RMJ

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The Agriculture and Forestry Issue: Looking to the Future

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CENTER *for* RURAL POLICY *and* DEVELOPMENT

Seeking solutions for Greater Minnesota's future

The Center for Rural Policy and Development, based in St. Peter, Minn., is a private, not-for-profit policy research organization dedicated to benefiting Minnesota by providing its policy makers with an unbiased evaluation of issues from a rural perspective.

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Center for Rural Policy and Development
600 S. Fifth Street, Suite 211 • Saint Peter, Minnesota 56082
(507) 934-7700 • (877) RURALMN

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Editor's note

Marnie Werner

When we started approaching authors for this year's Rural Minnesota Journal, we explained to them that the focus of agriculture and forestry should be not so much on these two topics themselves but the impact they have on the communities dependent on them. What we got was an interesting mix of discussions, ranging from the issue of water quality policy to Minnesota's place in the global marketplace.

When I consider the role agriculture and forestry have played in Minnesota's history, it's tempting to think that role has diminished over the years to some bit part in today's economy, and looking at the numbers of people involved, that would seem to be true. One hundred years ago, more than half the people in the state lived on farms; today that number is more like 2%. Forestry was a tremendous force in settling the state and constituted Minnesota's first major economic boom, but today there are no longer miles of timber floating down the rivers to the major lumber mills. But these changes shouldn't fool anyone.

No one knows how times have changed more than a farmer or someone in the forest industry. New technology, the financial landscape and that overarching issue of the day, climate change, have had an impact in the last ten years like at no other time. In fact, as I was editing the articles for this edition of the Journal, I was struck by how many of the seemingly different articles ended up being about climate change and the role agriculture and forests can play. The Journal starts with a discussion of biofuels beyond ethanol, which ones are economically viable and to what degree. Next, we go to a discussion from the Minnesota Department of Agriculture on the remarkable role Minnesota's agricultural industry plays in global markets and how it continues to grow with inroads into China and Vietnam. Articles follow on forestry and water policy and their impact on the state's economy. Then railroads: shortline rail

companies are making a comeback, but a variety of situations are posing roadblocks.

Whether you agree that climate change is happening or not, carbon sequestration, the practice of trapping greenhouse gases in the form of carbon, is a major front-burner issue in national and international policy, and it turns out that agriculture and forestry are inherently involved. The next article presents scenarios on just how. An article on the Conservation Reserve Program discusses how perceptions of it have changed over the years and how its role could change again. And finally, The Hormel Institute presents us with the ultimate in cutting-edge technology, finding therapies and preventatives for cancer through food.

I was driving out along a county road one evening, thinking how the giant green combines silhouetted against the sunset looked like dinosaurs roaming across the landscape. That's how some people outside of rural Minnesota, and even some living here, think of agriculture. But those who know modern agriculture know that this is about as close as farming comes to the age of dinosaurs today. These giant creatures are guided by GPS technology and complex spraying formulas, and the brains of the outfit, the farmer inside, is consulting the Internet to check weather and market prices and what's going on in Brazil and Russia and how that might affect the price of corn here in six months.

That farmer is also paying close attention to Washington, D.C., keeping track of how new issues like climate change legislation and cap and trade regulations may affect operations and the bottom line. And should he — or she — be looking at ways to diversify into other markets, beyond ethanol and into pharmaceuticals, and should some of those unplanted reserve acres go into a cover crop that could be sold for cellulosic biofuels? The same can be said for forestry. While it's in the middle of a major change right now, it's still a key industry and will evolve and change as it has before.

Indeed, agriculture and forestry are far from dinosaurs. After 200 years, they keep adapting to the same landscape in new and different ways, and these articles will give some insight into just how they're doing so. We hope you enjoy them.

Will New Technologies Preserve Minnesota's Ethanol Industry?

Douglas G. Tiffany & Steven J. Taff

One of the great economic development success stories of the last decade has been Minnesota's financial and political investment in the corn ethanol industry. Starting from a base of essentially zero production in the late 1980s, the state helped create an industry that today produces over a billion gallons of ethanol each year and employs over 1,000 workers.

But the desirability of continuing this success story has recently been called into question. The environmental performance of corn-based ethanol has been challenged at a time when the industry is struggling financially. We are also hearing about a host of technologies that are said to be capable of profitably making biofuels from non-grain feedstocks and at the same time deliver better environmental performance than the plants that are now operating.

In this article we discuss how emerging political and technological developments in this important industry might affect Minnesota communities.

A long history of state and federal industry support

Over the years, we've seen a great many policy goals attached to corn-based ethanol, including energy security, local economic development, improved environmental quality, and (only very recently) reduced greenhouse gas emissions.

Public support for corn grain ethanol dates back at least to the Carter administration, as the nation faced higher crude oil prices caused by supply restrictions by OPEC. This resulted in significant early investment in alternative energy technology improvements, among them corn ethanol. The energy independence argument, made in the 1970s and made again today, is valid: the more ethanol we produce, the less foreign oil we need to import. But the net effect is modest at best, given current technologies. Too, the foreign oil

that Minnesota imports and that we're trying to replace is largely from Canada, not from the Middle East. Whatever its validity, the fact remains that with the early 1980s drop in oil prices came an abandonment of the goal of developing alternative domestic sources of transportation fuel, taking with it the economic fortunes of many small ethanol producers who could no longer compete with oil.

Minnesota followed a decade later with a simple direct subsidy per gallon of production, paid to the operators of the ethanol plant. The subsidy was 20 cents per gallon, up to a maximum of 15 million gallons per year — at the time a typical ethanol plant capacity. (Since 2003, nearly all new plants have been rated at either 50 million or 100 million gallons per year.) The subsidy was credited with helping early ethanol start-ups by providing some comfort of state support for these fledgling businesses.

Environmental goals started to replace energy security and economic development goals when the federal government began enforcement of the Clean Air Act. By 1995, the use of oxygenates became important as gasoline was modified to burn more cleanly in urban settings to reduce health effects of tailpipe emissions. Ethanol works well as an oxygenate and also serves to increase the octane of gasoline. However, the petroleum industry favored an oxygenate they could produce (i.e., methyl tertiary butyl ether [MTBE]) from relatively cheap natural gas and from the by-products of petroleum refining. In contrast farm states like Minnesota actually mandated that ethanol be the oxygenate of choice over MTBE.

The increase in demand led to a sizable and persistent price premium for ethanol compared to gasoline. This was accompanied by a major state decision to require that all gasoline sold in Minnesota be blended with 10% ethanol year round, after a period when federal carbon monoxide standards required oxygenated gasoline during the winter months. The creation of a year-round market represented an enormous boost for ethanol demand, most of which was met by Minnesota producers.

The most recent boom in ethanol production began in 2005, when MTBE was banned by numerous states and when the Energy Policy Act of 2005 failed to grant the manufacturers of MTBE liability protection from environmental damage and health claims.

Even more recent demand enhancement came in the form of the federal renewable fuels standard (RFS) requiring that a stated (and increasing over time) proportion of U.S. motor fuel consumption be in the form of "renewable" fuels, which could only be accomplished by production of corn ethanol and to a much lesser extent with biodiesel.

Big changes in ethanol's economic and policy world

Two new stressors have appeared in recent years. One is driven by a concern about global climate change, and one is driven by concerns about the underlying economics of the corn ethanol industry itself.

Before we focus on the industry's financial prospects and speculate upon their effects on local economies, let's consider how ethanol fits into Minnesota's stated intent of reducing greenhouse gas emissions from motor fuel combustion.

Both the Governor and the Legislature have set ambitious greenhouse gas (GHG) reduction targets. Because corn grain ethanol and other biofuels are biological systems, it is clear that to some extent any greenhouse gases emitted when ethanol is burned in our cars are offset by the "sequestration" of the same gases when the corn plant is growing. So, when we compare the "greenhouse footprint" of ethanol to that of gasoline, we take into account the amount of carbon dioxide that is removed by the next year of growing corn plants and contained in their tissues. As a result, ethanol has a calculated lower amount of net carbon dioxide emissions than a fossil fuel like gasoline, which results in the dispersion of a substantial amount of geologically "old" carbon from crude oil.

However, recent research has resulted in a substantial shift in the way that GHG scoring is conducted. In previous "life-cycle analysis" — the scoring of fuel emissions from all emissions at the farm, in transport and at the fuel plant, as well as at the tailpipe of our cars — resulted in ethanol scores being lower than gasoline. However, if we also take into effect — as the federal government recently proposed — the so-called indirect land use change effect, the effect on ethanol could be dramatic.

The indirect land use effect is a subtle and hard-to-measure concept. In brief, it holds that increased U.S. ethanol production leads to increased corn demand, which shows up in markets as higher prices for corn. That, of course, was one of the initial arguments proposed in favor of ethanol industry subsidies: the rise in local corn prices, which farmers, of course, support.

However, what if the higher corn prices lead farmers, whether in the U.S. or elsewhere, to plant more corn? And what if the land they plant to corn was previously grassland or forest? Plowing up grassland and cutting down forests for corn has an undeniable immediate effect on GHG emissions, which rise in the immediate aftermath of land conversion and would require years or decades of grain production for biofuels and attendant reductions in GHG reductions to overcome.

This has become a major policy issue. Should fuel-scoring take indirect land use change into account? Should ethanol be "blamed" for all of these emissions? And if it should, how do we measure such an elusive concept?

A just-released federal regulation proposal answers the first question by saying: yes, we should take indirect land use change into account. Depending upon the economic/engineering technique that is applied, the indirect land use factor, when combined with all the other LCA scores for ethanol (planting, harvesting, shipping, processing), can make ethanol look *worse* than gasoline.

If this proposal becomes law, then the effect on grain ethanol demand could be substantial. Lower demand and resulting lower prices would be a harsh blow to Minnesota's ethanol industry.

In addition to arguing directly against the proposals to include indirect land use change in the first place and against the particular scoring system the federal government has proposed, the ethanol industry has also taken steps to demonstrate that the current system does not accurately reflect the "true" GHG profile for corn ethanol, at least in Minnesota. If successful, this argument might so reduce the score for corn ethanol that it would end up lower than gasoline even if indirect land use change is included.

The second step is to encourage the development of new ethanol technologies such as cellulosic ethanol that rely not upon corn grain as a feedstock, but upon other plant materials. This leads us to our second major industry development: the promise of cellulosic ethanol technologies.

New technologies to resolve old problems?

At present, there is not a single cellulosic ethanol facility now in operation in the entire country. Why not? The reason is simple: the technology isn't ready for commercial operation at this time. In addition, the development of a supply chain to induce production, harvest, storage, transportation and pricing of bulky, biomass materials is non-existent. While it is possible to make ethanol from cellulosic materials such as corn stover, grass and wood and that the federal government has offered subsidies and supported substantial amounts of research, we still don't know whether or not anybody can make money by manufacturing cellulosic ethanol.

To address this deeper economic question, we've analyzed several different proposed technologies and compared them to the conventional corn grain ethanol system. With this exercise we identify the major determinants of profit in the proposed new cellulosic ethanol industry.

Focusing on the processing plant, we modeled costs of production and rates of return on invested capital for alternative methods of producing ethanol. Our goal is to provide a consistent set of estimates for the performance of the competing methods of producing ethanol in terms of net production cost before subsidies and also rate of return on invested capital after receipt of the subsidies. We seek to understand the relative competitiveness of the technologies, not report the earnings to the stockholders at their annual meeting. We are aware that there are additional second-generation biofuels, such as biobutanol and dimethyl ether that could be considered; however, we have chosen to analyze methods that have been described in detail in the literature with estimates of capital costs and operating expenses.

The methods of ethanol production analyzed here are:

1) Corn grain feedstock with purchased natural gas and electricity
2) Corn grain feedstock using corn stover for process heat
3) Corn grain feedstock using corn stover for process heat and selling electricity to the grid
4) Biochemical production using corn stover as a feedstock
5) Biochemical production using switchgrass as a feedstock

The dry-grind ethanol plant using corn and purchased natural gas and electricity for power that dries its distillers dried grains and solubles (DDGS) is by far the most common technology among Minnesota's ethanol producers.

The five ethanol production systems are compared by first constructing consistent and transparent budgets of each technology. Baseline assumptions are identified, then sensitivity analysis is performed on key variables.

Costs of production can be calculated for ethanol, the principal product, by determining the total costs and reducing them by the revenue from by-products such as DDGS, electricity sales and then dividing by the number of gallons of ethanol produced. The costs of production of ethanol at baseline conditions are shown below. Figure 1 reflects current technology costs with ethanol yields of 2.75 for corn, 57.6 gallons per dry ton for stover and 60.8 gallons per dry ton for switchgrass. We set baseline prices at $1.65 per gallon for ethanol, $114 per ton (DDGS), $6 per MMBTU (natural gas), $3.50 per bushel (corn), $89 per ton (corn stover) and $102 per ton (switchgrass).

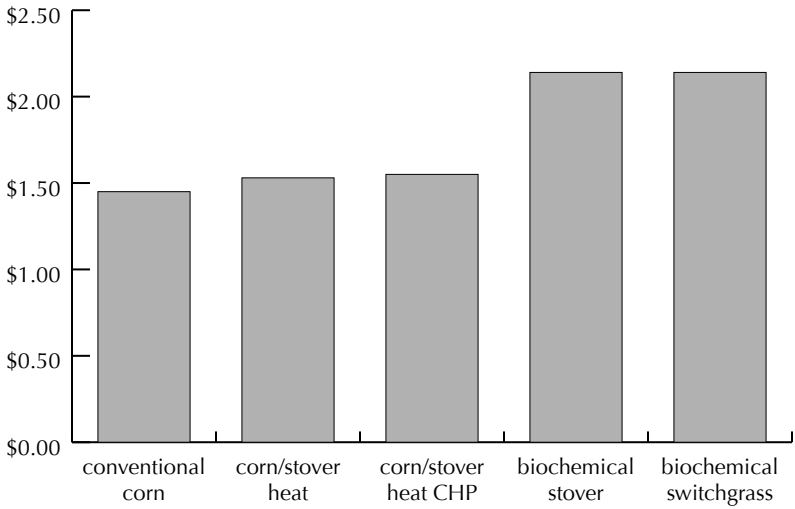


Figure 1: *Baseline net costs per gallon of ethanol reduced by by-product sales.*

Examination of the revenues and expenses of the five methods of making ethanol offers additional information about the ability of each technology to compete under various conditions. The value of the by-products can be very important with the DDGS in the case of conventional dry-grind ethanol plants as well as those using biomass as fuel for process heat. In the case of the two plants that use biochemical processes to convert the cellulose and hemi-cellulose fractions to ethanol, the value and amount of the electricity that can be sold to the grid are also important.

We applied capital costs for the projects based on the "nth" plant concept, which means that we are modeling installed plant costs after the contracting industry has sufficient experience to build plants with the facility shown today. We are sure that capital costs will be much higher for early plants until the engineering companies gain experience in building such plants. We expect there will be a variety of pre-treatments and other technologies that people try, so it may be some time before the design-build firms arrive at a point where the assembly and installation costs conform to the well-practiced routines we see in evidence with the conventional dry-grind ethanol plants.

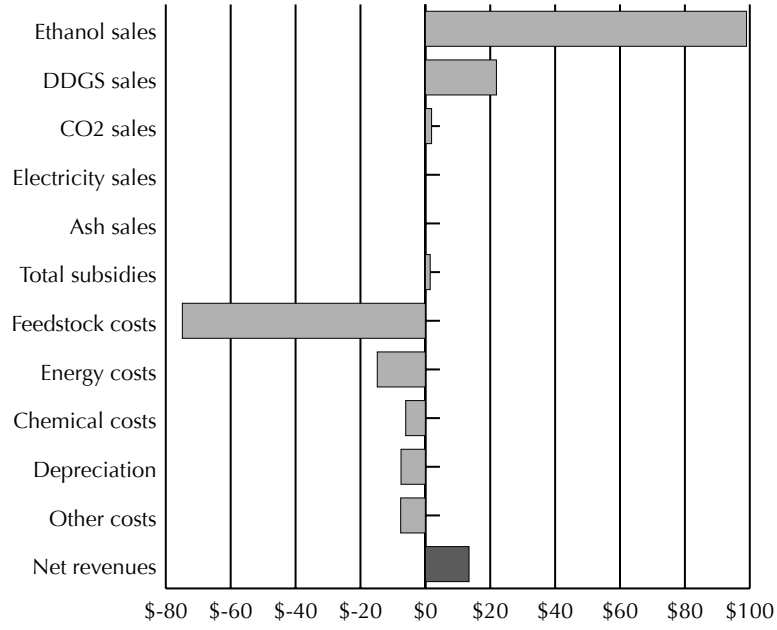
While we have used yields of ethanol and by-products available in the literature, we are cautious about the ability of the biochemical corn stover and biochemical switchgrass plants to achieve

performance on the more or less continuous basis that we see among the dry-grind plants. Until yields of ethanol and by-products occur predictably and on a sustained day-after-day basis with little "down time," the investment community will be wary of investments in these technologies, despite apparently favorable projected returns on the novel technologies.

Some important financial aspects of the five competing technologies are summarized in Figures 2 and 3, which show a breakdown of revenues and expenditures for the conventional corn starch plant and for the futuristic corn stover cellulosic plant. The percent of total revenue from ethanol sales ranges downward from a high of about 80% in the case of the conventional dry-grind plant. In contrast, by-product electricity sales represent only about 5% in the case of the two biochemical technologies.

Especially important is the level of subsidies received in addition to the prevailing subsidy represented by the Volumetric Ethanol Excise Tax Credit (VEETC), which is 45 cents per gallon of ethanol blended with gasoline in 2009. Our analysis reveals much higher levels of subsidy to the biochemical processes applied to corn stover and switchgrass. The two figures reveal the magnitude of the high

Figure 2: *Conventional corn using natural gas and electricity: Revenues and costs (in millions of dollars).*



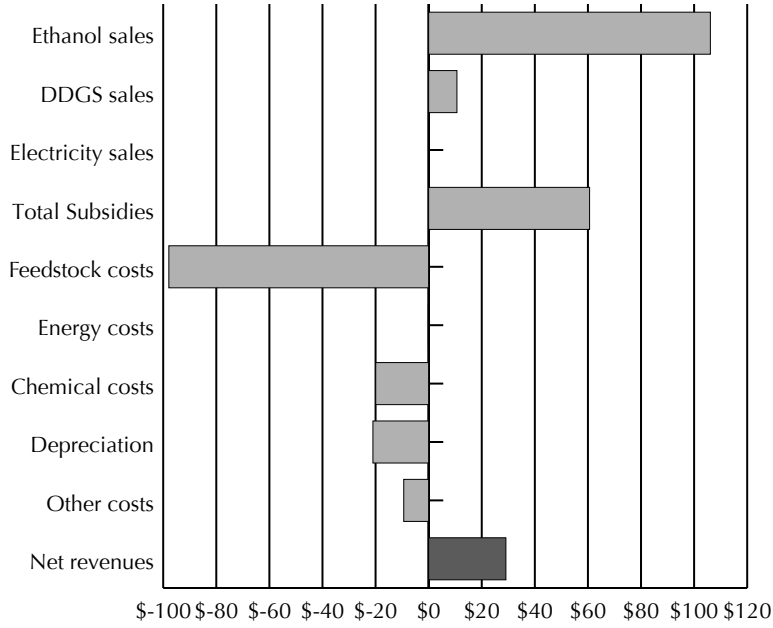


Figure 3: *Biochemical corn stover: Revenues and costs (in millions of dollars).*

proportion of net revenues represented by subsidies for technologies that utilize cellulosic feedstocks.

Financial performance

We calculate the annual average percent return on invested capital (ROI) by dividing the first complete year's pre-tax profit by the total invested capital in each project. Figure 4 illustrates the rates of return on invested capital for the five competing methods of producing ethanol, other by-products and receipt of incentive payments under baseline conditions. Using our baseline prices and yields, conventional dry-grind ethanol plants using corn have an ROI of 12%, just above the 11.5% ROI of the dry-grind ethanol plant using corn stover for process heat.

The ROI advantage of the biochemical corn stover plant over the switchgrass plant is largely due to the cost of the feedstock assumed under baseline conditions. Corn stover is a crop residue remaining after production of the primary product, corn grain, which justifies the rental of the land. Switchgrass production requires the long-term rental of land for that dedicated energy crop and several years

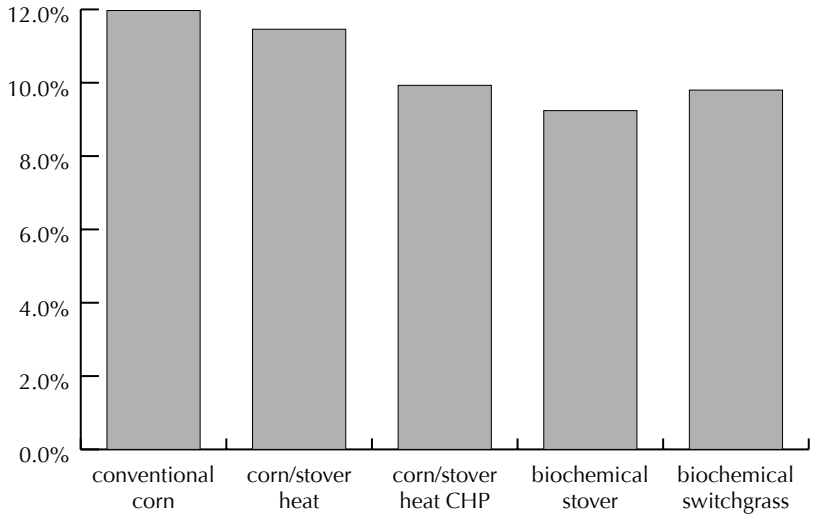


Figure 4: *Annual pre-tax rates of return on invested capital.*

of low yields during establishment. This said, the levels of the ROI are not nearly as important as the relative levels as we compare the competing technologies.

We used Monte Carlo analysis to look at the implications of varying key assumptions jointly. Briefly, the analysis calculates the resulting ROI for each feedstock and conversion technology 10,000 times in this report, each time drawing a value for each input variable from a specified range of possible values. Each calculated outcome is plotted in a probability density function to show how the outcome varies with the systematic variation of all the input variables, jointly.

In the next two figures, we show how the financial performance of each competing technology varies critically with the assumptions about future technology, market prices, and policies, specifically subsidies. In particular, the two cellulose technologies are examined under a wide range of conversion efficiencies: how much ethanol can be extracted from a given quantity of feedstock (stover or switchgrass). The range we use is bounded at the lower end by current efficiencies, which were used in the first several charts, up to and through rates that have been promised, but not so far delivered.

Figure 5 displays box and whisker plots that show the distributions of possible rates of return when all possible combinations of variables in their ranges are included. In the figure,

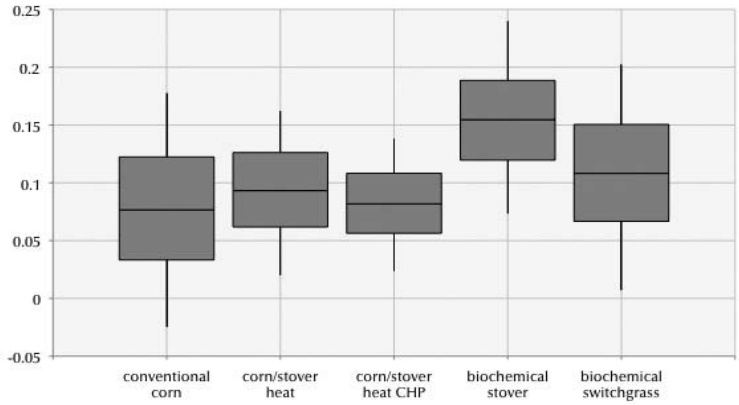


Figure 5: *Distribution of possible rates of return on invested capital.*

the bar within each box shows the median ROI for that technology. The box itself is bounded by the 25% and the 75% confidence interval values, while the tips of the vertical whiskers extend the distribution to the 5% and the 95% values.

Our comparison of rates of return on five technologies for making fuel ethanol demonstrates the importance of the substantial subsidies and incentives that have been enacted to reward cellulosic and advanced biofuels technologies when they become commercial. Our analysis of prospective cellulosic technologies is based on the concept of capital cost of the nth plant, which assumes that the substantial knowledge and installation short-cuts witnessed in today's dry-grind plants can be achieved in the biochemical plants using corn stover and switchgrass.

By-product values are important for project economics for conventional dry-grind plants or other technologies under development. However, levels of subsidies and incentives are more important when it comes to ensuring that the technologies being developed for advanced biofuels and cellulosic ethanol will produce attractive returns on invested capital. At this time uncertainty surrounds the amount of incentives or premiums that might be paid for ethanol produced with a low carbon footprint, whether enacted at the state or federal levels.

Figure 6 shows a corresponding comparison of the average rates of return for the competing technologies *without* receiving subsidies. (Recall that the current blender credit is captured in our ethanol market price: it is not considered a subsidy in the present context,

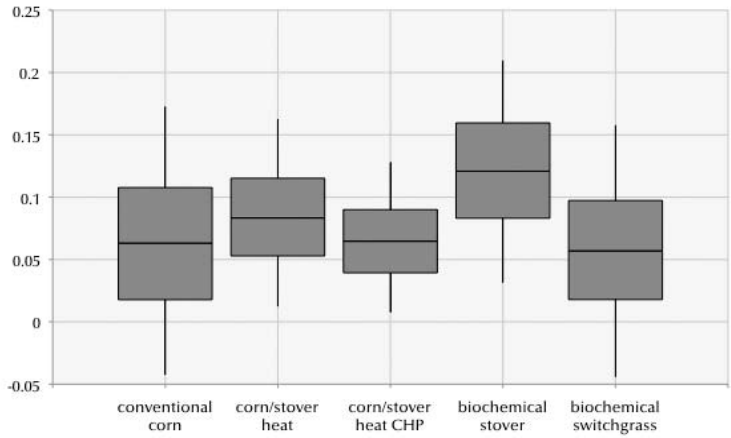


Figure 6: *Distribution of possible rates of return on invested capital with no subsidies.*

because it is not paid directly to the ethanol producer.)

