Role of dead wood in depicting human impact in natural spruce-fir forests in temperate NW-Himalayas

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1. Introduction

1.1. Background

The massive chain of mountains known as "The Himalayas[1]", in north-west India (Figure 1) is a site for large cover of natural forests. In its temperate zone between elevations of 2000m and 3500m, mixed stands of *spruce (Picea smithiana (Wall.) Boissier)* and *fir (Abies pindrow Royle)* constitute the most conspicuous forest community (Champion and Seth 1964).

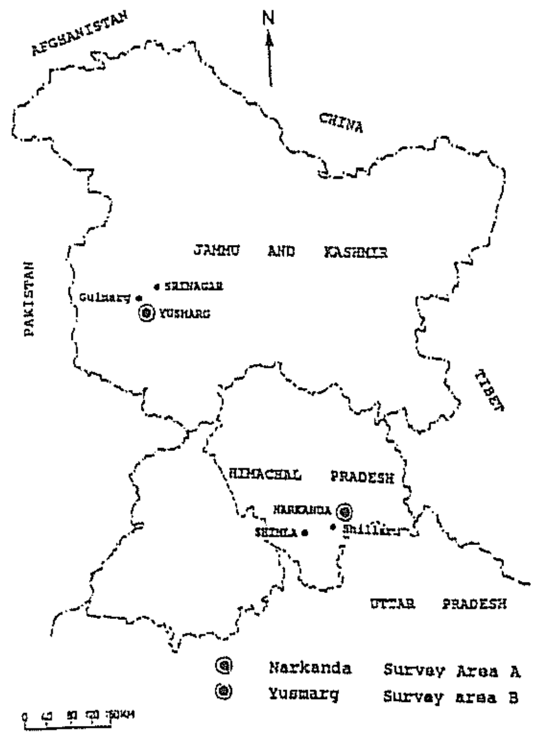

Figure 1: Site of spruce-fir forests and survey sites in the NW-Himalayas

Spruce-fir forests represent ecologically the most vital ingredient of the natural vegetation, and have an emphasizing role in modifying local microclimate, watershed management, soil protection and biodiversity conservation, and are of high socio-economic and aesthetic value. In spite of their enormous importance and overall traditional relationship between the forests

[1] In ancient sanskrit, Himalayas means "Abode of snow" (Him: Snow, Alaya: Abode).

and local communities in this region, the unrelenting processes of use and abuse have disturbed their structure and dynamics.

The reasons behind the above predicament are varied: overuse[1] and degradation caused by dense population, use of wood as fuel and building material, uncontrolled grazing and mounting infrastructural build-up in the NW-Himalayas. This disturbing situation is further complicated by the ensuing disregard of sustainable forest management.

The belt of *spruce-fir* forests is influenced by the regional climate, which is dominated by the monsoon and by the local climate originating in the mountain system itself. *Mixed coniferous forests* of *spruce* and *fir* extend up to an area with annual precipitations higher than 1300mm (Champion and Seth 1968). However, the total annual precipitation and its seasonal distribution show a marked disparity in the natural range of distribution of these forests. As a rule, due to the reduced impact of the monsoon, annual precipitation undergoes a gradual decrease from the southeast to the northwest of the Himalayas. There is also a decrease along the south-north axis (i.e., the inner Himalayas are drier). In monsoon areas, annual precipitation is as high as 2500mm (Troup 1921). Humidity is especially high throughout the monsoon irrespective of exposition (Osmaston 1922). During July and August, relative humidity is usually above 90% (Singh 1982, unpubl.). Conversely, the climate of the Kashmir valley –having a substantial cover of such forests- is dominated by winter rainfall falling chiefly in the form of snow.

1.2. Human impact

Even until the beginning of 19th Century the Himalayas enjoyed reprieve. Many authors claim that the degradation of the Himalayan Mountain Forests largely occurred in the last 150 Years (Schlagintweit 1872; Lawrence 1895; Ribbentropp 1890; Troll 1939; Uhlig 1959) since the needs of low population density were limited and insignificant (Seebauer 1985). According to Tucker (1982), the commercial timber exploitation under colonial rule was the primary cause of deforestation.

Intensive use sparks off a network of inexorable processes resulting in the ecological devastation of natural vegetation. However, these processes are by no means restricted to the socio-economic health or environment of a region but also extend to the physical existence of mankind. The high intensity of uses is directed at the mountain forest ecosystem. Hence their

[1] The multiplicity and magnitude of uses (primary: timber, fuel wood, industrial consumption; secondary uses: resin, medicine, food, fodder, dyes etc.) highlight the onslaught these forests have been and are exposed to.

role in altering or degrading such ecosystems can hardly be denied. It follows that the structure and developmental dynamics of natural *spruce-fir forests* are affected. Heske (in Schweinfurth 1957) sums up the impact of above uses as "perforation" in the forest canopy.

Logically therefore, when the structure and developmental dynamics of such forests is investigated, the varied human impact must also be considered.

1.3. Objectives

A comprehensive study on structure and developmental dynamics of *spruce-fir forests* affected variedly with human impact (Kotru 1993) was carried out on Northwest India. It considered a set of six *spruce-fir* stands ranging between pristine condition and those subject to intensive human impact. The major aboveground elements of forest ecosystems were studied, including the old stand, ground vegetation, and natural regeneration. Since dead wood is a major component of such forest ecosystems, its significance in assessing the disturbance and developmental dynamics is of value. Hence the present study deals with dead wood features in such forests and its role in depicting the human impact on pristine forests.

2. Methods

2.1. Survey areas and survey plots

Survey are	Plot no.	Aspect	Elevation (m above see level)	Slope (°)
A	1	65 ENE	2455	29
	2	64 ENE	2485	25
	3	40 NE	2580	19
B	4	90 E	2320	17
	5	10 N	2365	20
	6	90 E	2385	14

Table 1: General features of the survey plots

Investigations were conducted in the two main states of Northwest India. One in the Federal State of Himachal Pradesh near Narkanda (survey area A, altitude between 2400m-2500m a.s.l., geographical location between 31°8\` to 31°42\` NL and 77°18\` to 77°48\` EL), and the other in the State of Jammu and Kashmir near Yusmarg (survey area B, altitude approximately 2300m a.s.l., geographical location between 33°33\` to 34°33\`NL and 74°28\` to 74°55\`EL). The study conducted in old-growth stands is based on six survey plots. Each area includes three survey plots. As demonstrated in Table 1, survey area A is situated at somewhat higher elevation and is steeper than the survey area B. According to compartment history files, silvicultural measures were carried out in survey area A 35 years back.

