Agriculture, Ecosystems and Environment, 22/23 (1988) 351-362
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

19. The Design and Use of Living Snow Fences in North America

DALE L. SHAW

Colorado State Forest Service, Colorado State University, Fort Collins, CO 80523 (U.S.A.)

ABSTRACT

Shaw, D., 1988. The design and use of living snow fences in North America. *Agric. Ecosystems Environ.*, 22/23: 351-362.

Living snow fences are rows of trees and shrubs planted to control snow along land transportation routes, and which have the potential to (1) provide snow control, (2) enhance wildlife habitat, (3) provide winter livestock protection, (4) furnish environmental beautification and (5) offer long-term economic benefits. Disadvantages include the difficulty of establishment on some sites, the length of time to reach serviceable height, the high initial cost as compared to some structures, the degree of maintenance during the establishment period and the amount of land required.

Primary features of living snow fence location and design include (1) distance from road, (2) length, (3) species, (4) number of rows, (5) spacing and (6) wildlife components. Each of these is discussed at length.

Maintenance, which is the effort required to obtain satisfactory survival and growth, can present a number of problems in arid regions with limited precipitation. In such areas, issues which must be dealt with include irrigation, weed control, and protection from grazing livestock, big game animals, rodents, hot, dry winds and grasshopper damage. Solutions to these problems are discussed.

DEFINITION

Living snow fences are rows of trees and shrubs planted to keep snow drifts off land transportation routes and to provide other benefits.

HISTORY

The first major attempts in the United States at using tree barriers to control snow along land transportation routes were initiated by railroad companies. Finney (1934) reviewed tree planting efforts by railroads and reported that in 1905 the Great Northern Railway Company planted trees for snowdrift control in North Dakota. By 1909, over 96 000 trees and shrubs were planted with

0167-8809/88/$03.50

survival of rates greater than 80%. Worthington (personal communication, 1986) reported that many of these plantings survived and still provide protection.

In 1914 the Minneapolis, St. Paul and Saulte Ste. Marie Railway Company began experimenting with tree plantings in North Dakota and Montana. By 1916, the Canadian Pacific Railway Company was in the tree-planting business. Efforts were successful and by 1934 a considerable mileage of living snow fence was in operation.

In 1927 the Wyoming State Highway Department initiated a living snow fence program (Walter, 1984). Drought during the 1930s caused high mortality and the effort was discontinued. Other states, including Michigan and Pennsylvania, initiated living snow fence plantings in the late 1920s and early 1930s.

ADVANTAGES

Living snow fences offer a long service life and high storage capacity plus other benefits (Fig. 1). The effective service life of living snow fences under arid climatic conditions has been conservatively estimated at 50 years (Nickerson, 1982). This can be compared with the Wyoming structural barrier design with an estimated life of 25 years and the Canadian structural fence or slat fence with an estimated life of 5–7 years (Perko, 1984). Long service life is a critical element in keeping barrier costs at a minimum (Fig. 2).

A critical consideration in barrier efficiency is height. In general, when barrier height is doubled, snow storage capacity increases four times, when other factors remain equal. An indication that living snow fences have greater storage potential than most structures is the height reached by conifers commonly

Fig. 1. Living snow fences are designed to keep snow drifts off roads and to provide other benefits.

Fig. 2. This remnant of an early Wyoming living snow fence still provides highway snow control.

used in snow barriers. In Colorado, 20-year site capability studies showed average heights of 6 m for Rocky Mountain juniper (*Juniperus scopulorum* Sarg.), 6.25 m for eastern redcedar (*Juniperus virginiana* L.) and 7 m for ponderosa pine (*Pinus ponderosa* Dougl.) (Olmsted, 1985). These studies were for varying land classifications and for sites under irrigation.

In contrast, the tallest structural barrier commonly used, the Wyoming structural barrier, is only $\leqslant 3.75$ m in height. Lower barriers such as the Canadian structural fence at 1.2 m high quickly reach capacity in many storms. When winds continue to blow following such storms, drifting continues and the road may require a number of plowings. With taller trees and shrubs, capacity is rarely reached and the barrier continues to capture and store snow, thus helping to eliminate continued and costly snow removal.

Living snow fences offer the potential to purchase many other benefits with the same money. These benefits include enhanced wildlife habitat, winter livestock protection, spring calving areas, environmental beautification and long-term economic savings.

DISADVANTAGES

Possible negative aspects of living snow fences are relative, and are usually discussed in comparison with structural snow barriers. These are (1) structures can be erected almost anywhere, while living snow fences are difficult to establish on rocky sites with thin soils, (2) structures can be erected in a short period of time while living barriers take time to reach effective heights, (3) initial establishment and maintenance costs of living snow fences may be higher than for some structures, (4) highway department personnel may not be accustomed to dealing with living plant materials and (5) plantings require permanently dedicated land use (Nickerson, 1982).

