrow* (94.7), *Cedrus deodara* (55.1). Density 0.213, frequency 21.42%, coverage 23.49%. fragmentation is due to Glacier disturbance; cone harvesting for the seed threatens *P. roxburghii*.

11. Cedrus–Perritiopsus Community (Ushu)

In this community Two specieswere present: *Cedrus deodara* (141.1) dominant, *Perritiopsus jaquemontii* (87.2). Density 0.285, frequency 28.56%, coverage 43.66%.

12. Cedrus–Quercus baloot Community (Ushu)

In this community two species were present: *Quercus baloot* (176.2) dominant, *Cedrus deodara* (40.8). Density 0.166, frequency 16.66%, coverage 113.18%.fragmentation is caused by Glacier disturbance; stumps present.

13. Pure Cedrus Community (Ushu)

In this community Only *Cedrus deodara* (211.9). Density 0.119, frequency 11.9%, coverage 20.25%was present

14. Pure Cedrus Community (Matiltan)

In this community Only *Cedrus deodara* (214.2). Density 0.14, frequency 14.28%, coverage 34.01% was present. Fragmentation was caused by Grazing that prevents regeneration.

15. Pure Perritiopsus Community (Matiltan)

In this community Only *Perritiopsus jaquemontii* (216.6). Density 0.166, frequency 16.66%, coverage 56.84%was present.Grazingand landslides minimize regeneration.

16. Pure Cedrus Community (Matiltan)

In this community Only *Cedrus deodara* (204.7). Density 0.047, frequency 4.76%, coverage 5.41%.was present ,stumps showed deforestation.

17. Pure Cedrus Community (Dorgah)

In this community Only *Cedrus deodara* (211.9). Density 0.011, frequency 11.9%, coverage 23.56%was present.fragmentation is due to Glacier disturbance.

18. Pure Cedrus Community (Mai banalGlacier Area)

In this community Only *Cedrus deodara* (133.2). Density 0.166, frequency 16.66%, coverage 19.42% was present. Old stumps showed deforestation while overgrazing prevents regeneration.

19. Cedrus–Pinus wallichiana Community (Panar Kad)

In this community only two species: *Cedrus deodara* (121.7) dominant, *Pinus wallichiana* (94.7). Density 0.166, frequency 16.66%, coverage 25.47%.fragmentationis due to Glacier.

20. Pure Cedrus Community (Panar Kad)

In this community Only Cedrus deodara (209.5). Density 0.095, frequency 9.52%, coverage 14.96%was present.

21. Cedrus–Pinus wallichiana Community (Palogah)

In this community only two species: *Cedrus deodara* (191) dominant, *Pinus wallichiana* (27.6). Density 0.186, frequency 19.04%, coverage 23.88%were present.

22. Pure Cedrus Community (Palogah)

In this community Only *Cedrus deodara* (211.9). Density 0.119, frequency 11.9%, coverage 8.28%was present. 2022 flood removed topsoil; stumps indicate deforestation.

23. Cedrus–Pinus wallichiana Community (Palogah)

In this community only two species: *Cedrus deodara* (167.9) dominant, *Pinus wallichiana* (43.9). Density 0.118, frequency 11.9%, coverage 14.33%were present.

24. Pure Cedrus Community (Palogah)

In this community Only *Cedrus deodara* (211.9). Density 0.011, frequency 11.9%, coverage 8.28% was present.

25. Pure Cedrus Community (Palogah)

In this community Only *Cedrus deodara* (209.5). Density 0.095, frequency 9.52%, coverage 14.96%was present. Stumps indicate deforestation.

26. Acer Pice–Abies Community (Chashma Shifa)

In this community three species: *Picea smithiana* (116.2) dominant, *Acer caesium* (47.8), *Abies pindrow* (47.3). Density 0.117, frequency 11.9%, coverage 18.72%were present.

27. Juniper–Abies–Betula Community (Chashma Shifa)

In this community three species were present that is: *Abies pindrow* (77.2) and *Juniperus* (77.2) co-dominant, *Betula utilis* (39.2) less abundant. Density 0.237, frequency 23.8%, coverage 6.09%. Fragmentation is due to Road and river

28. Cedrus–Abies Community (Fator Shai)

In this community only two species: *Cedrus deodara* (170.8) dominant, *Abies pindrow* (40.8). Density 0.115, frequency 11.9%, coverage 26.97%were present.

