ECONOMIC IMPACT ASSESSMENT OF LEAFY SPURGE IN SOUTHERN MANITOBA

FINAL REPORT

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Rural Development Institute, Brandon University

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Executive Summary

In 1999, the LSSG undertook efforts to estimate the amount of leafy spurge infestation in Manitoba at that time, and its potential impact. Estimations of the amount of leafy spurge came from a survey of weed control districts, reports from southern Manitoba agricultural representatives and information from a 1981 survey. Economic impacts were calculated based on the reduced carrying capacity of the land and an estimation of the secondary economic impacts.

Findings from these efforts were contained in the 1999 report, *Leafy Spurge Impact Assessment* prepared by the Leafy Spurge Stakeholders Group (LSSG). These findings indicated that

(a) there were at least 340,000 acres of leafy spurge in Manitoba;

(b) there was a total economic impact of $20 million based on the *direct costs* associated with a reduced carrying capacity of grazing, the impacts on public lands for recreation and reduced habitat value, and the impact of infestation on right-of-ways and *the indirect or secondary* economic impacts.

The report cautioned that the analysis was based on data that was available at that time and that the estimated number of acres was an underestimation of the extent of infestation across Manitoba.

Driven by the 1999 report's acknowledgement of the underestimation of acres of leafy spurge at the time, the nature of leafy spurge patch expansion and current economic values, the Rural Development Institute on behalf of the LSSG, sought and received funding support to prepare the 2010 economic impact assessment of leafy spurge in southern Manitoba.

The aim of this report is to assess the economic impact of leafy spurge in the province, with a focus on southern Manitoba. The acreage of leafy spurge was based on geographic land use information, existing databases on known spurge infestation and consultation with weed supervisors and technical experts. In addition to presenting a map showing the potential distribution of leafy spurge in southern Manitoba, the report also provides a brief overview of the invasion process with a focus on identifying the economic factors which cause the spread of invasive species. Calculations for direct costs were based primarily on the value of lost grazing capacity of pastures, and indirect costs were calculated using an animal production input-output multiplier of 2.36.

This 2010 economic impact assessment found that, based on available information and data, there are in excess of **1.2 million acres** of leafy spurge in Manitoba. The areas most affected are pastures, natural areas, hay or forage land, and road sides, rail lines and utility corridors. This represents a 3.5 times increase of infested areas in ten years.

This acreage of leafy spurge results in a total economic impact to Manitoba of **$40.2 million,** nearly a twofold economic impact over the 1999 assessment. This total is comprised of $10.2 million in direct costs based on the value of lost grazing capacity of pastures for livestock production, $5.8 M in costs for chemical applications specifically for leafy spurge on roadsides, and indirect costs of $24.1 M.

1.0 Overview of the Report

This report describes the economic impact of leafy spurge in southern Manitoba based on data collected and available in 2009. This data includes the best available information on the acreage of leafy spurge infestation in Manitoba and economic variables from 2009. The report also provides a brief overview of the invasion process with the identification of economic factors that contribute to the spread of invasive species such as leafy spurge.

While the long-term efforts to document and to research invasive alien species in croplands have helped eradicate, manage and control these species, these extensive efforts are in stark contrast to the lack of effort for invasive alien weed species, such as leafy spurge, that invade natural vegetation. Pasture lands, natural areas and hay lands suffer from far too little documentation, research, or intensive efforts for eradication, management and control of invasive weed species (Thomas & Leeson, 2007).

The report is organized into the following sections:

- Section 2 provides general background including a summary of the *Leafy Spurge Impact Assessment* (LSSG, 1999) and the context of the 2010 report. It also includes a brief description of the spread and movement of invasive species such as leafy spurge.
- Section 3 outlines the *density and distribution* of leafy spurge, defines the study area and provides available data by rural municipality.
- Section 4 contains the *method and findings* of this assessment, as well as a summary. Included are the *direct and indirect economic causes* or activities that increase the spread and movement of invasive species and the *direct and indirect costs* of leafy spurge.

2.0 Background

Leafy spurge is an invasive alien weed species that has infested several millions of acres of pastures, hay/ forage land, recreational areas, road sides, rail lines, utility corridors and gravel pits across the Great Plains of North America. The most vulnerable areas of infestation of spurge are native prairie pastures in North America. This also includes the roadsides, rail lines, gravel pits and utility corridors that are part of, or near to native prairie pastures (DiTomaso, 2000; Leitch, Leistritz & Bangsund, 1994; Leistritz, Bangsund & Hodur, 2004; Wallace, Leitch & Leistritz, 1992).

2.1 The 1999 Leafy Spurge Impact Assessment

One of the most severely infested regions of the Great Plains is southern Manitoba, also referred to as agro-Manitoba. The problem ranges from severe in some parts to moderate or light in others. In 1998, a group of interested stakeholders came together to form the Leafy Spurge Stakeholders Group (LSSG). The objectives of this broad coalition of agriculture groups, all three levels of government, non-profit organizations, and environmental organizations were to:

- raise awareness of the problem of leafy spurge;
- provide accurate information on the extent, economic impact;
- provide information to landowners on best management practices for control; and to,
- coordinate leafy spurge efforts in Manitoba to ensure the best use of resources.

In 1999, the LSSG undertook efforts to estimate the amount of leafy spurge infestation in Manitoba at that time, and its potential impact. Estimations of the amount of leafy spurge came from a survey of weed control districts, reports from Manitoba agricultural representatives and information from a 1981 survey (LSSG, 1999). Economic impacts were calculated based on the reduced carrying capacity of the land and an estimation of the secondary economic impacts.

Findings from these efforts were contained in the 1999 report, *Leafy Spurge Impact Assessment.* (LSSG, 1999). These findings indicated that

(a) there was at least 340,000 acres of leafy spurge in Manitoba;

(b) total economic impact was estimated at of $20 million based on the *direct costs* associated with a reduced carrying capacity of grazing, the impacts on public lands for recreation and reduced habitat value, and the impact of infestation on right-of-ways and *the indirect or secondary* economic impacts.

The report cautioned that the analysis was based on data that was available at that time, and that therefore, the estimated number of acres presented in the report was an underestimation of the extent of infestation across Manitoba.

2.2 The 2010 Economic Impact Assessment of Leafy Spurge in Manitoba

Ten years after the release of the *Leafy Spurge Impact Assessment* (LSSG, 1999) the magnitude of the distribution and density of leafy spurge across agro-Manitoba continues to concern producers, land managers and policy makers. At the heart of these concerns are the economic and environmental questions and decisions needed to address the persistent challenge of leafy spurge in the province. These decisions include the amount of resources that should be used to

control, manage or eradicate leafy spurge and the extent to which these efforts should be a component of provincial legislation and regulation.

These concerns and questions underscore the importance of the economic impact assessment of leafy spurge. For example, economic information will help policy makers, program managers and land owners allocate resources, enforce or revise regulations for the prevention and management of the spread of leafy spurge, and help promote research and development of new chemical treatments or the introduction of new biological control species. Biocontrol methods and agents, such as certain species of flea beetles, are explained in the publication *Integrated pest management (IPM): Leafy spurge prevention and control* (LSSG, 2007).

The issues associated with leafy spurge invasive have, traditionally, been the responsibility of ecologists and rangeland biologists. In recent years, as invasive species have become more widespread and their impacts on global trade and human health have escalated, policy makers and the scientific community have started to call increasingly for the input of economists and social scientists. In fact, a strong case can be made that the spread of invasive species and the extent to which they are eradicated, controlled or managed are fundamentally an economic problem in terms of their causes, effects and remedies.

The challenge is that invasive species have many unique and unusual biological characteristics that set them apart from other species, meaning that economic analysis does not lend itself easily to conventional economic models. For example, leafy spurge has a rapid and effective reproductive capacity that enables it to spread and adapt quickly to a variety of different landscapes. The best we can offer in this study is an underestimation of acres of leafy spurge given the data available.

The 2010 economic impact assessment reflects many of the premises used in the *Leafy Spurge Impact Assessment* (LSSG, 1999). There are however, some important differences (Table 1). Firstly, the amount of leafy spurge acres was calculated using geographic land-use information in combination with existing site coordinates. Secondly, the 2010 report uses (a) reduced carrying capacity and its impact on gross revenue and (b) the reduction in rental value of grazing land. Both reports estimated the costs to control leafy spurge on rights-of-way.

Driven by the 1999 report's acknowledgement of the underestimation of acres of leafy spurge at the time, the nature of leafy spurge patch expansion and current economic values, the Rural Development Institute on behalf of the LSSG, sought and received funding support from the Agricultural Sustainability Initiative to prepare the 2010 Economic Impact Assessment of Leafy Spurge in Manitoba.

