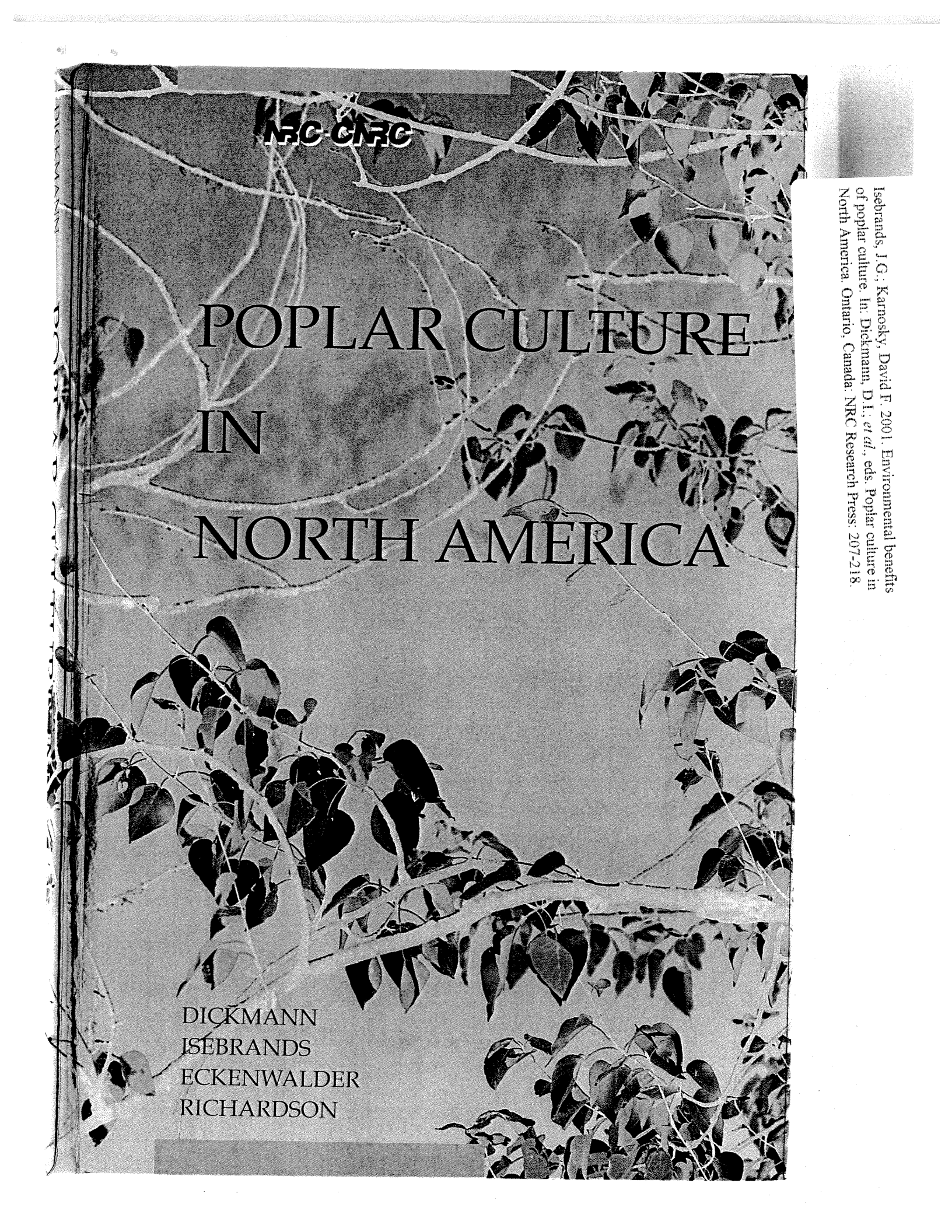




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POPLAR CULTURE IN NORTH AMERICA

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Poplar Culture in North America

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CHAPTER 6

Environmental benefits of poplar culture

J.G. Isebrands and David F. Karnosky

*To plant trees is to give body and
life to one's dreams of a better world.*

Russell Page

Introduction

Poplars have important values above and beyond wood or fiber production. Poplars have been planted for environmental purposes for centuries. There are reports of poplar plantings dating back to early Chinese history and biblical times in the Middle East. When immigrants came to North America in the 18th and 19th century, they often brought cuttings of their favorite poplar to plant on their new-found land or garden in the New World. Thus, the long history of planting poplars in the Old World was preserved and continued in the New World. J.E. Rogers (1906) wrote about the merits of planting cottonwood (*Populus deltoides*) — “it can be planted for shade and ornament, for windbreaks and to hold banks of streams — it endures heat and soot, and has dignity with added years.” Because the early settlers were mostly agrarian, they often planted native cottonwoods for wind and snow protection of their farmsteads and animals as well as to decrease soil and wind erosion; but there were also a significant number of linear plantings of poplars in cities for protection, visual screens, and aesthetics.

