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Implications of Native Prairie Conversion in the RM of Monet

By:

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RRM 421: Group Project in Renewable Resource Management

Executive Summary

Historically, the amount of native prairie in Saskatchewan has been decreasing at an alarming rate. To better understand how much of this invaluable habitat has been lost, the Native Plant Society of Saskatchewan performed a survey in 2001. Using a series of air photos they discovered that only 21% of original native prairie had been conserved (Hammermeister et al., 2001). To determine if this decreasing trend has continued over the course of the past 13 years, the Prairie Conservation Action Plan (PCAP) has collaborated with the University of Saskatchewan's fourth year Renewable Resource Management students. The focus of our project is to explore the area of native prairie in the Rural Municipality (RM) of Monet, how it has changed, and how these changes influence the native plant and animal communities as well as soil quality.

To perform this project a number of methods were used, including Geographic Information Systems (GIS), air photo analysis, research, and regular contact with industry professionals. With this information, in terms of native prairie, we were able to determine that the major sources of change in the RM of Monet came from agricultural, and oil and gas activity. Due to the intrusive nature of oil and gas activity in the RM of Monet, we have chosen to concentrate on the implication that this activity has on wildlife, plants and soil quality, while still including impacts from agriculture in our scope.

Our results determined that the amount of native prairie remaining in the RM of Monet decreased from 27% to 26% (1418 ha) between 2001 and 2014. We discovered that the Ferringuous hawk (*Buteo regalis*), Sprague's pipit (*Anthus spragueii),* and Burrowing owl (*Anthene cumicularia*) will all be negatively impacted by land conversion and the associated habitat fragmentation, this is of special concern because they are all federally listed as SARA (Species at Risk Act) animals. Further research also revealed that the SARA-listed Low milk vetch (*Astragalus lotiflorus*), Rocky mountain pincushion plant (*Navarretia saximontana*), and Rough penny royal plant (*Hedeoma hispida*) species are also negatively impacted as a result of increased invasive species, and loss of biodiversity associated with crop developments. In terms of soils we found that with further agricultural development, we will see an increase in wind

and water erosion and require extensive additional soil conservation practices to limit these forces. Soils were also heavily influenced by the increase of oil and development, as they experienced increased levels of compaction, hydrocarbon and brine pollution.

Overall, both agriculture and oil and gas development have influenced the native prairie grassland in the RM of Monet. A large portion of the remaining grassland is a part of the former Prairie Farm Rehabilitation Act (PFRA), which is being dismantled because the program's goals have been completed. The future of this land and the rest of the remaining grassland will be affected by tax and royalty rates and public policy surrounding PFRA land. We recognize that economic decisions surrounding native prairie grassland do not incorporate the ecosystem goods and services that provide public benefits, so the amount of lost native prairie likely reflects an inefficient relationship between conservation and development.

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Background

Introduction

Native prairie is an incredibly important part of Saskatchewan's landscape, as it provides habitat for a vast variety of flora and fauna and provides protection for a valuable soil resource. However, this habitat is now in direct competition with several industries, including agriculture, and oil and gas development. The consequences of this development has resulted in the loss of huge quantities of native prairie, which has in turn impacted the local plant and animal communities along with the region's soil quality.

According to an inventory taken of native prairie in Saskatchewan, by the Native Plant Society of Saskatchewan in 2001, less than 21% of Saskatchewan's native prairie remains (Hammermeister et al., 2001). The conservation of this habitat is often left in the hands of the landowners, as the majority is privately owned (Skeel et al., 2001). This native prairie is at risk, as economically it may be more feasible for many landowners to convert this habitat to farm land. However, through efforts including the Prairie Farm Rehabilitation Act (PFRA) program some areas of native prairie have been conserved by government.

To better understand the changes that are occurring in Saskatchewan's native prairies, the Prairie Conservation Action Plan (PCAP) and the University of Saskatchewan have requested that we perform a preliminary assessment. As a group of fourth year Renewable Resource Management (RRM) students we have all received training that qualifies us to do this, however due to time and resource limitations, the scope of the project has been limited to assessing the native prairie in the Rural Municipality (RM) of Monet #257 (Figure 1).

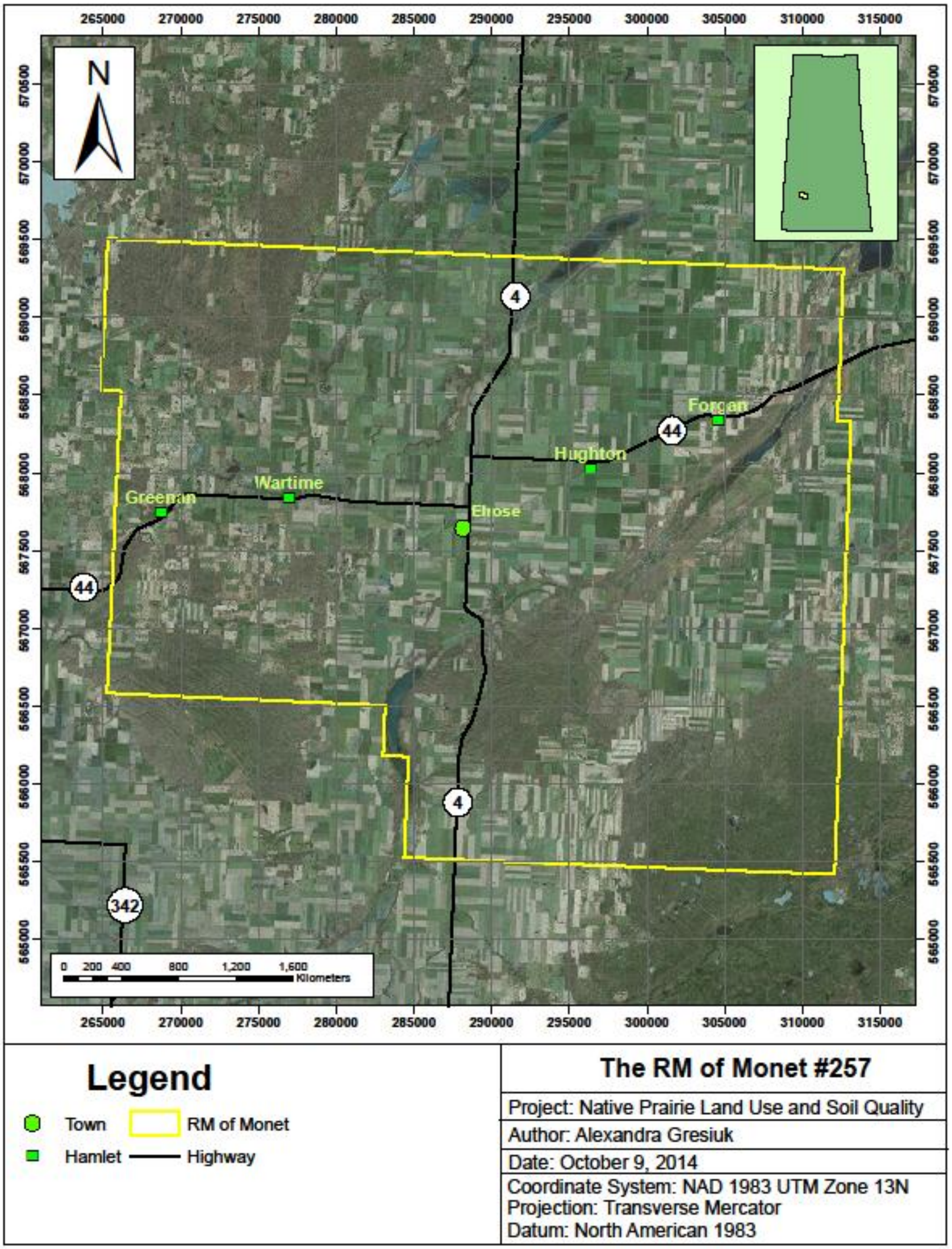


Figure 1: The location of the RM of Monet.

This assessment has consisted of reviewing the remaining native prairie in the region, identifying the forces changing the area, determining how these changes impact native plant and animal communities, as well as soil quality, and predicting how these trends will change in the future.

Pressure from agriculture, oil and gas development has resulted in the natural grasslands being one of the most modified landscapes in Canada (Nasen, 2009). The RM of Monet is not immune to these forces and as a result it will provide the basis for our research. By identifying the changes in native prairie in this area it is our hope to provide a framework for a broader exploration of land use change across the prairies utilizing Geographic Information Systems (GIS) application.

Brief History & The Prairie Farm Rehabilitation Act (PFRA)

The RM of Monet was organized in 1909 during a thriving time as several large ranching operators grazed cattle on the grasslands, and just before the railway was built in 1913 that contributed to an increasing population and profitable agriculture production (Town of Elrose & RM of Monet #257, 2013). Agriculture thrived until the Dirty Thirties arrived with a severe drought. Coupled with poor farming practices, the Dirty Thirties drove settlers away and led to the failure of farms (Rick Ashton, personal communication). Farmers needed to summer fallow in order to produce crops but the wind would erode the soil during the summer making production low (Gray, 1978). Eventually, farmers wanted to leave because agriculture was no longer profitable.

In response to this economic and environmental disaster, the Government of Canada and the Government of Saskatchewan (along with Alberta and Manitoba) collaborated to form the Prairie Farm Rehabilitation Act of 1935 (Phillips, 2015). The PFRA was created to address soil erosion and water development by acquiring and purchasing large tracts of land (Rick Ashton, personal communication).

In the RM of Monet, two pastures were formed: the Fairview and Monet pastures. The Monet community pasture is located in the southeast portion of the RM of Monet in two blocks, while the community pasture of Fairview was in the northwest corner (Figure 7). All lands that were and are a part of the PFRA were chosen because they were abandoned, purchased from owners wishing to sell and/or from settlers wishing to relocate out of the drought zone (Rick Ashton, personal communication). For example, the Fairview community pasture was created from prairie and reseeded homestead land unfit for farming in 1955 (Elrose and District History Book Committee, 1985). The RM of Monet was amalgamated with the RM of Fairview in 1966 (Elrose and District History Book Committee, 1985).

Under the PFRA program patrons pay rates for summer grazing on the pastures and the pasture manager is responsible for regulating the amount of cattle and providing bulls (Elrose and District History Book Committee, 1985).

As of 2012, the PFRA program was deemed completed because the lands have been converted from poor-quality cultivated lands to grass cover (AAFC, 2014). Over a five-year period, the lands will be phased out of federal government involvement in management (Phillips, 2015). The provincial government that the lands reside in will own the sections after the transfer (AAFC, 2014). As of 2013, the Fairview pasture in the RM of Monet has been transferred to the province of Saskatchewan and the Monet pasture will be transferred to Saskatchewan by April 2016 (Rick Ashton, personal communication).

Environmental Characteristics

Geography

The majority of southern Saskatchewan is characterized by rolling hills that mark what is referred to as a hummocky landscape. Similar features can be seen stretching from mid-Alberta, down through to northern Iowa, in what is known as the Prairie Pothole Region (PPR) (Fraser and Keddy, 2005). The origins of this unique area began with the end of the Wisconsin Glaciation approximately 11,000 years ago (Fraser and Keddy, 2005). During this period the majority of southern Saskatchewan was covered by the Laurentide Ice Sheet and as it retreated, the distinctive “potholes” developed as a result of the uneven settling of till in ground moraines (Fraser and Keddy, 2005).

The RM of Monet is located in southwestern Saskatchewan, approximately 335 km northwest of Regina. As of 2011 this region was home to 495 people (Town of Elrose & RM of Monet #257,

2013) with the majority of the population residing in the town of Elrose. The RM was originally established in 1909, however it was not until the 1960s, when it joined with the RM of Fairview, that it reached its current boundaries. Since 1909, the economics of this region has been based heavily in agricultural activities.

Climate

The RM of Monet is situated within a region known as Palliser's Triangle (Figure 2) as well as both the Mixed and Moist Mixed Grassland Ecoregions (Figure 3). The climate in these areas is best defined as a semi-arid steppe, as they see fairly low levels of precipitation, hot summers and cold winters (Canadian Geographic, 2014). A variety of conditions lead to the development of these characteristics, however the driving force is the rain shadow cast by the Rocky Mountains. The result is a dry region on the east side of the mountains with an annual water deficit of 524 mm (Dale-Burnett, 2006).

