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WBECON: A windbreak evaluation model 1

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Curriculum Vitae

Mr. Rasmussen has been a District/Extension Forester for the Nebraska Forest Service (NFS) in northeast Nebraska for seven years. The NFS is a state agency within the Department of Forestry, Fisheries & Wildlife of the Institute of Agriculture and Natural Resources at the University of Nebraska-Lincoln. On the district level, the NFS is a service organization that provides technical assistance to private landowners, public agencies, and rural communities on all aspects of tree planting, care and management through Rural Forestry Assistance and Urban Forestry Assistance programs.

WBECON: A WINDBREAK EVALUATION MODEL.
1. COMPARISON OF WINDBREAK CHARACTERISTICS

by: John Kort and James R. Brandle

Abstract

The development of an effective simulation model to evaluate the economic returns from an investment in a field windbreak requires a set of standard windbreak index values that will allow for comparisons for windbreak benefits over a wide range of conditions. These values should be adjustable to local conditions allowing the user to adapt the model to local cropping systems and climate. The program requests information concerning geographic location, climatic conditions, windbreak costs, cropping systems and windbreak characteristics and asks the user to verify or adjust the assigned value.

Windbreak costs for site preparation, tree establishment, weed control, maintenance, renovation and removal are presented. Twenty-eight crops are rated relative to their response to shelter. Twenty-nine different types of windbreaks are rated for protective value, mature height, mature width, mature age, lifespan and competitive zone at maturity. Twelve different windbreak designs are illustrated.

PRESENTATION SUMMARY

The development of an effective simulation model to evaluate the economic returns from an investment in a field windbreak requires a set of standard windbreak index values that will allow for comparisons of windbreak benefits over a wide range of conditions. These values should be adjustable to local conditions allowing the user to adapt the model to local cropping systems and climate.

The model is divided into two segments, an initialization program (WBINIT) and the analysis program (WBECON). The initialization program requests information concerning geographic location, climatic conditions, windbreak costs, windbreak designs and species and cropping systems. Once the user selects the parameters the program assigns index values and asks the user to verify the appropriateness of the values or to adjust the values within certain limits. This information is then stored in a data file for use in the analysis program (WBECON).

CLIMATIC AND GEOGRAPHIC INPUTS

While the program is designed to operate primarily within the Great Plains region of the U.S. and Canada, it has the capability to accommodate users in other areas. For these areas the user must enter additional information and parameters into the basic program statements. The User's Manual directs the user to the proper areas of the program and provides the necessary directions to adapt the program.

WINDBREAK COSTS

The cost of establishing and maintaining a windbreak varies with location, site conditions and cultural practices required. The program sets a range of values for each geographic region but allows the user to calculate their actual costs and to insert them into the data base. Directions and a worksheet are provided in the User's Manual to assist in setting these costs for local conditions. Practices and costs are outlined in Table 1. Renovation costs are assumed to be zero for a well managed and maintained windbreak; however, an opportunity is provided in the analysis program for these costs to be entered if desired.

WINDBREAK DESIGNS

We have developed twelve windbreak designs to accommodate different protection requirements throughout the region. When damaging winds are predominately from one direction, parallel windbreaks, perpendicular to these

Table 1. Costs in dollars for windbreak establishment, maintenance, and removal in the Great Plains and Canadian Prairies.

Practice	Can. Pr.	N.G.P	C.G.P.	S.G.P
Site Prep.	48.00	41.00	35.00	875.00
Establishment	90.00	148.00	275.00	649.00
Replant (yrs 2-5)	58.00	66.00	91.00	204.00
Maint. (yrs 6-10)	48.00	10.00	10.00	151.00
Maint. (yrs 11-90)	25.00	3.00	3.00	71.00
Renovation	0.00	0.00	0.00	0.00
Removal	600.00	1320.00	1320.00	1320.00

winds provide adequate protection. If an area is exposed to damaging winds from more than one direction, additional windbreaks are needed to provide complete protection. The windbreak designs illustrated in Figure 1 provide different degrees of protection and the user selects those designs which are appropriate for their area. The analysis program calculates the area protected for each design taking into account the type of windbreak, tree growth and wind direction.