In our efforts to peer ahead and gain some perspective on the success of advancing technologies that may be commercialized in the next five to ten years, our model reminds us that yield levels as well as the percentage of time that a plant is operating will be critical in efforts to overcome risks and attract private investment in the advanced biofuels and cellulosic ethanol plants.

What does all this mean for Minnesota communities?

We think there are two main lessons to be drawn from our analysis.

First of all, expectations for reducing the carbon footprint for biofuels now prevail based on complete life cycle analysis. There are high hopes that advanced biofuels and cellulosic processing methods will deliver these improvements over the prevalent corn dry-grind mills that use coal or natural gas for process heat and purchased electricity. Second, we know that the existing plants can be vastly improved in terms of their environmental performance if biomass is used as fuel to produce process heat and electricity. Corn stover and switchgrass harvest systems are being developed that may ultimately serve as "bridge technologies" to cellulosic ethanol or advanced biofuels using biochemical or thermochemical methods.

This leads us to our second conclusion. The next-generation ethanol production technologies won't just spring into being. There are a host of technical issues remaining to be resolved, and the

financial performance of these systems — even with the optimistic performance assumptions we make here — leaves a lot to be desired. Without the additional boost of public policy support to reduce costs or to raise final product demand, the industry will be unlikely to move very quickly into the next generation of production technologies. We find ourselves in a situation similar to what Minnesota faced twenty years ago: a new industry that depends critically upon additional government support to move forward to provide the jobs and income — and the fuel — that this state, lacking fossil energy resources, so earnestly desires.

Minnesota Agriculture in the Global Market

Kurt Markham

Overview

America's agriculture sector is undergoing dramatic changes. The driving forces of change include expanded global production and expanded and diversified global demand. While the current economic crisis has caused a global economic slowdown, exports have continued to provide jobs and economic activity for Minnesota's agriculture industry.

When you consider that 95% of the world's population and two-thirds of the world's purchasing power is located outside of the United States, it only makes sense to encourage Minnesota producers and companies to make their mark in the export arena. The U.S. Department of Agriculture (USDA) estimates Minnesota farm exports make up 30% of annual farm receipts.

Minnesota is the seventh largest agricultural exporting state in the United States. Minnesota farmers sold nearly $6 billion in

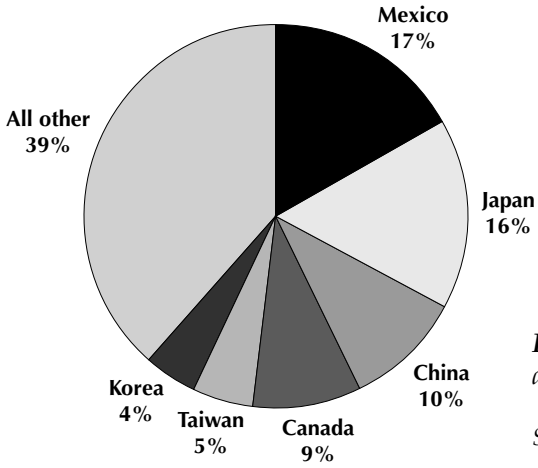


Figure 1: *Minnesota top ag export markets (2007).*

Source: MDA/AMS

soybeans, corn, livestock, wheat, and other food to foreign markets last year, a 50% gain in five years.

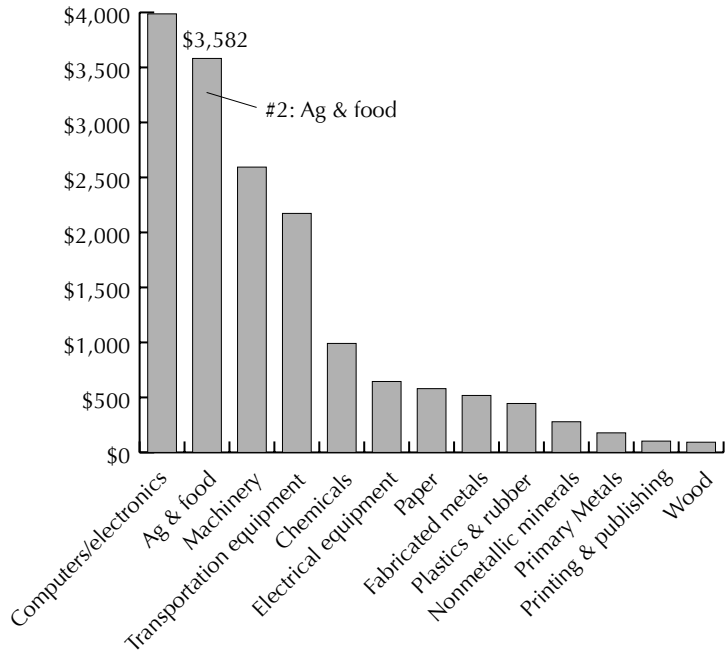
Agricultural exports help boost farm prices and income, while supporting about 38,365 jobs both on the farm and off the farm in food processing, storage, and transportation.

Minnesota's agricultural and statewide economy is increasingly dependant on exports. Agriculture is the second largest exporting sector in Minnesota (after computers and electronics), contributing 19% of the state's total exports.

Minnesota's top agricultural export commodities include soybeans and soybean products, corn, livestock/meat, wheat and wheat products, processed vegetables, dairy, feed/fodder, and poultry.

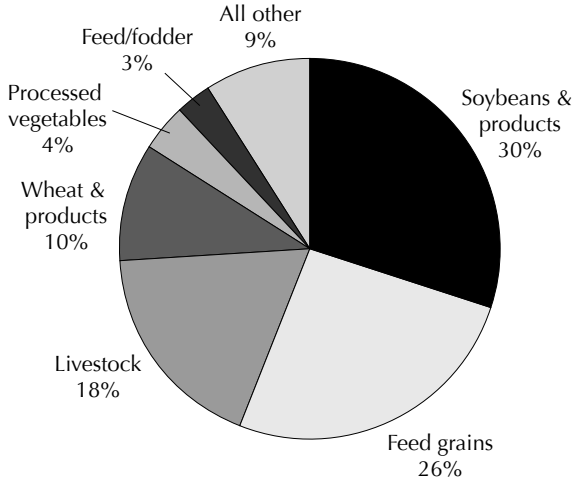
Global demand is increasing, and with that is increasing competition among suppliers. Minnesota producers are ready to meet the growing foreign demand for food and feed. In the top ten

Figure 2: *Minnesota manufactured and ag exports: 2007 ranking (in millions of dollars).*



Source: MDA/AMS

Figure 3: *Minnesota agricultural exports by commodity (2007).*



Source: USDA, MDA/AMS

of livestock producing states, Minnesota is in a prime position to provide plenty of raw and processed export products.

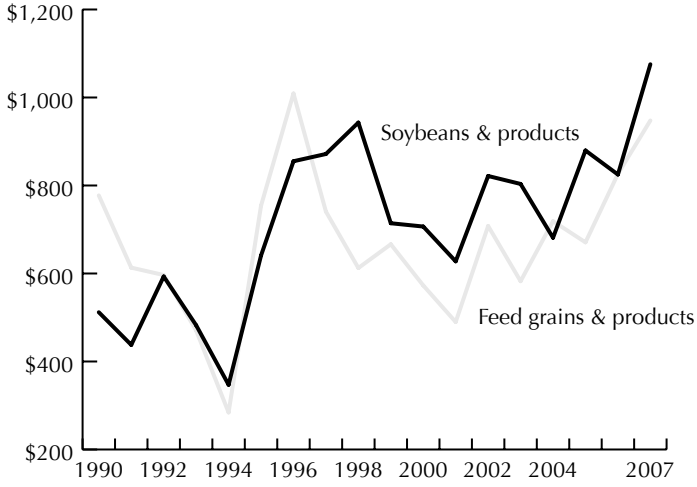
Minnesota exports more soybeans than any state but Iowa and Illinois, $1.08 billion worth last year (Figure 4). This was up from $825 million from the previous year, a 30% growth. About one third of the state's soybean crop is exported in the form of raw soybeans (38%), meal and cake (34%), oil (17%), and flour (11%). In addition, exports of feed grains went up 15% during the same period, to $948 million.

In 2007, wheat and wheat product exports totaled $355 million, and increase of 29% over the previous year (Figure 5).

All livestock and livestock products accounted for $641 million in 2007, up 13% from the previous year (Figure 6). Of all meat exports, poultry comprises 20%, pork 32%, and beef 2%.

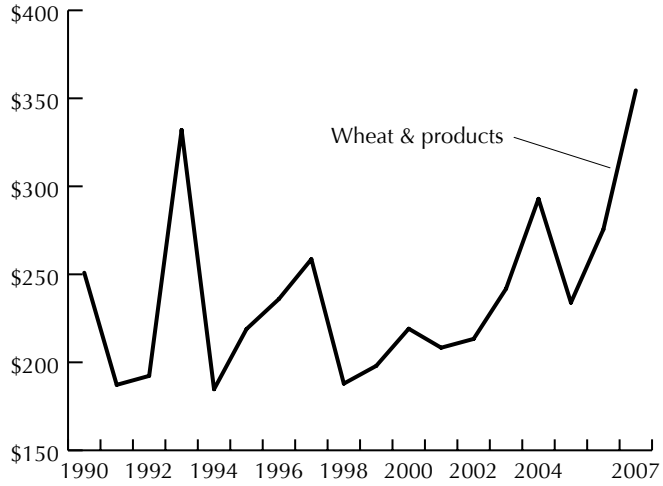
In 2007, Minnesota exported $92 million in poultry products, up from $79 million the previous year (Figure 7).

Figure 4: *Minnesota soybean and feed grains export trends (in millions of dollars).*



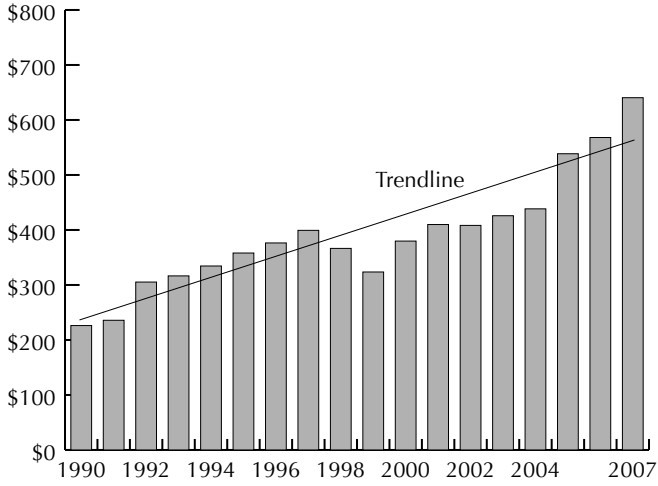
Source: USDA/NASS

Figure 5: *Minnesota wheat export trend (in millions of dollars).*



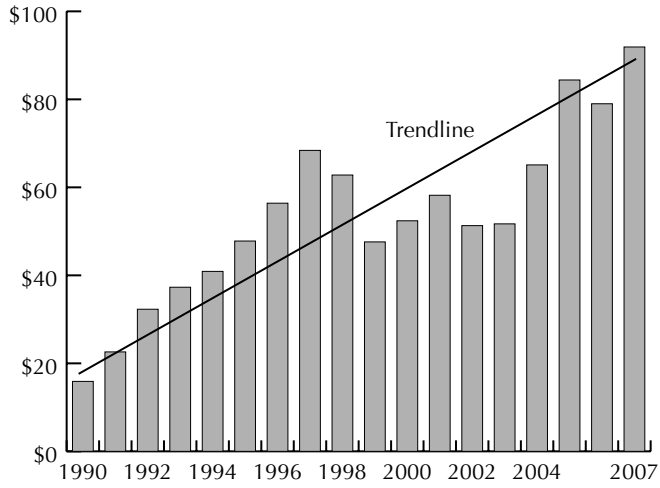
Source: USDA/NASS

Figure 6: *Minnesota livestock export trend (in millions of dollars).*



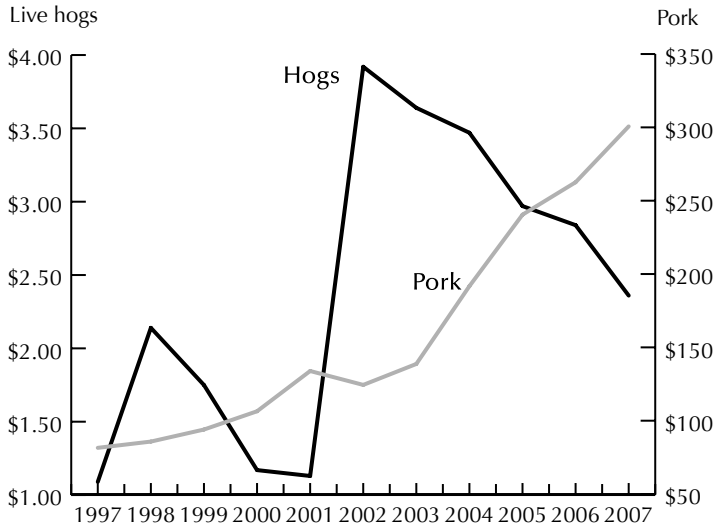
Source: USDA/NASS and MDA/AMS

Figure 7: *Minnesota poultry export trend (in millions of dollars).*



Source: USDA/NASS and MDA/AMS

Figure 8: *Minnesota hog and pork export trend (in millions of dollars).*



Source: USDA/NASS and MDA/AMS

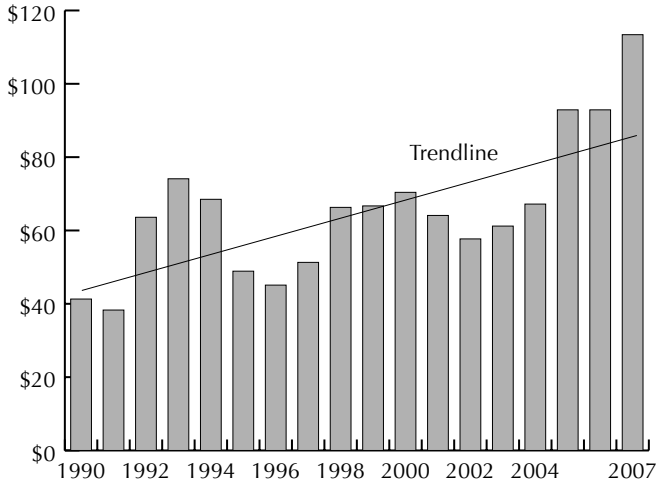
Minnesota is the third largest pork producer and exporter in the United States, with about 14% of the state's pork exported (Figure 8). Six primary markets — Japan, Canada, Mexico, China, Russia and Korea — represent an 87% market share.

Minnesota is the sixth largest dairy producer and fifth largest dairy exporter among all U.S. states. In 2007, Minnesota dairy exports reached a record-high of $113 million. Dairy exports include cheese (23%), whey (18%), milk powder (13%), buttermilk (13%) and butter (4%).

Minnesota's largest dairy export markets are Mexico, Canada, Japan, China, Philippines, Indonesia, Malaysia and Korea, with a combined market share of 68%.

The Minnesota Department of Agriculture (MDA) is committed to promoting Minnesota products in international markets and to finding new opportunities to add value to these products. If Minnesota's farmers, ranchers, and food processors are to compete successfully in the 21st century, they will need more open access to growing global markets. MDA recognizes this and has strong, established trade relationships with China, Mexico, Canada, and Japan.

Figure 9: *Minnesota dairy export trends (in millions of dollars).*



Source: USDA/NASS and MDA/AMS

China Partnership

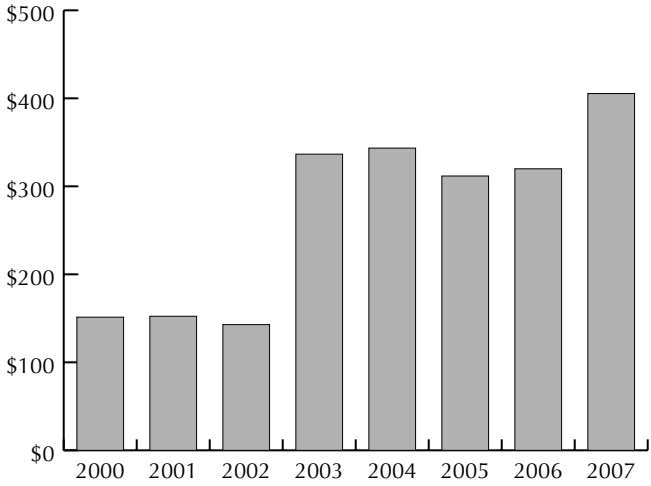
One of Minnesota's greatest export success stories is our trade relationship with China. China is the fastest growing market in the 21st century. In 2004, China's population was 1.3 billion with a gross domestic product equaling $1.65 trillion. The following year, Minnesota Governor Tim Pawlenty launched the Minnesota-China Partnership to strengthen and broaden Minnesota's relationship with China. The Minnesota Trade Office (MTO) in St. Paul established an office in Shanghai, China, that same year to provide services designed to help Minnesota companies do business in China (Figures 10 & 11).

Likewise, MTO and Minnesota Department of Agriculture staff began working together to help Minnesota agribusiness companies export their products or services to China.

Since then, China has become an attractive market for not only agriculture and processed foods, but other business sectors as well. Today, China is Minnesota's fourth-largest trade partner, purchasing more than $400 million worth of Minnesota products every year.

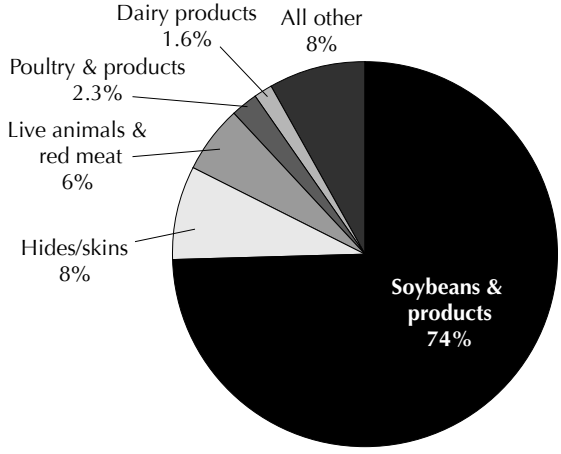
The Minnesota-China Partnership (www.Minnesota-China.com) continues to create new opportunities and increase the economic activity for both entities through annual trade missions, international business development programs, strengthening existing relationships with Chinese government and business leaders, and promoting greater understanding of U.S. – Chinese relations.

Figure 10: *Minnesota ag exports to China (in millions of dollars).*



Source: MDA/AMS

Figure 11: *Minnesota ag exports to China (2007).*



Source: MDA/AMS

Taiwan Partnership

MDA has also developed a very deep-rooted relationship with representatives of Taiwan's food and agriculture industry. Taiwan is an ideal market for small and medium-sized business, as its business climate is very friendly to international visitors, its businesses are well-versed in the import process, and it provides a great opportunity to branch into Mainland China with the assistance of a Taiwan partner. MDA staff and Minnesota businesses have visited Taiwan once each year since 2006, and in return USDA's American Institute in Taiwan has brought buying delegations to Minnesota. Taiwan has remained an essential export business partner for the state, ranking as our fifth largest export market in 2008.

Small companies can be big fish in international ponds. In emerging markets, often the first companies to establish a presence are rewarded with brand loyalty from customers. Many buyers in emerging markets want to purchase smaller volumes of product that multinational companies prefer not to serve. A small or medium-sized supplier that has a quality product with attractive labeling and a proper price point for the market can step up to supply the customer and grow the brand as the consumer market grows. Investing early in a market can often pay dividends in the long term.

Aggressive Marketing

The Minnesota Department of Agriculture Marketing Services (AMS) Division works to discover and develop potential markets for Minnesota's farmers and agribusinesses. AMS international trade experts assess prospective global markets and aggressively pursue them. AMS staff provides assistance to farmers and agribusinesses in evaluating market entry methods, understanding and obtaining regulatory requirements, finding partners, arranging shipping and financing, and many other activities.

MDA also works closely with the Food Export Association for the Midwest USA, a private, non-profit association that offers services to help companies promote their Midwestern food and agricultural products in foreign markets. MDA is one of 12 state Departments of Agriculture or agencies working with the Food Export Association. The Association offers partial reimbursement of export marketing expenses as well as numerous trade events that link U.S. suppliers with foreign buyers. The strong relationship between MDA and the Food Export Association is one reason why Minnesota continues to be a national leader in the agri-trade industry.

In 2008, Minnesota companies reported $15 million in export sales as a result of MDA-sponsored trade missions to four countries:

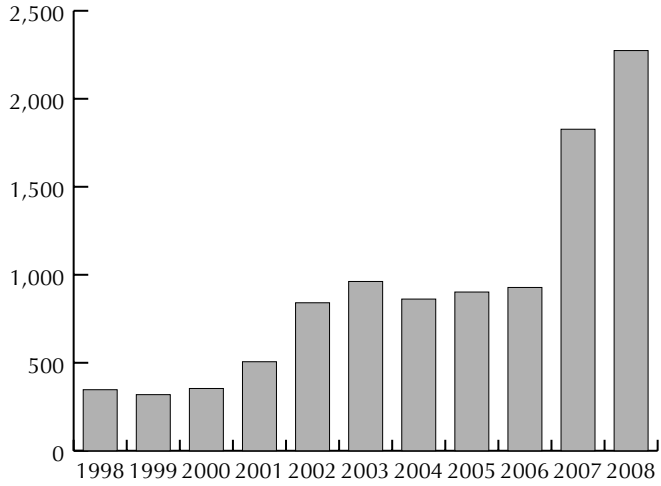
China, Taiwan, Cuba and Vietnam. For these trade missions, the MDA reports a return on investment (ROI) of $633 for every $1.

Emerging Markets

Through the MDA's aggressive international marketing program, more trade opportunities are opening up in Cuba and Vietnam. A major factor contributing to these emerging export opportunities is the expansion of the biofuels industry, in which Minnesota is leading the way. The potential use of biodiesel in transportation has seen significant development worldwide. While several states, including Minnesota, have mandates for blending biofuels into vehicle fuels, at least 17 countries have also implemented similar mandates at a national level. Minnesota has more than enough production capacity to meet its biodiesel mandate, creating an export opportunity.

With 17 ethanol plants in operation in Minnesota, the supply of ethanol's bi-product, dried distiller's grains (DDGs), is abundant and readily available as a feed supplement to livestock producers. In 2008, DDG exports were 4.5 million metric tons or about one fourth of all U.S. produced DDGs — and nearly double over the previous year. Mexico, Canada, Turkey and Southeast Asia were the top markets importing DDGs from Minnesota.

Figure 12: *Minnesota DDG production trend (in 1,000s MT).*



Source: PRX

Minnesota is the leader in sales of DDGs, livestock, and dairy products to Cuba, a market viewed as both lucrative and largely untapped. Since 2002, Minnesota has actively been pursuing trade relations with Cuba in preparation for the lifting of the U.S. trade embargo. MDA hosted trade missions to Cuba that year and had a major presence at the island's largest trade event, Feria Internacional de la Habana. This was the first year U.S. companies were allowed to participate in the expo since the embargo was imposed.

As a result of these efforts, says MDA Commissioner Gene Hugoson, Minnesota has a very positive reputation in Cuba for the quality of agricultural products we have to offer.

He believes the solid relations that have been established will help Minnesota companies negotiate future sales contracts.

Total U.S. sales of agricultural goods to Cuba reached a record high of $431 million in 2007, up from $321 million in 2006. Minnesota exports to Cuba were valued at $18.3 million. Although the recent Congressional discussions of lifting trade restrictions to Cuba have cooled, Minnesota will continue to strengthen its relationships with Cuban officials.

Minnesota producers also have their eyes on another emerging market: Vietnam. MDA has launched a three-year market development plan for Vietnam. Again, establishing trade relationships with this budding region of Southeast Asia is extremely important. While worldwide economic factors have slowed exports, Vietnam remains an evolving market that cannot be overlooked. In 2006, the region accounted for $3.6 billion of food and agriculture imports from the U.S., or about 15% of the total U.S. product sent to Asia as a whole. That's significant considering the large consumer market of China totaled $6.7 billion, or about 25%, for that same year.

Vietnam is the second fastest growing economy in Asia, posting growth of 8% in 2006 and 2007. Vietnam's per-capita Gross Domestic Product (GDP) reached $700 million in 2006, a sevenfold increase from 15 years ago, and the government of Vietnam continues to pursue its ambition of becoming a middle-income developing country by 2010. With its accession to the WTO in January 2007, the market will become increasingly more accessible to U.S. exporters by means of lowered tariff rates and quotas. Further, foreign direct investment became possible in the market beginning in January 2009.

These growing markets are suitable to Minnesota suppliers who are willing to visit the market, develop a long-term relationship with a partner, offer smaller less-than-container-load (LCL) shipments to start the market, and offer marketing and education support. Large, global brands haven't been the only success stories in these markets.

Private label brands and brands offered by small- and medium-sized companies are now very well-known to consumers because these companies chose to invest in the market early.

Trade Disruptions

While Minnesota's global market opportunities continue to expand, we cannot neglect the impact food safety concerns have on agricultural exports. This has been painfully evident this spring during the H1N1 novel influenza virus outbreak and its impact on the pork industry. Nearly 20 countries placed restrictions on or banned imported pork as a result of the virus being incorrectly dubbed "swine flu." Although the H1N1 strain is not food-borne, fears that it would spread through animal products prompted restrictions on live pigs, pork, cattle, poultry, livestock, and feed.

The three countries most affected by these bans — Mexico, the United States and Canada — are among the world's top pork exporters, along with the European Union, Brazil, Chile, China and Hong Kong.