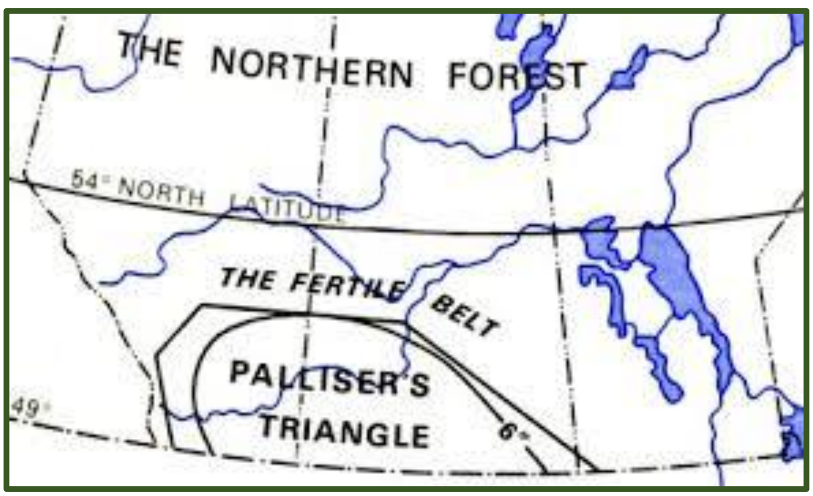


Figure 2: A map depicting the range of Palliser's Triangle in Canada. Sourced from: http://members.kos.net/sdgagnon/vaa.html

Like most of Saskatchewan, Palliser's Triangle experiences cold winters and warm summers. These extremes are caused by the movement of the continental arctic air mass, which originates in the sub-polar regions of Canada and is known to be very cold and very dry (Heidorn, 2005). During the winter months it will descend into the southern region of Saskatchewan and generate the extreme temperatures that mark this season. Come summer, the mass retreats and is replaced by warm summer temperatures (Douglas & McIntyre, 2004).

The RM of Monet reflects the norms of the climate found in Palliser's Triangle. On an annual basis it will receive only 382 mm of precipitation (Government of Canada, 2014a), with January temperatures averaging -12.3°C, and July averaging 19.5°C (Government of Canada, 2014a).

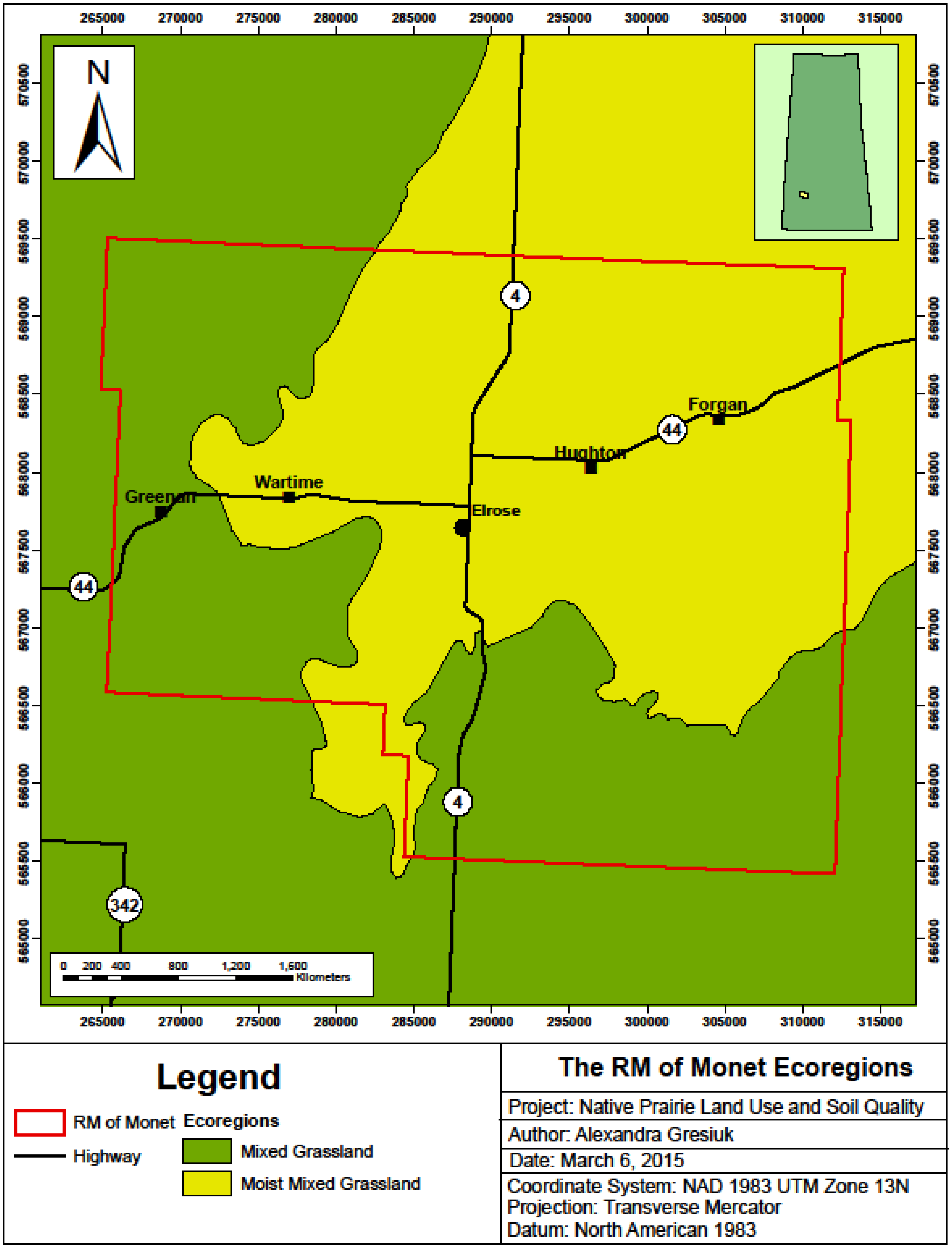


Figure 3: Ecoregions in the RM of Monet.

Soils of the RM of Monet

Within the RM of Monet there are over 457 individual soil map units in the soil survey conducted for the region in 1993 (Saskatchewan Soil Survey Staff). In order to keep the soil narrative concise and relevant this report groups map units by soil association. Map units that are purely one association or are dominated by that same association have been grouped as a single entity (ex. Ra soils) and their characteristics summarized. These "dominant" soils exist in soil complexes such as RaHr, where the first association is the main one present while the second association is present at specific slope positions or is intermixed (Saskatchewan Soil Survey Staff, 1993). After grouping map units by soil association there still remains over 25 soil associations present in the RM of Monet. This report focuses on 6 associations chosen due to either their significance in the entire RM, areas of native prairie or areas of native prairie loss. These 6 associations account for a large majority of the 3 aforementioned areas (Table 1; Table 2; Table 3). In terms of the native prairie in the RM of Monet, roughly 64% is within either the Fairview or the Monet pasture; both of which were a part of the PFRA program. The Fairview pasture contained 17% of the native prairie and the Monet pasture contained roughly 47% (Figure 4; Figure 5; Government of Canada, 2013a).

The Ardill (Ad) soil association, on its own, does not have a significant presence in the RM of Monet but as the dominant soil in a complex does (Table 1). It accounts for less than 1% of the landscape but it is the dominant association in complexes for over 8% (Government of Canada, 2013b). Ad soils also underlay 10.5% of the native prairie within the RM. All the Ad soils in the RM are Orthic Brown Chernozems (Government of Canada, 2013b). Chernozems have an upper layer (A horizon) that is at least 10cm thick, containing 1-17% organic carbon. Chernozems of the Orthic Brown exist in the Brown Soil Zone and have a middle layer (B Horizon) that is thicker than 5 cm that contains no alkaline earth carbonates. The Orthic Brown designation indicates a lack of further distinctive features (Soil Classification Working Group, 1998).

Table 1: Summary of soil characteristics for the most significant associations found within the RM of Monet (Government of Canada, 2013a; Government of Canada, 2013b; Figure 4). Class descriptions are abridged from tables in the soil survey for the area (Saskatchewan Soil Survey Staff, 1993).

Soil Association	Total	Pure	Majority of Complex	Parent Material	Dominant Texture	Dominant Soil Type	Dominant Capability for Agriculture	Limitations to Agriculture	Slope Gradient	Wind Erosion Potential	Water Erosion Potential
	%	%	%				class		%	class	class
Ardill (Ad)	8.7	0.3	8.4	Glacial Till	Clay Loam	Orthic Brown Chernozem	5	T, W, S	5-15	3	2
Fox Valley (Fx)	4	1	3	Lacustrine	Silty-Clay Loam	Orthic Brown Chernozem	3, 5	T, W, S	2-10	2-3	2
Haverhill (Hr)	21.2	12.9	8.3	Glacial Till	Loam	Orthic Brown Chernozem	5	T, W, S	10-15	3	2-3
Hillwash (Hw)	2.4	2.4	-	Undifferenti-ated Mineral	Undiffere-ntiated	Regosol	6	T, W, P, S	10-30	N/A	N/A
Regina (Ra)	36.7	30.9	5.8	Lacustrine	Heavy Clay	Orthic Vertisol	2	C	0.5-5	3-4	1-2
Sutherland (Su)	4.7	3.8	0.9	Lacustrine	Silty Clay, Silty-Clay Loam	Orthic Dark Brown Chernozem	2	C	0.5-5	2-3	1-2
Total	**77.7**										

Capability for Agriculture

Class 2: Soils have moderate limitations that restrict the range of crops or require moderate conservation practises.

Class 3: Soils have moderately severe limitations that restrict the range of crops or require special conservation practises.

Class 5: Soils have very severe limitations that restrict their use to the production of native or tame species of perennial forage crops. Improvement practises are feasible.

Class 6: Soils are capable of producing native forage crops only. Improvement practises are not feasible.

Limitations to Agriculture

T: Unfavorable topography due to slope steepness, irregular field pattern or lack of soil uniformity.

W: Excess water caused by either poor soil drainage, a high groundwater table or to seepage and local runoff.

S: Variety of adverse soil characteristics. Where more than two of the following are present: insufficient soil water-holding capacity, adverse soil structure in the upper layers affecting plant growth and/or water movement, low soil fertility or excessive soil salinity.

P: Excess stones, increasing difficulty of tillage, seeding and harvesting.

C: Moisture deficiency due to insufficient precipitation.

Table 1 (con't): Summary of soil characteristics for the most significant associations found within the RM of Monet (Government of Canada, 2013a; Government of Canada, 2013b). Class descriptions are abridged from the soil survey for the area (Saskatchewan Soil Survey Staff, 1993).

Wind Erosion Potential

Class 2- Low: Good soil management and average growing conditions may produce a crop with sufficient residue to protect these soils against wind erosion.

Class 3- Moderate: Average growing conditions may not supply adequate residue to protect these soils against wind erosion. Enhanced soil management practises are necessary to control erosion.

Class 4- High: Average growing conditions will not provide sufficient residue to protect these soils against wind erosion. Coarse-textured soils may be seeded to pasture or to forage crops to prevent severe degradation of the soil.

Water Erosion Potential

Class 1- Very Low: Conventional soil management will produce sufficient residue to protect the soil from water erosion.

Class 2- Low: Conventional soil management and average growing conditions should produce sufficient residue to protect the soil form water erosion.

Class 3- Moderate: Conventional farming practises will result in a steady loss of soil due to water erosion. Conservation practises should be instituted to prevent degradation of these soils.

Table 2: Percent of areas of native prairie underlined by significant soil associations (Government of Canada, 2013b).

Soil Association	Pure (%)	Majority of Complex (%)	Total (%)
Ardill (Ad)	0.8	9.7	10.5
Fox Valley (Fx)	0.6	0.3	0.9
Haverhill (Hr)	42.9	20.7	63.6
Hillwash (Hw)	7.4	-	7.4
Regina (Ra)	2.1	1.3	3.4
Sutherland (Su)	>0.4	<0.1	0.5
			86.3

The capability for agriculture of Ad soils in the RM of Monet is mostly Class 5 (Table 1). This means these soils have very severe limitations reducing their use to native or tame perennial forage crops but improvement practises are still feasible. The topography in the areas of Ad soils in the RM, is hummocky with moderate to strong slopes (Saskatchewan Soil Survey Staff, 1993). The combination of topography and a lack of moisture in the RM limits agriculture. These factors, along with soil texture, also contribute to the Ad soils in the RM mostly have a moderate susceptibility to wind erosion and a low susceptibility to water erosion (Table 1). Enhanced soil management is necessary to prevent wind erosion and conventional soil management and average growing conditions should produce sufficient residue to protect the soil form water erosion (Table 1).

Fox Valley (Fx) soils are present in 4% of the RM of Monet and only underlay less than 1% of areas of native prairie. The Fx soils are also Orthic Brown Chernozems (Government of Canada, 2013b). In terms of capability for agriculture, these soils are split between areas of Class 5 and Class 3 (Table 1). Class 3 soils have moderately severe limitations that restrict the range of crops or require special conservation practises (Table 1). Limitations are topography, excess water, and a combination of adverse characteristics. The topography is described as undulating with gentle or moderate slopes (Saskatchewan Soil Survey Staff, 1993). The majority of Fx soils in areas of lost native prairie have a low susceptibility to water erosion. Susceptibility to wind erosion ranges from low to moderate. Areas of low susceptibility with good soil management and average growing conditions may produce a crop with sufficient residue to protect these soils against wind erosion. In terms of erosion Fx soils are at similar risk to Ad soils; the difference being Fx soils having a gentler topography (Table 1).

