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Tree fall susceptibility to storms in major forest types in a part of Central Himalaya

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Abstract. Tree fall in Kumaun Himalayan forest was analysed for seven years from 1978 to 1984 between 250 and 2,600 m amsl. The tree fall was episodic. As one storm during a night in1981 alone accounted for about 80% of the tree fall encountered during the seven years of study. The percentage of standing crop that was affected by tree fall varied from species to species. In the entire study area chir pine (*Pinus roxburghii*) forest and *P. roxburghii* exhibited the highest tree fall, and it was respectively 3.30 and 3.45% of stocking density. Tree fall increased up to 30-40 cm diameter class where after it declined.

Key words: Central Himalaya, tree fall, *Pinus roxburghii*, wind storm

Introduction

Wind storms may account for very large inputs of coarse woody debris as a result of snapping and uprooting of trees (White 1979). Coarse woody debris plays a crucial ecological functions, as habitat for autotrophs and heterotrophs, in energy flow and nutrient cycling, and by influencing soil and sediment transport and storage (Harmon *et al.* 1986). Information on coarse woody debris in relatively natural ecosystems also helps in assessing the impact of intensive forestry practices, such as short term rotations and yarding unmerchantable volume. Catastrophic wind damage has been reported from several parts of the world (Franklin and Debell 1988; Harmon *et al.* 1986); however, no information exists for the Indian Central Himalayan forests. This study includes a brief report on the effect of a major wind storm on the tree fall in a series of forest types along an elevational gradient of 250-2,600 m amsl in Kumaun Himalaya. The objectives of the study were (i) to assess the effect of a storm and stocking density of trees on tree fall by making observations for seven years, and (ii) to find out susceptibility of *Pinus roxburghii* to windthrow as affected by resin tapping.

Material and methods

Study site and climate

Observations were made in an area of the Central Himalaya, India within an elevational range of 250-2,600 m amsl between 29°13'- 29°34' E long and 79°14'- 79°49' N lat.

The mean monthly temperature ranges between 12.0 °C (January) and 30.0 °C (May) at 300 m amsl, 9.2 °C (January) and 23.0 °C (July) at 1,500 m amsl, and 4.5 °C (January) and 22.0 ° C (May) at 2,000 m amsl. Above 1,500 m amsl snow fall is common, but it melts rapidly below about 2,000 m amsl. Severe frost is common from December to February. Of the total annual rainfall which varies from 1,560 mm at 300 m amsl to 2,510 mm at 2,000 m amsl nearly three-quarters occurs during mid-June to mid-September, the monsoon period.

Except for the foot hills where soil is alluvial, it is fairly deep and colluvial. The soil is sandy loam and slightly acidic (pH= 5.7-6.7) (Singh and Singh 1987).

Forest vegetation

Sal (*Shorea robusta*) forest occurred below 800 m amsl, mixed broadleaf (*Holoptelea integrifolia, Mallotus philippensis, Ehretia laevis* and *Terminalia tomentosa*) forest between 800 and 1,000 m amsl, chir pine (*Pinus roxburghii*) forest between 1,000 and 1,800 m amsl and oak (*Quercus leucotrichophora, Q. floribunda, Q. semecarpifolia* and *Q. lanuginosa*) forest above 1,800 m amsl (Singh and Singh 1987). While sal is subdeciduous with soft leaves, chir pine and oaks are evergreen with about one year leaf life span.

Methods

Data collected by the State Forest Department on tree fall for different forests for seven years, i.e., 1978-1984 for an area of 59,552.5 ha encompassing various compartments (a forest's working unit, ranging in size in this case from 6 to 204 ha), here after referred to as stands, were used to describe the tree falls. In each stand, trees >10 cm diameter were enumerated. Of the total area, 50% consisted of chir pine (*Pinus roxburghii*), 4% sal (*Shorea robusta*), 24% oak (*Quercus* spp.), 1% other conifers, 14% other broadleaf species forests, and 7% was treeless and/or was occupied by river beds (not considered for this study) and landslips, etc. (Dwivedi and Mathur 1978).

