

Literature Review-
Quantity of Native Prairie Remaining in Saskatchewan, 2011

For the Saskatchewan Prairie Conservation Action Plan

Complied By:
M-over-C Land & Cattle Co. Ltd.
Julie MacKenzie P.Ag.
Hazenmore, SK
(306)264-3884
njmackenzie@xplornet.com

Lewis and Clark were the first to explore the Northern Great Plains and report on the vastness of grass, wildlife and diverse plant communities across the plains (Kirby, 2010). Since then, the Northern Great Plains (NGP) have changed drastically. Settlement, conversion to annual cropland and modern agriculture have all impacted the quantity of native prairie remaining. This literature review's goal is to gauge the amount of native prairie currently remaining in Saskatchewan. It will also help to identify where knowledge gaps may exist. For the sake of this review, native prairie has been defined as *native aquatic and terrestrial habitats within the Prairie Ecozone of Saskatchewan which includes four eco-regions: Aspen Parkland, Moist-Mixed Grassland, Mixed Grassland and Cypress Upland* in line with the Saskatchewan PCAP's definition and overall goals.

Previous Estimates

In 1994 the Southern Digital Land Cover (SDLC) Digital Data Files were compiled and deciphered by the PFRA (now AAFC-AESB). Many agencies and organizations have used this data and continue to use it today. From the SDLC Hammermister et al. (2001) estimated the amount of native prairie remaining in Saskatchewan at 21%. Hammermister et al.(2001) published this data, which now, 17 years later, is still the source used by many in the native prairie field (Nernberg and Ingstrup 2005, Askins et al. date unknown). The accuracy of classifications of native wetlands and native prairie/tame grass in the southern digital land cover has been questioned since the SDLC was created (Deschamps. personal comm. 2011).

Samson and Kopf (1994) provided estimated current area of tall grass, mixed grass and short grass prairie over the Northern Great Plains. They estimated that 18.7 % of mixed grass prairie and 14.2 % of short grass prairie remained in Saskatchewan. Today, their estimates for the NGP are still widely referenced in current scientific research.

In 2002 Gauthier et al. published data on the amount of grasslands remaining. Although published in the same time frame as Hammermiester et al. (2001), and with Gauthier and McGovern co-authoring on both papers there are differences in the estimation of the total grasslands remaining as Gauthier et al. (2002) define grasslands to generally *include land that is in perennial grasses and herbaceous species for grazing or other uses including native range, seeded tame pasture, abandoned farm areas and other noncultivated uses (e.g. ditches, riparian areas etc.)*. Therefore, some non-native vegetation could be counted in this estimate of 24.4% of grasslands remaining.

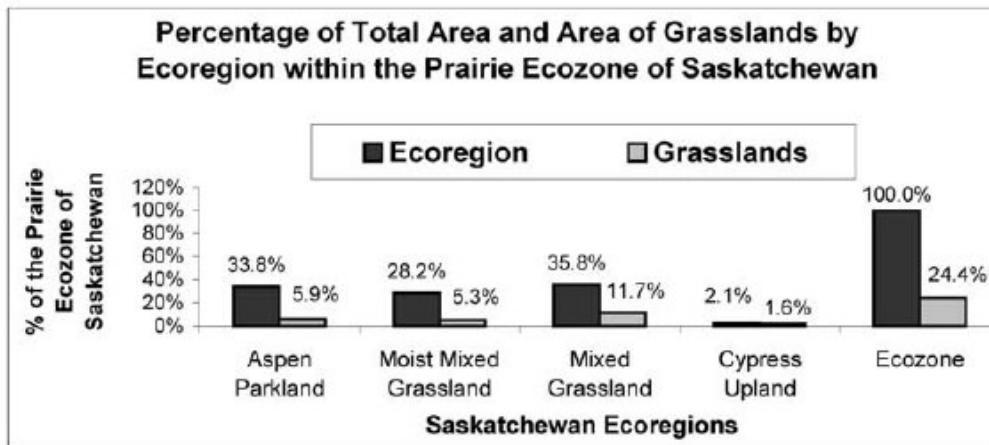


Figure 1. Percentage of Total Area and Area of Grasslands by Ecoregion within the Prairie Ecozone of Saskatchewan (taken directly from Gauthier et al., 2002).

