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Original Article

Forest disturbance and degradation in western Himalayan moist temperate forest of Pakistan

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Abstract

This research aims to investigate forest disturbances and the underlying factors driving forest degradation in the past several decades in the western Himalaya, Pakistan. The results revealed four major disturbance sources (geological, climatic, biotic, and anthropogenic). Data (frequency of events) were recorded using point and fixed area methods (0.1 ha). The analysis shows average frequency (0.045 or 27% of disturbance) through climatic sources (natural fire, wind, snow & floods, which shows the impact of climate change on these mountains; Landslides damaged large areas (11%–16 %) through a geological source. Humans also have a great impact on land clearing for agriculture and infrastructure (35%) from logging, shifting cultivation and counter fire. Most of the disturbances occurred on higher altitudes (>2,800 m a.s.l.), whereas the mid-range elevation (1,900–2,700 m a.s.l.) were only influenced by snow. The landslide was recorded on low elevation (>1,900 m a.s.l.), but there are some landslide events that were observed on a higher elevation. This study focused on the stability of mountain forests for long-term planning. Anthropogenic activities need to be restricted and more afforestation projects need to plan, that increase the forest-covered area.

Keywords: Disturbance, Altitude, Degradation, Moist-temperate climate, Sustainability

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Introduction

Temperate forest zone covers about one-fourth of the forest land of the world, most of these forests lie in mountainous regions (Frelich, 2002), and thus are highly sensitive to natural disturbances (White, 1979). Historically, there are some disturbance events in the mountainous regions because of the ecology of the mountains (Rogers and Station, 1996; Siebert and Belsky, 2014). The scale and level of ecological disturbances are often determined by topography, site variation and other ecological factors (Pickett and White, 1985). Ecological factors (biotic and abiotic) vary with altitude and aspect (Picó et al., 2008). The structural dynamics of the forest depend on natural disturbance (White, 1979). Structural dynamics and topographic diversity in the mountain regions lead to ecological disturbances in these forests; They are landslides, landslips, rock-falls, fires, wind-throws, herbivore/grazing, snow damages, floods, and earthquakes (Barnes et al., 1997; Frelich, 2002). The present study focuses on the western Himalayan moist temperate forest of Pakistan among nine forest ecological zones. The stand structure of western Himalayan moist temperate forests of Pakistan is highly significant for the diversity and sustainable management, which influence the forest productivity (Abbasi et al., 2013; Ammer, 1996; Lindenmayer and Franklin, 1997). In this part of the world, the mountainous disturbances are responsible for the diversity and characteristics of the forest community (Gao et al., 2014; Laginha Pinto Correia et al., 2017; Wilfahrt et al., 2016). Ecological disturbances constitute an important component of the mountain landscape ecology as they affect the structure, function, and composition of mountain ecosystem (Barnes et al., 1997) and at the same time, influence ecological succession (Frelich, 2002; Yang et al., 2018). Like flora, the fauna is also influenced by such ecological disturbance which often results in migration, intervention and introduction of different species to the prone sites (Coyle et al., 2017; Raffa et al., 2008; Wardlaw et al., 2018) for establishment and colonization (Alexandrino et al., 2016; Kwon, 2014) of the ecological niche. The management of these forests also requires an in-depth knowledge of the ecosystem changes and adaptations over a period of time, for the assessment and modeling of forest resources (Al-Yemeni and Sher, 2010). Disturbance intensities and frequencies of the events in the mountainous regions affect the management and conservation of natural resources, the flora is low sensitive towards ecological change as a comparison to the fauna of the habitat (Raffa et al., 2008; Renne and Tracy, 2013).

The productive and protective functions of the mountainous forest ecosystem are severely degraded by different disturbance factors (Gunn et al., 2019). Energy and fuelwood consumption, which contributes to forest degradation, is often higher in the mountainous regions compared to the settled areas (lowlands) (Sulaiman et al., 2017). Forest management and anthropogenic activities also enhance soil transition and increase forest litter, which provides favorable ground to the degradation process (Zhu et al., 2019). The intensity of the forest degradation process is linked to decision making and policy formulation from the government, landowners, and companies (Morales-Barquero et al., 2015). Unmanaged grazing system results in the trampling and compaction effects (Sulieman, 2018) which deteriorate fragile pasture and grassland in the mountains (Bormann et al., 2015; Mack et al., 2013). Recent climate change phenomena enhanced forest degradation in mountain regions, temperate forests and riverside forests (Ahmad et al., 2018; Gunn et al., 2019; Munawar et al., 2015).