Table 1: Similarities and differences between the *Leafy Spurge Impact Assessment* (LSSG, 1999) and the 2010 economic impact assessment

Report	Calculations of distribution and density of leafy spurge	Direct economic costs	Indirect economic costs
Leafy Spurge Impact Assessment (LSSG, 1999)	Survey of weed districts. Information from weed supervisors and agricultural representatives.	Based on 1999 values: Reduced carrying capacity of pastures as measured by AUMs. Costs associated with the impact of spurge on recreational activities. Costs to control of leafy spurge on rights-of-way.	Multiplier effect of 2.2 (no reference)
2010 economic impact assessment	Geographic land-use information used to identify the most likely areas of infestation and consultation with weed supervisors.	Based on 2010 values: Reduced carrying capacity of pastures as measured by AUMs. Costs to control leafy spurge on rights-of-way.	Multiplier effect of 2.36 for Animal Production (Statistics Canada)

2.3 Understanding 'invasiveness'

Two characteristics are embedded in the term *invasive foreign or 'alien' species.* Firstly, there are biological processes that occur as they enter a new environment, establish themselves and begin to change the balance of native plant and animal communities (Emerton & Howard, 2008). Secondly, these species cause or have the potential to cause harm to the environment, economics and/or human health.

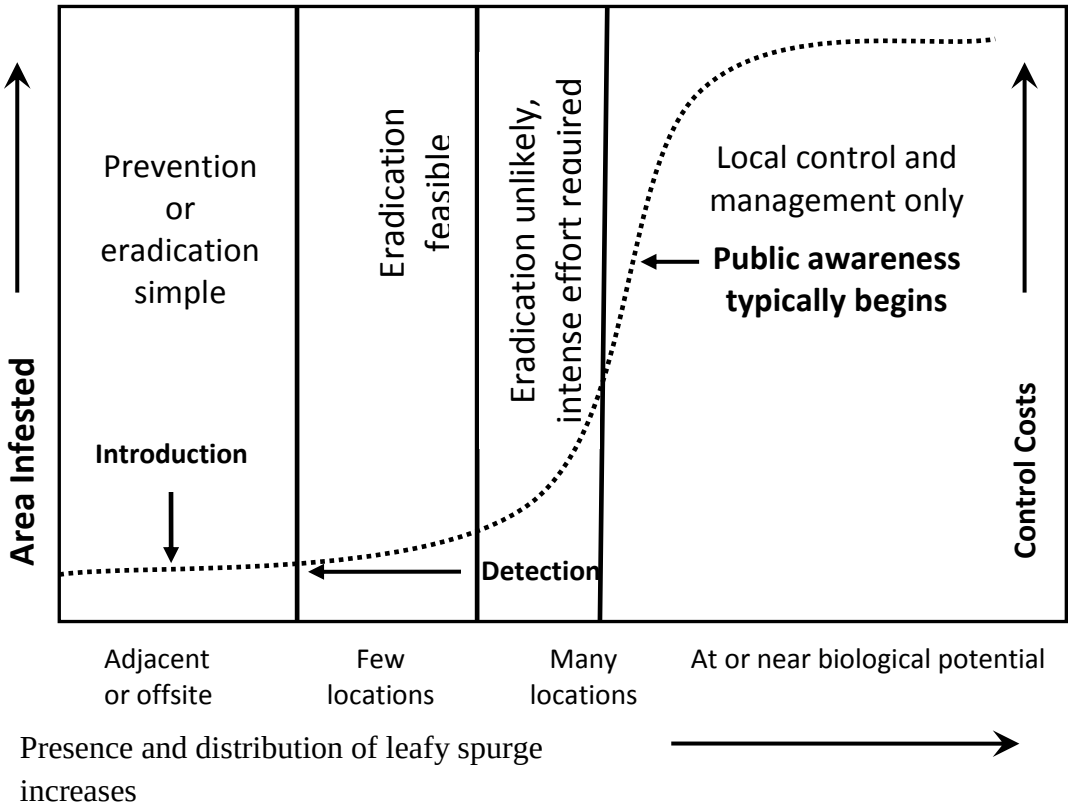
The ability or propensity of a species such as leafy spurge to become 'invasive' comes from several biological advantages (Emerton & Howard, 2008). In the case of leafy spurge these biological advantages include:

- capacity for rapid expansion and growth;
- effective reproductive capacity including two episodes of seed production and long-lived seed stock;
- broad environmental tolerance;
- ability to establish populations in disturbed habitat such as cleared land, roadsides, construction sites and gravel pits; and
- natural competiveness with native species for food, space and water.

Potentially invasive species move along *pathways* or routes. Primary pathways introduce the species into an area and include roads, rail lines and utility corridors. Once introduced, invasive weed species continue to spread through secondary pathways such as water and wildlife migration routes. The means by which they move are known as *vectors.* Vectors include the agricultural equipment, recreational vehicles, wildlife, and in the case of leafy spurge, gravel or hay that is contaminated with leafy spurge seed.

The time (days, months or even years) from introduction to invasive spread and the extent of the spread varies considerably from one stage to another, one situation to another and one species to another. As time goes by and the invasive species expands in terms of its presence (distribution) and prevalence (density) the economic costs and control efforts must increase while the biodiversity and control potential decrease. Using the example of leafy spurge (Figure 1), at the earliest stages of introduction, prevention or eradication is simple. However, as the area of infestation increases, control costs also increase (curved line). Furthermore, eradication is unlikely, control costs increase significantly and the control potential is limited to management of the spread.

Figure 1: Influence of the levels of infestation on the potential of control and control costs of leafy spurge



Regardless of the time and extent, it is clear that prevention and early detection of the invading species is cheaper and more effective at the introduction stage of invasion. Predictive models can be extremely helpful in identifying potential pathways and vectors of introduction and spread.

3.0 Calculating the distribution and density of leafy spurge

The goals of the data collection and analysis process were to develop a process that could be replicated by others and to provide a reasonably accurate accounting of the acreage of leafy spurge. While these goals were met to a great extent, the precise acreage of leafy spurge acreage will continue to be a challenge even though leafy spurge is widely distributed across Manitoba. There have also been increased efforts in recent years by several organizations (such as the Manitoba Weed Supervisors Association, the Rural Development Institute, the Leafy Spurge Stakeholders Group and the Invasive Species Council of Manitoba) to implement and maintain long term records including the development of on-line invasive species mapping and survey database known as the Prairie Region Invasive Plant Species (PRIPS) database. Much of the data consisted of site coordinates which provided information on the presence of leafy spurge but yielded very little information on (a) the number of acres infested or (b) the density of the spurge on the particular site.

3.1 Defining the study area

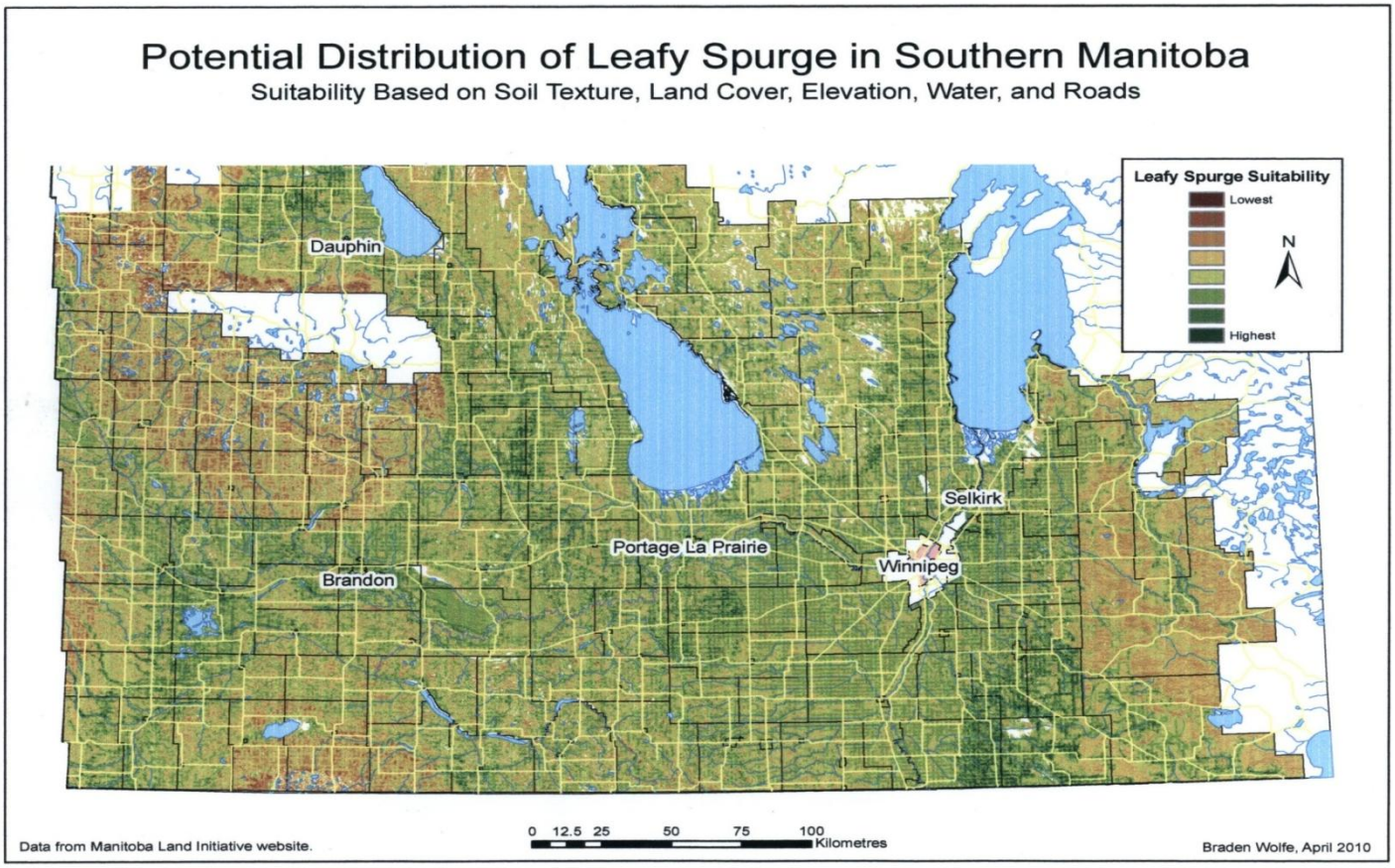
Based on the data collected, the study area is composed of four groups (A, B, C and D) of rural municipalities. Although the study is for Manitoba as a whole, we have information for 79 rural municipalities. There are 21 for which we have no data or there is no spurge reported. A complete listing of rural municipalities can be found in Appendix A.