As more has become known about the H1N1 virus, restrictions have been lifted. But the ongoing financial side-effects to the pork industry may not be totally known for some time. The situation underscores, however, the importance of strong relationships with countries we do business with and ramped up promotion of our food and agriculture products as being of high quality and safe to eat. From the producer to the consumer, food safety is an issue that needs to be addressed at every level of the food chain *before* it enters the export market. The melamine disaster in China is one example we should and have learned from.

Minnesota will continue to strengthen existing relationships and build new ones around the world. The MDA will maintain its close ties with Taiwan and encourage trade with Vietnam and Cuba. As we look toward our global future, more Minnesota companies will find the opportunity to match their products with the right markets, and MDA will continue to assist them in maintaining a competitive advantage.

The Future of Forestry in Minnesota's Economy

Jim L. Bowyer

Predictions of the future often first require consideration of the past and an accounting of the present. What is the situation today, how did we get here, and what are the current and emerging trends that are likely to shape tomorrow? The future of Minnesota's forest sector will undoubtedly be informed by its turbulent past and the no-less tumultuous present.

Minnesota's forests before forestry

About a half-century before professional forestry was introduced to North America, Minnesota's forests were heavily impacted by a combination of agricultural clearing and indiscriminate logging. Forest loss was substantial, with the heaviest losses in southern Minnesota, where hardwood forests gave way to homesteads, pastures, and tilled soil. In the northern part of the state, the greatest impact on forests was due to logging.

Minnesota's first sawmill opened in 1830 in Marine on St. Croix, followed by another in Stillwater in 1840. Then activity shifted to Minneapolis, where water power could be harnessed to run the mills. By 1880, and for three decades thereafter, the state was one of the nation's leading lumber producers. In 1900, the peak year for Minnesota lumber production, some 2.3 billion board feet of lumber (equivalent to about 4.6 million cords of wood) were sawn by an industry that employed over 15,000 people in the mills and another 23,000 felling and transporting timber. As a sign of the coming transition of Minnesota's forest industry, the Northwest Paper Company had been established two years earlier (1898) in Cloquet. By 1910, what had once been viewed as an inexhaustible supply of white, red, and jack pine was in noticeable decline, and over the next twenty years what had been a thriving lumber industry simply faded away as the supply of large trees ran out. It was a scenario that had played out in state after state.

The effect of unconstrained exploitation on the state's forests was breathtaking. Forests had covered an estimated 65% of the land area of Minnesota (or about 31.5 million acres) in the 1820s; by 1895 this had been reduced through logging, agricultural expansion, and growth of cities and towns to less than 25% of the land area (just over 12 million acres).

Not coincidentally, individual states began to act to protect forests within their borders, and in 1891 Congress gave the President, for the first time, authority to protect forest lands; establishment of federal forest reserves soon followed. Shortly thereafter, in 1898, the nation's first forestry school was established in North Carolina. Then came the turn of the century and with it the establishment of three more college-level forestry programs, at Cornell, Yale, and Minnesota (1903). Establishment of the Forest Service within the U.S. Department of Agriculture occurred two years later, and in 1911 the Minnesota Forestry Service was established.

As early actions to protect forests were reinforced by establishment of forest-oriented agencies and educational institutions, the area covered by eastern forests — Minnesota's among them — stabilized, and began to re-grow. Areas that had been heavily logged, and in some cases unsuccessfully homesteaded, slowly returned to forest cover as human activity shifted elsewhere. By 1935 the forest area in Minnesota had rebounded to just under 20 million acres, though trees were smaller and forests dominated by different species than previously.

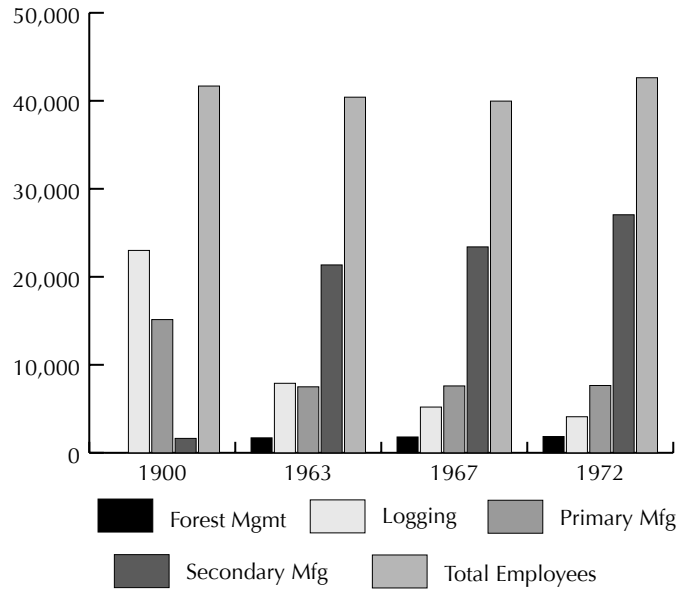
In 1950 what was left of the forest products industry was now focused on products that could be made from small trees and wood fiber, such as paper, fiberboard, and match sticks. The harvest from Minnesota's forests was less than 1 million cords in that year, and the forest sector employed fewer than 10,000; included among employees of the sector was a growing cadre of people involved in forest management, a job category that had been entirely absent a half-century earlier.

By the mid-1960s the state's paper industry began to expand, and timber harvests, though still only a fraction of peak levels, began to rise. The mid-'70s marked the beginning of a new period of forest industry investment; over the next two decades, both forest harvest levels and forest-based employment doubled. New industries and new technologies paved the way, bringing sophisticated and recycled paper products, oriented strandboard, and oriented strand lumber. This time around the sawmill industry was a minor player, with product lines reflecting the smaller average diameters of forest trees.

A new forest industry, a new look

The revitalized Minnesota forest industry that emerged in the mid-twentieth century was different not only in the nature of the primary wood products manufacturers located in the northern part of the state, but also in that a sizeable secondary industry producing wood products of all kinds took up residence primarily in the southern part of the state, and in the Twin Cities metropolitan area in particular. The southern industry included manufacturers of cabinets, store fixtures, furniture, building components, and a number of specialty products; almost all of the wood used by this industry was (and is) imported from other states and regions. In addition, Minnesota became the home of the first and third largest window manufacturers in North America, both having been established based on the earlier availability of local pine. By mid-century this industry relied almost exclusively on wood raw materials obtained from outside Minnesota's borders, yet maintained Minnesota-based manufacturing facilities. Indications of the fundamental shift in industry structure can be seen in the changing make-up of the work force from 1900 to the early 1970s (Figure 1).

Figure 1: *Makeup of Minnesota's forest sector workforce, 1900, 1963, 1967 & 1972.*

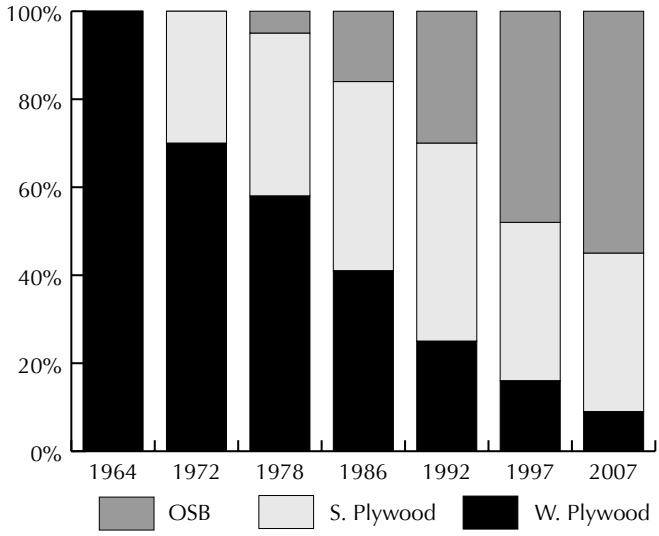


Source: Hillman and Moore (2003); Phelps (1980).

Whereas the forest industry of 1900 was comprised almost wholly of loggers and sawmill workers, and with very few working in secondary manufacturing (planing and milling), the industry of the early 1960s was heavily oriented toward secondary manufacturing. Moreover, logging employment was only about a sixth of what it had been six decades earlier. Total employment in the sector, however, was remarkably similar in 1900 and the period 1963-1972.

The early 1980s marked the beginning of what the Minnesota Forest History Center describes as the state's "Second Forest Revolution." In the decade that followed, based in part on forest survey data that showed timber removals well below annual growth, Minnesota's paper industry invested over $2 billion in expansion and modernization and increased output by almost 80%. The state's timber harvest volume increased accordingly, bringing wood removals to 4 million cords in 1993, the highest level since 1900; another 500,000 cords were imported to support production activity. Paper output increased in the form of de-inked and recycled paper products, the result of another half-billion in investment. In 1993, Minnesota was the nation's seventh leading producer of paper (McLaren 1994).

Figure 2: *Production of OSB and softwood plywood in the United States, 1964–2007.*

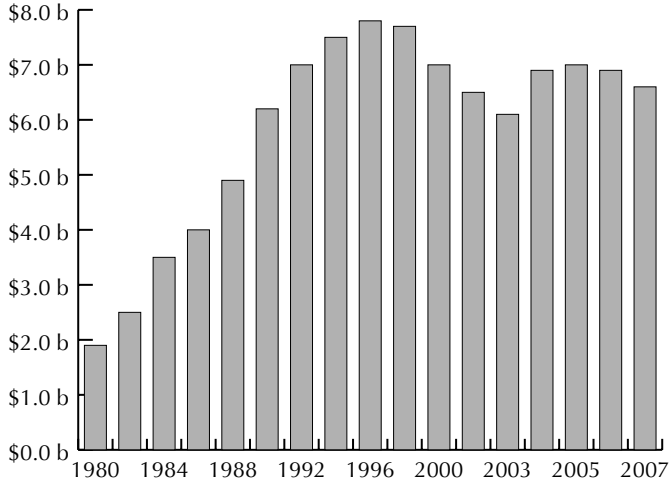


Forest industry growth in Minnesota was also fed by emergence and growth of the oriented strand board (OSB) industry. Commercial-scale production of waferboard began in Minnesota, and as that technology transitioned to OSB, Minnesota led the nation in production volume. As a lower cost substitute for softwood plywood, produced both in the western and southern United States, OSB popularity and production grew as softwood plywood production in Oregon and Washington (W. Plywood) declined (Figure 2). As with paper, the favored raw material for OSB production was small-diameter aspen. Minnesota's abundant, low-cost wood made the state a prime location for OSB industry development.

By 1995, harvest levels reached 4.1 million cords, forest sector employment reached 57,000, and the forest industry overall was the state's third largest manufacturing industry, with direct contributions of the forest sector to the state's economy approaching $8 billion (Figure 3).

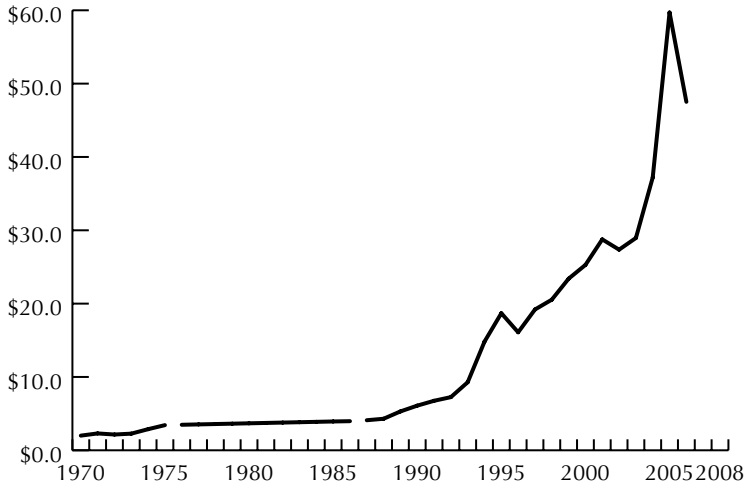
As harvest levels rose, some Minnesotans reacted with alarm, recalling over-harvesting of the state's forests 100 years earlier. In response to a citizen petition, the Minnesota Environmental Quality Board, commissioned what became known as the Generic

Figure 3: *Value of forest products manufactured in Minnesota (in billions of dollars).*



Source: Minnesota Department of Natural Resources, Minnesota Forest Resources Annual Report *(2007).*

Figure 4: *Average stumpage price received by public agencies for Minnesota aspen, 1970–2008.*



Source: Minnesota Department of Natural Resources (2009).

Environmental Impact Statement (GEIS) on Timber Harvesting. The GEIS effort involved an extensive examination of the environmental effects of timber harvesting on Minnesota's forests, aesthetics, water bodies, fish, wildlife, outdoor recreation, and historical/cultural values at different harvest levels — 4.0 million, 4.9 million, and 7.0 million cords annually. The final report, completed in 1994, led to passage of the 1995 Sustainable Forest Resources Act and to creation of the Minnesota Forest Resources Council, a 17-member board representing a wide range of public and private organizations with an interest in forest resources issues. One finding of the GEIS was that harvests of about 4 million cords could be sustained indefinitely with minimal environmental impact. The study also suggested that expansion of harvests to 5.5 million cords annually was sustainable over the long term, but that additional mitigation efforts would be necessary to protect non-timber forest values at that harvest level.

A fresh environmental assessment that largely endorsed forest practices, combined with record levels of economic activity and employment, appeared to place Minnesota's forest industry of the mid-1990s in a very strong position. But there was a price to pay for success, in this case in the form of rising raw material costs. As harvest levels grew, wood costs did as well (Figure 4), and within a 30-year period, from the early 1970s to the end of the century,

stumpage prices within the state increased 10 to 12 fold for the primary pulpwood species, aspen, from an average of about $2 to over $25 a cord (Lothner et al. 1979; Minnesota DNR 2007). Similar trends were seen for the vast majority of other pulpwood and sawtimber species.

While heralded as great news for forest landowners and land management agencies, reports began to surface that Minnesota's wood costs were among the highest in the world, a reality confirmed by a 2003 study of the competitiveness of the state's wood products industry (Minnesota Governor's Advisory Task Force 2003). At that point, prices were under $30 a cord. The high prices were not a good omen in a world of rising global competition and increasing Asia-directed foreign investment. And then, within three years, stumpage prices doubled. It was increasingly obvious to most observers that a shakeout was in the offing.

Changing global realities

Changing industrial wood production

At precisely the time that Minnesota was entering its second forest revolution, events far outside the state's borders presaged what could be called a global forest revolution. After decades of research and field trials, significant plantations of fast-growing tree species began to appear in tropical and subtropical regions. Such

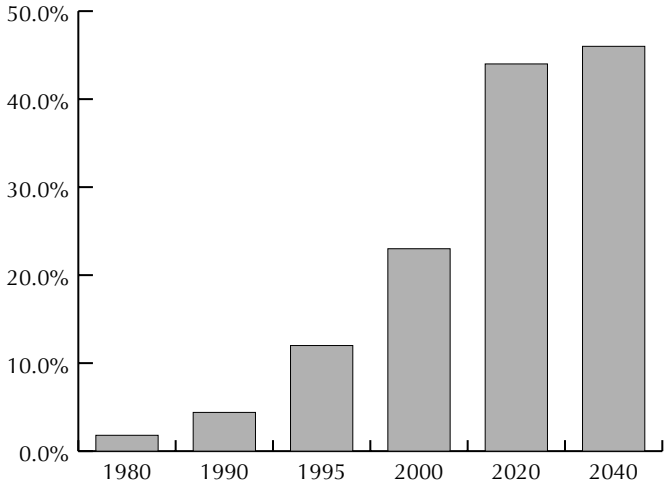
Figure 5: *A 3-year-old eucalyptus plantation in Vittoria, Brazil (Aracruz, S.A.) illustrates the rapid growth potential of wood fiber plantations.*

plantations were being systematically located on highly productive sites, translating to rapid, and sometimes spectacularly fast, growth (Figure 5). Harvest cycles were often six to seven years and shorter, meaning that plantation-grown wood began to appear in world markets very soon following plantation establishment (Figure 6).

By 1995, almost one eighth of the world's fiber supply was coming from fast-growing plantations, even though such plantations covered an area equivalent to less than 2% of the area of forests globally. Just five years later the fiber percentage was 27% and the area 3.5% of total forest area worldwide. Over 40% of these plantations were located in Asia, with an increasing forest plantation estate in South America.

As the importance of plantations in global fiber supply grew, so, too, did growth rates. Reported yields from plantations of the sub-tropics were sobering: Reports of wood yields of 20–25 cubic meters per hectare per year (4-5 cords per acre per year) were not uncommon. In addition, by 2000, annual yields as high as 45-70 m^3 with some hardwood species (9-14 cords/ac/yr) were reported. In contrast, the statewide average growth of aspen in Minnesota in natural forests was (and is) approximately 0.3 cords/ac/yr, with the best sites producing about 0.75 cords/ac/yr. Hybrid poplar in plantation settings in Minnesota have achieved yields as high as 4 cords/ac/yr in trial plantings.

Figure 6: *Contribution of plantations to world timber harvest.*



Source: Brooks, USDA Forest Service (2001).

Given that production rates were high and plantations were located in low-wage regions, plantation fiber costs tended to be very competitive globally. Early on, plantation managers were content to ship fiber in the form of market pulp to mill locations around the world. Eucalyptus pulp, for instance, was routinely shipped from the east coast of Brazil to paper mills in northern Wisconsin as long ago as the 1980s. But just as local and regional governments in the United States are passionate about finding ways to add value to raw materials locally, the same is true in the world's developing regions. Thus, in the '90s what were originally plantation-fed pulp mills began to be converted to paper mills.

Shifts in global paper consumption

In 1982 global consumption of paper and paperboard was 170 million tons, and North America accounted for 40% of that. Just 23 years later (2005), paper and paperboard consumption globally was 370 million tons, with the North American share of that consumption 27%. The rate of consumption growth in various regions during the decade of the 1990s provides an explanation of the rapid shift. During a period in which North American paper consumption grew at a 0.7% annual rate, consumption in the world's developing regions grew at 3% plus year-on-year; paper consumption in China grew at 4.6% annually (Table 1).

It is worth noting that regions experiencing the most rapid growth in paper consumption were the same regions in which rapid expansion of fast-growth plantations was occurring. It is not surprising, then, that paper production capacity began to shift to these regions. In 1980, for instance, 2% of global pulp and paper

Table 1: *Rate of increasing demand for paper and paperboard, 1990s.*

Region/Country	**Annual rate of increase in paper consumption**
China	4.60%
Asia (except Japan, China)	3.95%
Latin America	3.50%
Africa	2.95%
Western Europe	1.60%
North America	0.70%

Source: Kuusisto, I. 2004.

production capacity investment occurred within China; by 2000 this percentage was *38%*. Thus, what was not long ago viewed as fertile ground for market growth of North American (and Minnesota) paper became instead a major global competitor in pulp and paper manufacturing.

An evolving structural panels industry

As oriented strand board (OSB) grew in popularity in the 1990s, production capacity grew as well. Manufacturing plants of increasing size appeared across southern Canada and the eastern and southeastern United States, all supplied by low-density, low-cost hardwood and softwood raw materials. Overcapacity was a chronic problem as rising demand stimulated investment that often did not anticipate fluctuations in the domestic housing market. Significant downturns occurred in 1991-92 and again in 2001, stressing an already highly competitive OSB industry. Minnesota's OSB mills were particularly impacted by rising raw material costs regionally, and by increasing economies of scale in new plants being established elsewhere. The most recent housing downturn (and subsequent collapse) led first to temporary curtailment of production and then to what is described as "permanent" closure of Minnesota mills. Over a period of just 2½ decades the new industry had come and gone. There is little likelihood of a resurgence of this industry in Minnesota.

Changing Minnesota forests

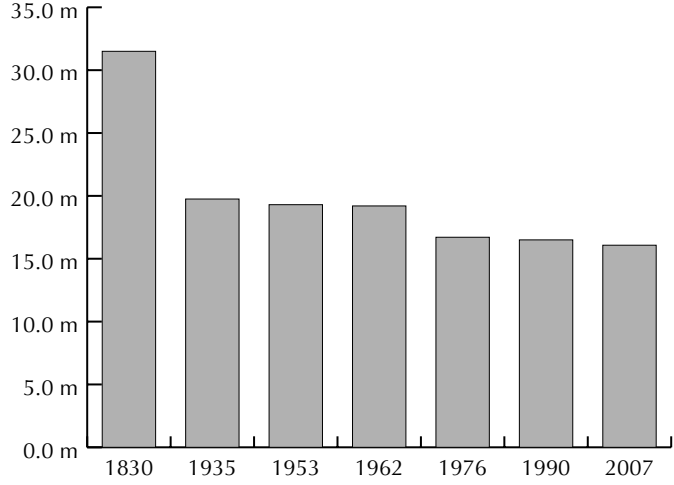
More or less stabilized forested land base

As explained by the Minnesota Historical Society:

> *When Euro-Americans began to settle in Minnesota in the early 1820s, they found about 19.5 million acres in natural prairie systems and about 31.5 million in forests. Fewer than 200 years later, only about 0.3% of the natural prairie remains. And forests have shrunk to fewer than 18 million acres.*

As noted previously, actions to protect Minnesota's forests that began early in the 20th century succeeded in halting forest loss by the 1930s (Figure 7). In addition, some of the lands that had been cleared early in the logging boom returned to forest cover during the period 1895-1935. For the next three decades following the 1930s the forest land base in Minnesota remained stable. Then, largely due to completion of the interstate highway system north of the Twin Cities, and urban expansion, forest cover declined by another 2.8 million

Figure 7: *Area of forest land in Minnesota, 1820–2007 (millions of acres).*



Source: Minnesota Historical Society (2002); Minnesota Department of Natural Resources, Division of Forestry (2008).

acres between 1962 and 1976. Since the mid '70s, there has been slow but steady loss of forests within the state (from 16.7 million to 16.1 million acres) due to urban encroachment.

Declining forest land per capita

Despite relative stabilization of forest land in recent years, the inescapable effect of ongoing population growth is gradually reducing the area of forest on a per-capita basis (Table 2). For instance in the period 1950 to 2000, while the total area of forest in

Table 2: *Forests then, now, and future — Minnesota.*

Year	Population (in millions)	Total forest area (millions of acres)	Commercial forest area (millions of acres)	Forest area per capita (acres)
1950	2.99	19.3	17.4	6.5
2000	4.92	16.4	14.8	3.3
2050	6.79	16.4	14.8	2.4

Source: Forest data from Minnesota Department of Natural Resources, Division of Forestry. Population data and projection from Minnesota State Demographic Center.

Minnesota declined by 15%, forest area per capita declined by 49%; the difference is explained by a 65% increase in population. There were similar declines in the area of forest available for periodic harvest (commercial forest). In the future, even should there be no further forest loss in Minnesota, the area of forest on a per-capita basis will continue to decline due to population growth. What this likely means is increasing conflict over forest land use, including periodic harvesting, regardless of how well lands are managed.

Forest fragmentation and intergenerational shifts

Forest fragmentation is defined as the breakup of a continuously forested landscape into various forest and non-forest uses. One form of this phenomenon is segmentation of a forest block into a number of separately owned parcels (also known as parcelization), something that tends to occur as land is passed on from one generation to the next. Ever smaller ownerships, involving an increasing number of land owners, can make management difficult. When some of those parcels are occupied by primary residences or second homes, not only does active management become extraordinarily difficult, but a number of forest values become compromised as well.

In Minnesota's north woods there is great demand for vacation homes, a situation that is stimulating second home development in previously remote areas. As an indication of the magnitude of change taking place, in a single decade — from 1990 to 2000 — the number of new recreational properties in northern counties jumped 25%. The current economic situation notwithstanding, recent divestiture of land holdings on the part of Minnesota's forest industries raises the possibility of an acceleration of this trend. Consequently, forest fragmentation has become a major issue in Minnesota.

In the words of John Myers (2006), a Minnesota environmental journalist:

> *The north woods is being sold off, divided up, and developed into weekend cabins and retirement homes like never before. Conservation leaders say the state needs to act now or lose a big part of its forest heritage forever. The rapid breakup of large tracts of forest is being called a threat to ecological diversity as forest plots get smaller and more fragmented, eating away key habitat for birds and wildlife and making it harder to manage for threatened species. Development is endangering water quality because of erosion and runoff. And development means less land open for*

logging to supply the forest products industry. No Trespassing signs are closing off land to public recreation such as hunting, birding, and hiking.

In some ways Minnesota is better protected against forest fragmentation than other states, because of its pattern of forest ownership. Here, over one half of forests are publicly owned (27% state, 13% country and municipal, 13% federal). Nonetheless, half of the wood that feeds the state's forest products mills comes from privately owned forest land, with 11%-12% flowing from forest industry-owned forest land. This latter category of forest land is at greatest risk for changes in ownership that could result in fragmentation.

Among the many implications of increasing forest fragmentation, the difficulty of periodic timber harvesting in a landscape characterized by multiple ownerships and checkerboard home site development looms large as a challenge for the state's forest-based industries.

Forest industry sell-off

Rising land values and federal tax law that effectively subjects forest industry-owned land to double taxation has led to a massive sell-off of forest land on the part of the forest industry nationally. Vast acreages of forest have been sold in Minnesota over the past five years as part of the national trend.

For the most part, lands owned by the forest industry in Minnesota have been in large contiguous blocks, have been well managed, and have been open to the public for hunting, fishing access, and other forest recreation. The sale of these lands to real estate trusts, timber management organizations, and others increases the risk of fragmented development.

A perfect storm

Entering the 21st century, all of the factors considered thus far — intensifying globalization, changing industrial wood production, shifts in global paper consumption, evolution of the wood panels industry, forest fragmentation, declining forest area per capita, sharply rising stumpage costs — were squeezing Minnesota's forest sector. Then came the economic repercussions of 9/11 and, a few years later, the mortgage bubble and housing collapse.

