Tallgrass Ontario

Agro-economic Applications of Tallgrass Prairie Species in Southern Ontario

A Literature Review & Critique

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1 Introduction

Prior to European settlement, it is estimated that southern Ontario supported as much as 2000 km^2 of tallgrass prairie, savannah and open woodland habitat; now less than 21 km^2 of this area remains [96]. The main reason for the scarcity of tallgrass prairie is that it typically occurs on well-drained sandy soils[93] that, historically, have been attractive to settling farmers and, more recently, to residential and commercial developers [95]. In order to protect the last remnants of this rare ecosystem and encourage restoration of tallgrass habitats where possible, the Ontario Ministry of Natural Resources (OMNR) and non-governmental organizations like Tallgrass Ontario are spearheading a variety of initiatives. This research report is one such initiative.

In January of 2001 Tallgrass Ontario, a non-profit organization dedicated to the preservation and restoration of tallgrass prairie remnants in southern Ontario, hired Dougan & Associates to compile a review of existing and potential uses for tallgrass species on agricultural lands in southern Ontario. The primary objective of this research was to scour the current literature, both in publications and on the internet, for feasible ways in which farmers (and other landowners) may be able to re-integrate some indigenous tallgrass species into either their arable or marginal lands, and possibly generate income at the same time.

The information presented in this report is based on a review of 92 scientific and technical sources, 75 internet sites, and interviews with 10 experts in the various applications identified. Based on our understanding of the project from the request for proposal and subsequent correspondence with Don Gordon, Program Coordinator for Tallgrass Ontario, we have synthesized a review that:

- focuses on applications that would be pragmatic for farmers (and possibly other landowners) in a southern Ontario context,
- is based on current scientific and technical literature,
- is supplemented by telephone interviews with relevant experts,
- highlights economic as well as ecological opportunities and/or limitations of the various applications,
- identifies information gaps and areas of future research, and
- provides our opinion regarding the agro-economic potential of the various applications.

Notably, our research has focused on species found exclusively in southern Ontario's tallgrass prairie communities included in described in the current Ecological Land Classification manual from the OMNR[93] and as listed in the Tallgrass Communities Recovery Plan [95].

We have also provided two spreadsheets (in MS Excel™) digitally on disk summarizing the papers and internet sites referenced for this review so that Tallgrass Ontario can have two searchable databases that may be referenced or added to in the future.

2 Agro-economic Review

2.1 Herbaceous Biomass Production

The term "herbaceous biomass production" is an all-encompassing term that includes bioenergy production, either from indirect biochemical/thermochemical conversion into various biofuels (i.e. ethanol, methanol, methane, pyrolysis oils) or from direct combustion (heat, steam or electricity generation), as well as production of raw materials such as pulp and lignin [(7)]. Herbaceous biomass production has focussed almost exclusively on grasses to date, some of which happen to be species indigenous to southern Ontario's tallgrass communities. The following sections provide information on each of these applications [(as listed in Table 1)] with specific reference to the tallgrass species used and their relative yields.

2.1.1 Indirect Bioenergy Production: Biofuels

With the growing concern about rising greenhouse gases combined with rising oil, gas and electricity prices, bioenergy crops (primarily perennial grasses) are gaining importance on environmental as well as economic agendas [(T. Perkins, pers. comm., D. Smith, pers. comm., see Table 2)]. Certainly, one partial solution to Canada's commitment to reduce its greenhouse gas emissions could be to implement bioenergy crops on marginal agricultural soils. Growing and harvesting these crops has a number of environmental benefits when compared to conventional row cropping or methods for obtaining other types of fuel.

The actual cultivation, harvesting and processing techniques for biofuel grasses is more "environmentally sensitive" because they create a closed loop carbon cycle by utilizing atmospheric CO^2 for photosynthesis during their growing period, and releasing it during the combustion process. Then, during the next growing season, the same amount of CO^2 that was released is absorbed again through photosynthesis, provided equal amount of land is kept in bioenergy crops. In addition to the biomass carbon sequestration ability of the above ground material, biomass crops also have the potential to store carbon below ground, in roots and oil. Also, the perennial nature of these grasses requires less fieldwork to be carried out (seeding and tilling), which also reduces the fossil fuel consumption from farm machinery use [(91)].

Bioenergy production using perennial grasses can also have significant agricultural benefits relative to traditional annual row crops, including reduced soil erosion and runoff; increased incorporation of soil carbon, improving soil texture and chemistry; reduced use of agricultural chemicals; and reduction in atmospheric releases of CO^2 [(6, 56, 68)]. Once established, perennial grasses can be produced for many years without the annual replanting cycle that causes soil loss and degradation. The deep, well developed root systems of these grasses exceeds the above ground biomass, and provide a strong energy storage reserve, more stable yields during stress years, and increased soil organic matter. This latter attribute is one of the keys to perennial grass

Table 1. Summary of agro-economic applications of tallgrass species in Ontario and evaluation of their economic and ecological potential in southern Ontario based on the current research and available information.

AGRO-ECONOMIC CATEGORY	APPLICATION	ECONOMIC POTENTIAL	ECOLOGICAL POTENTIAL	SPECIES USED	COMMENTS
Biomass production	Biofuels (Indirect)	High	Low	Switchgrass	Abundant information from Canada and the US show that there is good potential for biomass crop applications.
		Moderate	Low	Cordgrass	Preliminary studies show it has potential.
		Unknown	*Unknown*	Big bluestem	Little information currently available.
		Unknown	*Unknown*	Indian grass	Little information currently available.
	Direct combustion	High	Moderate	Switchgrass	Promising research from the US and Canada show that there is good potential for direct combustion applications. Southern Ontario test trials needed. Increasing fossil fuel & wood costs could help this market.
	Pulp fibre	Moderate	Moderate	Switchgrass	Further research required todetermine optimal pulping conditions.
		Unknown	*Unknown*	Cord grass	Little information currently available.
		Unknown	*Unknown*	Big bluestem	Little information currently available.
Other raw material uses	Building materials	*Unknown*	*Unknown*	*Unknown*	Only information on straw from western Canada collected.
	Mushroom compost	High	Low	Switchgrass	Research required to study the potential.
Foraging/grazing	foraging/grazing	High	High	Switchgrass, indian grass, big bluestem, side oats grama, little bluestem	Southern Ontario test trials needed (majority of research done in the US).
		Low	Low	Lupine	European varieties are alkaloid free, but our native lupine contains these toxic alkaloids
		Unknown	*Unknown*	Cup plant	Southern Ontario test trials needed (majority of research done in Russia).
Filter strips/erosion control	Filter strips/erosion control	Low	High	Switchgrass	Research shows switchgrass is as good as trees for these purposes. An assortment of prairie species could be used thereby making it more ecologically sound
Seed production	seed production	High	High	Many tallgrass species	Increases in the demand for native seed will fuel this market; currently there isn't enough native seed production to keep up with the demand.
Honey production	honey production	High	High	Many tallgrass species	Ecological and economically feasible!
Other crops	Cut flowers	Low	Moderate-low	Blazing star, butterfly milkweed	Production must start small, large scale production might be uneconomical, and markets must exist nearby.
	Plant derived oils	Low	Low	Milkweed species, evening primrose	Relatively few prairie species are used for this purpose; both potential product & market research are required.
	Pharmaceutical & herbal	Low	Low	Seneca snakeroot, purple coneflower	Relatively few prairie species are used for this purpose; both potential product & market research are required.
	Plant derived cellulosic fibres: seed floss	Low	Low	Milkweed species	Misconceptions about milkweeds and the presence on the weed list could prevent development of this use.