29. Pure Cedrus Community (Fator Shai)

In this community Only *Cedrus deodara* present (IVI = 209.5). Density 0.095, frequency 9.52%, coverage 24.04%.

30. Abies–Betula Community (Fator Shai)

In this community only Two species: *Betula utilis* dominant (IVI = 140.7) and *Abies pindrow* (85.2). Density 0.216, frequency 26.28%, coverage 7.85% were present. *Betula utilis* was likely to be deposited by glacier movement.

31. Abies–Betula–Pinus–Populus Community (Fator Shai)

In this community Four specieswere present that are : *Abies pindrow* (142.4) dominant; *Betula utilis* (19), *Pinus wallichiana* (27.7), *Populus alba* (29.2) less abundant. Density 0.17, frequency 19.04%, coverage 20.79%.

32. Abies–Populus Community (Kelshai)

In this community two species: *Abies pindrow* (134.5) dominant, *Populus alba* (79.5). Density 0.142, frequency 14.26%, coverage 17.51%were present deforestation was occurs along road side.

33. Abies–Populus–Pinus Community (Kelshai)

This community was comprises of three species: *Abies pindrow* (99.8) dominant, *Populus alba* (61.8), *Pinus wallichiana* (59.5). Density 0.213, frequency 21.42%, coverage 22.28%.

34. Abies–Corylus–Acer–Fraxinus Community (Mahodand)

This community have Four species: *Corylus colurna* (99.8) dominant; *Abies pindrow* (66.8), *Fraxinus xanthoxyloides* (39.5), *Acer caesium* (19.7) less abundant. Density 0.233, frequency 21.42%, coverage 40.19%.

35. Pure Salix Community (Mahodand)

In this community Only *Salixtetrasperma* present (IVI = 233). Density 6.66, frequency 33.3%, coverage 9.02%.

36. Pure Salix Community (Mahodand)

This is a pure Salixtetrasperma *communit with* (IVI = 219). Density 0.19, frequency 19.04%, coverage 5.22%.

37. Pure Pinus wallichiana Community (Mahodand)

Only *Pinus wallichiana* community with (IVI = 209.5). Density 0.095, frequency 9.52%, coverage 9.87%.

38. Pinus–Abies Community (Mahodand)

In this community only Two specieswere present: *Pinus wallichiana* (583) dominant, *Abies pindrow* (120.7) less abundant. Density 0.166, frequency 16.66%, coverage 703.7%. fragment was disturb by glacier

39. Pure Pinus wallichiana Community (Mahodand)

This is pure *Pinus wallichiana* community with (IVI = 223.8). Density 0.23, frequency 23.8%, coverage 28.34%. Stumps indicate deforestation; trees are drying due to summer water rise and sand silt deposition.

40. Pure Pinus wallichiana Community (Mahodand)

This is pure Pinus *wallichiana* community with (IVI = 209.5). Density 0.095, frequency 9.52%, coverage 7.64%.

41. Pinus–Abies Community (Mahodand)

In this community Two specieswere present: *Abies pindrow* (120.7) dominant, *Pinus wallichiana* (95.7) less abundant. Density 0.166, frequency 16.66%, coverage 23.55%.

42. Pure Pinus wallichiana Community (Mahodand)

This is pure*Pinus wallichianacommunitywith* (IVI = 231). Density 0.21, frequency 21.42%,coverage 26.43%. Stumps indicate heavy deforestation; trees drying due to silting and high summer water flow.

Dominant Species vs. Main Threats in Kalam Valley

Table 4.3 Dominant Species vs. Main Threats in Kalam Valley

Cedrus deodara	Road construction, tourism infrastructure, agricultural land conversion, glacier disturbance, grazing preventing regeneration, heavy logging (stumps), flood damage
Pinus wallichiana	Glacier disturbance, deforestation for timber, trees drying due to water level rise and silting, summer flooding
Quercus baloot	Tourism development, residential construction replacing forest
Perritiopsus jaquemontii	Road fragmentation, fuelwood cutting, grazing, landslides
Picea smithiana	Road–river fragmentation, logging
Abies pindrow	Glacier disturbance, roadside deforestation, grazing, mixed-species competition
Betula utilis	Glacier deposition of trees, unstable terrain
Corylus colurna	— (no specific threat noted beyond general forest pressure)
Salix tetrasperma	Excess water flow altering habitat
Pinus roxburghii	Overharvesting for edible seeds (chilghoza), destructive cone collection, slow regeneration

Concept Map: Dominant Species & Threat Hotspots in Kalam Valley

1. Spatial Zones & Dominant Species

Upper Kalam & Gaheel–Jalband belt

Dominants: *Quercus baloot*, *Cedrus deodara*, *Pinus wallichiana*

Threats: Tourism infrastructure, hotel/residential expansion, complete stump removal.