During the period July 2000 to July 2005, the United States lost more than 3 million jobs in manufacturing (Wial and Friedhoff 2006). As noted by the American Forest and Paper Association (2006), the nation's forest products industry was part of this trend, losing over

150,000 manufacturing jobs and some 350 paper and forest products manufacturing facilities in less than a decade (from early 1997 to mid-2005). In the four-year span of 2001-2005, job losses in two of the hardest hit sectors — pulp and paper and wooden furniture — totaled 32,700 and 56,500, respectively. Approximately 17,000 logging jobs were lost during this period as well (U.S. Department of Commerce 2006). In addition, most other sectors of the domestic forest products industry have lost market share to imports. In a period of just six years (1999-2005), overall U.S. imports of wood products (measured in dollars) increased 49%, while exports remained flat (U.S. Department of Agriculture, Foreign Agricultural Service 2006).

In Minnesota, where forest products manufacturing has been dominated in recent years by pulp and paper, oriented strandboard, and wooden windows, a downward trend in the wood products industry is evident. Whether viewed in current or constant dollars it appears that the industry peaked in the mid-1990s (Figure 3). As measured in constant dollars, the value of forest products manufactured in Minnesota in 2007 was only 63% that of fifteen years earlier. Figures from the Department of Natural Resources in a 2003 report (containing 2001 employment data) indicated statewide employment in forest products industries at 55,200, with 25,200 employed in primary processing and 30,000 in secondary; in the December 2008 edition of the same report (containing 2008 employment data), total employment statewide was estimated at 31,850, with 17,440 jobs in primary processing and 20,410 in secondary processing. Thus, in a span of only seven years forest products employment within Minnesota is estimated to have dropped by 42%, and secondary industry employment by 32%.

Thus, despite careful planning and myriad changes in how industry operates, Minnesota finds its primary forest sector in decline once again. The national and global economic cycles, housing industry woes, foreign competition, emerging economies, world fiber costs, aging manufacturing facilities and more have combined to negatively impact the local industry, resulting in recent years in rising layoffs, production curtailments, and even permanent plant closures across the northern counties. The secondary industry is also impacted by a number of these factors, most notably by the current deep recession in both housing and the general economy and by intensifying foreign competition. All of this raises questions about what the state's forest sector will look like in the decades ahead, and what role the forest sector is likely to play in Minnesota's economy going forward.

The pathway to a third forest industry renewal: Trends that could help define a better future

Conservation easements

In 1999 a Minnesota State Forest Legacy Program was inaugurated with the goal of protecting large, mostly intact blocks of privately owned forest land from development. Designed to involve partners from across society, the legacy concept involves establishment of conservation easements in negotiations with key forest land owners. A conservation easement involves a commitment of a landowner to forego future development for a specified period of time, or in perpetuity, in return for a payment based on a calculation of the present value of future development potential (although payments are often less than this value). Easement agreements often allow ongoing management of land, including timber harvesting, but prohibit forest conversion, subdivision, or a change in land use such as residential development.

Since the beginning of the State Forest Legacy initiative, several environmental organizations, the Minnesota Department of Natural Resources, the state legislature, and several Minnesota foundations — most notably the Blandin Foundation — have taken significant steps to bring contiguous blocks of forest land under conservation easements. To date, almost 250,000 acres of forests have been protected using this mechanism.

The emergence of forest certification

In the early 1990s, certification of forest practices and of wood products was introduced as a way of encouraging responsible forestry in the world's tropical regions where most of the environmental and social problems were viewed to exist. The certification concept was soon refined to include all forests, and now at least 80% of the world's certified forests are located in the northern hemisphere.

About 8% of the total forest area worldwide is now certified by one or more certification programs, including more than 13% of the managed forest area, and now nearly 13,000 companies are chain-of-custody-certified to produce products that can be traced back to certified lands. The certified forest area continues to grow; the area of certified forest globally grew by nearly 9% from 2007 to 2008, and the number of certified forest product manufacturers (chain-of-custody certificates) increased by 50% during the same time period.

Demand from green building programs (see next section) and responsible paper procurement policies are helping drive the market for certified wood and paper products. Through the participation

of state land management agencies, county land departments and private landowners, Minnesota has more than ten years of experience with forest certification and has a higher percentage of certified forestland (just over 50%) than any other state. There are more than 100 Minnesota companies with chain-of-custody certificates for producing certified forest products, including the oldest continuously active certificate held by St. Cloud-based Colonial Craft.

The green building movement gains momentum

Inspired by events that began with the oil embargos of the 1970s, efforts to encourage the construction of energy efficient, durable, healthy buildings were initiated in the late 1970s and early 1980s. Such efforts were later expanded to include water efficiency, the use of environmentally responsible materials, and minimization of impacts on the building site. Dubbed "green building standards" by those involved in development, lists of requirements and recommendations and programs to support their implementation, appeared first in the United Kingdom and Canada, and then in the United States. The Leadership in Energy and Environmental Design (LEED) program of the U.S. Green Buildings Council, today the most popular green building program, was introduced in 2000.

Currently over 80 green building programs, three of them national in scope, operate in the United States. By every measure, participation in such programs is increasing rapidly.

There are a number of implications of the green building movement for the forest sector, the most obvious being that virtually all green building programs award or require the use of certified wood. All signs point to substantial growth of the certified wood products market as homebuilding and the commercial/industrial construction sectors emerge from recession.

Another common element in virtually all green building programs is local sourcing of materials, which is generally defined as raw material sourcing and product manufacture within 500 miles of product use (or within 1,500 miles if shipping is via rail or ship). As with certified wood, markets for local products can be expected to expand in the future.

Growing carbon concerns

All over the world there are growing concerns about the accumulation of carbon dioxide and other greenhouse gases in the upper atmosphere. The United States, which has long opposed efforts to reduce carbon emissions, now appears poised to take steps

to participate. A carbon cap and trade program, or some form of carbon tax, are distinct possibilities.

Attention to carbon inevitably leads to consideration of how emissions of carbon-containing compounds can be reduced or how such compounds might be captured and stored. Forests, and the wood they produce, play a major role in the carbon cycle. Thus, management of forests so as to maximize carbon storage, use of long-lived wood products that are one half carbon by weight, and use of wood for carbon-neutral energy production are emerging as important strategies in managing carbon and addressing the climate change issue.

Rising concerns about energy security

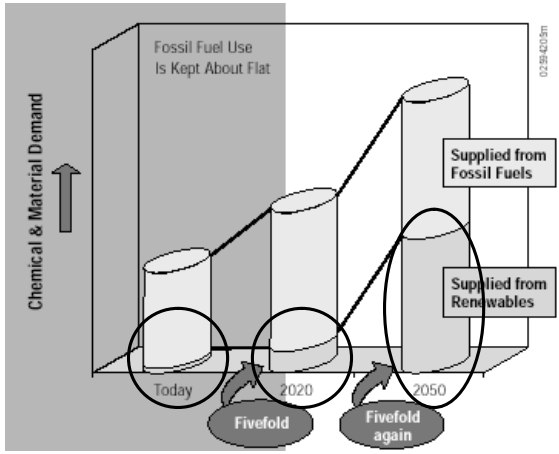
Concerns about carbon are directly linked to fossil fuel use. But fossil fuel consumption has also become an issue due to worries regarding long-term supply. Both of these factors are behind current government efforts to stimulate development and use of renewable energy including bioenergy. The goal of shifting a greater portion of energy production to renewables represents a major opportunity for both the agricultural and forest sectors. Rising use of biomass for production of heat, steam, electricity, and liquid fuels using a number of current and developing technologies is clearly part of the future — a future that appears even brighter when the potential for joint agricultural sector/forest sector bioenergy development is considered.

Increasing interest in bioenergy and biochemicals

The possibility that petroleum could become scarce and/or inordinately expensive raises issues not only with respect to availability of transportation fuels, but with availability of a wide range of industrial chemicals, lubricants, plastics, and synthetic fibers as well. Thus, concerns about energy security are stimulating interest in development of both energy from biomass and new types of biomass-derived products.

A 1999 industrial chemicals and materials future scenario developed by the U.S. Department of Energy provided an example of the magnitude of potential. The authors envisioned that 10% of industrial chemicals and materials would come from renewable resources by 2020 (~$400 billion/year in products, or two times the value of forest products produced in that year), with as much as 45%-50% from renewable sources by 2050 (Figure 8). More recently, the U.S. Departments of Energy and Agriculture have announced a goal of producing a sustainable supply of biomass

Figure 8: *Projected biochemical production in the U.S., 1999-2050: Chemical and material demand 10% from renewable resources by 2020. About $400 billion per year in products (two times current forest products).*



Source: U.S. Department of Energy, 1999.

sufficient to displace 30% or more or the country's present petroleum consumption (Perlack et al. 2005).

Implications for forestry in Minnesota: Many questions

The future of forestry in Minnesota is an open question dependent, in part, on how the citizens of the state, the forest-based industries and decision makers respond to the new realities and the lessons of history. The way in which several recent trends unfold is also likely to have a significant impact on forestry's future in the state.

Whatever strategy is pursued, there are a number of factors favorable to Minnesota's forest sector that can serve as a foundation for renewal. Strengths of this sector are that it:

- is reasonably well diversified between primary and secondary manufacturing;
- includes significant manufacturers of non-commodity products that may be difficult for foreign manufacturers to successfully target;
- is supplied (for those industries that use Minnesota wood) by forests that, to a greater extent than any other state, are environmentally certified as well managed;

- has well-established large players that add value to wood that originates in other regions (i.e. the local industry is not wholly dependent upon locally grown wood);
- enjoys strong political support within local and state units of government;
- benefits from innovative tax policy such as the Sustainable Forestry Incentive Act (SFIA) and 2c Managed Forest Land Tax Classification that help support management and reduce landowner costs;
- is supported by a vibrant research and development enterprise that is focused on wood and biomaterials development;
- has strong baseline data and modeling capacities to support evaluation of forestry potentials and alternative courses of action, including those related to carbon credit markets;
- has a track record of successful alternative energy development, including examples in the agricultural sector with ethanol production and with locally owned wind production;
- has established models of how bioenergy could be further developed, including the Laurentian project on the Iron Range and the district energy facilities in the Twin Cities; and
- is supported by well designed public interest institutions, including the Minnesota Forest Resource Council which aids in evaluating and addressing the needs of the sector and making policy recommendations.

On the other hand, Minnesota's forest industry also faces a number of challenges in addition to those discussed earlier. These include:

- relatively high costs of environmental compliance, including a lengthy time period for completing reviews;
- long distances to developing and foreign (and especially Asian) markets;
- relatively high raw materials costs;
- an aging infrastructure and workforce;
- declining budgets and reduced staffing for key land management agencies and research institutions;
- reduced funding and staffing for private landowner assistance programs that can facilitate more active forest management;
- increased parcelization, fragmentation and housing

development that takes forest land out of production;
- apparent warming of the climate and the potential increase in insect, disease and general forest health problems; and
- invasive exotic pests, including the Emerald Ash Borer (EAB), which may negatively impact forest productivity and which is already impacting the state's nurseries.

How all of these factors will impact the future of the forest sector going forward is unclear at this point, with what is likely to happen dependent, in part, upon the answers to the following questions:

1) To what extent will regional and national consumers embrace green building practices, environmentally certified wood products, and local purchasing?

2) Will Minnesota's forest sector act to take maximum advantage of the opportunities related to the high percentage of certified forest land in the state?

3) Will efforts to retain areas of privately owned contiguous forests and to minimize forest fragmentation succeed in keeping significant lands in active management status, or will large areas of what are now intact forests be parcelized and subject to residential and other development?

4) In what form will wood-based bioenergy development occur? Will development be characterized by community-dominated district heating, commercial production of wood fuel pellets, or by production of liquid transportation fuels in large-scale biorefineries? The pattern of development is likely significant since only the biorefinery route offers potential for large-scale biochemicals production.

5) As wood-derived energy grows in importance, will consumers embrace environmentally certified energy products?

6) To what extent will efforts to reduce carbon emissions formally recognize and create incentives for use of biomass fuels and products? Should the United States develop a cap and trade system that recognizes both avoided emissions and carbon storage in long-lived products, then wood-based industries will likely experience significant growth.

Similarly, science-based incentives for carbon sequestration within forests that recognize positive impacts of forest management on carbon stores would also have the effect of stimulating forest retention and active management.

7) Can Minnesota's forest sector adapt to a new model that focuses less on commodity products and to a greater extent on high value-added niche products?

Crystal ball gazing

Nobel laureate in Physics, Dr. Nils Bohr once observed that: "Prediction is very difficult, especially if it's about the future." With this in mind, and fully recognizing the difficulty and inherent hazards of forecasting, a few things regarding the near- to mid-term future of forestry in Minnesota appear evident:

- The economy and housing market will eventually rebound, and demand for construction, communication, and other products will rebound as well, pumping new life into local, regional, and national forest sector enterprises.

- Minnesota, and the rest of the world, will continue to use significant volumes of forest products, ensuring demand for such products into the foreseeable future.

- The forest products industry of the future will be structurally different from the recent past.

- OSB production is unlikely to return to Minnesota in the foreseeable future.

- Energy products will play an increasingly important role in Minnesota's forest sector.

- There is a low likelihood of future industry growth oriented toward high-volume commodity products (other than energy products) that require large volumes of wood. More likely is development of niche oriented, higher-value added products.

- Markets for certified wood products (perhaps including bioenergy products) will grow in the region and nationally, creating significant opportunities for Minnesota's forest sector.

- Societal attention to carbon management will create new and expanded markets for wood products and new opportunities for forest owners and managers.

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Can We Find a 21st Century Approach to Agriculture and Water Resources Policy?

Warren Formo

Agriculture has undergone major changes since the first crop and livestock domestications some 10,000 years ago. Productivity increases due to invention and advancing technology have reduced the labor required for farm production to the point that fewer than 2% of us find it necessary to produce food. Increasing productivity also enabled population growth, economic growth and economic consumption to occur without increasing land use. In fact, agricultural land use in Minnesota has actually declined during the past half century due to competing land uses. Still, farmland constitutes the single largest land use category in the state.

By definition, those who manage a resource are the stewards of that resource. Minnesota farmers manage nearly 27 million acres, or about one half of the land area of the state; thus farm practices are of great interest when soil and water resource sustainability are considered. This is a familiar concept to farmers, who have long recognized the need to maintain soil fertility and tilth while protecting water resources. Their practical problem solving approach is largely responsible for the development of the diversity of management systems in place on Minnesota farms today. Farmers have discovered multiple approaches to farming, which contributes to sustainability.

Recently however, agricultural practices have come under increased external scrutiny from newcomers to the conversation with limited understanding of farming and related soil-water interactions. Many of these newcomers are simply unaware, having lost their agrarian connections as society becomes increasingly urbanized. They are genuinely seeking assurance that farming practices are sustainable. They want to know that farmers are caring for their land and livestock appropriately; they want to know that our food production system is sustainable.

Background

The modern era of agriculture in Minnesota began with European settlement in the early 19th century. Early settlers found a familiar climate, fertile soils and abundant water in much of southern and western Minnesota. They brought with them the crop and livestock production practices with which they were experienced, which naturally coincided with the types of food demanded in the market since most non-farming Minnesotans shared the same cultural background (logical, but this still does not explain the existence of lutefisk).

Productivity was the primary measure of good stewardship in this era. Production data based on output that could be weighed or counted are readily available. Measures of resource protection or depletion were not yet available.

In the 1930s, dust storms and other visible signs of soil erosion prompted farmers to begin searching for new practices to prevent their land from becoming less productive. In 1933 the federal government formed the Soil Erosion Service as part of the Department of the Interior to provide technical assistance to resource managers — primarily farmers — to help them identify practices that would reduce or prevent erosion. In 1935 the Soil Erosion Service was moved to the Department of Agriculture and renamed the Soil Conservation Service. Since 1994 the agency has been known as the Natural Resources Conservation Service.

A significant amount of agricultural research throughout the remainder of the 20th century was dedicated to increasing production per acre while reducing visible soil loss. In addition to the environmental benefits of soil conservation, farmers were also motivated to protect the future productive capacity of their land by enhancing soil quality. Through the efforts of farmers, researchers, resource advisors and inventors, some of whom were also farmers, a whole series of agronomic tools were developed, including new tillage and planting equipment, herbicides, fertilizers, improved crop genetics and farmland drainage. Used in varying combinations depending on the specific crop, soil type and location, these tools changed farming in Minnesota dramatically. Soil organic matter content, which had been declining, began to stabilize and today is actually increasing on many Minnesota farmlands.

Prior to World War II, the moldboard plow was the centerpiece of virtually every farm tillage system. Today, a wide array of tillage systems is in use on Minnesota farms, ranging from continuous no-till (directly seeding crops into the soil without tillage) to moldboard plowing (perfectly acceptable in many programs on suitable soils).

Visible erosion has been eliminated under all but the most extreme weather conditions, but accurate measures of soil loss are still not available.

Efforts to control soil erosion have likely had a positive impact on water quality as well. Reduced tillage intensity and increased plant material (crop residue) on or near the soil surface holds soil in place on most croplands. Some formerly cropped areas with high erosion potential, usually due to steepness of slope or proximity to water, have been retired from crop production and planted to grass, shrubs or trees. These changes resulted in visible improvements, but accurate measurements attributing observed water quality improvements to changes in farming practices under a wide range of conditions are still not available.

Water conservation practices today

During the past 50 years, practices adopted by Minnesota farmers have likely reduced soil loss significantly, but a precise measurement of the reduction in soil loss due to their adoption is not possible — the numbers generated by models are merely estimates. Through decades of adaptive management, Minnesota farmers have perfected long lists of practices expected to protect soil and water while optimizing productivity. In fact, almost every practice identified as a BMP (best management practice) for soil or water quality was first tried by a farmer. No-till, minimum till, strip till, ridge till, terraces, contour farming, grass waterways, buffer strips, filter strips, precision nutrient management, herbicide incorporation, manure testing, manure incorporation, manure storage, integrated pest management, irrigation management, managed grazing, water management, and field windbreaks to name a few, all of these BMP concepts were conceived, born and raised on farms.

Farmers made many of these changes, often investing tens of thousands of dollars, pursuing short-term economic gains due to increased productivity, reduced operating cost, or both. Farmers also recognized the potential for long-term economic gain as soil quality improved over time. The evolution of farm practices continues yet today as part of an ongoing exercise in finding the appropriate crop and/or livestock production system for any given place and time. Experiment and experience combine to identify what, where and how something will be produced, depending on soils, climate and other factors. There are very basic reasons that Minnesota farmers do not grow pineapples or mangos.

But Minnesota farmers do grow a lot of other things. According to the United States Department of Agriculture, Minnesota farms

produced crops and livestock valued at $13 billion in 2007. Measured by value of sales, primary crop and livestock production categories are corn, soybeans, hogs, milk and dairy products, beef, poultry and eggs, wheat, hay, sugarbeets, potatoes, sweet corn, peas and edible beans.

Variation in production systems adds another dimension to the diversity of Minnesota agriculture. Some production systems have achieved their own market status, such as organic, but the vast majority are slight variations in management protocol involving crop rotation, tillage, fertility application, pest management or drainage in crop systems. Livestock system combinations are even more complex due to species differences, along with variations in housing, nutrition, genetics and other factors.

In addition to adopting production practices that protect water quality, Minnesota farmers also participate in voluntary land retirement programs. Currently 1.7 million acres of farmland are enrolled in the Conservation Reserve Program to protect wetlands, enhance water quality and provide wildlife habitat. Many of these areas are in buffer strips or grass waterways; some are under 10- to 15-year contracts while others are under permanent easement. Periodic spikes in crop prices typically elicit concerns that some of these acres might return to production, but in recent years the actual change in acreage enrolled has been negligible, further evidence of the stewardship ethic demonstrated by Minnesota farmers. Another element of the Conservation Reserve Program worth noting is that it was established in 1985 with goals of reducing erosion, providing wildlife habitat *and* reducing grain inventories. These acres are available during times when grain inventories are low, and with the increased adoption of reduced tillage farming systems, water quality concerns can still be adequately addressed in many cases.

The Conservation Reserve Program is estimated to reduce soil erosion by about 670,000 tons of soil annually. This figure is an estimate, derived from a model — not measured. The inability to accurately measure soil savings from improved farming practices and the installation of buffer strips or other structures is a major hindrance to addressing water quality concerns in agricultural settings.

"Data rich, information poor"

Advances in technology allow the detection of invisible substances in water at levels unimagined only a few years ago. Satellites provide geographic information and imagery from miles above the Earth at resolutions down to less than one meter.

Agronomy and soil scientists have collected huge volumes of data on crop inputs and production. Researchers have gathered mountains of water quality data; little information has been gathered, however, connecting specific farming practices with water quality under a broad range of conditions.

Ward, Loftis and McBride first referred to the "data-rich, information-poor" (DRIP) syndrome in 1986, calling for a new approach to collecting and using water quality data. Twenty years later, we have a lot more water monitoring data, but little progress in making the information more useful. Large volumes of water condition monitoring data are collected, with little ability to associate activities on the land with changes in water quality. In other words, it is relatively easy to determine that a water body is polluted; it is much harder to understand the processes by which it became polluted.

The Clean Water Act, passed in 1972, provides the foundation and framework for states to manage water quality. The Clean Water Act requires states to determine designated uses for all water bodies, set water quality standards protecting the designated uses, then monitor the water bodies relative to the standards. Those waters that do not meet one or more standards are designated as "impaired." Generally, once a lake, river or stream is placed on the list of impaired water bodies, the state is required to conduct a TMDL (Total Maximum Daily Load) study to identify the sources contributing to the impairment and allocate the pollutant reductions needed to bring the water body in line with standards, a problem solving process much easier described than implemented.

During the first decades after passage of the Clean Water Act, implementation was targeted toward "point" source pollution. Primarily consisting of wastewater treatment plant and industrial discharges, point source dischargers operate under a permit system, which generally limits both the mass and concentration of certain pollutants. As a result, discharges have been reduced but not completely eliminated. Discharge permits generally hold point source dischargers to a performance standard, in which they are allowed to discharge at a level equal to the discharge resulting from the best available, economically achievable technology. This regulatory approach has produced significant water quality improvement.

A March 2009 Minnesota Pollution Control Agency report states that, "Minnesota has been successful in controlling end-of-pipe discharges from wastewater treatment plants and industries to our state's waters." According to the report, Minnesota wastewater

treatment plants discharged about 1.5 million pounds of phosphorus and 1 million pounds of ammonia into Minnesota waters in 2007. These numbers sound staggering, but they represent dramatic improvements in wastewater treatment technology. Throughout the 1990s and up until about 2003, phosphorus discharges in the range of 3 million pounds annually were common, twice current discharge rates.

These reductions in nutrient discharges are well documented and show the dramatic influence of technology and invention in reducing water pollution. Bear in mind that only a few generations ago many communities discharged raw sewage directly into Minnesota's rivers and lakes. Only after recognition that this was a problem were solutions pursued, as was the case with farmers' efforts to reduce visible soil erosion. A primary difference exists, however, in our ability to measure the results when dealing with point sources; solutions to non-point runoff do not lend themselves to the same regulatory approach.

While the Clean Water Act has been relatively successful in dealing with point sources, application to non-point sources has been challenging. Non-point sources are diffuse, widespread sources, like agricultural runoff, and by their very nature are difficult to quantify. Again, we have water data, we have crop data, but we do not have adequate data on the interaction of soil and water in agricultural landscapes. In order to establish load estimates, the pollutant source assessment process relies on statistical models to generate estimates of runoff. While these models may generate pollutant loading numbers useful for planning on large scales, farmers typically find that these estimates have little value in making management decisions at the field level.

The Clean Water Act is intended principally to address anthropogenic impacts, and thus efforts are made to sort out "natural background" levels. Variable definitions and expectations of natural background complicate application of the Clean Water Act, both in the process of setting water quality standards and in pollutant source assessments. Natural background is sometimes defined as occurring in nature, and at other times is defined as loadings from manmade sources that are essentially uncontrollable. This is especially troublesome for the agricultural community and other clean water advocates in addressing "turbidity" impairments, which are caused by sediment or plant material suspended in water, causing it to appear murky or cloudy. The absence of water quality data from the early years of European settlement hampers efforts to determine natural background levels, though it may be of interest to

note that the most common lake name in Minnesota is Mud Lake.

The application of turbidity standards is just one example of the challenges in implementing water quality programs in agricultural regions. Similar challenges plague discussions on nutrients and bacteria, which are also natural components of the environment. Implementation of water resource protection, like agriculture, is constantly evolving, incorporating scientific advances and invention along with changing expectations and definitions. As more is learned about nutrient cycles, sedimentation processes and the life cycle of bacteria, standards can be updated to better reflect the full range of landscape characteristics, the best technology available to farmers, widespread geological variation and weather extremes. In the process, actual, not modeled, positive and negative farm runoff impacts must be discovered at field scale, and then connected to other activities within a watershed. How do farmed areas, wetlands and urban areas interact, relative to water quality? There are many theories, even a few models, but the conversation is dominated by perceptions because science can only get us to the point of "sometimes" or "under certain conditions." Hugh Hammond Bennett, leader of the soil conservation movement in the 1920s and 1930s and the first head of the Soil Conservation Service (now the Natural Resources Conservation Service), summed up the situation this way: "If there were some standardized simple remedy for the ills of the land that could be applied indiscriminately, the job of soil conservation would be comparatively easy. But there is about as much variety in erosion and the performance of the water and wind as in the landscape of the country."

Bennett made these comments in 1943. Ward et. al. wrote of the need to measure the right things in order to manage the right things in 1986. And it is still true today; until adequate water monitoring data is collected in such a way that it can be linked to practices on farmland, under a full range of different farming systems and landscape and climatic conditions, water quality discussions will continue to languish well into the 21st century.

Expanding the Effective Use of the Rail System in Rural Minnesota

Matthew Pahs

In Minnesota, the rail network is an integral component of the transportation system. It has not only been a key player in the growth of the state, but remains a significant factor in a multimodal freight transportation system supporting current farms and businesses in rural Minnesota. The cost-effective long-haul transportation of both bulk commodities and manufactured goods provides Minnesota with market access from a geographic location that is challenged in its distance to and from those markets. In 2007, railroads moved more commodities, at a lower cost per ton mile, than at any time in their history. They continue to be three to four times more fuel efficient and cost effective than long-haul trucking for land transportation of high-volume moves. Over twenty railroads operate in the state, including four major railroads, providing an economic link to markets around the world. Minnesota has a relatively high percentage of freight moved by rail compared to other states, over 30% by tonnage, due partially to the presence of the iron deposits and Great Lakes terminals in the north and diverse agricultural production in a majority of the rest of the state. Minnesota currently is home to the eighth largest rail system in the nation.