Table2. Summary of interviews with selected agro-economic experts Winter 2001.

CONTACT (POSITION)	COMPANY / AFFILIATION	COMMENTS
Owen Steele (Biologist)	Ducks Unlimited Canada (DU)	• Use native plants for providing upland nesting habitat & mitigating impacts of agriculture on buffers • Use grasses for pasture (haven't researched much in this area, but are hoping to do more) • Use sculpture seeding technique (97,98) in which they tailor 6-8 plant species to the site, using mainly grasses • Use cultivars for planting purposes • Work has taken place in southern Ontario throughout the range of tallgrass prairie • A research arm of DU called the Institute of Wetland and Waterfowl Research (IWWR) evaluates varieties in conjunction with the university of Manitoba • Found non native cool "tame" grasses were too expensive to manage • Native plants cost more up front, but in the long run they are don't need fertilizer or mowing
Mary Gartshore (Owner)	Pterophylla *(native plant nursery)*	• Concerned about monocultures of seed and plants (cultivars) from Western States; this seed is inexpensive, but has different genetics than s. Ontario species and could contain diseases • Due to the high heating prices, local landowners have been researching the possibilities of using switchgrass for pellets for heating of their tobacco driers instead of natural gas; the expense of the equipment and the 3 year establishment time is limiting its present use • Ecological varieties (Ecovars™) are acceptable as long as they are developed from the local area • Knows people using prairie grasses for controlling slope erosion
Jeff Passmore	Iogen Corporation (biofuel company)	• Planted a couple of hundred acres of switchgrass in southeastern Ontario to see yields and growth • Will be using wheat straw the first couple of years
Terry Perkins	Iogen Corporation (biofuel company)	• Their research is done by REAP, they have 300 acres that will be partially harvested in fall and a large ethanol plant in Ottawa • Switchgrass as a biofuel is practical only for marginal land that is fallow or is very difficult to grow a crop on • Switchgrass takes 3 years to establish • Plan to build more plants on the prairies and use grass for biofuel • Straw is currently their main source of product, which yields 1 tonne/acre, switchgrass will yield 4-5 tonnes
Roger Samson (Executive Director)	REAP (biofuel research company)	• Their research is on the internet; additional information available for a price • Have done trials in southern Ontario and all over the world, and confirmed interest in switchgrass
Dr Donald Smith (Professor & Researcher)	McGill University Plant Sciences Dept	• His research has taken place in Quebec • Biofuel is one of the highest areas for potential, due to the Kyoto aggrement that recommends the reduction in greenhouse gases • However, economically the pulp market is currently depressed • Would have done more research on cord grass which showed potential, but couldn't get enough seed • Believes in using local seed
Al McKeown (Researcher)	Simcoe Agricultural Research Station	• Conducted research on the nematodes and tallgrass prairie species that showed native plant stock are highly resistant to nematodes that other cultivars might not be • Best to use local "ecovar" *(see glossary)* to create cultivars • We need to use local genetic stock if we are doing using plants for agricultural purposes
Doug McRory (Apiary Specialist)	Agriculture Canada	• Beekeepers in other parts of Canada move their hives around, ie burn over areas are plentiful with fireweed in western Canada, while orchard and vegetable growers use this technique in southern Ontario • Some beekeepers plant lots of basswood and market it as basswood honey, another honey is Purple Loofestrife

Tibor Szabo (Entrepreneur & Landowner)	(part time business selling honey as well as seeds and plants to other beekeepers)	• Sells plants to other growers that are have high nectar or pollen amounts and flower for long periods • Of the 16 varieties, he sells 2 are native *Liatris spicata* and *Pycnanthemum verticilatum var pilosum* • His literature reviews show *Pyncnanthemum verticilatum var pilosum* will produce 1700 kg/ha of nectar • Knows of one other individual in southern Ontario that is doing the same thing on a part-time basis
Glenn Fox (Professor & Researcher) *author of* (83)	University of Guelph, Dept. of Agriculture and Economics	• The organization REAP has had disappointing results with switchgrass and biomass • His paper found that switchgrass for fibre was not financially competitive with fossil fuels but was with hardwood lumber • Since the time of writing the report the pulp market has become depressed

contributions to soil conservation, improving soil structure, increased water-holding capacity and infiltration, nutrient conservation and availability, and decreasing soil erosion and runoff [84].

The main tallgrass species that has been studied for biofuel purposes is *Panicum virgatum* (switchgrass) and the bulk of the research has been conducted in the United States (US). Switchgrass was selected for development as a bioenergy feedstock in the US because of its high yield potential, adaptation to marginal sites, high nutrient use efficiency, and wide geographic distribution. Other important considerations were switchgrass' positive environmental attributes, including positive effects on soil quality and stability, cover value for wildlife, and relatively low inputs of energy, water and agrochemicals required per unit of energy produced [1, 68, 84]. Another benefit for farmers is that it can be harvested with conventional hay-making equipment [8].

Studies from the USDA's Bioenergy Feedstock Development Program report average yields of fully established stands of the best-adapted switchgrass varieties of approximately 7 tons dry matter per acre, which results in over 5000 l/ha ethanol (500 gal/acre) with 75% conversion efficiency [99]. A comparison of the energy budgets for corn, which is the primary current source of bioethanol, and switchgrass, reveals that the efficiency of energy production for a perennial grass system can exceed that for an energy-intensive annual row crop by as much as 15 times [84].

Biofuels do, however, have some practical drawbacks as compared to conventional fossil fuels. For example, the relatively high concentrations of inorganic elements (such as water and nitrogen) in herbaceous biofuels as compared to fossil fuels (such as coal) can cause difficulties in combustion systems such as boilers [7]. High nitrogen and ash contents may also reduce chemical output in thermochemical conversions, and are known to damage industrial machinery in general [5]. This obstacle may be overcome by carefully timimg switchgrass harvest. Studies have shown a close relationship between maturity (measured by cumulative degree days) and the chemical composition of switchgrass. They concluded that allowing switchgrass to reach maturity minimizes the concentrations of inorganic elements, while maximizing lignocellulose concentration[7].

In terms of applications in a southern Ontario context, recent research into growth performance and yield characteristics of various switchgrass cultivars grown in southern Quebec suggests that switchgrass has potential as a biomass crop in short-growing–season areas (including areas of Ontario and Quebec where silage corn is grown) [2, 3, 5, 72]. These yields compare well to those reported in northern USA [27]. There is also unpublished research in Ontario that, to date, is showing promising results. For example, T. Perkins of IOGEN, a biofuel research company in eastern Ontario, reported that while they have found straw to yield 1 tonne per acre, switchgrass will yield 4-5 tonnes per acre.