Predictive model of leafy spurge infestation in Manitoba

Predictive models for invasive species combine various geographic features of a landscape with the biological characteristics of the species. Predictive models are helpful at all stages of invasion but are particularly useful for predicting and monitoring new introductions (Gillam, Johnson, Hild & Hammerlinck, 2001).

The following predictive map (Figure 2) illustrates the areas in southern Manitoba that are most susceptible to leafy spurge. While the predictive map has value in its confirmation of the known distribution and density of leafy spurge, its most important value is to identify areas for new introductions of leafy spurge or for where spurge infestations are at a level which can be controlled and managed. That said, the infestation of leafy spurge is a complex process moving along a number of pathways and vectors. Some of these pathways and vectors, such as water courses and the movement of wildlife, cannot be controlled. Other pathways and vectors, such as road sides and the movement of gravel or contaminated equipment can be controlled.

Figure 2: Potential distribution of leafy spurge in southern Manitoba



In the case of leafy spurge, the predictive model is centered on southern Manitoba which is the most likely range of leafy spurge. The model compares seven criterion of environmental data (soil texture, land cover, elevation, slope, aspect, distance to water and distance to roads) with the biological requirements and growth factors of leafy spurge. The predictive model illustrated for leafy spurge is illustrated in Figure 2, Potential Distribution of Leafy Spurge in Southern Manitoba. Inaccuracies in the map could be a result of growth factors not having the same amount of influence on the development of leafy spurge. For Manitoba, the most important characteristics are soil type and land cover (Wolfe, 2010).

3.2 Data collection and analysis processes

Ultimately, the following data collection and analysis processes were used to calculate the amount and density of leafy spurge in Manitoba.

- The number of acres of leafy spurge was based on statistical land use information contained in the series, *Soil and Terrain Information Bulletins for RMs in Manitoba* (1996) produced by the Land Resource Unit, Agriculture and Agri-Food Canada, Brandon Research Centre. These bulletins contain geographic data on the type and acreage of each type of land use for every rural municipality in Manitoba. The land use types were cropland, hay / forage land, waterways, pastures, trees, and infrastructure which consists of roads, railways, and utility corridors which include gravel pits.

- Given that leafy spurge infestations are primarily a problem in pastures, hay land and along roads, railways and utility corridors, it was reasonable to assume that if leafy spurge infestations were present, they would be located in pastures, hay / forage land and roads, railways, utility corridors and gravel pits. Based on these bulletins, a spreadsheet containing gross acres of hay land, pasture land and transportation corridors of each rural municipality was prepared. The data from the information bulletins were compared with the survey information from the *Leafy Spurge Impact Assessment* (LSSG, 1999) and information contained on the Prairie Region Invasive Plant Species (PRIPS) database.
- The density of leafy spurge in a given area refers to the percentage of the leafy spurge plants as a component of the overall vegetative cover in an area (see Figure 4 in section 4.3). The following four categories of density were used: 0-10% density, 11-30% density, 31-60% density and 61-100% density.
- Each of the rural municipalities with recorded presence of leafy spurge were subsequently placed in one of these four categories based on the survey information from the *Leafy Spurge Impact Assessment* (LSSG, 1999) and information contained on the Prairie Region Invasive Plant Species (PRIPS) database. The initial analysis of both distribution and density was circulated for review to the project steering committee. As well, 19 weed supervisors from several weed districts were contacted by telephone in order to add more details on the density and distribution of spurge in their districts.
- The amount or number of acres of leafy spurge is a median amount determined by using (a) the low end of each of the four categories as the minimum number of acres and (b) the high end as the maximum number of acres.
- While hay / forage land is reflected in the amount of acres infested by leafy spurge, it was not used in calculating the economic impact of spurge. At the time of this report, there was no evidence to quantify the impact of leafy spurge on the sale or value of hay.

As described above, the rural municipalities reporting a presence of spurge were categorized into four groups based on estimates of the density of the spurge infestation. These densities are presented as a range of 0-10% or trace level of leafy spurge density, 11-30% or low level of leafy spurge density, 31-60% or moderate level of leafy spurge density, and 61-100% or high level of leafy spurge density.

The following four tables depict the minimum, median and maximum acres of spurge for each grouping of rural municipalities. Totals for the study area are found in Table 6 in section 3.3.

Group A Rural Municipalities (table 2)

These municipalities have leafy spurge infestations that have a high level of density and are also widely spread throughout hay / forage land, pastures, along road sides, rail lines and utility corridors. Based on the median number of acres of leafy spurge and at the high level of spread and density, **80% of hay / forage land, pastures and roadsides, rail lines and utility corridors,** have infestations of leafy spurge. Seven (7) rural municipalities fall into this category of infestation.

Table 2: Group A rural municipalities with a high level of spurge density (61-100%)

Land use type	Acres by land use type	Median acres of leafy spurge	Minimum acres of leafy spurge	Maximum acres of leafy spurge
Hay / forage land	66,308	53,047	40,448	66,308
Pastures	495,329	396,264	302,151	495,329
Roadsides, rail lines, utility corridors	53,098	42,478	22,435	53,098
Totals	**614,735**	**491,788**	365,034	614,735

Group B Rural Municipalities (table 3)

These municipalities have leafy spurge infestations that have a moderate (31-60%) level of density and are also widely spread throughout hay / forage land, pastures, along road sides, rail lines and utility corridors. Based on the median number of acres of leafy spurge and at the high level of spread and density, **45% of hay / forage land, pastures and roadsides, rail lines and utility corridors,** have infestations of leafy spurge. Fifteen (15) rural municipalities fall into this category of infestation.

Table 3: Group B rural municipalities with a moderate level of spurge density (31-60%)

Land use type	Acres by land use type	Median acres of leafy spurge	Minimum acres of leafy spurge	Maximum acres of leafy spurge
Hay / forage land	80074	36033	24823	48045
Pastures	466105	209747	144492	279663
Roadsides, rail lines, utility corridors	99490	44770	30842	59694
Totals	**645669**	**290551**	200157	387401

Group C Rural Municipalities (table 4)

These municipalities have leafy spurge infestations that have a low (11-30%) level of density and are also widely spread throughout hay / forage land, pastures, along road sides, rail lines and utility corridors. Based on the median number of acres of leafy spurge and at the high level of spread and density, **20 % of hay / forage land, pastures and roadsides, rail lines and utility corridors,** have infestations of leafy spurge. Thirty-nine (39) rural municipalities in Manitoba have a low level of spurge density.

Table 4: Group C rural municipalities with a low level of spurge density (11-30%)

Land use type	Acres by land use type	Median acres of leafy spurge	Minimum acres of leafy spurge	Maximum acres of leafy spurge
Hay / forage	214762	42952	23624	64428
Pastures	1671243	334248	183836	501372
Roadsides, rail lines, utility corridors	226060	45212	24866	67818
Totals	**2112065**	**422412**	232327	633618

Group D Rural Municipalities (table 5)

These municipalities have leafy spurge infestations that have a trace (0-10%) level of density and are also widely spread throughout hay / forage land, pastures, along road sides, rail lines and utility corridors. Based on the median number of acres of leafy spurge and at the high level of spread and density, **20 % of hay / forage land, pastures and roadsides, rail lines and utility corridors,** have infestations of leafy spurge. Twenty-one (21) rural municipalities have a trace level of leafy spurge. Furthermore, most of this infestation is along roadsides, rail lines and utility corridors.