The presented study focusses on the western Himalaya in Pakistan, which is the youngest and highly diversified mountainous forest of the world in terms of species composition, stand structure, geology, and terrain (Abbasi et al., 2012). The study investigates the levels of disturbance through relative frequency, types, and impact of disturbances along with the altitude and is aimed to help forest managers to protect and conserve the mountainous forest.

Material and Methods

Forest of the region

Locality

An entire moist temperate forest of Himalaya in Pakistan was examined to identify the disturbance events. Coordinates of the region are 33.262143dd, 35.829804dd, 72.128056dd, and 75.359444dd (South, North, West, and East Ends, respectively). The altitudinal variation is between 1,200 and 3,300 m a.s.l., elevation interval of 100 m were observed, these altitudinal zones area considered as transect for the data comparison.

Ecological range of studied area

Ecological ranges vary with altitudinal variation in the region. The study area is a pure temperate region of the Himalayan Mountains. Research site represents (Fig. 1) western Himalayan mountain range, surrounded by Karakoram and Hindukush mountains on northern and western side, whereas southern side with Pothohar Plateau and plains of Indus river (Gardelle et al., 2013; Kaila, 1981; Mahmood et al., 2011; Singh and Jain, 2002). On lower elevation, ecological zones of Subtropical Chir Pine Forest are found with major Species of *Pinus roxburghii* Sargent and *Quercus incana* Roxb. On upper elevation, Sub-alpine pasture with scattered trees species *Abies pindrow* Royle. and other non-woody vegetation is found. From Hindukush and Karakoram Mountain range, vegetation is the same, only with the addition of *Quercus ilex* L. and *Pinus geradiana* Wall.

Natural vegetation cover

Vegetation cover varies on the lower elevation to higher and from dry temperate to moist temperate. *Pinus wallichiana* A.B. Jackson, *Cedrus deodara* Roxb., *Taxus baccata* L., *Picea smithiana* Wall., *Abies pindrow*, *Pinus roxburghii*, *Quercus dilatata* Royle, *Viburnum nervosum* D. Don, *Indigofera heterantha* Wall., *Quercus ilex* L., *Aesculus indica* Wall., *Prunus cornuta* Wall., *Acer caesium* Wall., *Quercus incana*, *Alnus nitida (Spach)* Endl.Gen., *Populus ciliata* Wall., *Pistacia integerrima* J. L. Stewart, *Parrotia persica* (DC.) are major species that are abundantly available in the region (Amjad et al., 2014; Champion et al., 1965; Lughmani, 1961).

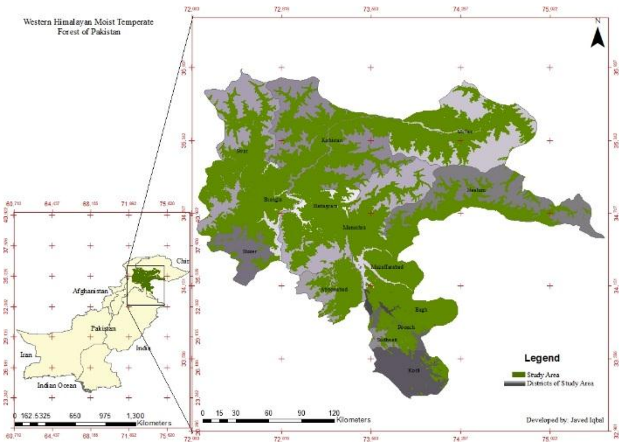
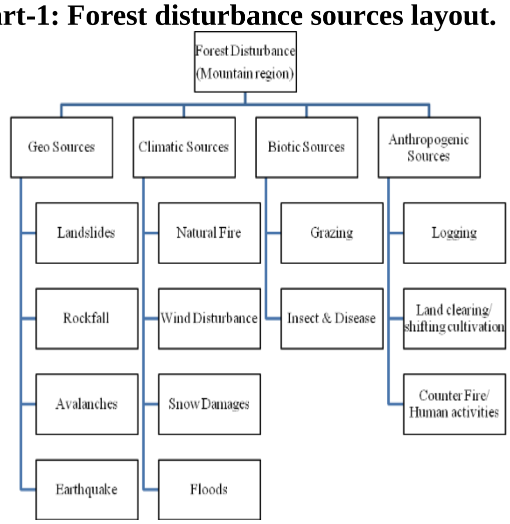


Figure-1: Study area map (created in ArcGIS 10.6 Academic version).