Bulk movements of iron ore, coal, grains, ethanol, and aggregates from terminals scaled for trainload-sized shipments have become the norm on major railroads and have reshaped the economics and distribution patterns for commodity movements in the state. Most local distribution and collection of goods, including virtually all less-than-carload, package, and express shipments, are moved by truck rather than by railroads. In addition, long distance domestic and international cargo is now routinely transported in standardized shipping containers ("marine" or "intermodal" containers), offering costs well below truck transport as well as providing enhanced cargo protection and security. Final distribution of these cargo containers

is performed by truck from a few centrally located container transfer yards, including three in the state, and supplemented by significant container distribution by truck to and from Chicago. Gaining access to this container service has been difficult for smaller railroads serving rural Minnesota.

As major freight railroads have recently concentrated on trainload lots of bulk cargo and long-distance transport of containerized cargo, there is a move to the use of heavier cars. Major railroads are using increasingly heavier railcars to reduce costs, requiring smaller railroads to use the same standard cars. Smaller railroads may find difficulty in financing improvements to track and bridges to meet this standard.

Development of the biofuel industry in Minnesota has created an opportunity for railroads. As demand for ethanol and biodiesel increases, the need to transport these fuels to distant markets will provide opportunities to rural Minnesota.

In 2007, the Minnesota Department of Transportation (Mn/DOT) completed a freight study for Southwest Minnesota. The study identified key issues related to the freight system in Minnesota, including potential opportunities and challenges. This article will discuss the existing rail system in Minnesota and expand upon the findings of the 2007 study with specific attention to issues facing railroads and the shippers that use the system in rural Minnesota.

The rail system in Minnesota

Starting in 1862, the rail system grew parallel to Minnesota's population growth and in fact shaped much of Minnesota's distribution of cities and businesses across its rural frontiers. At the system's peak of 9,362 miles in 1930, the vast majority of Minnesota's population was within ten miles or less of daily passenger and freight service. A network of rail corridors existed in the state that was formative for the economy in key business sectors, including agriculture, forestry, energy, and mining. Railroad route mileage has been reduced since 1980 to approximately 4,500 miles, although the system generally still offers wide geographic coverage. Despite this significant reduction, Minnesota still has the eighth largest rail system in the nation, based on rail miles.

Railroads are divided into three classes of operation — Class I, II and III — assigned by the federal Surface Transportation Board. These classes are based upon the railroad company's gross operating revenues and generally reflect the type of service provided: long haul (Class I), regional (Class II), and local (Class III).

The majority of route miles in the Minnesota rail system today are owned and operated by four Class I Railroads: BNSF Railway

(1,598 miles), Canadian Pacific (750 miles), Union Pacific (462 miles), and the Canadian National (436 miles). These railroads provide long-haul service across the United States and Canada and offer interchange to national and international markets. The DME, the only Class II, or regional railroad in Minnesota, operates on 472 miles of track.

The remainder of the state's route mileage is operated by 16 Class III railroads (totaling 763 miles) and three private railroads (totaling 57 miles). These smaller railroads, also referred to as short line railroads, continue to provide important local and regional access for businesses. Most are relatively low-volume lines that experience peak traffic around the grain harvest season. Other major commodities transported include taconite, aggregate, clay, and ethanol.

Opportunities and challenges: Shuttle train service

During the past two decades, Class I railroads have realized dramatic productivity gains in coal and more recently in grain transportation using the shuttle train service concept. Shuttle trains (i.e., unit trains contracted on a full trainload basis) are dedicated to one commodity that can be rapidly loaded and unloaded, and railcars must be able to be quickly cycled for the next load. Common attributes of the shuttle train concept include: farm delivery to elevators by five-axle tractor semi-trailer combination trucks; an average farm-to-elevator haul of up to 75 miles; and elevators loading a full train of high-capacity (100-ton payload) railroad hopper cars. Elevators must be able to load an entire 100- to 110-car unit train in 15 hours or less.

The Class I shift to 70- to 125-car shuttle trains is due in part to a focus on long-haul grain movement from Minnesota to distant domestic markets in the Pacific Northwest and the Gulf of Mexico. Terminals that loaded grain in blocks of 26, 54, and then 75 rail cars only a few decades ago are increasingly moving in these larger 100+ rail car sets. The types of grain shuttled in Minnesota include corn, soybeans, wheat, and distillers dried grains (DDGS). The latter is a byproduct of ethanol production, serving as animal feeds and protein supplements similar to corn and soy meal. As the average size of ethanol plants grow, their primary product of liquid ethanol is also now moving in shuttle trains of specialized tank cars to all points in the nation.

The grain shuttle trains provide an efficient service for the Class I railroads and for large grain farmers located near the shuttle loaders. It puts additional pressure, however, on the rail network

to accommodate loading and unloading of these long trains and requires longer sidings for trains to wait for other trains to pass. In addition, it has created problems for some of the regional and short-line railroads and other shippers. For example, many farmers wishing to take advantage of the lower shuttle train rates are forced to truck their grain 75 to 100 miles to the nearest shuttle loading elevator.

The average equipment cycle time for unit trains hauling grain is 18 to 24 days, but often can be turned completely within 10 days. This compares to single car loads and small blocks of cars that historically took 30-90 days for the equipment to be returned. Using grain shuttle trains, the Class I railroads hope to replicate productivity gains they have demonstrated in coal transportation in the past three decades, essentially a "conveyor on wheels," but scheduled to fit the varying needs, destinations, and markets of the grain trade.

Shuttle train elevators must be able to load a shuttle train within a specified time limit, often 12-15 hours, using hopper cars able to carry 100 tons in a car having a loaded gross vehicle weight of at least 286,000 pounds each. Elevators must also have track structure in place so that an empty 110-car train (over a mile long) can be easily placed for loading and minimal switching by the rail carrier.

From the viewpoint of some of the regional and short-line railroads, the Class I railroads appear to be phasing out smaller shipments in favor of shuttle trains and longer lengths of haul. A common concern is that the Class I railroads will offer discounted shuttle rates to shippers, but will not offer the same lower rates to short lines so they can solicit 100+ cars from multiple shippers. In addition, grain transportation rates are sometimes lowest for elevators that can commit to consecutive loading of shuttle trains.

Another concern is that the shuttle trains receive priority during car shortages, exacerbating the problem for shippers without shuttle-loader access. Despite this concern, principally, on the part of small shippers and elevators, the improved car utilization and shorter operating cycles have essentially eliminated the majority of car shortage issues that proved almost disastrous to the American grain industry during the 1950s, '60s and '70s. In addition, because shuttle train service focuses on the more profitable long-haul service to the Pacific Northwest and the Gulf of Mexico, a reduction in rail service at competitive rates to ports on the Mississippi and Lake Superior has been occurring, as well as increased truck activity in the form of longer hauls and more concentration of traffic around shuttle terminals as previously discussed.

In Minnesota, three Class I railroads, the BNSF, Union Pacific, and Canadian Pacific, offer similar shuttle train contracts and service. They are joined by several regional and short line rail carriers that participate in these contract terms and structures for several on-line shippers. Although some short line railroads are able to transport rail cars bearing a weight of 263,000 pounds, the 286,000-pound hopper car requirement has made it more difficult for several of Minnesota's short line railroads to interline grain shipments with Class I carriers. Many of Minnesota's short lines are unable to carry the heavier cars without substantial track replacement or maintenance and bridge replacement or reinforcement. Current contract and tariff structures do not allow enough short line cost recovery in the revenue sharing formulas to address this problem, and shippers have been averse to paying extra to their local carrier in most cases. The Federal Railroad Administration (FRA), the Association of American Railroads, and the Class I railroads are also evaluating the feasibility of moving to a heavier car specification for four-axle cars, at 315,000 pounds gross weight. This may be the norm in five years, further exacerbating the infrastructure investment dilemma for short line railroads.

Currently, 61 of Minnesota's more than 650 licensed elevators can meet shuttle train loading requirements. In order to meet the required loading speeds and hold 75-110 grain hoppers at one time on dedicated sidings, the majority of shuttle elevators have had to invest from $1 million to $3 million in capital improvements. In return, the financial incentives for shuttle train loading can run from $70 to $100 per car tied to the loading site with similar incentives for qualified unloading facilities, or up to 30% less than a single carload rate for an average haul.

The collection area for grain going to these facilities usually covers a 75-mile radius, compared to local elevator collection that historically was within 15 miles. Because of the rail rates and the collection areas they promote, many areas in Minnesota and the Dakotas have experienced 80% of their export crop moving through 10% to 15% of the total number of elevators distributed throughout the rural areas. This has led to a reduction in use of local elevators across rural Minnesota, often causing them to go out of business or be shifted to use as local farm storage during the off season.

With the current trend toward more on-farm consumption for value-added agriculture products (livestock and poultry), and local consumption of grains for ethanol and biofuels, some in the industry have raised concerns about an overbuilt capacity of shuttle train facilities. Given the investment requirements, it is likely that only the largest elevators or those associated with large international grain firms will survive future market consolidations.

Opportunities and challenges: Intermodal

In addition to the use of shuttle train operations to increase efficiencies, there is also a trend towards intermodal shipping. Rail intermodal shipping involves the transportation of freight in intermodal containers, sometimes referred to as "marine" containers. They are transferable between other modes of transportation, such as trucking. Freight transport efficiencies can be achieved with intermodal shipping, including reduced transfer time, reduced overall transport time and cost, reduced damages and loss, and improved security.

The dramatic increase in demand for intermodal transportation services is being driven primarily by global trade and imports of consumer goods to the United States. In addition, food security issues are contributing in part to the growing demand of containerized intermodal shipments. There are also operational efficiencies that support containerized grain shipping: containerization makes it easier to satisfy consumers with specific shipping needs; containerization allows the producer full control of the product from the field directly to the customer rather than the process of trans-loading or handling a commodity multiple times via several different modes of transport from field through local collection terminals to the final destination; and, by retaining control of container loading, farmers may extract higher prices for premium or specialty products without marketing through an intermediary.

Freight security has always been an issue in regard to pilfering and theft, but several high profile food crises recently (e.g. mad cow disease, genetically altered seed, salmonella, etc.) resulted in new protocols that now apply to food and grain shipments to many international markets. Identity Preserved (IP) food products and the need to trace grain and food through the supply chain to export markets now dictate the use of sealed intermodal containers.

The containerized delivery of grain is typically accomplished in one of two ways: bagged or packaged grain from the farm is palletized, trucked to a transload warehouse, and loaded into containers; or bulk grain from the field is loaded directly into a container that has been sanitized and lined with a plastic bag, then sealed. At that point, containers are drayed (locally trucked) to the nearest intermodal rail ramp, from where it moves by container unit trains to a seaport. Utilizing containers, the specialized grain producer can control the individual shipment from the farm to its final overseas destination rather than merely from the farm to the first elevator.

The demand is increasing for localized access to intermodal/

containerized freight in rural Minnesota. A short line intermodal rail service in Montevideo provides localized loading of intermodal containers and a guaranteed immediate transfer of those containers by a short line railroad to a Class I long-haul containerized train service via the Twin Cities to major U.S. seaports for connections to final destinations in Asia, Europe and Latin America. These regularly scheduled, expedited shipping services are provided to ethanol producers for DDGS, to growers and processors of Identity Preserved food-grade soybeans and wheat products, and to other value-added soybean feed and specialized grains. Demand likely exists in other parts of rural Minnesota for similar local intermodal access to distant markets via an efficient and cost-competitive service. The challenge is coordinating this innovative short line railroad service with Class I railroad services.

Development and operating costs for intermodal container terminals on short line railroads have been shown to be significantly lower than those on Class I railroads. In addition, shorter truck hauls and lower drayage costs contribute to the economies of developing short line intermodal terminals, improving the shipper's profitability, market price competitiveness, and the health of the local agricultural economy. However, obtaining rail cars and containers, particularly during periods of high demand, is a major issue of concern and a roadblock to the expansion of local container access. The marine and rail companies do not have the assets to disperse a large number of containers to local sites throughout the rural areas and not have them returned promptly with revenue loads in them. If this issue can be resolved and appropriate agreements with railroads can be achieved, rural intermodal container terminals could provide shippers in rural Minnesota with another rail option, making more effective use of the rural rail system.

Opportunities and challenges: Size and weight

Increasing weight capacity on rail continues to be an issue for short line and regional railroads. Class I railroads, including the UP and BNSF, have implemented new maximum gross weight for four-axle freight cars, increasing the recent maximum of 263,000 pounds to 286,000 pounds gross weight per car. They have also required that regional and short line railroads that interchange cars with them be able to handle the heavier cars. This is a concern for short lines already operating with marginal track and bridge structures and 10-mile-per-hour speed limits.

To remain competitive, regional and short line railroads with marginal conditions may choose to adopt the use of heavier cars,

without major infrastructure upgrades. The upgrade of ties and roadbed, rail size, and bridge capacity is expected to require financial investments above and beyond the financial capacity of many rail operators to pay for or be covered by existing revenue streams. The lack of profitability and capital to make these necessary improvements threatens their long-term viability and in turn the locally responsive service and local access to major markets they provide. In addition, shippers on regional and shore lines who own their sidings and yards would also need to upgrade their track.

Currently, the Class I railroads are considering a further upgrade to 315,000 pounds maximum gross car weight. While many consider the 286,000-pound limit a manageable problem, the same parties consider the 315,000-pound limit completely unworkable for many lines with substandard track and light bridges. While these new, heavier car designs require larger wheels, bearings, and metallurgical improvements as well as testing and FRA approvals, their wide-scale adoption will very likely occur in the near future, possibly in the next five years.

This poses a potential for reducing the railroad system's rural capacity and access for shippers on short and branch lines at a time when it is most needed for economic expansion. The structural challenges are analogous to those faced by local and county roads under heavier truck and farm equipment loads. The actual track structure may even survive at very low operating speeds and marginal conditions, but bridges in particular may be prone to catastrophic failure under the bigger cars, effectively embargoing the line and shutting down the entire rail operation for all users on that route or branch.

The other main constraint to expanded railroad operations is vertical clearance above the rail. This is a concern particularly for Class I railroads, due to the movements of extra-height equipment like tri-level auto racks and double-stack container well cars for intermodal service. Many railroads do have vertical clearance obstructions, restricting operations of trains using these cars. For many of these lines, vertical clearances for signals, bridges, and power lines, among other objects, need to be increased to at least 23 feet. Vertical clearance issues are not a major concern on many short line railroads, where this specialized equipment normally does not run.

Horizontal clearance issues may curtail some oversize/over-width shipments, such as wind turbine components, that may need transportation in the near future. As demand increases for wind energy generation equipment, shippers may wish to use regional or

short line railroads to deliver equipment across Minnesota. This has been tested successfully on at least one short line in Minnesota and may be possible on many other short line railroads, although this service is not currently being utilized.

Opportunities and challenges: Biofuels

The increasing use of biofuels has created opportunities for rural Minnesota by offering another market for agricultural commodities. Ethanol and biodiesel are the two main types of biofuels, i.e., renewable, non-fossil fuels, produced from biomass sources such as corn and sugar cane, and vegetable oils such as canola and soybean oil. A majority of all biofuels are moved from production plants to blending locations via rail, creating opportunities for railroads and rural production locations.

The origins of the biofuels industry in the United States can be traced back to the oil price shocks of the mid-1970s and early 1980s. During that time, federal and state governments underwrote several research initiatives to accelerate the commercial development of biofuel technologies. In 1980, the Minnesota Legislature passed a tax credit for agricultural alcohol gasoline (more commonly referred to as the "blender's credit") that reduced the state fuel tax liability for blenders mixing ethanol and gasoline in Minnesota. In turn the credit reduced state transportation funds while having little effect on the level of in-state ethanol production. When the blender's credit failed to spawn a sizeable state ethanol industry, lawmakers reworked the subsidy, and in 1986, the legislature created the ethanol development fund to make direct payments to Minnesota ethanol plants per gallon of ethanol produced. The payment amount has changed many times but for most of the 1990s hovered around 20 cents per gallon. As a result of these incentives, Minnesota has become a leader in developing the ethanol industry.

The future of U.S. agriculture will be significantly impacted by the biofuels industry. Since 2000, biofuels have become the largest U.S. renewable energy source for the massive transportation fuel industry. There are many potential benefits to biomass fuels such as reducing America's dependence on imported foreign oil, reducing air and water pollution and offering new marketing opportunities for rural Minnesota. The industry's growth also poses new problems in commodity distribution, resource use including water and power for the plants, competition with food production and livestock feeds, and a continuing vulnerability to petroleum price variations.

Rail service is particularly critical for ethanol plants, transporting 60% or more of their outbound product, including ethanol and

byproducts such as DDGS, via rail. Service is provided to national markets, as well as for some inbound traffic to plants. Without the rail connections, virtually any ethanol plant cannot remain viable as most of their production is traded into national markets. Because ethanol plants now require more and longer sidings to accommodate unit trains and other rail loading requirements, these facilities have become more expensive to construct.

Opportunities and challenges: Increased freight traffic

Because of the increased market opportunities provided by new and expanding shuttle train service, intermodal service, and development of the biofuel industry, safety is an increasing concern at rail grade crossings. Increases in truck traffic and/or train traffic at highway/rail grade crossings may require enhancements to grade crossing safety, including active warning devices such as flashers and gates. Rail switching operations near plants, new rail crossings of roadways, and increased train speeds may also increase safety concerns. Mn/DOT's statewide grade crossing safety improvement program implements safety enhancements at crossings with existing conditions that exhibit the highest potential risk; the program does not accommodate safety enhancements needed due to newly introduced development.

The majority of collisions with trains occur on local, county, and CSAH (County State Aid Highway) roads, indicative of the large number of at-grade crossings and lower levels of protection at a large percentage of these rural railroad grade crossings. Although the number of crashes and fatalities at grade crossings has been trending downward over time, occasional grade crossing accidents do continue to occur.

The growth in farmer owned and operated heavy trucks and larger, slow farm equipment suggests that Operation Lifesaver, an education program that provides educational material to schools and civic organizations, and state-supported grade crossing safety education programs would be well served to begin focusing on agricultural areas and the agricultural user.

Minnesota Rail Service Improvement program

To help prevent the loss of rail service on lines potentially subject to abandonment by railroads, the Minnesota Legislature in 1976 created the Minnesota Rail Service Improvement (MRSI) program. Using state-developed eligibility rules, the state and rail users enter into contracts with railroads for rail line rehabilitation or contractors for rail service improvements. For rehabilitation

projects, when the project is completed, the railroad repays the state and rail users out of the operating revenues produced on the line. These reimbursements are returned to the Minnesota Rail Service Improvement Program account to fund future projects. For capital improvement projects, the shipper repays the state over a period of 10 years.

These funds were loaned to rail users and rail carriers to rehabilitate deteriorating rail lines, to improve rail-shipping opportunities, and to preserve and maintain abandoned rail corridors for future transportation use. Previously, funds have been used for improving, extending and moving rail sidings, construction of grain storage bins, fertilizer storage, building warehouses along the rail siding, and improving the speed of loading into rail cars. The success of this program has enabled it to fund itself for the last 25 years. MRSI provides funding for projects in the following categories:

Rail Purchase Assistance: If a railroad line has not been abandoned and is to be used for continued rail service, the MRSI Program can provide regional rail authorities funding up to 50% of the costs in the purchase of railroad corridors, if the rail authority is willing to operate the railroad line for rail freight transportation.

Capital Improvement Loans: This is a revolving loan program where loans are offered for capital improvements related to an increase in rail transportation, either to improve service or facilities. This may include construction of extended sidings to allow shuttle train operation, trackside storage and equipment. Since about 1992, the loans have had a $200,000 cap per project. The project must be competitively bid and supported by the servicing railroad. In 2008, the legislature authorized the use of funds to make capital improvements directly to railroads.

Rail Rehabilitation Loans: This program provides low- or no-interest loans to rehabilitate and preserve rail lines. A rail authority, rail line owner, or carrier may qualify for a 15-year loan at negotiated rates. If a rail authority owns the property, the state can provide up to 80% of the project costs with the rail authority providing 10% and the shippers providing the other 10% of the project costs. If the rail line is owned by a private carrier, the state can provide up to 70% of the project costs, 20% by the railroad and 10% by the shippers to complete the

project costs. State funds can be used for a rehabilitation if the line is in a deteriorated condition and the improvements have the probability of keeping the line in operation and viable, both for the railroad and for the on-line shippers. The line must be returned to at least FRA Class I standards, 10-mile-per-hour safe operating speeds with 263,000-pound cars and continuously maintained during the 15-year loan term.

Rail User & Rail Carrier Loan Guarantee: This program guarantees up to 90% of a loan to assist rail users and carriers in obtaining loans.

State Rail Bank: This program aims to acquire and preserve abandoned rail lines for a future transportation use, including reinstalling rail lines when needed.

Funding for the MRSI Program is provided by the Legislature through bonding or general fund appropriation. The level of funding offered to the MRSI Program directly relates to the amount of assistance available to short line railroads in Minnesota.

Conclusions

Minnesota has one of the largest rail networks in the country, providing a multimodal freight transportation system to and from rural Minnesota. Twenty railroads operate in the state, providing an economic link to markets around the world.

Due to the trend toward shuttle train operations and intermodal containerization, rural Minnesota shippers have more and better opportunities to connect to distant locations via efficient rail services. The ability to move Minnesota agricultural commodities such as corn, wheat, and soybeans long distances on rail has provided Minnesota farmers with a significant cost-effective access to markets. In addition, development and expansion of the biofuel industry in Minnesota provides new value-added uses for Minnesota's agricultural commodities, providing expanded market opportunities and more income for the rural agricultural community.

These opportunities also present challenges, however. Access to container service has been difficult for smaller railroads serving rural Minnesota. Shuttle facilities necessitate longer farm-to-elevator truck hauls for delivery of commodities. Increasing weight on rail lines is threatening structural integrity of the short line rail system. Short line railroads may find difficulty in financing improvements to track and bridges to accommodate heavier loads. In addition, safety

at rail grade crossings is a growing concern with increased rail and roadway traffic, particularly around major shuttle and intermodal facilities that generate a lot of freight traffic.

MRSI funding is available for short line railroads. The purpose of the program is to help prevent the loss of rail service in Minnesota, and therefore, rail lines that would be potentially subject to abandonment or otherwise in need of improvements are eligible for funding through this program. The level of funding for MRSI is ultimately decided by the Minnesota Legislature.

Mn/DOT is currently developing a Comprehensive Statewide Freight and Passenger Rail Plan that will identify issues, trends, and deficiencies on the rail system in Minnesota. This plan will not only set priorities for investment on rail lines in the state, but examine appropriate levels of funding for preservation and rehabilitation. With increased public and private investment in the rail system likely in the near future, new opportunities will become available for rural shippers in Minnesota that use the rail system.

Trapping Greenhouse Gases: A Role for Minnesota Agriculture in Climate Change Policy

Cheryl Miller

Introduction and background

In 2009, America's role is taking shape in one of the central challenges of our times. In April, after a two-year scientific review ordered by the Supreme Court, the U.S. Environmental Protection Agency found that carbon dioxide contributes to air pollution that may endanger public health and the welfare of current and future generations. In May, legislation to establish the nation's first-ever limits on greenhouse gas emissions began moving through Congress. The massive "American Clean Energy and Security Act of 2009," or Waxman-Markey bill, would set aggressive emission reduction goals and establish a national cap-and-trade program that would dwarf existing carbon markets. The Obama Administration has consistently placed energy and climate policy at the center of its domestic and international agendas.

These developments follow activities in many American states over the past decade. A case in point is Minnesota, where an effective bipartisan effort has been under way. Minnesota has the nation's strongest renewable energy standard, requiring utilities to produce at least 25% of total energy from renewable sources by 2025. In 2007, legislation established aggressive emission reduction targets and time tables. This was followed by a Governor-led initiative to involve a wide cross-section of stakeholders in advising the government on how to reach targets. The Minnesota Climate Change Advisory Group developed 46 recommendations across all economic sectors. Gov. Tim Pawlenty also helped launch the Midwest Governors Greenhouse Gas Accord, an agreement among 11 member and observer states and Canadian provinces to cooperate in region-wide energy efficiency, bio-economy, cap-and-trade, and other programs. In mid-2009, the group's proposals — reflecting a Midwestern perspective on energy and climate issues — are being forwarded to Washington and state capitols for action.

In all the activities cited, there is unanimity on one point: broad and sustained participation across society will be needed to reduce GHG emissions sufficiently to slow global warming. Although energy efficiency, fuel efficiency, and reducing carbon intensity in energy and industrial sectors are the principal focus of development and regulatory activity, there is an appreciation for the role land use and related products can play, particularly in rural states with large resource bases in forestry and agriculture.

Terrestrial carbon sequestration — natural absorption and storage of carbon dioxide (CO_2) in plant tissue — and protection, expansion, and enhancement of carbon stocks on the land is the focus of this paper. It summarizes research, analysis, and recommendations of the Minnesota Terrestrial Carbon Sequestration Initiative, an effort based at the University of Minnesota to develop information and foster a public dialogue about carbon sequestration options in the state. Since its inception in 2005, its advisory group of government and stakeholder representatives has tasked researchers to produce scientific, economic, and policy information to increase public understanding and guide state policy. In 2007, the Minnesota legislature funded a comprehensive assessment of the potential capacity for carbon sequestration in Minnesota's terrestrial ecosystems, including an inventory of Minnesota lands having high carbon stocks; a quantification of the ability of various land use practices to sequester carbon; identification of monitoring sites and demonstration projects; and an analysis of state policies affecting terrestrial carbon stocks. Part I of the paper summarizes key findings and conclusions of those assessments. Part II describes alternative approaches to financing the broad deployment of terrestrial carbon sequestration activities. Traditional conservation programs on public and private lands and opportunities presented by the emerging carbon market auctions and offsets are also described.