WINDBREAK STRUCTURE

We have used six characteristics to describe windbreaks composed of commonly used windbreak species. These are: 1) protective value (PV), 2) width of the root competition zone at maturity (MCZ), 3) height at maturity (MHT), 4) mature age (MA), 5) width of the windbreak at maturity (MLO), and 6) life-span (LS). These characteristics are defined below and the values are given in Table 2.

Protective value: The protective value is a coefficient used to adjust the yield benefit due to a windbreak and is based on the relative effectiveness of the windbreak. The base value is 1.0 and is assigned to a single row eastern redcedar windbreak on 6-8 ft. spacing and a single row caragana windbreak on a 1-2 ft. spacing. All other windbreaks are related to these two standards based on windbreak structure.

Root competition zone at maturity: The competitive zone is a measure of the degree of competition between the windbreak and the adjacent crop at the mature age of the windbreak. It is expressed in feet and defines the width of the area of reduced yield adjacent to the windbreak. It is measured from the center of the windbreak and is assumed to be directly proportional to the height of the windbreak, increasing at a constant rate from year 1 to mature age.

Height at maturity: The height at maturity is the effective height of the windbreak at the mature age. These values have been developed primarily from USDA-SCS technical guides and represent an average height over a wide range of soil and climatic conditions. Of all the index values this parameter should reflect local growing conditions and should be adjusted by the user. The analysis program assumes a constant growth rate from year 1 to mature age. Mature height is assumed to be the maximum height throughout the life of the windbreak. This is a simplification of a tree growth curve but was considered to be a good approximation.

Mature age: The mature age is the age at which the tree reaches a mature height.

Width of the windbreak: Width of the windbreak is a measure of the total width of the strip of land that is removed from production and includes the width of the tree row(s) and any land included in the maintenance of the windbreak.

Life-span: Life-span is the age to which the windbreak is expected to survive and remain effective.

Table 2. Standard index values used in the field windbreak model.

WINDBREAK, SPACING	PV	MHT	MA	LS	MLO	MCZ
GREEN ASH, 3 FT	.95	40	30	70	16	48
GREEN ASH, 6 FT	.85	40	30	70	16	40
GREEN ASH, 10 FT	.75	40	30	70	16	32
GREEN ASH, 15 FT	.65	40	30	70	20	32
CARAGANA, 1 FT	1.0	16	25	80	20	16
WILLOW SPP., 8 FT	.80	45	25	50	45	54
MIXED ASH AND CARAGANA	.95	40	30	70	20	40
MIXED AM. ELM AND CARAGANA	.95	50	30	60	20	70
MANITOBA MAPLE (BOXELDER)	.85	30	20	45	45	45
GR. ASH, MAN. MAPLE, CARAGANA	.90	40	30	50	45	56
E. REDCEDAR, 6-8 FT	1.0	30	30	60	20	24
SCOTS OR AUSTRIAN PINE 6-8 FT	.85	40	30	75	20	34
CEDAR AND PINE, 8 FT	.90	30	30	60	20	29
ALT. GR. ASH AND PINE, 10 FT	.80	40	30	70	20	33
SIBERIAN ELM, 6 FT	.85	30	20	35	25	54
SIBERIAN ELM, 10-12 FT	.75	35	20	40	25	60
POPLAR OR COTTONWOOD, 10 FT	.65	65	30	50	30	110
SPRUCE, 6 FT	.95	40	40	85	30	44
SPRUCE. 10 FT	.90	45	40	85	30	45
BUR OAK, 6 FT	.80	45	40	90	25	59
BUR OAK, 12 FT	.70	50	40	90	30	63
RUSSIAN OLIVE, 4 FT	.90	20	15	35	25	30
RUSSIAN OLIVE, 8 FT	.85	20	15	35	25	30
OSAGE-ORANGE, 6-8 FT	1.0	30	30	75	35	60
SIBERIAN LARCH, 3 FT	.90	40	30	50	15	30
SIBERIAN LARCH, 6 FT	.80	40	30	50	15	30
SHORT SHRUB, 3-4 FT	1.0	8	20	50	15	8
TALL SHRUB, 4-5 FT	1.0	12	20	50	20	12
2 ROW GR.ASH/PINE, 10 FT	1.0	40	30	70	30	30