The size of each of the six survey plots is 70m x 70m with the area of the main plot (area of major data collection) being one fourth of a hectare. A systematic network of 100 x 1-m^2 sample plots formed the survey units within each plot. Two surveys with an interval of five-year were possible only for survey area A, survey area B could be surveyed once only. The focus of this article will be dead wood on the forest floor.

2.2. *Arrangement of survey plots according to magnitude of human impact*

The integral part of any forest ecosystem is the range of disturbances varying from those that are inbuilt (e.g. decay of veteran tree and its eventual fall) and do not alter the structure irreversibly to those that wholly or dramatically change the system (e.g. fire).

Disturbance-Indicators	Survey area A						Survey area B					
	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Plot 6	
Cuttings	Heavy	3	Low	1	Heavy	3	Medium	2	Low	1	Low	1
Grazing	Heavy	3	Medium	2	Heavy	3	Heavy	3	Low	1	Low	1
Lopping	Medium	2	Medium	2	Heavy	3	Heavy	2	Medium	2	Low	1
Trampling	Heavy	3	Low	1	Heavy	3	Medium	2	Low	1	Low	1
Access	Easy	3	Medium	2	Medium	3	Medium	2	Medium	2	Hard	1
Understory	Poor	3	Medium	2	Poor	3	Medium	2	Rich	1	Rich	1
Deadwood	Poor	3	Medium	2	Medium	2	Poor	3	Medium	2	Rich	1
Canopy density	Low	3	Medium	2	Low	3	Medium	2	Medium	2	High	1
Sum	23		14		22		19		12		8	
Rating (Sum/8)	**2.9**		**1.7**		**2.7**		**2.4**		**1.5**		**1**	

Table 2: Various disturbance indicators and their ranking

Therefore, it is obvious that all-pervading human impact in spruce-fir zone is observed in many ways prior to any detailed survey. Furthermore, the absent or least human interference, allow undisturbed development of stands perpetuating their pristine background (e.g. no cuttings, no grazing signs etc.) in this way. Hence a classification of survey plots was undertaken according to first hand impression of human impact. On the basis of a set of disturbance indicators (e.g. felling and grazing, see also Table 2), survey plots were arranged into various so termed 'naturality classes'. Accordingly, on the scale of naturality classes, a gradient of human impact emerged which allowed an arrangement of stands into different classes as indicated in Table 3

As illustrated in Table 2, 8 types of disturbance indicators were outlined. The intensity of each indicator was ranked according to ordinal scale (e.g. Cuttings: None = 0, Low or Less=1, Medium=2, Heavy=3) denoted with numerical values. Accordingly for cuttings, value 1 would imply the origin of stumps mostly through natural process (i.e. death) with very few having cutting scars, whereas value 3 would mean a pure human impact (i.e., axe scars on most of the stumps). The application of afore-mentioned scale is at best understood by the fact that under totally pristine conditions all the disturbance indicators will have a value "0". Thus value 1, in general, stands near to natural developmental conditions, whereas value 3 reflects intensive human impact. The average of numerical values was taken to obtain the mean degree of disturbance. On the basis of mean values, classes were made to differentiate between varied degree of disturbance which in other words would display varying degree of naturality (Table 3). Accordingly, plots could be arranged into various *naturality classes.*

Thus in survey area A, both the plots 1 and 3 were very heavily disturbed, whereas plot 2 showed a low disturbance. A clear transition from nearly pristine (plot 6) to highly disturbed status (plot 4) could be achieved in survey area B.

Naturality or Disturbance class	Disturbance rating (0 indicates totally pristine forests)	Survey area A	Survey area B
Pristine (I)	< 1.0	-	-
Nearly Pristine (II)	1.0 – 1.4	-	Plot 6
Low Disturbance (III)	1.5 – 1.9	Plot 2	Plot 5
High Disturbance (IV)	2.0 – 2.4	-	Plot 4
Very High disturbance (V)	> 2.5	Plot 1, Plot 3	-

Table 3: Scale of naturality classes

In all 5 *naturality classes* surfaced in Table 3, leaving the first class unoccupied as totally pristine or untouched forests in the Himalayas now rare and chiefly located in remote and steep areas (Mostly in Bhutan, personal observation 1986 and 1998).

The definition of pristine or natural stands here is understood as given by Froehlich (1954). He characterized natural forests as a conglomeration of all dbh (diameter breast height) and age-classes, which have originated naturally i.e., without human impact and were never systematically used. All dead wood elements (standing or down logs) remain in the forest unutilized. According to this author a sporadic small-scale cuttings do not change the status of natural or pristine characteristics.

Classification of plots according to disturbance indicators though subjective are relevant since use of deadwood is one of the main uses by the local communities and forest harvesting.

It has to be maintained that according to records (compartment history file) major structural changes (in survey area A) may have occurred due to silvicultural measures 35 years back. In combination with the present human impact (lopping, grazing etc.), disturbances in natural forests in survey area A are to be seen as recent. This applies to plot 4 in survey area B as well. However, undisturbed soil (according to the result of soil profiles) in survey area A do not hint at excessive and age-old human impact.

2.3. *Procedures for dead wood survey*

The major inroads into perpetual dynamic processes could be made by the standing dead volume in each stand. Understandably in natural forests, such dead trees whether decomposed or in non-decomposed state, over a given period of time become a part of the forest floor. Thus inquisition into the past structural changes reflecting on present structures and development dynamics can be achieved by investigating coarse woody debris on the forest floor. Furthermore, this may prove helpful for projecting the future development of a stand.

Hence coarse woody debris in the form of snags and down logs can be a major structural feature of natural and pristine forests. Among the four major biomass compartments basic for any changes in the biomass within ecosystem, dead wood (others being green living biomass, forest floor, organic matter in the mineral soil) whether standing or on the forest floor, is the imprint of previous structural changes. Its characteristics as shift in biomass from one compartment to another, it sheds light on the developmental dynamics of any forest ecosystem.

