NEW DEVELOPMENTS FOR CONTROL OF SNOW AVALANCHES IN THE WESTERN EUROPEAN ALPS[1]

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Abstract.--Reforestation of snow avalanche starting zones is accomplished by stabilizing slopes with man-made snow support structures and planting appropriate conifer seeds or seedlings. Existing over-mature protection forests must be maintained by thinning, seedling establishment, and promotion of the proper species mix. Man-made obstructions or deflection dams often complement snow stabilizing structures and protection forests, especially above climatological timberlines.

INTRODUCTION

Snow avalanches have been a long standing threat to life and property in the European Alps. Many avalanche tracks start in previously forested areas, or areas in which reforestation could be developed through effective seeding practices and preventive avalanche control in starting zones.

This paper reports on the deforestation and reforestation of European snow avalanche tracts, with special attention to methods for initiating new and maintaining existing "protection forest" stands. The information for this report was obtained by the authors who were among the few Americans to join a 1983 workshop study tour entitled "Silviculture of Mountain Forests with Regard to Snow Avalanches and Erosion." Figure 1 shows the study tour route and major stops. This study tour was sponsored by the working parties on "Silvicultural Problems in Mountain Regions" and "Snow and Avalanches," under the direction of the International Union of Forestry Research Organizations (IUFRO). In addition to reforestation, the workshop participants inspected experimental devices which physically obstruct snow glide and control moving avalanches. Figure 1 shows the study tour sites.

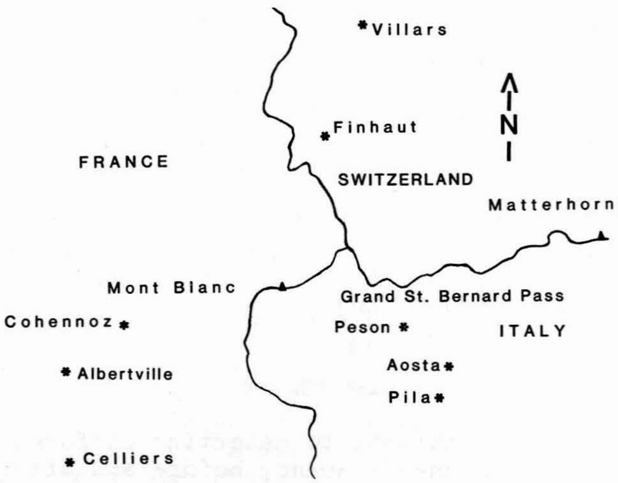

Figure 1.--Study tour sites.

Forest Practice and Avalanche Control in the Alps

Sparse references indicate many denuded European alpine slopes below the climatologically possible timber line were once heavily forested. Frutiger (1972) refers to the year 1834 when devastating water torrents destroyed forests in Switzerland. He attributed this activity to "salt-works, smelters, and overgrazing of mountain pastures." Snow avalanches, which developed on these partially denuded slopes, quickly completed the denudation process. Figure 2 shows a "protection forest" established on grazed slopes at Realp, Switzerland.

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Figure 2.--"Protection Forest" at Realp, Switzerland.

South facing slopes are often less forested than north facing slopes; agricultural demands and dryness have probably accentuated the deforestation processes here. It is not surprising that the pressure to maintain grazing practices has mitigated against reforestation in many areas where private land holdings far exceed those of federal agencies, as in Austria. Because uncontrolled erosion tends to devastate open slopes the federally sponsored reforestation movement has gained support in most alpine lands in spite of the resulting decrease in available grazing. In areas where avalanches threaten important human activity and reforestation is politically unpopular, man-made snow control structures such as snow rakes are used. However, these permanent devices for prevention of snow avalanches in starting zones do little to control erosion.

Since the early part of this century, the subtle expanding influence of tourism has made avalanche control a very high priority in alpine recreational areas where reforestation, according to Ragaz (1975) "is without doubt the safest, most durable and cheapest protective arrangement. In contrast to constructed control devices, it fits harmoniously into the landscape and at the same time performs manifold functions." Since World War II, the development of huge ski areas such as Les Arcs, Villars sur Ollon, and Serfaus, has attracted literally millions of tourists to the Alps for both winter and summer recreational activity. The infusion of recreation money into otherwise economically depressed alpine agricultural communities is a welcome development. It is now necessary to control avalanches so that recreationists, upon whom the economies depend, may travel efficiently and safely through threatening terrain.

Another facet of the growing need for avalanche control along transportation routes is the increasing necessity for workers from the agrarian communities to travel quickly from alpine home to city factory.

