# AVALANCHE FREQUENCY ON A SLOPE WITH AND WITHOUT DEFENSE STRUCTURES[1]

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Abstract.--Avalanches in an avalanche starting zone were observed and mapped over a period of 25 years. After the first ten years of observation, temporary support structures were erected on part of the test area. Their influence on avalanche frequency was determined by comparison of the periods before and after installation.

Figure 1: Test area Stillberg (centre) as seen from the opposite slope. (Photograph: J. Rychetnik, March 19, 1981).

## INTRODUCTION

The test area Stillberg (figure 1) is a typical avalanche starting zone near the upper timberline, with an average of 38 avalanches per winter. It covers 10 ha and is situated in the Dischma Valley near Davos, Switzerland, on a NE-facing slope with inclination 38 degrees, between 2000 and 2230 m in elevation. The slope is much broken by ridges and gullies, particulary in the upper part of the area.

This area was selected more than 25 years ago for testing biologically, technically and economically suitable afforestation procedures for use in an ava-

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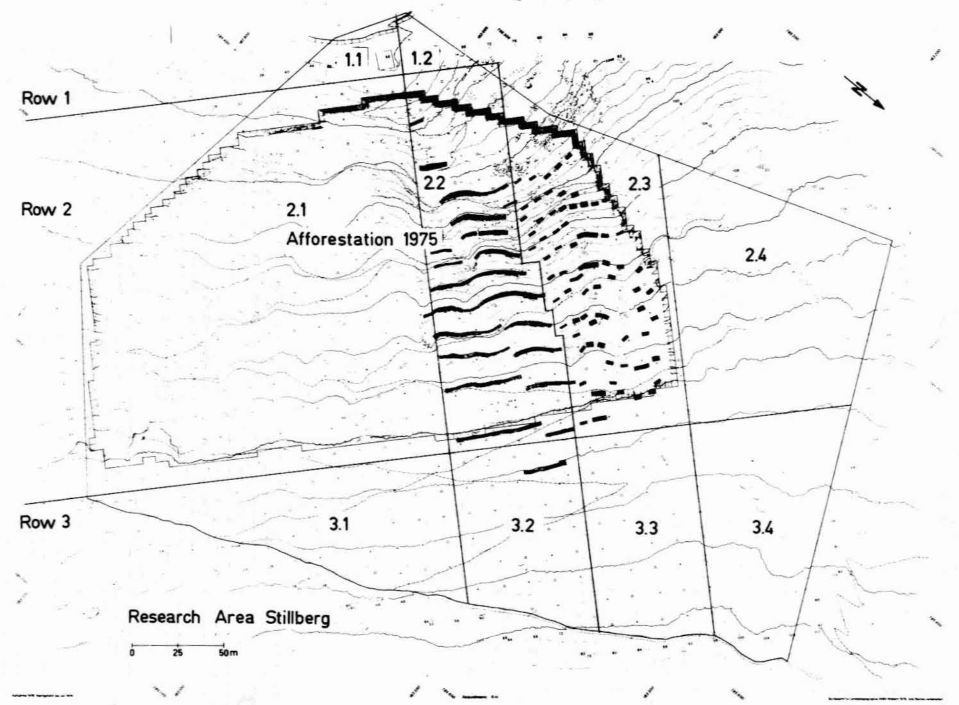


Figure 2: Test area Stillberg; general layout and arrangement and designation of the subareas.

lanche starting zone. The research was carried out as a joint project of the Swiss Federal Institute for Snow and Avalanche Research (SFISAR) and the Swiss Federal Institute of Forestry Research (SFIFR). The SFISAR observed and mapped the avalanches and also measured snow distribution and snow cover extension from 1959 onward.

## METHODS

In the years 1968 - 1975, after the initial phase with climatic measurements and afforestation pre-tests, support structures were erected on part of the test area (in der Gand 1972), and some 4 ha were afforested (see figure 2) with Swiss stone pine (*Pinus cembra* L.), European larch (*Larix decidua* Mill.) and mountain pine (*Pinus mugo* Turra) (Frey 1977). The three species were planted in the same sequence on area units (AU) of 3.5 x 3.5 m with a spacing of 0.7 x 0.7 m and 25 plants of each species. Within the network of forested area units, where the trees were planted with as few gaps as possible, the area unit of 12.25 $m^2$ was the smallest unit of area used in the investigation of the interrelationships between site, vegetation and forest plants, and climatic and other factors. The area unit was also used in the present analysis of avalanche activity.