Other warm season grasses have also been investigated as biomass feedstocks in short season areas of Quebec [5], although there is not nearly as much research on these species as switchgrass. Evaluation of cultivars of *Spartina pectinata* (cordgrass), *Sorghastrum nutans* (indiangrass), *Andropogon gerardii* (big bluestem) and *Calamovilfa longifolia* (prairie sandreed) showed some potential, particularly for cordgrass, which had the highest seasonal yields per plant. Dr. D. Smith, Researcher in the Department of Plant Sciences at McGill University in Montreal, confirmed that cordgrass showed potential in his preliminary research but that he couldn't find adequate quantities of seed to conduct full trials (Table 2).

It is important to realize, however, that although there is a sizeable body of literature and related research dedicated to herbaceous biofuel production, the ecological implications of a farmer converting parts of their land to switchgrass production for such applications has no real ecological value in terms of tallgrass recovery. The bulk of the research undertaken concerning switchgrass and the other tallgrass species listed above in terms of biofuel applications has been geared towards the needs of high production agricultural operations. This means that the research and trials have focussed on the development of non local cultivars uniformly exhibiting all the "best" qualities for production purposes in a monoculture setting. Similarly, most research on perennial warm-season grasses as herbaceous biofuel crops has emphasized a single harvest of very mature, nearly senescent biomass to optimize yield [1], a harvest management is suitable only for a dedicated biomass feedstock system. These monocultures of tallgrass cultivars would not contribute to natural tallgrass systems in any way, and might actually be detrimental to them if there was genetic exchange between the cultivars and the indigenous populations. In addition to the ecological concerns about manipulated cultivars developed from non-local seed sources breeding with local native populations, there is the danger of large-scale disease and/or pest problems where biofuel systems use cultivars. If large-scale production is the objective, the use of locally developed Ecovars™ (see glossary) or ecological varieties are considered safer for any neighbouring tallgrass communities since it ensures that a local seed source has been used and that there is at least some genetic diversity within each population (M. Gartshore, A. McKeown, D. Smith, pers. comm., Table2).

Other poorly explored alternatives include moving away from the monoculture approach or integrating biofuel uses with other agricultural applications. Seeding mixtures of several of the tallgrass prairie grasses may reduce the probability of disease and insect problems [56], while monocultures of switchgrass could potentially be used as a combination filter strip, nutrient sink, biomass energy, and forage crop in an integrated system of farm waste management [6]. Current research from Texas has examined ways of determining harvest management recommendations to provide quality switchgrass forage for livestock as well as biomass, allowing a diversified farmer more flexibility to satisfy multiple goals [1]. However, further research would be necessary to determine if similar multiple-use goals for switchgrass could be met in more northern climates such as southern Ontario. These types of "mixed farming" or integrated approaches might lend themselves to satisfying the ecological objective of expanding selected tallgrass species coverage in southern Ontario, as long as seed is not imported from the western US.

Despite the limited ability of biofuel production from tallgrass species to contribute to tallgrass recovery, this application does appear to be one of the most potentially feasible and lucrative markets for tallgrass species in southern Ontario and Canada. As a testament to this potential, the IOGEN Corporation has built a $25 million ethanol-from-cellulose demonstration plant adjacent to its enzyme manufacturing plant in Ottawa, ON Canada [100] which tests various feedstocks including switchgrass. Nonetheless, research still needs to be done in Ontario regarding agricultural practices that optimise yield, optimising harvest and storage conditions, development of a market for processing biofuels, and mechanisms of technology transfer. This will likely follow in the footsteps of US researchers, who have already begun to look at the economics of harvesting and storing switchgrass as a biofuels feedstock [8, 9, 10, 68], and continue to be actively involved in research into genetic improvement of switchgrass through molecular biology as well as traditional breeding techniques [6].

2.1.2 Bioenergy Production: Direct Combustion

Another emerging biomass energy market opportunity in our environment of rising gas prices is that of densified biomass fuels used for heating, primarily in wood pellet stoves. This technology is apparently being explored by tobacco farmers in southwestern Ontario looking to use switchgrass pellets instead of natural gas for heating their tobacco driers [M. Gartshore, pers. comm., Table 2]. Currently, approximately 100,000 tonnes of pelletized wood residues are being exported annually to Scandinavia from Canada [89], but the market within Canada remains unexplored.

As with biofuel research, the tallgrass species of choice for this application has been switchgrass as it offers the greatest economic and environmental benefits in relation to other perennial grasses. Compared to other biofuel pathways, switchgrass pellet heating offers the highest net energy yield per hectare, the highest energy output to input ratio, the greatest economic advantage over fossil fuels, and the most significant potential to offset greenhouse gases [89]. In addition, the use of perennial grasses for pelletizing purposes has been facilitated by the development of new pellet stove technology. Close coupled gasifier pellet stoves, designed to handle moderately high ash content fuels, burn switchgrass fuel pellets with a combustion efficiency of 82-84% [87].

Switchgrass also proved economical as it lowered processing costs due to its minimal drying compared to wood, and could be produced at even greater cost savings if it were produced in closer proximity to the given energy market. Costs in eastern Canada as of December 2000 are estimated to be $46-$68/tonne delivered to a pellet plant, while pelleting itself is estimated to cost about $60/tonne. Assuming a farm price of $120/tonne, switchgrass pellets provide the same cost for heating as oil at 25 cents per litre, or a delivered natural gas price of 25 cents per cubic metre [89]. This is a very competitive rate given the current price of natural gas. In addition, switchgrass pellet heating is “environmentally friendly”, and estimated to reduce greenhouse gas emissions by 93% compared to oil heating [89].

Notably, despite its commercial potential, switchgrass production for direct combustion would not contribute to tallgrass habitat recovery any more than switchgrass production for biofuel because of the requirement for monocultures of mature, nearly senescent biomass to optimize yield [Appendix 1]. As with biofuel production, the use of locally developed Ecovars™ [see glossary] or ecological varieties is considered safer both for the commercially used grasses and the nearby natural habitats [M. Gartshore, A. McKeown, D. Smith, pers. comm., Table 2].

2.1.3 Pulp Fibre

Increased wood cost, coupled with increasing concern for future fibre supplies has strengthened the pulp and paper industry's interest in alternative fibre sources, although there appears to be a current glut in the pulp market (G. Fox, D. Smith, pers. comm., Table 2) that illustrates this particular market's potential volatility. Nonetheless, there does appear to be future potential for pulp fibre to compete with hardwood even if it can't compete with fossil fuels [83].