In this chapter, our primary focus is on current uses of poplars for environmental purposes. The use of poplars for shelterbelts on the prairies is not new, as both the United States and Canada have had a long history of shelterbelt programs (Munns and Stoeckler 1946; Roller et al. 1972; Kort and Turnock 1996). No matter which

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environmental use one pursues with poplar planting, it is essential that one choose the appropriate clone for the intended site and use (Dickmann and Isebrands 1999). Consideration must be given to soil, microclimate, pests and diseases, and environmental ethics (i.e., exotic versus native material) in making this choice. We cannot emphasize enough the importance of this point, as in our experience there are innumerable examples of planting failures due to hasty deployment of the inappropriate poplar clone for the site.

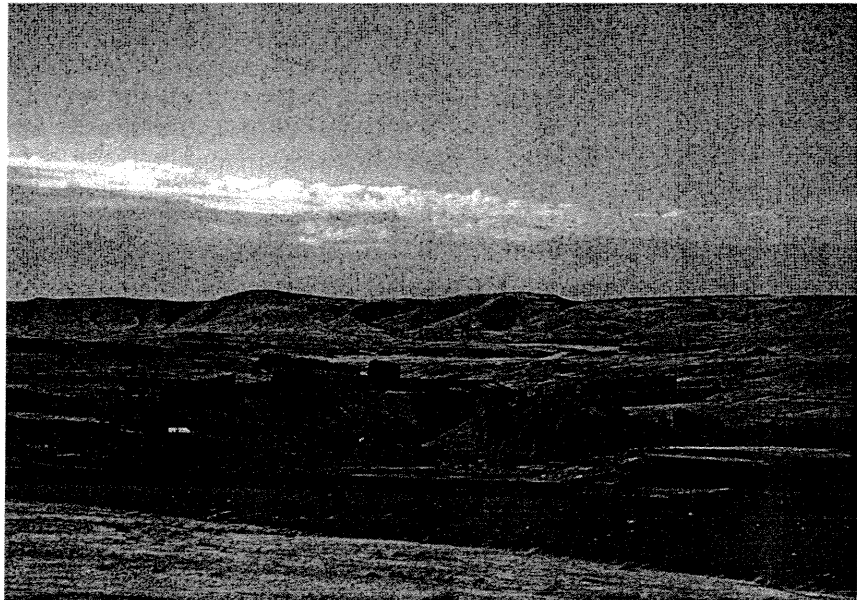
Protection plantings: windbreaks and shelterbelts

Poplars have been used for farmstead windbreaks and field shelterbelts in North America since the days of early settlement. The early settlers used poplars because they grew rapidly under various soil, site, and climatic conditions, and provided rapid protection to farmsteads, livestock, and crops (Scholten 1988; Zsuffa et al. 1996). By definition, windbreaks are single or multiple rows of trees established for environmental purposes, usually around farmsteads. Shelterbelts are usually larger in size, surrounding fields of agricultural crops. Native poplars, (e.g., cottonwood) were primarily used in the early days (Jones and Parker 1916), but subsequently shelterbelt tree improvement programs identified hybrid poplars with low branching crowns, rapid growth, and drought resistance, which were considered more desirable for windbreaks and shelterbelts (Roller et al. 1972). Recently, the pendulum has swung back in the direction of native poplar species. For example, the Prairie Farm Rehabilitation Administration (PFRA) Shelterbelt Centre at Indian Head, Saskatchewan, Canada, currently produces only *P. deltoides* 'Walker' and three clones selected from its open-pollinated offspring (PFRA 1999).