Data collection pertaining to dead wood was based on a complete survey of a whole plot (main survey) and on the 100 x $1m^2$ sample plots within a plot. Standing dead wood got estimated by survey of the stand parameters (dbh and height). For the determination of dead wood volume on the forest floor i.e., down logs and snags, *Smalian's formula* was used: Volume = length (basal area at butt-end + basal area at top-end) /2.

For the overall calculation of the dead wood on the forest floor only stumps higher than 30 cm were considered (but smaller than snags), which would mean that actual dead wood volume may be a bit higher. Location and measurement of each log (coordinates) as per length and diameter (top and butt end), species, when possible, and as per the extent of decomposition were noted. In general, according to the decomposed state or intactness of dead wood, three decay classes were assorted:

- Decay class 1: Logs still retained original structure with none or faint signs of decomposition in smaller patches.
- Decay class 2: An intermediary stage between advanced and beginning decomposition, patchy disintegration widely seen.

- Decay class 3: Decomposition is almost complete. Original structure is barely perceptible.

In addition, a surveillance of dead wood cover was undertaken on the 100 $1m^2$-sample plots in 10% intervals.

2.4. *Crown projection maps*

Inclusion of major woody structural features on the forest floor such as stumps and down logs in combination with the crown-projections maps and location of dead trees can be useful in explaining the overall stand dynamics and a link for reconstructing a broad view of stand characteristics in past is established. This was done for all plots. However, for a better explanation only plot 6 was used to demonstrate link between major canopy gaps and origin of down logs.

3. Results

3.1. *Number of down logs*

Figure 2 contains the number of dead logs for each plot. Apparently, pristine-like plot had maximum number of 214 dead wood logs per hectare. This underlines the fact that most of the logs here remain on the forest floor (no gleaning). The lowest number of logs were recorded on the highly disturbed plot 4, which is nearest to the habitation.

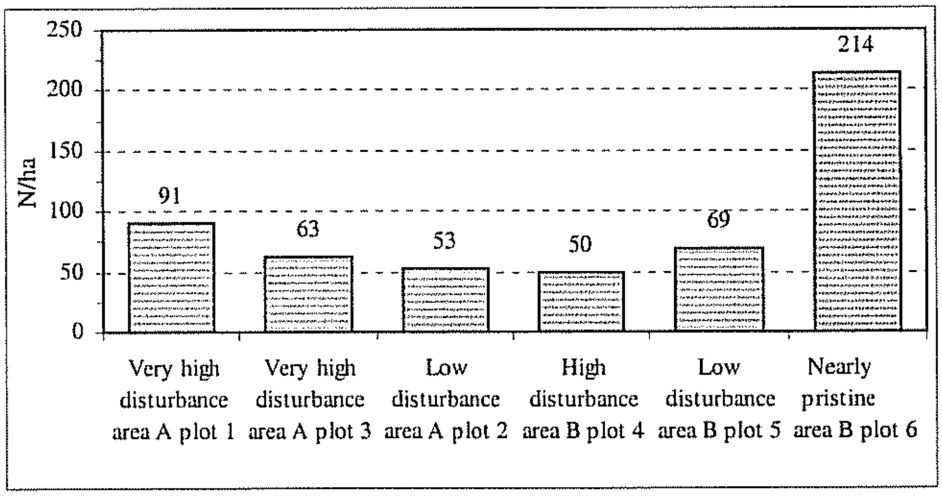

Figure 2: Number of dead wood logs (N/ha) on the forest floor

3.2. *Dead wood volume as per species*

Species-wise composition of dead wood (down logs and stubs) is illustrated in Figure 3. With $197m^3/ha$, the maximum amount of dead wood was noticed for pristine-like stand (plot 6). For all other stands volume of deadwood is far lower with a minimum of $17m^3/ha$ recorded on plot 5. That substantial dead wood (50m^3/ha) noticed on the highly disturbed plot 3 is mainly due to the presence of few large sized down logs[1]. Moreover, the reason for the accumulation of substantial dead wood whenever recorded in such disturbed stands is related to the large-sized logs not being transportable.

Frequency of down logs was clearly highest on plot 6 (see Figure 2) but the major part of dead wood here composed of few logs (*fir*). One of them (dead wood log) not completely lying on the main plot (see Figure 8) measured 32m. The top and butt-end diameter of this log was 72.5 cm and 114 cm respectively. Since this log is partly decayed, its massive size prior to its departure from the main canopy hardly needs endorsement. In addition, its volume (92.2 m^3/ha) signifies the shift of huge biomass from above-ground structure to the forest floor. It can be claimed that the fall of such veterans point out the major structural changes taking place in these stands over a given particular time. Therefore, not only biomass is added to the forest floor but also a major gap is created, implications of which can be decisive for the stand development.