Total tree fall for each species in each year and after individual major wind storms was computed on a per hectare basis by summing up the tree fall for each species, over all stands, and then it was divided by the total area of all the stands. Similarly, tree fall on a per hectare basis for dominant species (in a range of size classes) of sal, chir pine and oak forests during a wind storm of 1981 was also computed. Trees were divided into 10 cm diameter classes from 10-20 cm up to >80 cm class. A total of 15 trees unaffected by fire of *P. roxburghii* distributed in different girth classes (25-55 cm cbh; cbh= circumferance at breast height) were measured for length, width, and depth of the scars made for resin tapping on the basal part of the tree trunk. Data presented for the depth were measured at the middle of the scars. However, for calculation of volume, depth was measured at base, middle, and at top of each scar. Area and volume of total scars for a given tree were calculated by multiplying length and width and area by depth, respectively.

Analysis of variance (ANOVA) and correlation were made following Snedecor and Cochran (1967).

Results

The average wind velocity during storm free months for seven years (May 1981-April 1988) was 2.91 m/sec with a maximum in March (4.00 m/sec) and a minimum in November (2.26 m/sec)(Table 1). The wind velocity at the time of storm could not be measured.

The tree fall across the years ranged from 0.003 to 1.971 /ha/yr, with a mean of 0.356±0.269 /ha/yr. The tree fall during normal years was in the range of 0.003 to 0.275 (mean 0.087± 0.040; average of six years). Of the total tree fall during 1978- 1984, about 80% occurred during 1981 (Fig. 1) of which 98.6% (1,09,118) fell due to a single wind storm during April 1981.

ANOVA ($P<0.01$) indicated significant differences between species in different stands. In the entire study area, wind caused tree fall was 1.945 /ha, of which 99.0% was recorded for *P. roxburghii*, 0.3% for *Quercus* spp., 0.2% for other conifers, 0.1% for *S. robusta* and 0.4% for other broadleaf species. Total tree fall was 1.30% for all species of the available stocking density (number of trees growing in a specified area), 3.30% for *P. roxburghii*, and 0.002% for other species during 1981 storm .

The total tree fall during a wind storm for *P. roxburghii* in chir pine forest was significantly higher (3.599±0.149 /ha) compared to others (*Quercus* spp.= 0.014 /ha, *S. robusta*= 0.054 /ha, other conifers= 0.725 /ha) in their respective forests. *P. roxburghii* (3.45% of the total stocking density) had higher tree fall compared to *Quercus* spp.(0.01%) and *S. robusta* (0.10%) in their respective forests.

ANOVA indicated significant differences ($P<0.01$) for different diameter classes in different years for the entire study area. Total tree fall for all species, other species and *P. roxburghii* during the wind storm increased up to 30-40 cm diameter class whereafter it declined (Table 2).

Tree fall and its proportions with reference to stocking density in different diameter classes in three major forest types are given in Table 3. ANOVA showed significant differences ($P<0.01$) between different diameter classes of different species.

One to twenty nine (average 12.9±2.5 scars/tree) scars per tree occurred due to resin tapping. Number of such scars were positively related to girth of the trees [$Y= -24.158 + 0.989\ X$, $r= 0.937$, $P<0.001$; where X is cbh (circumference at breast height) in cm and Y is number of scars]. These scars were distributed in rows around the trunk with classes from one (for lowest girth class) to six (for highest girth class). In each row a number of scars were in the range of one to seven. The initial scar in each of the row occurred about 0.4-0.6 m above the ground. The length and width of the scars were 1.44±0.197 (0.36±0.01 for lowest girth class to 2.08±0.13 m for highest girth class) and 0.11±0.004 m, respectively. The length of the scars made for a row was positively related to the girth of the trees ($Y= -1.228 + 0.073\ X$, $r= 0.889$, $P<0.001$; where X is cbh in cm and Y is length in meter). The number and length of the scar increased with time by making more scars one above the another to tap more resin. The depth of the scar was about 0.06±0.002 m. The total area and volume under scars were 0.524±0.104 m^2 (0.038±0.002 m^2 for lowest girth class to 0.902±0.100 m^2 for highest girth class) and 0.025±0.005 m^3 (0.002±0.0001 m^3 for lowest girth class to 0.043±0.0045 m^3 for highest girth class),