Part I: Assessing terrestrial carbon sequestration in Minnesota

The global carbon cycle is one of the fundamental natural processes that define and support life on earth. Carbon flows through four major pools: the atmosphere, oceans, land (terrestrial biosphere), and the earth's interior. Carbon is one of the primary constituents of living things, comprising roughly 40% of the dry weight of biomass. In addition, the carbon cycle plays a key role in moderating the earth's climate system, using CO_2 in the atmosphere to trap solar radiation needed to warm the earth.

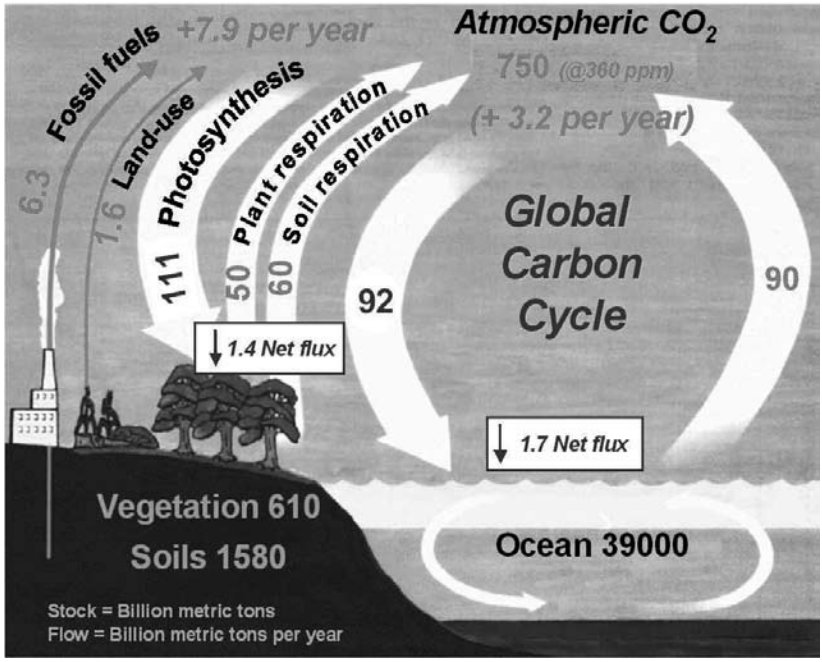

Figure 1: *Gloal carbon cycle.*

Source: University of Michigan, http://www.globalchange.umich.edu/. ../carbon_cycle.jpg

In the past several hundred years, human activities — principally the burning of fossil fuels and deforestation — have greatly accelerated flows of carbon as CO_2 out of the land and the earth's interior and into the atmosphere. Fossil fuel (coal, oil, and natural gas) combustion releases carbon that has been locked in the earth for millions of years and has raised atmospheric CO_2 concentrations 35% higher than at the beginning of the industrial era. Overwhelming scientific evidence has confirmed that excessive buildup of atmospheric CO_2 is warming the earth to unprecedented levels and setting in motion long-term (century to millennial) changes in the earth's climate. Although once thought to be a problem that would evolve slowly, more rapid shifts in weather patterns are now observed around the world (IPCC, 2007).

Carbon flows between land and atmosphere occur through photosynthesis, when green plants absorb sunlight and take up carbon dioxide from the atmosphere, and through plant respiration and decomposition, when carbon dioxide is returned to the atmosphere. The seasonal uptake and release of carbon dioxide

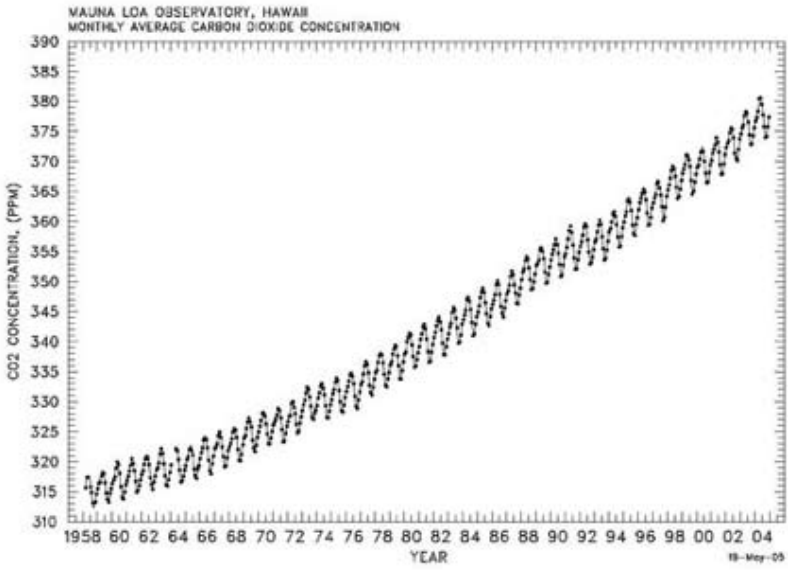

Figure 2: *Mauna Loa Curve.*

Source: http://www.globalchange.umich.edu/globalchange1/current/labs/Lab12_VirtualEarthquake/Carbon_files/image004.jpg

by northern hemisphere vegetation is graphically portrayed by the Mauna Loa Curve, a jagged upward-trending line tracking atmospheric CO_2 concentrations at a federal observatory in Hawaii beginning in the 1950s. This now-famous curve documented for the first time the rapid rise in carbon dioxide in the earth's atmosphere (Keeling, 1976).

Terrestrial carbon sequestration[1] occurs when the quantity of carbon in terrestrial carbon pools increases over time. Increases in the size of the terrestrial carbon pool occur at the expense of the atmospheric CO_2 pool, thus leading to a decrease in the quantity of greenhouse gases in the atmosphere, or at least a decrease in the rate of increase of atmospheric CO_2 concentrations. Organic carbon is a concentrated form of carbon dioxide: 3.67 tons of carbon dioxide are condensed into a single ton of organic carbon. Carbon can be stored for hundreds of years in trees or thousands of years in soils.

Different land cover types store varying amounts of carbon, with higher amounts in forests and perennial plants. Numerous other factors affect the ability of ecosystems to store carbon — age and condition of vegetation, temperature and precipitation, landscape, and land use history all play a part, as do human activities. The

conversion of natural vegetation to arable or urban land results in releases of stored carbon; reforestation and re-vegetation re-start the slow sequestration process. Except for wetland drainage, large-scale land conversion in the northern hemisphere has largely abated and in New England, extensive forests have been re-established. This is not the case in the southern hemisphere, where tropical deforestation accounts for roughly 20% of human-generated GHG emissions each year. At present, the global land mass is believed to function as a small net sink (more CO_2 in-flow than out-flow), although concern is increasing about wildfire and other impacts of climate change that may reduce the ability of ecosystems to sequester carbon.

A major part of Minnesota's carbon pool resides in millions of acres of forests and peatlands (bogs, marshes, fens, and other wetlands). Peatlands contain, on average, 750 metric tons of carbon (or 2,752 $mtCO_2$) per acre. Across the state, peatlands are estimated to sequester over 15 billion tons of CO_2, or over twice the annual total GHG emissions of the United States. On an acre-by-acre basis, forests average about 100 metric tons of carbon (or 367 $mtCO_2$), or about one eighth as much carbon as peatland, but are much more susceptible to loss by fire, invasive pests and disease, and land use conversion. Between 1976 and 2008, Minnesota fires destroyed an average of 14,600 acres of forest per year (MDNR, 2008); Minnesota's no-net-loss laws have reduced net wetland loss to approximately 450 acres a year (MBWSR, 2005).

Changes in land use, land cover, and land management can alter the rate of carbon sequestration by enhancing CO_2 uptake by plants and/or by slowing its decomposition and the return of CO_2 to the atmosphere. Conversion of annual crops to perennial grasses or forest slows the return of carbon to the atmosphere because biomass is not harvested and relatively more carbon is transferred to the soil. Converting annual cropland and areas of depleted soils to deep-rooted perennials or woody species essentially increases the carbon capacity or density per unit of land area.

How much additional carbon can a particular management practice sequester? For some purposes, simply knowing if land use or management changes tend to increase or decrease carbon stocks is sufficient. For other purposes, such as determining the potential sequestration (and GHG mitigation) capacity of Minnesota's forest and agricultural land, it is necessary to quantify carbon sequestration rates and capacities of different land cover types, and then multiply by the land area involved.

The table below presents quantified estimates of thirteen different land use, land cover, and management changes prevalent

Table 1: *Estimated changes in C sequestration rates upon land use or cover change for the state of Minnesota. Estimates are means of all studies with standard deviations (SD) among studies within a land use/land cover change category, except where noted.*

Sector		Land use/ cover change	Estimated C and CO_2 sequestration rate upon land use/cover change^					
			Total biomass	Soil	Sum	Level of Certainty		
			metric ton C $acre^{-1}$ yr^{-1} ± SD (n) (90% confidence interval)			of the mean rate£	that C sequestration > 0	metric ton CO_2 $acre^{-1}$ yr^{-1} ± S.D.*
Wetland	a	Peatland restoration	0.2 ± 0.1 (5) (0.1 – 0.2)		0.2 ± 0.1	Medium	Very high	0.7 ± 0.4
	b	Prairie pothole restoration	N.A.	1.2 ± 1.9 (27)$ (0.6 – 1.9)	1.2 ± 1.9	Low	Very high	4.5 ± 6.9
Forestry	c	Annual row crop to forests	1.3 ± 0.5 (11) (1.1 – 1.6)	0.2 ± 0.1 (7) (0.1 – 0.2)	1.4 ± 0.5	High	Very high	5.5 ± 1.8
	d	Annual row crop to short-rotation woody crops	1.5 ± 0.6 (5) (0.9 – 2.1)	0.4 ± 0.4 (2) (-1.2 – 2.0)	1.9 ± 0.7	High	Very high	7.0 ± 2.6
	e	Increased forest stocking	0.2 ± 0.3 (29)$ (0.2 – 0.3)		0.2 ± 0.3	Low	High	0.8 ± 1.0
Agriculture	f	Annual row crops to pasture/hay land		0.1 ± 0 (3) (0.1 – 0.2)		High	High	0.4 ± 0.1
	g	Annual row crop to perennial grassland		0.4 ± 0.4 (24) (0.3 – 0.6)		Low	High	1.6 ± 1.6
	h	Conventional to conservation tillage		0.1 ± 0.1 (16) (0 – 0.1)		Low	Very low	0.3± 0.5
	i	Inclusion of cover crops in row crop rotation		0.2 ± 0.1 (4) (0.1 – 0.3)		Medium	High	0.6 ± 0.3
Perennial Grassland	j	Low diversity to high diversity grassland		0.1 ± 0.4 (4) (-0.4 – 0.5)		Low	Very low	0.1 ± 1.39
Urban	k	Turfgrass to urban woodland	0.24 ± N.A. (1)			Low	Very high	0.9 ± N.A.

in the state, denominated in metric tons of CO_2 per acre per year ($mtCO_2/ac/yr$). For policy purposes, this is also shown in megatons per year (million metric tons, or Mt/yr). Annual carbon sequestration rates are based on averages from empirical studies in areas with climates and soils similar to Minnesota. In interpreting the chart, note the range of variation and degree of scientific confidence in the numbers reported. Land use and management changes are divided into groups based on scientific confidence in their positive sequestration values. The high-confidence group includes conversion of annual row crops to forests, short-rotation woody crops, and wetlands. The low-confidence group includes conservation tillage[2] and increased diversity of plant species. Although these latter practices have recognized environmental benefits, their carbon sequestration benefits are uncertain.

Increasing the amount of carbon sequestered is but one of numerous benefits resulting from these land use and management changes. Most of the listed sequestration techniques are best management practices (BMPs) well known and widely used to protect or enhance soil, water, wildlife, and social values. Reforestation and afforestation (planting trees on converted forestland) protects and stabilizes soils, regulates stream flows, and provides habitat niches for different wildlife communities. Forestation, short-rotation woody crops, and increased forest stocking increase timber supplies and biomass fuels. Establishing prairie and wetlands on land retirements, riparian buffers, and marginal land moderates flood pulses, reduces turbidity and excess nutrients in waterways, and increases wildlife habitat and biodiversity. Converting marginal cropland to pasture and managing soil carbon enhances soil fertility and moisture retention, reduces erosion, and contributes to regional water quality protection and floodwater retention. These BMPs can also be useful in adapting to a warming climate and increasing incidences of flooding, drought, and other negative consequences of climate change.

Table 1 notes:
^Estimates refer to a timeframe of ca. 50 yr, except for short-rotation woody crops where estimates apply only to the duration of the stand rotation.
[£]Based on coefficient of variation (CV): CV<40% -High; CV 41-80% - Medium; CV >81% - Low.
[*]Total C sequestration rate converted to CO_2-C equivalent by multiplying by 3.67.
[$]Mean, standard deviation and confidence interval values were estimated by linear regression of: row b) chronosequence data from a single study including many sites; row e) differences in biomass C accumulation between insufficiently and well-stocked forest stands in response to stand age (for stands <30 years).

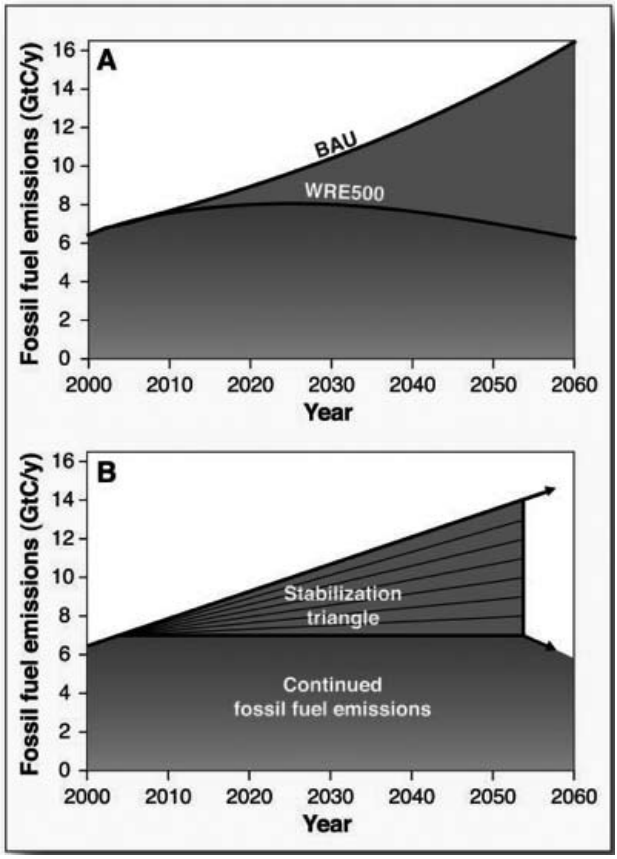

Figure 3: *Pacala and Socolow wedges*

Source: Science Magazine
http://www.sciencemag.org/.../zse0320427630001.jpeg

How might such practices be applied on farms? Including winter cover crops in annual crop rotations sequesters on average 0.6 $mtCO_2/ac/yr$. Winter rye cover crops are considered a relatively low-cost carbon sequestration technique because they do not require conversion to other land uses. The practice is widely promoted to protect against soil erosion and protect water quality and is regarded as an important strategy for replenishing soil organic carbon if corn stover or other crop residues are removed. Converting marginal lands unsuitable for crop production to perennial grasses or woody biomass increases carbon sequestration by an average of 1.6 $mtCO_2/ac/yr$ and 7.0 $mtCO_2/ac/yr$ respectively. The land cover change

increases soil and water protection and may be a source of income in livestock and biofuel production. Planting shelterbelts and forest riparian buffers could sequester an average of 5.5 $mtCO_2/ac/yr$, with similar benefits.

In communities, residential and open space tree-planting programs increase carbon sequestration depending on density of plantings and can significantly reduce urban heat island effects and carbon emissions associated with heating and cooling homes. These benefits augment an already impressive list of environmental, social, and economic benefits that community forests and greenways provide.

What scale of effort is needed to make a significant contribution to greenhouse gas reduction goals? A paper influential in climate policy circles (Pacala and Socolow 2004) evaluates a portfolio of existing technologies that could be ramped up over the next 50 years to stabilize atmospheric CO_2. The analysis assigns each technology a "wedge" of reductions needed to stabilize rising emissions. The paper concludes that a massive program to increase carbon sequestration on hundreds of millions of acres of forest and farmland worldwide would be needed to produce a 10% – 20% "wedge" of global greenhouse gas emission reductions.

Using these percentages as a benchmark, several scenarios were constructed to illustrate the scale of effort needed to meet Minnesota's policy calling for a 30% reduction in greenhouse gas emissions by 2025. The scenarios are not recommendations but an example of what might be achievable over the next 15 years. The conclusion: it may be possible to increase terrestrial carbon sequestration by 3 million to 6 million metric tons of CO_2 per year, or a 6% – 12% wedge of the 45 million metric tons in greenhouse gas emission reductions by 2025. This represents a modest but important contribution to the state's emission reduction goals.

In the calculations below, the quantity of carbon sequestered by a land use practice is calculated by multiplying the carbon sequestration rate by the area of land (acres) affected. When an area of land is converted from one land use to another, the quantity of carbon sequestered is calculated by multiplying the area of land times the difference between the sequestration rates associated with the two land use practices. Often the number of years the practice will be in affect is also calculated.

The acreages used in these scenarios are meant to reflect current conditions or previous experience in Minnesota. Many variations are possible; readers are encouraged to attempt making "back of the envelope" calculations of their own.

Table 2: *The impact of lost carbon sinks on reaching emissions reductions goals.*

Land use change	C loss rate (metric tons CO_2 $acre^{-1}$)	Acres changed	Total C Loss (metric tons CO_2 yr^{-1})
Loss of forests to wildfire	367	14,600	535,820 – 1,071,640
Peatlands to annual row crops or urban	2,732	450	1,229,400
Perennial grasslands to annual row crops	1.6	144,000	230,400
Totals		NA	1,995,620 – 2,531,440

Scenario One: Potential losses from carbon sinks

The first scenario[3] focuses not on potential gains but estimated CO_2 losses from forests, wetlands, and grasslands. It projects a 14,600-acre loss of forestland based on average annual forest fire losses reported by the Minnesota Department of Natural Resources and 450 acres of peatland loss based on the most recent Minnesota Board of Water and Soil Resources report of annual net wetland loss (DNR, 2008; BWSR, 2005). Forest carbon losses from fire are estimated at 10%-20% of carbon stocks per acre (Frelich, private communication). Annual loss of forest and wetland area is multiplied by estimated carbon stock/acre in the initial land cover, because the vast majority of carbon is lost immediately upon conversion. Changes in perennial grassland is based on 2008 Farm Bill reductions in the Conservation Reserve Program, which could result in an 8% reduction of Minnesota's 1.8 million acres in CRP, primarily grasslands. Carbon losses from grassland conversion occur more slowly and are here estimated at 1.6 mt CO_2/ac/yr. The scenario assumes 144,000 acres of grassland are converted to cultivated crops upon contract expiration in 2009. Carbon losses per acre are based on estimates from MDNR peatland inventory, the USDA-NRCS STATSGO and NASIS database, LMIC land cover data, and the U.S. Forest Service FIA and Carbon Calculation Tool.

Scenario Two: Biofuels production in agriculture and forestry

The second scenario estimates the sequestration benefits of converting annual row crops to land cover types having the greatest

Table 3: *Sequestration benefits of converting row crop land to different types of cover.*

Biofuel options	C sequestration rate (metric tons CO_2 $acre^{-1}$ yr^{-1})	Acreage	Total C Sequestration (metric tons CO_2 yr^{-1})
Annual row crop to forests	5.5	200,000	1,100,000
Annual row crop to short-rotation woody crops	7.0	200,000	1,400,000
Annual row crops to perennial grassland	1.6	100,000	160,000
Inclusion of cover crops in row crop rotation	0.6	600,000	360,000
Totals		1,100,000	3,020,000

potential to provide biomass feedstock for fuel and energy (e.g., forest, short-rotation woody crops, and perennial grasses). The scenario also includes adoption of cover crops in corn rotations — not as biofuels but to enable a higher proportion of crop residues to be used for biofuel without depleting soils. This scenario addresses carbon sequestration only and does not include larger CO_2 emission reductions potentially possible when renewable fuels replace fossil fuels. Land use options in this scenario also provide water quality and other environmental benefits. At the scale described below, 500,000 acres of land conversions and 600,000 acres of cover crops would be gradually implemented over the coming 15 years, and by 2025, annually sequester approximately a 6% wedge of the 45 million metric ton reduction target. Including avoided emissions would increase this wedge significantly.

Scenario Three: Multiple conservation benefits

The third scenario represents a broad conservation agenda aimed at improving water quality, wildlife habitat, forest health, and other environmental services over the coming 15 years. Numerous local, state, and federal programs exist to accomplish these objectives and could be leveraged to increase carbon sequestration. Land use and management changes proposed in this scenario total over 4 million acres, representing about 7.5% of Minnesota's total surface

Table 4: *Estimated benefits of mulitple conservation strategies.*

Multiple options	C sequestration rate (metric tons CO_2 $acre^{-1}$ yr^{-1})	Acreage	Total C Sequestration (metric tons CO_2 yr^{-1})	Loss of Working Lands
Prairie pothole restoration	4.5	300,000	1,350,000	yes
Afforestation	5.5	100,000	550,000	maybe
Annual row crop to short-rotation woody crops	7.0	100,000	700,000	no
Increased forest stocking	0.8	2,000,000	1,600,000	no
Annual row crops to pasture/hayland	0.4	300,000	120,000	no
Annual row crops to perennial grassland	1.6	700,000	1,120,000	no
Inclusion of cover crops in row crop rotation	0.6	600,000	360,000	no
Totals		4,100,000	5,800,000	

area, though much of it remains as working land. The potential gain in carbon: 5.8 Mt CO_2/yr or approximately 13% of 2025 emission reductions.

As the scenarios illustrate, large acreages will be needed to significantly contribute to Minnesota's GHG reduction goals. The table below lists carbon sequestration techniques most optimal for large-scale adoption in different eco-regions. How effectively different strategies can be applied and scaled up without compromising economic and environmental resources will be essential to win broad social support now and in the future. Among the numerous avenues for complementary action are major economic and conservation programs, including water quality improvement, flood protection, sustainable forestry, urban greenways, fish and

Table 5: *Opportunities for Improved Carbon Management, by Minnesota eco-region.*

Eco - Region	Complementary land use / management
Northwest Tallgrass Aspen Parklands	• Grassland establishment (native and perennial) • Woody and grass biofuel production • Improved pasture and hayland management • Wetland restoration
Northeast Mixed Forests	• Woody biofuel production • Improved pasture and hayland management • Enhanced stocking forest & shrublands • Ecological restoration of public forests
Central Broadleaf Forest	• Woody biofuel production • Cover crops on annual row crops • Afforestation / Reforestation(restoring former forestland back to forest) • Improved pasture and hayland management • Grassland establishment (native and perennials)
West and Southwest Prairie	• Grass biofuel production • Cover crops (south-central) • Improved pasture and hayland management • Grassland establishment (native and perennial) • Wetland restoration
Urban Areas	• Urban / community forests • Wetland restoration • Afforestation / Reforestation

wildlife protection and restoration, and biofuel production.

Recommendations

The findings and analysis presented above lead the Minnesota Terrestrial Carbon Sequestration Initiative to recommend a three-step program to policymakers.

Recommendation #1: Preserve existing large carbon stocks in peatlands and forests by identifying and protecting areas vulnerable to conversion, fire, and other preventable threats.

Forests and peatlands contain very large carbon stocks, estimated at 15 billion metric tons. Release of this stored carbon can result from human activities and environmental stressors. Such releases would accelerate global warming and require greater reductions in CO_2 emissions elsewhere. Vulnerable areas should be identified and stop-loss activities applied, including forest thinning and controlled burns to reduce wildfires, discouraging loss of natural vegetation in development, and avoiding mining, drainage, and cultivation of organic soils. Similar efforts to reduce conversion of perennial grasses should be considered. Applicable programs on private land include Forest Legacy Program, Native Prairie Bank, Reinvest in Minnesota, Wetlands Conservation Act, and programs of private organizations.

Recommendation #2: Promote land use and land cover changes most certain to cause carbon sequestration by including them in local, regional, and statewide conservation, renewable energy, and sustainable development priorities.

Wide differences exist in the carbon sequestration benefits of the thirteen land use, land cover, and management changes most applicable in Minnesota. The most prudent approach in the near term is to incorporate carbon objectives into broader environmental, economic, and renewable energy programs, with a focus on those land use/cover/management changes with the highest sequestration rates and medium to high certainty regarding their positive sequestration value. Numerous public and private programs to improve water quality, flood protection, forest productivity, and biodiversity could increase carbon benefits at little additional cost. Designing programs to integrate climate mitigation (lessening CO_2 buildup) and adaptation (reducing its impacts) could help address costs and uncertainties of sequestration projects and increase long-term public support.

Recommendation #3: Invest in monitoring and demonstration programs to build public, practitioner, and investor confidence in terrestrial carbon sequestration as a viable emission reduction strategy.

A major conclusion of this assessment is that protecting and enhancing the state's carbon stocks is an important resource management strategy needing research and education to be implemented successfully. However, given the uncertainty surrounding rates of carbon sequestration following land use/land cover change, the state should undertake a program to establish 1) monitoring sites for quantifying carbon sequestration rates of different land use/land cover conversions and 2) demonstrations of land use/land cover changes that are most promising for carbon sequestration. Such a program will increase public confidence in the viability of terrestrial carbon sequestration as a CO_2 mitigation strategy.

The monitoring and demonstration network envisions a linked system in which a small number of monitoring sites complement and inform an extensive network of demonstration projects around the state.

