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ABSTRACT—This paper reviews the evidence for nonagricultural benefits of windbreaks in the Great Plains. Windbreaks may provide recreational opportunities, scenic beauty, fuelwood, and wildlife habitat in addition to agricultural benefits. Quantitative studies demonstrate that windbreaks on the Great Plains provides important wildlife habitat for woodland edge species, substantial opportunities for recreation, a potentially important source of fuelwood, and enhanced scenic beauty.

Introduction

Agricultural benefits of windbreaks are well documented (e.g., Baer 1989). These benefits include: erosion control, increased crop yield, livestock protection, snow trapping and control, and improved energy efficiency in farmstead heating. Such benefits have been communicated to landowners by the Cooperative Extension Service and other agencies in an effort to encourage windbreak planting and maintenance.

Despite these educational efforts regarding the benefits of windbreaks and despite assistance by government agencies to help establish more windbreaks, the number of windbreaks on the Great Plains has been decreasing for the past three decades. For example, in a 13-county study area in Kansas, Sorenson and Marotz (1977) found that 20% of the windbreaks present in 1962 had disappeared by 1970. Cable (1992) surveyed Kansas farmers and found that, although most were aware of the agriculture-related benefits of windbreaks, 6.2% of the farmers had removed windbreaks within the last 10 years. On the average, they had removed 1.5 windbreaks with an average length of 0.5 miles. The primary reason for removal was to increase tillable acreage.

In addition to windbreaks being removed, others are being lost to age-related deterioration. Of the windbreaks studied in South Dakota, 61% received a rating of fair, poor, or no barrier. A fair rating indicated that 30 to 40% of the canopy was missing. (Schaefer et al. 1987)

The existence of nonagricultural benefits has been presumed but not well documented. Some attributes were included in lists of windbreak benefits based on the intuitive belief that they exist, rather than on empirical evidence. The purpose of this article is to review research conducted on the lesser known windbreak benefits, specifically, those related to wildlife, recreation, fuelwood, and aesthetics.

Wildlife Benefits

Many studies of wildlife have been done in windbreaks compared to the small number of studies on recreational and aesthetic values of windbreaks. The oft-repeated statement that windbreaks are "good for wildlife" is an oversimplification. Like any habitat type, windbreaks are good habitat for some species and unsuitable habitats for others.

Windbreaks benefit some species by providing food, reproductive sites, escape cover, and shelter from severe weather. For example the widespread planting of windbreaks on the plains in the years after the Dust Bowl is thought to have contributed to range expansions by: fox squirrels (*Sciurus niger*), Mississippi kites (*Ictinia mississippi*), and other woodland species (Love and Knopf 1978; Podoll 1979).

Most wildlife studies in windbreaks have focused on bird populations. In their review of the literature (Johnson and Beck 1988) calculated that at least 108 bird species use windbreaks (e.g., Fig. 1). Of these, they estimated that 29 species benefited substantially, 37 moderately, and 42 only a little or incidentally. Examples of species richness data for breeding birds in windbreaks includes: 17 species in 7 Minnesota windbreaks (Yahner 1982), 44 species in 69 windbreaks in South Dakota (Martin and Vohs 1978), 64 species in 81 North Dakota windbreaks (Cassel and Wiehe 1980), and 60 species in 34 Kansas windbreaks (Cable et al. 1992).

Several studies have estimated densities of breeding birds in windbreaks. For example, in South Dakota, Emmerich and Vohs (1982) found mean population densities per 40 ha of 3,306 individuals and 1,953 individuals for multi-row and single-row windbreaks, respectively. Yahner (1982) found 617 nests in 7 Minnesota windbreaks and reported an overall mean nest density of 88.5 nests per ha, with a range of 28.8 to 186.4. So, both bird biodiversity and bird reproductive activity are relatively high in Great Plains windbreaks in the growing season.