Current Estimates: Saskatchewan

Current estimates of native prairie in Saskatchewan are varying. Over the past 17 years, few consortiums have taken a shot at new estimations.

Environment Canada's Prairie & Northern Region Habitat Monitoring Program for the Prairie Habitat Joint Venture area¹ has conducted on-ground monitoring in Saskatchewan to estimate land use changes and wetland loss in the area from 1985-2001. They concluded it appeared as though wetlands are consistently being lost over time (5% loss) but there are only slight changes in cover and use in the general sense. Native upland losses over the study area occurred in the upland grasslands, low shrub, tall shrub and tree areas at rates of 8%, 5%, 4%, and 3% respectively. Over the same time period, Watmough and Schmoll (2007) estimate overall native grassland area lost within the PHJV study area to be 9%.

Nature Conservancy of Canada's (NCC) *Conservation Blueprint of Canada's Prairies and Parklands* (Riley et al. 2007) gauged the amount of native cover remaining in the Canadian Prairies and Parklands and within each province. The Conservation Blueprint estimates over the entire Canadian prairies only 34% native cover remains and over 90% of land had agriculture practices associated with them. In the Conservation Blueprint, Riley et al. (2007) estimate that 29% of natural cover² remains in Saskatchewan. However, when The Conservation Blueprint was explored further, Thorpe and Godwin (2009) explained that 1) the NCC Blueprint is based on the 1994 Southern Digital Land Cover data, and 2) it does include areas that are outside of the said prairie/parkland ecoregion. Recalculating the area and using Riley et al.'s data, Thorpe and

¹ The Prairie Habitat Joint Venture Area includes data from the Boreal Transition, Aspen Parkland, Moist Mixed Grassland, Mixed Grassland. No data is included from the Cypress Uplands.

² The Nature Conservancy of Canada defines natural cover as major lakes and rivers, grasslands/shrublands, woodlands, wetlands, and mud/sand/saline areas.

Godwin (2009) estimate 26.6% native cover remaining. However, the fact still remains that the 1994 Southern Digital Land Cover data is being used and is 17 years old.

Thorpe and Godwin (2009) used Historic Statistics Canada Data to show the trends in natural cover as reported by producers during the Agriculture Census conducted every 5 years.

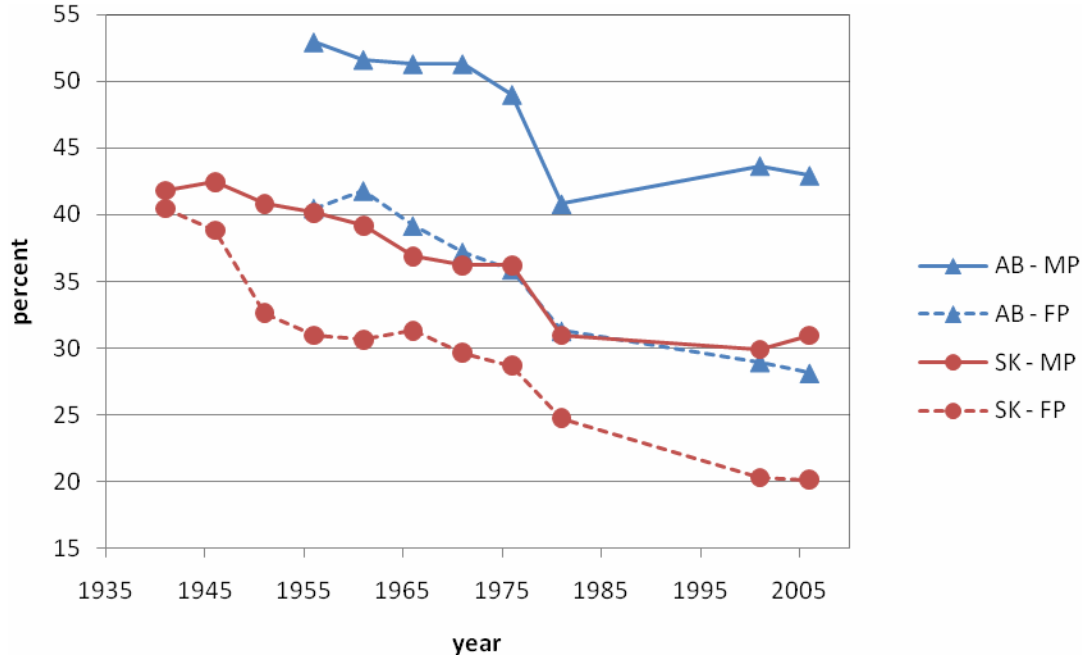


Figure 2. Trends in native rangeland as a percentage of total farmland from 1941 to 2006, based on Census of Agriculture data, for selected Census Divisions in the mixed prairie (MP) and fescue prairie (FP) in Alberta (AB) and Saskatchewan (SK) (taken directly from Thorpe and Godwin, 2009).