Another soil association with significant presence in the region is the Haverhill (Hr) soil association that occupies 21.2% of the RM of Monet and underlies 63.6% of the native prairie in the region (Table 1; Table 2). In this RM the Hr soils are all Orthic Brown Chernozems (Government of Canada, 2013b). Hr soils are poor agricultural soils with most of these soils in the RM being in Class 5 of capability (Table 1). Many areas in the RM containing Hr soils are limited by: topography, excess water caused by factors such as seepage and runoff, or in some areas a combination of a variety of characteristics such as lack of fertility, salinity or adverse soil structure (Saskatchewan Soil Survey Staff, 1993). The topography in these areas is hummocky with most slopes being strong (Saskatchewan Soil Survey Staff, 1993). The Hr soils generally have a moderate susceptibility to wind erosion (Table 1). Water erosion susceptibility ranges from low to moderate. However, most areas are dissected or gullied which may lead to increased erosion in those regions. Hr soils in the RM of Monet with low susceptibility should be sufficiently protected from erosion, but areas with moderate susceptibility will require conservation practises to prevent a steady loss of soil (Saskatchewan Soil Survey Staff, 1993). In terms of erosion Hr soils are also at similar risk to Ad soils but generally have even steeper slopes (Table 1).

Hillwash (Hw) soils occupy 2.4% of the RM of Monet but Roughly 7% of the native prairie in the RM of Monet is underlain by soils of the Hw soil association (Table 1; Table 2). This association is noteworthy as its soils are primarily non-arable and are associated with the steep and eroding escarpments of escarpments and valleys of rivers creeks and tributaries (Soil Classification Working Group, 1998). The Hw soils in the RM are all of Regosolic soil order (Government of Canada, 2013b). Regosolic soils are the least developed soil order lacking a middle layer (B horizon). Their A horizon is also insufficient (lacking the richness or depth) to be designated as a Chernozemic A horizon (Soil Classification Working Group, 1998). The agriculture capability in these areas is mostly Class 6 meaning that they are capable of producing native forage crops only (Table 1). However they may have some value as pasture land (Soil Classification Working Group, 1998). Topography is the primary limitation but other limitations include excess water, erosion damage and excess stones or a combination of adverse effects (Table 1). The topography is hummocky or inclined with slopes ranging from moderate to very steep (Saskatchewan Soil Survey Staff, 1993). Being weakly developed soils in steep slope positions these Hw soils are at the greatest risk of being degraded to the point of no longer being soils (bare parent material). Any land use change in these areas would have to be carefully managed in order to prevent this.

The most commonly occurring soil association within the RM of Monet is the Regina (Ra) soil association, which occupies 36.7% of the RM (Table 1). These Ra soils are found throughout the north-central region of the RM (Figure 4). The Ra soils in this region are almost all Orthic Vertisols (Table 1). Vertisolic soils occur in areas where the soil texture is heavy, being dominated by clay, causing a shrink-swell characteristic. This means that when wet the soil expands and when dry the soil shrinks creating cracks which result in soil mixing. Their A horizon has similar characteristics to Chernozemic soils but lack a distinctiveness from the rest of the layer comprising the upper part of the soil. The Orthic designation refers to a lack of further distinct features (Soil Classification Working Group, 1998). Dark Brown soils are richer than soils of the Brown soil zone resulting in a darker colour. In terms of capability for agriculture Ra soils are among the best agricultural soils in the Dark Brown soil zone; having good drought resistance, fertility, and favourable topography (Saskatchewan Soil Survey Staff, 1993). The Ra soils found in this RM are primarily in agriculture capability Class 2 with the primary limitation being moisture deficiency from low levels of precipitation in the region (Table 1). The topography of the RM in most areas occupied by Ra soils is undulating (Saskatchewan Soil Survey Staff, 1993). With this topography Ra soils have a moderate to high susceptibility to wind erosion but low susceptibility to water erosion. This means in areas of high susceptibility to wind erosion average growing conditions and conventional management would not provide enough residue to prevent wind erosion, but the residue should be sufficient to prevent water erosion (Table 1). Areas with shallow gullies may experience higher rates of water erosion on gully edges if left unprotected (Saskatchewan Soil Survey Staff, 1993). The reason that these richer more agriculturally desirable Ra soils have a higher susceptibility to wind erosion than the poorer soils is likely to due to its texture in conjunction with the climate of the region. The shrinking and swelling of this heavy clay soil with its very fine texture can lead to the deterioration of soil structure resulting in a single dense mass (Environment Agency, 2007; (Agriculture, Food and Rural Development, 2015). If there is a lack of plant residue and it remains dry for an extended period of time then this lack of structure combined with a fine texture and a lack of topography to slow wind speeds leaves this soil highly susceptible to wind erosion.

Sutherland (Su) soils present in 4.7% of the RM of Monet but only underlay 0.5% of native prairie in the region (Table 1; Table 2). The best Su soils also are good agricultural soils (Soil Classification Working Group, 1998). These Su soils are Orthic Dark Brown Chernozems (Table 1); differing from the Orthic Brown Chernozems in that they occur in the Dark Brown Soil zone having a richer, darker colour. The Su soils in the RM mainly are in Class 2 in terms of capability for agriculture; the primary limitation being a lack of precipitation. The topography in these areas is undulating (Saskatchewan Soil Survey Staff, 1993). The susceptibility to wind erosion and water erosion both vary between low and moderate (Table 1). Having a texture with a lower percentage of clay than the Ra soils means the Su soils are less susceptible to wind erosion. In all circumstances, the parent material of all significant soil associations are very calcareous (Government of Canada, 2013b) resulting in calcareous soils on many of these associations' upper slopes and knolls where the soils are thinner (Saskatchewan Soil Survey Staff, 1993).

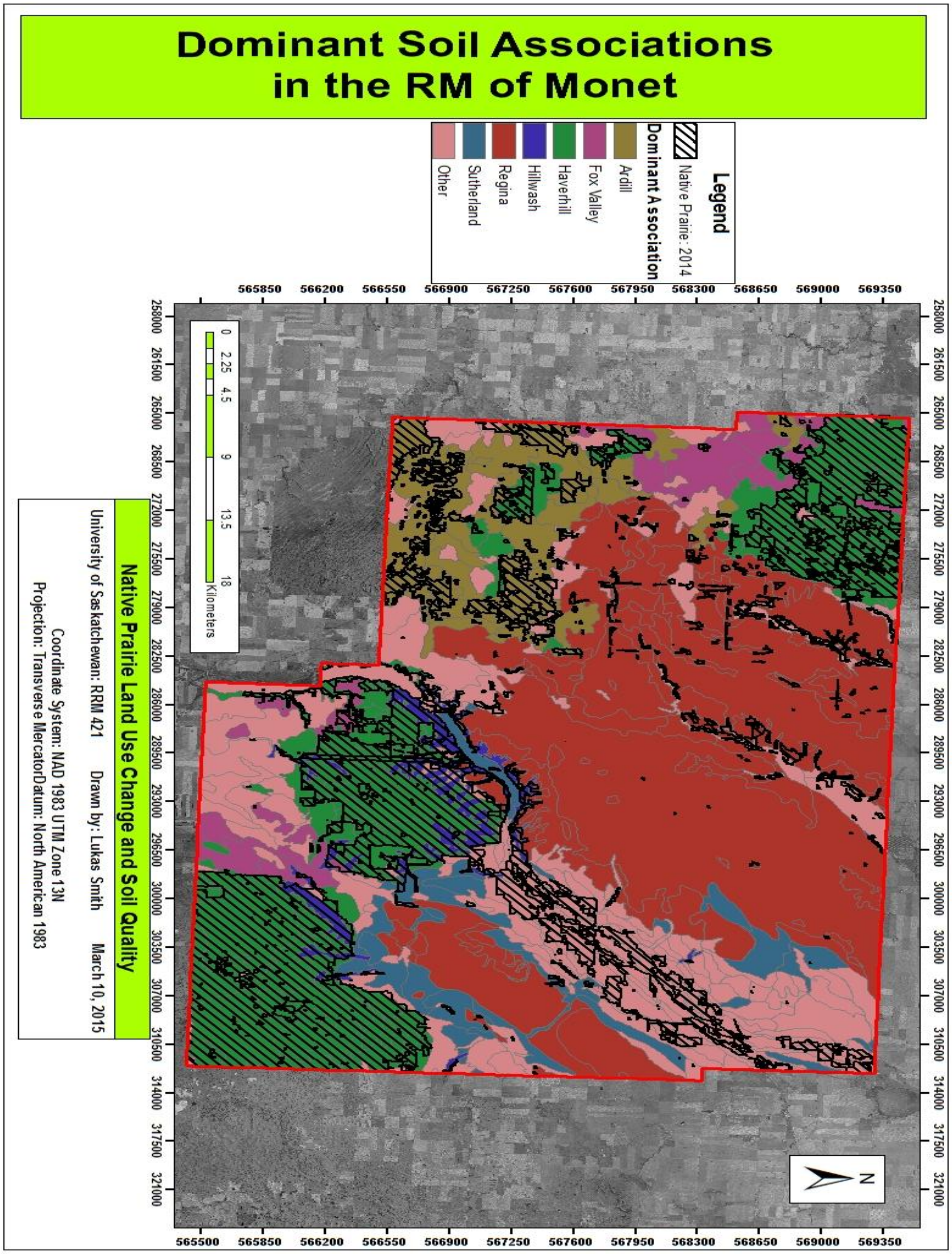


Figure 4: Map showing the location and distribution of the dominant soil associations in the RM of Monet in relation to areas of native prairie.

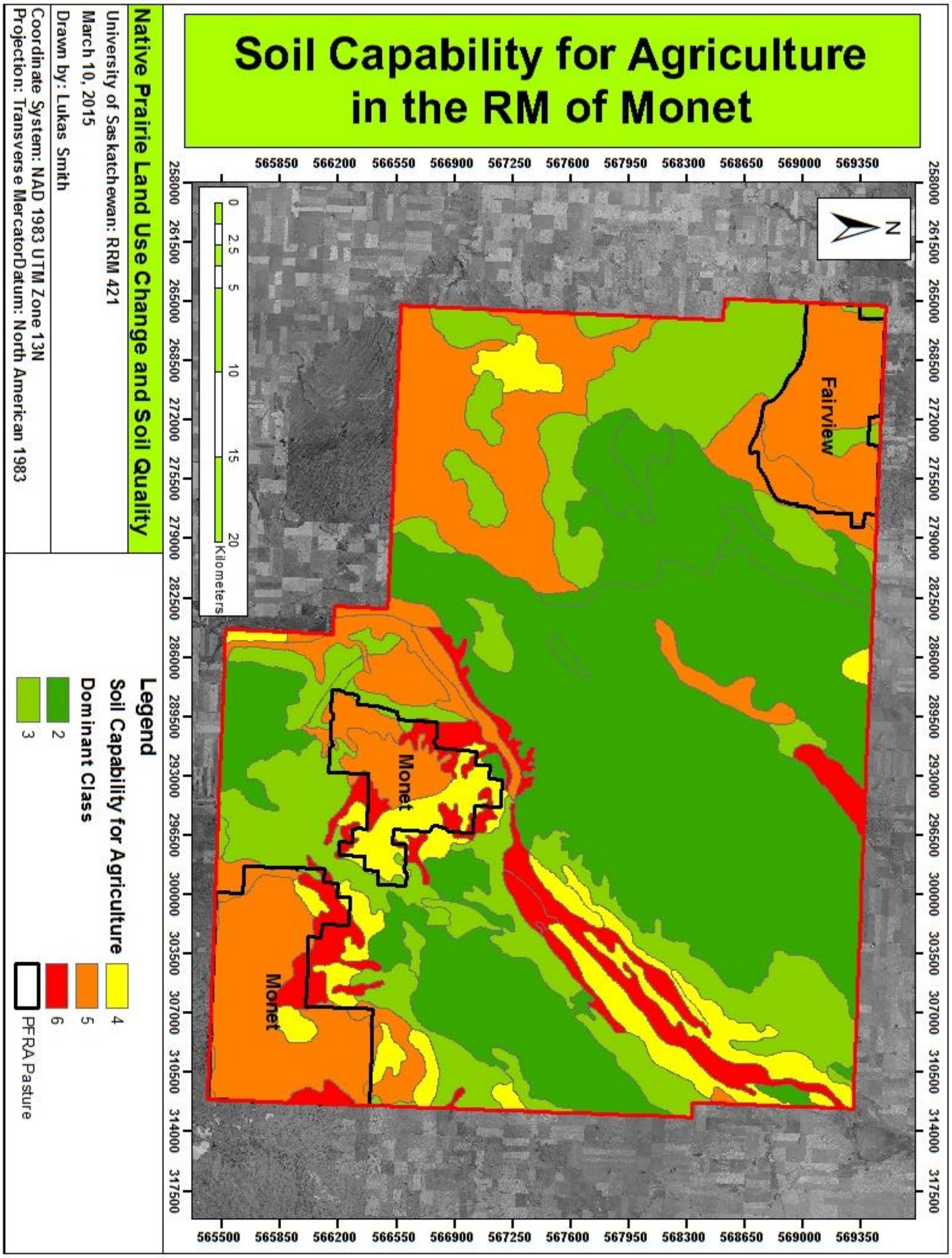


Figure 5: Map showing the location and distribution of soil capability for agriculture classes in the RM of Monet in relation to the PFRA pastures present. The Fairview pasture is defunct as of 2013.