Anakar Corridor (Steep Slopes)

Dominants: *Cedrus deodara*, *Perritiopsus jaquemontii*, *Picea smithiana*, *Abies pindrow*

Threats: Road construction, fuelwood harvesting, agricultural conversion, glacier fragmentation.

Ushu–Matiltan–Dorgah Sector

Dominants: *Cedrus deodara*, *Quercus baloot*, *Pinus roxburghii*

Threats: Glacier disturbance, grazing pressure, overharvesting of chilghoza cones, landslides.

Palogah–Panar Kad

Dominants: *Cedrus deodara*, *Pinus wallichiana*

Threats: Glacier disturbance, flood damage (2022), deforestation.

Chashma Shifa

Dominants: *Picea smithiana*, *Abies pindrow*, *Juniperus*

Threats: Road–river fragmentation, limited regeneration space.

Fator Shai–Kelshai

Dominants: *Cedrus deodara*, *Abies pindrow*, *Betula utilis*, *Populus alba*

Threats: Glacier influence, roadside deforestation, grazing.

Mahodand Basin

Dominants: *Pinus wallichiana*, *Salix*, *Corylus colurna*

Threats: Excess water flow, silting, summer flooding, tree drying, heavy logging.

4.1.8 Drivers That Cause Fragmentation

Fragmentation happens when a larger forest is divided in to smaller and isolated patches; the main cause of forest fragmentation is anthropogenic, although some natural events can also be contributed to fragmentation some of the main causes of forest fragmentation are following,

Human Induce or Anthropogenic Causes

1. **Deforestation**

Deforestation is the major cause of fragmentation it is the cutting of trees for various purpose such as logging, urbanization, wood purpose and many more, the Major cause of deforestation is agriculture, increasing demand of agriculture products has created more incentives to convert forest into agriculture land once the forest is converted to farm land it is gone forever.

2. **Fire**

Another cause of deforestation is fire millions of acres of forest are destroyed by fire every year fire is often use by the local people to clear the land for crops forest can change the structure of forest even it opens up for the invasive species.

3. **Agriculture**

Converting forest area to agriculture land and fruit plantation, clearing of forest in large scale for the purpose of farmland is the main cause of forest fragmentation as majority of the local community are relying on agriculture in kalam valley so they are un aware of the importance of forest so they are cutting the forest for the purpose of farmland and thus induced fragmentation and loss of forest

4. **Urbanization**

Urbanization is the migration of human population to urban areas, which result in deforestation and habitat loss also decrease biodiversity, it can also increase the transport of invasive species that can thrive native species

5. **Overgrazing**

Overgrazing is the repeated and heavy grazing over an area for several years that can deteriorate the forest of that area, vegetation cover is reduce and thus soil erosion is started which soon convert these forest areas into barren land, Overgrazing also leads to fragmentation

6. **Climate Change**

Change in climate may cause natural disturbance such as storms, wildfires and disease outbreak. Some tree species are also starting migration from the area due to climate change,

7. **Energy projects**

Dams and powerhouse constructions are also a main cause of forest loss. Recently Gorkin kalam hydel power project is in under construction resulting in major loss of forest and forest area in kalam valley

Natural Causes of Fragmentation.

1. **Wild fires**

Natural fires can burn a lot of forest areas leaving behind the barren land and fragmented patches

2. **Geological Events**.

Flood, landslides and earthquakes can also cause fragmentation of the forest

Discussion

Kalam valley is situated at the upper part of the Swat district with an elevation of 2000m., the winter is extremely cold while in summer the climate become very pleasant. The annual mean temperature of the valley is 13.4 °C, and the annual rainfall averages 639 mm. high temperature recorded is up to 35 °C while the average low temperature falls up to - 8° C.