As alpine communities have become less dependent upon wood products and consequently less concerned with proper forest management, the governments have been forced to assume the role of forest management. Many high elevation forests which started growing just after 1850 are now over-mature and even-aged. Such forests are very susceptible to damage by wind, snow, and disease. With a depressed lumber market and high transportation costs, necessary thinning and planting of new trees is usually supported by the government.

Maintenance of Existing Protection Forests

The most beneficial silvicultural treatment for forested slopes composed of single species, even-aged trees is to induce a forest of mixed ages and species by harvest and regeneration. This activity however, is hampered by destructive snow processes such as glide and creep, snow fungus diseases, lack of sunlight, and competition from understory forbs.

Establishment of New Protection Forests

Many active avalanche starting zones and upper tracks can be stabilized by man-made structures, thus preventing creep and glide and initiation of avalanches in starting zones. Snow rakes, bridges, and diversion or arresting dams, are among such devices. These structures are expensive, unsightly, and require extensive maintenance. The control that they provide, however, is the first line of attack for establishing tree regeneration. Figure 3 shows avalanche defense structures and initial reforestation at Andermatt, Switzerland in 1967. Figure 4 shows the same site in 1983. If avalanche defense structures are used below the climatological timber line, they are usually constructed of wood. When a protection forest has matured enough to control avalanches, the man-made structures can be left to biodegrade in place.

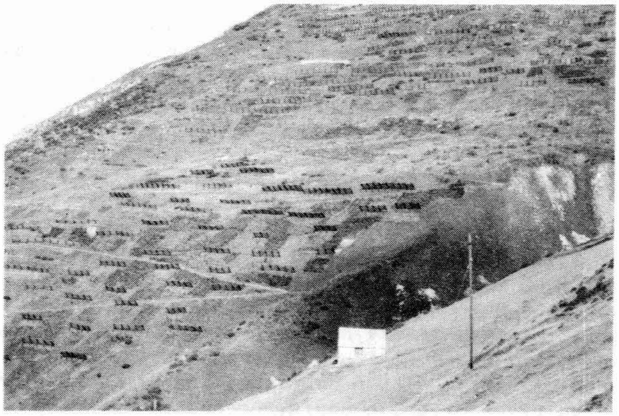

Figure 3.--Avalanche defense structures and initial reforestation at Andermatt, Switzerland in 1967.

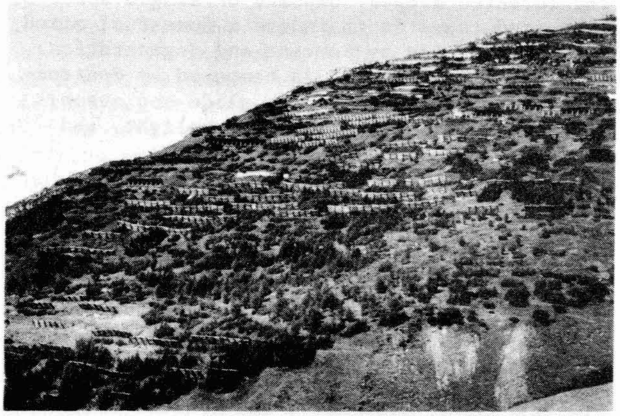

Figure 4.--Avalanche defense structures and reforestation at Andermatt, Switzerland in 1983.

In establishment of tree seedlings, the most successful practice has been to "imitate nature" by planting trees in multi-aged and multi-sized clumps rather than in grid patterns. Seedlings should be chosen from stock that is acclimatized to the local alpine environment.

EXAMPLES OF FOREST PRACTICE AND AVALANCHE CONTROL IN THE MT. BLANC AREA

Maritime Climate Environment

French Savoie Alps near Albertville, France

Cohennoz is an area with two or more meters of snow accumulation and 4 to 7 months of snow cover. The moist maritime summers support lush vegetation.

The forests near Cohennoz have been protected from overcutting by forestry laws originating about 150 years ago. With 80 or more years growth, these even-aged Norway spruce (Picea abies) and white fir (Abies alba) forests are decadent and subject to damage by disease, snow, and wind. Forestry management by thinning and selective removal is increasing production from less than 1 m^3 per hectare to 4.5 m^3 (after first 15 years of management) and to 6 m^3 after 30 years of management.

The main management problem is tree regeneration in this aging forest where extensive shade is prevalent, and there is competition from understory herbaceous vegetation, snow damage, and a cold climate. Opening the forest canopy to allow sunlight penetration makes the slope susceptible to avalanching. Mechanical scarification and seed or seedling planting has not been effective. The managers are currently experimenting with both seed plantations and transplanting 20 cm height natural seedlings from a nearby lower altitude forest. They are creating small linear openings in which to plant trees. These linear openings must run across rather than down the slope, otherwise they could become avalanche starting zones. Planting in appropriate microsites may be crucial to seedling survival. Successful plantations often develop and spread from initial ridge top sites rather than from troughs susceptible to intense snow glide.