Not surprisingly, the well-researched switchgrass displays promising qualities for papermaking purposes, and has been investigated as a potential pulp fibre crop in Quebec and eastern Ontario. Potential benefits of growing switchgrass for pulp include low production costs, adaptable to soils that cannot sustain grain production, good rotation crop, good soil sustainability, availability of mechanical harvesting and baling, low fertilization and weed control requirements, high crop yield (10-12 t/ha/annum) and low extractives and ash content [12, 13, 14, 15]. Soda pulp from switchgrass showed excellent mechanical properties, and has potential as a reinforcement component in newsprint making [14], while kraft pulping results show a 45% yield, with quality similar to hardwood pulp [12, 13, 15]. Switchgrass pulp is of high enough quality to replace 15-20% of hardwood pulp in paper furnish [12] and has many desirable attributes with respect to fibre production. These include [88]:

1. Stable and productive yields: 6-13 oven dry tonnes per hectare per year
2. Drought tolerant and well adapted to marginal soils
3. Ash contents of 2.5-3.5% for spring harvested material compared to 6-10% for cereal straws in western Canada
4. Minimizes competition for land with high value cash crops and provides access to agricultural land for fibre production that is not well suited for tree growing
5. Lower estimated delivered cost to mills than hardwood chips in eastern Canada

For existing pulp mills located in agricultural regions, dedicated fibre crops could provide a stable, cost-competitive supply of fibre with a quality superior to most agricultural residues. The main advantage of perennial grasses is that they can produce more fibre per hectare of land than hardwood trees in most of North America, and can be harvested annually. With most switchgrass acreage on idle or inferior land, these grasses could provide additional farm receipts that would strengthen the rural economy. It has been estimated that adding 15% switchgrass pulp to the fine paper and hardwood market pulp currently produced in eastern Ontario and southwestern Quebec, would require less than 5% of the agricultural land base and provide new farm receipts of $20-40 million a year [88].

Other recent studies suggest that the total land area required to satisfy the potential demand for switchgrass fibre for pulping in eastern Ontario is estimated to be between 22,000 and 48,000 hectares. With yields of 10 metric tons per ha and prices of $50 per metric ton, 22 000 ha would produce $11 million gross revenue annually, making this a potentially attractive crop for farmers [83].

Resource Efficient Agricultural Production (REAP) – Canada has published detailed management guidelines for the commercial production of switchgrass in eastern Ontario. Recommended varieties include Cave-in-Rock, Pathfinder and Sunburst, although new varieties with improved seedling vigor and yield are currently under development [66]. A single spring harvest (late April to end of May) improves winter survival, weed control, reduces fertilizer requirements and improves the combustion and paper-making properties of the harvested material. Maximum production is attained during the third growing season, with yields of 8-13 metric tonnes per hectare. Once established, a switchgrass stand may last 10 years or more. The perennial nature of switchgrass, along with its low input requirements and high productivity, contribute to low costs of production relative to most traditional row crops. Research indicates that at $50 per dry tonne, the crop is profitable for eastern Ontario farmers, with 50% of the costs related to harvesting and transporting the crop to a conversion plant [98]. Any efficiency gains made in these two areas will strongly influence returns to farmers.

As with biofuel and pellet production from switchgrass, despite the commercial potential and practical feasibility, switchgrass production for pulp production could only have a very limited ecological contribution to tallgrass habitat recovery in that it would increase the abundance of this particular species in southern Ontario [Appendix 1]. Again, locally developed ecological varieties would need to be used instead of cultivars for this crop to represent an ecological benefit (however marginal) instead of a risk. The potential ecological value of tallgrass pulp crops could be enhanced if additional research on optimising pulping conditions for other tallgrass prairie grass species such as *Calamovilfa longifolia, Spartina pectinata, Andropogon gerardii* that have already shown some potential as pulp sources is pursued [15], and these species are grown in combination with switchgrass.

2.1.4 Other Raw Material Uses

In eastern Ontario, switchgrass appears to be headed towards commercialization for a variety of biomass uses. In addition to the applications already described (cellulosic ethanol, pellet fuel for space heating, and pulp) it has shown potential for use as livestock bedding (a substitute for cereal straw), and mushroom compost [90]. Commercial trials of mushroom compost from switchgrass have show it to be a suitable substitute for winter wheat straw (which is often in short supply), particularly because it contains fewer weeds. This could be a relatively high value market for switchgrass, as winter wheat straw is being purchased at approximately $100/tonne [87].

Construction material manufacturing is another area of recent interest. Research in western Canada has focused on the use of crop residues including wheat, barley and flax straw to produce building panels. Several companies in Saskatchewan are using flax straw to produce biodegradable mats, and the potential to use prairie grasses in place of straw in panels or erosion control/geotextiles / fibre mats in Ontario could be investigated [101].

As with the other biomass applications already discussed in this section, the ecological value of a monoculture crop of switchgrass would be limited [Table 1].

2.2 Forage/Grazing

Not unlike the biomass industry, research in alternate species for forage and grazing has focussed on warm-season grasses, with a significant amount of research on switchgrass, although some other prairie grasses have also been examined as well as a other selected forbs. The main difference with this research is that the focus is usually the animal's response to the foodstock, rather than the production attributes of the grass itself. Interest in warm-season grasses has increased in recent years for summer grazing and hay production because in summer, high temperatures and in some cases, low soil moisture limit forage production by cool-season grasses. Warm-season grasses are also characterized by high optimal temperatures for photosynthesis, creating forage potential in northern temperate regions during the critical months of July and August, as part of a complementary grazing system [4].

Studies in the US have identified various cultivars of switchgrass as having potential for highest yields [4, 25, 26, 27], while there has also been some research on *Sorghastrum nutans* (indiangrass) [25, 27], *Andropogon gerardii* (big bluestem) [4, 25, 27], *Bouteloua curtipendula* (sideoats grama) [23] and *Schizachyrium scoparium* (little bluestem) [23, 27].

Factors that influence animal performance include the management system utilized (i.e. rotational grazing is preferred to continuous grazing), stage of growth at which grazing is initiated, leaf to stem ratio, stocking rate, and fertilization. However, it is difficult to extrapolate the results of these studies to southern Ontario, as most are from the Midwest, Great Plains and southern US, with significantly different climate and livestock management systems. In the US, research found that development of compatible, persistent, native warm-season grass and native legume mixtures could increase forage yield and quality during summer months [24, 37].

Notably, the influence of various grazing systems and stocking rates on native tallgrass prairie grass pastures has been studied in the US. Researchers found that continuous and rotation grazing had similar affects on herbage composition over time in that standing crop of all major herbage components, including forbs, declined as stocking rate increased, but higher standing crop at the end of the grazing season was observed in the rotation units [28, 29].

In terms of forage quality, cattle are well adapted to the utilization of perennial warm-season grasses, based in digestibility studies [31, 39]. Although warm-season grasses have a high fibre and low crude protein content, and low dry matter digestibility, they have relatively high intake and support reasonable rates of average daily gain in cattle when they are grazed [32]. Generally, warm-season grasses appear more suited to animals with lower nutrient requirements such as beef cattle versus high performing dairy animals. However it is possible to increase the crude protein value of some grasses (i.e. switchgrass, indiangrass and big bluestem) via nitrogen fertilization [33, 34] and burning [33]. Nutritive value of warm season grasses (i.e. digestibility and intake) has been reported to decrease from spring to summer, closely following morphological development of the plant [3].