Vegetation

The native vegetation that is prevalent in the Mixed Grassland Ecoregion, and Moist-Mixed Grassland Ecoregion consists of different wheat grasses (*Triticum*) along with diverse deciduous shrubs; the more frequent being Roses (*Rosa*), Chokecherry (*Prunus virginiana),* Snowberry (*Symphoricarpos*) and Wolf willows (*Elaeagnus commutata*) (Saskatchewan Conservation Data Centre, 2014). The arid sites of the Mixed Grassland Ecoregion are overshadowed by Blue grama (*Bouteloua gracilis*) and Needle grasses (*Hesperostipa comata*) alongside Prickly pear cactus (*Opuntia pinkavae*) (Saskatchewan Conservation Data Centre, 2014). The Mixed Grassland and Moist Mixed Grassland Ecoregions consist of Trembling aspens (*Populus tremuloides*) and Willows (*Salix*). Other herbaceous species are established around the perimeter of wetlands, rivers, and lower slope positions of valleys (Saskatchewan Conservation Data Centre, 2014)**.** Saline areas in the Mixed Grassland Ecoregion are dominated by Alkaligrass (*Puccinellia distans*), Red samphire (*Salicornia rubra*), and Wild barley (*Hordeum jubatum*) (Saskatchewan Conservation Data Centre, 2014). The Saskatchewan Conservation Data Centre (2014) notes that there are plant species that classify under the Species at Risk Act (SARA) within the RM of Monet. The species at risk are the Rough penny royal (*Hedeoma hispida*), the Rocky mountain pincushion plant (*Navarretia saximontana*) and the Low milk vetch (*Astragalus lotiflorus*) (Saskatchewan Conservation Data Centre, 2014).

Wildlife

The wildlife species that are evident within the Mixed and Moist Mixed Ecoregions include the Pronghorn antelope (*Antilocapra americana*), Deer (*Cervidae*), Coyote (*Canis latrans*), Rabbit (*Lepus curpaeums*), and Ground squirrel (*Urocitellus richardsonii*). These regions also provide valuable habitat for several waterfowl species that utilize the North American Waterfowl Migratory Route (Saskatchewan Conservation Data Centre, 2014). According to Environment Canada (2013), in the PPR there are a total of 341 bird species, 26 of which are listed under the federal Species at Risk Act (SARA) while 18 are listed as at risk by provincial documents in Alberta, Saskatchewan and Manitoba. The North American Waterfowl Migratory Route is correlated to the Mixed Grassland Ecoregion, and therefore wetland drainage adversely affects waterfowl species. This natural habitat supports many bird species, however, the conversion of land to agriculture is causing displacement of bird species (Environment Canada, 2013). Nasen (2009) claims that these habitats are considered endangered, making the RM of Monet an important point of conservation. Wetlands are what define the PPR and, therefore, as these wetlands are drained for agricultural production, many bird species thriving in the PPR have faced degradation, and fragmentation (Environment Canada, 2013). Many of these species have begun to be listed as threatened.

The RM of Monet is home to four SARA species including the Burrowing owl (*Athene cunicularia*), Sprague's pipit (*Anthus spragueii*), Ferruginous hawk (*Buteo regalis*) and the American badger (*Taxidea taxus*). We will focus on three of these species (Burrowing owl, Sprague's pipit and Ferruginous hawk) due to the limited information on the American badger.

Economics of Land Use Change

According to general economic theory, land use change is driven by differing prices of competing types of land use (Titenberg and Lewis, 2012). For the purposes of this project, some competing land uses include oil and gas development, agriculture and conserved native prairie grassland. Economically speaking, each land use type has its own bid rent function, which represents the net benefits per acre of land (Tietenberg and Lewis, 2012). Titenberg and Lewis (2012) explain that land use conversion occurs when one of these bid rent functions shifts either to a more beneficial use or a less beneficial use. When land is converted, it must decrease the amount of land used for another purpose. For example, native prairie grassland decreases because it is converted to cultivated lands in order to produce food to support the growing population. The conversion of land can be inefficient when considering areas like native prairie because ecosystem goods and services cannot be quantified. Brown et al. (2007), explain that ecosystem services refer to the ecosystem and its associated species' ability to sustain and fulfill human life through natural processes that produces tangible and intangible ecosystem goods. Ecosystem goods are things like timber, forage, wildlife habitat or water purification. Some authors differentiate between ecosystem services and ecosystem goods but others do not; we have lumped them together as ecosystem goods and services (EGS) for our purposes.

The literature shows limited resources for the economics of land use change in Saskatchewan. However, literature about the Prairie Pothole Region (PPR), which is in Saskatchewan as well the United States, is more common. Most of the research entails the northern United States of the PPR. This is somewhat applicable to the project at hand because of the similar landscapes of the RM of Monet and the northern United States where agriculture dominates.

For example, Rashford et al. (2010) explains that grasslands in northern, central United States, are being converted to farmland at an increasing rate because of the high productivity of the PPR which is most correlated to the soil quality of the potentially converted land. The authors describe the grasslands as largely privately owned so landowners make decisions in their own self-interest as opposed to considering the interests of the society that might be affected. The model that Rashford et al. (2010) developed incorporates economic incentives about returns for alternate uses of land to predict the rate that grassland will be converted to other uses. On the other hand, a paper by Wright and Wimberly (2013) analyzes the actual rate of grassland conversion in the United States Western Corn Belt, which is also a part of the PPR. These authors argue that increasing commodity prices for soybean and corn are creating incentives to convert land in order to farm these crops for profit. While soybeans and corn are not grown in the RM of Monet, a more general similarity applies. As global population increases, the demand for food in the form of various crops will increase and with it, the demand for more arable land, which could come at the expense of native prairie grassland.

As with agricultural activity, oil and gas wells have the ability to influence native grasslands. Oil and gas development is a profitable industry and if there are existing pools of oil or gas underneath native prairie grassland, a clear incentive to develop exists. Ecosystem goods and services can be affected through oil and gas well development just as with agricultural production because both alter the landscape.

Both Rashford et al. (2010) and Wright and Wimberly (2013) agree that native prairie grassland in the PPR is often undervalued because the ecosystem goods and services, such as biodiversity, wildlife habitat, etc. cannot be quantified in land prices. For this reason, land use change that occurs may or may not be in the best interests of society.

Land Use and Conversion in the RM of Monet

For the RM of Monet specifically, the town of Elrose website provides some basic information on the economy. Unsurprisingly, the dominant sector is agriculture, which produces a variety of field crops in the region. Previously, wheat, durum wheat, and barley were commonly grown crops in the region, but now they are less popular because other crops have proved to be more profitable (Town of Elrose & RM of Monet #257, 2013). Current crops grown instead include lentils, peas, chickpeas, soft wheats, canary seed, mustard, flax, canola and some specialty crops. The region's mix of soils has helped define the land use of the region, with both cattle and crop production occurring in the area. Land use changes that are occurring include new oil and gas developments, in particular, new oil wells in the Coteau Hills region and southeast of Elrose. New gas wells are appearing in the west of the RM. Lastly, new water pipelines will be built to transport water south of Rosetown from the South Saskatchewan River (Town of Elrose & RM of Monet #257, 2013). Farming, grazing, oil development, gas development and infrastructure involve the use and conversion of land, which threaten native prairie grasslands within the RM of Monet. These changes are driven by the economic incentives and profitability of different crops and other land use practices such as drilling for resources.

Saskatchewan Prairie Conservation Action Plan

A group of prairie conservation stakeholders first met in 1995, which eventually led to the formation of the PCAP partnership in 1998. The PCAP partnership brings together 30 agencies and organizations, representing producers, industries, provincial and federal governments, environmental non-government organizations and research and educational institutions (Prairie Conservation Action Plan, 2014). These agencies and organizations are all working towards a common goal and vision of prairie and species at risk conservation in Saskatchewan. The PCAP partnership recognizes the importance of partnerships beyond Saskatchewan borders both nationally and internationally (Prairie Conservation Action Plan, 2014). There are many benefits associated with PCAP's expanded partnership such as consultation on common issues, sharing resources, experiences and solutions. The PCAP Partners work together to deliver innovative and critical prairie conservation activities that represent the shared objectives of a diverse mix of stakeholders and that benefit the social, cultural, economic and ecological fabric of

Saskatchewan (Prairie Conservation Action Plan, 2014). PCAP partners value the prairie and view it as a valuable resource; they recognize the important role it plays as a working landscape. The SK PCAP Partnership is an action-orientated organization that believes that more can be accomplished when acting and working together rather than alone. Goals are an important part of the PCAP Partnership, implementations plans are set in place and the partners commit and work towards achieving the set goals. The Saskatchewan PCAP will play an important role in determining questions associated with the conservation of Saskatchewan's native prairie and species at risk. PCAP continually develops five-year action plans, which focus on goals similar to the questions we are focusing on in this project. These goals consist of prairie and species at risk education and awareness, responsible land use on native prairie, and native prairie ecosystem management. Although there is an increasing awareness of the diminishing native prairie in Saskatchewan, loss of native prairie still occurs. The PCAP partnership has proven to be an important forum guiding conservation and management efforts within Saskatchewan's Prairie Ecozone (Prairie Conservation Action Plan, 2014).

Project Concern

Native grasslands provide many benefits including those that are natural, economic and societal. Prairie provides habitat for wildlife (particularly native species) and contributes to biodiversity. Native grassland supplies rangeland for grazing livestock, harbours a genetic resource for future medicines and fuels, and provides opportunities for the recreation sector. Additionally, native prairie is intertwined with the history and culture of Saskatchewan (Hammermeister et al., 2001). For these reasons, it is important to conserve the native grassland remaining in Saskatchewan.

To evaluate the impact of land use change on prairie landscapes, an inventory of remaining native prairie must be taken, and the factors threatening it must be identified and quantified. The last inventory predates the current resource boom and with the termination of the Prairie Farm Rehabilitation Administration, Saskatchewan's native grassland is more vulnerable than before. As native grassland is lost, Saskatchewan's flora and fauna are impacted, along with the province's soil quality. It is the goal of this project to assess the remaining native grasslands, study the land use change, and how these changes have influenced plants, animals, and soils all within the foundational study area: the RM of Monet, SK. In doing so we will provide a framework for a broader exploration of land use change across the prairies through geospatial analysis.

Project Objectives

Following several in-depth conversations with PCAP and the soil science department at the University of Saskatchewan, we were able to define three major objectives for our project:

- Determining the percentage of remaining prairie in the RM of Monet
- Identify land use changes influencing native prairie in the RM of Monet
- Identify implications of lost native prairie on soil quality, wildlife and plant in the RM of Monet

In addition to these objectives, we explored the economic drivers influencing the identified land use changes and the various ecosystem goods and services provided by the native prairie in the RM of Monet. This additional research provided an explanation for the conversion of native prairie and a more in-depth narrative for our report.

Summary

Saskatchewan native grasslands have already been significantly reduced and continue to face the threat of land use change. Due to the benefits provided by native grassland, it is important that it be conserved. It is the goal of this student group, in partnership with PCAP, to provide information on remaining grassland and the challenges posed by land use change within a particular region of Saskatchewan, the RM of Monet. The RM of Monet is situated within the unique natural features that are the Palliser's Triangle and PPR. Characteristics of these features are reflected in the climate, soils and topography found in the RM. These environmental factors in turn influence the suitability of the region for economic activities like agriculture, as well as oil and gas development. As part of this project the percentage of native grassland remaining in the RM of Monet will be determined, land use changes will be identified and the impact of these changes will be quantified. It is intended that the completed project be used as a framework for a similar process to be done for the entire province of Saskatchewan. In doing so, we will provide a framework for a broader exploration of land use change across the prairies without incorporating field work.