The following procedure was applied to all avalanches observed and mapped since 1959:

- digitization
- plotting for graphic checking of digitization and data transmission
- projection onto the network of area units (test area Stillberg = 8692 units; see figure 3a)
- YES/NO decision on area units only partly struck by avalanches and corresponding assignment of 1 or 0 to the area units
- representation of each digitized avalanche in a matrix in which each point represents one area unit. 1 indicates that 50 % and more of the area unit was struck by the avalanche, 0 that it was not (figure 3b).

This procedure allowed the determination of avalanche frequency for each area unit for selected avalanches and defined periods.

To determine the influence of the support structures on avalanche activity, the test area Stillberg was divided into 10 subareas (see figure 2). The subareas of the first row (1.1, 1.2), situated on

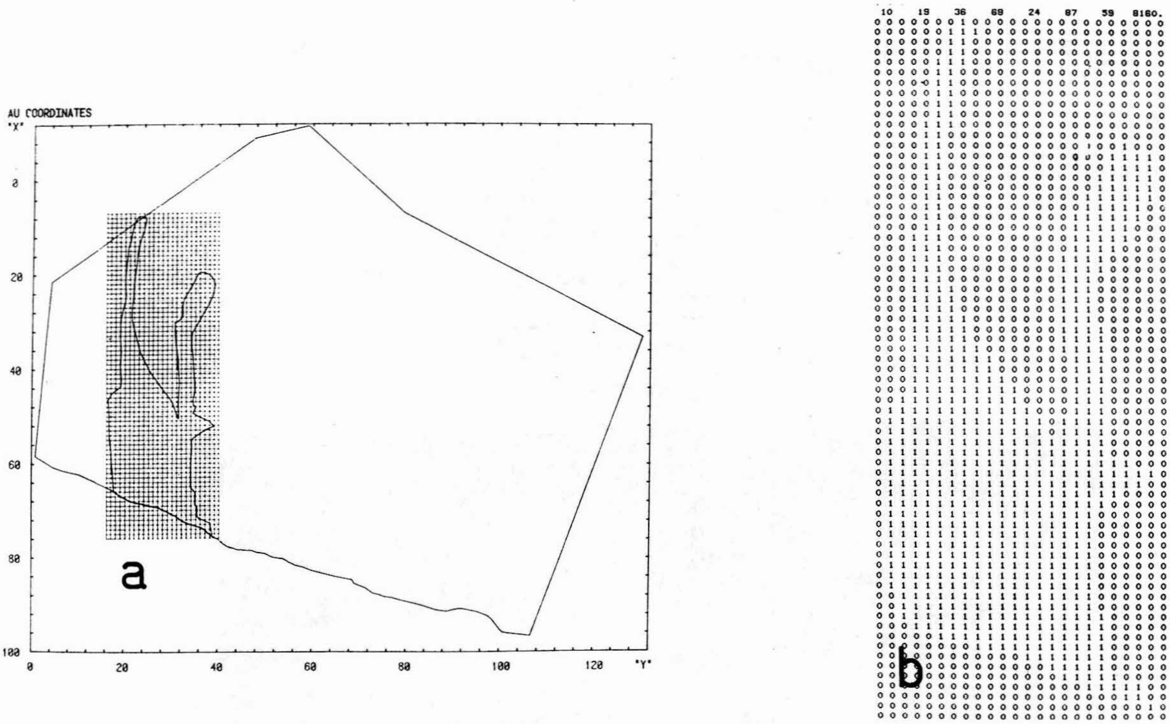


Figure 3: 3a: avalanche no. 10, 4th February 1980, represented on the area unit grid.
3b: matrix for avalanche no. 10

the terrace above the afforested zone, were not included in the following comparisons. Subarea 2.1, in the southern part of the test area remained without avalanche defense structures and their influence on avalanche build up troughout the study period. The same was true for subarea 3.1, although there was the possibility of its being influenced by avalanches spreading from the area with defense structures. Subarea 2.2 had a continuous arrangement of supporting structures, subarea 2.3 a discontinuous one. The sections 3.2 and 3.3, directly below, may have been strongly influenced by the structures. Subareas 2.4 and 3.4 lay in the northern part of the test area, without defense structures.