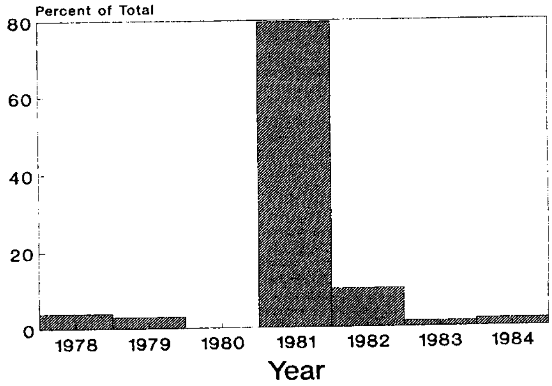

Fig.1. Distribution of free fall in different years.

Months	Wind velocity
January	2.45±0.21
February	3.02±0.35
March	4.00±0.27
April	3.98±0.52
May	3.55±0.37
June	2.78±0.36
July	2.85±0.30
August	2.27±0.29
September	2.80±0.21
October	2.32±0.21
November	2.26±0.20
December	2.67±0.17

Table 1. The average wind velocity (m/sec) for different months (average of seven years; May 1981 to April 1988) at 1,800 m amsl (source: Nainital Observatory).

Diameter classes (cm)	Stock density (tree\ha)			Tree fall (tree\ha)		
	Total	P.roxburghii	Others	Total	P.roxburghii	Others
10-20	47.79	16.37	31.06	0.139	0.136	0.003
20-30	38.21	14.73	21.88	0.347	0.343	0.004
30-40	26.62	10.91	15.71	0.619	0.613	0.006
40-50	18.43	8.05	10.38	0.496	0.493	0.003
50-60	10.93	5.50	5.43	0.245	0.244	0.001
60-70	4.52	1.98	2.54	0.076	0.075	0.001
70-80	1.79	0.63	1.16	0.020	0.019	0.001
>80	0.91	0.22	0.69	0.003	0.003	-

Table 2. Stocking density before wind storm and tree fall after wind storm in different diameter classes for entire study area.

Diameter classes (cm)	Sal		Chir pine		Oak	
	1	2	1	2	1	2
10-20	0.0084	0.07	0.2359	0.88	0.0048	0.02
20-30	0.0168	0.10	0.6411	2.42	0.0032	0.02
30-40	0.0164	0.11	1.1468	5.89	0.0026	0.01
40-50	0.0084	0.13	0.9208	6.40	0.0017	0.01
50-60	0.0025	0.14	0.4564	4.64	0.0005	0.01
60-70	0.0008	0.19	0.1399	3.98	0.0002	0.01
70-80	0.0008	0.70	0.0356	3.11	0.0004	0.02
>80	-	-	0.0047	1.10	0.0002	0.01

Table 3. Tree fall (1; tree/ha) and its percent of stocking density (2) in different diameter classes for dominant species in three major forest types during wind storm.

respectively and were positively related to girth ($Y= -0.949 + 0.039 X$, $r= 0.890$, $P<0.001$ for girth vs area; $Y= -0.047 + 0.002 X$, $r= 0.900$, $P<0.001$ cbh vs volume where X is the cbh in cm and Y is the area in m^2/volume in m^3).

Discussion

Tree fall was distinctly higher during a wind storm year as compared to normal years. Differences of tree fall between species in different stands may be due to differences in stocking density. The area occupied by different forest types (sal, chir pine, oak and other conifers) and total tree fall of dominant species during wind storm were positively related, according to $Y= -14{,}757 + 2{,}101 X$ ($r= 0.897$; $P<0.05$), where X is percent area occupied by different forests and Y is tree fall/ha of dominant species during wind storm.