Different researchers have used Statistics Canada data in varying ways to calculate the amount of native prairie remaining. Every 5 years Statistics Canada conducts the Agriculture Census in which all land used for agriculture production (including federal and provincial lands) is surveyed for land use as defined by cover types (cropland, native pasture, wetlands, seeded grass).

In 2010 Bailey, McCartney and Schellenberg published *The Management of Canadian Prairie Rangeland* in which they added non-grazed public lands to 2006 Statistics Canada Data. Based on the prairie ecoregion size estimate of 24,096,600 ha in Saskatchewan (Hammermiester et al. 2001), Bailey et al. have estimated that 19.4% of native prairie remains in Saskatchewan.

	<u>Alberta</u>	<u>Saskatchewan</u>	<u>Manitoba</u>	<u>Canadian Prairies</u>
<u>All Lands Grazed: grassland & forest range</u>				
Natural land for pasture*	6,529,916	5,175,864	1,548,223	13,254,000
Crown and PFRA past**	921,884	808,975	167,137	1,897,996
Military rangeland***	419,487	18,000	44,516	482,000
<u>Natural Grassland Only</u>				
Natural grassland*	4,832,120	4,140,707	636,008	9,908,835
Crown & PFRA pasture**	460,942	404,488	83,568	948,998
Military grassland***	299,471	12,000	24,281	335,752
Parks grassland***	80,938	109,266	72,844	263,049
<u>Total natural grassland</u>	<u>5,673,471</u>	<u>4,666,461</u>	<u>1,116,702</u>	<u>11,456,634</u>

*Statistics Canada Census 2006 refers to natural lands that are used for livestock pasture. No information is reported for areas of natural grassland not being grazed by livestock, as found in parks, military bases and other conservation areas.

**From Horton 1994, and McCartney & Horton 1999

***Estimated by the authors

Table 1. Quantity of Native Prairie Remaining on the Prairies broken out by Province- *natural grassland only* figures used in 19.4% calculation (taken directly from Bailey et al. 2010).

Current Estimates: Northern Great Plains

Thorpe and Godwin (2009) compiled historic trend, natural land for pasture as percent of total farmland data for the Canadian Prairies. Trends show an overall leveling, however, the high percentage of overall natural lands remaining is reflective of the high percentage of prairie remaining in Alberta.

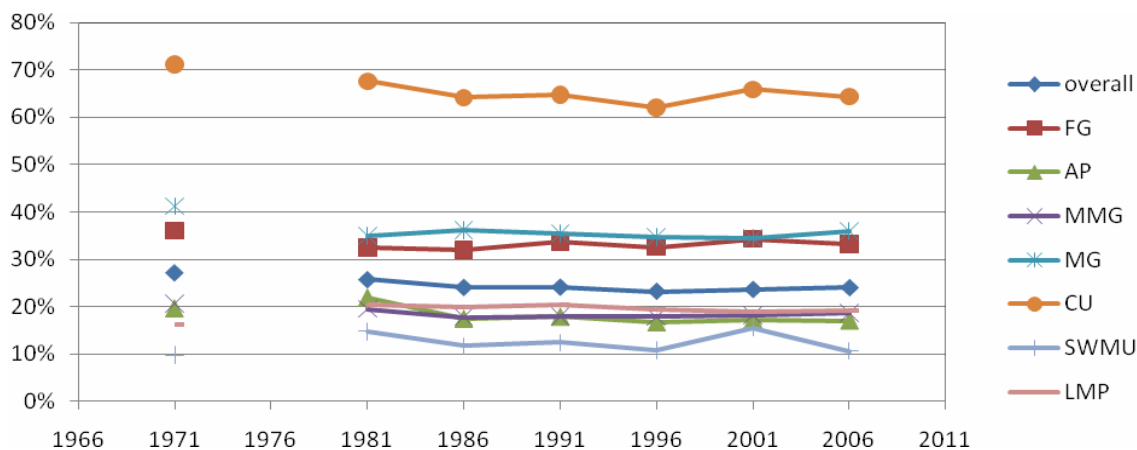


Figure 3. Trend in “natural land for pasture” as a percentage of total farmland, by Ecoregion, based on Census of Agriculture data from 1971 to 2006 (taken directly from Thorpe and Godwin 2009)