PV = Protective Value; MHT = Mature Height (feet); MA = Mature Age; LS = Life-span; MLO = Land out of production (feet); MCZ = Competitive zone.

The values in Table 2 have been derived from various sources and from our experience in the field. In all cases they form the default values and are adjustable within the WBINIT by the user. The initializatin program allows the user to identify the windbreaks to be included in their data base and asks them to accept or adjust each variable for local conditions. In addition the user may add additional windbreak designs and index values to their data base.

CROPPING SYSTEMS

Based on our experience and the literature we have developed a series of index values for 28 different crops. The index values are coefficients which are used to reflect relative crop response to protection with winter wheat having a value of 1.0. These values are listed in Table 3.

Table 3. Crop index values for 28 crops common to the Great Plains.

SPRING WHEAT	1.0	WINTER WHEAT	1.0
BARLEY	1.1	OATS	1.0
RYE	1.05	BUCKWHEAT	1.1
GRAIN SORGHUM	1.1	PEARL MILLET	1.3
CANARY SEED	1.0	CANOLA	1.2
FLAX	1.2	COTTON	1.2
CORN (GRAIN)	1.05	CORN (SILAGE)	1.2
SWEET CORN	1.3	SUNFLOWERS	1.25
POTATOES	1.2	SUGAR BEETS	1.2
SOYBEANS	1.3	DRY BEANS	1.3
FRUITING VEGETABLES	1.5	LEAFY VEGETABLES	1.5
ALFALFA SEED	1.25	ALFALFA FORAGE	1.4
SORGHUM FORAGE	1.3	MIXED GRASS FORAGE	1.3
CLOVER FORAGE	1.2	SUMMER FALLOW	0.0

SUMMARY

The values assigned in the WBINIT and used in WBECON represent our best estimates based on our experience and the literature. They are the first generation of values and will benefit from input from program users. by no means should they be taken as the final value for these important parameters. We envision that over the next several years as the program is used the values of these parameters will evolve and that sets of values will become recognized for local areas. We hope that our willingness to share the program on an unlimited basis will encourage users to share their data files with us as we continue to refine the model and its accuracy.

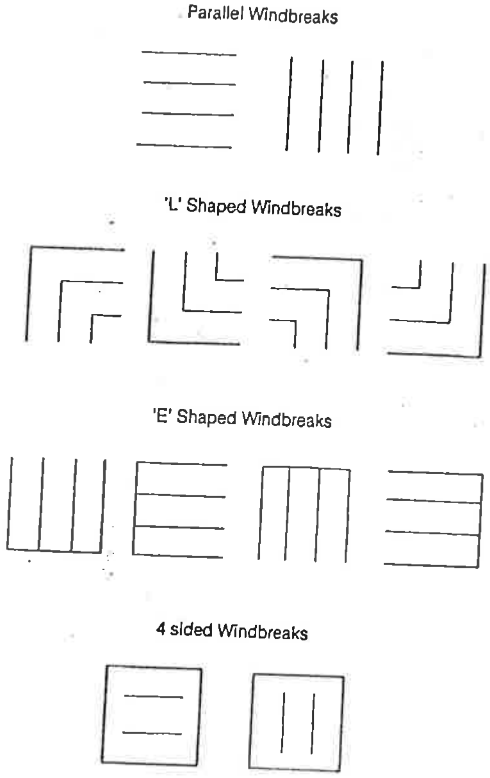

Figure 1. Windbreak designs available for use in the windbreak evaluation program.

