2. Shelterbelt efficiency criteria

In order to ensure the shelterbelt meets expectations, it is imperative that efficiency criteria be well understood. Porosity, height, length, width, transverse profile and orientation are the key elements that have an incidence on shelterbelt efficiency.

2.1 Porosity

Shelterbelt porosity is defined as the ratio of perforated area to the total surface area exposed to the wind (Equation 1).

$$\text{Porosity } (\phi) = \frac{\text{Perforated area}}{\text{Total surface area exposed to the wind}} \times 100\% \qquad \text{(Equation 1)}$$

Porosity, which is the percentage of perforated area, is the most commonly used descriptor of the structure of thin artificial windbreaks and narrow natural barriers (one or two rows of trees). For wider natural hedges, optical porosity is not equal to effective porosity because it only defines the gaps in the surface area exposed to the wind and does not take into account the three-dimensional voids through which air can flow (Heisler and DeWalle, 1988). When in comes to porosity, there is no single ideal value. Porosity needs to be adjusted according to protection needs. To do so, it is important to understand the impact of porosity on wind speed and snow distribution over the protected area.

2.1.1 Impact of shelterbelt porosity on wind speed reduction

Low porosity in shelterbelts (i.e., very dense) will generate maximum wind speed reduction, whereas moderate porosity will generate less important reductions. However, a moderately dense shelterbelt will provide better average protection over 20 H, where H is the height of the shelterbelt (Figure 4).

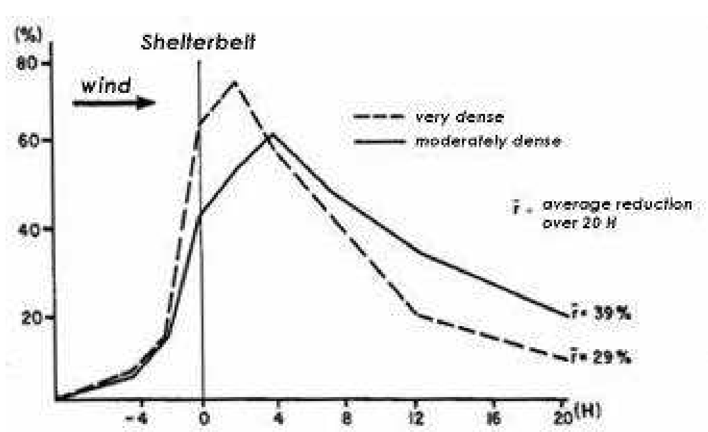

Figure 4 – Wind speed reduction (% of wind measured in open area) at various distances from a windbreak made of very dense and moderately dense common reed screens (adapted from Nägeli, as used in Guyot, 1977)

These observations (adapted from Nägeli, 1946, as used in Guyot, 1977) have served as reference for numerous experts who now believe that optimal protection is obtained with porosity levels of 50%. Heisler and DeWalle (1988) note, however, that Nägeli overestimated the decline in protection as distance increases from a very dense shelterbelt. Since this particular shelterbelt was the last of a series of four consecutive barriers, the turbulence created by the first obstacles is likely to generate a more rapid recovery of air flow on the lee side of the shelterbelt under study. However, these authors state that a shelterbelt that is too dense ($\phi < 30\%$ for an artificial windbreak) can generate massive air down flow between 8 and 10 H, which can damage crops. Based on these considerations as well as on numerous results found in the subject literature, we believe that optimal wind speed reductions are obtained, in terms of intensity and length of protection, with porosity levels around 40%. This corresponds to a moderately dense to dense shelterbelt.

2.1.2 Impact of shelterbelt porosity on snow accumulation

A dense shelterbelt will generate greater snow accumulation on both sides, compared to a looser shelterbelt, although snow will be distributed over a shorter distance (Figure 2). To generate even snow accumulation in the field, a low winter density shelterbelt should be selected.

2.2 Shelterbelt height

With all other conditions unchanged, the area of influence of a shelterbelt extends to a length equivalent to the structure's height (Van Eimern and al., 1964). The boundaries of the protected area are commonly described as the distance at which wind speed reduction falls under 20% at a height of 0.5 H from the ground. In the case of a moderately dense shelterbelt, this distance is 20 H, and the maximum wind speed reduction is obtained around 4 H (Figure 4).

The level of protection varies depending on the Z/H ratio, where Z is the height from ground level at which wind speed is measured (Figure 5). As this ratio drops, so does relative wind speed (μ/μ_0), thus generating better protection. For example, a 4-meter high shelterbelt will be more effective in protecting low rising crops such as strawberries than an apple orchard because the Z/H ratio is higher in the second case. Figure 5 illustrates a reduction in wind speed in an area ranging up to 5 H on the windward side of the shelterbelt.