Windbreaks also provide shelter from severe weather throughout the year. The moderating effect of windbreaks appears important for some

Figure 1. Dark-eyed Junco (*Junco hyemalis*) in windbreak. Photo by the author.

species during winter, particularly in areas where little other cover exists, by providing a temporary refuge from winter storms. However, studies also indicate that overall avian use of windbreaks in winter is sporadic. In North Dakota, Rotzien (1963) found 17 species in 8 windbreaks over 3 winters and noted more birds in the windbreaks during times of severe weather. Cassel and Wiehe (1980) found only house sparrows (*Passer domesticus*) wintering and breeding in the same windbreak. They concluded that, although other species may occasionally forage or seek shelter in a windbreak, no other species could be considered a winter resident in a single windbreak. In South Dakota, Emmerich and Vohs (1982) found 9 species (mean density=586 individuals per 40 ha) in 14 multi-row windbreaks and only 2 species (mean density=15 individuals per 40 ha) in 14 single-row windbreaks. Bird use in winter is difficult to predict based on short-term weather conditions and is affected by the availability of other needs, particularly food, in or near the windbreak (May 1978; Stormer and Valentine 1981; Yahner 1981). So, although windbreaks may contain few birds species at any one time during

the winter, they can serve as refuges during periods of severe weather, particularly if they are designed with outside shrub rows (to limit snow penetration) and are of sufficient height and width.

The moderating effects of windbreaks also play an important role in aiding thermoregulation of species in adjacent areas during periods of cold wind (Johnson and Beck 1988). For example, Bennett and Bolen (1978) reported that windbreaks planted near small playa lakes on the Texas High Plains protected wintering ducks from winter winds, thereby enhancing the ducks' ability to conserve energy.

Small mammals also use windbreaks. Johnson and Beck (1988) found references to 28 species of mammals studied in windbreaks. Of these, the data suggest that 7 species are highly dependent on windbreaks in agricultural areas: eastern cottontail (*Sylvilagus floridanus*), desert cottontail (*S. auduboni*), gray squirrel (*Sciurus carolinensis*), fox squirrel (*S. niger*), white-footed mouse (*Peromyscus leucopus*), southern red-backed vole (*Clethrionomys gapperi*), and European bank vole (*C. glareolus*).

No large mammals are considered to be highly dependent on windbreaks; however, white-tail deer (*Odocoileus virginianus*) use windbreaks for food, cover, and fawning areas (Popowski 1976; Podoll 1979). Windbreaks also provide travel corridors and hunting areas for large mammalian predators (Order Carnivora) (Shalaway 1985).

Not all windbreaks are equally valuable as habitat for a wide variety of species. Schroeder (1986) reviewed the literature and developed a model to predict avian species richness. In this model, species richness was positively related to the following six characteristics: area, number of rows, plant diversity, windbreak height, canopy closure, and configuration (i.e., presence of outside shrub rows). This model was tested and revised (Schroeder et al. 1992), using the abundance of snags and foliage height diversity as well as shelterbelt size as predictors of avian species richness. This study found that windbreak size is the most important determinant of bird diversity.

In spite of all these studies, some ambiguities still exist that need to be addressed regarding the benefits of windbreaks for wildlife. For example, a better understanding of predator-prey relationships associated with windbreaks is needed. Gates and Gysel (1978) reported unusually high levels of nest predation and brown-headed cowbird (*Molothrus ater*) parasitism along human-made forest edges, and suggested their "ecological-trap hypothesis." Windbreaks may attract predators. Predators may use them as travel corridors or as concentrated aggregations of food for prey. Moreover, when few

Figure 2. Wild turkey (*Meleagris gallopallo*) at edge of windbreak. Courtesy of the Kansas Forest Service.

other trees occur in an area, windbreaks may provide the only perches and fulfill other habitat requirements for avian predators that otherwise would not be present.

In an effort to promote windbreak planting and maintenance, windbreaks have been touted as beneficial for ring-necked pheasants (*Phasianus colchicus*) and other game birds (Fig. 2). However, some studies indicate that windbreaks planted to increase these populations instead can have a detrimental effect on gamebird populations because of the aforementioned predator-prey relationships (e.g., Petersen 1979; Snyder 1985; Potts 1986; Hudson and Rands 1988; Carroll 1989). Consistent with the "ecological-trap" hypothesis is the finding by Lyon (1961) that windbreaks improved hunter success. More pheasants were killed with less hunter effort. So, the research seems to indicate that windbreaks may enhance gamebird *hunting*, but not necessarily gamebird *populations*.

The role of windbreaks in the context of landscape ecology needs additional study. Windbreaks may have a positive effect on some species

because they can serve as travel corridors to food resources in adjacent fields or as "stepping stones" for migrating birds or those dispersing between riparian habitats and other wooded tracts (Yahner 1983). On the other hand, Samson (1980) noted that several species of prairie birds require large expanses of prairie, including upland sandpipers (*Bartramia longicauda*), Henslow's sparrows (*Ammodramus henslowii*), and greater prairie chicken (*Tympanuchus cupido*). He argued that recommendations to increase habitat heterogeneity through tree plantings on open prairies be viewed with caution.