Table 5: Group D rural municipalities with a trace level of spurge density (0-10%)

Land use type	Acres by land use type	Median acres of leafy spurge	Minimum acres of leafy spurge	Maximum acres of leafy spurge
Hay / forage land	82264	2604	0	5209
Pastures	818097	29364	0	58728
Roads, rail lines, utility corridors	207067	9830	0	19659
Total	**1107428**	**41798**	0	83506

3.3 Total distribution and density of leafy spurge in southern Manitoba

Based on these **median** numbers, the total number of acres of infested with leafy spurge (hay / forage land, pastures, and roads, rail lines and utility corridors) amounts to **1,246,549 acres**. These median values exist within a range of 797,517 acres at minimum distribution assumption to 1,719,350 acres at maximum distribution assumption (Table 6). In summary, over **38% of all hay / forage land, pastures, roadsides, rail lines and utility corridors in agro-Manitoba** appear to have some level of leafy spurge infestation.

Table 6: Total minimum, median and maximum acres of leafy spurge in Manitoba by land use type

Land use type	Acres by land use type	Median acres of leafy spurge	Minimum acres of leafy spurge	Maximum acres of leafy spurge
Hay / forage land	443,408	134,636	88,895	183,990
Pastures	3,450,775	969,623	630,479	1,335,092
Roads, rail lines, utility corridors	585,714	142,290	78,183	200,268
Total	**4,479,897**	**1,246,549**	797,517	1,719,350

4.0 Estimating the Economic Impact of Leafy Spurge

Estimating the economic impact of leafy spurge involves calculations of direct costs (reduced carrying capacity of pastures for cattle; plus control costs for roadsides, rail lines and utility corridors) and indirect costs (using a multiplier for the direct impacts in the cattle production sector). This section also defines the limitations of the study.

4.1 The influence of economic factors on invasive species

Invasions of alien or foreign species are the outcome of very complex biological interactions; however, their introduction can be traced back to direct and indirect economic factors (Emerton & Howard, 2008; Evans, 2003). Economic causes and conditions operate at all stages of invasiveness from the introduction of a species and the subsequent progression of stages of invasiveness - establishment, naturalized spread and invasive spread.

These economic causes either advance the invasiveness, or act as catalysts to halt and control the spread. According to Emerton and Howard (2008) economic factors can affect human behaviors and attitudes toward invasive species either by promoting and supporting responses or by undermining efforts with conflicting policies and activities.

When applying economic analysis to invasive species, Emerton and Howard (2008) advised that a first step is to distinguish between the direct and indirect economic conditions or causes that have led, or which are leading to a species becoming invasive in a given situation.

- *Direct economic causes* are the production and consumption activities which, on their own, introduce, establish and spread invasive species. The following table, adapted from Emerton and Howard (2008), sets out examples of the indirect and direct economic causes of the spread of leafy spurge in Manitoba based on the stages of the invasion process.
- *Indirect economic causes* are conditions that encourage people to behave in particular ways which introduce, establish and spread invasive species. Indirect economic conditions also hamper the ability of human and natural systems to deal effectively with invasiveness.

Even though the determination of the extent of the influence of direct and indirect causes is highly complex, its relevance rests in the identification of the economic causes that undermine efforts to control the spread of invasive species. Table 7 provides some examples of the direct and indirect economic causes of the spread of leafy spurge in Manitoba.

Table 7: Direct and indirect economic causes of leafy spurge at various stages of invasion.

Stage of invasion	Examples of direct economic causes of leafy spurge invasion	Examples of indirect economic causes that affect human behavior	Examples of indirect economic causes that hamper the ability of human or natural systems to respond to leafy spurge
Introduction	Shipments of contaminated seed, forage and gravel	Limited funding to promote awareness and early detection Limited funding to map and monitor introductions	Lack of standards for weed free products such as hay and forage seed Lack of weed supervisors in local area
Establishment	Costs to modify or convert cattle operations for sheep and goat livestock production even though sheep and goats eat leafy spurge and provide a good economic return Cost of chemical controls	Land zoning and development	Extensive focus on arable cropland weeds and little attention on invasive alien weed species in natural vegetation or hay / forage land.
Naturalized spread	Disturbance of land for development or utility corridors	Property rights of land owners Demand for acreages	Mowing of roads and railways Movement of gravel
Invasive spread	Lack of budgets for control programs Limited investment for research and development for integrated pest management options for invasive alien weed species in pastures, natural areas or hay / forage land	Few control options for individual land owners or managers	Lack of weed supervisors in local area Concentration of research efforts for arable crops Inadequate or no compliance with the Province of Manitoba *Noxious Weed Act*

4.2 Limitations to the economic impact assessment of leafy spurge

With specific reference to leafy spurge in Manitoba, the limitations for this economic assessment come from (a) the availability of empirical evidence to support a number of claims of economic impacts of leafy spurge; (b) market fluctuations; (c) the currency of available data on the distribution and density of spurge; and (d) the attribution of the multiplier effect of livestock grazing. While there is data for 79 rural municipalities, there is no data for 21 additional rural municipalities (see Appendix A).

In terms of the *availability of empirical evidence*, leafy spurge has been cited as having an impact on a number of economic variables such as decreased land values, lower tax revenue, the impact on recreational activities, decreased market value of forage and increased costs for water conservation have been suggested. To date however, these variables have been cited only anecdotally and there is no empirical evidence to their reliability or to the level of their significance. For these reasons, these variables have not been included in this study.

A third type of land use affected by leafy spurge is hay or forage land. However, no economic analysis was completed. While leafy spurge is present in hay or forage land acres, no economic attribution could be attached to the impacts. For example, at the time of this report, Manitoba did not have a Weed Free Forage Program. As well, there was no empirical evidence showing the extent to which leafy spurge limits forage production. That said, hay infested with leafy spurge has a very limited market (goat and sheep producers) and is usually avoided by other cattle and horse producers. Refer to Appendix B of this report for illustrations.

Furthermore, for any of these variables, it would be a serious challenge, perhaps impossible, to separate the presence or absence of leafy spurge out of several other variables. For example, decreased land values may be influenced by access to roads or availability of water for livestock or humans. For *market fluctuations*, there are always limits to which analysts can adequately reflect current changes such as shifts in markets and consumer demands. As evidenced by the efforts to quantify the extent and significance of impacts from such events as the bovine spongiform encephalopathy (BSE) crisis in 2003 or swine flu in 2009, there are continual and often rapid shifts in market values that limit the ability of analysts to definitively state claims. Furthermore, the relationships networks that produce or move the good or service add their own levels of complexity (Emerton & Howard, 2008).

The *currency of available data* on the distribution and density of spurge limits the level of precision of the number of acres of spurge, its location and its density. It would be impossible, and likely not a good use of resources, to identify every acre or parcel of leafy spurge in Manitoba. Ranges and median values for distribution and density of leafy spurge are used to mediate this limitation.

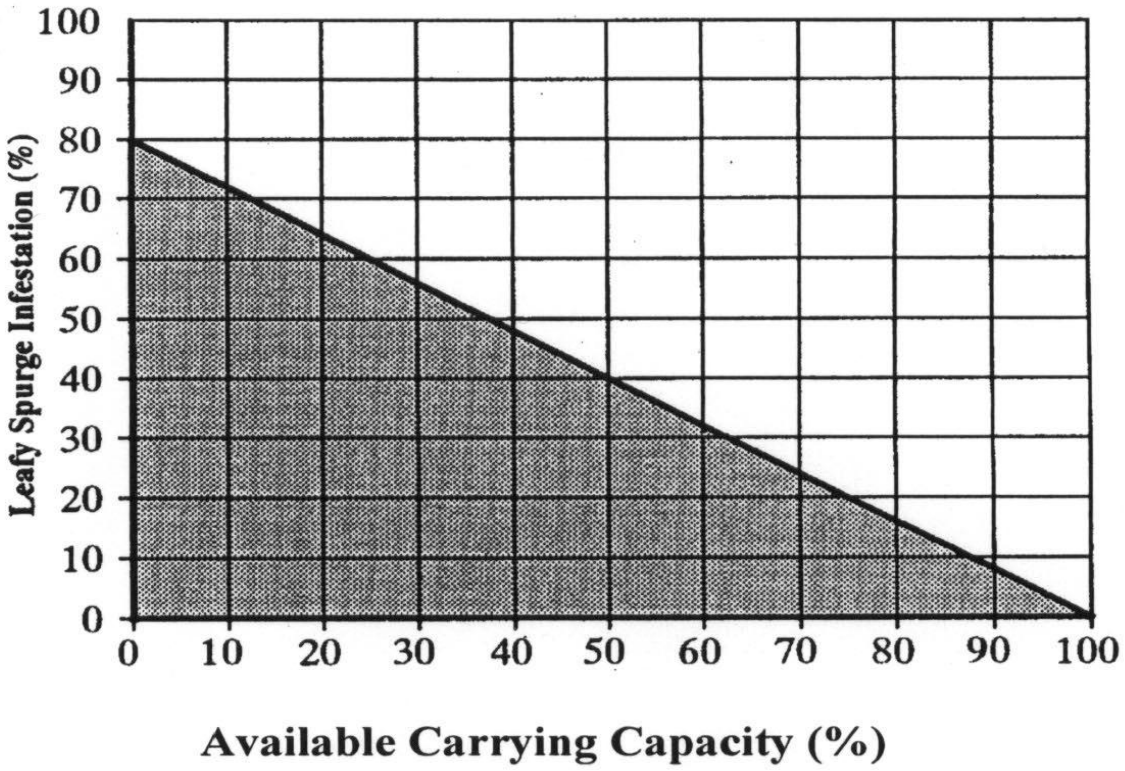
Finally, the absence of a *multiplier effect* specifically for livestock grazing in Manitoba should signal that there may be limitations to the indirect costs that are attributed to infestations of leafy spurge. Specifically, the multiplier effect of 2.36 is based on Animal Production factor determined by Statistics Canada; however, this multiplier may be too high for this component of Animal Production.