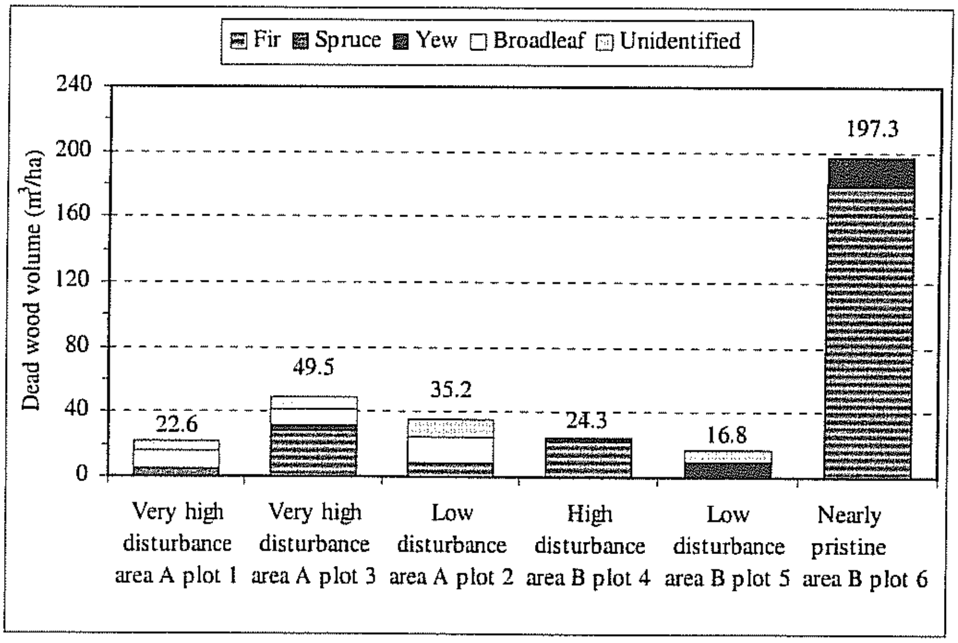

Figure 3: Amount of dead wood comprising down log and smaller snags

In general, as displayed by Figure 3, dead wood mostly comprises *fir* (except plot 5). Whereas *fir* is substantially represented on plots 3, 2, and 4, it understandably dominates on plot 6 by representing nearly 90% of the dead wood volume. Barring plots 1 and 2, *yew* is conspicuous in dead wood and represents over half of it on plot 5. Higher volume of yew in relatively undisturbed stands therefore is in conformity with its higher dead wood on plots 5 and 6. The

[1] Small sized down logs get consistently removed by the nomads and by villagers needing fuel wood.

major portion of the broadleaf dead wood found in survey area A is represented by *oak*. A sizeable part of dead wood could not get identified. The main outcome of dead wood analysis (on forest floor) can be summed up as follows:

- Dead wood on the forest floor is a major structural feature of *spruce-fir* forests irrespective of presence or absence of human impact.
- Total volume of dead wood (standing and on forest floor) is clearly higher on the plots less or least affected by human impact.
- Higher volume of dead wood is associated with the structural changes of the overstory (i.e., fall of senescent veteran).
- On highly disturbed plots mostly large-sized woody debris not transportable easily (with human effort) remains on the forest floor.

3.3. *Total dead wood volume according to main survey*

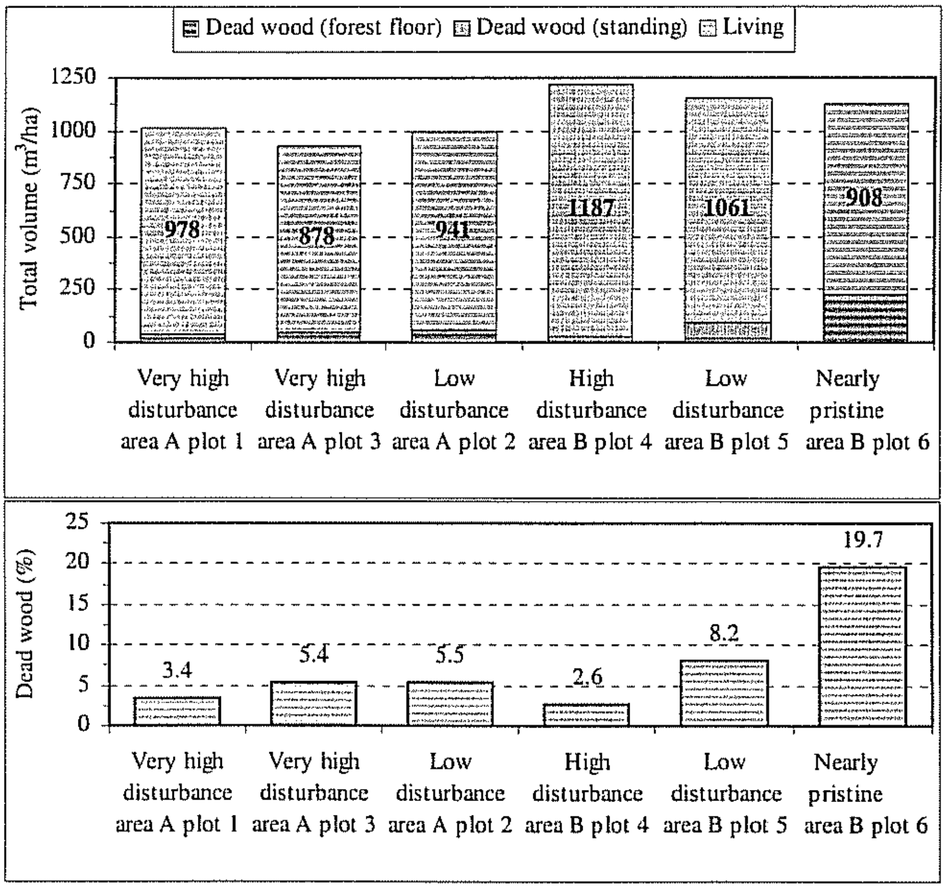

Figure 4: Volume of dead wood and its percentage of total volume (living and dead)

Figure 4 contains the total volume including the volume of the dead wood (standing and on the forest floor) and the ratio (%) of total dead wood volume to the total volume (standing crop and dead wood on the forest floor). Results indicated in Figure 4 are based on the main survey of a whole plot. As a rule, the volume of dead wood is higher on plots unaffected by recent human impact (plots 2, 5, and 6). Thus dead wood on plot 6 amounts to roughly 20% of the total volume. Least volume of dead wood (2.6%) is registered for the high disturbed plot 4 in survey area B. It can be attributed to low mortality and immediate gleaning of dead wood (at least small-sized down logs). Its shift from standing crop to the forest floor on disturbed plots (1, 3, and 4) is low. Hence in general, the percentage of dead wood is somewhat less. However, it is obvious in Figure 4 that all the plots have a varied set up of standing dead wood and the woody debris on the forest floor. Interestingly, the maximum standing dead wood of plot 5 will eventually become a part of the forest floor, a process that has culminated on pristine-like plot 6 in the past (huge dead wood on the forest floor).