Farmstead windbreaks of poplars protect farm homes, buildings, equipment, orchards, and livestock from cold winter winds. They moderate summer heat and winds, improve living conditions for people and animals thereby increasing farm value, beautify the landscape, decrease noise and dust, and provide wildlife habitat (Fig. 1). Field shelterbelts protect crops by decreasing soil erosion and moisture loss, filter field runoff, increase populations of wildlife and beneficial insects, serve as a site for animal manure disposal, and produce biomass for wood and energy (Andre 1960). Shelterbelts have been shown to increase crop yields by up to 20% by decreasing stress on the plants. In the prairie states and provinces, poplars are also used as living snow fences to keep blowing snow off roads and access drives. They, thereby, save energy, store snow at low cost, provide wildlife habitat, improve aesthetics, harvest water in dry regions, and provide long-term protection over the years.

A new concept called "timberbelts" recently has been introduced by agro-foresters. Timberbelts are multiple-row windbreaks designed to provide all the environmental benefits of windbreaks and shelterbelts, while also producing economic benefits from salable small-diameter wood products on short rotations

Fig. 1. Farmstead shelterbelts of poplars protect orchards and vineyards along the Columbia River in eastern Oregon and Washington.



(i.e., 7–10 years) or large-diameter material on longer rotations. Poplars are ideally suited for the timberbelt concept, providing farmers additional income with potential markets for pulp, oriented strandboard, veneer, solid wood products, and carbon credits (Kuhn and Josiah 2000).

Erosion control

By integrating engineering and biological expertise, poplars and willows can be used to control the erosion of banks of streams, rivers, and reservoirs. Poplars (and willows) are combined with manmade structures (i.e., rock toes) to protect natural beauty and valuable personal and cultural properties along the rural or urban stream or reservoir banks. The poplars' roots bind to the toes and strengthen the stream banks where they are planted. This approach decreases soil erosion on valuable property and maintains a more natural stream or reservoir bank without increasing stream flow or bank erosion. The advantages of erosion control are both environmental and economic; natural plant materials are low cost, provide natural habitat, minimize flooding, and are self-sustaining (Illinois State Water Survey 1999). The approach is currently being used extensively throughout the Mississippi river watershed. It is notable that poplars and willows are also beginning to be used to preserve Native American cultural sites along its tributaries.

Riparian buffer systems

Poplars are well suited for riparian buffer systems in North America and in recent years have received increased attention from farmers and farm agencies. Riparian buffers are by definition streamside plantings of trees, shrubs, or grasses that intercept contaminants from both surface runoff water and ground water before they reach the stream (Fig. 2). Poplars (or willows) protect streambanks from soil erosion and act as filters from the adjacent fields or urban landscape before the contaminants such as excess nitrates and pesticides reach the stream. Studies show that riparian buffers of poplars can retain as much as 70–90% of nitrates and 75% of sediments compared to unbuffered streams (Haycock and Pinay 1993). The trees along the streams in many parts of North America also provide shade to keep water cool for trout and salmon habitat. Riparian poplar buffers also provide improved wildlife habitat, decreased flood damage, improved biodiversity, value from recreational hunting and fishing, and economic returns from biomass and wood products. These buffers will increase in importance as financial incentives to landowners from state and federal agencies become more popular. Such incentives are needed to make riparian buffers more economically attractive to landowners and to reward them for their environmentally based management practices.

Not all poplars are suited for planting in riparian areas. Many hybrid poplars are not flood tolerant and should not be planted on land that is subjected to frequent flooding. Those lands are more suited for plantations of native cottonwoods,

Fig. 2. Riparian buffer of poplars and willows along the Minnesota River in south central Minnesota.



balsam poplar, and cottonwood hybrids, as they are better adapted to wetter soils in riparian ecosystems.

Phytoremediation and wastewater reuse

Phytoremediation and wastewater reuse are emerging technologies that are cost effective, aesthetically pleasing, and environmentally sound approaches for cleaning up and remediating contaminated soils and water. Poplars and willows are the two most common tree genera being used for phytoremediation because they grow rapidly, are easily propagated, and adapt well to riparian sites. By definition, phytoremediation is the use of green plants for on-site risk remediation of contaminated soils, sludges, sediments, and groundwater, through contaminant removal, degradation, or confinement (U.S. EPA 1998). Poplars are being used throughout North America to clean up sites with heavy metals, salts, pesticides, solvents, explosives, radionuclides, hydrocarbons, and landfill leachates. Poplars are well suited for phytoremediation because they can remove contaminants from soil and water in several ways, including degrading them, confining them, or by acting as filters or traps. Poplars are also being used as vegetative caps on municipal and industrial landfills because they take up large quantities of water from rainfall and groundwater. This consumption of water decreases the tendency for surface and groundwater contaminants to move toward drinking water aquifers, streams, or lakes.