The village of Celliers receives over 1500 mm of annual precipitation, much of it as heavy wet snow with accumulation up to 4 meters. Here the Erosion Control Division of the French Forest Service has worked for 30 years to stabilize avalanches on a 60-100% south slope above a year round access road. The goal is to eliminate avalanches by using control structures and reforestation in the 1800-1900 m elevation starting zone. Reforestation up to timber-line may eliminate expensive maintenance of control structures. In addition to snow rakes in the starting zone, the project involves 2500 m of terraces and 4000 transplants of Norway spruce and stone pine (Pinus Montana) per hectare at a cost of about $10,000 per hectare. After 30 years, the protection forest (figure 5) is only minimally established and cannot be relied on. This project (including maintenance) cost 15 million Fr Fr (about 2 million dollars) from 1950-1981.

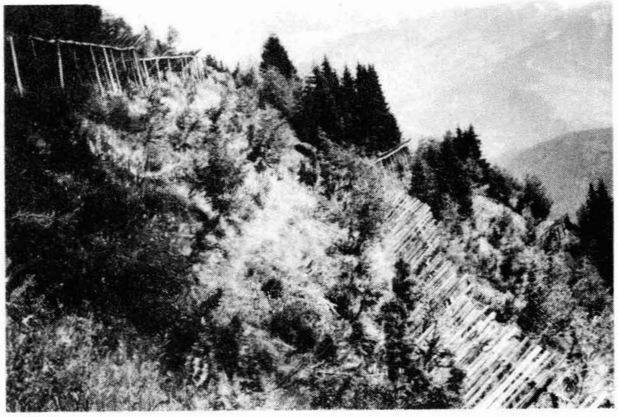

Figure 5.--Protection forest establishment at Celliers, France.

The proposed solution for establishment of a successful protection forest involves "copying nature" by transplanting uneven aged and sized trees into 10-tree clumps on appropriate microsites. Criteria for the best microsites are not known. Another technique is to prune spruce (figure 6) to grow as a dense, large diameter tree to resist snow creep. Nitrate fertilization accelerates tree growth, but also stimulates competing shrubs.

Figure 6.--Spruce seedling with top leader removed to promote large diameter bushy growth form, Celliers, France.

Villars, Switzerland

Villars receives up to 4 m of snow annually. Above this newly established resort village relatively low elevation avalanche starting zones occupy pasture lands surrounded by moderately thick forests. These snow creep and glide starting zones are stabilized by snow rakes designed by H. In der Gand of the Swiss Federal Institute for Snow and Avalanche Research (figure 7). In this moist climate, snow rake pole diameter must be small enough, i.e., 14 cm or less, to dry out and resist summer rotting. A properly built snow rake may thus last 50 years. Seedlings are being established in conjunction with these snow rakes. A major difficulty is browsing on new seedlings by chamois and deer.

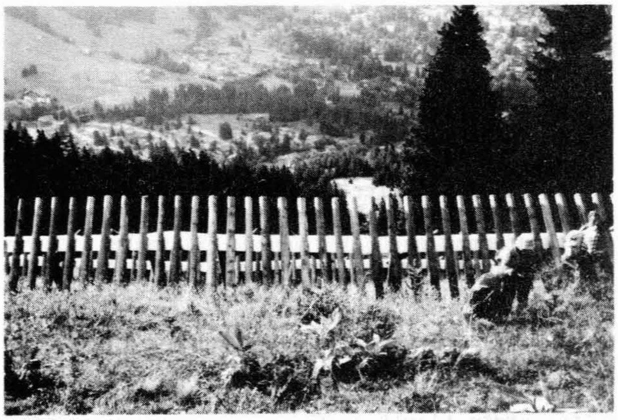

Figure 7.--Snow rake at Villars, Switzerland.

Continental Climate Environment

Aosta, Italy

The valley of Aosta, in northwestern Italy, has a Continental climate; spring snowfall is greater than winter snowfall, and the growing season is drier and colder than that of the previous study locations. Over the past several hundred years the largest and best trees have been regularly harvested. During the past 20 years, management has adopted silvicultural thinning practices to assure a species and age mix for optimum production and protection.

The Peson avalanche runs into the Torrento Artavanez above the highway to Grand St. Bernard Pass, a major international route. Avalanches here have often blocked the highway and destroyed communication and hydropower installations. This avalanche path is controlled by a series of earthen dams which can retard or catch up to 6 million m^3 of snow from a 40 ha starting zone.

