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Windbreaks and shelterbelts for soil conservation: A review

D Udhaya Nandhini, B Sakthinathan
Assistant Professor, Department of Agriculture Karunya University, Coimbatore, Tamil Nadu, India

Abstract
A comparative study of radiation characteristics of a polarized switchable microstrip planar array of triangular patch antenna printed on synthesized LiTiMg ferrite substrate with a normal magnetic bias field has been done and reporting here. Radiation patterns and some important characteristics of proposed array antenna have been compared with the same geometry printed on RT duroid and silicon. 61% miniaturization and high quality factor are some advantages of using LiTiMg ferrite compare to RT duroid. With the biasing of external magnetic field perpendicular to the ferrite substrate arise some tunable behavior which has been elaborated by the generation quasi TEM, magnetostatic and spin waves. In this analysis spin wave exchange term (ω_r) which depends upon the static internal field (H_{ex}), has also included in the dispersion formula because the wavelength of microwave approach the inter-atomic distance of ferrite material which is the main cause of generation of spin waves in such types of layered structures.

Keywords: agroecological factors, windbreaks, shelterbelts, environmental buffers

Introduction
Windbreaks are narrow strips of trees, shrubs and/or grasses planted to protect fields, homes, canals, and other areas from the wind and blowing sand. Shelterbelts, a type of windbreak, are long, multiple rows of trees and shrubs, usually along sea coasts, to protect agricultural fields from inundation by tidal waves. Where wind is a major cause of soil erosion and moisture loss, windbreaks can make a significant contribution to sustainable production. There is a long tradition of using windbreaks in semiarid temperate regions of North America, Europe, and Asia for crop- and soil-protection from wind and wind erosion (van Emiren *et al*., 1964) [1], as well as in the semiarid tropics (Vandenbeldt, 1990) [2]. Shelterbelts have also been traditionally used for a long time in several places, most notably on the Bay of Bengal coast of India and Bangladesh.

Windbreaks also protect structures and livestock, provide wildlife habitat, improve aesthetics, and provide tree or shrub products. Also, when used as a living screen, windbreaks control views and lessen noise.

A shelterbelt is a barrier of trees or shrubs. The term “field shelterbelt” is used to distinguish between rows of trees or shrubs on agricultural fields from those planted in other ways: around farmyards or livestock facilities (farmstead shelterbelts), on marginal lands to change land use or in block plantings to provide woodlots or wildlife habitat.

Benefits
Properly placed field shelterbelts provide agronomic and other benefits. The main agronomic benefits include the following:
- Reduced soil erosion by wind
- Increased moisture for crop growth due to two factors:
  - → Snow trapping
  - → Reduced moisture loss through evaporation
- Potential for increased crop yields
- Reduced wind damage to crops

Other benefits
- Wildlife habitat and shelter
- Improved safety in winter travel due to reduced snow drifting
- Lower costs of snow removal from roads
- Beautification of the prairie landscape - Windbreaks beautifies the countryside and provides fall and winter color to the landscape.
- Reduced environmental effects of agriculture
- Provide potential source of income for farmers (e.g. biomass, timber and non-timber products)

The benefits from windbreaks in the temperate zone are similar to those in the tropics. Under normal arid conditions on the U. S. Great PLalns, windbreaks modify the microclimate of the protected zone by decreasing wind velocity. Consequently, vertical transport of heat is reduced and humidity is increased behind a windbreak, which generally reduces evapotranspiration. Furthermore, during periods of water stress, stomatal resistances are lower in crops protected by windbreaks than in crops grown in the open. Lower stomatal resistance tends to result in increased photosynthetic rates in the protected area. Air temperatures within the protected zone are generally warmer during the day and cooler at night than in unprotected zones. During the summer, the warmer day temperatures may increase evaporation from plants, but during early spring they may be beneficial for the establishment of most crops. Another microclimatic influence of the windbreaks is the conservation of, or increase in, soil moisture due to more evenly distributed snow and, thus, snowmelt in the spring. These beneficial effects can result in increased crop production in areas protected by windbreaks.

Reduced soil erosion by wind

A field shelterbelt modifies the microclimate, mostly in its downwind vicinity. This modified microclimate includes reduced wind speed and, therefore, reduced soil erosion. A significant reduction of wind speed occurs downwind for a distance extending to approximately 20 times the height of the shelterbelt and also 3 to 5 times its height on the upwind side. Therefore, a shelterbelt 5 m in height will provide a degree of protection for soils and crops for a total distance of up to 25 times its height, or 125 m.