Potential benefits of warm season grasses for producers include [82]:

1. Extension of the grazing season through the hot summer months.
2. Reduced requirements for fertilization, which cuts down production costs.
3. Safeguarding against drought.
4. The opportunity to turn less productive (marginal) lands into useable pasture.
5. The opportunity to increase the stocking rate.

Potential drawbacks of warm season grasses that limit their use to producers include [82]:

1. Slow establishment as compared to cool season grasses (i.e. it may be difficult for producers to set ground aside for an entire year just to get the crop established).
2. The need for active and unconventional management, especially during the establishment year (i.e. invading cool season grasses have to be controlled; overgrazing must be changed).
3. The need for adequate cool season pasture acreage in order to give the warm seasons the rest they require (ie. rotational grazing is a must for these grasses to be used properly).

Potential applications for southern Ontario are promising, although there do appear to be some constraints related to climate. Studies conducted on switchgrass and big bluestem to approximate forage yield and quality, and guide management strategies, suggest there is potential for warm-season grass production in southwestern Quebec [3]. In general, cultivars from more northern areas had higher ground cover ratings, flowered and matured earlier than those from more southerly regions [3]. Difficult stand establishment in spring and limited overall production because of low spring and fall temperatures are the main disadvantages of warm-season grasses in areas such as Ontario [3]. However, slow and inconsistent establishment has been overcome in some areas of the US using conservation tillage and early planting [35, 70], and seed treatments (including stratification, bleach, acid, hydrogen peroxide, and mechanical scarification) have been investigated to improve germination and emergence [38, 62, 70]. Clearly, more research is needed to determine the forage potential and optimal management systems of native warm-season grasses in southern Ontario.

Other tallgrass prairie species investigated for animal forage include *Silphium perfoliatum* (cup-plant). Interest in cup-plant as potential forage and silage crop has been centred primarily in Russia [58]. Cup-plant is a long-lived perennial with potential to produce high biomass and highly digestible forage in wetlands where other forages do not grow or produce well. However, moisture control is essential for the production of high quality silage [78, 80]. Further research would be necessary to assess its potential in southern Ontario.

Several European species of lupines have been investigated for use as forage and grain legumes, including white lupin (*L. albus L.*), yellow lupin (*L. luteus*), and blue or narrow-leafed lupin (*L. angustifolius*). However, unlike the North American native lupine (Lupinus perennis), these introduced European lupins have been bred to reduce or eliminate toxic alkaloid compounds. The native lupine contains alkaloids and therefore is not recommended for forage [102].

Given that there are a greater number of tallgrass species with forage/grazing potential and that this activity, if properly managed, does appear to be workable for natural tallgrass communities [28, [29)], there is the possibility of contributing significantly to tallgrass recovery by planting a number of these species on marginal agricultural lands [Table 1].

2.3 Filter Strips/Erosion Control

Vegetative buffers, filter strips and hedges have the potential to substantially reduce runoff, sediment and sediment-bound pollutants from source areas, and improve surface water quality. These strips act to filter nutrients, sediment, organics, pathogens and pesticides from agricultural runoff. Although this application does not provide any direct income, it does contribute to soil conservation and improved water quality, which are tremendously valuable. Unfortunately, although this is an ideal opportunity for restoration of a diverse tallgrass community including perennial grasses and forbs, all the research conducted to date has focused on grasses.

Warm-season grasses are good candidates because they are robust, have stiff stems and increased tillering compared to most cool-season grasses, and switchgrass, once again, is a leading candidate due to its wide area of adaptation, determinate seeding habit, smooth seed characteristics for ease of handling, prolific foliage production and flooding tolerance [41]. Switchgrass filter strips removed significantly more nitrogen and phosphorus than did cool-season grass filter strips of bromegrass, timothy or fescue [16], while nitrogen recovery by switchgrass in an Alabama study has been estimated at 65.5%, which compares favorably with the 50% recovery quoted for wheat and corn [86]. Switchgrass filter strips also removed atrazine and metolachlor from runoff under experimental conditions by slowing runoff velocity and increasing herbicide infiltration and retention in soil [17, 18].

Hedges of stiff, erect grasses with dense tillering, such as switchgrass have uses in erosion control to trap sediment, build bioterraces, diffuse concentrated flows of runoff water and increase ponding and infiltration, and protect downwind soils and crops from wind erosion [19]. As a long-lasting, non-tree plant wind-barriers, a single row of uniformly spaced switchgrass plants outperformed slat-fencing and other herbaceous plants including sorghum and kenaf [20].

Although the economic and ecological value of having monocultures of switchgrass as filter strips or for erosion control are limited [Table 2], it would definitely be worthwhile examining the potential for natural or semi-natural tallgrass communities to perform the filtration and soil conservation functions listed above.

Despite the fact that buffer strips provide no direct economic returns to landowners, the importance of buffer strips in providing habitat for wildlife as well as contributing to soil conservation and water protection is becoming more widely recognized. A good example of this are the initiatives that have been undertaken by Ducks Unlimited over the past few years (DU). Habitat loss, including the conversion of native grasslands to exotic grasses and forages, is the primary cause of declining populations of gamebird species such as the northern bobwhite in eastern US [76]and re-establishing native warm-season grasslands improves wildlife habitat characteristics for many species. In an initial attempt to improve wildlife habitat adjacent to wetlands, DU Canada has been investigating the merits of native plant species that were historically present in Ontario (Table 2). This evaluation has evolved from establishment issues to investigations of stand resiliency and habitat quality (63), and has led to research on the development of "ecological varieties" and sculptured seeding techniques (see Glossary, 61, 63). Unfortunately, DU's focus has been on the waterfowl rather than the plants themselves, and so their research has focussed on western Canadian and US Ecovars™. However, this presents an opportunity for Tallgrass Ontario to educate DU and promote the multiple benefits of indigenous tallgrass species as excellent candidates for these buffer naturalizations.

2.4 Seed Production

The demand for native tallgrass seed is, according to our interviews, already greater than the supply (O. Steele, D. Smith, M. Gatshore, pers. comm., Table 2). Markets for prairie seed production include private individuals, contractors, corporations and government agencies (60), as well as non-governmental organizations like Ducks Unlimited (O. Steele, pers. comm., Table 2). Mandated use as well as increasing public interest in native species plantings are all helping fuel the demand for native seed. Meeting that demand presents both opportunities and challenges for the native seed industry.

As the demand for native species plant material grows, and as planting objectives become more diverse, there will be a need for increasing amounts of both wild harvest and cultivar seed (61). As the industry continues to expand, use of production-block seed should be encouraged to reduce collection pressures on native prairie remnants (60). However, the use of cultivars greatly reduces the diversity of gene pools. As has been recognized by seed certifying agencies in both Canada and the US, there is a need for native seed classes that have characteristics somewhere between "wild harvest" and "cultivar" (61). The development of "ecological varieties" (Ecovars™) (which share some characteristics with both what is now known as Source Identified and Selected plant material in the US) has been the focus of seed production by groups such as Ducks Unlimited (61). The species is subjected to minimal selection pressure, with reasonably dependable seed production being the primary selection criterion (61). As a result, it retains more genetic diversity than would be the case if it were taken to cultivar status, and is more suitable for diverse planting objectives. Ecovars™ development is ultimately the most practical approach since seed yields of prairie grasses harvested from prairie remnants are generally much lower than from commercial fields (22, 74), and there may be considerable variability in yield even among cultivars (73).