Scenic Beauty

Windbreaks on the Great Plains have changed the landscape of the region (Fig. 3). Most foresters have assumed that the change was for the better, aesthetically. "Enhanced scenic beauty" often has been included in publications promoting the benefit of planting windbreaks. The inclusion is despite a lack of no direct empirical evidence to support that belief and despite anecdotal evidence that some landowners do not like windbreaks because they "blocked the view" or "made me feel closed in."

Studies in forested regions indicate that, for the most part, people prefer diversity in the landscape (Cherem and Traweek 1977; Ribe 1986; Axelsson-Lindgren and Sorte 1987), and shelterbelts do add diversity. However, other studies indicate that people prefer "natural" rather than "unnatural" components in the landscape (Daniel and Boster 1976; Benson and Ullrich 1981; Miller 1984; Vining et al. 1984). Although trees typically are thought of as being natural, the linear nature of windbreaks betrays their unnatural origins. So, because windbreaks consist of natural plant materials, but are human-made and unnatural to the plains region, the existing literature did not clearly indicate whether they were perceived on average as enhancing or detracting from the landscape.

A recent study assessed the scenic beauty of windbreaks in Kansas (Cook and Cable 1995). The objectives were to determine the relationships among windbreaks, other landscape characteristics, and scenic beauty. Judgement differences in scenic beauty were evaluated in relation to background characteristics of the observers and consistency of the judgements over two separate viewings of the same scene by the same viewer.

The study was conducted using the Scenic Beauty Estimation (SBE) technique, which has been used widely in forest environments (Daniel and Boster 1976). Sixty color slides of various agricultural landscapes in central

Figure 3. View of windbreaks from the air. Courtesy of the Kansas Forest Service.

Kansas were shown to subjects, and they were asked to rate the slides for scenic beauty. Each slide was taken in August after wheat harvest, but before sorghum harvest. Slides were selected that minimized the appearance of human objects such as roads and farmsteads and that had similar sky conditions. The landscapes ranged from having no trees to have large shelterbelts. One hundred and eighty university students were asked to rate each slide on the scenic beauty scale using standard SBE procedures. Nothing was mentioned to the students about windbreaks or their significance to the study. A scenic beauty measure (SBE) was calculated for each slide, using a program written by the Rocky Mountain Forest and Range Experiment Station (RMRATE: Brown et al. 1990). Correlation and multiple linear regression were used to look for relationships between SBE's and vegetation characteristics. And, correlation and principal component analysis were used to assess the relationships between SBEs and viewer characteristics.

Background windbreaks, which appeared as thin green lines at the horizon, were not correlated with the measure of a slide's scenic beauty.

However, midground windbreaks did have significant correlation ($P<0.05$). Foreground vegetation was not correlated highly with SBE. Using step-wise, multiple regression, midground shelterbelts consistently entered the predictive relationship, and this factor was highly significant in the final regression equation ($P<0.01$; $R^2 = 0.724$). Not only did this study indicate that windbreaks do contribute to the scenic beauty of the Great Plains landscapes, but it also showed that background characteristics of the observer did not alter their scenic quality evaluations of windbreaks in the landscape. In addition, scenic beauty ratings remained consistent over two viewings by the same individual. Thus, windbreaks had a positive influence on scenic beauty when viewed from a moderate distance.

Recreation Benefits

One of the most important recreational activities associated with the habitat effect of windbreaks is hunting. In 1989, a survey was sent to 1,501 randomly selected hunters in Kansas to determine their use of windbreaks (Cable and Cook 1990). The results demonstrated that windbreaks are an important recreational resource. Virtually every type of hunting that occurs in Kansas takes place in or adjacent to windbreaks, at least some of the time. They are particularly important in providing opportunities for hunting quail, pheasant, and deer. Some of the key findings of this study follow.

First, much of the hunting in Kansas takes place in windbreaks. Hunters averaged 1,368,741 hunter-days annually in windbreaks, representing 40.7% of the total days spent hunting in Kansas. This is particularly noteworthy because the "total days" included the pursuit of ducks, rails, and other game seldom found in windbreaks. Over 81% (81.2%) of the respondents hunted in windbreaks at least some of the time. Moreover, 6% of all hunters said they hunted in windbreaks 100% of the time. Hunters who used windbreaks spend an average of 50.1% of their hunting time in them and hunted at an average of 5.3 sites with windbreaks.