3.4. Dead wood cover-% as per sample plots

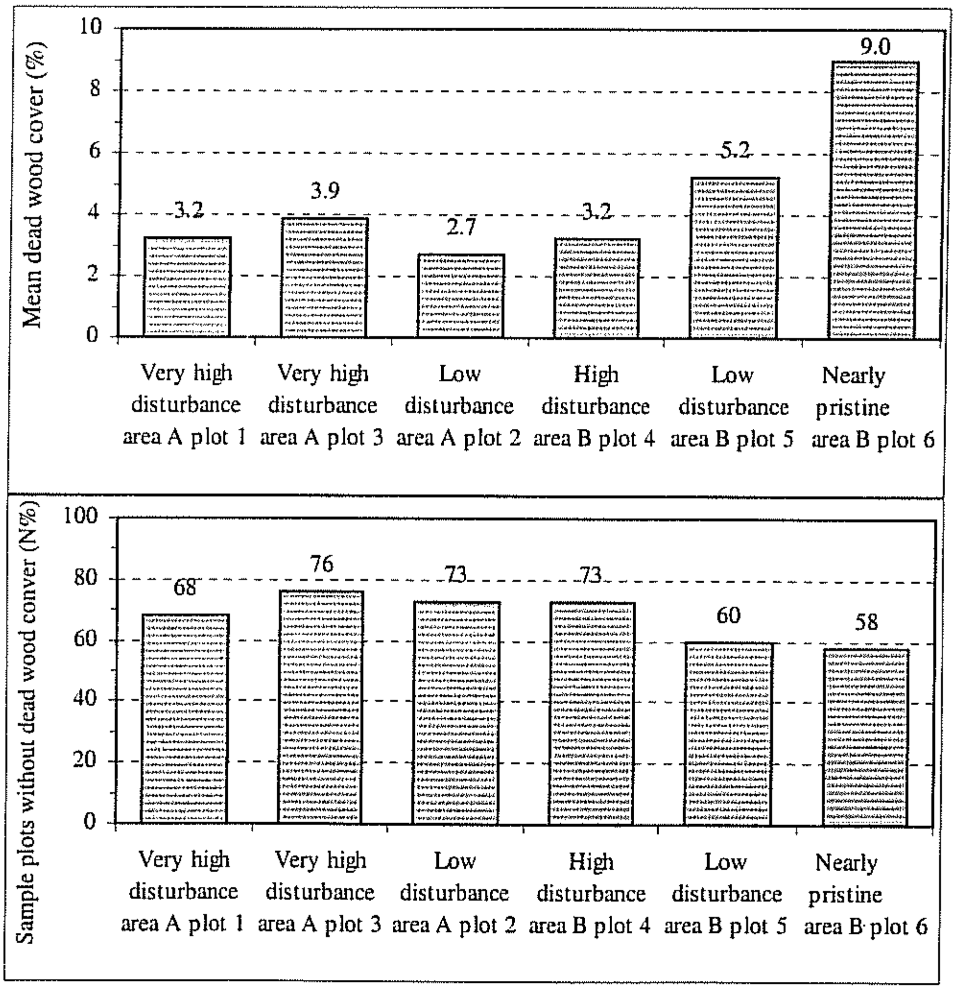

Figure 5: Dead wood cover on sample plots

In addition to the main survey, dead wood cover (%) was determined on the sample plots. In accordance with the findings made in previous point, the maximum volume of dead wood on plot 6 was equally verified by the results obtained on sample plots (Figure 5). Accordingly, on this plot 9% of the plot-area is covered by dead wood on the forest floor, followed by the low disturbed plot 5 with over 5%. All other plots had a low dead wood cover-%.

Interesting feature of dead wood cover (%) however, is that most of the small sample plots had no dead wood. On an average for the plots 1 to 4 over 72% were without dead wood cover. But even on the pristine-like plot 6 and the low disturbed plot 5 in the survey area B around 60% of sample plots behaved similarly. Since the presence of dead wood cover is mostly synonymous with the frequency (i.e., sample plots are occupied by dead wood), it can be claimed that woody debris is sporadically distributed. However, the partly contagious distribution of such logs especially on plot 6 can be ascertained in Figure 8. This kind of distribution to some extent is due to fallen tree breaking into many parts but aggregated on limited forest floor.

3.5. *Decay class according to main survey*

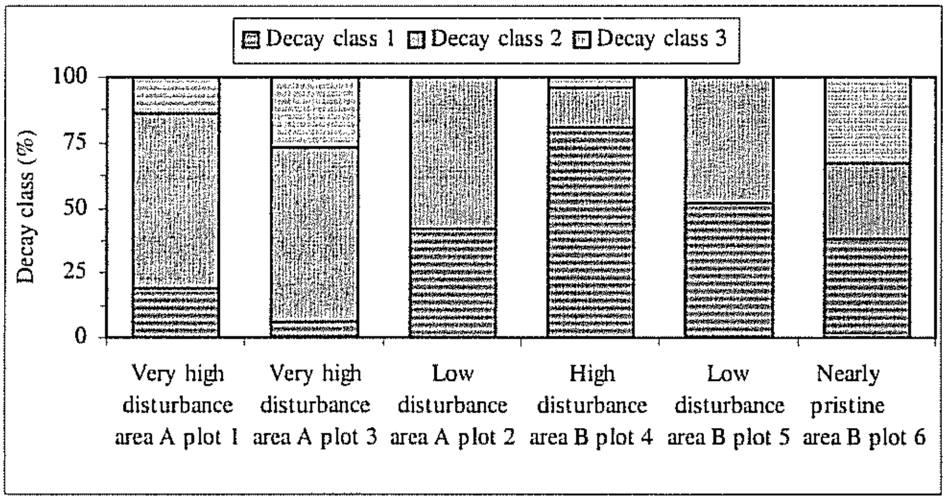

Figure 6: Distribution of dead wood according to decay classes in percent

The time of origination of dead wood and its periodic or constant addition to the forest floor can be different. Hence due to the unequal time of decomposition as well as the size of dead wood, woody debris can be seen in variable decaying stages. The above aspect (difficult to establish except when cut) can be interesting for ascertaining the intervals of major structural changes in the stands. On the other hand, dead wood in various decaying stages can endorse the disturbed or undisturbed course of the stand development.