The study period extended over 25 years and was divided into three parts: period 1 (1959 - 1969) before the erection of the support structures; period 2 (1969 - 1975) during the erection, as the transition phase with annually increasing area with support structures; and period 3 (1975 - 1982) after the completion of installation and reforestation.

## RESULTS

The occurrence of slab avalanches before and after the erection of the support structures (periods 1 and 3) is summarised in figures 4 and 5.

Each symbol represents the avalanche frequency range per area unit during the relevant period. The graduations within the avalanche frequency range were adjusted to the unequal lengths of the observation periods so as to give approximations of frequency over equal periods.

As expected, avalanche frequency increased from the upper to the lower part of the study area and from the ridges to the gullies. Those sites with few or no avalanches were located on the upper terrace and on ridges. The apparent absence of avalanches from the area shown at the right-hand side in figure 4 was due to previous fencing and the cessation of observations outside the fence. That caused a distortion of the data on average avalanche frequency in subareas 2.4 and 3.4. Comparison of the y-coordinate sections 58 - 94 (subareas 2.2 and 2.3 with defense structures, subareas 3.2 and 3.3 below the structures) in figures 4 and 5 reveals a reduction of avalanche frequency in this area.

The average frequency of slab avalanches per area unit in the subareas of the test site Stillberg during the three

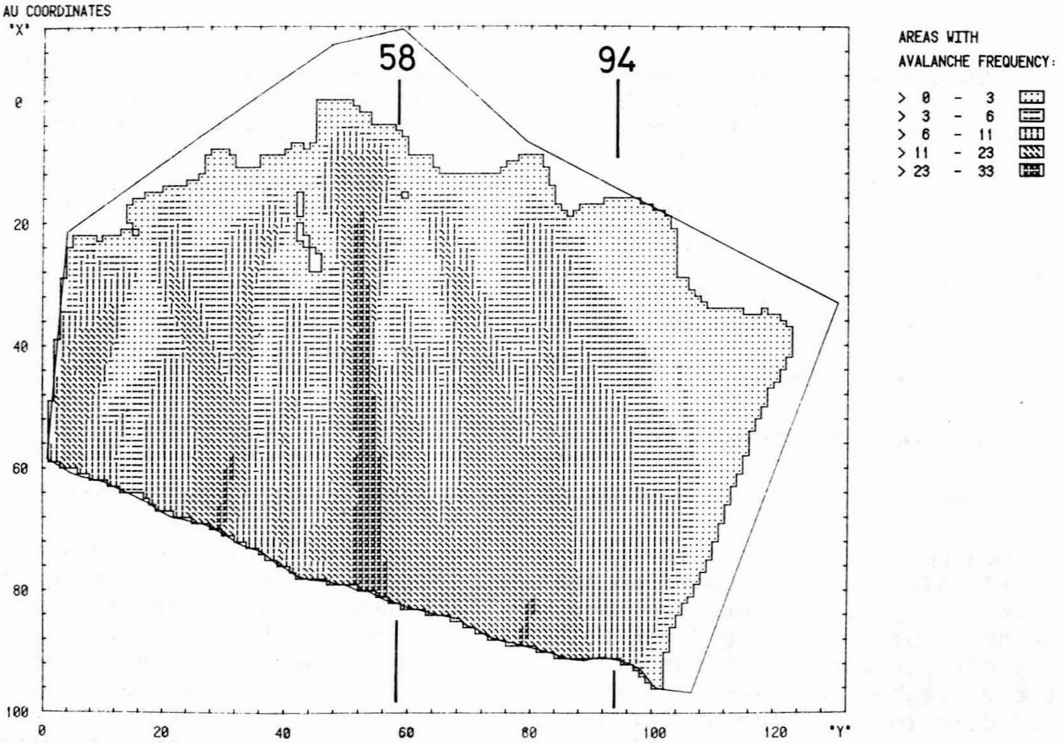


Figure 4: Frequency of slab avalanches in the area units (AU) of the test site Stillberg during the period 1959 - 1969 (in the y-coordinate section 58 - 94, subareas with defense structures and those below the defense structures).