Methodology

Assessment of Native Prairie

In order to determine the amount of remaining prairie in the RM of Monet and what forces have been driving the changes to this landscape, GIS (geographic information systems) was used in tandem with a variety of open source data. The first piece of open source data we received was retrieved as a .tiff file from the "Land Cover for Agricultural Regions of Canada" (Government of Canada, 2009), which allowed us to identify the amount of native prairie as it existed in 2001. To make this data set more manageable it was first clipped to the boundaries of the RM of Monet, after which the unnecessary data was removed (cropland, tame pasture, wetlands, and various forest types). What we were left with was a shape file that described how much native prairie remained in the RM as of 2001. To determine how much native prairie existed as of 2014 we took this new shape file and placed it over SPOT imagery that had been taken in 2014 and was hosted by Esri. The boundaries of the native prairie were then adjusted according to where native prairie could be seen in these air photos.

When looking for native prairie, we searched for areas that were uncultivated, lacking in trees and/or development, had darker colours, and displayed a variety of shade variation, as this would indicate a variety of grass species. Should the areas once covered by the native prairie shape file not meet the above standards, we were able to conclude that it was no longer native prairie, and the areas land use had changed. Due to the inability to ground proof, tame pasture will not be differentiated between cultivated lands because of the difficulty in assessing the difference, so the lost native prairie could include tame pasture.

To identify the type of land use change occurring in these areas we took two approaches. This first involved taking a closer look at the air photos and, where possible, identifying these changes on our own, in doing so we were able to identify new agricultural developments (additional cultivated lands), and what appeared to be industrial developments in the form of well pads. Unfortunately, we were unable to differentiate between the types of agricultural lands, as we lacked the experience to do so, however SaskEnergy has made all new oil and gas well developments available to the public (Saskatchewan Industry and Resources, 2015). With this data we were able to determine the amount of oil and gas wells in the RM of Monet, as well as the dates that they were installed. The metadata that came with this information came in point form, which meant that we were unable to see how much land had been lost to these structures. To overcome this, individual well pads were measured allowing us to conclude that the average area of a gas well pad is 0.6 ha and 0.75 for an oil pad. With these averages, we were able to calculate how much of the native prairie in the RM of Monet was lost to oil and gas development by multiplying their values by the number of wells that appeared in areas of native prairie.

Assessment of Soils

To identify the soils that occur in the RM of Monet and how they are influenced by the economic forces changing the landscape, we took two approaches. The first was using GIS to utilize detailed soil survey data and land inventory data, made available by the Government of Canada, to identify the dominant soil associations in the RM and their capability for agriculture. Using shape files from the aforementioned resources, the assessment of native prairie as well as pasture land shape files from the Government of Saskatchewan, various clips were performed in GIS to ascertain relationships between land use, land cover, and soil characteristics. Microsoft Excel was used in conjunction with ArcGIS attribute tables to analyze the data produced from these clips. Several joins were required to append all the relevant data from the detailed soil survey together. Clips were performed between shape files of lost native prairie and soil associations as well as between soil associations and remaining native prairie. These clips were overlaid by the Canada land inventory shape file and visually compared in order to determine capability for agriculture as well as the corresponding limitations. The Saskatchewan soil survey for the RM of Monet, was used along with the data product specifications to interpret the data and provide the information needed to describe the soil characteristics. This approach provided information on agriculture and its potential impact on soil quality. However, once the significance of oil and gas development in the area became clear a second approach was required to determine potential effects. This approach was research based. The research involved reviewing peer reviewed journal articles, industry websites, encyclopaedias, and communicating with professionals in remediation and soil science fields.

Assessment of SARA Species

Determining the SARA listed species in the RM of Monet was a fairly straightforward process. To do this, we contacted the Saskatchewan Conservation Data Center (SKCDC), who collects data from consults performing surveys for industry in the area, and requested the relevant data for the RM of Monet. After signing a data sharing agreement, the information was made available to us, and we were able to visually display it using GIS. In order for us to better understand how these animals are influenced by the identified land changes, we performed research that utilized information from peer reviewed journal articles, theses papers, the Government of Canada website, and encyclopaedias.

Assessment of Economics

Once we had identified the forces that were changing the native prairie in the RM of Monet, we explored why these forces were dominant. To do this we researched changes in relevant policies such as the PFRA system and royalties, discussed our findings with industry professionals, and used GIS to explore what areas were changing and which ones experienced no changes. The information gathered was then applied to general economy theory regarding land use change including a discussion of ecosystem goods and services that was used to explain why change is occurring. Additionally, recent market changes, such as the decreasing price of oil, were discussed in order to provide speculation into the future of resource development and native prairie in the RM of Monet.

Results

Native Prairie

The RM of Monet has an area of approximately 165,199 ha and, as of 2001, 27% (43,208 ha) remained as native prairie. The majority of this prairie was protected by community pastures, with the north western Fairview pasture protecting 6,703 ha of native prairie, and the south eastern Monet pasture protecting 15,808 ha. Combined, these areas have conserved 54% of the total native prairie in the RM of Monet.

As of 2014, the amount of native prairie has decreased down to 26% (41,789 ha), with a total loss of 1,418 ha over the course of 13 years. There are three major sources that are responsible for this loss including, 1,355 ha to cultivated land, 61.5 ha to oil wells, and 1.8 ha to gas wells (figure 6).

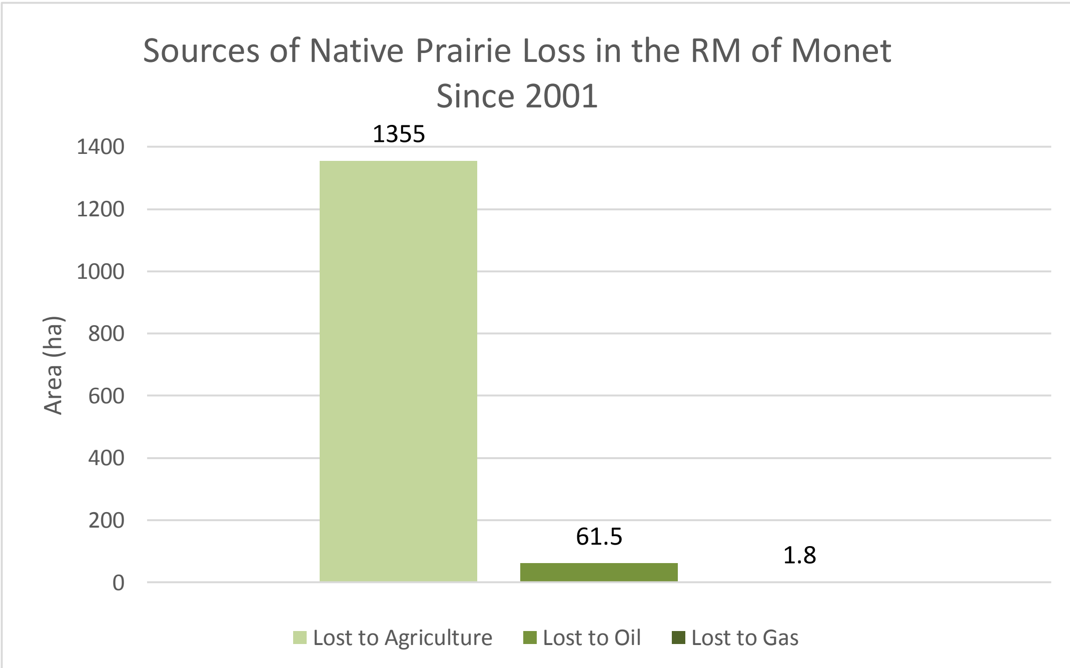


Figure 6: A summary of the sources of native prairie loss in the RM of Monet from 2001 to 2014.

As of 2001, only 87 oil wells and 16 gas wells had been developed in the RM of Monet (Figure 12), however over the course of the next 13 years 268 additional oil wells had been installed along with an additional 20 gas wells. Of these new developments, three gas wells and 82 oil wells were installed in what has been classified as native prairie, resulting in the loss of a combined 63.3 ha of grasslands.

Historically, 6702.8 ha of native prairie has been preserved by the former Fairview pasture and 15808.3 ha is preserved by the Monet pasture as of 2014 (Figure 7).

Soil

The majority of lost native prairie (Figure 7) was distributed throughout the RM of Monet's soil associations as indicated in table 2.

Table 3: Percent of areas of lost native prairie underlined by significant soil associations (Government of Canada, 2013b).

Soil Association	Pure (%)	Majority of Complex (%)	Soil Complexes* Present	Total (%)
Ardill (Ad)	0.1	17.2	AdVa, AdWw	17.3
Fox Valley (Fx)	1.5	3.8	FxAd, Fx-Birsay (By), FxWw	5.3
Haverhill (Hr)	2.1	23.0	HrBy, HrFx, Hr-Hatton(Ht), HrVa, HrWw	25.1
Hillwash (Hw)	7.2	0	-	7.2
Regina (Ra)	17.8	3.8	RaSu, RaWr	21.6
Sutherland (Su)	4.2	0.4	Su-Elstow(Ew), SuRa, Su-Tuxford(Tu)	4.6
				81.1**

***In the description for soil complexes the first association is the main soil type while the second association are only present at specific slope positions or are intermixed (Saskatchewan Soil Survey Staff, 1993). **Soil associations underlying less than 4.5% of areas of lost native prairie were deemed insignificant for the purposes of this report.**

Two of the larger patches of lost native prairie occurred in an area of Hr soils in the southwest corner of the RM of Monet (Figure 4; Figure 7). The specific soil association of this patch is a HrVa complex with slopes ranging from moderate to strong slopes (Saskatchewan Soil Survey Staff, 1993). It has a sandy loam texture and when sampled was classified as an Orthic Brown Chernozem. The capability for agriculture of this patch is mostly Class 5 but some portions may be Class 4 (Figure 5; Figure 7; Government of Canada, 2013a). Class 4 soils have severe limitations that may restrict the range of crops or require special conversation practices (Saskatchewan Soil Survey Staff, 1993). The main limitations are topography and excess water. In terms of erosion this patch is highly susceptible to wind erosion and moderately susceptible to water erosion (Government of Canada, 2013b). Being a more coarse textured soil, this patch may be seeded to pasture or forage crops to prevent severe wind degradation (Saskatchewan Soil Survey Staff, 1993). As for the remaining Hr dominated soils, in areas of lost prairie, their characteristics follow the generalizations that were described in the background albeit with less dissections and gullies on the landscape (Government of Canada, 2013b). Most frequently, the largest patches of native prairie lost coincide with the Regina soil association (Figure 4; Figure 7). As a whole, Ra dominated soils occupying areas of lost native prairie match the characteristics outlined in the background (Government of Canada, 2013b).

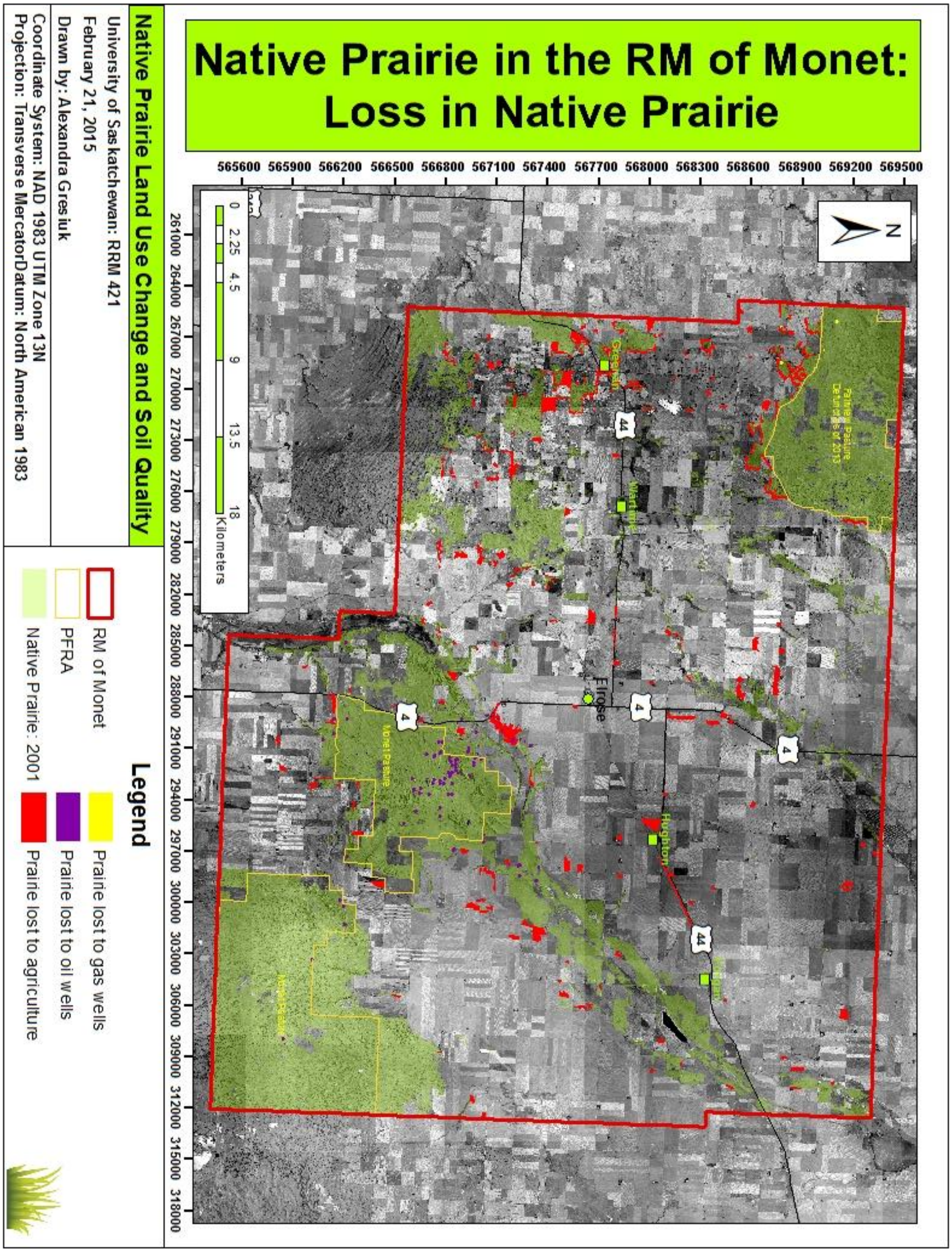


Figure 7: Map showing native prairie loss from 2001-2014 grouped according to loss by oil, gas and agriculture.