Curriculum Vitae

Jim is an Associate Professor of Forestry in the Department of Forestry, Fisheries and Wildlife at the University of Nebraska. His area of research is the effects of shelter on crop production and over the last several years has been working to develop a windbreak economics model. Last summer he was on faculty development leave at the PFRA Shelterbelt Centre in Indian Head, Saskatchewan where he and John Kort combined their efforts. The two papers today are a result of their efforts.

WBECON: A WINDBREAK EVALUATION MODEL. 2. ECONOMIC RETURNS FROM A WINDBREAK INVESTMENT IN THE GREAT PLAINS

by: John Kort
James R. Brandle

Abstract

An economic simulation model to determine the value of a windbreak investment has been developed. The model determines the net present value of field windbreaks under a variety of situations including different windbreak designs, cropping patterns, economic conditions and land owner inputs.

Sensitivity analysis of each of the components indicated that the investment was most sensitive to the increases in yield and discount rate. The investment was least sensitive to grain price and base yield before shelter.

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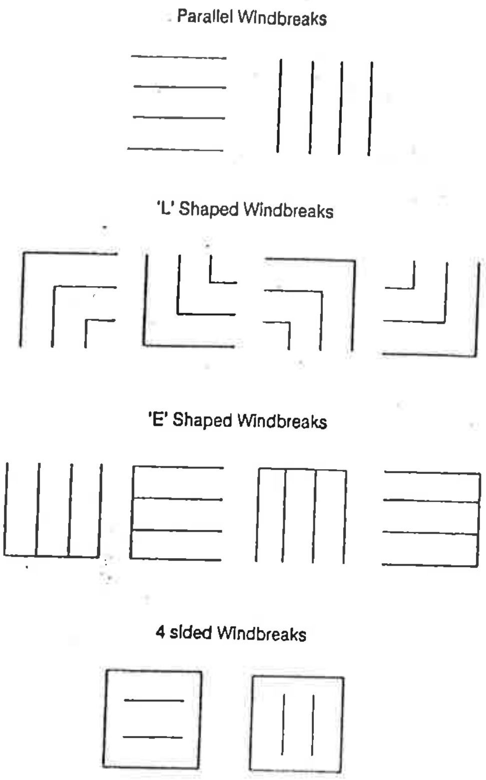

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PRESENTATION SUMMARY

INTRODUCTION:

Although shelterbelts are known to increase crop yields, the yield increase depends on a number of environmental and agronomic factors. Many of these factors were discussed by Kort (1988) in a review on benefits to field and forage crops. But knowledge of yield increases alone does not give a true picture of the economic viability of field shelterbelts. Shelterbelt input costs, life span, growth rate and savings from the reduction in tilled land also need to be taken into account. This paper describes a BASIS computer program called "WBECON" which calculates the return from a shelterbelt system installed to protect a 160 acre (65 ha) field. The analysis is based on user inputs and field measurements.

INPUTS:

Brandle and Kort (1991) have discussed the derivation of many of the values used in the program. Inputs to this model include: soil and climatic data, windbreak costs, windbreak characteristics and cropping costs. Additional inputs are entered by the user and will vary from one farm to another.

CALCULATIONS:

The model calculates the yield increase of a 160 acre (65 ha) field which is protected by a shelterbelt system chosen by the user. The benefits are calculated for each year of the shelterbelt's life and summarized over the shelterbelt's life-span. Data for yield increases are taken from averages compiled from Stoeckeler (1962), Lehane and Nielsen (1961), and McMartin et. al (1974).