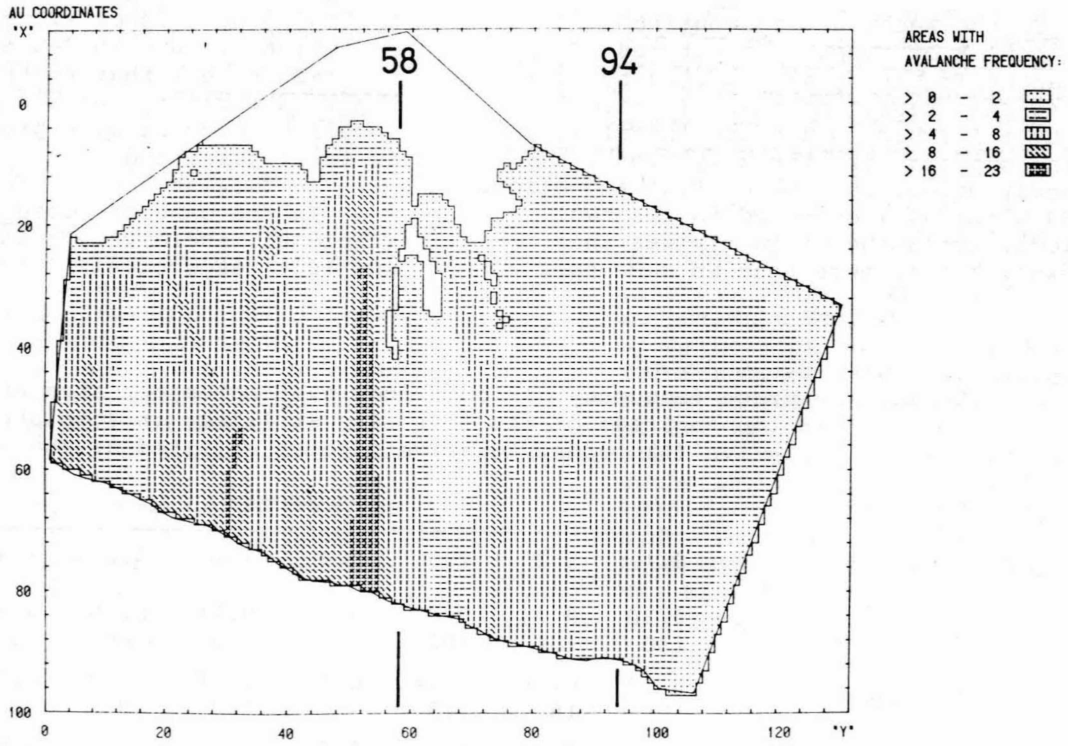


Figure 5: Frequency of slab avalanches in the area units (AU) of the test site Stillberg during the period 1975 - 1982.

Table 1: Average frequency of slab avalanches per area unit (AU) in the subareas of the test site Stillberg in absolute and relative (%) terms. Relative figures adjusted; see text.

| | Periods | Subareas | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2.1 | 2.2 | 2.3 | 2.4 | 3.1 | 3.2 | 3.3 | 3.4 |
| 1 | 1959 - 1969 | 0.79<br>100 | 0.70<br>100 | 0.54<br>100 | 0.16<br>- | 1.49<br>100 | 1.60<br>100 | 1.32<br>100 | 0.34<br>- |
| 2 | 1969 - 1975 | 0.82<br>100 | 0.38<br>52 | 0.44<br>79 | 0.48<br>100 | 1.70<br>110 | 1.02<br>61 | 0.99<br>72 | 0.77<br>100 |
| 3 | 1975 - 1982 | 0.76<br>100 | 0.28<br>42 | 0.43<br>84 | 0.45<br>100 | 1.52<br>106 | 0.71<br>46 | 0.75<br>59 | 0.60<br>84 |

observation periods is shown in table 1. The actual values were adjusted so that the first row (period before erection of defense structures) and the first column (subarea without supporting structures over the 25 years) represent 100 %. This was done to eliminate as far as possible the variation between winters and between the different sectors of terrain. For the reasons mentioned above, the subareas 2.4 and 3.4 in the period 1959 - 1969 were excluded from the consideration of the results.

