15 Modeling a Field Shelterbelt System with the Shelterbelt Agroforestry Modeling System

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15.1 INTRODUCTION

Field shelterbelts (ones used primarily to protect crop fields) have been an important component of agroecosystems in certain parts of the world for centuries. The primary microclimatic influence of shelterbelts is windspeed reduction (Caborn 1957; Grace, 1977; McNaughton, 1988), which can improve crop production (Stoeckler, 1962; Kort, 1988), reduce wind erosion (Tibke, 1988), reduce the movement of fugitive pesticides and fertilizer (Tibke, 1988), reduce odor emissions from animal enclosures (Tyndall and Coletti, 2000), and increase economic returns (Brandle et al., 1992a). Other documented shelterbelt effects include increased wildlife habitat (Johnson and Beck, 1988; Johnson et al., 1994), sequestration of carbon (Brandle et al., 1992b), increased abundance of natural enemies of insect pests (Dix et al., 1995), and improved aesthetics (Sutton, 1992).

Although shelterbelts produce multiple effects and some of those effects have been intensively studied, estimation of the benefits and costs of a specific shelterbelt on an individual farm is a
TABLE 15.1
Shelterbelt Effects, the Impact of Shelterbelts on the Effects, and How to
Simulate or Quantify the Benefits and Costs of the Effects

<table>
<thead>
<tr>
<th>Effect</th>
<th>Impact of Shelter</th>
<th>How to Simulate/Quantify</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop yield</td>
<td>Yield increase or decrease, depending upon growing</td>
<td>Use model described in this chapter</td>
</tr>
<tr>
<td></td>
<td>season conditions</td>
<td></td>
</tr>
<tr>
<td>Carbon sequestration</td>
<td>Trees and soil sequester C; fuel usage is reduced</td>
<td>Directly measure or use yield equations; straightforward calculations</td>
</tr>
<tr>
<td>Wind erosion</td>
<td>Reduces erosion where it is a problem</td>
<td>WBECON methodology (Brandle and Kort, 1991); WEPS model (Wagner, 1996) when it includes multiple subregions</td>
</tr>
<tr>
<td>Fugitive pesticides</td>
<td>Reduces spread of chemicals but can also kill trees</td>
<td>Cannot be done presently</td>
</tr>
<tr>
<td>Wildlife</td>
<td>Increased numbers of animals which can be a benefit or a cost</td>
<td>Only willingness to pay estimates can be made by landowners</td>
</tr>
<tr>
<td>Natural enemies of insect pests</td>
<td>Little impact unless there is a dense network of belts</td>
<td>Cannot be done presently</td>
</tr>
<tr>
<td>Odor emissions</td>
<td>Some reduction possible</td>
<td>Cannot be done presently</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>Potentially valuable contribution</td>
<td>Only willingness to pay estimates can be made by landowners</td>
</tr>
</tbody>
</table>

complex task that is best done by a computer model. In 1991, our research group began developing a system to estimate site-specific effects, benefits, and costs for sheltered fields that produce maize (Zea mays L.) and soybeans (Glycine max L.) that can be used to help develop tools that individuals can use for decision making. The system is called SAMS, which stands for Shelterbelt Agroforestry Modeling System (Mize, 2000), and it is being developed as a useful tool for landowners who are interested in establishing shelterbelts on their land. As far as we know, SAMS is the only model that has been developed specifically to predict crop yield and other effects in a shelterbelt system (a shelterbelt and adjacent cropland). Although SAMS was initially developed to predict crop yield in a sheltered field, we are incorporating benefits and costs associated with carbon sequestration and increased wildlife usage into SAMS. Eventually, SAMS will include the benefits and costs of other effects discussed in this chapter (see Table 15.1). SAMS is being developed as a web site and currently has the URL of http://oriolae.ae.iastate.edu/sams.

Other shelterbelt modeling research includes Easterling et al. (1997) who used EPIC (Erosion-Productivity Impact Calculator) to evaluate the potential of shelterbelts to ameliorate climate change-induced crop stress. Also, WBECON (Brandle and Kort, 1991; Kort and Brandle, 1991) is a model that evaluates economic aspects of shelterbelts; however, it uses published crop yield curves, representing an average response over a variety of fields, to estimate yield response for individual farms, whereas SAMS estimates crop yield curves for individual fields.