Although wildflower seed can be purchased from commercial producers, the species of interest are not always available in sufficient quantities to meet demands, and available seed may not be adapted to specific conditions on the planting site (M. Gatshore, pers. comm., Table2). Often seed companies will subject their plant populations to a selection or breeding process to improve appearance or production characteristics (increase flower size, plant size, seed set, etc.), but this "improvement process" could decrease the chance for survival on poor planting sites by reducing genetic diversity and potentially increasing susceptibility to insect, disease, and environmental stresses. For these reasons, many US highway departments and other customers are increasingly requesting local ecotypes of seed for their plantings. However, the potential market for seed of specific ecotypes may not be large or lucrative enough to encourage larger growers to initiate production [67].

Although this application would require an understanding of tallgrass species and native plant nursery techniques (such as seed collection), there definitely appears to be a growing market for locally adapted tallgrass seed in both the US and Canada. Given the wide range of species that could be planted and the fact that they would need to be ecological varieties, tallgrass seed production has the potential to meet both ecological and economic objectives for an entrepreneurial landowner [Table 2].

2.5 Honey Production

The beekeeping industry in Ontario has come through several difficult years, due to price uncertainty and parasitic mite problems, but is currently in a strong position [103].

Honey in many different forms is one of the most sought-after commodities. Other honey by-products that are increasing in their market proportion include [104]:

- beeswax for candles and in household products such as polishes;
- pollen, which is rich in protein and used as a diet supplement;
- propolis, which is becoming widely known and accepted as an ingredient in cosmetics and lip balms as well as a tonic; and
- royal jelly, a special feed produced by worker bees and fed to the queen bee, used in skin creams and lotions, and gaining a reputation as having a beneficial effect on aging skin.

Honey production also offers an ancillary benefit to farmers since many agricultural crops, particularly fruits and vegetables, require honey bees to transfer pollen in order to ensure a good seed set. The pollination value contributed to Ontario Agriculture by honey bees is estimated at $94,000,000 in 2000 [103].

Tallgrass prairie species with potential for honey production include *Pycnanthemum pilosum* (mountain mint), *Asclepias* spp. (milkweeds), *Monarda fistulosa* (wild bergamot) and *Silphium perfoliatum* (cup-plant). Mountain mint appears to be an exceptional bee forage, with the advantage of late summer blooming which continues well into the nectar production dearth period that follows the clover and alfalfa blooming season [42, 45, 59, 71]. *M. fistulosa* has anecdotal evidence of utilization by honeybees, although further research is necessary [43, 59], while various species of *Asclepias* (e.g. *Asclepias tuberosa*) are also highly attractive to honeybees, and are capable of contributing a significant amount of nectar when most other summer blooming plants are at an end [44, 55]. Cup-plant has also received some attention as a potential combined forage and nectar plant in Russia and is worthy of further research [58, 79].

In southern Ontario, there are few local beekeepers using native plants specifically for their nectar source [D. McRory, pers. comm., Table2]. Two beekeepers in southern Ontario are currently growing plants that they sell to other beekeepers. T. Szabo, one of these people, has a part-time business selling plants to other beekeepers that are good nectar and pollen producing plants. Of the 16 varieties he sells two are native; *Liatris spicata* and *Pycnanthemum verticilatum var pilosum*, both of which are known for their plentiful blooms and good nectar supplies. *P. verticilatum var pilosum* will produce 1700kg/hec of nectar (Tibol Szabo pers comm., Table 2).

Honey production is another application for tall grass species in Ontario that could meet both ecological and economic objectives (Table 1), as a diversity of forbs could be planted (along with grasses) to sustain a bee population dedicated to the production of "tallgrass honey".

2.6 Other Applications

2.6.1 Cut Flowers

There may be some opportunity for farm diversification through field production of cut flowers in southern Ontario (46, 77), although most studies have focused on production techniques in the southern and central US (47, 48, 49,105). The cut flower market can include components of 'pick your own', retail and/or dried flowers, although cut flowers are a labour-intensive crop that require more water than many other field crops and natural rainfall is probably not reliable enough to make flower production economically realistic. Overhead watering may also result in more diseases, and can damage the flowers, and drip irrigation is recommended to place water uniformly around the plant (47, 48, 49,105).

Prairie wildflowers commonly used in the cut flower business to date include butterfly weed (*Asclepias tuberosa*) and spiked blazing star (*Liatris spicata*). There may be many more prairie wildflowers and grasses that have the potential for both cut and dried flowers. It will be important for prospective producers to start small, as well as thoroughly investigate the market potential. However, this could be a small business venture in combination with one or more of the applications listed in this section.

The ecological value of this application is limited (Table2), primarily because the removal of the plant at its "aesthetic peak" would limit its role in providing habitat and/or food for wildlife, and would also limit its reproductive potential.

2.6.2 Plant Derived Oils

Monarda fistulosa L. var menthifolia is a cultivar of the native *Monarda*, commercially grown for the essential oil, geraniol. Geraniol has a fruit/rose aroma, and is used by the flavour and fragrance industries in the production of perfumes and soaps. However because of the specialized equipment required (steam distillation), the number of producers, primarily in the prairie provinces, is expected to remain low. In addition, there is some reluctance in the industry to use natural-source oils, likely due to inconsistent supplies and quality [50, 51, 52, 106, 107].

Milkweed seeds are another potential oil source as they contain approximately 23% triglycerides. The oil from *Asclepias speciosa* and *Asclepias syriaca* is currently being investigated as an alternative source of triglycerides used in the cosmetic, industrial and non-edible vegetable oil industries [92], and milkweed seed meal or press cake generated from the oil recovery process also has demonstrated nematicidal activity in greenhouse and field plot tests when used as a soil amendment [reference cited in 92, 108]. However, as discussed below, *A. speciosa* is not native to Ontario, and all milkweeds are on the noxious weed list. Further research into the potential of tallgrass milkweeds would be required to determine their potential value in a southern Ontario context.

2.6.3 Pharmaceuticals & Herbals

Research into pharmeceutical and/or herbal applications for tallgrass species indigenous to Ontario is very limited and currently does not show a lot of economic promise. Furthermore, it is likely that production for this purpose would require a dedicated monoculture crop, which would serve a very limited ecological function.

Polygala senega (Seneca snakeroot) has a small pharmaceutical market, and is under consideration in several provinces as a new or alternative crop. The greatest current interest is in Japan, where it is cultivated on a modest scale (in 1993, 10 tonnes of root were produced in Japan, suggesting an appreciable potential for cultivation in Canada) [54]. Wild populations in Manitoba and Saskatchewan are currently the major sources of supply for the North American market, and a large tonnage is also being exported to Europe. Demand is estimated to have an annual growth rate of 5 percent. Because of over-harvesting in the past years, there is a need to cultivate the root. In 1995, the root sold for US$6.50 - $8.00/lb, with most of the ten tons of wild harvested root product going to Japan, Europe and the US [109].