There is also evidence that poplars are particularly useful in degrading chlorinated solvents such as trichloroethylene (TCE). Researchers at the University of Washington are using this approach in the Pacific Northwest of the U.S., and similar approaches may be possible with poplars adapted to other regions of North America.

Poplars are also well suited for disposal of agricultural, industrial, and community wastewater. Because poplars take up large quantities of water (see Chap. 3), they are an ideal woody plant for secondary wastewater management. They are a low cost alternative to wastewater treatment systems and wastewater distribution systems. The wastewater provides the poplars with essential water and nutrients, and the trees provide an aesthetic, economic, and environmentally sound system. The trees decrease soil erosion, provide protection from wind, and produce valuable biomass and wood products while performing an important environmental benefit. Poplars have also been used in the Northeastern U.S. and Canada for strip mine reclamation (Davidson 1979).

On agricultural land, poplars can be used for taking up excess irrigation water that often contains high levels of nutrients, pesticides, and other contaminants. Poplar plantations also have potential for applications of livestock wastes from dairies, cattle, hog, and poultry confinement operations. For example, large dairy operations are expanding into the arid portions of the western U.S. Some dairy

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Fig. 3. A poplar plantation in Woodburn, OR, used to take up and reuse municipal secondary treated wastewater. Note wastewater emitter to the right of the tree in the foreground.



operators are using hybrid poplars as an alternative for applying wastewater to their land. Test plantings of hybrid poplars, irrigated with dairy wastewater, will help determine their viability to protect water quality and produce wood products. The trees can also serve as a buffer between the operations and streams or public access areas. We believe these applications are likely to increase in importance as agricultural regulations become more stringent.

In communities, poplar plantations have value for managing municipal and industrial wastewater and landfill leachate (Smesrud et al. 2000). The poplars take up the nutrient-laden wastewater that might otherwise contribute to problems of nutrient loading in streams. The communities then reap the same economic and environmental benefits that are provided by poplars in agricultural settings (USDA 2000).

There are several municipalities currently using poplar plantations for their wastewater treatment. Notably, the city of Woodburn, OR, in cooperation with

CH2M Hill, Inc., of Portland, OR, is discharging secondary treated wastewater (5 million L/day) that has high levels of ammonia on a nearby 34 ha poplar plantation (Fig. 3). The results have been so successful that the project is being expanded to 120 ha.

Bioenergy

Poplars are currently being used as an environmentally acceptable source of biomass for wood and energy. Wood chips can be mixed with traditional fuels such as coal to produce electricity. This approach is cleaner, cheaper, and more suitable than coal alone. The forest products industry in the western U.S. is growing poplars on short rotations for fiber (i.e., less than 10 years), and after chipping the aboveground portion of whole trees, the residual biomass is used for hog fuel in the pulp mill to generate a renewable, low-polluting source of electricity (Fig. 4). Poplars are also used extensively as a local source of firewood throughout North America.

The U.S. Department of Energy (DOE) Biofuels Feedstock Development Program (BFBP) has been funding research on biofuels with poplars and willows

Fig. 4. Piles of residual barking chips from a Fort James Corporation whole-tree chipping operation of short-rotation hybrid poplars in western Oregon are loaded for hog fuel.