A look at Figure 6 suggests that the portion of dead wood on plot 4 is of recent origin as 81% are attributed to decay class 1. Far lesser is the percentage of other decay classes (2, and 3) indicating that dead wood does not remain in the stand for a long time. Interestingly, including plot 6, where decay classes are somewhat evenly distributed. Even highly disturbed plots (1 and 3) have substantial percentage of decomposed dead wood. This is purely due to large down logs, which cannot be gleaned by human effort. This is further verified by a very high percentage of dead wood in decay class 2. One third of dead wood on pristine-like plot 6 is in advanced decayed stage. Understandably down logs here remain undisturbed until decomposition. That all the decay classes evenly distributed may be related to the constancy in addition of dead wood with its decay over time equally remaining constant.

3.6. Decay class as per sample plots

Distribution of decay classes ascertained on the sample plots (Figure 7) exhibit in comparison to the main survey (Figure 6) a reverse trend on plot 1 and 2. All other plots showed similar distribution of decay classes. Disparity in the assessment of decay classes as per the main survey and the survey conducted on the sample plots may have the following reason: While conducting the main survey, decay class was assessed according to the overall visibility of a particularly decay class. On sample plots, decay class was assessed to the part falling in the sample plot area. Since the same down log often contain all degrees of decayed wood, disparity emerging amongst two procedures is understandable.

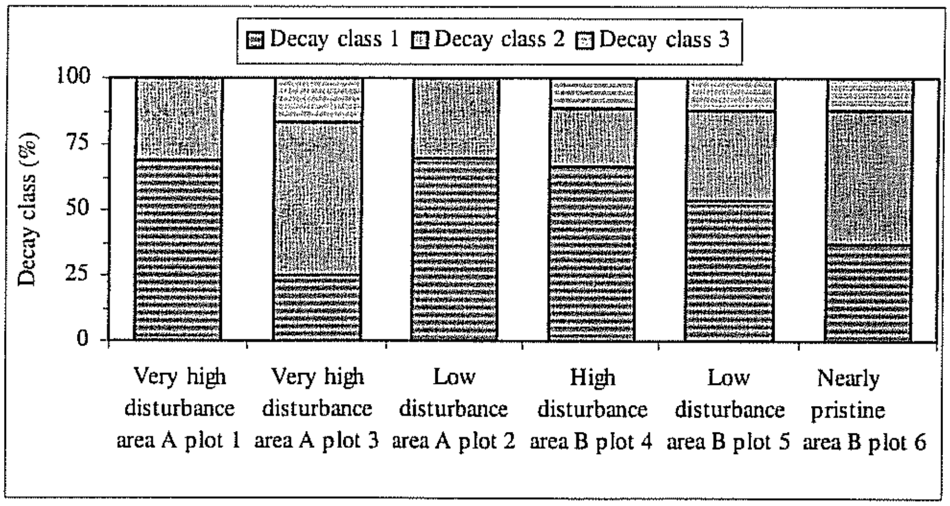

Figure 7: The percentage of dead wood according to decay classes on sample plots

Although the assessment of decay class on the sample plots is easier and precise due to clear focus on the piece of dead wood but may lead to error since only a small part of log lies in sample plot area. In general, the main survey proved reliable as long as the logs were shorter. For longer (>10m) it is often difficult to come to a conclusion unless dead wood is of recent origin.