The purpose of a monitoring network is to assess changes in the state's net carbon balance related to land management. It would establish baselines and carry out periodic measurements of three main conditions: 1) the area of land converted from one land use to another; 2) the annual net carbon sequestration rate associated with a land use conversion; and 3) the annual rate of carbon flux between various ecosystems and the atmosphere. Measurements could be extrapolated across the region to estimate carbon sequestration resulting from land use or management changes at sites not monitored. Measurements should be obtainable in a relatively short five-year time period and should be followed up over a longer (20- to 100-year) timeframe.

Demonstration projects would be used to educate land managers about sequestration techniques; document the carbon results of selected management practices; assess financial and other costs and benefits of integrating sequestration practices into existing activities; and test applicability of various decision-making tools. Demonstrations of all sequestration techniques suitable in Minnesota should eventually be undertaken. An initial set of projects can be undertaken through collaborations with existing studies or projects around the state. Five projects are being proposed:

- *Assessing carbon impacts of sustainable forestry techniques* in the

Manitou River region north of Lake Superior. Carbon benefits of increasing forest diversity and the proportion of long-lived tree species will be evaluated, along with applicability and accuracy of forest carbon management tools.

- *Carbon benefits of wetland restorations* in the Red River Valley will investigate the compatibility of carbon management practices with flood reduction, wetland habitat, and water quality goals.
- *Carbon benefits of winter cover crops* in the Zumbro River region will be added to long-term research on cover crops by a group of farmers, local and state agencies, and University of Minnesota researchers.
- *Carbon benefits of perennial biofuels* will be assessed in partnership with Koda Energy to improve understanding of carbon sequestration implications of perennial grasses harvested for biofuel. The project builds upon an extensive study of perennial biofuel systems in central Minnesota.
- *Carbon benefits of urban forestry and green infrastructure* in the Minnehaha Creek watershed in the Twin Cities metropolitan area will be evaluated and incorporated into watershed planning.

Part II. Financing terrestrial carbon sequestration

The scale of effort described above — protecting and increasing carbon stocks on millions of acres of land — presents enormous challenges. Even if multiple-benefit strategies that leverage existing programs are used, competition for land, management expertise, and long-term commitments to sequestration practices will challenge landowners and policymakers. What financial resources could support this level of effort?

A major portion of Minnesota's existing carbon sink is forests and peatlands in the public domain. Federal and state government, and dozens of county and municipal-level agencies manage these and other open spaces for different purposes, among them wilderness protection, habitat, recreation, timber, grazing, and mining. Focusing a major effort on public lands would reap the advantages of both permanent protection and skilled management. Before undertaking such a program, it will be essential to determine if detrimental effects could occur and to promote sustainability and consistency with other goals.

Government is also the most immediate source of support for increasing carbon sequestration on private lands, using the infrastructure of private lands conservation programs built over the last century. The federal government provides billions of dollars annually in financial and technical assistance to landowners. In particular, the U.S. Department of Agriculture cost-shares many best management practices affecting carbon stocks on farmed land, wetlands, and forests. The state of Minnesota also offers assistance through cost-share programs, easements, loans, tax incentives, and other instruments in such programs as Reinvest in Minnesota, Agricultural BMP Loan Program, Sustainable Woodlands Program, Native Prairie Bank Program, and Permanent Wetland Preserves. Together these programs could provide the essential foundation for expanding carbon sequestration in the state.

In the past decade, a new paradigm has emerged for funding large-scale conservation efforts through voluntary and mandatory carbon reduction programs. The Kyoto Protocol and current and proposed programs in the United States and elsewhere utilize a "cap-and-trade," or market-based, approach for managing GHG pollution. Such programs set emission reduction targets (caps) and time tables, then provide two flexibility mechanisms that regulated sectors and companies can use for compliance. The most-commonly used mechanism is tradable allowances. Each company is issued a specific number of allowances entitling the holder to emit one metric ton of greenhouse gases (equivalent to one metric ton of CO_2, or

CO_2e). Companies can use allowances to cover internal emissions up to their cap; reserve or "bank" them for future years; or sell them to other entities. A major unresolved issue is the proportion of allowances that will be distributed for free, auctioned, and/or based on set fees.

The second flexibility mechanism refers to carbon credits, or "offsets," that companies may purchase to count against their required reduction. Carbon offsets, also denominated at one metric ton of CO_2-equivalent, are credits for emission reduction or sequestration occurring in un-capped sectors of the economy. The most common sources of offsets are renewable energy, methane collection and combustion, energy efficiency, destruction of industrial pollutants, and carbon sequestration. Economic analyses suggest that the use of carbon offsets lowers costs by 50% or more (Goulder and Nadreau, 2002), thereby increasing the political viability of compliance.

The Midwest Governor's Greenhouse Gas Accord, a consortium of nine states and two Canadian provinces aimed at reducing emissions in the region, recently completed work on a set of recommendations for a cap-and-trade program. These recommendations have been forwarded to Congress for possible inclusion in federal legislation; if enactment of national policies is delayed, the recommendations will become the basis for model rules to be adopted by Midwestern states. The recommendations call for reductions in GHGs 20% below 2005 by 2020 and 80% below 2005 by 2050. They call for a cap on emissions from electrical and industrial sectors, and on fuels used in transportation and in residential, commercial, and industrial buildings. Allowances are issued using a combination of free, auction, and fee-based distribution. Offsets may be used for up to 20% of a regulated company's total emissions. Note that this percentage refers to total emissions, not emission reductions. A company emitting 1 million tons of CO_2e per year could purchase offset credits for up to 200,000 tons of that amount.

The focus of discussion in Congress is the American Clean Energy and Security Act of 2009 offered by Rep. Henry Waxman (Calif.), specifically Title VII: The Global Warming Pollution Reduction Program. It sets annual emission reduction targets and rules for meeting them, including offset program rules. Using 2005 as a baseline, the bill calls for 42% reduction in 2030 and 83% reduction in 2050. Domestic and international offsets may be used for up to 2 billion tons of CO_2e (2,000 $MtCO_2e$) each year. The bill creates an Offsets Integrity Advisory Board to make recommendations to the U.S. Environmental Protection Agency on the establishment

of the offset program, including what project types should be eligible to offset greenhouse gas emissions. The Board is expected to recommend that a single offset registry be used, along with a single set of standards for quantifying offsets and ensuring that they adequately mitigate carbon emissions. Regulation-quality standards are more rigorous than many voluntary offset programs, typically specifying that a carbon offset must be:

- *Real*, meaning the effects of a project must be comprehensively accounted for, including leakage (i.e., increases in emissions occurring elsewhere that are triggered by the existence of a project, such as increased timber harvest elsewhere because of restrictions at a project site);
- *Additional,* or "in addition to" removals that would have occurred under business-as-usual projections. Start-up dates are specified (i.e., "not before 2001") and justifications are required to explain why the project would not have occurred without carbon finance;
- *Verifiable*, meaning that effects can be measured with reasonable precision and certainty by a third-party certified verifier;
- *Permanent*, meaning that the offset project results in permanent reduction, avoidance, or removal of greenhouse gases or is backed by guarantees and safeguards to minimize and replace non-permanent removals. With few exceptions, offset registries in the United States have required an offset project to be secured by a permanent easement;
- *Enforceable*, consistent with regulations and administrative rules.

When established, the new U.S. carbon offset market will dwarf today's voluntary market, which in 2008 transacted 123 $MtCO_2e$ valued at $705 million. Although carbon offset prices have been low in the United States and volatile worldwide, they are expected to rise as GHG regulation becomes more prevalent and demand increases. A range of carbon market issues — volatility, liquidity, integrity, and enforceability of market transactions — can be expected to emerge in coming years. How they are handled will determine the level of public confidence and long-term viability of market approaches to managing pollution.

For terrestrial carbon sequestration to fully participate in these markets, advances are needed in several key areas: improved understanding of carbon sequestration; improvements in the quality, standardization, and practicality of reporting systems; avoidance of negative socio-economic and environmental impacts; and close

monitoring of the impact of offsets on emission reduction efforts. This last condition refers to concern that low-cost offsets will deflect attention from more expensive replacement of fossil fuel combustion, the main driver of global warming. Another key consideration is the impermanence of carbon sequestration and/or the willingness of landowners to enter long-term or permanent contracts to maintain sequestered carbon stocks used as offsets.

If some types of land-based activities are not included in offset programs or if landowners opt not to participate in them, other options are possible. The Regional Greenhouse Gas Initiative (RGGI) is a nine-state cap-and-trade program operating in the Northeast United States. Rather than issuing free allowances, RGGI conducts quarterly auctions. In early 2009, auction prices were just over $3/mt CO_2e and were projected to raise $606 million during 2009. Auction proceeds are devoted primarily to energy efficiency projects, but some states also use proceeds to fund carbon sequestration projects. This strategy removes the need for strict accounting and monitoring because carbon removals are in addition to, not an offset for, capped emissions. Particularly during the early years of cap-and-trade programs, when carbon prices are low and trading mechanisms untested, the use of auction proceeds to finance carbon sequestration could have advantages by providing up-front financing, minimal accounting requirements, and low monitoring and transaction costs. In these early years, combining traditional conservation programs with carbon market auctions and offsets could provide the expertise, outreach, and finance needed for a large-scale and long-term effort.

Endnotes

[1] Geologic carbon sequestration refers to the capture of carbon dioxide emissions from industrial sources and storage in deep geologic formations.

[2] Recent research (Baker et al, 2006; Blanco-Canqui and Lal, 2008) raises questions about whether reduced tillage increases soil organic carbon or simply re-distributes it in the soil column. Although conservation tillage is an important farm practice deserving broad implementation, its carbon benefits are uncertain and need further research.

[3] This scenario has been revised to include losses from forest fire and changes in 2008 Farm Bill.

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Landowner Attitudes and Perceptions Regarding Wildlife Benefits of the Conservation Reserve Program

Martin D. Mitchell & Richard O. Kimmel

Introduction

Landowner perceptions of farmland programs are important for their successful implementation. Our purpose was to survey landowners who were participating in the Conservation Reserve Program and those who were non-participants in 1997 and 2006 to determine: (1) were there differences in how each group perceived the CRP and its associated environmental impacts; and (2) did these perceptions change from 1997 to 2006? We found that all landowners had a dramatically enhanced sense of environmental awareness regarding wildlife habitat, particularly pheasant populations, relative to the CRP in 2006, and that perceptional differences between participants and non-participants had noticeably narrowed from 1997 to 2006, indicating increased awareness of the intended conservation benefits of the CRP. While these results show that the Conservation Reserve Program has served its purpose of conserving habitat while controlling production, we believe the CRP has other new purposes in the energy area. For that reason, we believe the CRP should be reauthorized in the 2012 Farm Bill to reflect a prudent balance between farm, energy and environmental issues, which are increasingly becoming intertwined in rural locales.

Agricultural programs are dependent both on government legislation from which the programs originate and the landowners who implement these programs. Landowner acceptance of agricultural programs is paramount for success. Indicative of such interest were the large sign-ups for annual set-aside programs in the 1960s and the commensurate decline of multi-year land retirement programs such as the *Cropland Conversion Program of 1962* and the *Cropland Adjustment Program of 1965* (Berner 1988, Kimmel and Berner 1998).

A multi-year land retirement option was not available again until the Conservation Reserve Program (CRP) was authorized in the *Food and Security Act of 1985* (Kimmel and Berner, 1998). In Minnesota, a sign-up of 1.9 million acres of CRP land during the 1980s demonstrated the landowner interest in this program, and hence the CRP has been re-authorized in the Farm Bills of 1996, 2002 and 2008, albeit the current authorization lowers the national enrolled total from 39.4 million acres to 32.0 million acres as of FY 2010 (*Public Law 110-234*). Currently, almost 1.7 million acres are enrolled in Minnesota and the current CRP is set to expire October 1, 2012 (USDA 2009 and *Public Law 110-234*). The popularity of the current CRP provides a platform from which future modifications can be made to address traditional environmental issues such as soil erosion and more contemporary environmental and economic concerns related to wildlife habitat, diversification of biofuel feedstocks, energy independence and rural income stabilization.

The purpose of this study was to survey landowners in the Corn Belt region of south central Minnesota to better understand: (1) their attitudes and perceptions about the CRP; (2) its impact on wildlife abundance; and (3) whether landowner attitudes have changed over the past 10 years. Several studies described the characteristics of CRP participants (Force and Bills 1989, Hatley et al. 1989, Mortensen et al. 1989). Miller and Bromley (1989) evaluated interest of CRP participants in improving wildlife habitat and stressed improved communication between farmers and wildlife professionals. Likewise, Kurzejeski et al. (1992) found that when wildlife information was available, landowner participation in wildlife conservation measures increased.

More recent studies focus on the CRP's socio-economic effects and its perceived impacts on the rural environment. Leistritz et al. (2002) examined the socio-economic impacts of CRP in six different agricultural sub-regions of North Dakota. This study centered on surveying CRP participants and community leaders from the agri-business sector who were not participants in the CRP. In another North Dakota study, Bangsund et al. (2004) modeled the effects of greater hunting opportunities resulting from the CRP relative to the opportunity costs of the landowners enrolled in the CRP. For Minnesota, studies indicate that hunters spend approximately $150 per hunter per year resulting in millions of dollars in economic impact on rural communities (Baumann et. al 1990, Southwick Associates 2003 and Dutton 2008). Soil erosion, a traditional environmental concern of farm programs in general, is dealt with by the CRP because the program specifically targets highly erodible

lands and places them in perennial land covers involving nominal to no cultivation (Buskol et. al 2001). Finally, the United States Geological Survey (USGS 2003) conducted a national survey of CRP participants to determine their perceptions of wildlife, vegetation, and the general impacts of the CRP on the rural landscape. This study parallels the USGS work, though ours is narrower because it covers: (a) a smaller geographical range, (b) specifically selects landowners from in-place Minnesota Department of Natural Resources (MDNR) study areas targeting upland birds, and (c) was conducted in 1997 and later in 2006.

Study area

Our study area was centered on the till plains of south central Minnesota, which are located in the northern portion of the US Corn Belt (Hart and Ziegler 2008). The natural vegetation consisted of warm season grasses such as Indian grass (*Sorghastrum nutrans*) and Switchgrass (*Panicum virgatum*). Oak/grass savannas were located in drier areas caused by sandier soils. Hardwood forests were found along riparian corridors and incised river valleys and ravines (Marschner 1974). Ring-necked pheasants (*Phasianus colchicus*) were introduced successfully into Minnesota in 1916 following the substantial diminishment of prairie-chickens (*Typanuchus cupido)* due to unregulated hunting and habitat modification associated with farming (MDNR 1986). Pheasants remain an important upland game bird. Since 1950, a vast expanse of corn and soybeans replete with artificial drainage abounds and grasslands are far scarcer. Indeed, less then 1% of the natural tall grass prairie remains (Tester 1995). Notable exceptions of grassland that often contain a mixture of native and introduced cool season grasses or residual tall grass prairies are mainly found in publicly held wildlife areas, Conservation Reserve Program (CRP) lands, and Re-Invest in Minnesota (RIM) lands. The latter two comprise long-term agricultural set aside programs.

Methods

In our 1997 survey, we asked landowners in south central Minnesota about land ownership, enrollment in the CRP, opinions on whether the CRP improved habitat for wildlife, and factors influencing land-use decisions (Kimmel et al. 1997). A 25-question, 6-page survey was mailed to 263 landowners who owned property located on 15 9-square-mile study areas in south central Minnesota that the DNR used for monitoring the abundance of ring-necked pheasants (*Phasianus colchicus*), gray partridge (*Perdix perdix*), and

meadowlarks (*Sturnell spp*.) based on degrees of CRP land ranging from 0% to 30% (Kimmel et al. 1992, Haroldson et al. 2006). In February 2006, we prepared a smaller 14-question telephone survey and interviewed 60 landowners chosen from the 1997 survey sample. With both studies, we divided the landowners into CRP participants and non-participants using a 50/50 ratio to identify differences in perceptions between these two groups.

Results

For the 1997 survey, 219 of the 263 surveys were returned. Undeliverable surveys and deceased landowners accounted for 44 unreturned surveys. Thus, the response rate for deliverable surveys was 83.0%. Our telephone-based survey in February 2006 had a 100% response rate with 31 CRP participants (52%) and 29 non-participants (48%) comprising the final sample.

In 1997, land enrolled in the CRP on the 15 study areas averaged 81.9 acres per farm. In 2006, this figure dropped to 37 acres. Landowners enrolled in the CRP owned an average of 390 acres in 1997 and 399 acres in 2006. Landowners without land enrolled in CRP owned an average of 280 acres both in 1997 and 2006.

In 1997, the most common response for not enrolling eligible land into the CRP related to higher potential income from crops compared to CRP payments (68%) and increased crop prices (56%). In 2006, the most common reason for non-participation was ineligibility (41%), followed by the opportunity costs of growing crops (28%).

Landowners with CRP land in 1997 indicated they enrolled land because of: (1) concern for soil erosion (73%); (2) provision of wildlife habitat (67%); (3) most profitable use of land (52%); (4) low risk associated with payments (36%); and (5) easiest way to meet conservation compliance (36%). Personal retirement (15%), and reduced labor (15%) were secondary factors. Most landowners (73%) indicated their selection of a cover crop for CRP land was to benefit wildlife. In 2006, landowners listed soil erosion control (36%), conservation/buffer strips (33%) and wildlife (29%) as the most popular factors for program participation.

In 1997, only 35% of landowners with CRP land and 27% of landowners without CRP land indicated wildlife abundance was an important consideration in their choice of farming practices. By contrast, 94% of the participants in 2006 considered wildlife abundance important when selecting a farming practice. As for non-participants in 2006, we found 67% also considered wildlife as important when selecting a farming practice.

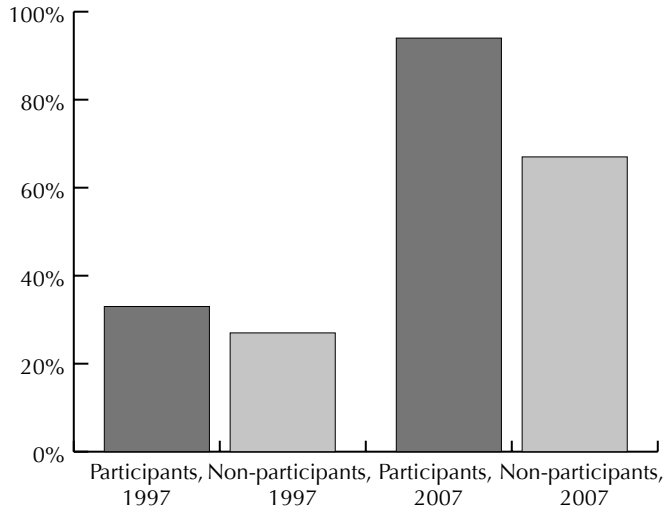
Most landowners with CRP land in 1997 (93%) indicated that the CRP improved pheasant habitat in the vicinity of their farm. The majority of landowners without CRP land (70.5%) also indicated enhanced pheasant populations. A majority of all landowners (52%) indicated the CRP improved habitat for white-tailed deer (*Odocoileus virginianus*) and gray partridge. Fewer landowners (38%) indicated that the CRP improved habitat for meadowlarks.

For 2006, 98% of all respondents agreed with the statement: "The CRP has improved the overall wildlife habitat in Minnesota." Moreover, 92% of those surveyed answered they agreed with the statement: "The CRP has improved the wildlife habitat in your area." There were only nominal differences between participants and non-participants and both groups felt pheasants (85%) and white-tailed deer (34%) were the major beneficiaries.

Discussion

Land ownership acreage between participants and non-participants were similar in 1997 and 2006. In 1997, the most common reasons for not enrolling were directly related to anomalously high prices for corn and soybeans, which, for example, in July 1996 were $4.43 a bushel for corn (Food and Water Watch 2007). The leading factor in the 2006 survey was ineligibility, a

Figure 1: *Was wildlife an important consideration in the choice of farming practice? Percentage of CRP participants and non-participants answering "yes," 1997 & 2007.*



situation that occurred after the USDA tightened the criteria for CRP eligibility in 1996 and made the program more competitive. On the national level, these changes favored greater acreage in the Great Plains states within the prairie pothole region (USDA 2004). Interestingly, corn prices at roughly $2.30 a bushel were much closer to historic averages (1990-2006) (Barnaby 2008).

Although the average size of CRP fields in our study area declined from 82 to 37 acres, the statewide aggregate acreage in 2006 was only about 100,000 acres below its late 1980s peak of 1.9 million acres (USDA 2006). This situation stems from CRP lands in Minnesota being more concentrated in the Red River valley (Lopez et al. 2000).

The most significant changes in landowner perception between 1997 and 2006 concern wildlife perceptions (Figure 1). In 1997, approximately one-third of the CRP participants indicated wildlife was important in farming considerations. This increased dramatically to 94% in 2006. A similar increase from 27% to 67% also occurred with non-participants. This change is indicative of realizing heightened wildlife benefits associated with the CRP particularly as they pertain to game species such as pheasants and white tailed deer. Interestingly, the 1997 and 2006 surveys yielded virtually identical results (93% and 92%, respectively), when examining the perception that CRP was a positive factor in improving wildlife habitat at a localized scale.

Our findings paralleled a national study conducted by the USGS (2003), which examined CRP participants and their environmental perceptions of the program. This study found that in the Corn Belt 73% of landowners agreed that CRP had positive changes for wildlife and 59% agreed the program provided additional opportunities to view wildlife. As noted, our 2006 survey found that 92% of our respondents (participants and non-participants) agreed with the statement that the CRP "improved wildlife" in the local area. Both groups overwhelmingly (98%) felt the CRP improved wildlife in Minnesota at large, a finding that extends beyond one's immediate bounds.

The USGS (2003) found that CRP was sometimes viewed negatively by participants as a source of weeds (33%) and attracted unwanted hunters seeking permission to hunt (23%). Our 2006 survey found only 3% of all respondents "strongly agreed" with these criteria, although 27% and 33% "agreed" with these statements, respectively. On one hand, our 15 study areas in south central Minnesota mirror the Corn Belt regional findings, yet on the other, the intensity of these negative attributes is more muted.

The USGS (2003) also found that about 14% of the participants felt the CRP added to an unkempt appearance. In our 2006 survey, the participants matched the USGS' regional finding. However, almost 25% of our non-participants felt CRP fostered an unkempt farm appearance. It is possible that the latter could be due to ignorance. Non-participants simply may not recognize a CRP field and instead view it as unorderly relative to the manicured appearance of heavily cultivated corn and soybean fields, which dominate the regional landscape. Unlike lands enrolled in a similar state-funded set-aside program called Reinvest in Minnesota (RIM), signage is not offered for CRP fields.

Finally, Leistritz et al. (2002) found that non-CRP participants, (agri-business professionals) in North Dakota felt the CRP drained money from local economies because land taken out of production did not require the same amount of purchased inputs (fertilizers, insecticides, etc.) as cropland and encouraged human population loss through retirement and relocation elsewhere. Although we did not survey agri-business professionals, the majority of our non-participants in 1997 (52%) felt the CRP was at least somewhat important in stabilizing rural incomes. In 2006, about 65% of our non-participants said the CRP was financially good for farmers. As for retirement and its perceived impact on population loss, our 1997 survey found retirement to be inconsequential when making a CRP decision. We did not survey for this criterion in 2006.

In summary, our most significant findings were that: (1) in 2006, 98% of all respondents surveyed found that the CRP benefited wildlife in Minnesota at large and that pheasants were the major beneficiaries; and (2) landowners in general presently "consider" wildlife populations when making farm-related decisions at much higher rates than in 1997. Our survey results in south central Minnesota paralleled the USGS (2003) regional Corn Belt findings, but with some qualifications, the most notable being more muted negative feelings towards CRP lands. Overall, both the non-participants and participants find the CRP to be a popular program; perhaps the finding that best states this is: 56% of those surveyed in 2006 would change absolutely nothing if given the chance to re-authorize the CRP, while the other 44% recommended essentially minor or nominal changes.

Future implications

As farm, energy and wildlife policies increasingly intersect, The Conservation Reserve Program and its future reauthorizations harbor many tangible effects for rural Minnesota. Minnesota

ranked fourth nationally with a bountiful harvest of over 650,000 pheasants in 2007 (Laingen 2008). Hunting and/or bird watching comprise additional stimuli for rural-based economies, especially when the hunters originate from urban or suburban areas (Laingen 2008). Essentially, a flow of capital to rural locales occurs. Although other factors such as climatic conditions influence the pheasant population, the CRP does have a positive impact on the population of upland game and non-game birds throughout the corn/soybean region of southern Minnesota because it creates habitat (Haroldson et al. 2006). Indeed, Minnesota's pheasant harvest from 1990 to 1999 averaged 375,000 birds a year and climbed to 475,000 a year from 2000 to 2008, a clear departure from the low harvest of 265,00 per year in the 1970s, when long-term set-aside programs were not available (MDNR, unpublished data 2009). As noted, the CRP is popular within rural Minnesota both with participants and non-participants alike, and the trend is toward greater popularity based on environmental and income stabilization benefits.

The *Food Conservation and Energy Act of 2008 or Farm Bill of 2008* cut the national cap on CRP acreage from 39 million to 32 million acres (*Public Law* 110-246). The popularity of the CRP with rural landowners as demonstrated by our study supports an increase in the CRP cap during the next re-authorization and a re-examination of CRP rents and grassland utilization in light of the rise of corn-based ethanol. Ethanol, which was previously a minor factor in rural America, including Minnesota, has boomed in the last few years. For example, the national capacity for ethanol distillation surged from 1.75 billion gallons in January 2000 to 3.9 billion gallons in 2005 and finally to 10.3 billion gallons as of March 2009 (Renewable Fuels Association 2009). Minnesota currently ranks fifth in ethanol production with a capacity of 862 million gallons.