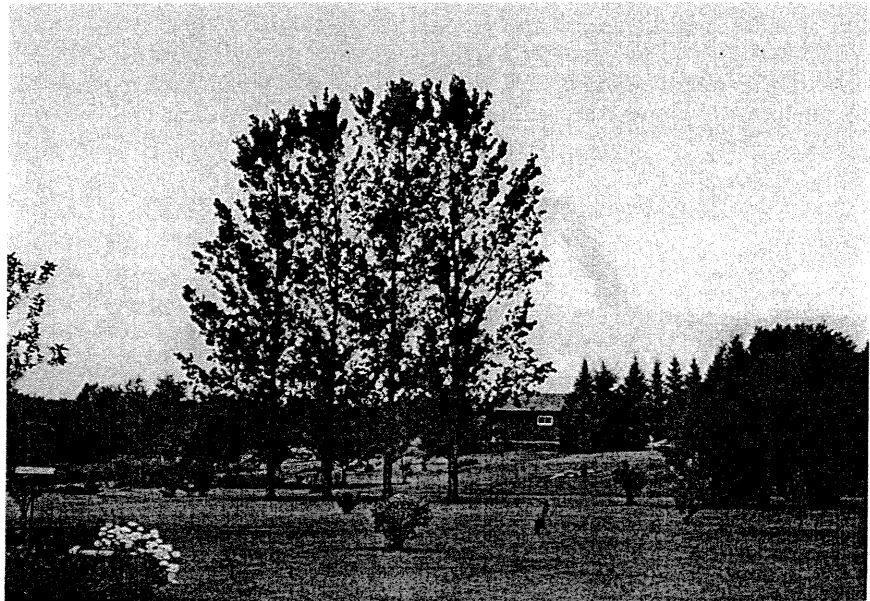
since the early 1970's. Their goal has been to develop and demonstrate environmentally acceptable crops and cropping systems for low cost, high-quality biomass for energy. At this time, there are no commercial operations that depend totally upon poplar biomass as a fuel source. However, a 50 MW power plant that utilizes whole-tree hybrid poplar biomass as a fuel is under construction in southeast Minnesota. Over the years, millions of U.S. dollars have been made available from DOE to various research institutions across North America to improve short-rotation poplar crops through genetics, physiology, pathology, silviculture, and environmental studies.

Carbon sequestration

As the world's population grew and the use of energy increased, atmospheric concentration of carbon dioxide (CO₂) has increased dramatically. Continued increases may have significant effects on the global environment and economy through climate change and global warming.

Trees provide a natural mitigation strategy by capturing and storing CO₂ in their biomass and in the soil, while in turn releasing oxygen back to the atmosphere through the process of photosynthesis. Establishing fast-growing poplar windbreaks, shelterbelts, amenity plantings, and short-rotation plantations thereby

Fig. 5. Landscape planting of hybrid poplar provides a visual screen in northern Wisconsin.



hold promise as a viable carbon sequestration strategy throughout North America. For example, Kort and Turnock (1996) reported that poplar shelterbelts on the Canadian prairies could contain between 61 and 222 tons of carbon per kilometer after 40 years, depending on the soil type. Efforts are underway in the U.S. and Canada to offer payments or carbon credits to growers for carbon sequestration and storage as part of the United Nations 1997 Kyoto Protocol for stabilizing carbon dioxide levels in the earth's atmosphere. Poplars in North America may well play an important role if this protocol is approved and implemented.

Urban amenity plantings

The genus name *Populus* is derived from the Latin "*arbor populi*" — the tree of the people. It is an appropriate name, as poplars have been used for urban amenity plantings historically throughout the world. Planting poplars provides benefits to individuals and communities throughout North America. These benefits are primarily environmental, economic, and psychological. They also provide other social benefits including aesthetics, historic preservation, and living memorials.

The environmental benefits of poplars include moderation of summer and winter climate, improvement of air quality, protection of water reserves, and creation of bird and other wildlife habitat. A single poplar tree is said to provide cooling to a house equivalent to a single room air conditioner. Poplars also help screen homes from heavy wind, and they filter the air we breathe by removing dust particles and air pollutants such as ozone and sulfur dioxide (Karnosky 1976). They intercept water, store it, and decrease runoff, thereby reducing soil erosion. Poplar trees are utilized by squirrels, songbirds, and other animals for food, shelter, and nesting sites. Psychologically, people feel more peaceful and serene in the presence of trees.

Community benefits of poplar plantings include enhanced property values and privacy, as well as visual screens of objectionable views (Fig. 5). Poplars decrease noise and decrease glare and reflection. They enhance the value of schoolyards, other public and industrial areas, serve as arboretum and landscape trees, beautify city streets and highways (Fig. 6), and make golf courses more scenic and challenging (Fig. 7). On the whole, poplar amenity plantings and other trees enhance the quality of life of community residents.

Climate change

Tropospheric carbon dioxide (CO₂) and ozone (O₃) are increasing simultaneously in the atmosphere as a result of increased human activities such as fossil fuel burning and land use change. Our research has shown that increases in these greenhouse gases will affect the future health and productivity of poplar trees and stands (Karnosky 1976; Isebrands et al. 2000). In general, poplars are very sensitive to climate change episodes; for example, poplar growth and productivity

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Fig. 6. Highway planting of hybrid poplars for aesthetics and soil erosion control in northern Iowa.