TABLE I

A comparison of estimated installation and maintenance costs for snow fences

State	Cost ((U.S. $) km^{-1} $year^{-1}$ row^{-1})			Source
	Wyoming structural barrier design	Canadian structural fence[1,2]	Living snow fence[3]	
Wyoming	3075	—	292[4]	Perko, personal communication, 1986
South Dakota	—	204	22	Erickson, personal communication, 1986
Nebraska	—	780	89	Nickerson, 1982
Colorado	—	1004	240[4]	Zebroski, personal communication, 1985
Minnesota	—	2310	23–42	Shelito, personal communication, 1986

[1]Variations in costs primarily reflect differences in labor costs.
[2]Expected life of Canadian structural fence is 5–7 years.
[3]Expected life of living snow fence is 50 years.
[4]Higher costs reflect more intensive establishment technique in semiarid areas. These might include drip irrigation and plastic, gravel or other mulches.

ECONOMICS

Some data are available on the costs of establishing living snow fences and on erecting and maintaining structural barriers. These are summarized in Table I. However, this is only one aspect of the economics concerning snowdrift control on land transportation routes. Of equal or greater importance are data on long-term costs of snowdrift removal and driving hazards with and without barriers. In other words, over a given period of time, to what degree were snowdrift removal, auto damage and human injury costs decreased with barriers? Although highly important, data are lacking or at best highly limited on these aspects of barrier economics.

CHARACTERISTICS OF INDUCED DRIFTS

Research directly related to living fences for snow control along land transportation routes is limited (Loucks, 1983) (Fig. 3). For example, a critical factor in determining proper living snow fence location in relation to distance from a road is length of drift cast at barrier capacity or equilibrium. However, as pointed out by Sturges (1984), studies discussing snow storage by shelterbelt-type plantings all had the same deficiency: barriers studied were not at equilibrium. Consequently, this discussion of induced drifts is based primarily on research involving structural barriers.

Fig. 3. Research directly related to living snow fences, such as the outdoor modeling shown above, is very limited.

For barriers of a given height, drift length downwind is considerably shorter behind solid fences as compared to more open ones. In research which tested downwind drift length from barriers of varying densities, those with porosities of 50–60% were the most efficient in catching and storing blowing snow (Finney, 1934; Pugh and Price, 1954; Caborn, 1960; Price, 1961; Sturges, 1984).

In studies conducted outdoors in Wyoming, drift lengths behind model shrub barriers with porosities of 8, 15, and 23% averaged nine times barrier height (h). Average deposition downwind with a 36-% porous shrub barrier was $12h$ (Peterson and Schmidt, 1984). Drifts downwind from a structural fence with 50% porosity ranged from 25 to 30 h (Sturges, 1984). The same author reports that a bottom gap of 10–15% of h enhances performance by displacing drifts downwind and thus increases drift length and stored volume when compared with barriers lacking such a gap. Without the bottom gap, upwind drifts may build to as much as 10 h, thus creating a streamlining effect which reduces snow catching and storage capacity (Jairell and Tabler, 1985).

Price (1961) reports that structural fences may be inclined with the wind to 30° without disadvantage. Larger angles reduce snow-collecting capacity. Design for the Wyoming structural barrier calls for an inclination of 15°.

Snow-trapping efficiency near the end of a snow fence can be considerably less than at other portions of the barrier. This is due to generation of turbulent eddies at the snow fence boundary, an acceleration of converging air flow at the ends of the snow fence and the response of air flow to lateral pressure gradients developing behind the barrier (Tabler, 1973). This results in rounding of drifts and loss of storage capacity at the ends of the snow fence (Fig. 4). This rounding, or end effect, may extend inward as much as 12 h (Tabler, 1980). Thus, barriers should extend well beyond the areas to be protected. In

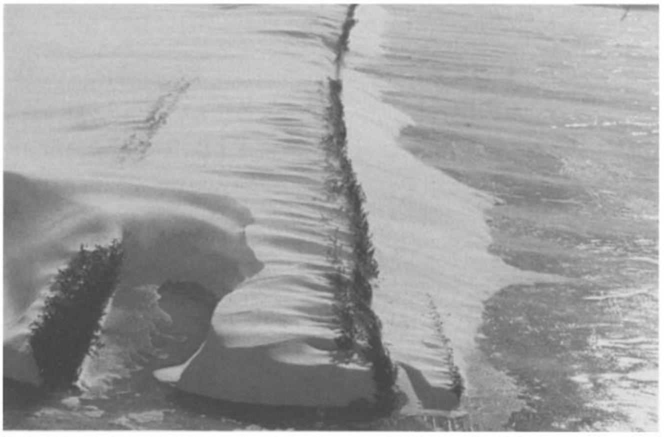

Fig. 4. Snow trapping efficiency at a snow fence's end can be considerably less than at other portions of the barrier.

minimum barrier length should be at least 30 times the height of the barrier (Tabler, 1973).