Chart-1: Forest disturbance sources layout.



Data collection procedure

Analytical plot selection and establishing

Transect of 100 m interval from 1,200 to 3,300 m a.s.l was set as a demarcated area for events records Figure 1 (22 transect). Full inventory was conducted in all the forest circles in (Khyber Pakhtunkhwa [Hazara Forest Circle, Azad Jammu and Kashmir (Forest Department) and Punjab Forest Department (Rawalpindi North Forest circle)] with an official record from the forest departments for the year. Data regarding fire, snow damages (also verified during winter), wind damages, and disease were available from the forest department. In addition to these records, data were also recorded with the help of local people who identified events in the region, data along the roads, paths, trail, and valleys are also recorded in detail. Transects were used as a reference to analyze the data for any variation due to altitude in the region.

Data collection reliability

Due to the high variation in the events, the data were recorded in the available record from the Forest Department. Identification of snow damages and wind damages were verified with forest professional in the field who had experience and knowledge in tree demarcation for harvesting, counter check also did during winter to verify the data for snow damages.

Fieldworks for damages considerations, sources, scales, citations

The data were collected during summer from June to August due to limited access snow damage data were recorded during winter. Materials for the data were based on the management plan (working plan) of the forest for historical events record, Global Positioning System (GPS) to record coordinates and altitudes, data record Performa and measuring tape were used to record point data information, evaluation proforma (Annex-I) were used for detail record, plot demarcation (area were classified into different elevation zones with 100 m interval started from 1,200 to 3,300 m) (Charan et al., 2012; Khattak, 1964; Yusuf, 1955). For the measurement of gradient/slope, vertex/Suunto clinometer were used (Prodan, 1968; Sweden, 2007). Due to species composition, aspect, terrain, and accessibility, the sampling size and intensity were highly influenced (Pretzsch, 2009), to avoid these problems, the area was categorized into different elevation as mentioned before (No. of altitudinal transects were 22), and every possible disturbance was recorded in the study area for detail studies.

Annex-I. (Data collection performa).												
Plot No.	**Coordinate X**	**Coordinate Y**	**Altitude**	**Veg;Type**	**Slope**	**Water/ Moisture**	**Event Type**	**Intensity**	**Source**	**History**	**Season**	**Remarks**
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
Description												
Plot No.		Give the number to the plots for proper recognition										
Coordinate X		Coordinates were recorded with GPS in Metrics system										
Coordinate Y		Coordinates were recorded with GPS in Metrics system										
Altitude		Elevation was recorded from above sea Level in Meter										
Veg; Type		Vegetation types (Mixed, Conifers, Broadleaves, Mature, Young stand, regeneration or bare-land)										
Slope		The slope was recorded with Sunnto or Vertex in %										
Water/Moisture		Categorized as near the water source, stream, moist area with springs or marshy area										
Event Type		Fire, snow, wind, landslide, rockfall, landslip, earthquake, flood										
Intensity												
Source												
History												
Season												
Remarks												

Statistical analysis

The data were obtained from 22 transects along the altitudinal gradient from 1,200 to 3,300 m asl. Frequencies of events were recorded within the transects line for statistical analysis.

The data were tested as the *null hypothesis* (H_0) stating that "there is no difference between the disturbance events along with the altitudinal variation," whereas the *alternative hypothesis* (H_1) stated that "there is a difference between disturbance events along with the altitudinal variation." Relative frequencies were calculated as follows:

$$\text{Relative frequency} = \frac{\textit{Number of individuals in each sample site}}{\textit{total number of population}}$$

The non-linear regression was fitted to the data and the variance of the data were calculated by analysis of variance (ANOVA). For individual events, arithmetic means (μ) were calculated. Correlation among the events was also calculated, univariate statistical analysis was also made through the PAleontological STatistics (PAST). The statistical analysis finds the difference between the disturbance events along with the altitudinal variation. The disturbance also represents through percentage from the analysis. The data were analyzed and graphically represented through SigmaPlot, PAST3.2.1, RStudio, and MSExcel.