This chapter describes methods of estimating the benefits and costs associated with some shelterbelt effects and explains how these effects are or will be incorporated into SAMS. The chapter does not present an in-depth discussion of the effects. Two recent comprehensive reviews of shelterbelt technology provide good background material on shelterbelt effects (Nuberg, 1998; Brandle et al., 2000).

For many farmers the most important shelterbelt effect, often the only effect they expect, is increased crop yield. As a result, much of the research on shelterbelts has focused on yield and
associated microclimatic variation across sheltered fields. Our discussion on modeling a shelterbelt system will begin with modeling crop yield.

15.2 MODELING CROP YIELD ACROSS A SHELTERED FIELD

Although shelterbelt systems have been studied for decades, as far as we know, there has been no attempt until recently to develop a model capable of simulating crop yield across individual sheltered fields. Our research group began developing such a model in 1991 (Mize and Qi, 1994). As a modeling framework, we divided a shelterbelt system into three components: the crop being grown in the sheltered field; the microclimate, which influences crop yield; and the shelterbelt, which influences the microclimate across the field (Figure 15.1). Using these three components, a model to simulate crop yield across a sheltered field could be developed by combining: (1) a shelterbelt model that would simulate characteristics of a shelterbelt, (2) a microclimatic model that would use the simulated shelterbelt characteristics to simulate microclimate at specific locations across a sheltered field, and (3) a crop model that would use the simulated microclimate to simulate yield at those locations. Predicted yields would be combined to estimate a field level yield.

Next, we briefly describe crop, microclimatic, and shelterbelt modeling and how such models are being used to simulate crop production in SAMS.

15.2.1 CROP MODELS

Models capable of simulating crop yield for most major agronomic crops have existed for at least 25 years. Early models simulated yield using empirical approaches, in which yield was computed as a function of major inputs, such as planting date, cumulative rainfall during the growing season, and yield potential. In the mid 1970s, researchers began to develop more process-based crop growth

![Diagram](image_url)

**FIGURE 15.1** Conceptual model of components used to predict crop production in a sheltered field.
models. These models extended the mathematical representation of plant growth by simulating daily rate of plant growth and integrating this rate over the season to ultimately compute final yield. Processes, such as photosynthesis, respiration, carbon partitioning, and soil water and nutrient stresses, are computed by solving mass balance differential equations and are calibrated to field data. Examples of these models include CERES (Jones and Kiniry, 1986), CROPGRO (Hoogenboom et al., 1994), and SUCROSE (Kuehn et al., 1982). Our research group works primarily with the DSSAT (Decision Support Systems for Agrotechnology Transfer) models (Hoogenboom et al., 1994). Inputs to these models include daily weather (maximum or minimum temperature, rainfall, solar radiation, windrun—optional), soil properties (water holding capacity, rooting depth), crop genetics (development and reproductive rates, stress response, photosynthesis parameters), and management practices (planting date, row spacing, variety traits) (Figure 15.1). These models have been used to simulate influence of global climate change and crop management on maize and soybean production and are being used widely in Iowa to simulate optimum management practices in row crop production (Paz et al., 1998; Sexton et al., 1998; Garrison et al., 1999).

Simulation of maize and soybean yield under sheltered conditions requires crop growth models that are sensitive to varying microclimates across a sheltered field. The DSSAT models, including the CROPGRO soybean and CERES-Maize models (Hoogenboom et al., 1994), respond to daily maximum and minimum temperatures and windrun, all of which are influenced by a shelterbelt, through the use of the Penman Monteith equation for simulation of evapotranspiration. These models recently have been used to simulate the impact of shelterbelts on maize and soybean yield across a field. Qi et al. (2001) used the soybean model to simulate the potential yield response in a sheltered environment using long-term historical weather data. They used a theoretical wind response function to compute the windspeed reduction at different distances from the shelterbelt using actual unsheltered windspeed data for 14 years. Mize et al. (2005) used the CERES-Maize and SOYGRO models to simulate effects of microclimatic changes in windspeed and temperature due to shelterbelts on maize and soybean yield. They used empirical functions derived from measurements of windspeed and temperature to compute daily windrun and daily maximum and minimum temperatures at a location near a shelterbelt from windspeed and daily maximum and minimum temperatures at an open site. These served as inputs to the maize and soybean models for a 2 year period for a field in Indiana, and both models showed sensitivity to microclimatic differences.