Increased moisture for crop growth

Field shelterbelts reduce evaporation and trap snow providing more moisture for crop growth. Snowdrifts accumulate mostly on the leeward side (sheltered from the wind) of a shelterbelt. A dense barrier such as willow, caragana or spruce traps a narrower, deeper drift than a more porous barrier such as poplar, ash or Siberian larch. Shallow, uniform snow trapping over a greater portion of the field is preferable, but the trade-off for more even snow distribution may be reduced protection.

Stubble left as tall as possible enhances snow trapping, and a crop residue cover further reduces evaporation. Field shelterbelts use moisture and nutrients from a greater depth than most annual crops. However, additional moisture accumulated in the sheltered zone more than compensates for moisture used by the shelterbelt. Maintaining adequate fertility in the whole field should also compensate for nutrients taken up by the shelterbelt system.

Reduced wind damage to crops

Crops benefit from the reduced wind speeds in the protected zone. The plants are less likely to be twisted by the wind or sandblasted by eroding particles.

Productivity (Leeward Side)

Windbreaks improve crop growth and are “consistently reported in the literature to increase crop yields”. These effects are documented in over 676 field year studies, done in 14 different countries. Yield increases range from 5-50%, with 200 studies on corn and soybeans showing a weighted average gain of 12-13%. Windbreaks improve soil moisture, soil & air temperatures, relative humidity, and CO2 levels. Windbreaks improve crop quality, promoting earlier crop flowering, maturity, and improve pollination. This is especially important for vegetable and specialty crops.

Structure of windbreaks

Windbreaks usually consist of multistory strips of trees and shrubs planted at least three rows deep. They are placed on the windward side of the land to be protected, and are most effective when oriented at right angles to the prevailing winds. While their length and height may vary dramatically, it is common in the dry savannas and steppes of Africa to plant windbreaks 100 m long or more, with a peak height of 10 m. Small living fences and hedgerows can also act as windbreaks for small sites such as home gardens and nurseries. However, windbreaks are distinguished from boundary plantings and living fences by their orientation, which must face the wind, and by their multistory, semi permeable design.

They may conform to roadside, boundary, and floodplain lines, but must be specifically designed to slow the wind. Very dense windbreaks may do more harm than good since they will tend to create strong turbulence that will scour the soil on the windward side and damage crops on the leeward side. Conversely, gaps in the trees will channel the wind, actually increasing the velocity on the leeward side and promoting soil erosion and damaging crops. The protected zone created by windbreaks is defined as the area, on both leeward and windward sides, where wind speed is reduced by 20% below incident wind speed. The effective distance of protection is expressed as multiples of the height (H) of the tallest rows of trees.

Practical windbreak effects extend to a distance of 15-20 H leeward and 2-5 H windward of the windbreak; but usually a common calculation of the extent of protected area is 10 H leeward. This means if the trees are 10 m tall, crops up to 100 m in the leeward direction will be protected. The protective influence will diminish with increasing distance from the windbreak. A permeable windbreak will shelter a longer stretch of cropland than a dense windbreak. The most effective windbreaks provide a semi permeable barrier to wind over their full height, from the ground to the crowns of the tallest trees. An "ideal" windbreak should consist of a central core of a double-row planting of fast - and tall - growing species such as Eucalyptus spp., Casuarina spp., or neem (*Azadirchta indica*), and two rows each of shorter spreading species such as Cassia spp., Prosopis spp. or Leucaena spp. on botffsides of the central core. Agave spp. are also used, especially on the outer rows (away from crop fields).

Since the trees change their shapes as they grow, it is usually necessary to mix several species of different growth rates, shapes and sizes in multiple rows. Some fast-growing species should be used to establish the desired effect as rapidly as possible. In addition, some of the trees selected may not be as long-lived as others. Fast- and slow-growing species as well as trees with longer and shorter life-spans should thus be mixed to extend the useful life of the windbreak. Mixing species also provides protection against attack from diseases or insects that can easily destroy single-species stands.

Diversifying the species in the windbreak can also bring a wider variety of useful products to local users. A fully developed windbreak can yield wood, fruit, fodder, fiber, and honey for sale and home use. Where animals are allowed to graze nearby, at least some of the lower, outer trees or shrubs should be relatively unpalatable, while fodder species may fit closer into the center or along an inside edge where they are not exposed to animals, but can be cut by hand. Neem has been successfully used in Niger; its unpalatable leaves protect it from damage by livestock.