Results and Discussion

Mountain forests are very fragile and sensitive to natural disturbances due to the topography, flammable material, situation, and location of the forest stand. The sources are divided into climatic, Geo, biotic, and Anthropogenic (Chart 1), which are highly active in the study area since the last two decades. Due to the productive function of the moist temperate forest, Forest disturbance is highly sensitive to management activities, climate change, and anthropogenic activities. Intensity or severities of disturbance were classified according to the relative frequency between the minimum and maximum (0–0.1635) on a different elevation in the study area. The univariate statistic summary is also attached (Annex-II). Data were analyzed and classified as in the Table 1.

Table-1: General event summary description (Source: Field Data).

Major source	Source type	Min–Max (RF)	Avg. RFrequency
Climate	Natural Fire	0–0.1489	0.045464
	Wind Damages	0.0241–0.0964	0.045441
	Snow Damages	0–0.0748	0.04545
Geo	Landslide	0.0098–0.0882	0.045436
	Rockfall	0–0.1042	0.045455
Biotic	Grazing	0–0.0849	0.04545
	Insect & Disease	0.0122–0.0976	0.045473
Anthropogenic	Logging	0–0.1635	0.045445
	Shifting Cultivation	0–0.1414	0.04545
	Counter Fire	0–0.0901	0.045468
Total		0.0315–0.0686	0.045445

Climatic sources

Natural vegetation in the mountains region is highly resistant to climatic disturbances, such as: fire, wind, and snow damages, due to the adaptability, but they are also highly sensitive in case of uncertainty and intensity of events (Bartels et al., 2016; Yu et al., 2016).

Natural fire

These events are not so common in moist temperate forests. Fire is the main contributor to ecological stability in the mountain region but is extremely dangerous with intensity and geographical situation. Animals, Rockfall, and high temperature ignite flammable material, which is the main source of fire in these regions. The results show that there are high threats in the lower as well as the upper elevations of mountainous forests (38.29% and 55.31%). Lower elevation or transition zone are affected due to high temperature and availability of flammable material, i.e., *Pinus roxberghii*, and grasses. The pre-upper regions are also threatened by lightning and low density of the stand, but these regions are less affected by such disturbance as compared to the lowland forests. The data show that most of the fire events occur on a high elevation 2,800–3,300 m (55.31%) or on a low elevation from 1,200 to 1,900 m (38.29%) due to natural lightning/thunders and availability of flammable material with species composition, such as *Pinus roxberghii*, whereas in the mid-range elevation, (2,000–2,700m) fire is not very common (6.38%) due to high moist condition, the complexity of species composition, and low flammable material amount (Fig. 2).

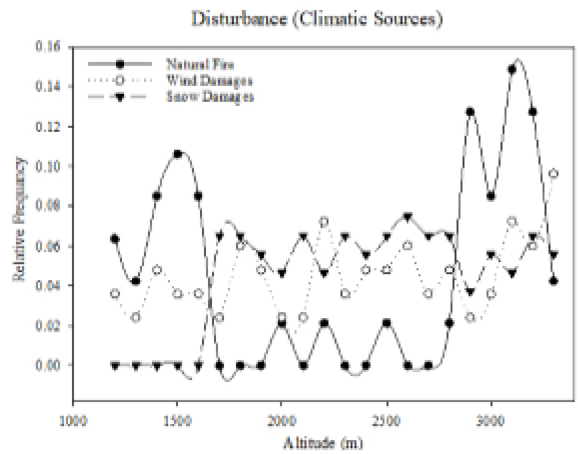


Figure-2. Low snow damages were recorded on low elevation as compared to mid and high altitude. Natural fire is low on mid altitude compared to low and high altitude. Wind damages are almost same in region.

Wind disturbance

It affects the stand structure, enhance fire intensity, and composition of the stand on a very large scale in fragile mountain regions (Quine and Gardiner, 2007). The data showed that altitude does not a matter for wind disturbance, as the patches which were recorded are influenced by the terrain (ridges, mound, or peaks) and soil water; (31.32%, 34.93%, and 33.73% Lower, mid, and high altitude, respectively).

Snow damages

High numbers of snow damages were recorded on mid-level altitude (48.59%) because of stand competition, diameter, height ratio, and also due to the gradient which increases the velocity, whereas on low and high elevations (18.69% and 32.71%), there is less competition for growth, gentle gradient, and normal distribution of diameter height ratio.

Annex-II: Statistical summary.