The study site started from Gaheel, Jalband, and kass valley Boyon, Shahoo and Kokonail valley and extended up to Mahodand at one side and Anakar village at the other side the valley contains rich woody vegetation. The vegetation of the area is variable composed of variety of climax species.

The survey was proposed to determine and analyse the existing population of the woody plants species. For the measurement and analysis of woody species of the area line transect method were used .In each transact DBH were measured using calliper, for the calculation of the dominant species in each community Important Value Index (IVI) value were used. This is the novel study of the woody plants of the valley.

Vegetation analysis of woody plant species was also documented by Rahman*, et al.* (2023), Diktaş Bulut, N. (2023), Rivas *et al.* (2021) and Cadavid-Florez *et al.* (2020

Fragmentation is the process in which the natural forest of the area is shifted gradually or suddenly into smaller and isolated units. Because of these fragmentations the forest become smaller patches and more complex fragments such study was also illustrated by Julio *et al.,*(2023) and Noh *et al,* (2022)

Forest fragmentation affects the flora of an area which results in the decrease in the availability of food and shelter for the many species which result in the extinction of the species. Forest fragmentation is found worldwide resulting in the making of large scattered patches that loss the connection forests are susceptible to anthropogenic pressure such as deforestation, overexploitation, habitat loss, and fragmentation, High number of fragmentation also lead to the loss of connectivity and thus so combination of climate change it can be dangerous for biodiversity. Climate change can change ecosystems. Deforestation can affect the fragmentation and because of limited gene flow affect the forest biomes. Dispersal, and also population interactions, which can eventually result in the loss of few endangered species, especially those with small populations or controlled arrangement Jaramillo *et al*., (2023), Julio *et al,* (2023), Mann *et al.* (2023)and Lapola *et al.* (2023).

Topography of the area showed that the area is much slope and mountain terrain that caused the agriculture expansion toward the marginal lands that caused the forest degradation and fragmentation. This aligns with Rosti *etal* (2022) who identify topography as a serious factor of land-use patterns. Such fragmentation is further intensified by infrastructure development and agricultural encroachment, which collectively degrade environmental reliability, as emphasized by (Girvetz etal; 2008). In hilly areas, inefficient farmland use (e.g., small, scattered plots) speed up abandonment, deteriorating fragmentation through secondary ecological impacts

Ali *et al.,(* 2025). Contextualize these dynamics within broader socio-ecological systems, where terrain-mediated agricultural pressures directly compromise habitat connectivity.

Many plants species that live in forest in the past are now living in fragmented of the forest and this show the impact of forest fragment on forest structure and also important for the protection of forest environment and preservation of forest, Noh *et al.* (2022) ,Cadavid-Florez *et al.,* (2020) and Rahman*,et al,* (2023).

The vegetation variety of Kalam Valley reveals a distinct altitudinal and climatic stratification, with *Cedrus deodara*, *Pinus wallichiana*, *Quercus baloot*, *Abies pindrow*, and *Picea smithiana* making the structural backbone of the forest landscape (Abdullah *et al.*, 2022; Fischer *et al.*, 2021). In the Upper Kalam and Gaheel–Jalband belt, oak–cedar–pine stands typify mid-montane mixed conifer–broadleaf systems that stabilize slopes and stand diverse bushes, yet are increasingly fragmented by tourism-driven infrastructure and complete stump removal (Calbi *et al.*, 2021; Roshani *et al.*, 2022). The Anakar corridor's steep slopes support high-elevation conifer complexes dominated by *Cedrus*, *Perritiopsus*, *Picea*, and *Abies*, but road construction, fuel wood harvesting, and agricultural encroachment are accelerating edge effects and soil destabilization (Debinski & Holt, 2000; Diktaş Bulut, 2023).