Various species of game were pursued in Kansas windbreaks. Kansas hunters spend 29.4% of their time in windbreaks hunting quail, 28.7% hunting pheasant, and 13.7% hunting deer. Time allocated to pursuing other game species included: doves (9.1%), rabbit (9.0%), squirrel (3.2%), coyote (2.7%), turkey (1.3%), prairie chicken (1.3%), and waterfowl (1.1%).

Second, hunting in Kansas windbreaks contributed to the states' economy. The U.S. Fish and Wildlife Service estimated that resident hunters in 1985 spent $74.9 million on hunting, spending $28.1 million on in-state, trip-related expenses (US Department of Interior 1988). Attributing 40.7%

of the total hunting occurred in windbreaks as estimated from the survey, then hunting in windbreaks by residents accounted for $30.5 million worth of expenditures annually. Nonresident hunters added an additional $13.5 million to the economy (US Department of Interior 1988). Assuming that nonresident hunters had similar hunting patterns to residents, windbreak hunting would have added an additional $5.5 million to the economy.

Although it is unlikely Kansas would lose these expenditures, if all windbreaks were removed, fewer windbreaks would represent fewer places to hunt. Fewer places to hunt would concentrate hunters and potentially lower both the quantity of hunting opportunities and the quality of the experience. As the quantity and quality of the hunting experience diminished, hunters might take fewer trips or discontinue hunting.

A contingent valuation analysis of hunting in windbreaks found that the average trip expenditures to the hunter's "favorite windbreak site" were $74.38/trip (Cook andCable 1990). The net willingness-to-pay additional trip expenditures to the favorite windbreak site was $56.51. The aggregate net benefit, representing willingness to pay increased travel costs in excess of reported expenditures, of hunting at their favorite windbreak sites for all Kansas hunters using windbreaks was calculated to be at least $21.5 million annually. This estimate for the net value of windbreak hunting is conservative, because many hunters used multiple windbreak sites, in addition to their "favorite" one, and because the study did not include out-of-state hunters or hunters under the age of 16.

Other recreational activities occur in windbreaks. While conducting wildlife surveys in windbreaks in central Kansas, I often found fire rings, or even barbecue grills and picnic tables, in the larger windbreaks. As part of the hunter survey, hunters were asked if they participated in other recreational activities in windbreaks. And 20.9% reported that they did. Activities mentioned included: camping, picnicking, birdwatching, photography, walking, horseback riding, trapping and target practice. Apparently larger windbreaks are conducive for most recreation activities associated with wooded areas.

Fuelwood Cutting

Information about fuelwood consumption in Kansas, Nebraska, South Dakota, and North Dakota was gathered from a telephone survey sponsored by the USDA Forest Service during the fall of 1994 (May 1996). Nine hundred households were sampled from each of the four states. Overall, 4.3% of households cut fuelwood in windbreaks in the four-state region. The percentages of households cutting fuelwood from windbreaks were similar

across all four states: 4.4% in Kansas, 5.0% in Nebraska, 4.4% in North Dakota, and 3.7% in South Dakota.

The average amount of wood cut from windbreaks annually by these households were: 2.0 cords in Kansas, 1.4 cords in Nebraska, 2.4 cords in North Dakota, and 2.4 cords in South Dakota. The average for the four-state region was 2.0 cords. As one would expect, the species of wood harvested corresponded to those species often found in windbreaks: elm, ash, cottonwood, and osage orange. In addition, surveyed 25.0% of Kansas landowners with windbreaks on their property identified "provides wood products" as a reason for having them (Cable 1992). Moreover, 4.1% said it was the most important reason. Fuelwood would have been included in that categorical response.

Although the percentage of households burning wood from windbreaks is low, it still represents many households in the central and northern plains region. In many areas on the plains, windbreaks may provide the only source of fuelwood.

Summary

Windbreaks, which are planted for their direct economic benefits to farmers of protecting soil, livestock, and crops and saving energy, also provide recreational benefits, such as hunting, and enhance the scenic value of the landscape for the general public. Windbreaks also provide habitat for many species that otherwise would not be present in some areas and additional habitat for indigenous woodland species. While windbreaks are not equal substitutes for natural forest or riparian strips, they do contribute substantially to the diversity of fauna in agricultural landscapes of the Great Plains.

If the trend of windbreak removal and deterioration continues, some wildlife populations, recreational opportunities, fuelwood supplies, and scenic beauty of rural landscapes will be affected negatively. The quantification and articulation of these nonagricultural benefits may assist policy makers in allocating resources to encourage windbreak establishment or maintenance.

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