Echinacea is well known to the general public as an herbal remedy. It is widely used to treat cold and flu symptoms and has several other purported uses. The root is the most commonly used for medicinal purposes. *Echinacea angustifolia* and *Echinacea purpurea* are the two varieties that have been found to contain the greatest amount of the active ingredient. Both of these species are present in Ontario but neither is native. *Echinacea pallida* is the only native variety and it is found at only one site in southern Ontario .

Evening primrose (*Oenothera biennis*) is native to southern Ontario, occurring in dry meadows, waste places, and along roadsides. Evening primrose oil is high in gamma-linolenic acid (GLA), which is readily converted in the body to prostaglandin E1. GLA has been employed in the treatment of conditions for which prostaglandins could be beneficial, including: premenstrual syndrome, benign breast disease, cholesterol regulation, platelet aggregation, blood pressure regulation, obesity, atopic disease, multiple sclerosis, arthritis, mental disorders, rheumatism, alcoholism, and childhood hyperactivity. While evening primrose has been cultivated for GLA production, producers must be aware of recent biogenetic developments such as using gene splicing to produce GLA in canola. Poor winter survival in test plots at the Agriculture Canada Research Station at Morden, Manitoba has resulted in removal of evening primrose from the Western Canadian evaluation trails. As well, the plant is not necessarily characteristic of prairies and is looked at as weedy by many. Therefore acceptance in Southern Ontario as an alternative crop has been low

2.6.4 Plant Derived Cellulosic Fibres

Only milkweed seeds have been explored for their potential as cellulosic fibres. The seed floss from milkweeds was used as a substitute for kapok (*Ceiba pentandra*) when supplies were truncated in World War II, and recently the floss, which has similar properties to goose down, has been investigated as a hypoallergenic fiberfill material for use in pillows and comforters. Most of the research is from the American heartland, where production, harvesting, and floss extraction procedures and equipment needed by a new milkweed industry closely parallel the procedures and equipment already in use by the well-established cotton industry [(81)]. One company, Ogallala Down, is currently marketing Hypodown© which is 80% goose down and 20% Asclepias floss [(114)].

Notably, these products are based on research on *Asclepias speciosa* and *Asclepias syriaca*. *A. speciosa* does not occur in Ontario, while *A. syriaca* is on the Ontario Weed list with all other milkweeds. Before potential products of milkweed can be investigated, the native plants must be removed from the noxious weed list. Even if this could be accomplished, the negative perception of milkweed by farmers and potential consumers could prevent these products from gaining a foothold in the market.

3 Discussion

In the context of this project, we feel it is important to understand that it can be challenging, if not impossible, to satisfy agro-economic as well as ecological objectives with many of the applications presented in this paper, as illustrated in Table 1. Not surprisingly, many of the large-scale applications of tallgrass species (i.e. biomass applications) that have high economic potential, would provide marginal ecological benefit in terms of tallgrass recovery (although, as mentioned, they do provide a number of broader environmental benefits with respect to climate change and soil conservation). Clearly, introduction of a monoculture for harvesting as a biomass or herbal/pharmaceutical applications, even if it is an indigenous tallgrass species, cannot be considered tallgrass ecosystem restoration. There are however, a number of potentially profitable applications that could include a complement of indigenous tallgrass species and serve to provide a semi-natural tallgrass habitat. Low intensity forage grazing, tallgrass seed production and honey production using tallgrass species are all applications with excellent potential for providing both ecomonic and ecological “returns”. At the other end of the spectrum are applications with very limited economic value, at least in any direct sense, but potentially high ecological value. For example, buffer strips of tallgrass forbs and grasses would provide opportunities for expansion of tallgrass habitat and connectivity between tallgrass remnants. Since buffers are typically required or desired along riparian corridors, tallgrass species in these zones would insure input of indigenous seed into the local watershed.

From a management perspective, it is important that landowners interested in trying to recreate genuine tallgrass habitats should be made aware that prescribed burning should be seriously considered as a management tool for tallgrass restoration projects. Natural frequency of fires is relatively infrequent (on average, in the range of once every 3 to 4 years for tallgrass prairies [(95)]) and fires are known to provide numerous ecological benefits to tallgrass communities (i.e. encourage the vigorous re-growth of dominant grasses, suppress the establishment and growth of fire intolerant trees and shrubs, and keep fuel loads in check [(94)]). Notably, the OMNR is currently developing a simple computer program to provide landowners/land mangers with the tools to conduct a safe prescribed burn, which could help farmers/landowners become more comfortable with the idea of burning and also educate them about the benefits of burning. This may not be such an insurmountable challenge as many landowners already burn grass along their hedgerows and roadways to keep the area clean. Alternately, mowing can be presented as an acceptable, albeit inferior, management tool.

Areas of future research for southern Ontario applications have been identified on the body of text and Table 1. As is evident from this review, biomass applications of switchgrass are already quite well researched, and, given the limited ecological benefits of these applications, we do not feel this area is worth pursuing. Conversely, we feel that trials in the production of honey (and honey by-products) from tallgrass species, as well as studies testing the effectiveness of tallgrass communities as effective buffer and filter strips would serve well in furthering these applications. The uses of tallgrass communities in low intensity grazing should be another area of high priority for future research. In terms of applications of tallgrass species in pharmaceutical and/or herbal applications, there would need to be a substantial amount of market research and detailed investigation into the chemical properties of the various tallgrass species by-products themselves before pursuing this further.

4 Glossary

The following definitions were adopted from references 61, 63, 66.

Cultivar: A variety that has originated and persisted only under human cultivation. Usually genetically uniform, and the performance and adapation has been well documented.

Tested/Selected types: Plants which have undergone some genetic selection and varying degrees of testing on planting sites. Usually have greater genetic diversity than the cultivar, but the performance and adaptation has not been fully investigated.

Source-identified types: Typically straight from the field, with the most genetic diversity. No information has been developed on the performance and adaptation of source-identified plants beyond what can be inferred from the collection site.

Ecovar™: Ecological variety, used by Ducks Unlimited. May share some characteristics with both source-identified and selected plant material. The species is subjected to minimal selection pressure, with reasonably dependable seed production being the primary selection criterion. As a result, it retains more genetic diversity than would be the case if it were taken to cultivar status.

Sculptured seeding: An ecological seeding technique used by Ducks Unlimited, based on matching site capability with appropriate plant species to create a diverse plant community capable of maximizing wildlife benefits. This is an ecological approach to revegetation based on matching site capability with appropriate plant species to create a diverse plant community capable of maximizing wildlife benefits. A number of seed mixes are used on different range sites in the same field to produce a better adapted, more sustainable planting (see 97, 98 for details).

Nematocidal: A compound that is toxic to nematodes, some of which are capable of causing disease in plants.