With all other conditions unchanged, snow storage capabilities are generally quadrupled when the shelterbelt height is doubled (Shaw, 1988). There are therefore compelling reasons for using trees and tall shrubs in shelterbelts.

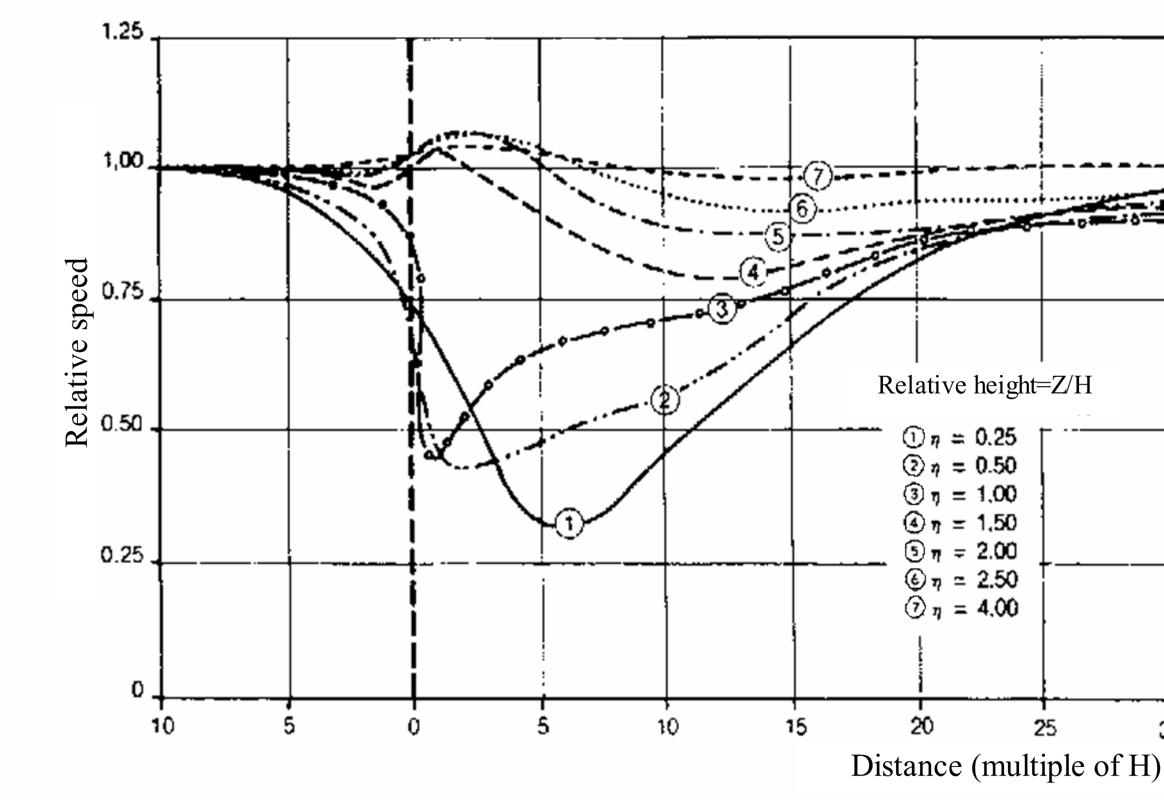

Figure 5 – Impact of a permeable windbreak ((0.45 < ϕ< 0.55) and H = 2.2 m) made of common reed screens on relative wind speed at varying heights (adapted from Nägeli, 1953, as used in Guyot, 1989)

2.3 Shelterbelt width

Several American authors (Hintz, 1986; Smith and Scholten, 1980) recommend planting very wide shelterbelts using close to 10 rows of trees and shrubs. However, studies conducted by Read (1964) have demonstrated that hedges that are narrow and dense are as efficient as very wide hedges. Studies conducted in wind tunnels (Harrje and al., 1982) indicate that additional rows do not play a role in significantly reducing home heating costs. Furthermore, the more rows there are in a shelterbelt, the more trees are needed and the higher the costs. Wider barriers also require more care and take up more space. Livestock may however find them convenient as they offer a dryer environment, which can promote better weight gain (Quévillon, 1990).

Two or three rows of trees and shrubs, spaced at 3 to 4 metres, should be sufficient to adequately protect farm buildings, work areas and pastures. When planting 3 rows, it is possible to introduce a wider variety of plant species, thus facilitating renewal of the hedge and ensuring protection is maintained in the advent of pest infestation or disease.

2.4 Shelterbelt length

Wind flows not only over the shelterbelt but also around the end points of the barrier. Consequently, the shelterbelt should be sufficiently long to ensure adequate protection. According to Nägeli (1953), as used in Guyot (1989), the shelterbelt should have a minimum length of 11.5 H (Figure 6). Superior lengths will produce equal increase in the width of area where protection is optimised.