LOCATION

The function of a snow barrier is to modify wind flow and cause airborne snow to be deposited in drifts, thereby depriving the wind of its snow load so that snow is not deposited where it is not wanted (Price, 1961). Location of the living snow fence in relation to distance from the road is critical in that the deposition of snow must terminate short of the roadway (Fig. 5). Extent of

Fig. 5. Barriers placed too close to the road can result in huge drifts being deposited on the road.

drift deposition downwind is the important consideration when deciding how far the leeward row should be from the road.

At least three important factors influence the volume of snow reaching a barrier. These include (1) the kind and height of ground cover to windward, (2) the direction of land slope to windward and (3) the distance snow is transported before reaching the barrier (the fetch distance) (Shaw, 1985).

In general, the taller and denser the ground cover is to windward, the less is the leeside drifting. Also, there is less drifting with land sloping down toward the barrier than with land sloping upward. Long, open and level fetch distances cause significant amounts of snow to be transported before reaching the barrier.

Another factor influencing the minimum distance a barrier can safely be placed from the road is the anticipated duration and intensity of winter storms. This is directly related to barrier capacity at equilibrium. If the area's storm history indicates that the barrier will probably never reach capacity, then distance from the road can be considerably less than in areas with a history of prolonged and severe blizzards.

The number of rows and species planted also help determine fence to road distance. For example, if a number of dense conifer rows are placed 15 m or so apart, the leeward row may be closer to the road than if only one or two rows of hardwoods are used.

SPECIES SELECTION

Factors important in species selection include (1) planting objectives, (2) local weather history, (3) species longevity, (4) soil type and fertility and (5) resistance to snow breakage.

The primary species, or 'backbone' of the planting, should have sufficient height and density to catch and store anticipated amounts of blowing snow. For the Great Plains of the U.S.A., preferred species are Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) and/or eastern redcedar (*Juniperus virginiana* L.). Where wildlife habitat enhancement, beautification, or other objectives are important, species such as American plum (*Prunus americana* Marsh.), smooth sumac (*Rhus glabra* L.), Russian olive (*Elaeagnus angustifolia* L.) or other locally adapted trees and shrubs may be used. Expected life span, especially in the backbone species, is important to barrier efficiency and long-term costs. Species which deteriorate quickly lose snow storage capacity and involve costly replacement.

Relevant weather history includes amount and seasonal distribution of precipitation, maximum and minimum temperatures and their duration, and winter storm frequency, intensity and duration. These factors influence the species that will survive and grow satisfactorily, the required barrier height and density and the degree of maintenance needed.

NUMBER OF ROWS

Economics, available planting space and planting objectives frequently dictate the number of rows. Also of major importance is the amount of blowing snow which must be stored. In areas where moderate amounts of blowing snow occur or where fetch distances are short, one row of tall, dense evergreens or one or two rows of shrubs may suffice. However, in areas such as the Great Plains where considerable snow storage capacity is required, multiple rows of conifers plus at least one shrub row are usually needed.

Objectives other than snow control can influence the number of rows needed. Where creation of wildlife habitat is important, greater planting width is desired and can be accomplished by adding rows or clumps of species beneficial to local wildlife. Studies have shown that in the northern Great Plains of the U.S.A., wide plantings are more useful to wildlife such as pheasants (*Phasianus colchicus* L.) than are narrow plantings (Capel, 1988).

Upwind terrain and vegetative conditions can be factors in determining the number of rows needed in a living snow fence since they influence the amount of windborne snow reaching the barrier. Where natural terrain features upwind limit fetch distance, fewer rows may be required. For example, terrain sloping downward toward a barrier may require less snow storage capacity. In addition, fewer rows may be required where considerable upwind vegetation exists.

From the snow storage standpoint, wide fences consisting of many rows are desirable in areas of heavy drifting events. In Japan, for example, very wide living snow fences known as 'snow forests' are established (R. Tabler, personal communication, 1984). Because of great width, downwind portions of these plantings can be placed immediately adjacent to highways. In a Russian study

Fig. 6. In wide plantings, most of the trapped snow is in the outside or windward rows.

cited by Bates and Stoeckeler (1941), it was found that in many types of wide plantings, practically all snow lodged within 20 to 24 m of the windward shrub row (Fig. 6).