Forrest et al. (2004) in the *WWF Ocean of Grass: A Conservation Assessment for the Northern Great Plains* analyzed the 1992 USDA land cover data. They estimated 57% of the NGP grasslands remain “untilled”. However, the authors do point-out some on-going trends today such as continued conversion to cropland in Blaine, Phillips and Valley Counties³ and that the amount of land in the US Federal Conservation Reserve Program is nearly equivalent to the amount of prairie broken since the 1960s.

Samson et al. (2004) report on a coarse scale, that approximately 30% of the Great Plains remains in natural vegetation. The tall grass prairie retains 13% cover, mixed grass prairie retains 29% cover, and the shortgrass prairie retains 51.6% cover. Samson et al. (2004) strongly suggests that although prairie remains, how natural lands function together, patch size, condition, and health play an even greater role in the functioning of the Great Plains ecosystem.

Northern Great Plains Research- changes seen in native prairie; Where are the losses being seen? And why?

Within the Northern Great Plains (NGP) changes in native prairie (including wetlands and uplands) are being seen. Although the literature is from varying geographic locations, it may indicate a trend that can be related back to Saskatchewan. Invasive species, woody encroachment, wetland modifications and cultivation have impacted NGP prairie.

Woody Encroachment

Historically, fire was an ecological process on the NGP. Today, species dynamics have changed within the native prairie with the presence of more woody species. Some acknowledge woody species invasion as a threat to native prairie and its function (Grant et al, 2004; Burkinshaw and Bork 2009).

Over the past 40 years on the Rocky Mountain Forest Reserve (SW Alberta) open grassland has declined from 1,111 ha to 465 ha - a decrease of 58% (Burkinshaw and Bork 2009). Impact of woody species is being seen in North Dakota also. The J. Clark Salyer National Wildlife Refuge⁴ is part of one of the largest continuous tracks of Northern Mixed Grass Prairie, but tree and tall shrub invasion has been prevalent over the past 60 year as discussed in Grant et al. (2004). The cover of trees and tall shrubs has doubled in the last 60 years, with expectations of a conversion to a 100% woodland in another 75 -130 years with a 100% loss of the native prairie structure. Grant et al. (2004) researched the impact habitat change had on grassland birds. They found that even 25% woody cover (primarily aspen and willow) resulted in habitat unsuitable for 9 grassland bird species⁵.

³ Phillips, Blaine and Valley County are directly south of Saskatchewan, in line with Val Marie, Grasslands National Park and Rockglen.

⁴ The J. Clark Salyer National Wildlife Refuge is in Bottineau and McHenry counties directly south of Morden MB, and Turtle Mountain Provincial Park

⁵ Including species: savannah sparrow, bobolink, grasshopper sparrow, bairds sparrow, chestnut collared longspur, upland sandpiper, western meadowlark, Le Conte's sparrow and sedge wren.

Wetland Change

Higgins et al.'s 2002 research confirmed that the ongoing negative perception of having wetlands intermixed with cropland could result in a greater wetland loss in NGP - upwards of 80% more loss to drainage could be expected in South Dakota. Bartzen et al. (2010) found that 90% of wetlands in the prairie pothole region were impacted by agriculture (grazing & cultivation). Changes in how wetland margins and wetland basins are impacted over time are seen below in Figure 4 and Figure 5.