3.7. *Crown projection and dead wood*

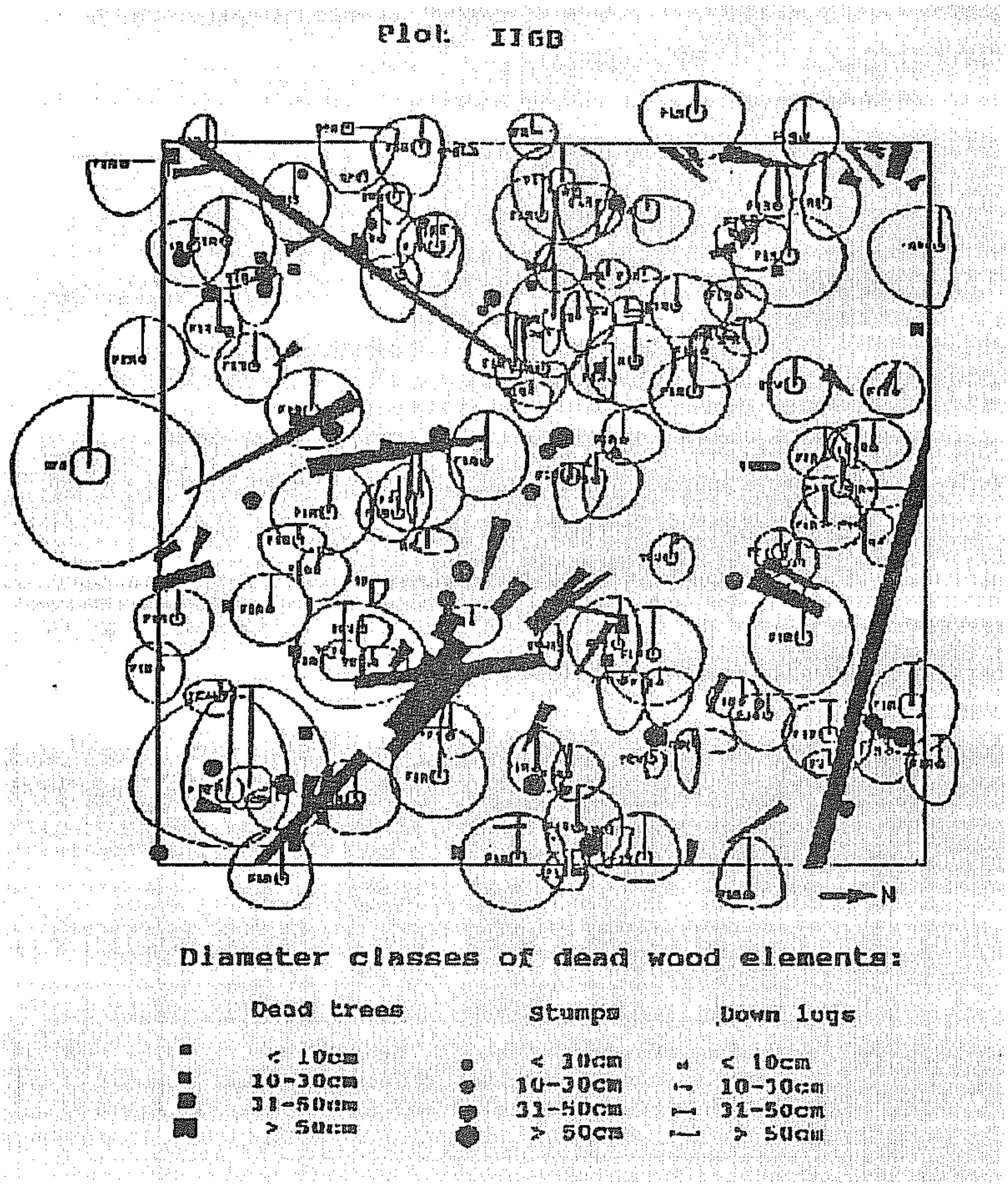

Figure 8: Crown Projection Map with dead wood logs on forest floor of plot 6

Crown projection maps can give a fair view of the horizontal structure but inclusion of woody structural features on forest floor such as stumps, down logs in combination with the crown-projection maps (synonymous with stand map) and location of dead trees can be useful in explaining the overall stand dynamics. A reconstruction of broad view of current stand characteristics linked to past changes. The remarkable feature of this pristine-like stand is the largely clumped accumulation of dead wood logs, the huge volume of which was described earlier. That few large-sized dead wood logs form the bulk can be seen in the lower half of the plot 6 (Figure 8). Figure 8 proves that the stumps as well as the dead trees are a part of various dense tree patches comprising the stand here. The large gaps (50-250 m^2) in the main canopy thus are explained to have resulted from the fall of veterans. Also the dead standing trees are shown. Both *spruce* and *fir* are capable of attaining remarkable sizes with *spruce* generally superseding *fir*. The largest *spruce* measured on this plot was 63m in height (dbh 1.53m) and its volume was 37m^3, it is obvious that fall of such a tree can be major event in the development dynamics of such stands.

As was evident, in all other plots the dead wood amount was less and corresponding largely to the gaps in the main canopy hence their figures are not depicted.

4. Discussion

Deadwood is probably the least predictable component of a natural forest ecosystem because it is greatly influenced by stochastic events taking place at infrequent intervals, adding primarily the standing volume to the dead wood component (Bormann and Likens 1979). Franklin et al. (1981) consider coarse woody debris to be major structural feature of northwestern forests of North America. In agreement with these authors, dead wood is a redeeming feature of all the stands irrespective of naturality classes. The amount of dead wood is associated with death or the fall of veterans. Total amount of dead wood (standing and on the forest floor) showed a clear maximum on the pristine-like plot (222m^3/ha = 20% of total volume). In all other stands it was considerably lower with a minimum of 31m^3/ha recorded on the highly disturbed plot 4. The amount of dead wood present varied in inverse ratio to human impact. This was verified on all the plots. For a remnant of pristine forest (near Lahnsattel, Austria) Mayer et al. (after Wessely 1987) put the percentage of dead wood in a natural mixed forest (*spruce-fir-beech*) at between 8% and 10% of the total standing volume. Dead wood of down logs given by Franklin and Warring (1980) for aforementioned natural stands (age 100 to 1000 years) had a range of 60-156 t/ha (i.e., 120-312 m^3/ha assuming 0.5t = 1m^3).

The heavy incidence of dead wood on the forest floor of the pristine-like stand (plot 6), however, does not imply that all undisturbed forests have very large amount of dead wood. Very considerate amount of dead wood on the forest floor is chiefly composed of large dead trees. Standing dead wood of large dimensions was registered on the low disturbed plot 5. Major structural changes in the past (e.g. on plot 6) have their origin in the overstory. This phenomenon is interesting and shows that after attaining a particular aboveground biomass, a dip of the same may be occurring. This is further supported by the fact that the total volume i.e., standing and down logs together, in survey area A was between 900 and 1000 m^3/ha and in survey area B between 1100 and 1200 m^3/ha respectively. This may also be the optimum volume reflecting a structural and developmental stage where a shift of biomass from upper canopy to forest floor takes place as most of the dead wood is of recent origin. Hence quantities of dead wood observed in pristine-like stand indicate a major structural change in the past. The frequency of such events could not be investigated. A stage prior to this could be observed on plot 5, since large amount of dead wood was still standing. In contrast on plot 4, where amount of dead wood was low, maximum volume was measured.

The presence of less dead wood on disturbed plots was not only due to low mortality (as a result of less intensive competition) but also a result of immediate gleaning of smaller down logs. As an example, in the first survey year, standing dead wood volume on plot 1 was 54m^3/ha. Five years later, theoretically, most of this should have been on the stand floor (since it was no longer standing and no decayed rests were lying on the forest floor) but only 22m^3/ha was recorded. This implies that approximately 30m^3/ha had been gleaned. That higher volume of standing dead wood is found on the undisturbed plots speaks for the impact of endogenic processes. Moreover, the reason for the accumulation of substantial dead wood whenever recorded in such disturbed stands is related to the large-size logs not being removable.

Dead wood elements surfaced as the major evidence and affirmation of *naturality classes* as well as indicated developmental dynamics. Mature or decayed stage of dead wood (decay class 3) was frequent in the pristine-like stand as dead wood remains in the forest. In whatever dimension, it is constantly added to the forest floor and since decomposition also remains constant, varied decaying stage are evenly distributed. On the disturbed plots, decay class 3 was found only when large non-removable trees remained on the forest floor.

Structural changes in the less disturbed stands are linked to the treefall, which promotes the process of succession. Such natural processes have been positively used in forest management in the shape of Gap-Cuttings elaborated by Mosandl (1983) in the semi-natural mixed stands in Alps.

There is a clear connection between the big canopy gaps and dead wood on the floor. After attaining the peak a dip in standing biomass occurs. Minor disturbance is related to autogenic processes taking place in a natural forest and succession commences on a very small area. It is also obvious that minor disturbances are synonymous with the endogenic changes mentioned as treefall. The driving force behind the developmental dynamics of these stands is largely of endogenous origin. The endogenous disturbances are linked to structural changes explained by dead wood corresponding to the gaps in the main canopy. These gaps are major sites for both shade-tolerant and intolerant so that an all aged forest develops.