SPACING

Primary factors that determine spacing in and between rows are planting objectives, available space, species used, available soil moisture and types of maintenance equipment (Shaw, 1980). It should be recognized that rows placed close to the outside or trip row may be nonfunctional from the standpoint of trapping drifting snow because these secondary rows may soon be covered by the windward row drift (Fig. 7). In other words, two outside rows placed close together may in effect serve as only one barrier.

Adequate spacing is critical between rows intended for winter wildlife food and cover. It is important to note that this includes the windward shrub row. When spacing is too close, trees and/or shrubs planted for wildlife can be covered by drifts and thus rendered useless when most needed (Hintz, 1984).

Where adequate space is available, spacing between rows in living snow fences should be extended to provide sufficient snow storage capacity. This is especially true in twin-row high-density plantings where spacing between twin sets may be as much as 30 m. Twin-row high-density windbreaks consist of a series of sets of two closely spaced rows with a gap between each set. High density refers to close spacing of rows within each set. Advantages claimed for the twin-row design include (1) relatively little space is used, (2) crown closure comes early, (3) access is allowed to individual trees at maturity and (4) replacement and/or renovation is easier than with traditional windbreak designs

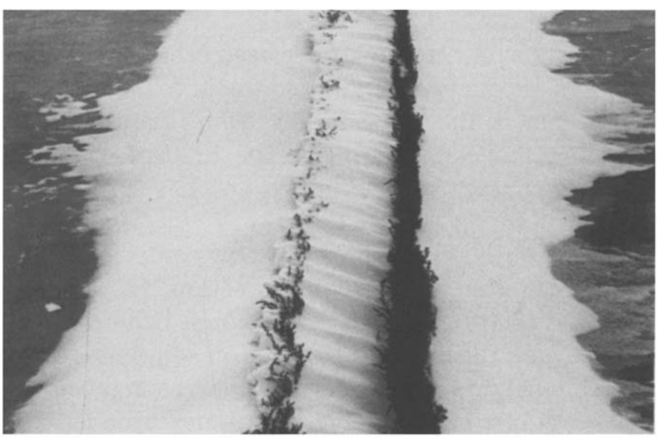

Fig. 7. Where row spacing is close, trees and shrubs planted next to the windward row will be rendered non-functional in many storms.

(Helwig et al., 1983). It should be noted that two closely spaced rows may not store any more snow than a single row. Spacing between twin sets may be as little as 7 m or as much as 30 m. In fields where large equipment is used for farming, wide spacing between sets is essential. As indicated above, such spacing offers potential for expansion of additional snow storage capability.

WILDLIFE COMPONENTS

A significant characteristic of living snow fences is their potential to enhance wildlife habitat. Wildlife habitat, where desired, can easily be made part of the living snow fence design.

Wildlife components should not be viewed as 'extras' but as practical and useful parts of the barrier. Components, such as shrubs useful to wildlife, can be an important part of the barrier's snow storage capability. Auxiliary components such as tall wheatgrass (*Agropyron elongatum* L.), alfalfa (*Medicago sativa* L.), or grain sorghum (*Sorghum* sp.) serve to catch and store snow. Addition of such cover crops (1) encourages more complete site preparation, (2) provides wind and shade protection for seedlings, (3) catches and holds snow to help increase soil moisture and (4) aids in weed control (Shaw, 1985).

A concern sometimes expressed is that development of wildlife habitat in conjunction with living snow fences will attract wild creatures to the extent that road kill is increased and additional driving hazards created. A study by Roach and Kirkpatrick (1985) revealed that incidence of road kill was not influenced by roadside plantings. For additional information and discussion of wildlife and windbreaks see Capel (1988) and Johnson and Beck (1988).

SUMMARY

Living snow fences, although not a new concept, have been used on a limited scale. In the U.S.A., beginning in 1905 and extending to the mid-1930s, living fences were planted along railroads in the Great Plains. Some state highway departments planted living snow fences beginning in the 1920s. In 1975 in Nebraska, the living snow fence concept was rekindled and has spread to a number of neighboring states.

Living snow fences have the potential to (1) provide snow control, (2) enhance wildlife habitat, (3) furnish winter livestock protection, (4) provide environmental beautification and (5) offer long-term economic benefits. Possible disadvantages are that they are difficult to establish on some sites, they require time to reach serviceable heights, the initial cost may be higher than for some structures, they may require considerable initial maintenance and they may use more space than structures.