In any given location, the program determines the distance, in multiples of H (H is the shelterbelt height) from each shelterbelt which affects the yield at that location. If more than one shelterbelt affects the location, the program adds the benefits together. A maximum value found by averaging peak values leeward of single north-south and east-west shelterbelts is used to limit the sum of benefits. The resulting increases for all locations are averaged over the entire field. The percent increase is then multiplied by three coefficients: a protective value (PV), a measure of relative shelterbelt effectiveness; a crop index (CI), a measure of crop responsiveness; and a soil index (SI), a measure of moisture stress to the crops. Yield losses due to land taken up by the trees and the competition by tree roots are subtracted from this value to produce a net average yield increase as a percent of the unprotected yield input by the user. These values are more fully discussed by Brandle and Kort (1991).

Since shelterbelts are most effective when perpendicular to prevailing winds, the computer calculates, based on the entered wind direction and shelterbelt design, whether the wind is perpendicular, parallel or diagonal to the chosen shelterbelt design. Yield benefits from diagonal winds are calculated to be intermediate between the benefits from perpendicular and parallel winds.

RESULTS AND DISCUSSION:

The model was run under a number of different scenarios in which the assumptions or factors used in the calculations were changed in a systematic manner to determine their effect on the main indicator of economic value, the net present value (NPV), using a five percent discount rate, of the shelterbelts over their life-span. Although the model includes shelterbelt and crop species common to the entire Great Plains, this analysis was conducted with trees and crops commonly used on the Canadian prairies and costs and benefits are expressed in Canadian dollars.

As standard inputs, we used a continuous spring wheat rotation with an input cost of $70/ac ($173/ha), a price of $3/bu ($109/T) and a yield of 30 bu/ac (2.04 T/ha). The economics were determined for single row shelterbelts of green ash **(Fraxinus pennsylvanica lanceolata** (Borkh.) Sarg.) at a 6 ft. (1.8m) in-row spacing. We assumed four parallel shelterbelts arranged perpendicular to the prevailing winds.

When four parallel shelterbelts, each 2640 ft. (800m) in length, were assumed, caragana was found to be less valuable than green ash, mainly due to its shorter height with a NPV of $6,799 compared to $11,534 for green ash. However, because of its greater protective value, when eleven caragana shelterbelts were planted on the land, the NPV was $17,453. This was more than for green ash, which yielded optimum benefits of $12,163 when five shelterbelts were planted on the land (Fugure 1).

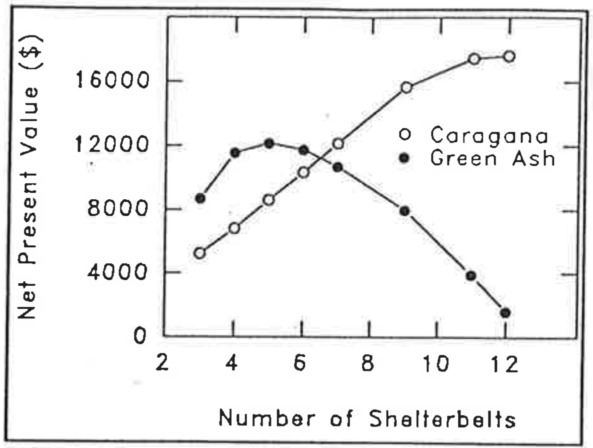

Figure 1. The effect of the number of green ash or caragana shelterbelts on their NPV on 160 acres (65 ha) of land.

Comparisons of different species were made using four shelterbelts in each case (Figure 2). The NPV for each species is not the maximum obtainable but reflects differences in height at maturity and other species characteristics. The highest NPV's were found for an ash-Caragana mixture ($14,472) and for pine ($13,131). Seven other designs also had high NPV's over $10,000 while the lowest NPV's were found with poplar (-$1,322), Siberian elm ($4,730) and short shrub barriers ($3,071). Poplar and Siberian elm are competitive and short-lived species while the low NPV from the shrub barrier was attributed to its height.