In ushu matiltan valley cedar oak chir pine forest play important role glacial foreland stabilization (Ahmed *et al.*, 2025), cutting of the branches of *Pinus gerardianafor the* cones and increased grazing are disturbing seed dispersal and ground cover integrity (Ali *et al.*, 2025; Ahoyo *et al.*, 2018). The Palogah–Panar Kad zone, dominated by cedrus deodara and pinus waliciana, has reducein number due to glacial disturbance and soil erosion, changing the climatic condition and potentially shifting species composition toward disturbance-tolerant taxa (Aalto *et al.*, 2021; Gohr *et al.*, 2021). Chashma Shifa's abies-juniper area are highly sensitive to roadand river fragmentation, with limited regeneration space creating a block in age-class distribution (Dorjey & Maurya, 2021). In Fator Shai–Kelshai, mixed conifer–broadleaf forest (*Cedrus*, *Abies*, *Betula*, *Populus*) are effected by glacierand also degraded by roadside deforestation and overgrazing, reducing structural diversity (Ali *et al.*, 2025; Bhat *et al.*, 2022). The Mahodand basin's blue pine–willow–hazelnut communities are strongly effected by water leveland seasonal flooding, silt deposition, and deforestation are shifting these systems toward open, degraded area (Blanco-Libreros & Ramírez-Ruiz, 2021; WWF-Pakistan, Year).

In all these communities human interference intersections with natural calamities creating mix threats (Fischer *et al.*, 2021; Girvetz *et al.*, 2008). The most susceptible systems are those with tapered habitat niches (e.g., Chashma Shifa riparian strips), high tourism exposure (Upper Kalam, Mahodand), and glacial adjacency (Ushu–Matiltan, Palogah–Panar Kad, Fator Shai) (Calbi *et al.*, 2021). Cedrus deodara stands need special attention due to their slow growth, cultural significance, and watershed protection role (Ali *et al.*, 2025; Abdullah *et al.*, 2022).

Conservation Implications These high valued forest stands need much more targeted and site specified conservation strategies (Roshani *et al.*, 2022). Cedrusrich forests should be selected for firm protection and supported with natural regeneration, while abies–fir–juniper corridors need controlled road development and buffer renovation to prevent further fragmentation (Dorjey & Maurya, 2021; Abdullah *et al.*, 2022). In glacial zones, adaptive supervision slope stabilization, controlled grazing, and community-led reforestation can mitigate both climatic and anthropogenic disturbances (Debinski & Holt, 2000; Ahmed *et al.*, 2025). Strengthening community participation through participatory forest management, along with application of sustainable harvesting limits, offers a sustainable pathway to balance ecological reliability with community livelihoods (Ahoyo *et al.*, 2018). Inserting these measures within land-use planning will be important to maintaining Kalam Valley's biodiversity and ecosystem services under increasing environmental change (Fischer *et al.*, 2021; Girvetz *et al.*, 2008).

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Contributions

SZ led the study, including conceptualization, proposal development, fieldwork, specimen identification, investigation, and drafting of the initial manuscript. MA contributed to the proposal, fieldwork, and final manuscript preparation. Contributed to study design and methodology refinement. AS assisted in proposal development, methodology refinement, and manuscript finalization. All authors reviewed and approved the submitted manuscript.

Ethics Declarations

Ethics Approval and Consent to Participate: All informants were fully informed about the study's objectives, and verbal consent was obtained.

Consent for Publication: Not applicable.

Competing Interests: The authors declare no competing interests.

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References

Aalto, I. J., Maeda, E. E., Heiskanen, J., Aalto, E. K., & Pellikka, P. K. E. (2021). Strong influence of trees outside forest in regulating microclimate of intensively modified Afromontane landscapes. *Biogeosciences Discussions*, *2021*, 1-34.

Abdullah, S. N., Malik, K. F., Noor, R., Arif, M., & Khan, W. (2022). Ethnobotanical diversity of Moist Temperate Mountain Forests: A Case Study from Ayyubia National Park, Western Himalayas, Pakistan.

In *Biodiversity, Conservation and Sustainability in Asia: Volume 2: Prospects and Challenges in South and Middle Asia* (pp. 857-871). Cham: Springer International Publishing.

Ahoyo, C. C., Houehanou, T. D., Yaoitcha, A. S., Prinz, K., Assogbadjo, A. E., Adjahossou, C. S., & Houinato, M. R. (2018). A quantitative ethnobotanical approach toward biodiversity conservation of useful woody species in Wari-Maro forest reserve (Benin, West Africa). *Environment,Developmentand sustainability*, *20*(5), 2301-2320.

Ali, A., Pulh, Z. A., Sajid, A., Kumar, S., Naqvi, S. H. A., & Sahar, U. (2023). Antibacterial potential and phytochemical investigation of medicinal plant (*Euphorbia hirta Linn*). *Pakistan Journal of Biotechnology*, *20*(01), 83-92.