### 15.2.2 Microclimatic Models

Numerical modeling of turbulent flow and microclimate near shelterbelts is a recent development. In 1995, Wang and Takle introduced a new approach for simulating flow fields in the vicinity of shelterbelts (Wang and Takle, 1995) and subsequently applied the model to shelters of variable porosity, irregular shapes, and oblique orientations to the wind (Wang et al., 2001). They also added soil layers and extended the model to include moisture and temperature. This allowed for simulation of differential patterns of heat and moisture flux across sheltered areas and provided a more complete set of microclimate factors for evaluating a wider range of sheltering influences. The model requires information about shelterbelt characteristics, including shelter height, width, cross-sectional shape, and specific surface area (area of leaves and branches per unit volume) of each cell in a grid representing a cross-section of the barrier.

The Wang and Takle (1995) model (WT model) captures many of the general features of windspeed and temperature in a shelterbelt system, but it has not been tested with field data, because appropriate field data, until recently, have not been available. While waiting to evaluate the WT model, we decided to pursue an empirical approach to predicting microclimate across a sheltered field. Intensive measurements of microclimate (windspeed and temperature) across various sheltered fields have been made, and the data are being used to develop regression equations to predict microclimate at specific distances from a shelterbelt using open-field (part of the field not under the influence of a shelterbelt) measurements as predictors (Mize et al., 2005). The statistical models are
complementary to the first-principles of the dynamical WT model and allow prediction of microclimate across a sheltered field that can be used for testing the WT model, when information about individual shelterbelts becomes available. If the WT model adequately predicts microclimate across a sheltered field, it will be used in SAMS. Otherwise, we will continue making intensive measurements and developing regression equations to predict microclimate for a variety of shelterbelts.

15.2.3 SHelterbelt Models

Because of the importance of tree and forest growth in forest management, models to predict their growth have been developed for more than 200 years (Fernow, 1907). Few forest growth models would be useful for predicting characteristics of shelterbelts, however, because they are based on data from expansive forests. Such models do not apply to narrow plantings, typical of shelterbelts in which most, if not all, trees are on the edge of the “forest.” Individual tree growth models have been developed for many species and are capable of predicting some shelterbelt characteristics, tree height in particular.

Presently, we are categorizing shelterbelts into what we call “types of shelterbelts.” All shelterbelts that have the same number of rows, the same species composition and spatial arrangement, and similar spacing are considered the same “type.” Models to predict shelterbelt characteristics are being developed for various types of shelterbelts.

One of the most important shelterbelt characteristics is the height of the tallest row in the shelterbelt (H). Many tree height growth models have been developed, but almost all require a measure of the quality of the environment, often site index (Avery and Burkhardt, 2002), which is seldom available for agricultural soils. We will develop height growth equations for groups of similar soil types by collecting height growth data on previously established shelterbelts on the various soil groups. Additionally, SAMS will allow users to indicate the expected height of their shelterbelt at age 50 to allow a better estimation of shelterbelt height for the user’s field.

If regression equations are used to predict microclimate across a field, only H needs to be estimated for each type of shelterbelt. If, however, we use the WT model, estimates of shelter width, cross-sectional shape, and specific surface area will be needed for each type of shelterbelt. Shelter width can be estimated by developing equations to predict crown radius by using data that can be collected with height growth data. Cross-sectional shape will be estimated by using data collected for each type of shelterbelt at different ages. The most difficult characteristic to estimate will be the specific surface area, and we are trying two methods to estimate that. The first method uses a series of equations developed from data collected during intensive sampling of individual shelterbelts (Zhou et al., 2002). The second involves actually estimating specific surface area on a sample of cells within individual shelterbelts. If the WT model is shown to be effective, the method developed by De Reffye et al. (1995) will be evaluated as a technique for estimating surface area.