Although some trees such as neem, Casuarina spp., and Eucalyptus spp. are widely used in windbreaks, they should be used selectively. Eucalyptus should not be used alone as it has a sparse understory and may negatively affect water availability and crop productivity in the vicinity. Neem is known to shade crops and thus reduce the land available for crop production. On the other hand, people have constructed successful windbreaks with such unlikely trees as cashew (*Anacardium occidentale*) and local Acacia spp. The species selected must fit together as a group into a larger overall design that, in turn, complements the local landscape and land-use system.

While diversity is important, there are constraints on species choice both for indigenous and exotic species. Environmental hazards such as insect pests (especially termites), wild and domestic animals, poor soil, and drought, will narrow the choice as well as reduce the tree's growth rate. Water management, especially during establishment, will be important, as in any attempt to establish trees in a dry environment. Micro catchments, hand watering, or irrigation should be anticipated.

Design Factors for Multi-Species Shelterbelts

- Density – determines degree of wind speed reduction
- Height – with density, determines length of protected zone, upwind and downwind
- Length – determines total area of downwind protection
- Orientation – place perpendicular to prevailing winds
- Continuity
- Species/Number of Rows – affect density, rate of height growth
- Cross section

Functioning of a wind break

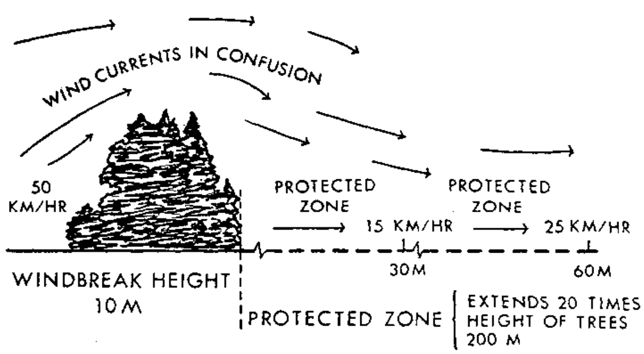

Fig 1

The effectiveness of the windbreak or shelterbelt is influenced by its permeability. If it is dense, like a solid wall the airflow will pass over the top of it and cause turbulence on the leeward side due to the lower pressure on that side; this gives a comparatively limited zone of effective shelter on the leeward side compared to the zone that a moderately permeable shelter creates. Optimum permeability is 40 to 50 percent of open space, corresponding to a density of 50 to 60 percent in vegetation. Gaps in the barriers should be avoided. Permeability of dense shelterbelt can be improved by pruning lower branches at 0.50-0.8 m from the soil level. It is generally accepted that a windbreak or shelterbelt protects an area over a distance up to its own height on the windward side and up to 10 times its height on the leeward side, depending on the strength of the wind. In reducing wind speeds, narrow barriers can be as effective as wide ones. Furthermore, a narrow shelterbelt has the advantage of occupying less land.

The shape of the cross-section of a windbreak or shelterbelt determines, to a great extent, the sheltering effect. To a large extent, the choice of tree or shrub species to plant, along with their planting arrangement, dictates the cross-sectional shape. In general, an inclined slope facing the wind should be avoided, as it only deflects the wind flow upward. Barriers with a clear vertical side provide best wingspread reduction.

Selection of tree and shrub species

In the selection of tree or shrub species for windbreaks or shelterbelts, the following characteristics should be sought:

- Rapid growth
- Straight stems
- Wind firmness
- Good crown formation
- Deep root system, which does not spread into nearby fields
- Resistance to drought; - Desired phonological characteristics (leaves all year long or only part of the year).

Sand dune stabilization

Sand dunes result from wind erosion. They are formed in many arid lands when winds regularly blow over poorly-vegetated areas. Sand dunes that are not covered with vegetation (because of over cropping or overgrazing) move in the direction of the wind at a speed which can approach 10 meters a year, endangering agricultural crops, forest plantations, irrigation canals, and roads. To prevent this encroachment, the sand dunes must be stabilized; one method of sand dune stabilization is to establish a vegetative cover.

In general, two types of sand dunes are recognized: coastal dunes and inland dunes. Techniques of stabilizing these two types of sand dunes through the establishment of a vegetative cover are discussed below.

Stabilization of coastal dunes

Coastal dunes originate from sand thrown up onto the shore by waves. At low tide, the sand dries and is blown away by the wind. When protective vegetation beyond the beaches is destroyed, coastal dunes move inland. To stop the advancement of coastal dunes, an artificial foredune should be constructed about 50 meters from the floodline. Normally, this initial barrier is built one year before a planting programme begins.