Research directly related to living snow fences is limited. Many decisions on location and design of living snow barriers must be based on a combination of experience with traditional farmstead and field windbreaks plus knowledge gained from structural snow fence research. The latter provides valuable insights into characteristics of induced drifts cast by snow barriers.

Primary considerations of living snow fence location and design include (1) distance from the road, (2) effective length, (3) tree and shrub species selection, (4) number of rows, (5) spacing in and between rows and (6) potential wildlife components.

REFERENCES

Bates, C. and Stoeckeler, J., 1941. Snowdrift control on highways by planting trees and shrubs. Lake States Forest Experiment Station, U.S.D.A. Forest Service, University Farm, St. Paul, MN, 16 pp.

Caborn, J., 1960. The dependence of the shelter effect of shelterbelts on their structure. In: Proc. 5th World Forestry Congress, 29 August-10 September 1960, Seattle, WA, pp. 1662-1664.

Capel, S.W., 1988. Design of windbreaks for wildlife in the Great Plains of North America. Agric. Ecosystems Environ., 22/23: 337-347.

Finney, E., 1934. Snow control on the highways. Bull. No. 57, Michigan Engineering Experiment Station, Michigan State College, East Lansing, MI, 62 pp.

Helwig, L., Baer, N. and Dronen, S., 1983. A new plan for shelterbelts/windbreaks: TR-HD (Twin Row-High Density). Cooperative Extension Service Publ. FS 813. South Dakota State University, Brookings, SD, 4 pp.

Hintz, D., 1984. Enhancing the wildlife values associated with windbreaks. U.S.D.A. Soil Conservation Service Tech. Note 190-LI-4, 10 pp.

Jairell, R. and Tabler, R., 1985. Model studies of snowdrifts formed by livestock shelters and pond embankments. In: Proc. Western Snow Conference, 16-18 April 1985, pp. 167-170.

Johnson, R.J. and Beck, M.M., 1988. Influences of shelterbelts on wildlife management and biology. Agric. Ecosystems Environ., 22/23: 301-335.

Loucks, W., 1983. Windbreak bibliography. Great Plains Agricultural Council Publ. No. 113, 111 pp.

Nickerson, D., 1982. Living snow fence. In: Proc. Great Plains Agricultural Council Forestry Committee Meeting, 22-24 June 1982, Dodge City, KS. GPAC Publ. No. 106, pp. 169-175.

Olmsted, E., 1985. Windbreak suitability groups. SCS Technical Guide No. 226. U.S.D.A.-Soil Conservation Service, Denver, CO, 37 pp.

Perko, D., 1984. To catch the snow. Wyoming Wildlife. 9-1. Wyoming Game and Fish Department, Cheyenne, WY, pp. 26-31.

Peterson, T. and Schmidt, R., 1984. Outdoor scale modeling of shrub barriers in drifting snow. Agric. For. Meteorol., 31: 167-181.

Price, W., 1961. The effects of the characteristics of snow fences on the quantity and shape of deposited snow. Union Géodésique Internationale. Association Internationale d'Hydrologie Scientifique. Assemblée Générale de Helsinki, 25-7-6-8 1960. Commission des Neiges et Glaces, pp. 89-98. (Publ. No. 54 de l'Association Internationale d'Hydrologie Scientifique).

Pugh, H. and Price, W., 1954. Snow drifting and the use of snow fences. Polar Rec., 47: 4-23.

Roach, G. and Kirkpatrick, R., 1985. Wildlife use of roadside woody plants in Indiana. Presented at 64th Annu. Meet. Transportation Safety Board, 14-17 January, 1985 in Washington, DC, 19 pp.

Shaw, D., 1980. The farmstead windbreak. Colorado State Forest Service, Colorado State University, Fort Collins, CO, 42 pp.

Shaw, D., 1985. Background data and guidelines: living snow fence planning and establishment. Colorado Interagency Living Snow Fence Program, Colorado State University, Fort Collins, CO, 20 pp.

Sturges, D., 1984. The geometry of snowdrifts cast by shelterbelts as determined by small-scale, outdoor modeling. Study Plan 321, Rockey Mountain Forest and Range Experiment Station, Laramie, WY, 13 pp.

Tabler, R., 1973. New engineering criteria for snow fence systems. Transportation Research Record 506, NAS-NRC, Washington, DC, pp. 65-87.

Tabler, R., 1980. Geometry and density of drifts formed by snow fences. J. Glaciol., 26(94): 405-509.

Walter, J., 1984. Living snow fence: 60 years ago it was new. The Highwayman, Spring, 1984. Wyoming State Highway Department, Cheyenne, WY, 13 pp.