Ali, I., Ansari, L., Siddiqui, B. N., Abbas, S. A., Zeb, A., & Khan, N. (2025). Current Status and Threats to Himalayan Birch and Its Socio-economic Impact on Local Community in Baltistan (Pakistan). *Journal of Asian Development Studies*, *14*(2), 86-97.

Assefa, F., & Gobezie, T. (2022). Effects of forest fragmentation on plant diversity and regeneration of woody species in Qenfot dry Afromontane forest, Northeastern Ethiopia. *Abyssinia Journal of Science and Technology*, 7(1), 29–38.

Bhat, A. M., Qureshi, R., & Yaseen, M. (2022). Phytochemical investigation and antioxidant activity of methanolic extract of Betula Utilis Bark. *Journal of Pharmaceutical Research and Innovation, 2(2), 4-12.*

Blanco-Libreros, J. F., & Ramírez-Ruiz, K. (2021). Threatened mangroves in the Anthropocene: habitat fragmentation in urban coastalscapes of Pelliciera spp.(Tetrameristaceae) in northern South America. *Frontiers in Marine Science*, *8*, 670354.

Cadavid-Florez, L., Laborde, J., & Mclean, D. J. (2020). Isolated trees and small woody patches greatly contribute to connectivity in highly fragmented tropical landscapes. *Landscape and Urban Planning*, *196*, 103745.

Calbi, M., Fajardo-Gutiérrez, F., Posada, J. M., Lücking, R., Brokamp, G., & Borsch, T. (2021). Seeing the wood despite the trees: Exploring human disturbance impact on plant diversity, community structure, and standing biomass in fragmented high Andean forests. *Ecology and Evolution*, 11(5), 2110-2172.

Coşkun Hepcan, Ç., & Hepcan, Ş. (2024). *Climate change vulnerability assessment of Karşıyaka, İzmir*. *Natural Hazards, 120*(7), 14869–14888. https://doi.org/10.1007/s11069-024-06798-5

Debinski DM, Holt RD (2000) A survey and overview of habitat fragmentation experiments. *Conservation Biology* 14:342–355

Deng, D., Dong, J., Zhang, Y., Liang, W., Liu, K., & Li, L. (2023). Analysis of the environmental Kuznets curve for forest fragmentation: The case of Beijing-Tianjin-Hebei region in China. *Forest Policy and Economics*, *151*, 102970.

Deniz, B.; Küçükerbaş, E.V.; Eşbah Tunçay, H.E.(2006) General Introduction to Landscape Ecology. *Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi*, *3*(2), 5-18.

Diktaş Bulut, N. (2023). Human-induced Forest fragmentation in Trabzon, Eastern Black Sea Region, Türkiye: a case study. *Forests*, *14*(8), 1622.

Dorjey, K., & Maurya, A. K. (2021). Ethnobotany of Juniperus polycarpos C. Koch (Cupressaceae) in the Himalayan cold desert of union territory of Ladakh, India. *Indian Journal of Traditional Knowledge (IJTK)*, *20*(1), 83-90.

Ferrari, R. (2015). Writing narrative style literature reviews. *Medical Writing, 24*(4), 230–235. https://doi.org/10.1179/2047480615Z.000000000329

Fischer, R., Taubert, F., Müller, M. S., Groeneveld, J., Lehmann, S., Wiegand, T., & Huth, A. (2021). Accelerated forest fragmentation leads to critical increase in tropical forest edge area. *Science Advances*, *7*(37), eabg7012.

Ghanbari, S., Sefidi, K., Kern, C. C., & Álvarez-Álvarez, P. (2021). Population structure and regeneration status of woody plants in relation to human interventions, Arasbaran Biosphere Reserve, Iran. *Forests*, 12(2), 191.

Girvetz, E. H., Thorne, J. H., Berry, A. M., & Jaeger, J. A. (2008). Integration of landscape fragmentation analysis into regional planning: A statewide multi-scale case study from California, USA. *Landscape and Urban Planning*, *86*(3-4), 205-218.