Rock and compacted earth dams were constructed in the 1960's and '70's to block snow movement in the detachment zone. After dam construction, the below timber-line slopes (1800-2200 m elevation) were terraced (200 m/ha) and container seedlings of Austrian stone pine (*Pinus cembra*) were planted. The terraces need continual repair and many seedlings must be replaced due to damage by deer and horses. Regeneration is relatively easy because of minimal shrub competition in this relatively dry continental climate. Forest management practice after a catastrophic event (avalanche, fire, grazing) calls for reinitiating tree growth with European larch (*Larix europea*), which is a natural colonizer of disturbed sites. As the forest matures, spruce becomes dominant. To avoid a single species, forest managers induce larch regeneration in the spruce forest. Larch has deeper roots and is more resistant to snow and soil creep and rolling rocks.

Pila is a large alpine ski area above Aosta. The Pila Forest is typical of medium-high elevation mature spruce and pine forests. It was harvested by clear-cutting about 200 years ago. Today there is little incentive to harvest or manage this forest, which has been growing without management for about 150 years. There is little local demand for timber harvest in this location; buildings are constructed primarily of stone and transportation costs are high. Because the local economy does not need or use the forests, except for avalanche protection, the Forest Service now must manage these high elevation protection forests. Many trees were damaged by snowload in 1980. The management prescription is to remove the dead wood and thin the live trees to convert a decadent forest susceptible to snow and wind injury to a mature mixed-species, uneven-aged forest. The forest managers thin the stand every 10 years by removing 10% of the timber. This promotes a mix of species and age. Since thinning forest productivity has increased from 114 to 142 m^3/ha/yr. Opening the stand also allows the remaining trees to strengthen and become more resistant to snow damage.

Finhaut, Switzerland

Since World War II, the Canton of Valais has converted from a mountain agriculture to a tourist based economy. Today less than 10% of the population practices agriculture and one-third of the population lives on tourism. With less farming, alpine and subalpine pastures are reverting to forest. With average forest productivity only 1 m^3/ha/yr, timber income cannot finance proper silvicultural practices. The people continue to debate who should finance management of avalanche protection forests.

Above the village of Finhaut, tree removal by logging and grazing induced avalanching which then spread via a succession of ever-expanding avalanche tracts. Avalanche size and destruction increased from the 1700's to the mid-Twentieth Century. The avalanche control priority was to first reestablish the forest with larch and then construct avalanche deflection devices. Larch successfully grows in some avalanche tracts. Currently 60 of a proposed 300 deflection dams, or "diques", have been constructed. Some lower slopes are terraced to better accept container plants which may grow from seed collected on the site. The terrace berms reduce erosion and provide warmer soil for seedling growth. These silviculturally managed forests will eventually provide better avalanche protection than virgin forests. The diques don't necessarily stop the avalanches. Rather than being perpendicular to the slope they are angled to slow and deflect the avalanche to a less active, safer slope. The diques are financed 50% by state, 30% by canton, and 20% by local funds. The largest structure here can stop or deflect up to 6 million cubic meters of snow. Figure 8 shows a large dique at the base of a cirque above Finhaut. Figure 9 shows a dique above Finhaut which deflects avalanches into a non-destructive path.

Figure 8.--Dique in cirque above Finhaut, Switzerland.

Figure 9.--Deflection dique above Finhaut, Switzerland.

CONCLUSION

In the European Alps, reforestation of snow avalanche paths reduces avalanche danger and erosion hazard. Reforestation is often initiated through terracing and/or planting after a slope is first protected by snow rakes or other deflection devices. Many existing avalanche protection forests are decadent and subject to catastrophic damage from snow, wind, and disease. Successful silvicultural management practices of thinning and regeneration must be applied to insure maintenance of these protection forests.

Success in establishment and maintenance of snow avalanche protection forests is often contingent on "copying nature's way" with practices such as clumping seedlings, seeking appropriate microsites, and promoting mixed-species, uneven-aged forests.

It may be appropriate to use the European experiments in silviculture to develop protective forestry in American avalanche starting zones. Although most Rocky Mountain avalanche starting zones are either above timberline or situated in a severe climate where trees will not grow, reforestation in less hostile sites should be on the forefront of avalanche reduction technology, particularly in maritime climates. In the drier Rocky Mountains, northeast facing, below-timberline, wind-loaded slopes may be good locations for protection forest silviculture. If areas beneath such avalanche runs are presently unoccupied by recreational facilities, the time will come when many of them will ultimately be developed. It is timely to commence experimental reforestation now because of the long growing intervals necessary to bring about effective forest stands.

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