In the section with continuous arrangement of support structures (2.2), avalanche frequency was reduced by 48 % during the transition phase (period 2) and by a further 10 % after installation of the support structures (period 3). Directly below, in subarea 3.2, reductions of 39 % and 54 % occurred in the two periods. Avalanche frequency was thus somewhat higher here than in the upper section (2.2). In the section with discontinuous arrangement of support structures (2.3), where the arrangement was approximately half as dense as in subarea 2.2, there were reductions of 21 % and 16 % in periods 2 and 3 respectively, and of 28 % and 41 % in the subarea 3.3 directly below. These results illustrate the well-known fact that avalanche defense structures cannot ensure absolute protection (EOFI 1968, Sommerhalder 1981). There is always the possibility of avalanches starting among the structures themselves, flowing between them, and spreading down lower slopes with an inclination of 30 - 50 degrees. Consequently the requirement that the potential starting zone directly below support structures should be covered with protection forest is fully justified.

Reforest the whole slope

In the case of loose snow avalanches (table 2), there were reductions of 3 % and 10 % respectively in the frequency of

- Density a factor
- avalanches not absolutely arrested.

Table 2: Average frequency of loose snow avalanches per area unit (AU) in the subareas of the test site Stillberg in absolute and relative (%) terms. Relative figures adjusted as above.

| | Periods | Subareas | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2.1 | 2.2 | 2.3 | 2.4 | 3.1 | 3.2 | 3.3 | 3.4 |
| 1 | 1959 - 1969 | 0.30<br>100 | 0.31<br>100 | 0.07<br>100 | 0.0<br>- | 0.71<br>100 | 0.75<br>100 | 0.33<br>100 | 0.0<br>- |
| 2 | 1969 - 1975 | 0.33<br>100 | 0.56<br>165 | 0.14<br>183 | 0.02<br>- | 0.88<br>113 | 1.49<br>181 | 0.78<br>215 | 0.08<br>- |
| 3 | 1975 - 1982 | 0.54<br>100 | 0.54<br>97 | 0.17<br>135 | 0.03<br>- | 1.58<br>124 | 1.22<br>90 | 0.98<br>165 | 0.07<br>- |

avalanches in subarea 2.2, with continuous arrangement of supporting structures, and subarea 3.2 directly below, during the period after installation of the support structures. Otherwise the frequency of loose snow avalanches per area unit, increased drastically during the transition phase (period 2) in subareas 2.2 and 2.3 and in subareas 3.2 and 3.3 below them after installation was completed (period 3). Loose snow avalanches started primarily in the dry fresh snow layer after snowfalls or, in spring, on moist snow surfaces as a result of radiation, rain or fresh snow. The starting point was often observed to be a tree or the head of a cliff. Snow falling from such places lead to the development of loose snow avalanches. The presence of the defence structures increased the number of such starting points substantially. In the period 1975 - 1982 the spread of loose snow avalanches from subarea 2.1 to subarea 3.1 (without defense structures and below), and from subarea 2.3 to subarea 3.3) with discontinuous arrangement and below), showed a general increase; the spread of avalanches from subarea 2.2 to subarea 3.2 (with continuous arrangement) and below) decreased. This shows that loose snow avalanches can start even among the defense structures and that their downhill spread is only limited by the braking effect of continuously arranged supporting structures.

## DISCUSSION

Any attempt to determine differences in avalanche frequency before and after the erection of defense structures is subject to the following difficulties:

- each winter is unique in terms of weather, accumulation and disappearance of snow cover, avalanche frequency etc.
- avalanches may also be unique or exhibit return periods longer than the study period
- the various sectors of terrain may be neither uniform nor interdependent; this was the case for the subareas of the test site Stillberg
- defense structures affect not only the development and extent of avalanches but also the deposition, accumulation, and melting of snow cover, i.e., the primary factors in avalanche development.

Some of these drawbacks can be lessened by using sufficiently long observation periods before and after the erection of defense structures. The general rule is: the greater the variability of the phenomenon, the longer the study period must be. In the present investigation, the period after installation was so short (7 years) that these results may be accepted only as trends.

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