Gohr, C., Blumröder, J. S., Sheil, D., & Ibisch, P. L. (2021). Quantifying the mitigation of temperature extremes by forests and wetlands in a temperate landscape. *Ecological Informatics*, *66*, 101442

Goparaju, L., & Ahmad, F. (2016). *Forest fragmentation impacts on biodiversity: A geospatial analysis in Saranda Forest, Jharkhand, India*. *Ecological Questions, 24*(1), 35–44. https://doi.org/10.12775/EQ.2016.004

Grant, M. J., & Booth, A. (2009). A typology of reviews: an analysis of 14 review types and associated methodologies. *Health information & libraries journal*, *26*(2), 91-108.

Grantham, H. S., Duncan, A., Evans, T. D., Jones, K. R., Beyer, H. L., Schuster, R., ... & Watson, J. E. M. (2020). Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity. *Nature communications*, *11*(1), 5978.

Green, B. N., Johnson, C. D., & Adams, A. (2006). Writing narrative literature reviews for peer-reviewed journals: secrets of the trade. *Journal of Chiropractic Medicine*, *5*(3), 101-117.

Hafeez, S. M. (2000). Bio-energy for meeting growing energy needs. In RWEDP (Ed.), *Wood fuel production and marketing in Pakistan: Proceedings of the national workshop, Faisalabad, Pakistan, 28–30 October 2000* (RWEDP Report No. 49, pp. 143–149). Bangkok: FAO.

Hill JL, Curran PJ (2003) Area, shape and isolation of tropical forest fragments: effects on tree species diversity and implications for conservation. *Journal of Biogeography 30(9):1391–1403*

Hussain, S. S. (1984). *Pakistan manual of plant ecology*. Islamabad: National Book Foundation.

Ilyas, S. Z. (2006). Biogas support program is a reason for its success in Pakistan. AmEurasian Journal of Scientific Research, 1(1).

Jaramillo, J. J., Rivas, C. A., Oteros, J., & Navarro-Cerrillo, R. M. (2023). Forest Fragmentation and Landscape Connectivity Changes in Ecuadorian Mangroves: Some Hope for the Future? *Applied Sciences*, *13*(8), 5001.

Kouki, J., Löfman, S., Martikainen, P., Rouvinen, S., & Uotila, A. (2001). Forest fragmentation in Fennoscandia: linking habitat requirements of wood-associated threatened species to landscape and habitat changes. *Scandinavian Journal of Forest Research*, *16*(S3), 27-37.

Kumi, E., Arhin, A. A., & Yeboah, T. (2020). Private sector participation in advancing the Sustainable Development Goals (SDGs) in Ghana: Experiences from the mining and telecommunications sectors. *The Extractive Industries and Society, 7*(1), 181–190. https://doi.org/10.1016/j.exis.2019.12.008

Larionov, M. V., Soldatova, V. V., Logacheva, E. A., Larionov, N. V., & Ermolenko, A. S. (2020). An ecological analysis of the composition and condition of woody plants in urban and suburban ecosystems of the Khopyor River Region. *IOP Conference Series: Earth and Environmental Science*, 421(6), 062025.

Liu, J., Coomes, D. A., Gibson, L., Hu, G., Liu, J., Luo, Y., & Yu, M. (2019). Forest fragmentation in China and its effect on biodiversity. *Biological Reviews*, *94*(5), 1636-1657.

Luchi, N., Ioos, R., & Santini, A. (2020). Fast and reliable molecular methods to detect fungal pathogens in woody plants. *Applied Microbiology and Biotechnology*, 104(6), 2453–2468.

MacArthur RH,Wilson EO (1967) The theory of island biogeography, illustrate. Princeton University Press, Princeton

Machida, W. S., Gomes, L., Moser, P., Castro, I. B., Miranda, S. C., da Silva-Júnior, M. C., & Bustamante, M. M. (2021). Long-term post-fire recovery of woody plants in savannas of central Brazil. *Forest Ecology and Management*, 493, 119255.

Mann, D., Gohr, C., Blumröder, J. S., & Ibisch, P. L. (2023). Does fragmentation contribute to the forest crisis in Germany? *Frontiers in Forests and Global Change*, *6*, 1099460.

Mann, D., Gohr, C., Blumröder, J. S., & Ibisch, P. L. (2023). Does fragmentation contribute to the forest crisis in Germany? *Frontiers in Forests and Global Change*, *6*, 1099460.