	RFGLS	RFGRF	RFCNF	RFCWD	RFCSD	RFBG	RFBID	RFAL	RFALCSC	RFACF	RFTDE
N	22	22	22	22	22	22	22	22	22	22	22
Min	0.0098	0	0	0.0241	0	0	0.0122	0	0	0	0.0315
Max	0.0882	0.1042	0.1489	0.0964	0.0748	0.0849	0.0976	0.1635	0.1414	0.0901	0.0686
Sum	0.9996	1	1.0002	0.9997	0.9999	0.9999	1.0004	0.9998	0.9999	1.0003	0.9998
Mean	0.045436	0.045455	0.045464	0.045441	0.04545	0.04545	0.045473	0.045445	0.04545	0.045468	0.045445
Std. error	0.005823	0.006664	0.010596	0.004038	0.005678	0.006732	0.005396	0.008588	0.00967	0.006643	0.002165
Variance	0.000746	0.000977	0.00247	0.000359	0.000709	0.000997	0.00064	0.001622	0.002057	0.000971	0.000103
Stand. dev	0.027311	0.031255	0.049701	0.018938	0.026634	0.031575	0.025307	0.040279	0.045356	0.031158	0.010155
Median	0.049	0.0417	0.0213	0.04215	0.0561	0.0566	0.0366	0.03365	0.0303	0.0541	0.0433
25 percentile	0.01715	0.0208	0	0.0331	0.02805	0	0.0244	0.0192	0	0.01575	0.03765
75 percentile	0.07105	0.0677	0.0851	0.0602	0.0654	0.068375	0.06405	0.0673	0.07575	0.0721	0.05455
Skewness	−0.03636	0.031617	0.780752	0.982059	−1.04327	−0.52991	0.718163	1.588823	0.813797	−0.30869	0.594811
Kurtosis	−1.4606	-0.91437	−0.75083	0.959551	−0.53303	−1.31855	−0.34111	2.608691	−0.47834	−1.41918	−0.34882
Geom. Mean	0.035113	0	0	0.042	0	0	0.03882	0	0	0	0.044406
Coeff. var	60.10737	68.7619	109.3212	41.6769	58.60138	69.47145	55.65395	88.63244	99.79403	68.52749	22.34624

Statistical summary of the data regarding Disturbance RF = Relative Frequency, GLS = Geo-source Landslide, GRF = Geo-source Rockfall, CNF = Climatic-source Natural Fire, CWD = Climatic-source Wind Damages, CSD = Climatic-source Snow Damages, BG = Biotic-source Grazing, BID = Biotic-source Insect/Disease, AL = Anthropogenic-source Logging, ALCSC = Anthropogenic-source Land Clearing/Shifting Cultivation, ACF = Anthropogenic-source Counter Fire, TDE = Total Disturbance Events.

Floods

Floods are one of the common natural disasters in the mountainous region, which enhances the landslides, erosion, and cutting of river banks. The floods damage the river banks where the sites are sensitive to erosion, landslides, and cutting. After-effects of the floods have a good impact in lowlands or on the river bed to provide a favorable condition for the succession process. There is no such quantitative data were recorded for floods due to limited time and resources.

Geo-sources

Himalayan mountains are the youngest mountainous range of the world (Shah and Moon, 2004), which make them hotspot for different geological activities as follows:

Landslide

Landslide is very common in the Himalayan Mountains due to the fragile ecosystem and less stabilized geological structure. Low landslides were found on a high elevation (6.86%) due to the stable geological formation and loess soil depth. Maximum landslides were recorded in low and mid-elevation (42.15% and 50.98%) due to steepness, moisture availability, less developed soil, and ground instability.

Rockfall

Rockfall is dangerous and cause a high level of casualties of human life and animals and also damage the forest stand. Rockfall events were recorded on barren areas with a steep slope, and also on high elevations, altitudinal variation doesn't influence rockfall events showed in Figure 3. (Low 43.75%, mid 50%, and high 6.25%)

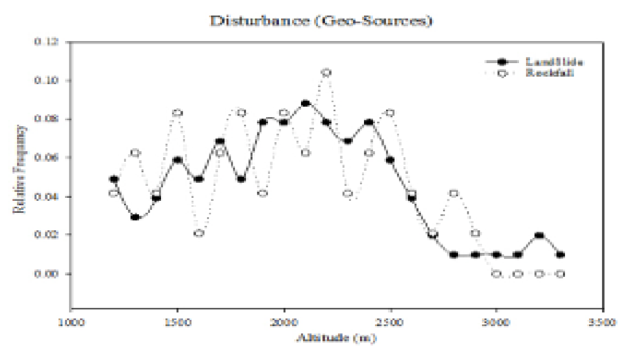


Figure-3: Only two type of Disturbance were found during data collection in Geo-Source. The data (relative frequency) show low events on higher altitude that is more than 2,700 m, as compared to mid and low

Avalanches

Avalanches are not so common in the mountains range of the research. But still, there are numbers of evidence were found in the valleys which identified the events and damages from avalanches. No such data were collected due to limited time and resources.