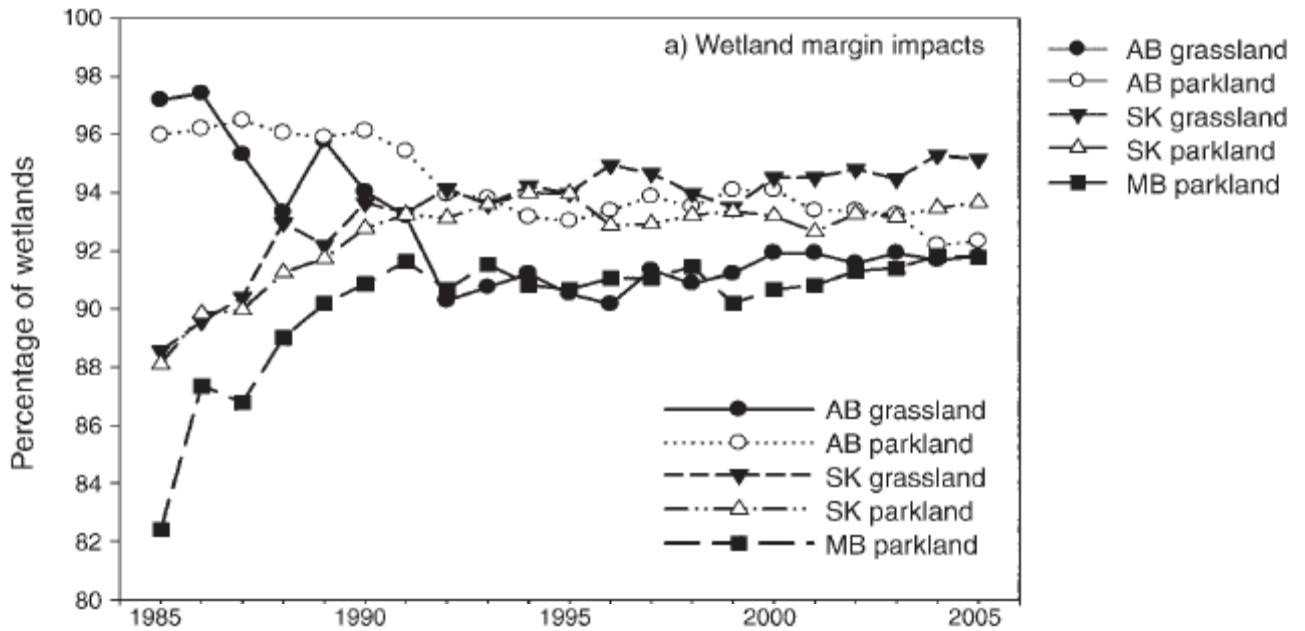


Figure 4. Percentage of Wetland impact along margins over time (Taken from Bartzen et al. 2010)

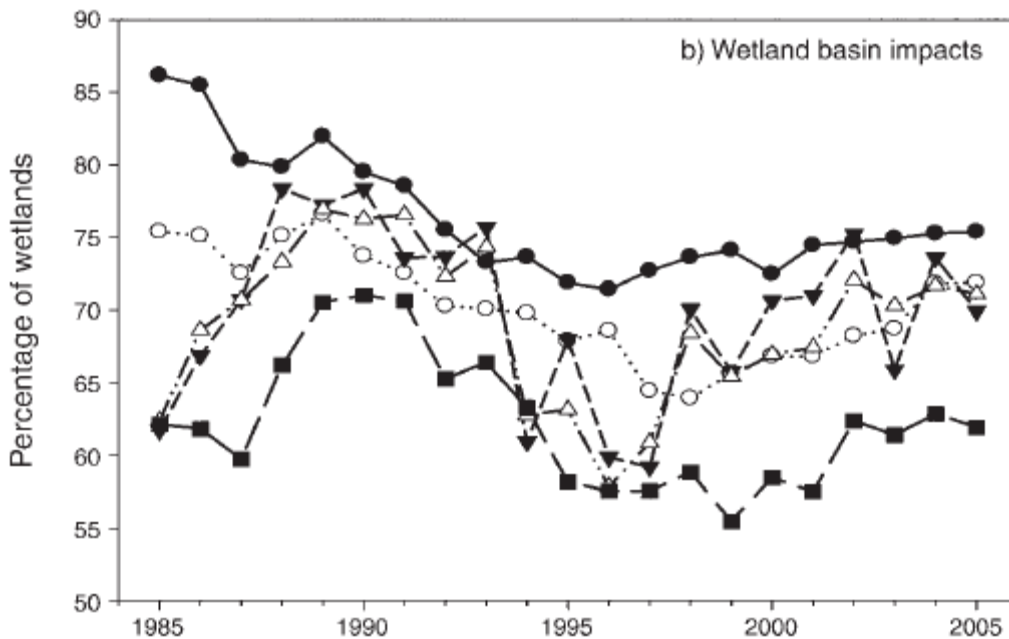


Figure 5. Percentage of Wetlands with basing impact over time (taken from Bartzen et al. 2010).