High tree fall (about 99% of the total tree fall) as a result of a wind storm for *P. roxburghii* in the study area seems to be related to the degree of open canopy, lack of well developed stratification (Singh and Singh 1987), severity of cuts made for resin tapping (Saxena 1979), low root:shoot ratio, low belowground biomass, and rooting depth of *P. roxburghii* trees (Table 4). Other factors include frequent burning (Saxena *et al.* 1984) and shallow soil in chir pine forest compared to other forests of the region. Futhermore, tree fall as a consequence of awind storm in chir pine forest is often considerable, specially in burnt areas and where resin channels are deep (Dwivedi and Mathur 1978). The method of resin tapping by french cup and lip method being employed is faulty; there is no check on the depth of the blaze. The deeper incisions weaken the trees which becomes susceptible to strong velocity storms (Khosla and Toky 1986). Furthermore, *P. roxburghii* has ability to colonize disturbed eroded sites and landslides with low organic carbon and nitrogen, and dry sites like quartzite rocks (Singh and Singh 1987). Drier and rockier soil with quartzite rock may also contribute to a higher tree fall in *P. roxburghii*.

In chir pine, a "natural concentrated regeneration system" is followed in which all the trees are clear felled except for a few seed bearing "mother trees" (10-25 / ha). Thus, the tree fall at a massive scale, such as in a wind storm should promote regeneration and expansion of *P. roxburghii* by allowing penetration of more light and creating more space as a result of opening of thecanopy.

For oak forests of the Central Himalaya, Rikhari

Features	Sal	Chir pine	Oak
Major species	*S. robusta*	*P. roxburghii*	*Quercus spp.*
Root:shoot ratio	0.26:1	0.22:1	0.34:1
Root depth (m/tree)	1.31±0.13	0.39±0.09	0.82±0.11
Root biomass (kg/tree)	260	60	130
Mean basal area (cm^2/tree)	263	70	89

Table 4. Certain features of dominant species of major forest types (based on Rana 1986).

(1990) has estimated tree fall (average of two years) in the range of 0.17- 0.50 /ha/yr which is higher compared to oak forest in this study. In the mid-elevation stand of a unmanaged 470 years old Douglas fir in Western Oregon, the tree mortality has been recorded 1.20 /ha/yr (Grier and Logan 1977), while MacMillan (1981) has reported 2.54 /ha/yr for oak forest in Indiana. Thus, in the present study tree fall was lower except for *P. roxburghii* compared to other studies conducted elsewhere. These differences seem to be related to the length of study period, the size of the area observed, and the nature of the catastrophe. A markedly lower tree fall of *Quercus* spp. than *P. roxburghii* is most likely to be due to higher root:shoot ratio.

Higher tree fall in the intermediate diameter classes for *P. roxburghii* seems to be related to continuous resin-tapping process which is done for trees of >25 cm diameter. The depth of such scars increased as a consequence of frequent fires in the chir pine forest (Dwivedi and Mathur 1978). When scars are made on all sides, the tree loses its strength and becomes more susceptible to windthrow. In higher diameter classes, a lower value for tree fall may be due to low density of large trees. Saxena *et al.* (1984) has also recorded fewer trees for >60 cm diameter classes in all the forests of the region. Harmon *et al.* (1986) has reported that large trees were susceptible to windthrow, indicating >10 % of the volume input by wind.

Harcomb (1987), Peet and Christensen (1987), Franklin *et al.* (1987) have reported a high rate of mortality in early successional, young forest, medium to low in mature, and old forest. In this study, *P. roxburghii* which forms early successional forest with poor diversity had higher tree fall than oak and sal forests which form climax vegetation for the region (Singh and Singh 1987).

To conclude, a wind storm affects species composition by causing more tree fall of one species than the other, and creating condition much favourable for regeneration of the species that is more vulnurable to tree fall. The expansion of *P. roxburghii*' in this region, in past, seems to be due partly to such catastrophic windstorm events. Management practices or, lack of such practices (unproper resin tapping) have also contributed to this situation.

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