Earthquake

Earthquake damages the forest land and also certain geo-structures in the mountain. Most of the earthquake disturbances enhanced other disturbance processes, such as the rockfall, landslip, and landslide.

Earthquake 2005 was the massive disaster in South-Asia, damaged thousands of hectors of forest land. Those destabilized areas need to re-vegetated, the earthquake also contributes to the disturbance.

Biotic sources

Life plays a vital role in changing the ecological structure. Mountain forests are heavily influenced by biotic factors.

Grazing

This factor has a high importance in mountainous forests with high floristic composition. These animals also play an important role in land improvement and soil degradation. Disturbance due to animals' movement and heavy grazing provides ground to the new plants but also destroys the growth of plant species. Disturbance due to grazing activities in the mountain is very high both on low (42.45%) and high (43.39%) elevation, because of nomadic and local graziers. Mid-range elevation covers about 14.15% of the grazing disturbance.

Insects and disease

They enhanced the disturbance in a diverse floristic condition in a mountainous forest. Insect and disease damages were affected by climatic change in recent years. Results showed that there is a high influence of insect and disease damage on the mid-elevation (57.31%), due to old growth, lighting/fire (High Altitude 23.17%), snow and wind damages provide favorable habitat, whereas damaged trees act as host to the insects which caused diseases.

Anthropogenic factors

Humans utilized the forests from early days of life, but from last few decades, they managed these forests on a sustainable basis, for maximum utilization of natural resources. From the past few centuries, industrialization and structural development have destroyed these forest resources. Deforestation of the forest also contribute to the disturbance phenomena; such events are: logging operation, land clearing for agriculture, or other uses and fire activities that burn the grasses for grazing purposes (McGovern et al., 2011).

Logging

Logging operations are key to maximizing the production of forest stand and replacing the forest with new plants. Data shows that there is more than 33% disturbance due to logging activities (legal or illegal). High Logging activities found on low altitude (56.73%), high altitude also contributes 26.92%.

Land clearing/shifting cultivation

It is very common and clearly visible, locals clear the forest land for agriculture or pastoral activities. Forests land clearing are prominent on the high (28.28%) and low (68.68%) elevation due to access to the residential area or close to the sub-alpine pasture. The only disturbance which is dangerous for the forest stands cover and protection of valuable species.

Counter fire/human activities

They are the beneficial cultural operation for the regeneration as well as for the harvesting of fodder crop for livestock on a lower elevation (48.64%). Such disturbances are highly productive for forest stand cover and composition. High Altitude is also affected by the counter fire 36.03% but the area of disturbance is less than 100 sq.m.

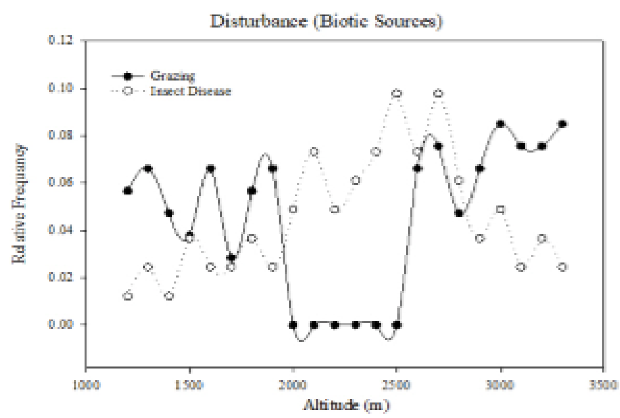


Figure-4: Insect- and Disease-infected trees were found throughout the region, high in the upper mid-range of altitude. Grazing activities were only found on low and high altitude range.