Fig. 7. Hybrid poplars planted on a golf course in central Wisconsin for beauty and a challenge for players.

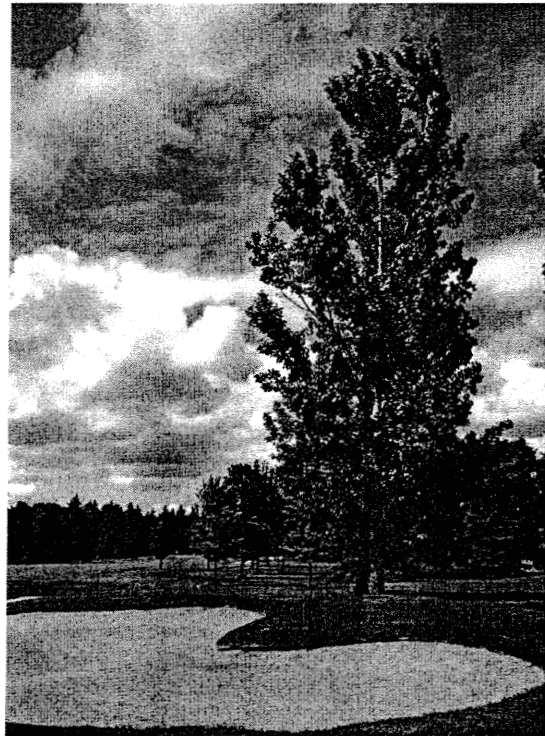
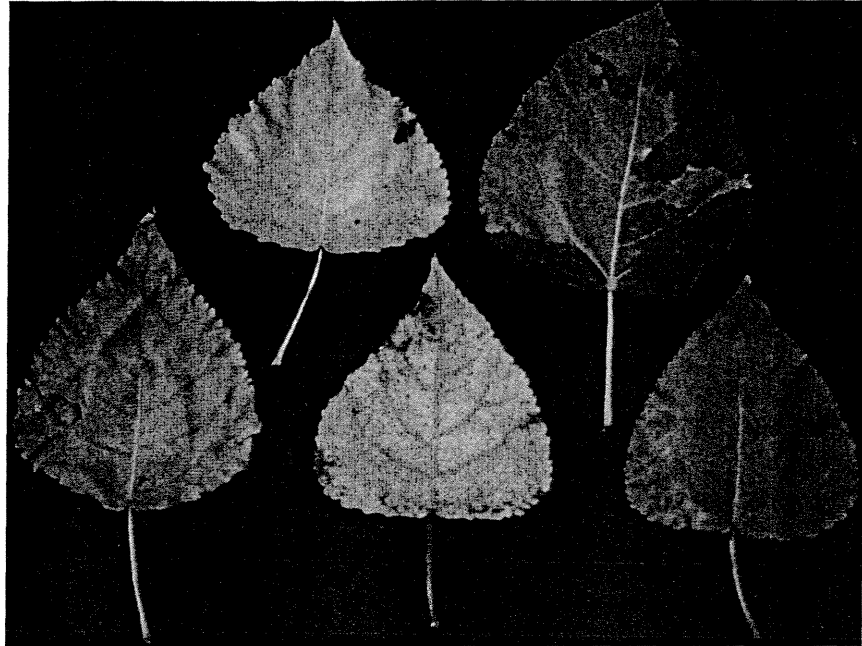


Fig. 8. Hybrid poplars vary in their sensitivity to tropospheric ozone exposure.



is increased by elevated CO_2 concentrations and decreased by sustained elevated O_3 concentrations (Fig. 8). Our results show that certain poplar clones are more sensitive to simultaneous interacting elevated CO_2 and O_3 . With hybrid poplars, one can choose specific hybrid poplar clones for planting in high air pollution environments (Dickson et al. 1998). Aspen (*Populus tremuloides*) clones also range in sensitivity from very sensitive to intermediate to very tolerant to these interacting stressors. However, our results show that on the whole, poplar growth will be less in a future climate scenario characterized by increased air pollution and elevated CO_2 than in today's climate. Future climate scenarios may also affect disease incidence as well as the size and severity of aspen leaf and wood boring insect populations. Fortunately, the large genetic diversity of poplars will likely allow us to continue our environmental use of poplars well into the future.