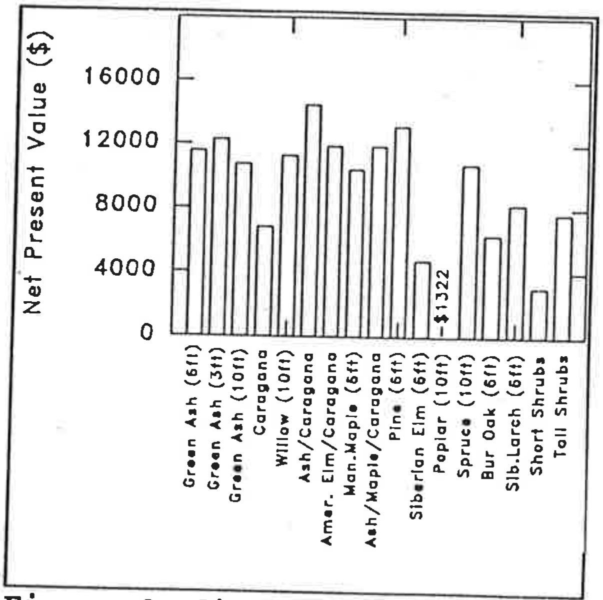

Figure 2. The NPV of seventeen common or potential shelterbelt designs at four shelterbelts per 160 acres (65 ha).

NPV was directly proportional to the protective value (PV), the crop index (CI) and the soil index (SI). The greatest percent yield increase resulted from dense shelterbelts, sensitive crops and crops which were drought-stressed (i.e. PV, CI and SI were high). The increase in NPV due to an increase in any of these indexes was greater for green ash than for caragana.

Shelterbelt width is often a matter of concern to farmers since they feel that wider shelterbelts reduce their yields. Our analysis showed, however, that the amount of land taken out of production at planting and the width of the shelterbelt at maturity had relatively little influence on the NPV. This was because any width increase of the shelterbelts was in the tree root zone which is generally an unprofitable cropping area. Competitiveness by shelterbelts depends on their root spread and the NPV of a shelterbelt depended strongly on the competitiveness of the trees. The poor returns of Siberian elm and poplar shelterbelts were attributed at least partly to their competitiveness while the root spread of green ash and caragana is much smaller, making them more suitable for field shelterbelts.

Life-span of the shelterbelts was relatively less important to the NPV as the shelterbelts became older because the five percent discount rate reduced the value of annual benefits in later years. The age at which the trees reached their mature height, however, affected the NPV of shelterbelts more strongly. A faster growth rate increased NPV substantially since dollars earned in the early years of the shelterbelt system had a greater present value than benefits later on. However, fast-growing species are often competitive and short-lived so that growth rate is not the most important characteristic of a good field shelterbelt species.

NPV's of shelterbelts were extremely dependent on the discount value used in the calculations and were approximately three and a half times greater at a three percent rate than at a seven percent rate (Figure 3). Although the application of such discount rates to soil conservation measures can be questioned, these results show that, from a crop production standpoint, shelterbelts were generally a good investment.

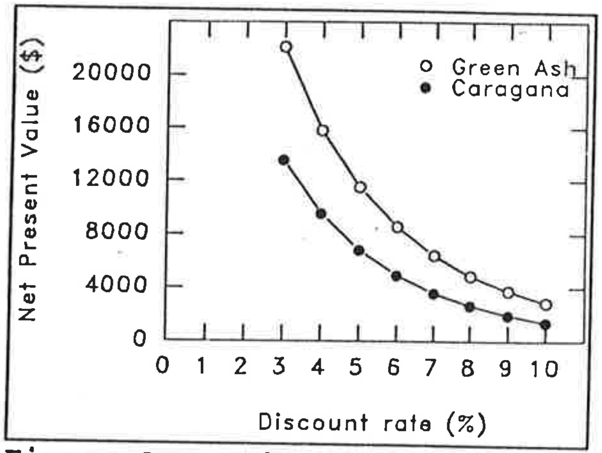

Figure 3. The effect of discount rate on the NPV of green ash and caragana shelterbelts.