One method of building a foredune is by mechanical fixation of the sand by fences or palisades, 0.5 to 1 meter high. The materials used for the fences or palisades may include twigs from trees or shrubs, brushwood, grass sheaves, reeds, bushes, palm leaves, old railroad ties, used oil drums, and earth. When the prevailing wind has a prevailing direction, parallel lines of palisading are sufficient; however, a checkerboard system is advisable where fluctuating winds are common. Sand piles up behind the palisade and, when the artificial dune that is formed reaches a height of 0.5 to 0.75 meter, a second palisade is built on top of it. Sometimes, the original barriers can be raised, when necessary, instead of building a new palisade. Once the foredune is established, it is possible to stabilize the sand behind it by seeding or planting a vegetative species that provides good ground cover and is able to withstand (at least partially) covering by sand.

Sand dune fixation also can be done by mechanical mulching;

that is, the spreading of solid material on the surface of the sand. Chemical fixation can also be employed. Chemical fixation consists of stabilizing the sand surface by covering it with a continuous crust of sprayed chemical substances, such as petroleum derivatives or latex mixtures. Vegetative establishment is usually a follow-up or a concurrent operation. Chemical fixation is advisable when the cost of labour is high and the chemicals are readily available. Sand dune stabilization with plant species is more permanent than mechanical mulching and chemical fixation techniques which are, in most cases, only temporary measures.

Stabilization of inland dunes

Inland dunes originate from sand produced by the weathering of rocks, mainly sandstone. The fine fraction can be blown far away, while the heavier fraction is blown short distances and forms dunes. Such dunes can pose serious stabilization problems, especially when the dunes are large and active. One way to combat this problem is by creating an artificial dune at the windward end of the dune.

The method followed is similar to the one used to create the foredune in the stabilization of coastal sand dunes. The stabilization of inland dunes also follows the same general lines as mentioned for coastal dunes. When a specific area of value (for example, an oasis) is threatened, protective work is initiated as close as possible to the area of concern, with the work gradually progressing toward the sand source area.

Canal-side plantation

In many arid countries, wherever rivers are available, efforts have been made to utilize the water for irrigation purposes through the construction of dams or using lift irrigation for the agricultural needs. Several thousands of kilometers of irrigation canals have been laid. The banks of such canals are available for planting purposes and constitute a considerable area for production of timber and firewood for the rural population. Full advantage is being taken of this in many countries like China, Egypt, India and Pakistan. A few rows of trees, varying from 4 to 6, are generally planted on each bank of the canal with an espacement depending on the characteristics of the species and the type of produce desired.

When designing a canal plantation, the requirement may be the same as for the design of irrigated plantations with respect to climatic and soil conditions and to supply and quality of water. However, it should be remembered that the only water supply available to the trees is seepage from the canal into the root zone. In some places, it is cheaper to grow trees and thus utilize the seepage water rather than prevent seepage by canal linings of concrete, asphalt or other material.

Choice of species for canal side plantations should take into account both the particular character of the plantation and its purpose. The roots of the trees should strengthen the banks of the canal and the trees should keep the canal and its banks well shaded in order to suppress weed growth and reduce evaporation. Species that tend to increase water seepage through the sides and bottom of the canal should be avoided. Where canals have an intermittent flow, such as flood discharge canals, only trees able to adjust to varying water levels in the soil can be used. Species that reproduce by suckers should not be planted along canals. Plantation techniques should favor deep planting and roots should be planted in the moist layer.

River-bank plantations

There are many areas where river lengths are considerable. The ground on either side of the river is partly within the reach of the high level of water during the period the rivers are in flood.

Beyond this level - and on the fringes of the agricultural land, strip plantation can be established to produce wood, fuel wood and fodder. Generally, the width of such strips is limited but does constitute a useful and productive linear plantation. Underground water is available at different levels. The species to be planted should be matched with this water level variation. Spacing within and between the rows depends on the characteristics of the species and the rotation planned for the crop. In the more arid areas, trees with xerophytic habit constitute the outermost rows while those close to the river bank are the ones with higher water requirement. In such locations, phreatophyte species such as Populus spp., Acacia nilotica, Dalbergio sisso, Prosopis spp. can be planted.

Conclusion

The age old practice of shelter belts & windbreaks are most useful in enhancing the soil conservation. Choice of species and planting arrangements for constructing multi-species shelterbelts should follow design considerations developed from simulation models and observations. This natural way of conserving the soil should be adopted commonly in the areas where the problem of high wind speed prevails.

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