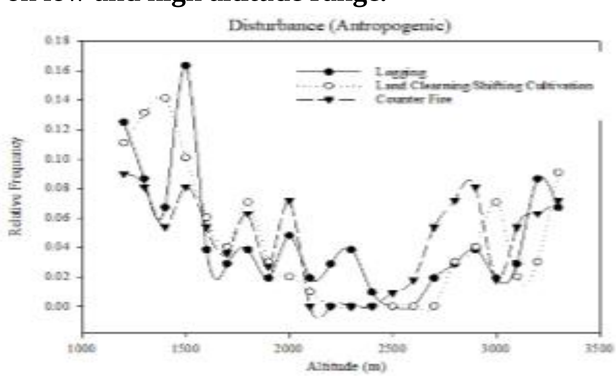


Figure-5. Human activities are very active in region, whereas the high activities on lower altitude and also on the high altitude.

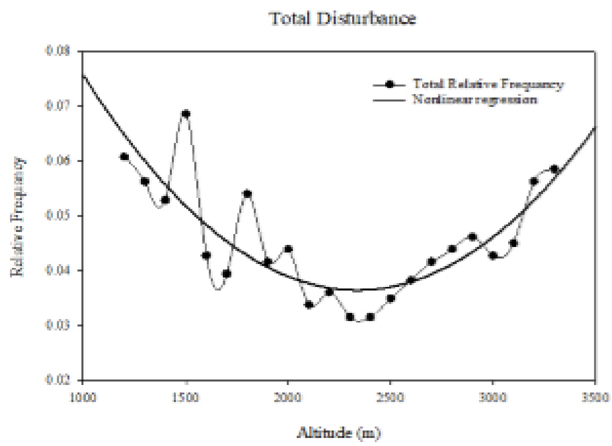


Figure-6: Equation: Polynomial, Quadratic *f* = *y*0 + *a*x* + *b***x*^2. Low impact of disturbance on mid range altitude due to less accessible and expose. Normality test and significance**

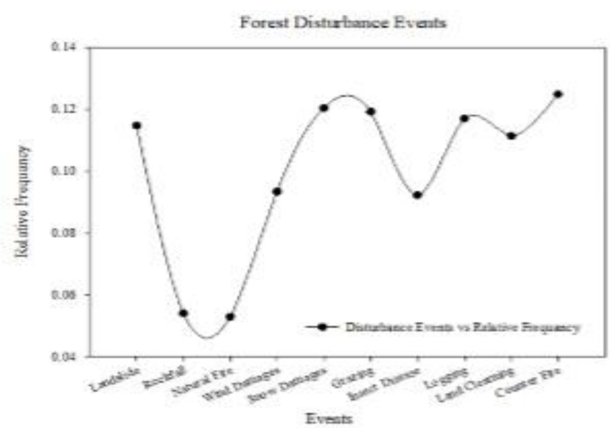


Figure-7: Graphical representation show low occurrence of Rockfall Natural Fire compare to the rest of disturbance event.

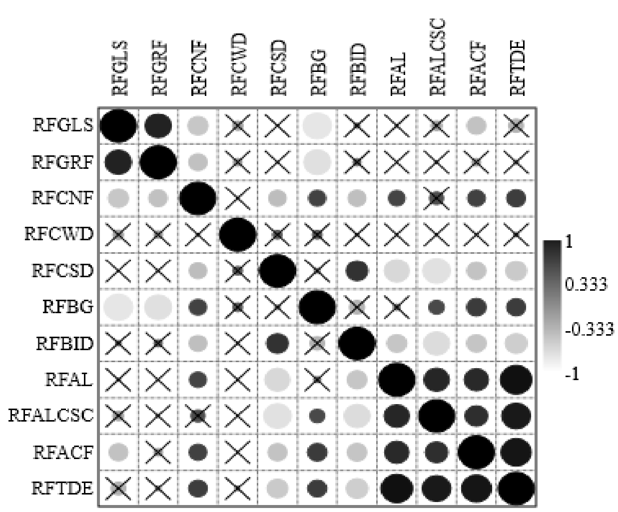


Figure-8: Correlation among the events, where crossed show *p* > 0.05 significance level.

Conclusion

Western Himalayan moist temperate forests have great importance; social, scientifically, and economically. There is a need for detailed studies regarding ecological disturbance and the development of a productive model for the stability and improvement of these forest resources. This study provides baseline information for advanced research by using geo-informatics, ecological, social, and economic models. From the results, it's clear that these forests are still in better condition, but if those events regularly occur and found, may lead to the deterioration and degradation of these diverse mountain forests. Data analysis was focused on the stability of mountain forests for long-term planning. Anthropogenic activities need to be restricted and increase afforestation activities to increase the forest-covered area.

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