4.3 Direct economic costs

Direct costs are based on the direct relationship between the on-site extent of the invasion and the product or service derived or intended from the site. The most significant direct costs of leafy spurge in Manitoba is the reduced carrying capacity of pastures for cattle grazing. Grazing capacity refers to the amount of available forage for livestock. Leafy spurge reduces the amount of available forage for cattle in two ways. Firstly, leafy spurge can compete very successfully with other plants species for available natural resources (soil, air, and water). As the area of spurge infestation increases the availability and variety of other types of plant decreases. Secondly, while sheep and goats will graze spurge, cattle totally or partially avoid leafy spurge infested sites.

As shown in Figure 3 as the infestation of leafy spurge infestation increases, the available grazing or carrying capacity for cattle decreases (Leitch, Leistritz & Bangsund, 1994; Hirsch & Leitch, 1998; Wallace, Leitch & Leistritz, 1992).

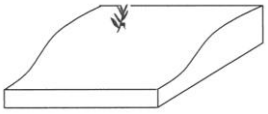
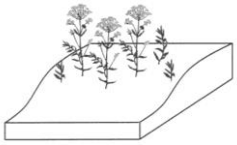
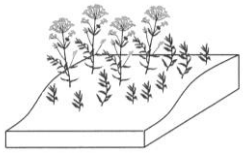
Figure 3: Reduced carrying capacity of cattle grazing as a function of percent infestation. Reproduced from Leitch, Leistritz & Bangsund (1994), p. 5



The percentage of leafy spurge infestation is determined by the distribution and density of the infestation. In the case of leafy spurge, the distribution is based on the presence or absence of spurge. The density of spurge is determined by the number of spurge plants in an area as a part of

the total vegetative cover. For the purposes of this economic assessment, the density of leafy spurge was based on the following four categories of density (Figure 4).

Figure 4: Categories of density of leafy spurge in Manitoba

			
T = (Trace; rare): between 1% and 10% cover	L = (Low; occasional plants): between 11 and 30% cover	M = (Moderate; scattered plants): between 31 and 60% cover	H = (High; fairly dense): between 61 and 100% cover

Adapted from Montana State University Extension Services (1997), *Mapping Noxious Weeds,* in consultation with the Manitoba Weed Supervisors Association and Manitoba Agriculture, Food and Rural Initiatives.

Another known direct cost is the expense incurred by municipalities or other organizations to control leafy spurge on roads, rail lines and utility corridors.

4.3.1 Reduced carrying capacity of pastures

The economic impact assessment of leafy spurge in Manitoba in 2010 is based on a biophysical economic model which assesses the value of the direct and indirect costs of the good or service affected by the species (Emerton & Howard, 2008). In this economic analysis the good or service affected by leafy spurge is the forage available for livestock grazing, specifically cattle. While other livestock sectors may also be affected by leafy spurge, and may be affected at different rates than cattle, for the purposes of this analysis, all livestock production losses are calculated on the basis of cattle production, that is, as if all pastures[1] were used for grazing cattle.

Leafy spurge infests pasture land and reduces other plant species. As leafy spurge infestations increase, other plant species decrease. Furthermore, cattle avoid eating leafy spurge. The reduction of species suitable for cattle grazing reduces the grazing or carrying capacity of pastures. Carrying capacity is defined as the highest sustainable stocking rate that can be 'carried' in a particular pasture (Leistritz, Thompson & Leitch, 1992). Thus, the variable used is the loss of grazing capacity as measured by Animal Unit Months (AUM).

Carrying or grazing capacity of pastures for livestock grazing is measured in AUMs. The AUM measure of 1 is the amount of forage matter required to support one (1) 1,000 pound cow or cow-

[1] For the purposes of this analysis, all land categorized as pasture was considered as grazing land.

calf pair for one month. The determination of an AUM is based on constant variables such as soil textures and vegetation zones. In Manitoba, the calculations of AUMs for grazing land are produced regularly by Manitoba Agriculture, Food and Rural Initiatives. The AUMs vary from region to region and rural municipality by municipality. For example, a few pastures in some municipalities have low carrying capacity or AUM ratings (< 0.20) while other pastures in a few municipalities can support more animals per acre and have high ratings of AUMs (> 1.25 AUM). For the purposes of this study, the average AUM for each group of RMs has been used as well as the average of all municipalities.

Table 8 presents the **available or baseline acres** of pasture as presented in the *Soil and Terrain Information Bulletins for RMs in Manitoba*,[2] the average AUM / per acre, the total optimal AUMs for each group of rural municipalities and the total for the four groups. This table does not take into consideration the reduction in grazing capacity caused by infestation of leafy spurge.

Table 8: Available acres of pasture and optimal AUMs by groups of municipalities

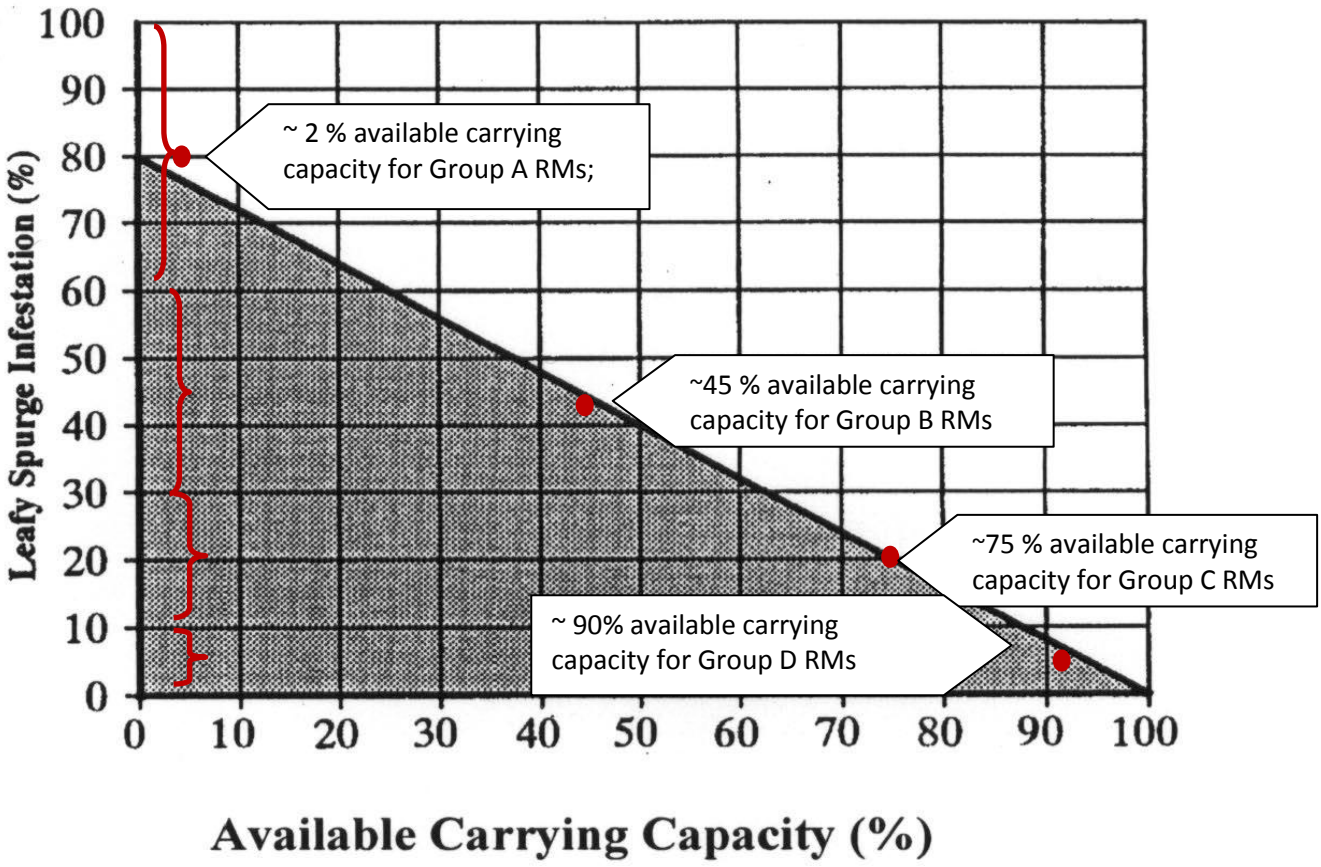
Rural municipalities	Available acres of pasture	Average AUM capacity per acre	Optimal AUMs
Group A	495329	0.45	222898
Group B	466105	0.71	330935
Group C	1671243	0.55	919184
Group D	818097	0.62	507220
Total	**3450775**	**0.58 average**	**1 980 237** [a]

a This number is the sum of the optimal AUMs. If the total available acres of pastures was used (3,450,775) and the average AUM capacity (0.58), the result would be 2,001,450 AUMs. However, for analysis purposes the sum of the optimal AUMs 1,980,237 was used.