Meunier, F., van Der Heijden, G. M., Schnitzer, S. A., De Deurwaerder, H. P., & Verbeeck, H. (2021). Lianas significantly reduce aboveground and belowground carbon storage: a virtual removal experiment. *Frontiers in Forests and Global Change, 4, 663291.*

Ngwira, S., & Watanabe, T. (2019). An analysis of the causes of deforestation in Malawi: A case of Mwazisi. *Land*, *8*(3), 48.

Noh, J. K., Echeverria, C., Gaona, G., Kleemann, J., Koo, H., Fürst, C., & Cuenca, P. (2022). Forest ecosystem fragmentation in Ecuador: Challenges for sustainable land use in the Tropical Andean. *Land*, *11*(2), 287.

Page NV, Qureshi Q, Rawat GS, Kushalappa CG (2010) Plant diversity in sacred forest fragments of Western Ghats: a comparative study of four life forms. *Plant Ecology 206(2):237–250*

Primack, R. B., & Morrison, R. A. (2013). *Essentials of Conservation Biology* (5th ed.). Sunderland, MA: Sinauer Associates.

Rahman, M. M. (2023). Impact of habitat fragmentation on the Diversity of Flora and Fauna of Bangladesh. *Available at SSRN 4451469*.

Rahman, M. M. (2023). Impact of habitat fragmentation on the diversity of flora and fauna of Bangladesh. *SSRN*. https://doi.org/10.2139/ssrn.4451469

Ramírez-Delgado, J. P., Di Marco, M., Watson, J. E., Johnson, C. J., Rondinini, C., Corredor Llano, X., & Venter, O. (2022). Matrix condition mediates the effects of habitat fragmentation on species extinction risk. *Nature Communications*, *13*(1), 595.

Ranta P, Blom TOM, Niemela JARI, Joensuu E, Siitonen M (1998) The fragmented Atlantic rain forest of Brazil: size, shape and distribution of forest fragments. *Biodiversity Conservation 7(3):385–403*

Rawlik, K., Nowiński, M., & Jagodziński, A. M. (2021). Short life–fast death: decomposition rates of woody plants leaf-and herb-litter. *Annals of Forest Science*, *78*, 1-30.

Raza, M. Y., & Cucculelli, M. (2024). Sustainable energy changeover in Pakistan: prospects, progress,

Rehman, F., & Khan, A. (2022). Environmental impacts of urbanization encroachment in the lowlands of khyber Pakhtunkhwa, Pakistan. *Sustainability*, *14*(19), 11959.

Roshani; Sajjad, H.; Kumar, P.; Masroor, M.; Rahaman, M.H.; Rehman, S.; Ahmed, R.; Sahana, M. Forest Vulnerability to Climate Change: A Review for Future Research Framework. *Forests* 2022, 13, 917. https://doi.org/10.3390/ f13060917

Rosti, H., Heiskanen, J., Loehr, J., Pihlström, H., Bearder, S., Mwangala, L., & Rikkinen, J. (2022). Habitat preferences, estimated abundance and behavior of tree hyrax (Dendrohyrax sp.) in fragmented montane forests of Taita Hills, Kenya. *Scientific Reports*, *12*(1), 6331.

Siddiqui, R. (2004). Energy and economic growth in Pakistan. *The Pakistan Development Review*, 175-200.

Silva Junior, C. H., Aragão, L. E., Anderson, L. O., Fonseca, M. G., Shimabukuro, Y. E., Vancutsem, C., ... & Saatchi, S. S. (2020). Persistent collapse of biomass in Amazonian forest edges following deforestation leads to unaccounted carbon losses. *Science Advances*, *6*(40), eaaz8360.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333-339.

Taubert, F., Fischer, R., Groeneveld, J., Lehmann, S., Müller, M. S., Rödig, E., & Huth, A. (2018). Global patterns of tropical forest fragmentation. *Nature*, *554*(7693), 519-522.

Ullah, S., Syed, N. M., Gang, T., Noor, R. S., Ahmad, S., Waqas, M. M., & Ullah, S. (2022). Recent global warming as a proximate cause of deforestation and forest degradation in northern Pakistan. *PloS one*, *17*(1), e0260607.

Xu, G., Zhang, Y., Zhang, S., & Ma, K. (2020). Biodiversity associations of soil fauna and plants depend on plant life form and are accounted for by rare taxa along an elevational gradient. *Soil Biology and Biochemistry*, *140, 107640.*