15.2.4 Simulating Crop Yield in SAMS

Because of the importance of maize and soybeans in the Midwestern United States, CERES MAIZE and SOYGRO are the crop models presently used in SAMS. Other crop models can be easily incorporated. A conceptual model for predicting crop yield (Figure 15.1) shows the crop models to be at the heart of SAMS. Both crop models require four input files: crop management, crop genetics, soils, and weather. Presently, crop management and crop genetics are assumed to be uniform across a field, so only one set of crop management practices and crop genetics information is used to simulate production during an individual growing season. Presently, SAMS allows a user to select one of various generic soil groups to represent the soil in a specific field. The relationship between yield and distance from a shelterbelt has been studied thoroughly (Kort, 1988) and usually varies from a curved line, such as that shown in Figure 15.2, indicating a yield increase due to shelter, to a horizontal line, indicating no shelterbelt influence. To simulate response across a field in SAMS,
yield is estimated at eight distances (1H–25H with 25H assumed to represent an unsheltered location) from the shelterbelt, which requires that a daily weather file be created for each distance to reflect differences in microclimatic differences at each distance.

Yield per hectare on a field-level basis is calculated by multiplying the estimated yield per hectare at each distance by the proportion of the field represented by that distance and summing the values. An estimate of the yield per hectare in the field without a shelterbelt is calculated using the yield estimate for 25H.

Estimated yield under shelter varies from year to year, being strongly influenced by weather during the growing season. To estimate an average yield response, SAMS is run with weather data from multiple years. In the United States, there is a national network of recording weather stations that has collected weather data for many years, which allows simulation of yield with weather data collected relatively close to any area within the north central portion of the country where maize and soybeans are generally grown. Many parts of the world lack such long-term data, which would prevent simulation of yield for multiple years.

Presently, SAMS assumes that each shelterbelt is straight, which is usually true, and infinitely long, which is obviously not true. At this time, we are not able to model microclimate for shelterbelts that are not straight or near the ends of shelterbelts. Microclimate near the ends of shelterbelts is not the same as across the field near the center of a shelterbelt.

Although we have limited data for testing the ability of the crop models to predict yield across sheltered fields, to date both CERES MAIZE and SOYGRO have clearly shown yield differences associated with microclimatic changes caused by shelter (Qi et al., 2001; Mize et al., 2005).

15.3 SIMULATING AND QUANTIFYING OTHER EFFECTS

15.3.1 Carbon Sequestration

Shelterbelts sequester carbon in the crowns, stems, and roots of the plants in the shelterbelt, and soil under shelterbelts is often higher in carbon than the soil surrounding it. Brandle et al. (1992b) provided some of the first estimates of the storage potential of shelterbelts. They estimated the average carbon storage of a 20 year old, single row conifer windbreak (9.2 mg km\(^{-1}\)) and a 20 year old, single row hardwood windbreak (5.4 mg km\(^{-1}\)). Kort and Turnock (1999) estimated that the carbon reserve in Canadian prairie shelterbelts varied from 24 to 104 mg km\(^{-1}\), depending on species and age.

Individual shelterbelts are only useful for about 50 years, however, and at the end the trees are often burned, releasing the carbon to the atmosphere for no net sequestration, except for the root system, which will slowly decompose. However, a network of variously aged shelterbelts will sequester a substantial amount of carbon, above- and belowground, while the network exists.
Aboveground sequestered carbon in a shelterbelt can be estimated relatively easily by using well-established techniques used to estimate forest biomass (Avery and Burkhardt, 2002). Estimates for a specific shelterbelt could be developed by first measuring the heights and diameters of a sample of trees, which would be combined with equations to estimate tree biomass to estimate biomass per hectare. Adjustments would be needed to reflect the difference in biomass of forest grown trees compared to shelterbelt grown trees, which tend to have considerably more branches. As carbon sequestration estimates are developed for different types and ages of shelterbelts, equations similar to what foresters describe as yield equations (Avery and Burkhardt, 2002) could be developed that would estimate sequestered carbon for shelterbelts at different ages. This is being done for the prairie states in the United States (J. Brandle, 2002, Univ. of Nebraska, personal communication).

Belowground biomass in a shelterbelt is considerably more difficult to estimate than aboveground biomass because it is much more difficult to measure and its stability varies greatly, depending upon the size of the material. Presently, SAMS estimates aboveground tree biomass but not belowground biomass. Belowground biomass will be added when reliable estimates can be made relatively easily.

The major advantage of using shelterbelts relative to the carbon budget is the indirect benefits that flow from planting fewer acres of crops. Windbreaks are placed on land that is cropped annually, and by removing such land from row crop production, annual fuel usage is reduced, resulting in a reduction of carbon dioxide emissions. Over all, the potential of these indirect benefits is about double the amount of direct carbon storage in the wood of the shelterbelt (Brandle et al., 1992b), and these benefits remain even after a shelterbelt is removed.