As stated previously, as the level of leafy spurge increases, the carrying capacity of a particular pasture decreases. Figure 5 shows the impact of leafy spurge on carrying capacity of the four categories of leafy spurge density in pastures in Manitoba.

[2] These bulletins are based on LANDSAT satellite imagery and computer classification techniques. Although land use changes over time, this information is considered as a general representation of the following land use classes: annual crop land, forage, grasslands (pastures), trees, wetlands, water, and urban and transportation (towns, roads, railways and quarries). The land use class grasslands are defined as areas of native or tame grasses, which may contain scattered stands of shrubs. For the purposes of this report, grasslands are considered as pastures available for livestock grazing.

Figure 5: Spurge infestation and categories of reduced grazing capacity by groups of rural municipalities in Manitoba adapted from Leitch, Leistritz & Bangsund (1994), p. 5



Rural municipalities with a high level of density of leafy spurge (Group A) will have a carrying capacity of about 2% which is a reduction of 98%; pastures in RMs with a moderate level of infestation (Group B) will have a carrying capacity of 45% which is a reduction of 55%; pastures in Group C will have a carrying capacity of 75% which is reduction of 25%; and Group D will have a carrying capacity of about 90% with a reduction of 10%.

Table 9 shows AUMs for the groups of municipalities based on levels of infestation of leafy spurge.

Table 9: Available acres of pasture and reduced AUMs by groups of municipalities

Rural municipalities	Optimal AUMs	Carrying capacity based on infestation level of spurge	Available AUMs based on infestation level of leafy spurge	Loss of AUMS caused by leafy spurge infestation
Group A	222,898	2%	4458	218,440
Group B	330,935	45%	148,921	182,014
Group C	919,184	75%	689,388	229,796
Group D	507,220	90%	456,498	550,722
Total	1,980,237	__	1,299,265	680,972

When the optimal carrying capacity (as measured by AUMs) was adjusted based on the percent of the infestation level of leafy spurge, an estimate of the reduction or loss of AUMs was calculated. As shown above this loss was 680,972 AUMs.

4.3.2 The value of lost AUMs

As stated previously Animal Unit Months (AUMs) are used to determine how many animals (in this case, cattle) can be supported by an acre of pasture. AUMs are also used to determine the value of the pasture land. This information is helpful to determine land rental and to help producers calculate the production of their livestock operations.

AUMs are given a value based on supply and demand of pastures, the quality of the pasture, fencing and water availability and quality. In 2009, these rates for Manitoba ranged from a low of $12 per AUM for community (public) pasture rent (Agriculture Environmental Services AES Branch / PFRA) to $22 per AUM for private pasture rent. That said, it is generally recognized that AES Branch community pasture rental rates are low compared to open market rates for private land. For the purposes of this economic analysis, a reasonable AUM value was determined to be $15 per animal per month.

Table 10 presents the findings of the economic loss that can be attributed to leafy spurge and its effect on reducing the available grazing capacity (that is, forage) of pastures.

Table 10: Economic impact of leafy spurge based on the value of lost AUMs (monthly)

Rural municipalities	Loss of AUMS caused by leafy spurge infestation	$ Loss per Animal Unit Month ($15 per month)
Group A	218,440	3,276,600
Group B	182,014	2,730,210
Group C	229,796	3,446,940
Group D	550,722	760,830
Total	680,972	$10,214,580

In summary, the direct economic impact of leafy spurge as determined by the loss of grazing capacity for cattle based on the value of an AUM is **$10,214,580.** It is important to note that the above analysis is consistent with the methodology in existing literature (Leistritz, Thompson & Leitch, 2002) and the *Leafy Spurge Impact Assessment* (LSSG, 1999).

4.3.3 Economic analysis of costs to control leafy spurge on roadsides

Roadsides, rail lines and utility corridors are also affected by infestations of leafy spurge. While the *Soil and Terrain Information Bulletins for RMs in Manitoba* gave an accurate accounting of these acreages, they were presented as an aggregate. That said, a reasonable assumption would be that at least 40% of acreage would be roadsides and that these roadsides would have a minimum acreage of leafy spurge. Table 11 provides control costs for roadsides, rail lines and utility corridors.

At the time of this report, information from the Manitoba Weed Supervisors Association indicated that the cost to control leafy spurge on roadsides was estimated at $176 per acre for herbicide[3] excluding fuel, equipment and labour costs. There was no information on the costs that rail lines incur to control leafy spurge.

While it is known that many weed districts spend considerable resources and efforts to control leafy spurge, it was not possible to determine the precise extent of control. For example, some municipalities have greater infestations, more rail lines and utility corridors such as gravel pits.

For this analysis, *38% of the minimum acreage* of leafy spurge was determined to be a reasonable amount of infestation in each of the groups of rural municipalities. This percentage is derived from the gross acres of all hay / forage land, pastures, roadsides, rail lines and utility corridors in agro-Manitoba and the amount of acres of these areas that have leafy spurge infestations.

[3] Picloram is the chemical compound contained in a few herbicide products used to control a wide range of broad- leaved weeds. Most grasses are resistant to picloram making this compound one of the few can be used to effectively control leafy spurge in pasture or road side conditions.

Table 11: Acres of roadsides, rail lines and utility corridors (40%) at minimum acres of leafy spurge by groups of rural municipalities

Rural municipalities	Acres of roadsides, rail lines and utility corridors	(38%) at minimum acres of leafy spurge)	Costs @ $176/acre
Group A	22,435	8537	$1,502,512
Group B	30,842	11,720	$2,062,720
Group C	24,866	9450	$1 663 200
Group D	9830	3736	$657,536
Total	**87,973**	**33,443**	**$5,885,968**

4.3.4 Total direct costs

Total direct costs include loss of grazing capacity for cattle at a value of $10,214,580 plus control costs for roadsides calculated at $5,885,968. The total direct costs are **$16,100,548.**

4.4 Indirect economic costs

In addition to these direct impacts of leafy spurge there are ***indirect or secondary economic costs***. The value of indirect costs for this assessment is just over $18 million.

Indirect costs or impacts result from expenditures not made in other sectors of the economy as a consequence of reduced output in those sectors whose direct impacts are measured. Statistics Canada produces input-output tables, by sector, which shows the economic linkages across sectors of the economy. From these, a multiplier is determined which measures the indirect value accruing elsewhere in the economy for each dollar of output in a given sector. For this analysis, indirect effects are reported only for the direct impacts in the cattle production sector (using the category 'Animal Production' -- except Animal Aquaculture -- in the Statistics Canada input-output tables), as there are no suitable multipliers for grazing land rental value, or weed treatment, because these sectors or not identified in sufficient detail. Statistics Canada reports the multipliers by province, and the most recent table currently available is 2005. Therefore this analysis is based on the multiplier for Animal Production in Manitoba in 2005, a value of 2.36. In other words, for each dollar of output in the Animal Production sector, an additional $2.36 of value is added in other sectors of the economy (for example, transportation or meat packing).

In the case of leafy spurge, these are largely the inputs and outputs of business activities associated with beef cattle production. These inputs and outputs are combined into a number or *multiplier*, which is determined by the indirect economic value accruing elsewhere in the economy. The unit of measure is based on a multiplier for each dollar of output in a given sector.

Multipliers are used to estimate the positive effects of an economic activity that extend into secondary economic activities. They are also used to estimate the loss of secondary economic activities. In the case of leafy spurge, the indirect economic costs portray the loss of other economic activities.

There is, however, no specific multiplier that is attributed for livestock grazing in Manitoba or Canada. Therefore, the multiplier effect determined by Statistics Canada for the Animal Production sector of Manitoba was used. This multiplier has a value of 2.36 but this is likely too

high. A more reasonable or conservative multiplier may be 1.8 which has been used to determine the indirect economic activities for livestock grazing in Nevada (Alevy, Fadali & Harris, 2007). Calculations using both multipliers are presented in Table 12.

Table 12: Indirect economic costs of leafy spurge by group of municipalities, using Statistics Canada multiplier and Nevada grazing land multiplier

Rural municipalities	$ Loss per Animal Unit Month ($15 per month)	Statistics Canada (2005) multiplier of 2.36 [a]	Nevada livestock grazing land multiplier (Alevy, Fadali & Harris, 2007) of 1.8
Group A	3,276,600	7,732,776	5,897,880
Group B	2,730,210	6,443,296	4,914,378
Group C	3 446 940	8,134,778	6,204,492
Group D	760,830	1,795,559	1,369,494
Total	**$10,214,580**	**$ 24,106,409**	**$18,386, 244**

a The outcomes based on the multiplier effect from Statistics Canada was used to determine the economic impact of leafy spurge in Manitoba.