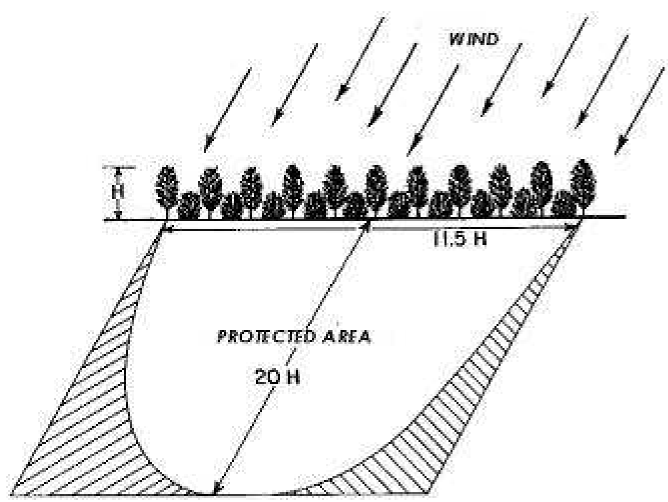

Figure 6 – Lateral air flow around a shelterbelt

2.5 Transverse profile

Transverse sections have little incidence on permeability; they are therefore more desirable. Profiles where trees are inclined windward have a tendency of lifting air streams over the shelterbelt and reducing porosity. However, in dry zones and on seashores where it can be difficult for trees to take root, an inclined profile and increasingly tall species can be beneficial (Guyot, 1977).

2.6 Shelterbelt orientation

The shelterbelt should be oriented perpendicularly across prevailing winds. When the wind hits a screen of trees at any other angle but 90 degrees, it has more ground to cover to flow through the barrier, which will reduce shelterbelt permeability.

2.7 Site topography

The site slope will also have an incidence on the length of the protected zone. A downslope towards the hedge will provide a greater surface of protection than an upslope (Figure 7).

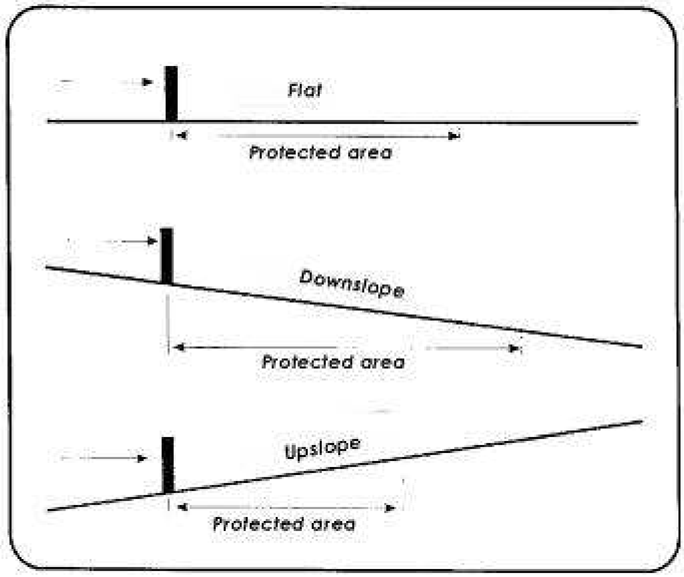

Figure 7 – Impact of topography on length of protected zone

References

GUYOT, G., 1977. Les effets aérodynamiques des brise-vent. Proclim E., tome 8E, no 3: pp137-188.

GUYOT, G., 1989. Les effets microclimatiques des brise-vent et des aménagements régionaux. Techniques agricoles. 170 (3-1989).

HEISLER, G.M. and DEWALLE, D.R., 1988. Effects of windbreaks structure on wind flow. Agric. Ecosytem. Environ., 22/23. pp. 41-69.

HINTZ, D.L, CLIFTON, W. and WIGHT, B.C., 1986. Basic windbreak design criteria for farm and ranch headquarters areas and large residential lots. Technical note LI-6. Lincoln,

SHAW, D., 1988. "The design and use of living snow fence in North America". Agric. Ecosytem Environ., 22/23. pp. 351-362.

SMITH, W.H., 1984. Pollutant uptake by plants. In: Treshow, M. (Ed.). Air Pollution and Plant Life. Wiley & Sons, New York, pp. 417-450

SOLTNER, D., 1984. Planter des haies, brise-vent et bandes boisées. Collection Science et Techniques Agricoles. Sainte-Gemme sur Loire.

VAN EIMERN, J., KARSCHON, R., RAZUMOVA, L.A. and ROBERTSON, G.W., 1964. Windbreaks and shelterbelts. WMO Technical Note no 59, 188 p. 42