Although the amount of carbon sequestered by a shelterbelt or not released because the land occupied by a shelterbelt was not farmed can be estimated with reasonable accuracy, the market for that carbon has not been well established in many parts of the world (Fischer et al., 1998). Until a carbon market becomes well established for shelterbelts, carbon sequestered in shelterbelts does not have a monetary value, although its potential value can be estimated by using current prices being paid in areas where there is a market. This is the approach used in SAMS.

15.3.2 Wind Erosion

Reduced wind erosion is a well-documented effect of shelterbelts (Brandle and Kort, 1991). In some areas, reduced erosion due to shelter is more important than increased yield. There are at least two methods to quantify the impact of wind erosion in a shelterbelt system.

WBECON (Brandle and Kort, 1991; Kort and Brandle, 1991) is being modified to value a shelterbelt's influence in reducing wind erosion. In the program, a landowner or a professional will be asked to estimate the annual loss in productivity due to erosion, usually somewhat less than 0.1% but sometimes higher. Regardless of the rate, it is applied to the unprotected part of the field each year. During the first 7 years after establishing a shelterbelt, the entire field is assumed to be unprotected. Starting in the eighth year, some of the field is assumed to be protected from wind erosion. It begins to receive a yield benefit and is no longer subject to a yield reduction due to erosion. The size of the protected area, a multiple of H, increases each year, and the size of the erosion-prone area decreases each year until the maximum protected area is reached. Then the unprotected area continues to lose productivity, whereas the protected area receives the yield benefit of the windbreak.

The Wind Erosion Prediction System (WEPS) is a model that simulates wind erosion (Hagen et al., 1995). It is a process-based, daily time-step computer model that uses weather files similar to those used by the crop models. When WEPS is capable of dividing a field into subregions, it will be a powerful tool for evaluating the influence of shelterbelts on wind erosion in individual fields. Even when that happens, the erosion predictions will need to be converted into estimates of the impact on crop yield, as is being planned for WBECON. Presently, SAMS does not account for the effect of shelterbelts on wind erosion, but it will be added in the future.
15.3.3 Movement of Fugitive Pesticides and Fertilizer

The movement of pesticides and fertilizers is a significant problem in some agricultural areas (Tibke, 1988). It is, however, only a concern for relatively few days per year and a problem only when those days are windy, but shelterbelts clearly can reduce the drift problem. On the other hand, herbicide drift has killed shelterbelt trees in some areas.

The WT model that we are evaluating for use in predicting microclimate across sheltered fields can also be used to simulate the effect of a shelterbelt on chemical drift across a field. The water vapor equation in the microclimate version of the WT model provides an analog for a trace gas constituent equation. Challenges to this approach include specification of the source function (e.g., surface flux of pesticide or other vapor into the atmosphere) and rate of capture of the fugitive vapor in the shelterbelt. Until these challenges are met, the benefits and costs of shelterbelts in reducing movement of pesticides and fertilizers cannot be simulated and will not be accounted for in SAMS.

15.3.4 Response of Wildlife

Trees and shrubs are seldom found in or near agricultural fields used to produce annual crops. Introducing either of them creates structure, which is particularly attractive to birds, and cover, which attracts other animals, such as small mammals and deer. Thus, shelterbelts generally attract birds and some other animals (Johnson and Beck, 1988). Shelterbelts can serve as corridors for wildlife, if they are not too isolated from woodlands, and if they contain conifers, they offer winter cover that reduces winter mortality.

Although we know that wildlife are attracted to shelterbelts, estimating the actual numbers and species of wildlife in a particular shelterbelt is difficult. The length, number of rows, species composition, and age of the shelterbelt are important factors in determining which wildlife species might be found in a shelterbelt. Wildlife usage also depends considerably upon the condition of areas around a shelterbelt (Johnson and Beck, 1988; Beecher et al., 2002).

As simulating the response of wildlife to a shelterbelt is difficult, so is estimating the value that a farmer would be willing to pay for increased wildlife in a shelterbelt system. Many farmers are interested in having more birds around, but deer and raccoons use shelterbelts and eat crops near shelterbelts. In the Midwestern United States, shelterbelts are often excellent places for pheasant hunting in the fall after crops have been harvested (Cable and Cook, 1990). Birds, however, can do substantial damage to crops such as sunflowers. Thus, wildlife attracted by shelterbelts can represent a benefit or a cost.