SARA Species

As a result of the declining native prairie, plant and wildlife species are facing various challenges. Environment Canada (2013) states that much of the land that provides habitat for different bird species has been converted to agricultural land. The fertile soils, evident within southern Saskatchewan, make the location very favourable for agricultural activity; therefore, much of the land has become cultivated (Environment Canada, 2013).

The addition of oil and gas wells, within the RM of Monet, is a large factor contributing to land use change, as the industry has seen an increased presence in the area. Nasen (2009) further states that oil and gas development sites can result in surface disturbance, the loss of native species, and the alteration of flora composition as a result of habitat fragmentation and degradation of native habitat. Due to the constant demand for oil and gas, it is likely that the number of wells in this area will increase over time. The construction of oil and gas reduces grassland biodiversity (Nasen, 2009).

The native prairie grasslands in the RM of Monet are home to several SARA species (Figure 13). The wildlife SARA species includes the American badger (*Taxidea taxus*), Sprague's pipit (*Anthus spragueii*), the Burrowing owl (*Athene cunicularia*) and the Ferruginous hawk (*Buteo regalis*). SARA plant species were also found in the RM of Monet, which include the Rough penny royal (*Hedeoma hispida*), Rocky mountain pincushion plant (*Navarretia saximontana*), and the Low milk vetch (*Astragalus lotiflorus*). These SARA species have the potential to be negatively affected as a result of diverse land use changes, including cultivation and oil and gas development.

Discussion

Soil Quality

Influence of Agriculture

Given the loss of native prairie in areas occupied by the significant soil associations if appropriate soil management and conservation practices are not implemented then the soils in these areas are likely to degrade. There would be a lesser risk of soil degradation if native prairie was not converted as the permanent cover they provide would be sufficient to protect against most degradation factors associated with agriculture. Other than the Ra and Su soils, significant soils in the RM of Monet are not great agricultural soils. The soil capability classes of the Ad soils, some Fx soils, Hr soils soils recommend that in terms of crop only native or tame species of perennial forage be planted. Of the significant soils, Hw soils are at the most risk to soil degradation from native prairie conversion and Su soils are at the least risk.

If converted to cropland all significant soils in the RM of Monet have some potential for wind erosion and therefore would likely require enhanced soil management practises at some point and need to be continuously well managed. With good soil management even areas with low susceptibility, like those occupied by Su soils, only produce sufficient residues to protect soil with average growing conditions. Below average years would require enhanced soil practises be implemented. Being that the RM of Monet is located in an area of relatively low precipitation there is an increased risk of wind erosion, especially in longer dry periods. The moderate-fine textures of the significant soils (excluding Hw soils) in the RM decrease this added risk as their water-holding capacity and infiltration rates extend the period of time during which sufficient soil moisture is maintained to deter win erosion. The topography of areas with Ad, Fx, and Hr soils that have moderate or steeper slopes makes areas at upper slope and top slope positions more vulnerable to wind erosion while depressional areas would be more protected.

If converted to cropland all significant soils (except some Su and Ra soils) in the RM of Monet have some potential for water erosion and therefore would likely require the implementation of conservation practises at some point, specifically years with below average growing conditions. Again the topography of areas with Ad, Fx, and Hr soils are more vulnerable to water erosion, especially if the slopes are longer. The steepness and length combine to increase the volume and force of water erosion increasing its effect (Ministry of Agriculture, Food and Rural Affairs, 2012).

The Hw soils are most at risk to soil degradation after native prairie conversion. The fact that native prairie has been lost in areas underlined by these soils is concerning. They are thin soil which means even a small amount of degradation is significant. The Hw soils are in areas with steep slopes further increasing erosion potential. These soils have an agricultural capability that suggests only native forage crops be planted on them making the conversion from native prairie to anything else seem impractical.

Su soils are least at risk to soil degradation after native prairie conversion. These soils have a medium-fine texture, a good capability for agriculture, gentle topography, are Dark Brown and out of the significant soils of the RM of Monet, the lowest potential for wind erosion and water erosion. Native prairie conversion in these areas is unlikely to have adverse effects on soil quality with good soil management.

With farming equipment increasing in size and weight, risk of soil compaction also increases (Duiker, 2004). While compaction occurs in all soils that agriculture equipment is driven over in the RM of Monet the significant soil that is at the most risk from compaction is the Ra soils. These soils are already at a high risk to wind erosion. If these soils were to be increasingly compacted, especially when wet (Environment Agency, 2007; Duiker, 2004) then there would also be an increasing issue with soil structure deterioration and the Ra soils would become even more vulnerable to wind erosion. However, it should be noted that most areas with Ra soils appear to have already been converted for agricultural purposes (Figure 4; Figure 7) and are in Class 2 of terms of agricultural capability. It is likely that land users in the area know how to properly manage these soils and that Ra soils converted from native prairie will also be properly managed.

If areas of native prairie loss were due to a conversion to pasture (perennial forage) then besides from initial tillage and seeding it is possible that the soil quality in these areas could actually increase. Although certain grazing practises can lead to soil compaction and degradation (Taboada et al., 2011) improved grazing management systems can result in an improvement to soil quality (Franzluebbers et al, 2012). These improved grazing management systems can benefit the restoration of surface soil fertility of degraded soils (Franzluebbers et al, 2012).

Influence of Oil and Gas

Looking at the RM of Monet it was determined that a major land use change impacting the native prairie in the area is associated with the addition of oil and gas wells. Of these new wells, 3 of 16 gas wells and 82 of 268 oil wells were established in what is classified as native prairie. The total loss of native prairie from wells is fairly small, only about 63 ha, but because of the invasive nature of these structures, their associated infrastructure, and the huge increase in their numbers, their potential impacts was well worth looking into.

Through the process of oil and gas developments soils are influenced physically, chemically, and biologically (McMillian et al., 2007). The majority of this influence is exerted during the construction of these wells and the associated infrastructure (PCAP, 2005). The consequences of these activities are long lasting and will influence the productivity of soils in the RM of Monet.

Physical Disturbance

When a pad site is being constructed a variety of heavy construction equipment is used and a great deal of soil is stockpiled. These processes negatively impact the physical properties of soil in a number of ways including (McMillan et al., 2007):

- Loss of soil bulk density
- Damage soil structure
- Redistribution of clay particles
- Reduced water infiltration and root growth
- Soil compaction
- Admixing of soil horizons
- Increasing susceptibility of the soils to wind and water erosion
- Loss of topsoil productivity

Other researches also point out that the topsoil (Ah horizon) from oil and gas production sites (following remediation) is extremely shallow, around two centimeters, compared to the undisturbed topsoil, around seven centimeters deep (Nasen et al., 2010).

Chemical disturbance

Waste material associated with oil and gas drilling may contain salts, metals, and hydrocarbons all of which may contaminate the areas' soil via spills during normal operation. The table below outlines how these pollutants could travel through the soil, how toxic it is, and the impact it may have on soil health.

Table 4: A description of potential pollutants that may affect the soils in the RM of Monet as a result of oil and gas development. Sourced from: (EPA, 2007), (Marrs, 2002), (Weber, 2009), and (Gresham, 2012).

	Chemical Type	Chemical Name	Detail	Source
PHC (Petroleum Hydocarbons)	BTEX	• Benzene • Toluene • Ethylbenzene • Xylenes	• Benzene - carcinogen • Toluene – reproductive and central nervous system effects • Ethylbenzene and Xylenes – respiratory and neurological effects	• Venting of natural gas pits
	PAHs	Polycyclic aromatic hydrocarbons	• PAHs -Possible carcinogen and reproductive effects	• Diesel exhaust • Natural gas flaring pits
	Diesel Fuel	Hydrocarbons	• Hydrocarbons fuel and exhaust – carcinogens from Benzene and PAHs	• Stimulation fluids • Oil-based drilling muds • Heavy equipment
Metals	N/A	Examples include: • Arsenic • Barium • Cadmium • Chromium • Lead • Mercury • Selenium • Zinc	Examples include: • Skin problems • Hair loss • Kidney damage • High blood pressure • Cancer • Risk of neurological damage	• Drilling muds • Metal contaminated water • Venting and flaring • Diesel exhaust

Brine is another pollutant associated with oil and gas activity (EPA, 2007). Impacts of this contamination include:

- Loss of soil structure by replacing calcium on clay particles
- Reduced ability to hold and transmit water
- Impaired plant growth

To better understand the implications of these pollutants we consulted a study created in south-central Alberta that explores the impacts of the oil and gas industry on soils. Conducted by Rowell and Florence (1993), it was found that the soil in regions of high oil and gas activity have increased levels of electro-conductivity and sulphate concentrations, as well as low soil pH, organic matter, and cation exchange capacity. The soil moisture content on oil and gas activity sites is lower.

Biological Disturbance

Plant roots and microorganisms are creating major habitat in Chernozemic soils, which include bacteria and fungi. Soil microbial communities are a primary component of ecosystem processes (Jackson et al., 2007). These characteristics are strongly influenced by the development of oil and gas wells within the region in the following ways (McMillan et al., 2007):

- Reduced soil organic matter content
- A loss of microbial biomass

The majority of this loss is associated with soils being stockpiled for several months at a time. Within these piles the soils become anaerobic, and experiences increased temperatures that result in the death of microbes and nutrient leaching (Harris et al., 1989). All of these forces reduce soil microbial function, which is essential to the soil ecosystem as it is responsible for soil organic matter decomposition and nutrient cycling (Grayston et al. 2004).

SARA-Listed Wildlife

The Burrowing owl (*Athene cunicularia*) is a SARA species within the RM of Monet that is declining in numbers as a result of increased agricultural development. Skeel et al. (2001) describes Operation Burrowing Owl (OBO) as a prairie stewardship program, organized within

Saskatchewan, to preserve the Burrowing owl *(Athene cunicularia*) from land use change. Burrowing owls (*Athene cunicularia*) nest in grassland plots throughout the prairies. The Burrowing owl (*Athene cunicularia*) utilizes burrows abandoned by the American badger (*Taxidea taxus*) (Skeel et al., 2001). As a result of land conversion, fragmentation, degradation and overall habitat loss, the population of the Burrowing owl (*Athene cunicularia*) has been acutely decreasing. From 1998 to 2000 there was a mean population decline of 21.5% in Saskatchewan (Skeel et al., 2001).

Agricultural processes have also affected Burrowing owls (*Athene cunicularia*) by introducing pollutants into their environment. Skeel et al. (2001) indicates that pesticides associated with agriculture, as well as increased traffic, and higher predation (a pressure associated with habitat fragmentation) has had unyielding negative impacts on the Burrowing owl (*Athene cunicularia*).

Figure 8: Burrowing owl. Sourced from: http://animal-kid.com/cute-baby-burrowing-owls.html

The American badger, another SARA species within the RM of Monet, is one of Canada's few grassland carnivores. Parks Canada (2013) mentions that the American Badger (*Taxidea taxus*) burrows in the ground searching for food; when they dig or burrow they improve soil quality. They are an important wildlife species but due to fragmentation, and loss of habitat from agriculture, a decrease in the species number is occurring (Parks Canada, 2013).

Figure 9: American Badger. Sourced from: http://www.ontario.ca/environment-and-energy/american-badger

The Ferruginous hawk (*Buteo regalis*) located in the RM of Monet, is a bird that requires a large hunting area and is currently suffering from the loss of hunting habitat due to agriculture conversion (Government of Canada, 2014b). It is also one of the SARA species that is negatively affected by oil and gas wells. The Ferruginous hawks (*Buteo regalis*) nesting success is decreased and hunting habitat is lost as a result of land conversion (Government of Canada, 2014b).