An effort to conserve wetlands for pintail ducks has been prevalent across the prairie pothole region of the NGP. However, fairly recent research by Skinner and Clark (2008) does sent a noteworthy word of caution. Although wetland conservation in areas of high wetland densities is important and beneficial to pintail ducks, priority grassland bird species such as the Sprague's pipit, chestnut collar longspur and lark bunting are not directly benefiting. To achieve maximum overall benefits the adjoining uplands composition and configuration need to be considered (Skinner and Clark, 2008).

Cultivation Trends

Cultivation trends south of the border have continued to be observed and analyses in recent years. The economics behind continued grass loss point to hardier, drought tolerant corn and soybean varieties, and improved no-till equipment along with a continued rise in corn prices fueled by the biofuels industry. Price increases seen from 2006 (\$2.50/bus) to 2007 (\$4.16/bus) have not declined, but continue to rise (GAO, 2007; Spring Creek Consulting, personal comm. 2010). Acquiring land for conservation can not keep up to grain prices (GAO, 2007). The ability for Conservation Reserve Program land to be put back into annual cropland production as they are released from the program may slow the loss of native prairie (Stephen et al. 2008). However, the construction of 6 new biofuel (ethanol) plants as of 2002 (Higgins et al. 2002) and more since with strong biofuel-orientated federal policies, show no slowing of the pressure for annual cropland.

Stephens et al. (2008) studied the conversion of native grassland to cropland in the Missouri Coteau in northern North Dakota from 1992-2002. Researchers found that 3.2% of the native grassland in the study area was lost over the study period. Stephens et al. estimate that 60,000 ha (148 000 acre) of grassland in the Missouri Coteau will continue to be lost every 10 years moving forward. Within their research, the predictive modeling that Stephens et al. developed was able to correctly forecast conversion of grassland to annual cropland approximately 70% of the time. Predictive modeling may provide those with conservation dollars to spend the ability to positively impact and conserve upland prairie and native wetlands most at risk of cultivation.

Bakker and Higgins reported that between 2001 and 2006 approximately 134,000 ha of prairie in South Dakota was lost to cultivation. Their work, on the habitat use of grassland birds in land is seeded back to perennial species and native species, reiterate the significance of maintaining native prairie habitat. Bakker and Higgins found that grassland bird abundance decreased by 40-60% in non-native grass stands.

Koper et al. studied changes on specific tall grass prairie patches in Manitoba between 1988 and 2006. Of 65 sites monitored, 15 (23%) had been tilled and 9 (13%) had suffered from invasive species to a degree where they would not be able to be restored. Small parcels which remained also continued to become smaller. Prairie is still being lost in Canada (Koper et al. 2010).

Saskatchewan Insight- local trends in the quantity of native prairie remaining

Smaller Saskatchewan studies can provide insight into the landowner's use of native prairie and trends in management. Although applying a sweeping brush painting all native prairie owners the

same is dangerous, smaller studies can provide an indication of what is happening on the ground and an indication of the quantity of native prairie remaining (i.e. decreased or static state).

In 2005, 326 Voluntary Prairie Stewards⁶, controlling 415,881 acres of native prairie were surveyed (SWA, 2005 unpublished data). They were asked questions as to their native prairie management, on-farm land uses and the values they place on their prairie. It should be noted that the demographics surveyed were primarily mixed (66%) or livestock producers (24%) and the remaining crop farmers (about 10%). Only 4 producers indicated that they have broken prairie (approximately 100 acres total), and all stated it was to square cropland fields⁷. Seven out of 326 producers, or 2% of producers did say they were thinking about breaking some native prairie for such reasons as field squaring, lack of productivity, need for farmland and for financial reasons. They listed barriers to the breaking their prairie as money, time, the hardwork involved and conscience. Interestingly, five out of seven of these producers were mixed producers, one was a straight livestock producer and only one was a straight grain producer.

Nature Saskatchewan also employs a suite of voluntary stewardship programs. Grassland retention through the Operation Burrowing Owl Voluntary Stewardship Programming was monitored in 1986 and 1993. LANDSAT imagery showed that within the highly cultivated areas of the Regina and Weyburn Plains voluntary stewards retained 66% of their remnant native prairie vs. non-participants retaining only 49% of remnant native prairie from 1986 to 1993 (Warnock and Skeel, 2004). This is an area where only 2% of native prairie remains (Hammermeister et al. 2001).