This was authenticated by combining the crown-projection maps with the location of dead wood elements (dead trees, stumps etc.). Bormann and Likens (1979) maintain that changes over time in a forest community (endogenous or exogenous) take many patterns. In addition to the patched arrangement, an array of varying sized gaps is intrinsic to these stands. Whereas on the highly disturbed plots gaps did not wholly correspond with various dead wood elements (stumps etc.), in less disturbed stands the reverse was the case. Overall, larger gaps were found in the disturbed stands. The largest was approximately $450m^2$ in plot 1. Rankle (1989) and Denslow (1987) consider gaps ranging between 100 and $100m^2$ as small disturbances. Froehlich (1954) links gaps in pristine forests to the death of a veteran. While it is immaterial how gaps have occurred, their ecological significance is of immense importance.

Dead wood elements surfaced as the major evidence and affirmation of *naturality classes* as well as development dynamics. Mature or decayed stage of dead wood (decay class 3) was frequent in the pristine-like stand as dead wood remains in the forest. In whatever dimensions, it is constantly added to the forest floor and since decomposition also remains constant, varied decaying stages are evenly disturbed. On the disturbed plots, decay class 3 was found only when large non-removable trees remained on the forest floor.

5. Conclusions and recommendations

The results have shown that the study of deadwood can prove effective in investigating the developmental dynamics of natural forests of *Spruce-fir*. Dead wood amount and its other characteristics (e.g. location) resulting from structural changes have revealed that endogenous processes are driving force for the development. These disturbances though of smaller scale, are linked to structural changes in the main canopy. In combination with crown projection maps dead wood elements verified the contagious distribution of trees. The major conclusions drawn are:

- Dead wood as a parameter is justified to be the indicator for assessing varied human impact.
- Deadwood, irrespective of human impact is a conspicuous feature of *Spruce-fir* forest stands.
- Scars on decay class 1 can help in assessing whether trees have been felled, cut or were natural as treefall.

- Subjective arrangement of forest stands according to *naturality classes* on the basis of set of criteria especially on the basis of dead wood is justified.
- *Spruce-Fir* forests are gradually losing their pristine character and dead wood characteristics essential for promotion of succession can inhibit the developmental dynamics.

In addition, the followings recommendations can be made:

- Disturbance indicators with dead wood characteristics as major parameters must find use in assessing the degree of naturality of forests.
- Along with other main stand parameters (e.g. basal area, density of natural regeneration etc.) dead wood characteristics should be used in describing the developmental dynamics of natural stands.
- A minimum amount of dead wood as a component for the promotion of natural regeneration and biodiversity must be left in such stands to preserve natural characteristics.

6. Zusammenfassung

Totholz als Indikator für die Intensität der menschlichen Einflussnahme in Fichten-Tannenwäldern des temperaten NW-Himalaya

Im Rahmen eines groß angelegten Versuchs im temperaten NW-Himalaya Indiens wurden die Struktur und die Entwicklungsdynamik der dort heimischen Fichten-Tannenwälder untersucht, um Konzepte für eine nachhaltige Bewirtschaftung dieser Wälder zu entwickeln. Ein wichtiges Element in diesen Wäldern, von dem in der vorliegenden Studie berichtet werden soll, ist das am Waldboden liegende Totholz. Es sollte geprüft werden, inwieweit liegendes Totholz als Indikator bei der Beurteilung des menschlichen Einflusses dienen kann und die Einordnung von Waldbeständen in verschiedene (Natürlichkeits-)Klassen in Abhängigkeit von der menschlichen Beeinflussung erleichtern kann.

Grundlage der Untersuchungen bilden 6 Versuchsparzellen in Altbeständen. Drei davon liegen bei Narkanda im indischen Bundesstaat Himachal Pradesch, und drei bei Yusmarg im Bundesstaat Jammu und Kaschmir.

In allen Wäldern im NW-Himalaya finden sich Spuren menschlicher Einflussnahme. Auch in den Untersuchungsbeständen waren diese Spuren in unterschiedlichem Ausmaße vorhanden. Durch die Erfassung von Störungsindikatoren, wie z.B. Hinweise auf Waldweide oder das Fehlen von Totholz infolge einer stark ausgeübten Sammeltätigkeit für Brennholzzwecke, konnten die Intensität der menschlichen Einflussnahme quantifiziert und Natürlichkeitsklassen ausgeschieden werden. Entsprechend den Natürlichkeitsklassen konnte ein Gradient der anthropogenen Einflussnahme aufgestellt werden, d.h. die Altbestände konnten in urwaldartige einerseits und wenig gestörte, mäßig und stark gestörte Parzellen andererseits eingeteilt werden.

Als herausragendes Merkmal zur Klassifizierung dieser Wälder in Natürlichkeitsklassen erwies sich das liegende Totholz. Die Anzahl der am Boden liegenden Baumstämme war auf der urwaldartigen Parzelle am höchsten. Auch wies die urwaldartige Parzelle mit 222m^3/ha den höchsten Totholzvorrat (stehend und am Waldboden) auf. Hohe Totholzmassen sind meist auf besonders dicke abgestorbene Bäume zurückzuführen. Die von Menschen stark geprägten Bestände wiesen hingegen wesentlich geringere Totholzmengen auf. Dennoch blieben auch in diesen Beständen immerhin noch Totholzvorräte von 17 bis 50m^3/ha am Boden liegen, vorwiegend bestehend aus von Menschen nicht transportierbaren großen Stämmen. Das von den Menschen praktizierte Totholzsammeln, führt nicht nur zu geringeren Totholzvorräten, sondern letztlich auch zu einer Reduktion der verjüngungsgünstigen Stellen auf Moderholz. Damit geht ein Verlust an Struktur in den natürlichen Wäldern einher.

Die im Rahmen der vorliegenden Studie entwickelten Natürlichkeitsklassen erlauben es, beliebige Fichten-Tannenwälder in der Untersuchungsregion entsprechend ihrem unterschiedlichen Grad der menschlichen Beeinflussung einzuordnen.

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