SAMS will incorporate the value of the response of wildlife to a shelterbelt by allowing a landowner to indicate an estimate of the annual value of the wildlife. On the basis of responses to willingness-to-pay (WTP) questions (Drake, 1992) that will be presented to landowners in the Midwestern United States, users will be presented with the maximum, minimum, and average values and allowed to use one of these values or input their own WTP value.

15.3.5 Abundance of Natural Enemies of Insect Pests

There are a variety of natural enemies, including insects, birds, rodents, and spiders, that control insect pests in agricultural settings (Dix et al., 1995). Shelterbelts offer natural enemies food and foraging sites, protection from the elements, travel corridors, reproductive habitat, and overwintering sites for some species.

In farms with a relatively dense network of shelterbelts, natural enemy populations might be high enough to have a significant impact on insect pests and result in savings due to reduced pesticide use (Dix et al., 1995). As the influence of natural enemies decreases with distance from the shelterbelt, shelterbelts would have to be relatively close together to have a significant impact on pesticide use. However, shelterbelt networks, when they exist, typically separate shelterbelts by at
least 20H. This density of shelterbelts is probably too low to support adequate numbers of natural
eenemies to have a significant impact on insect pests.

Little research is being done on the influence of shelterbelts on natural enemies. When more is
done and estimates of the value of natural enemies are developed, their effect and value will be
incorporated into SAMS.

15.3.6 Reduction of Odor Emissions from Animal Enclosures

Shelterbelts potentially are useful for reducing livestock odor, because of their ability to scavenge
particulate matter. Most odorous compounds associated with animal enclosures are easily absorbed
onto and carried by particulate matter (Hammond and Smith, 1981; Hammond et al., 1981).
Particulate matter emanating from animal enclosures tends to form a plume that stays at or very
near ground level (Smith, 1993). When odor plumes interact with shelterbelts, some particulate
matter is adsorbed onto tree leaves, some settles out on the leeward side of shelterbelts and is easily
incorporated into the soil, and some is mixed with air above the plume, that is, diluted. The result is
a reduction in the amount and concentration of particulate matter in odor plumes. Conifers may be
more effective particle traps than deciduous species (Smith, 1984) and can be more efficient at
removing particulate matter, because leaves are on the trees all year.

Although shelterbelts can reduce odor from animal enclosures, estimating the amount of
reduction and the value of that reduction cannot be done presently but is being evaluated (Joe
Colletti, 2002, Iowa State University, personal communication). When benefits and costs associated
with odor reduction can be estimated, they will be incorporated into SAMS.

15.3.7 Aesthetic Value

Many agricultural regions, particularly in the Midwestern United States, have evolved into highly
homogenous landscapes to facilitate mechanized production. This goes against a key factor of
aesthetic values—landscape variety (Berry, 1977; Hodge, 1991). Landscape variety includes func-
tional and visual diversity at a local level, such as riparian forests for water protection and wildlife
habitat and shelterbelts for erosion control and landscape corridors. With special reference to
shelterbelts, Ronneberg (1992) noted that studies have suggested "Visual diversity... (is) preferred
to open landscape."

Most people would agree that shelterbelts increase the aesthetics of many agricultural settings;
however, assigning a monetary value to the aesthetic value of shelterbelts is difficult. Considering
the old saying, "beauty is in the eye of the beholder," some farmers would be willing to pay solely
for the beauty it adds to the landscape, whereas other farmers would see no value in its aesthetic
contribution to the landscape. Although the aesthetic value of a shelterbelt to an individual farmer is
too difficult to predict, a range of values will be estimated using WTP as described in the section on
valuing wildlife. SAMS will incorporate the value of the aesthetic impact of a shelterbelt in the same
manner that the value of wildlife is handled.

15.3.8 Other Effects

There are other shelterbelt effects, and some will be discussed briefly here. Although shelterbelts
might increase beneficial insects, they could also harbor insects and diseases that damage the crops
and weeds, which would shed seed onto the field and increase weed problems. Shelterbelts increase
biodiversity, and sometimes reduce water erosion by functioning as a filter strip or a vegetative
terrace. Coniferous shelterbelts could reduce heat loss from farm animals. These effects could be
important in some situations but are probably not of much economic value on most farms.