4.5 The economic impact of leafy spurge: Direct and indirect costs

As shown in Table 13, the economic impact of leafy spurge totals **$40,206,957**. This total is composed of direct costs of **$16, 100, 548** and indirect costs of **$24,106,409** and is based on available information of the distribution, density and land use affected by leafy spurge.

Table 13: Economic Impact of Leafy Spurge, Total of Direct and Indirect Costs

	Direct Costs		Indirect Costs	
Rural municipalities	**$ Loss per Animal Unit Month ($15 per month)**	**Costs of control on roadsides**	**Statistics Canada (2005) multiplier of 2.36**	**Total**
Group A	3,276,600	$1,502,512	7,732,776	$12, 511,888
Group B	2,730,210	$2,062,720	6,443,296	$11,236,226
Group C	3,446,940	$1,663,200	8,134,778	$13,244,918
Group D	760,830	$657,536	1,795,559	$3,213,925
Total	**$ 10,214,580**	**$ 5,885,968**	**$ 24,106,409**	**$ 40,206,957**
Total Costs		**$ 16,100,548**	**$24,106,409**	**$ 40,206,957**

4.6 Conclusion

Evans (2003) stated that, "the true value of economics should therefore not be seen solely in the precision of the numbers generated, albeit this is important, but the extent to which the discipline aids decision makers to formulate consistent and rational decisions" (p.5). This economic impact assessment of leafy spurge presented the total economic impact composed of direct and indirect costs at over $40 million. Nearly all of this impact is due to the loss of grazing capacity (measured by AUMs) caused by infestations of leafy spurge.

This analysis was based on a biophysical or market price analysis methodology. The quantity of leafy spurge and the market prices attached to various economic variables are based upon the best estimates at a particular point in time, given existing knowledge, available data and current conditions. This included the following:

a) reasonable quantitative estimates of the quantity (distribution) and density of leafy spurge; and,

b) 2009 prices for the value of an Animal Unit Month which represents the unit of measurement of grazing capacity.

According to Emerton and Howard (2008) the economic valuation of an invasive species is imprecise and usually involves a high level of speculation. Even so, there is little doubt that leafy spurge poses a serious economic threat to livestock production in Manitoba. Based on that conclusion, three major recommendations emerge.

Alternative economic impact analysis models

To date, many of the efforts aimed at determining the economic impact assessment of leafy spurge is based on the biophysical economic model (Bangsund & Leistritz, 1991; Julia, Holland & Guenthner, 2007). For example, the *Leafy Spurge Impact Assessment* (LSSG, 1999) was also based on a biophysical economic model.

One of the most notable observations from the review of the literature was that most of the scholarly efforts behind economic assessment models for leafy spurge took place during the 1980s and into the mid-1990s. Since that time, the literature does not add significantly to the model developed in the 1990s.

The review of the literature also revealed the shift that many public policies as well as research and awareness efforts have made towards (1) the economic welfare of broader society; (2) identifiable measures of the various types of impacts in economic terms; and (3) the negative impacts of the invasive species or their probability of occurrence and the extent to which they can either be avoided or reduced. Some of the economic variables include market and trade impacts, land development, food security, environmental mitigation costs and financial costs (Evans, 2003). For example, the current federal policy framework, *An Invasive Alien Strategy for Canada* (2004) refers to a number of economic causes and costs which are also found in the programs, policies, funding and research efforts aimed at invasive alien species that pose biosecurity threats.

With specific reference to leafy spurge in Manitoba there are a number of economic causes and costs that have not been explored. These include private control costs (residential yards and gardens in acreages, golf courses), costs to treat cropland (forage and other crops, either

chemical or biological controls), the cost of education programs, recreational and wild-life related tourism losses on public lands, the 'value' of loss of wildlife habitat (especially as it impacts species at risk), the watershed and soil conservation impacts, potential trade implications (especially if 'weed-free' standards are implemented on exported forage/feed products), and the costs associated with treatment of leafy spurge in gravel pits or utility corridors.

Recommendation:

> That the Leafy Spurge Stakeholders Group, the Invasive Species Council of Manitoba and other interested agencies begin efforts to develop and coordinate a data base of economic indicators that can be used to describe and use other relevant economic variables. In addition, a chronology of the spread of this species would be very helpful in understanding its invasiveness.

Policy and program review of efforts to control leafy spurge in Manitoba

Economic impact assessments are necessary to make informed decisions about the control and management of invasive species. Economics is central not only to the cause as well as the impact of invasive species invasions. As stated by Evans (2003), nearly all of the invasions of alien species can be linked directly or indirectly to economic activities. For example, with specific reference to leafy spurge in Manitoba, a perennial and widespread cause of the spread of leafy spurge is through the sale and movement of gravel infested with leafy spurge. At the same time, this gravel is a valuable economic commodity. Thus, economic arguments are needed to provide more accurate and comprehensive assessment of the benefits and costs of control and management alternatives.

Economic impact assessments also have a function in international trade and the binding international agreements between countries to prevent the entry of invasive species. These agreements are within the rights of the importing country and are often justified based on economic and social arguments. In the case of leafy spurge in Manitoba, the factor of international trade is relevant to the sale and export of (a) Manitoba hay and (b) forage seed.

It is therefore critical to understand the economic dimensions of invasive species; however, these dimensions are complex and based largely on human behavior. As Julia, Holland and Guenthner (2006) stated:

> Assessments should recognize the interdisciplinary nature of the problem of species invasions: while ecosystem characteristics determine whether the appropriate conditions allow for the establishment of the invasive species, economic systems affect the state of the ecosystem through its use, and through the prevention and control measures implemented to stop the invasions, Thus, accounting for the economic and ecological links and feedbacks is critical to invasion assessments. (p.876)

The extent of leafy spurge infestation in Manitoba and the resources needed to eradicate, control of managing leafy spurge in Manitoba reflect both the challenge and the influence of economics. In spite of these difficulties, there is no doubt that leafy spurge seriously threatens what remains of our native prairie pastures. Nevertheless, it is obvious that any solutions or suggestions to policy changes (including legislative changes such as The Noxious Weed Act) must be firmly grounded in both science and economics that include variables that reflect current economic, social and environmental values.

Recommendation:

That a review of all relevant programs and policies be carried out to assess the effectiveness of these efforts and identify public priorities. This review would help guide the efforts of groups such as the Leafy Spurge Stakeholders Group, the Invasive Species council of Manitoba as well as various government departments in setting its priorities. The extent of research activities should also be assessed.

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Appendix A: Distribution and Density of Leafy Spurge in Manitoba

Table 14: Median acres of leafy spurge by land use type in Group A rural municipalities with a high level of spurge density (61-100%)

Rural municipality	Acres (median of range) of leafy spurge by land use type			Total acres of spurge by rural municipality
	Acres of spurge in pastures	Acres of spurge in hay / forage land	Acres of spurge in road sides, rail lines and utility corridors	
Cornwallis	40095	5868	8892	54855
Elton	13809	2930	4245	20984
North Norfolk	87403	18428	6010	111841
Pipestone	48993	8438	7320	64751
Sifton	90220	8673	4716	103609
South Cypress	92812	4215	5259	102286
Whitehead	25400	4826	4314	34540
Total	**398732**	**53378**	**40756**	**492866**

Table 15: Median acres of leafy spurge by land use type and rural municipalities in Group B rural municipalities with a moderate level of spurge density (31-60%)

Rural municipality	Acres (median of range) of leafy spurge by land use type			Total acres of spurge by rural municipality
	Acres of spurge in pastures	Acres of spurge in hay / forage land	Acres of spurge in road sides, rail lines and utility corridors	
Cameron	24429	2569	2376	29374
Clanwilliam	14555	82	1102	15739
Daly	15752	1899	2278	19929
Dufferin	9754	2260	4558	16572
Franklin	23490	5939	3735	33164
Lorne	13171	4068	3780	21019
Oakland	9871	2229	2096	14196
Rhineland	4327	628	5150	10105
Riverside	8685	1590	3773	14048
Saskatchewan	12490	2183	1871	16544
South Norfolk	11132	3086	2828	17046
Stanley	9365	1398	5371	16134
Thompson	5706	984	1947	8637
Victoria	16913	2531	1760	21204
Woodworth	32432	4987	2643	40062
Total	**212072**	**36433**	**45268**	**293773**

Table 16: Median acres of leafy spurge by land use type and rural municipalities in Group C rural municipalities with a low level of spurge density (11-30%)