In summary, the environmental uses of poplars for protection, erosion control, riparian buffers, phytoremediation, bioenergy, carbon sequestration, urban plantings, and CO_2 abatement will likely increase in the future as our population and social environmental needs increase. At the same time, society will reap the important aesthetic and psychological benefits that poplars inherently provide.

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References

- Andre, F. 1960. Midwest farm handbook. Iowa State University Press, Ames, IA. pp. 404–418.
- Davidson, W.H. 1979. Hybrid poplar pulpwood and lumber from a reclaimed strip mine. USDA For. Serv. Res. Note NE-232. 2 pp.
- Dickmann, D.I., and Isebrands, J.G. 1999. Caveat emptor. *Am. Nurseryman*, **109**: 60–65.
- Dickson, R.E., Coleman, M.D., Riemenschneider, D.E., Isebrands, J.G., Hogan, G.D., and Karnosky, D.F. 1998. Growth of five hybrid poplar genotypes exposed to interacting elevated CO₂ and O₃. *Can. J. For. Res.* **28**: 1706–1716.
- Haycock, N.E., and Pinay, G. 1993. Groundwater nitrate dynamics in grass and poplar vegetated riparian buffer strips during winter. *J. Environ. Qual.* **22**: 273–278.
- Illinois State Water Survey 1999. Streambank erosion. Misc. Publ. No. 149.
- Isebrands, J.G., Dickson, R.E., Rebbeck, J., and Karnosky, D.F. 2000. Interacting effects of multiple stresses on growth and physiological processes in northern forests. *In Responses of northern US forests to environmental change. Edited by R.E. Mickler, R.A. Birdsey, and J. Hom.* Springer-Verlag, Berlin, Germany. pp. 149–180.
- Jones, E.R., and Parker, E.C. 1916. Farm economy. Twelve courses of agriculture. H.L. Baldwin Publ., Minneapolis, MN. 416 pp.
- Karnosky, D.F. 1976. Threshold levels for foliar injury to *Populus tremuloides* by sulfur dioxide and ozone. *Can. J. For. Res.* **6**: 166–169.
- Kort, J., and Turnock, R. 1996. Biomass production and carbon fixation by prairie shelterbelts. PFRA Shelterbelt Centre Suppl. Rep. 95-6. 14 pp.
- Kuhn, G.A., and Josiah, S.J. 2000. Timberbelts: windbreaks that enhance production and produce profitable wood products. Gen. Tech. Rep. NC 215. p. 101.
- Munns, E.N., and Stoeckler, J.H. 1946. How are the Great Plains shelterbelts? *J. For.* **44**: 237–257.
- PFRA Shelterbelt Centre. 1999. Description of poplar clones. <www.agr.ca/pfra/shbpub/shbpub7.htm> (accessed 14 Feb. 2001).
- Rogers, J.E. 1906. The tree book. Doubleday and Page, New York. 571 pp.
- Roller, K.J., Thibault, D.H., and Hindahl, V. 1972. Guide to the identification of poplar cultivars on the prairies. Environment Canada, Ottawa, ON. Catalog No. FO 47-1311. 55 pp.
- Scholten, H. 1988. Farm shelterbelts, University of Minnesota, St. Paul, MN. NR-BU-0468.
- Smesrud, J., Dickey, J., Asare, S., Cox, A., Lanier, A., Jordahl, J., and Madison, M. 2000. Beneficial reuse of landfill leachate with hybrid poplar. USDA For. Serv. Gen. Tech. Rep. NC-215. p. 167.
- U.S. Department of Agriculture. 2000. Working trees for treating waste. USDA NPS 00-0254. 6 pp.
- U.S. Environmental Protection Agency. 1998. A citizen's guide to phytoremediation. EPA 542-F-98-011. 6 pp.
- Zsuffa, L., Giordano, E., Pryor, L.D., and Stettler, R.F. 1996. Trends in poplar culture: some global and regional perspectives. *In Biology of Populus and its implications for management and conservation. Edited by R.F. Stettler, H.D. Bradshaw, Jr., P.E. Heilman, and T.M. Hinckley.* NRC Research Press, Ottawa, ON. pp. 515–539.