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113. Government of Saskatchewan, Specialty Crops, http://www.agr.gov.sk.ca/docs/crops/special_crops/sce0190.asp
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5.3 Internet Sites Reviewed

Organization	INTERNET ADDRESS
Agri-Food Canada	aceis.agr.ca/misb/hort/honey_eng.html
Missouri Alternative Center	agebb.missouri.edu/mac/links/index.htm
Missouri Department Of Conservation	agebb.missouri.edu/mac/links/linkview3.asp?catnum=120&linknum=806
Ohio State University	agebb.missouri.edu/mac/links/linkview3.asp?catnum=120&linknum=807

University of Nebraska	agebb.missouri.edu/mac/links/linkview3.asp?catnum=120&linknum=809
Iowa State University	agebb.missouri.edu/mac/links/linkview3.asp?catnum=120&linknum=813
Iowa State University	agebb.missouri.edu/mac/links/linkview3.asp?catnum=216&linknum=1538
University of California	agebb.missouri.edu/mac/links/linkview3.asp?catnum=94&linknum=628
Bioenergy Information Network	bioenergy.ornl.gov/
Konza Prairie Research station	climate.konza.ksu.edu/HomePage.html
Ecological Projects, McGill University	eap.mcgill.ca/general/home_frames.htm
USDA-Plant Materials Program	plant-materials.nrcs.usda.gov:90/pmc/factsheets.html
Canadian Agricultural New Uses Council	quartz.cyg.net/~canuc/New_Crops/new_crops.html
Southern Crop Protection and Food Research Center- Agri-Food Canada	res2.agr.ca/london/pmrc/english/study/
AGNIC-Agricultural Network Information System	www.agnic.org/
Agriculture Canada	www.agr.ca/misb/spcrops/herb_e.html
Prairie Farm Rehabilitation Administration-Ag Canada	www.agr.ca/pfra/pfintroe.htm
Saskatchewan Irrigation Diversification Center	www.agr.ca/pfra/sidcpub/echinaca.pdf
Saskatchewan Ministry of Agriculture	www.agr.gov.sk.ca/Crops/Special_Crops.asp?firstpick=Crops&secondpick=Special%20Crops&thirdpick=Production%20Information&selection=Production%20Information
Saskatchewan Agriculture and Food	www.agr.gov.sk.ca/DOCS/crops/special_crops/Sce0190.asp?firstPick=Crops&secondpick=Special%20Crops&thirdpick=Production%20Information
Saskatchewan Ministry Of Agriculture	www.agr.gov.sk.ca/docs/statistics/livestock/00honeyprod.asp
Alberta Ministry of Agriculture, Food And Rural Development	www.agric.gov.ab.ca/agdex/100/8883001.html
Agricultural Research Council	www.agric.gov.ab.ca/crops/special/conf/domier.html
Alberta Ministry Of Agriculture, Food and Rural Development	www.agric.gov.ab.ca/crops/special/conf/gaudiel1.html
USDA	www.ars.usda.gov/
Appropriate Technology Transfer for Rural Areas	www.attra.org/attra-pub/herb.html
Appropriate Technology Transfer for Rural Areas	www.attra.org/attra-pub/nativebee.html
Canadian Plains Research Center	www.cprc.uregina.ca/
Prairie Ecosystem Study- Saskatchewan	www.cprc.uregina.ca/pecos/
Center for Great Plains Studies	www.emporia.edu/cgps/grplsst.htm
Mixed Grass Stewardship Program	www.escape.ca/~mxdgrass/index.htm
Essential Oil Company	www.essentialoil.com/
North Dakota State University	www.ext.nodak.edu/extpubs/alt-ag.htm
Great Lakes Grazing Network	www.glgn.org/
Proceedings of The Prairie Medicinal And Aromatic Plants Conference '97	www.gov.mb.ca/agriculture/crops/alternativecrops/pmap/bkp00s03.html
Manitoba Ministry of Agriculture	www.gov.mb.ca/agriculture/crops/alternativecrops/pmap/bkp00s05.html
Proceedings of The Prairie Medicinal And Aromatic Plants Conference '97	www.gov.mb.ca/agriculture/crops/alternativecrops/pmap/bkp00s05.html
Manitoba Ministry of Agriculture	www.gov.mb.ca/agriculture/crops/medicinal/bkq00s01.html
Manitoba Department of Agriculture	www.gov.mb.ca/agriculture/crops/medicinal/bkq00s06.html
Manitoba Ministry of Agriculture	www.gov.mb.ca/agriculture/financial/agribus/ccg02s00.html
Manitoba Ministry of Agriculture	www.gov.mb.ca/agriculture/financial/farm/cac06s01.html

Manitoba Ministry of Agriculture	www.gov.mb.ca/agriculture/research/covering/projects/98-02-08.html
Center for Grassland Studies	www.grassland.unl.edu/index.htm
Great Plains Resources	www.greatplains.org/
Purdue University- Center for New Crop Resources	www.hort.purdue.edu/newcrop/
Purdue University- Center for New Crop Resources	www.hort.purdue.edu/newcrop/nexus/Echinacea_nex.html
Purdue University- Center for New Crop Resources	www.hort.purdue.edu/newcrop/proceedings1993/V2-422.html
Purdue University- Center for New Crop Resources	www.hort.purdue.edu/newcrop/proceedings1993/V2-428.html
On Line Journal Article	www.hort.purdue.edu/newcrop/proceedings1993/v2-628.html
Illinois Grazing Manual	www.il.nrcs.usda.gov/grazing/grzmain.htm
Land Stewardship Resource Center	www.landstewardship.org/frameset.htm
Environment Canada Conservation Guide- Land Stewardship Contacts	www.mb.ec.gc.ca/nature/whp/lsd/df08s03.en.html
Environment Canada	www.mb.ec.gc.ca/nature/whp/prgrass/df03s00.en.html
Minnesota Grown Opportunities, Minnesota Dept of Agriculture	www.mgo.umn.edu/diversif/
Alternative Farming Info Systems	www.nal.usda.gov/afsic/
Alternative Farming Systems Information Center	www.nal.usda.gov/afsic/
Alternative Farming Systems Information Center	www.nalusda.gov/afsic/AFSIC_pubs/mherb.htm
New Uses Council	www.newuses.org/
USDA-Plant Materials Program	www.nhq.nrcs.usda.gov/BCS/PMC/eng/eng.html
Northern Prairie Wildlife Research Center	www.npwrc.usgs.gov/
Kansas State University	www.oznet.ksu.edu/___library/crpsl2/srl23.pdf
Saskatchewan Prairie Conservation Plan	www.pcap-sk.org/
Dell Point Inc.	www.pelletstove.com/right.html
REAP	www.reap.ca/
Farmer's Guide to the Internet	www.rural.org/Farmers_Guide/
Sustainable Agriculture Research Program	www.sare.org/diversify/index.htm
Switchgrass Information	www.uwex.edu/ces/forage/pubs/switchgrass.htm
Native Prairie Stewardship Prog- Saskatchewan	www.wetland.sk.ca/prairie_stewardship/index.htm
Center For Integrated Agricultural Systems	www.wisc.edu/cias/pubs/briefs/048.html