The Sprague's pipit (*Anthus spragueii),* also located in the RM of Monet, is most heavily impacted by oil and gas development, although, agriculture is a relevant influence. A study done by Bogard (2011) displayed that the population of Sprague's pipit (Anthus spragueii) was higher away from gas wells (it was not detected closer than 50m to the gas well) indicating the disruptive influence that natural gas wells have on this SARA species. The Sprague's pipit (*Anthus spragueii*) is one of many songbirds, which have responded negatively to this type of development (Bogard, 2011). Increased traffic and noise, alteration of vegetation (introduction of invasive species), pesticides for controlling invasive species, pollution from pesticides, and increased edge habitat are impacts affecting the Sprague's pipit (*Anthus spragueii*) due to oil and gas development (Bogard, 2011). As a result, natural habitat destruction, decreased reproductive success, and increased mortality rates have greatly disrupted the Sprague's pipit (*Anthus spragueii*) (Bogard, 2011). The consequences from oil and gas expansion, within the RM of Monet, has reduced the occurrence of Sprague's pipit (*Anthus spragueii*) in Saskatchewan.

SARA-Listed Vegetation

When lease sites are under development, the admixing of soil horizons and the removal of surface vegetation results in the loss of herbaceous litter (Nasen, 2009). The removal of vegetation from lease site construction, and maintenance, accelerates soil erosion and provides unfavourable growing conditions for germinating plants (Nasen, 2009). The absence of litter prevents shading, which increases surface temperature and removes soil moisture.

The re-establishment of native plant communities following surface disturbance (by invasives or non-invasives) can be difficult, as there are few documented examples of successful grassland restoration (Desserud et al., 2010). A study done by Nasen (2009) claims that lease sites tend to have a greater abundance of Alkaligrass (*Puccinellia distans*), Foxtail barley (*Hordeum jubatum*) and Russian thistle (*Salsola tragus*), lowering the biodiversity of the site.

With the continual production of oil and gas there is an increased presence of invasive species that create competition with native species (Nasen, 2009). This implies that the SARA species (listed below) in the RM of Monet are facing an increased level of competition as a result of increasing oil and gas development.

- Rough penny royal (*Hedeoma hispida*)
- Rocky mountain pincushion plant (*Navarretia saximontana*)
- Low milk vetch (*Astragalus lotiflorus*)

These plants are important to the Grassland Ecoregion and the RM of Monet. A study done by Nasen (2009), in southwest Saskatchewan, examined the spatial and temporal extent of petroleum and natural gas development, along with its effects on grassland ecology within a PFRA (Prairie Farm Rehabilitation Administration) pasture. This study found that increased annual production of both oil and gas resulted in a decline of desirable species diversity (Nasen, 2009).

Nasen (2009) claimed that on average, impacts were found to extend 25m from the wellhead; desirable species presence increased with distance from wellheads. With increases in oil and gas development, plants such as the Rough penny royal (*Hedeoma hispida*), Rocky mountain pincushion (Navarretia saximontana), and the Low milk vetch (*Astragalus lotiflorus*) may encounter increased competition with invasive species. As a result, there are native plant species have faced a decline in population, and may continue to do so if the development trend continues.

Figure 10: An operating well in southern Saskatchewan. Sourced from: Tom Yates

Economics

Agriculture & Petroleum Natural Gas (PNG) Development

A larger proportion of the change in native prairie was a result of newly cultivated land. However, rates of cultivation have limited potential for expansion, unlike the expanding oil and gas industry. The amount of native prairie cultivated was less than expected, which can be attributed to the poor soil quality in the areas of remaining native prairie in the RM of Monet as mentioned in the soil analysis. Additionally, the dismantled PFRA lands are subject to no-break, no-drain conservation easements that will further limit the expansion of cultivated lands (Rick Ashton, personal communication).

It is worth mentioning that farming is still profitable within the RM of Monet as seen by the continued crop yields since 2001 for the dominant crops such as peas, canary seed, lentils, wheat, etc. as seen in the table below. With this having been said we determined that the predominant influence on native prairie grassland in the RM of Monet is oil and gas well development, and so we have focused on the petroleum natural gas (PNG) industry in our analyses.

Table 5: Crop yield by year and bushels (bu) or pounds (lb) per acre (ac) in the RM #257 of Monet from 2000-2013 (Government of Saskatchewan, 2013).

Crop Year	Spring Wheat - bu/ac	Lentils - lbs/ac	Peas - bu/ac	Canary Seed
2000	33	1421.1	31.4	937.5
2001	15.3	429	5.3	250
2002	7.4	259	4.3	172
2003	20.3	772	14.9	516
2004	25.1	980	24.1	774
2005	36.6	1556	36.6	1056
2006	32.6	1217	36.7	692
2007	31.3	1173	33.4	980
2008	37.7	1231	21.1	889
2009	32.8	1620	30.3	1043
2010	36.8	1403	33.4	711
2011	35.5	1420	36.7	774
2012	30	1116	27.5	682
2013	50.3	1831	44.3	1296

The majority, 54%, of native prairie remaining in the RM of Monet is Crown land (PFRA pasture) so we have chosen to describe the PNG policy for Crown land development as opposed to private land. However, the steps are similar for starting production on private lands because the provincial government owns 78% of the subsurface mineral rights in Saskatchewan, which are the primary rights needed to access oil and gas (Fortugno, 2004). If a private landowner also owns the subsurface rights in addition to surface rights, they will have more input on who can develop the resources on the land. A mineral rights agreement would be established between the private owner and the oil and gas company (Fortugno, 2004).

Projects on grasslands in Saskatchewan require a project proposal to be submitted. The proposal will be screened and the province of Saskatchewan will determine if an Environmental Impact Assessment (EIA) is required (Nasen, 2009). For oil and gas developments that require an EIA the following additional components are necessary:

- Project scoping in order to delineate key issues and project boundaries
- Assessment of potential impacts of the project
- Assessment review by stakeholders
- Approval and recommendations for the project

Typically, follow-up and monitoring is required, however, Nasen (2009), explains that this is not common practice for oil and gas development on grasslands.

Crown lands with potential oil and gas production experience two stages: exploration and development (PCAP, 2005). In order for development to occur on Crown lands companies must go through a series of steps and obtain the appropriate permits.

First, seismic companies must submit a proposal to the Saskatchewan Ministry of Environment and the Saskatchewan Ministry of Agriculture. Once it is approved, the company is given a work authorization. When the Crown land is leased, the company can negotiate crossing fees and other concerns with the lessee (PCAP, 2005). Interestingly, leasing rates for oil and gas development are about $30-$60 cheaper per acre on pasture land as opposed to cultivated land. For example, the first year development fee for the first three acres on cultivated land is $780/acre, whereas pasture land is $720/acre (Government of Saskatchewan, 2012).

Second, mineral rights are available for purchase from Saskatchewan Ministry of Economy through a tender bid process. The company is still required to pay a royalty or share to the province for minerals produced. Once the rights are obtained, an environmental review is done of the proposed site. The Saskatchewan Ministry of Agriculture and a land company negotiate on behalf of the oil and gas company with the lessee, for consent to drill and other logistics such as fencing. The environmental review is assessed and approved by the Saskatchewan Ministries of Environment and Agriculture (PCAP, 2005).

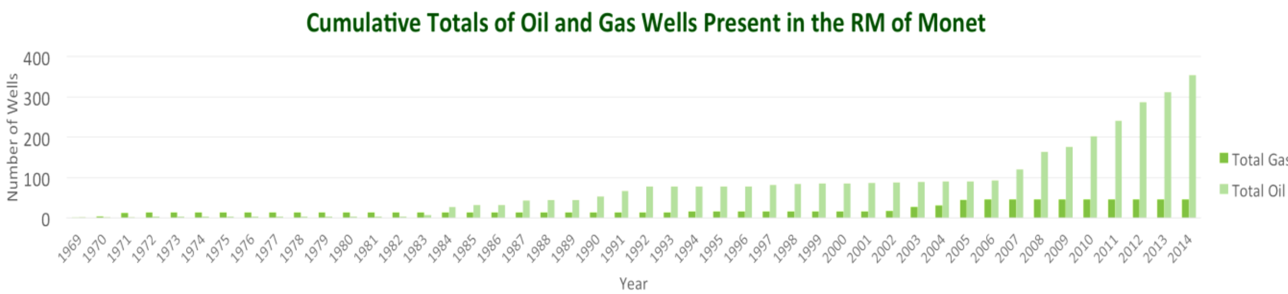
Additionally, in some RMs such as the RM of Monet, bylaws dictate that the oil and gas company also obtains a Development Permit (Town of Elrose & RM of Monet #257, 2013). Lastly, a well license is required prior to drilling on Crown and private land (PCAP, 2005).

Oil and gas royalties paid to the province of Saskatchewan were modified in 2002 to create a more competitive investment environment and a more simplified tax regime (Saskatchewan Industry and Resources, 2002). The changes in 2002 decreased some taxes and introduced a new 'fourth tier' royalty that applies to oil and gas wells with a finished drilling date on or after October 1, 2002. For example, one change reduced the corporate capital tax surcharge from 3.6% to 2.0% (Saskatchewan Industry and Resources, 2002).

Modifying policy to create a more competitive and attractive investment environment means that oil and gas companies are more likely to begin development. PNG development is important to Saskatchewan's economy, contributes to provincial revenue, and adds to the overall supply of oil and gas in the world. Incentives to increase production could have been a factor in the rapidly increasing number of wells on the native prairie in the RM of Monet. Additionally, the cheaper leasing fees for pastureland are an added incentive to develop on pasture rather than cultivated land, which could pose a challenge to native prairie in the region.

Since it became potentially easier and cheaper to invest in Saskatchewan while oil and gas prices were strong, the number of oil and gas wells increased drastically as shown in Figure 11 below. Increasing oil and gas wells on native prairie decreases the quantity and quality of the remaining native prairie grassland, which is a public loss because the ecosystem goods and services provided by native prairie grassland are lost or decreased as the land is fragmented. An

Figure 11: Cumulative Totals of Oil and Gas Wells Present in the RM of Monet from 1969 to 2014 (Saskatchewan Industry and Resources, 2015).



example of this is decreased quality and quantity of wildlife habitat for SARA species that we have discussed. This boom has produced significant development but recently some changes in the market have occurred. Gas prices are relatively stable and the quantity of wells in the RM of Monet is small compared to the amount of oil wells that have been developed in the RM of Monet. This is likely because there is only one pool of gas within the RM and it has already been significantly developed. Similarly, the oil wells already present are densely populated within the oil pools (Figure 12). Thus, there is potential for increased development but it may begin to be less dramatic in future years as reserves run out. On the other hand, our map only portrays the known pools; with future exploration, more could be discovered. It is obvious that not all the pools are shown from the data set we used because some wells occur outside the pools.

It is also worth mentioning that in the past several months, the price of crude oil has rapidly decreased (InvestmentMine, 2015). Several factors have influenced the decline in crude oil price. To begin, demand for oil is low because of improved efficiencies and a gradual switch to renewable energy (The Economist, 2014). Additionally, the market is optimistic about geopolitical risk despite the turmoil in Iraq and Libya, because the oil output in these countries has not decreased. Next, America now produces more of its own supply of oil so it imports less, which creates excess supply and drives the price down. Lastly, the Organization of Petroleum Exporting Countries (OPEC) has decided not to decrease supply to drive the price back up because significant members, such as Saudi Arabia, can tolerate very low prices (The Economist, 2014).

The decrease in price could affect the quantity of oil well development in the RM of Monet in the short-term because it is less profitable. However, judging by the steady increase in wells throughout the recession (2007-2008) and the continued production to date, it is unlikely that oil well development in the RM of Monet will be significantly hindered by falling prices, unless prices continue to plummet further reaching unprofitable levels. More likely, the producers most significantly hindered will be high cost operations such as offshore oil drilling in the Arctic (The Economist, 2014). This is not to say the low prices will not affect some local jobs associated with these wells within the RM of Monet.

Ecosystem goods and services are an important consideration in PNG development as prices and market changes. As was briefly explained in the background report, land use change is driven by different economic incentives that often do not include consideration of ecosystem goods and services, such as the factors contributing to the drop in crude oil prices.

In other words, positive externalities such as aesthetically pleasing views, wildlife habitat and biodiversity that are not included in the price of land create a market price that represents the private and not the social willingness to pay for the land (Field and Olewiler, 2011). One could say the costs of oil and gas development on native prairie grassland only represent private costs, and do not include potential negative effects on wildlife habitat and soil quality that we have outlined. Specific ecosystem goods and services provided by grasslands include filtering sediments and pollution, increasing water filtration, preventing soil erosion, providing pollination and pest control and providing habitat for plants and animals (Kotylak, 2011).