In 2009 the Lower Souris River Watershed (LSRW) in the southeast corner of Saskatchewan conducted land-use surveys for an Ecological Goods and Services Pilot Program. Producers (65 % managed livestock) were surveyed as to their past and current land-uses (1998, 2003, 2008).

⁶ As part of the Prairie Stewardship Program, landowners may decide to enter into a voluntary stewardship agreement to maintain and protect their native prairie and/or riparian areas to the best of their ability, notify SWA of any planned land use change that might impact the native prairie and/or riparian areas, and notify SWA of any intent to sell or transfer ownership of the areas under the agreement.

⁷ An overall loss of 0.0024% for what has been voluntarily conserved

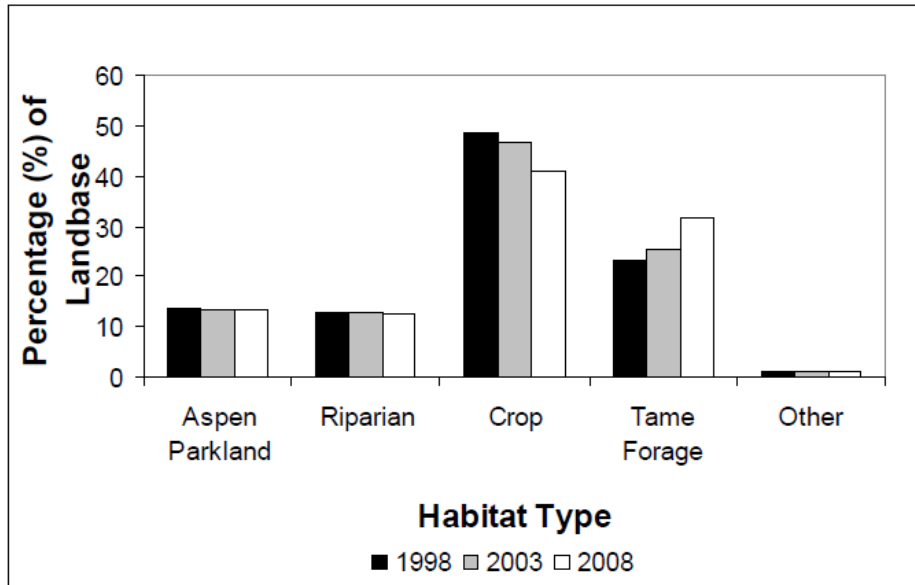


Figure 6. Percentage of surveyed land base in each habitat type during the 1998-2008 time period in the Lower Souris River Watershed (n = 87) (taken directly from Entem et al. 2009).

Results indicated that, over the surveyed land, the % cover of aspen parkland and riparian areas remained virtually static over the 10 year period (Entem, 2009). Overall, surveyed producers did manage higher percentages of native lands (27%) than the area average (15%), which is indicative of their management of livestock (65% of producers surveyed manage livestock).

Where To Go From Here?

This comprehensive literature search has shone the light on the lack of data generated in the past 17 years since the 1994 Southern Digital Land Cover mapping and data generation. The technologies to provide a comprehensive, accurate estimate of native prairie do appear to exist.

Satellite Imagery and Remote Sensing

LandSat imagery is available for approximately 2 cents/ km² (Bedard et al. 2008). Bedard et al. (2008) suggest that land cover classification maps obtain the most accuracy with many late spring and summer images combined. However, current LandSat imagery is requiring greater and greater gap fill which may become problematic over time (Bedard et al. 2008).

Many Canadian-based researchers have written papers on remote sensing that discuss the obstacles surrounding moving forward with nation-wide land use imagery. Creating cloud-free image mosaics, obtaining data during key growing season times, validating the land use program (that defines the image pixel as a certain cover class) with substantial ground truthing, and accuracy of programs are all obstacles (Kerr and Cihlar 2003, Latifovic and Pouliot 2005, and Bedard et al. 2008).

Bedard et al. (2008) cautions that with gap-filled imagery the differences in classification become greater (decreased accuracy) as more classifications are used, such as in natural areas or as terrain becomes complex. For example, in their research a discrepancy of 1.7% on hay/pasture was seen between two sets of imagery. This discrepancy in accuracy may be critical when dealing with the need to detect minute changes in natural habitat.