A number of the factors discussed above affected the crop yield increase caused by the shelter. Others, such as land occupied and shelterbelt and crop input costs, were independent of crop yield increase but did affect the NPV. The yield increase (excluding land occupied and competition) was varied directly to determine the yield increase that would be necessary from a four row green ash or caragana array to return a positive NPV. The break even yield increase for four caragana shelterbelts was found to be 2.5 percent while for four green ash shelterbelts, a 6.2 percent yield increase was necessary (Figure 4). The slopes of the lines for the two species were similar, giving an increase in NPV of $1,579 for each percent yield increase for caragana and $1,404 for green ash. Caragana, at eleven shelterbelts per 160 acres (65 ha) required a break even yield increase of 6.5 percent and NPV improved by $1,637 for each percent yield increase.

Cropping variables including crop inputs, crop price and unsheltered crop yield also affected the NPV of the shelterbelts. As crop input costs increased, the NPV increased in a linear fashion since costs were reduced but the income from the crop remained the same. Crop price and unsheltered crop yield affected NPV more for green ash than for caragana, since the percent yield increase was greater in a green ash system.

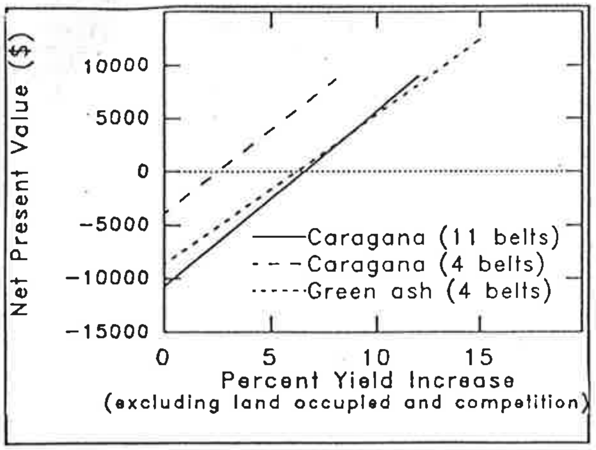

Figure 4. The effect of shelter-induced crop yield increase on the NPV for three shelterbelt systems.

SUMMARY AND CONCLUSIONS:

Many factors affected the NPV of a shelterbelt system but shelterbelt systems commonly used in western Canada such as green ash and caragana yielded positive NPV's using a series of reasonable assumptions under continuous wheat culture. NPV's of $5,354 to $12,374 were found for well designed green ash shelterbelt systems resulting from yield increases of between 10 percent and 15 percent (excluding land occupied and competitive decreases). For caragana, NPV's ranged from $3,954 to $8,691 based on yield increases of 5.0 percent to 8.0 percent. For the scenario of winter wheat in Nebraska protected by four Eastern Redcedar shelterbelts, NPV's ranged from $5,847 to $13,494 based on yield increases of 5.0 percent to 10.0 percent.

The computer program "WBECON" is a useful tool for analyzing shelterbelt benefits and can be used for extension as well as for policy analysis. Since the program is written in BASIC, users with some programming knowledge can, with the use of the manual, examine and change basic assumptions to accurately reflect shelterbelt effects in their area.

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Curriculum Vitae

Shelterbelt biologist at Agriculture Canada's PFRA (Prairie Farm Rehabilitation Administration) Shelterbelt Centre, Box 940, Indian Head, Saskatchewan, S0G 2K0 - Phone (306) 695-2284. The Shelterbelt Centre produces over 6 million coniferous and deciduous tree and shrub seedlings annually which are shipped to eligible prairie farmers for planting in shelterbelts to protect their fields and farmsteads. The Shelterbelt Centre also does extension for the shelterbelt program and applied research related to various aspects of nursery production shelterbelt establishment and usage. The shelterbelt biologist helps to develop shelterbelt design and usage recommendations and conducts studies to evaluate shelterbelt benefits for soil conservation and crop protection.