Prairie Farm Rehabilitation Act (PFRA) Lands

A significant portion of the native prairie left in the RM of Monet, approximately 54%, is from current and former PFRA lands. All PFRA land will eventually be Crown land once they are phased out of federal management (Rick Ashton, personal communication).

It is not clear whether the dismantling of the PFRA program will create a significant problem for the remaining native prairie grassland in the RM of Monet. The lands that have been transferred are available for purchase as one block, however, as of yet the 10 pastures in the province that have been returned to the province are being leased under 15 year renewable grazing leases (Rick Ashton, personal communication). The patrons that used the land under the PFRA have first pick, but another entity could buy the land if the former patrons refuse to lease or buy it (Rick Ashton, personal communication). Additionally, the land is subject to no-break no-drain conservation easements, which would severely limit cropland production on former PFRA lands (Rick Ashton, personal communication).

While the land is still predominantly used for grazing purposes, some new development is apparent. Oil and gas development occurred on the PFRA just as it does on Crown land, but with slightly stricter regulations (Rick Ashton, personal communication). Since 2001, two new gas wells, comprising 1.2 ha of land were converted in the former Fairview pasture (Figure 7). It is unclear how much of the old PFRA land may be influenced by cultivation in the future, as the policy decisions about the land are still unfolding but at present, the already converted land is not being used for agricultural production.

Furthermore, there are no known pools of gas wells in the old Fairview community pasture that we are aware of, so future gas well development could be limited (Figure 12).

The benefits provided by the remaining native prairie are still available even though the landscape is more broken up and some land is used for agricultural purposes. A benefit-cost analysis done of the PFRA system that included private, public and government's benefits and costs found a 2.5 benefit-cost ratio, representing the fact that conserving or using native prairie for grazing produces a significant overall benefit (Phillips, 2015). Some of these benefits include soil conservation, preservation of endangered species, access for scientific research, wildlife based recreation and biodiversity.

The province of Saskatchewan is making some effort to retain a few of the public benefits provided by the native prairie, under the PFRA, by continuing to use it for hunting and grassland research in addition to grazing (Phillips, 2015). These benefits, however, only reflect a small portion of the ecosystem goods and services provided by the region because hunting and research are two of a number of goods produced. For example, hunting and research remains but soil quality is negatively impacted and the SARA species habitat is degraded.

Conclusions & Recommendations

Over the course of the past 13 years, native prairie in the RM of Monet has indeed decreased. Major sources of this loss include oil and gas development as well as cultivation. Due to the invasive nature of oil and gas development, the majority of our research was focused on impacts associated with this land use change. The objectives of our project included determining the percentage of remaining native prairie, the impacts that land use change has had on soil quality, and SARA listed species within the RM of Monet.

Using various open sources of data, GIS analysis, and thorough research, we were able to make the following conclusions relative to our objectives. First, the percentage of native prairie remaining in the RM of Monet is 26%, down one percent (1418 ha) from the 2001 assessment. Second, the main implication of the land use change is the fragmentation of SARA species' habitat and the introduction of invasive species into native prairie plant communities. Thirdly, if agricultural activities were to expand into areas of native prairie, due to the generally poor soil quality and agricultural capability caused by factors such as soil texture and topography, then special conservation and enhanced management practices would be needed to prevent soil degradation. Finally, in terms of oil and gas development soil quality is primarily affected by hydrocarbons, metal pollution, and soil compaction.

To better understand the trends and land use change drivers we explored economic factors in the RM of Monet surrounding increased cultivation and PNG development. Included in this analysis was a determination of various ecosystem goods and services that provide benefits to the ecological community and surrounding populations. A majority of the remaining native prairie was found to be in community pastures that have an ambiguous future due to the ongoing dismantling of the PFRA program and formation of public policy. Additionally, recent government incentives have increased the appeal for PNG investment within the province of Saskatchewan.

Our recommendations include furthering research in various areas and potentially implementing new policy or regulations surrounding the remaining native prairie, including the PFRA lands. Specifically, additional research should be conducted to determine the cumulative effects of PNG well development on wildlife and plant SARA species. As of right now, research is limited and the total effects are undetermined. More study is needed to determine the long term and cumulative effects on impacted soils that have been reclaimed.

Ground truthing is recommended as we cannot be certain of the types of land use change (ex. differentiating between tame pasture and cultivated lands) and therefore comments on potential changes in soil quality in these areas may not be accurate assessments.

Overall, conservation is important for preserving the remaining native prairie, however, we do not mean to imply that zero loss of native prairie is necessarily the most efficient or desirable outcome. Assessing the equilibrium between development and conservation is another project in and of itself. It is worth noting that the amount of native prairie lost may not be most efficient because certain benefits of native prairie are not included in private decision-making and the grasslands are already disappearing quickly. With the dismantling of the PFRA system, new questions arise about how the remaining grassland will be managed. Further research on this topic is important to determine the fate of transferred PFRA lands.

Specifically, the grazing co-operatives currently leasing former PFRA lands under grazing leases could form a partnership with an organization concerned with native prairie conservation. For example, the Nature Conservancy of Canada could institute regulations that would preserve the native prairie under similar regulations of the former PFRA system.

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Appendix

Native Prairie in the RM of Monet: Oil and Gas

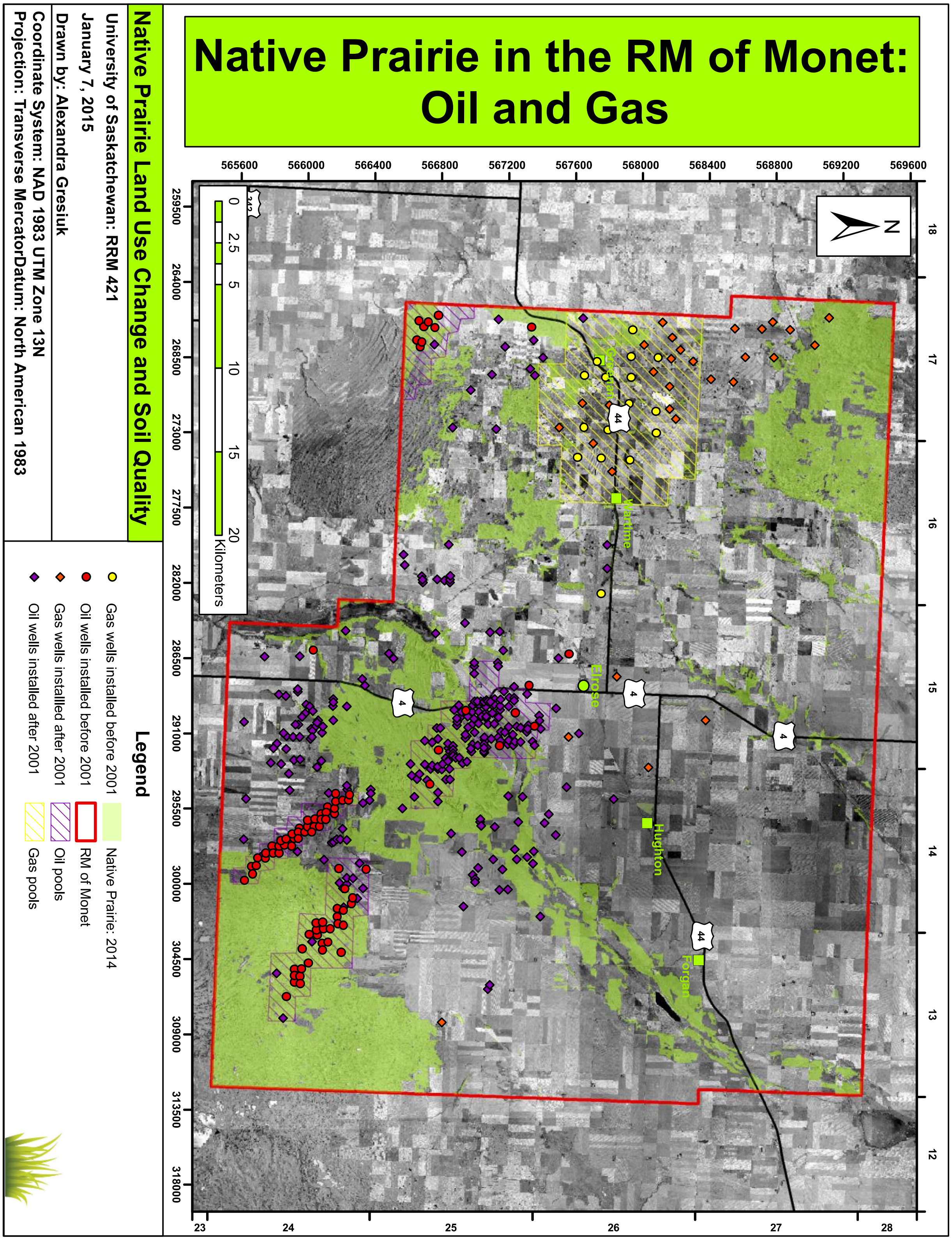

Figure 12: Map showing location and distribution of oil and gas wells and pools in relation to native prairie in the RM of Monet.

Native Prairie in the RM of Monet: SARA Species Sighted

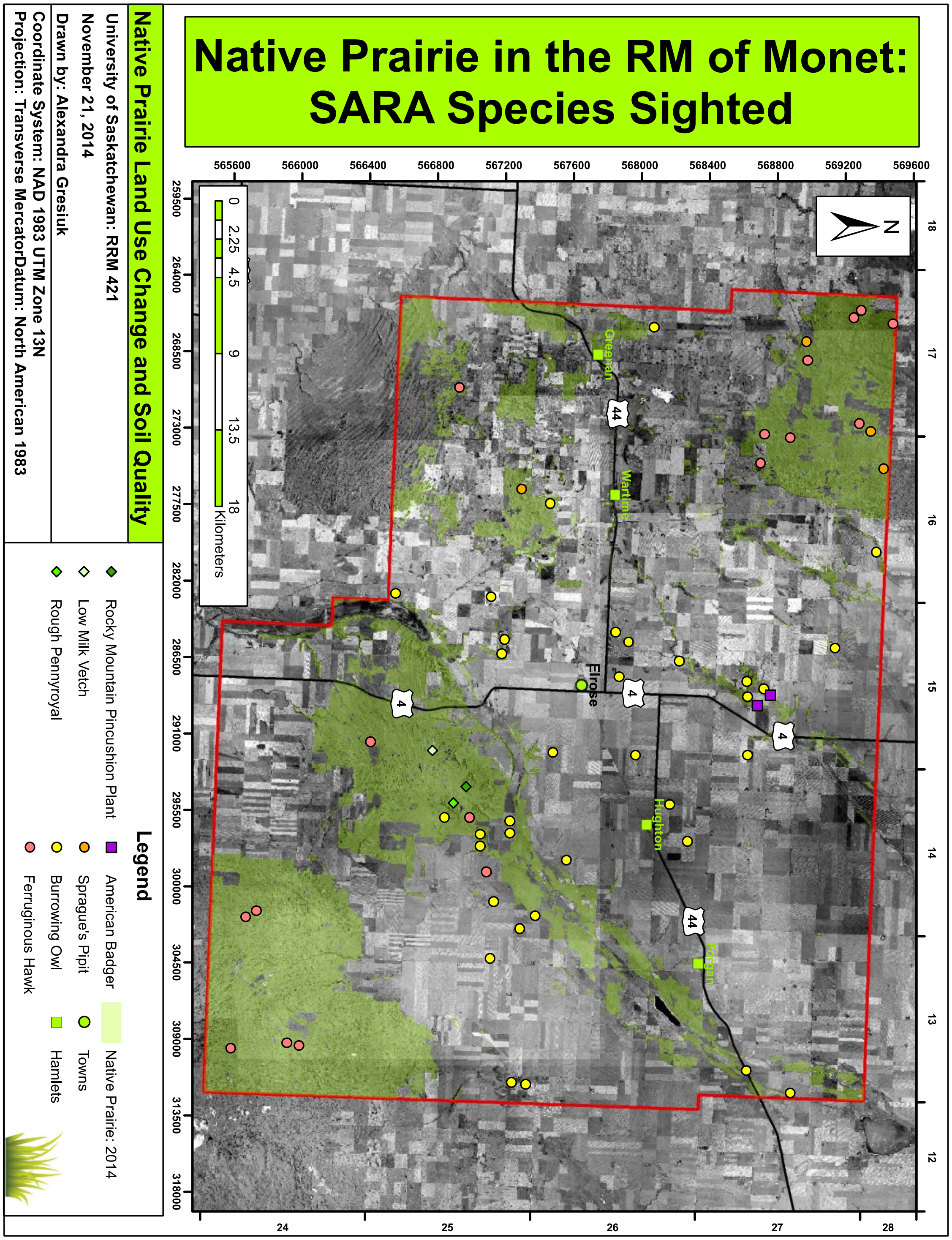

Figure 13: Map showing location and distribution of SARA species sightings in relation to native prairie in the RM of Monet.