Another, more interesting, effect is that shelterbelts can control snow deposition. The primary
impact of that would be increasing water availability in certain parts of the field, which presently is
not accounted for in SAMS. It is an important effect that we need to incorporate.
SAMS does allow users to enter estimates of the value of the effects just mentioned and others. Users are allowed to enter the value for “Other Values or Benefits” that can apply to anything to which the user wants to estimate a positive or negative value.

15.4 FINANCIAL AND ECONOMIC ANALYSES DONE BY SAMS

Financial and economic analyses associated with shelterbelt costs are relatively straightforward, although there are many scenarios that can be evaluated. The major problem is quantifying some benefits, such as aesthetics and wildlife.

At the SAMS web site, aside from information about basic crop management practices and characteristics of the shelterbelt to be simulated and the field in which it would be located, users are asked to enter a discount rate and costs for site preparation, planting, replanting, and maintenance. They also need to enter costs for capital, management, and up to four other costs. Additionally, they can enter their estimates of the values for aesthetics and wildlife and a lump sum value for all other effects for which they wish to estimate a value.

With these values entered, SAMS will estimate crop yield at multiple locations in the field for each of the years for which weather data are available. The yield estimates are used to estimate field-level yield with and without a shelterbelt. The field-level yield estimates are combined with the costs and benefits entered by the user to estimate the marginal net value of the shelterbelt and the break-even yield, the yield increase that the shelterbelt needs to cause to break even with the shelterbelt. Also, the average maize and soybean yield across the field when the shelterbelt is mature will be calculated and displayed.

SAMS is being developed for individuals to help decide upon establishing a shelterbelt and, as such, the value associated with a particular effect is meant to reflect the value to the individual, not society. Some of the effects of shelterbelts, such as improved aesthetics, control of odor, and increased wildlife, have value to the public as well as to an individual. Policy makers could use SAMS to estimate the cost of incentives needed to encourage farmers to establish shelterbelts that could produce public goods.

15.5 FUTURE OF MODELING FIELD SHELTERBELT SYSTEMS

As global warming gradually changes the climate around the world, current agricultural practices will become increasingly unsuccessful in some areas (McCarthy et al., 2001). Shelterbelts probably will be useful in compensating for some of the impact of climatic changes. To be efficiently used, however, much more needs to be known about the impact of shelterbelts and the impact of global warming on the growth of the shelterbelt.

As most agricultural fields contain multiple soil types, SAMS, which presently only accepts one soil type in a field, will need to be modified to accept multiple soil types. Within 2 years, we plan to modify SAMS so that a user can indicate up to four soil types within a field and the relative distribution within the field.

Our research group will continue developing SAMS with a primary focus on estimating crop yield and a secondary focus on estimating the benefits and costs of other effects, such as carbon sequestration. We are broadening the area over which we are collecting maize and soybean yield data and are developing plans to collect yield data for other annual crops, such as sugar beets (Beta vulgaris L.). Any crop that has a growth model that subscribes to the IBSNAT format and has windrun as an input variable could be incorporated into SAMS, although yield data from sheltered fields will be needed to evaluate the system’s ability to predict sheltered yield for each new crop.

Interestingly, once the crop model for a species is incorporated into SAMS, it could be used to simulate the effect of shelterbelts on crop yield wherever the crop is grown. But before SAMS could be used to simulate a crop’s response to shelter in a particular area, the characteristics of the shelterbelts in that area will need to be quantified, because species used in shelterbelts vary substantially around the world.
Although SAMS presently is being developed to simulate a single shelterbelt, it will eventually simulate the effects of a network of shelterbelts, which can be on a single farm or developed by cooperating neighbors or in countries like Russia and China where networks of shelterbelts exist. Research is being started to simulate crop yield near the ends of shelterbelts. Eventually, we anticipate developing a system that uses GIS to allow an individual with appropriate training to work with individual farmers to evaluate the impact of shelterbelts at the farm level.

In summary, we have made good progress in developing a system to simulate crop production across a sheltered field and are beginning to develop techniques to estimate a few other shelterbelt effects. We plan to incorporate other crops and shelterbelt effects into SAMS and believe that it will be a useful tool for landowners who are interested in establishing shelterbelts on their land. As global warming continues, SAMS will be useful to an increasing number of landowners looking for options to help them manage their farmland.

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