This ethanol boom stems from a convergence of four major factors. First, the Clean Air Act of 1990 resulted in mandating oxygenated fuels as a means of reducing carbon monoxide emissions in cold environments or in air basins prone to atmospheric stability, i.e. poor circulation (Duffield et al. 2008). Demands for Midwest-based corn ethanol further increased when California banned its petroleum-based oxygenate MTBE (methyl tertiary-butyl ether) in 2003 (US EPA 2004). Second, the *Alternate Motor Fuels Act of 1988* allowed automobile manufacturers to circumvent higher CAFE (corporate average fuel economy) standards by introducing flex fuel vehicles powered by E85, which the industry began producing in the late 1990s *(Public Law* 100-494). Third, the *Farm Security and Rural Investment Act or Farm Bill of 2002* contained a bioenergy

section aimed at increasing farm income through biofuel production (biodiesel and ethanol) (*Public Law 107-171 Title IX*). Fourth, as a result of market volatility associated with oil prices and Middle East instability, the *Energy Policy Act of 2005* and the *Energy Independence and Security Act of 2007* were passed (*Statutes at Large* 119:54 2005 and *Public Law* 110-140, *HR* 6 2007). These Acts attempt to diversify domestic energy production by means of subsidizing biofuels including those based on sugarcane and cellulosic feedstocks. The ultimate goal is to achieve 36 billion gallons per year of biofuels by 2022, most of which would be ethanol. Indeed, as of April 2009, 26 sugarcane/cellulosic ethanol projects were under construction in 22 states, though none in Minnesota (RFA 2009b). For example, one plant in Montana and another in Tennessee will use switchgrass as a major feedstock (RFA 2009b.)

The CRP provides a reserve of grassland that aside from comprising wildlife habitat, can also function as a cellulosic reserve in a more bio-fuel based transportation system, something that serves rural and urban-based interests. Essentially, the CRP can continue to serve as a rural income stabilization program especially given the volatility of commodities prices, which are increasingly tied to political and economic events associated with the energy markets, particularly oil. Our concern is that a short-sighted wholesale conversion of CRP land into corn or allied crops would not only result in a tangible drop in wildlife habitat and increased soil erosion, but would increasingly concentrate the biofuel sector into one feedstock, i.e. corn, leaving rural landowners in a more vulnerable position should the energy/commodity markets crash. In the meantime, as a nation we would lose a major cellulosic base that could easily be incorporated into a diverse biofuel regime with more nominal wildlife and soil erosion impacts.

The next Farm Bill clearly requires prudence in "balancing" the short- and long-term costs and benefits associated with achieving multiple objectives, which involve stabilizing rural income, protecting and enhancing the environment and habitat, plus fostering national security by moving away from complete dependence on foreign petroleum reserves.

Such balancing would incorporate the goal of achieving a diverse biofuel industry and provide at least one tangible method to achieve the goal of substantial energy independence in the next 10 years. Indeed, such deliberations are inherent in the present convergence of farm, energy, environmental and rural policy issues.

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In Pursuit of a Cure: Searching for Food-Based Cancer Therapies and Preventions at The Hormel Institute

Ann M. Bode

In spite of President Nixon's declaration of the "war on cancer" in 1971, deaths from the most common cancers, including pancreatic, ovarian, colon, lung, breast and prostate, are still rising. Cancer is a dynamic process that involves many complex processes and is therefore not likely to be prevented or cured by a "magic bullet." However, the design and development of chemical or natural agents that act on specific molecular and cellular targets is regarded as a rational approach to control cancer. This strategy for cancer control is based on the presumption that because cancer develops through a multistep long-term process, each step in cancer development can be a possible target for reversing or suppressing the process.

The toxicities associated with standard chemotherapy are as likely to kill the cancer patient as is the cancer itself. Thus, interest in alternative and novel approaches for the prevention and treatment of cancer has increased dramatically, especially in the last few years. The idea of using a chemical agent, drug or food supplement or whole food to stop or reverse the process of cancer development before tumors begin and grow (known as "chemoprevention") has ignited a worldwide revolution in the way scientists, physicians and the general public view cancer.

Research data from epidemiological and scientific experimental studies indisputably indicate that diet is one of the most important links to human cancer. Nutritional or dietary factors have attracted a great deal of interest because of their perceived ability to act as highly effective cancer fighting agents. The general public is clamoring to find the "magic pill" or "health food" that will prevent or cure cancer without unwanted side effects. The use of natural dietary compounds or whole foods for improving health has been around for many years but interest in their use has increased dramatically because of perceived health benefits without unwanted or unpleasant side effects. This is especially true in cancer prevention

and treatment. Nutritional or dietary factors and especially whole foods are professed as being generally safe, which is critical for their success in cancer prevention or treatment. Many individual or combinations of food agents are known to specifically attack *only* cancer cells or cancer-related molecular or cellular targets, which obviously minimizes the potential of undesired side effects often associated with chemotherapy.

On the other hand, one of our greatest challenges is to reduce the enormous amount of misinformation reported in the popular media regarding the health benefits of certain foods or food supplements. Regrettably, to determine whether a nutritional product has *real* health benefits is extremely difficult. The field includes many natural remedies used for centuries such as ginseng, herbal teas and substances like vitamin E, extracted from natural products. Hundreds of compounds are being extracted, concentrated and marketed and are purported to have major health benefits, but many of the claims are based mainly on circumstantial evidence. More and more people are using dietary supplements and herbal remedies without advice from a physician, sometimes with disastrous results. Unfortunately, much of the information regarding the effectiveness and safety of these remedies has been gleaned from anecdotal or historical accounts, which seem to be readily available from a variety of sources. Numerous substances derived from foods have been linked to decreased risk of developing cancer and thus interest in cancer prevention by dietary factors has skyrocketed. However, the available information is often confusing and contradictory due to the complexity of the many interactions that often occur between selected food components and molecular pathways related to development of cancer. Thus a critical need exists to 1) identify individual or combinations of dietary factors that can act as cancer preventive agents and effectively inhibit cancer development; 2) determine the molecular targets within cancer cells that are modulated by specific individual or combinations of dietary factors; 3) move these factors into clinical trials based on solid preclinical data; and 4) develop whole foods that are enhanced with specific individual or combinations of proven anticancer dietary factors.

Identifying natural anticancer agents

The Hormel Institute, a research unit of the University of Minnesota and located in Austin, Minn., is recognized as a world leader in scientific research focusing on the prevention of cancer. In 1942, Jay C. Hormel, son of Hormel Foods founder G.A. Hormel, brought The Hormel Foundation and the University of Minnesota

together to create The Hormel Institute, a medical research center that would become a division of the University of Minnesota Graduate School. The Hormel Institute is one of the oldest research institutes in the United States and during its early history was the nation's leading lipid research center. Among its most noteworthy accomplishments is the development of the first miniature pig, the Swiss Swine, for cardiovascular research and the discovery and naming of omega 3 and omega 6 fatty acids by Dr. Ralph Holman, a former executive director of The Institute. Perhaps The Institute's most infamous contribution was the provision of the pig(s) that played Arnold on the classic television sitcom "Green Acres."

Today, its reputation is growing rapidly as a center for developing and testing natural, dietary anticancer agents that are nontoxic and highly effective. Its strength is its ability to systematically identify and test hundreds of dietary factors purified from natural agricultural sources locally, regionally, nationally and internationally.

With the rapid development of knowledge and techniques in biology, especially molecular and cellular biology, substantial progress has been made in the study of cancer chemoprevention. A major focus of the work at The Hormel Institute is the discovery of mechanism(s) explaining the anticancer actions attributed to many chemopreventive compounds, especially natural dietary compounds that are considered safe because they are present in what we commonly eat or drink. Of particular interest are selected food factors that influence cell signaling events coinciding with promotion of various types of cancer.

Cancer has now surpassed heart disease as the number 1 killer of Americans under the age of 80. In order to facilitate the development of chemopreventive and chemotherapeutic agents that specifically target molecules important in cancer development, we must know the enemy — we must understand carcinogenesis or how cancer develops. The prevailing thought today is that cancer may be prevented or treated by targeting specific cancer genes, signaling proteins and transcription factors. Cancer is a multistage process, consisting of initiation, promotion and progression stages. The stage of initiation is short and irreversible and entails DNA or gene damage caused by a carcinogen such as cigarette smoke or sunlight. The promotion stage can occur over 5 to 50 years or more and is the period of time during which "initiated" cells multiply and divide to form cancers. The progression stage is the period during which the tumor presents itself. Although each stage could be a possible target for chemopreventive agents, the promotion stage, because

of its extensive length, has the most potential to be reversed and is especially susceptible to lifestyle changes.

By focusing on the molecular mechanisms explaining how normal cells can be transformed into cancer cells induced by tumor promoters (e.g., sunlight, diet, obesity, environmental factors, asbestos exposure, smoking, etc.), we have discovered that several specific cellular components, known as transcription factors and protein kinases, are critical factors in cancer development and significant targets for cancer prevention and treatment. A strength of The Hormel Institute's research is that it has shown that cellular proteins and genes are crucial targets for anticancer agents. Most notably, The Institute scientists have shown that anticancer agents can be developed that exclusively target cancer cells with no harm to normal cells. Specific dietary or natural compounds found in whole foods such as green and black tea, coffee, ginger root, chocolate (cocoa), honey bee propolis, rice, flax and flax seed, cabbage, broccoli, potatoes, tomatoes, berries, onions, and grapes (to name a few) have all been shown to exhibit potent anticancer activities.

Determining molecular targets of natural anticancer agents

The human body is composed of billions of biological components that make up complex and interconnected communication networks and intricate pathways designed to work together to promote optimal health. Understanding the integration of these pathways and how disturbances in their function might lead to diseases such as cancer is critical in determining how these pathways might be restored to normal operation to prevent or cure disease. Crucial players in these pathways are tiny molecules known as proteins, which are manufactured from genes that contain our DNA. Proteins are the miniature machines that allow us to live healthy, productive lives. Each protein has a unique 3-D shape that is specific for that protein's normal function, and if that shape is damaged, diseases such as cancer can occur. Furthermore, specific dietary factors or other small molecules are extremely important to researchers to investigate the proteins comprising biological pathways. These types of small molecules or dietary factors are also extremely valuable for treating and preventing disease. A fundamental challenge has been the ability to successfully identify food factors or other small molecules that are effective at modulating a particular biological process or disease state.

International Center of Research Technology

Over the last two years, The Hormel Institute has been working to create an International Center of Research Technology (ICRT).

The long-term goal of the ICRT is to provide the most advanced tools of technology available today to researchers working at biobusinesses, medical centers, colleges and universities throughout Minnesota and regionally. Working with its collaborative partners, including IBM, the Mayo Clinic, and the University of Minnesota Rochester, the ICRT is developing new technologies to accelerate discovery and facilitate comprehensive study of human disease by combining analyses of protein structure/function with advanced methods of data management and drug screening. The net result will be a greater understanding of biological systems for improving the quality of life in Minnesota, the nation, and the world and a dramatic, positive impact on economic development in bioscience and biotechnology statewide and regionally.

Drug discovery is increasingly dependent upon biotechnological advances that require massive amounts of computing power but are limited by inadequate access to high-end supercomputers. For successful drug development, researchers must systematically screen millions of small molecules to find a successful match between a chemical and its protein target, a process that can take years and requires a picture of the 3-D structure of the protein, many of which are not available. In collaboration with IBM, the ICRT houses an onsite BlueGene/L supercomputer that offers researchers access to the large-scale screening capacity necessary to identify small molecules, including dietary components, to be used to study the functions of biological pathways in health and disease. The ICRT already houses a state-of-the-art protein crystallography facility, which will be used in parallel with chemical screening to create a 3-D pictorial library of proteins with functions in diseases like cancer. These tools for studying proteins and pathways lay the foundation for even more complex future projects that will drive biobusiness and bioscience, creating hundreds of new jobs and facilitating opportunities for tech spin-off businesses in Minnesota and the region.

A number of research groups are accommodated in The Hormel Institute–all dedicated to studying and understanding the mechanisms that control the development of cancer cells. Several of the research studies have direct links to agriculture and thus have potential for collaboration with the agriculture industry. These research groups include:

The **Cellular and Molecular Biology** group, which is The Institute's largest research group and is led by Drs. Zigang Dong and Ann M. Bode. A major goal is to identify anticancer

agents that have low toxicity with fewer adverse side effects and might be used alone or in combination with traditional chemotherapeutic agents to prevent or treat cancer. Many dietary factors have potent anticancer activities that work through, as yet, unknown mechanisms. Over the years, this group has been working to identify those mechanisms through their work with cellular signal transduction pathways. Signal transduction is the process by which information from a stimulus outside the cell is transmitted from the cell membrane (e.g., through its receptor) into the cell and along an intracellular chain of signaling molecules to stimulate a response. Various dietary factors, including many isolated from green and black tea, potatoes, broccoli, peanuts, ginger root, or rice, can have effects on key signaling molecules critical in cancer development and prevention.

The **Cancer Biology** group, led by Dr. Johnny Lü, studies the cellular and molecular mechanisms by which the trace element nutrient, selenium, affects prostate cancer chemoprevention and treatment. This group also focuses on the identification and development of new cancer preventive and therapeutic agents based on Chinese and Oriental medicinal herbs. In particular, they investigate the feasibility for drug discovery from complex herbal mixtures expanding their efforts into additional Oriental medicinal herbs for prostate and breast cancer prevention.

The **Nutrition and Metabolism** research section is headed by Dr. Margot P. Cleary and focuses on the relationship between breast cancer or prostate cancer with the number of daily calories consumed and changes in body weight. Their work has shown that intermittent (i.e., ~every other day) caloric restriction is more protective against breast cancer or prostate cancer than is the same degree of caloric intake imposed by chronic (evenly spaced) restriction. They also focus on the study of the effects of obesity on breast or prostate cancer.

Moving natural anticancer agents into clinical trials

The Mayo Clinic and The Hormel Institute have formed a unique collaborative partnership, which includes an Office of Translational Research located within The Hormel Institute. The purpose of this office is to facilitate the development of dietary factors as chemopreventive agents to be tested in human clinical trials. One of the most promising agents at this time is an anticancer

agent formulated with a compound from ginger root. Investigators at The Hormel Institute and Mayo Clinic are also working together to identify and develop small molecules or dietary factors that will directly target specific cancer genes or proteins to stop the development and growth of a variety of cancers.

Developing whole foods enhanced with anticancer agents or the convergence of health-related research and agriculture

Globalization has changed and will continue to change local, regional and national economies. Minnesota is clearly an elite athlete in the global economic race and is poised to win because of our unique ability to join forces and unselfishly share our strengths as a state. To seize critical opportunities and develop the maximum potential, we must continue to establish and nurture firm relationships with one another so that we become increasingly knowledgeable about existing and future assets and continue to support each other through collaborative work and partnerships. This idea is clearly illustrated by the potential convergence of health-related research and agriculture in Minnesota. This cooperative effort could be one of the most crucial opportunities we have seen in years and will require the collaboration of a very diverse group of participants — medical research scientists and those directly involved in agriculture, our Minnesota farmers. The researchers have the capacity to identify the components of food that might have anticancer activity and the farmers have the ability to grow those components at an enhanced concentration in whole foods.

Over the last few years, researchers have begun to suspect that isolating a single compound from complex foods may not be effective cancer prevention even at high, relatively toxic doses, whereas combinations of lower, less-toxic doses of each compound might be most effective. This has been illustrated in various research studies showing that many food components seem to require a reaction with or dependence on other components in the whole food source to be effective. Epidemiologic studies suggest that eating diets rich in fruits and vegetables decreases the risk of developing cancer. No scientific evidence exists to support the idea that eating specific compounds isolated from foods prevents cancer. In fact, general clinical findings indicate that individual dietary components have not been very successful in preventing cancer. Examples of these studies include a large clinical study in which vitamin E alone had no effect on lung cancer, and unexpectedly, the risk of lung cancer in smokers was actually increased in men taking beta-carotene. Other studies with folic acid or selenium alone also had

no effect on colon or prostate cancer, respectively. In contrast, a combination of sulindac (a nonsteroidal anti-inflammatory drug) and difluoromethylornithine (DFMO) prevented colon polyp recurrence by 70% overall and by 92% for the highest-risk, advanced adenomas. In addition, green tea extract containing EGCG and other green tea components also appears to be more effective than EGCG alone. These types of results support the idea that isolating single compounds such as selenium, vitamin E, or beta-carotene may cause them to lose their potential anticancer and other beneficial effects, possibly even causing them to exhibit undesired cancer promotion effects, as in the case of beta-carotene. Likewise, to be active anticancer agents, EGCG or other polyphenol chemicals may require their complex, natural-combination forms because they depend on interactions with other whole-food components for efficacy.

Thus the idea of enhancing certain components in the whole food and producing those foods becomes very attractive and creates a union of health-related research and agriculture. Adding crops, grown specifically to improve human health, to Minnesota agriculture creates a landscape conducive to enhancing rural vitality. This strategy could eventually lead to industrially relevant and effective use of specifically grown whole foods to treat or prevent chronic diseases, especially cancer, in humans.

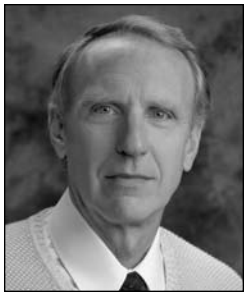
Functional foods and natural plant extracts for treating or reducing the risk of developing cancer have been rapidly gaining national and international recognition and acceptance. Preclinical testing of purified food compounds on cancer growth and development has and will continue to identify those compounds that are safe and highly effective. Those identified compounds might then be moved to the farm for enhancement in whole food production. Besides the humanitarian implications, the knowledge generated from the discovery and validation of effective anticancer dietary components and the enhancement in whole food could be applied to both agriculture and medicine and become a highly profitable industry for rural Minnesota. An example of this strategy has been ongoing with the University of Minnesota's Southern Research Outreach Center (SROC) in Waseca, Minn. In this collaboration, SROC has been working to develop a Minnesota-grown variety of ginger, which is enhanced in the major active compound, [6]-gingerol. Discussions and interactions have also begun to develop between The Hormel Institute and Minnesota "Farma" groups as a part of the Southern Minnesota Regional Competitiveness Project. To seriously pursue a potentially successful collaborative effort, substantial financial resources will be required.

American consumers appear to simultaneously eat in less healthy ways but are becoming more conscious of their health and the influence of food in their life. Thus, a growing demand for foods with specific characteristics has become very popular. Interest in organic foods, fortified and functional foods, foods considered "naturally healthy" or "better for you" has escalated. The market is driven by the science discovering the "health" benefits and documenting their effectiveness. Theoretically, foods could be developed that target genetic predispositions of individuals, creating the possibility of designing diets to address hidden deficiencies or to address individuals with specific health issues including diabetics, transplant patients, or cancer patients on chemotherapy. A real, working partnership between medical and health researchers and agriculture could provide Minnesota with a huge opportunity to develop and patent new health and medical foods and thus create an international market niche. Over the next five years, estimates are that these dietary components and their derivatives will generate a multibillion-dollar business. Drug discovery and natural food products comprise a huge market and the development of this bioscience and biobusiness could have tremendous impact on Minnesota agriculture and the rural economy.

About the Authors

DOUGLAS G. TIFFANY, Assistant Extension Professor at the University of Minnesota, has worked on numerous renewable energy topics. He has analyzed the economics of producing biodiesel, ethanol, electricity from wind, pyrolysis oil from biomass and biofuels or electricity from biomass. Tiffany has presented his work on college campuses, legislative hearings, and to farmer audiences. For 2001-2002, Tiffany was awarded the Endowed Chair of Agricultural Systems in the College of Agriculture at the University of Minnesota. Tiffany earned B.S. and M.S. degrees in Agricultural Economics at the University of Minnesota and has work experience in state government and commercial banking.

STEVEN J. TAFF is an associate professor and extension economist with the Department of Applied Economics and an Adjunct Professor with the Department of Forest Resources, both at the University of Minnesota. A former county extension agent and regional planner, Taff holds advanced degrees in urban and regional planning (M.S.) and in agricultural economics (Ph.D.) from the University of Wisconsin. At Minnesota since 1986, he specializes in the economics of agricultural and natural resource policies, with special emphasis on land management decisions in both rural and urban settings.



Taff is widely known for his attempts to bring economic science to bear on practical policy making. Some of his recent research

examines the economics of alternative energy systems, long-term carbon-reduction policies for energy producers, land ownership change in forested areas, and performance measures in landscape design.

KURT MARKHAM was appointed in 2001 to be the first director of the new Agricultural Marketing Services (AMS) Division within the Minnesota Department of Agriculture. With more than 30 years of experience in ag marketing, Markham helps coordinate efforts between farmers, commodity groups, grain companies and trade teams to increase value-added processing. In addition, he helps producers adjust to future trends by identifying marketing opportunities through consultation with the Minnesota Trade Office, federal trade officials, market research organizations, producers, processors and exporters.

Before joining the MDA, Markham was manager of strategic development for Commodity Specialists Company in Minneapolis and a project consultant for Country Information Brokering in Washington, D.C.

Recently he has been appointed to the Governor's Ethanol Coalition, Director of the U.S. Dairy Export Council, Executive Committee for Food Export Association of the Midwest, and State Administrator for the Agricultural Marketing and Bargaining Committee (mediator for producers vs. processors). Markham is also past president of North American Agricultural Marketing Officials.

DR. JIM BOWYER is professor emeritus, University of Minnesota Department of Bioproducts and Biosystems Engineering. He is an Elected Fellow of the International Academy of Wood Science; President of Bowyer & Associates, Inc. – a wood science and bioenergy consulting firm; and Director of the Sustainable Materials Program in Dovetail Partners, Inc. – a nonprofit organization in Minneapolis that collaborates to develop unique concepts, systems, programs, and models to foster sustainable forestry and catalyze responsible trade and consumption.

Bowyer has served as President of the Forest Products Society (1993-94) and of the Society of Wood Science and Technology (1987-

88), Vice President of the Consortium for Research on Renewable Industrial Materials (1992-2003), and Chairman of the Tropical Forest Foundation (2002-2008). He was Head of the University of Minnesota's Department of Wood & Paper Science from 1984 to 1994, and Founder and Director of the Forest Products Management Development Institute at the University of Minnesota (an organization dedicated to education and development of industry professionals) from 1994 to 2003.

WARREN FORMO is the Executive Director of the Minnesota Agricultural Water Resources Coalition, a consortium of producer groups working together to address water quality issues.

The MAWRC is dedicated to improving communication among the agricultural community, consumers, researchers and policy-makers regarding the economic and environmental effects of agricultural practices employed on Minnesota farms.

Formo holds a B.S. degree in Agricultural Education from the University of Minnesota. Prior to joining the MAWRC, he served as the Assistant Executive Director of the Minnesota Corn Growers Association, specializing in farm policy and organizational development. His work experience also includes 15 years as an active farmer, operating a diversified crop and livestock farm in West Central Minnesota.

MATTHEW PAHS is a transportation planner with the Minnesota Department of Transportation in Saint Paul. Currently working in the Freight, Rail, and Waterways section, he is responsible for leading studies that identify freight transportation issues in Minnesota. Pahs has eight years of experience in the field of planning, with a strong focus on alternate modes of transportation for passengers and freight. He holds a Master of Urban and Regional Planning degree from Portland State University and a B.S. in Urban and Regional Studies from the University of Wisconsin-Green Bay.

CHERYL MILLER is Project Coordinator for the Minnesota Terrestrial Carbon Sequestration Initiative, an interdisciplinary research and public policy forum at the University of Minnesota. In

this capacity, she facilitates discussions among scientists, government staff and user groups on carbon sequestration opportunities in the state. She has twenty years professional experience in land and water conservation, including a decade with Minnesota Audubon. In the 1990s, she worked on establishment of the Minnesota River CREP and on landmark flood reduction agreements for the Red River of the North. More recently, she has worked with groups around the Midwest on projects to better understand the role of forests and agriculture in climate stabilization. She has written and edited publications on conservation and sustainable management, most recently related to climate-related policies and terrestrial carbon sequestration. Miller has a B.A. in Journalism from the University of Iowa and an M.A. in Public Policy and Politics from the University of California, Davis.

MARTIN MITCHELL is a Professor of Geography at Minnesota State University, Mankato, and has lived in Minnesota since 1993. He is originally from the San Francisco Bay Area and graduated from California State University, Chico, where he studied geography and agricultural business. He holds a Ph.D. in geography from the University of Illinois and Master's Degree from the University of Georgia. He also worked as a land use planner in California. Since 1995, Mitchell has been involved with several joint projects with the Minnesota Department of Natural Resources addressing the CRP.

DICK KIMMEL is the Farmland Wildlife Research Group Leader with the Minnesota Department of Natural Resources, where he has been employed since 1981. He has a Ph.D. in Wildlife Management and an M.A. in Animal Behavior from West Virginia University. His research interests include avian habitat management, wildlife responses to farm programs, and mathematical modeling for hunting season logistics as related to wildlife populations and hunt quality.

ANN M. BODE is Associate Director of The Hormel Institute, University of Minnesota, and a research professor of cellular and molecular biology there. She received both her B.S. and M.S. from Southern Illinois University, Carbondale, and a Ph.D. in applied physiology from the University of Oregon, Eugene, and has been at The Hormel Institute since 1999. Before that, she was an associate professor of physiology at the University of North Dakota School of Medicine, Grand Forks, N.D. Her research interests lie in molecular mechanisms of chemopreventive food factors. She has authored 145 scientific research articles.

About the Center for Rural Policy & Development

In 1997, a group of rural Minnesota advocates came together around a bold idea: to create a rural policy think tank that would provide policy makers, rural advocates and concerned citizens with an objective, unbiased and politically "unspun" examination of contemporary rural issues.

Funded through a public-private partnership, the Center for Rural Policy and Development today is an independent non-profit research organization dedicated to the objective study of the economic, social and cultural forces that are impacting rural Minnesotans and the communities they reside in. Over the years, our audience has grown to include state legislators, city and county officials, community leaders, business executives, college presidents, school superintendents and everyday citizens concerned about rural Minnesota and its future.

Hopefully, you will agree that RMJ is one of those resources worth having. To that end, we invite you to visit our web site at www.ruralmn.org to learn more about the Center for Rural Policy and Development, our resources and programs, and ways you can support RMJ.