Rural municipality	Acres (median of range) of leafy spurge by land use type			Total acres of spurge by rural municipality
	Acres of spurge in pastures	Acres of spurge in hay / forage land	Acres of spurge in road sides, rail lines and utility corridors	
Archie	9938	495	670	11103
Argyle	6756	1836	1136	9728
Armstrong	35206	948	1796	37950
Arthur	8578	520	1120	10218
Birtle	10208	1190	1144	12542
Brenda	4992	478	1251	6721
De Salaberry	3779	1802	1141	6722
Gimli	5589	277	835	6701
Glenella	10230	530	767	11527
Glenwood	6119	1335	1043	8497
Grey	7033	3155	1981	12169
Harrison	5705	2904	793	9402
Headingley	578	112	330	1020
Lakeview	16579	598	593	17770
Langford	8511	179	932	9622
MacDonald	1883	1057	2438	5378
Miniota	13294	1381	1182	15857
Morton	10407	1796	1428	13631
North Cypress	13454	1694	1831	16979
Ochre River	9292	321	746	10359
Total	**188131**	**22608**	**23157**	**233896**

Table 16 (continued): Median acres of leafy spurge by land use type and rural municipalities in Group C rural municipalities with a low level of spurge density (11-30%)

Rural municipality	Acres (median of range) of leafy spurge by land use type			Total acres of spurge by rural municipality
	Acres of spurge in pastures	Acres of spurge in hay / forage land	Acres of spurge in road sides, rail lines and utility corridors	
Odanah	3520	13	619	4152
Pembina	6089	1134	1655	8878
Roblin	6107	863	917	7887
Rockwood	12581	2849	2276	17706
Roland	988	61	961	2010
Rosedale	11872	626	1181	13679
Rossburn	11176	2601	1087	14864
Russell	8643	1097	892	10632
Shellmouth	9632	645	754	11031
Ste. Anne	4590	1394	882	6866
Ste. Rose	10469	1549	926	12944
Strathclair	5810	766	941	7517
Strathcona	5664	1146	690	7500
Tache	4296	1360	643	6299
Turtle Mountain	7726	1491	2899	12116
Wallace	17523	1242	1925	20690
Westbourne	17957	1154	1921	21032
Whitewater	3330	509	924	4763
Winchester	6495	919	1090	8504
Total	**154468**	**21419**	**23183**	**199070**

Table 17: Median acres of leafy spurge by land use type and rural municipalities in Group D rural municipalities with a trace level of spurge density (0-10%)

Rural municipality	Acres (median of range) of leafy spurge by land use type			Total acres of spurge by rural municipality
	Acres of spurge in pastures	Acres of spurge in hay / forage land	Acres of spurge in road sides, rail lines and utility corridors	
Blanshard	819	108	209	1136
Cartier	280	94	278	652
Coldwell	4583	303	221	5107
East St. Paul	207	8	99	314
Edward	2809	262	255	3326
Ellice	3045	157	126	3328
Grahamdale	9569	530	519	10618
Hamiota	785	114	218	1117
Lac du Bonnet	0	162	294	456
Lansdowne	3972	218	257	4447
McCreary	2701	137	205	3043
Minto	1019	29	187	1235
Morris	496	72	541	1109
Park (north)	1173	116	68	1357
Piney	2153	406	390	2949
Reynolds	1073	0	532	1605
Ritchot	360	146	139	645
Shoal Lake	2036	83	213	2332
Silver Creek	1545	199	188	1932
St. Clements	1834	128	343	2305
Whitemouth	444	294	146	884
Total	**40903**	**3566**	**5428**	**49897**

Table 18: Rural municipalities in Group D rural municipalities with a trace level of spurge on road sides, rail lines and utility corridors only

Rural municipality	Acres of spurge on road sides, rail lines and utility corridors
Albert	258
Brokenhead	344
Ethelbert	246
Hanover	489
La Broquerie	183
Louise	346
Montcalm	230
Portage La Prairie	1026
Springfield	536
St. Andrews	524
St. Francois Xavier	58
West St. Paul	53
Total	**4293**

Appendix B: Options for Economic Assessment Models of Leafy Spurge

Table 19: Overview of selected economic assessment models applicable to leafy spurge in Manitoba

Model	Overview	Data collection and analysis	Strengths, weaknesses and applicability to leafy spurge in Manitoba
Biophysical or market price economic model	Commonly used method based on the direct and indirect costs of the good or service affected by the invasive species	Determine of the quantity the good affected (e.g., acres of spurge and loss of grazing capacity AUMs of cattle) Determine the market price of product Multiply price by quantity for direct costs; use multiplier factor for indirect costs	Relatively easy to use and simple statistical analysis Relies on actual market information which both a strength and a challenge due to market fluctuations Examples: The 1999 and 2010 economic impact assessments of leafy spurge
Production function model	Used when a good or service does not have a market price however they have the ability to affect other products	Determine the extent of ecosystem good or service to the other product Specify the relationship (input) and relate relationship to a physical change in the output Estimate the market value of the change in production	Commonly used and has a wide range of application Difficult to collect sufficient data or accurately predict relationship Product market fluctuations and influences can be a concern Examples: impact of leafy spurge on livestock

Model	Overview	Data collection and analysis	Strengths, weaknesses and applicability to leafy spurge in Manitoba
Biosecurity model	Based on the economic welfare of broader society. Budgetary considerations are part of the biosecurity model (Evans, 2003) Emphasis on preventing the introduction of new species (Heikkila, 2010)	Determine the extent of the potential damage by looking at other jurisdictions Identify economic measures by their probability of occurrence and extent to which they can either be avoided or reduced Variables include: consumer impacts, security and inspection costs, trade impacts and food security	Some of the economic variables of the bioeconomic model include market and trade impacts, food security, environmental mitigation costs and financial costs (Evans, 2003) Difficult to identify and isolate variables and collect sufficient data Examples: Policy framework for *An Invasive Alien Strategy for Canada* (2004) Early detection and rapid response efforts for new introductions of leafy spurge
Recreational or travel cost model	Applied to ecosystems that have a recreational value	Determine the total area and frequency of use of the area Estimate costs and benefits of travel of recreation Carry out a statistical regression Construct a demand curve relating to number of visits	Limited to calculating recreational values. Reliance on complex analytical techniques Several factors must be taken into account in order to avoid over-estimating impact Example: impact of leafy spurge on recreational use is difficult to determine.

Model	Overview	Data collection and analysis	Strengths, weaknesses and applicability to leafy spurge in Manitoba
Hedonic pricing model	The presence or absence of a species and its impact on what people will pay for a particular good or service affected by the invasive species	Decide on the indicator to be used i.e. the particular job or property Specific the relationship between wages and the property prices Collect data on the wages or property prices Use a multiple regression analysis to obtain a correlation between wages or property prices and the invasive species Derive a demand curve	Hedonic pricing model can be applied to a broad range of contexts Requires the collection of a large amount of data and detailed and complex analysis Very few examples exist due to the very large data sets needed to cover all aspects of the principal features affecting prices Example: impact of leafy spurge on land values and potential for reduced tax revenue to municipalities

Appendix C: Potential Impact of Leafy Spurge on Beef Herds and Sheep Flocks in Manitoba ~ An illustration

The potential impacts of leafy spurge on beef herds and sheep flocks present an interesting contradiction. Specifically, leafy spurge infestations bring about a grazing capacity for beef herds and by association, a reduction in the number of beef cattle. Sheep and goats however, are livestock species that can graze and take advantage of leafy spurge as a source of forage.

Animal Unit Equivalents (AUEs) can be used to illustrate this contradiction. In contrast to AUMs which are used to standard grazing capacity, Animal Unit Equivalents (AUEs) are used as a measurement of an animal unit based on the standard unit of a 1,000 lb. cow. This standard unit is given a value of 1 AUE (Manitoba Agriculture, Food and Rural Initiatives, nd). Each type of livestock is given a different AUE based on the standard unit of a 1,000 lb. cow. For example a sheep is given an AUE of 0.20 and a horse is assigned an AUE of 1.2.

AUEs are used in conjunction with AUMs to determine the stocking rate of pastures. For the illustrative purposes of this analysis, the standard measure of 1 AUE (that is, a 1,000 lb. cow) has been used to calculate the potential reduction in the beef cattle herd caused by the lost AUMs due to leafy spurge. The AUE of sheep (.20) is used to show how many sheep in Manitoba that could be raised to help control spurge in the province.

Based on the loss of 680,972 AUMs, which is the reduction of the available forage, Manitoba's **beef cattle herd is decreased by 136, 194** cows. Since sheep will eat leafy spurge, the reduction of suitable forage for cattle is good news for sheep production. More than **680,000 sheep could utilize leafy spurge for forage.**

Table 20: Number of head of livestock affected by leafy spurge

AUMs lost due to leafy spurge	Length of grazing season	AUE	Number of head of livestock [a]
680972	5 months	1.0 AUE (1,000 lb.cow)	Manitoba beef herd is decreased by 136194 cows [b]
680972	5 months	.20 AUE (1 sheep)	680, 870 sheep could utilize leafy spurge for forage [c]

a AUMs divided by the number of months of the grazing season (5) and divided again by the AUE.

b In January 2010, the beef cattle herd in Manitoba was estimated at 558,000 head (Honey, 2010). Eradication of leafy spurge could expand the Manitoba beef cattle herd by nearly 20%.

c Statistics Canada (2010) reported that the Manitoba sheep flock was ~ 71,000 head.