Latifovic and Pouliot (2005) reported on land cover time-series satellite data in Colorado. In that case there was a minimum accuracy of about 82% initially with the post-detection changes bringing error anywhere from 0% to 38%, which is still a significant error range. However, Latifovic and Pouliot's Canadian work with their further developed methodologies for map-updating, time-series, land cover has agreement over 92%, which is favourable (Latifovic and Pouliot 2005).

AAFC- Agri Geomatics has Circa 2010 Landcover for Ag Regions with data on crop type. With GIS ability, some useful land cover data may be extracted from these files (Agri Geomatics-personal communication 2011).

Grassland researchers continue to utilize different remote sensing techniques for a huge array of projects including estimating abundance of C3 and C4 plants, monitoring grassland health (Foody and Dash 2010, Zhang and Guo 2008) on small, local scales.

Census Data

Shortly, the 2011 Statistics Canada Census of Agriculture will be conducted. Comparing Saskatchewan's 2011 reported land-use to 2006 reported land-use will provide a valuable gauge as to the status of native prairie on-farm and on provincial and federal lands used for agriculture (i.e.-community pastures). Into the future Statistics Canada data should continue to be a vital tool and should be valued.

Key Recommendations

Through conducting this in-depth literature review, knowledge and research gaps have become apparent. To address the knowledge and research gaps the following key recommendations have been suggested for further follow up and discussion within the SK PCAP Partnership.

- 1) Analyze the 2011 census data as soon as available to gauge change from 2006 data. The continual update on Agricultural Land use changes is valuable.
- 2) Determine partners who are able to utilize remote sensing to determine native prairie and natural areas remaining
- 3) Determine and define who needs new data, why, and what uses need to be able to be derived from it.
- 4) Ensure when remote sensing work is carried out enough land use classes are defined that will help to determine what the continued threats are to native prairie (shrub and tree classes, invasive classes, cultivation and non-native perennial forage classes, revegetated native fields).

- 5) Continue to support small scale Saskatchewan studies that can provide insight into on-farm change and/or ground truthing in local areas. Useful insight can be gained.
- 6) Encourage the research of and writing on current and accurate literature on the quantity of native prairie remaining in Saskatchewan, land use changes, and results if prairie conservation efforts are working on the ground.
- 7) Raise awareness and acknowledge the realization that we, in the native prairie community, and as SK PCAP partners are continuing to work on 17 year old land cover data and base prairie estimates on that. For me what hit home was doing a count back- If in 1994, before the Southern Digital Landcover data, we would have been basing estimates on 17 year old figures, it would have been like basing our estimates of native prairie remaining on 1977 statistics.

References

Askins R.A., Chavez-Ramirez F., Dale B.C., Haas C.A., Herkert J.R., Knopf F.L., and Vickery P.D. date unknown. Conservation of grassland birds in North America: Understanding ecological processes in different regions. White Paper for AOU Conservation Committee. Contact Dept Biology, Connecticut College, New London, CT.

Bailey A., McCartney D., and Schellenberg M. 2010. Management of Canadian Prairie Rangeland,. Agriculture and Agri-Food Canada, Government of Canada, Swift Current Saskatchewan.

Bakker K.K., and Higgins K.F. 2009. Planted Grasslands and Native Sod Prairie: Equivalent Habitat for Grassland Birds? *Western North American Naturalist*, 69(2):235-242.

Bartzen B.A, Dufour K.W., Clark R.G., and Caswell F.D. 2010. Trends In Agricultural Impact And Recovery Of Wetlands In Prairie Canada. *Ecological Applications*, 20(2): 525–538.

Bedard F., Reichert G., Dobbins R., and Tre´ Panier I. 2008. Evaluation of segment-based gap-filled Landsat ETM+ SLC-off satellite data for land cover classification in southern Saskatchewan, Canada. *International Journal of Remote Sensing*, 29(7): 2041–2054.

Burkinshaw A.M., and Bork E.W.2009. Shrub Encroachment Impacts the Potential for Multiple Use Conflicts on Public Land. *Environmental Management* , 44:493–504.

Grant T.A., Madden E., and Berkey G.B. 2004. Tree and shrub invasion in northern mixed-grass prairie: implications for breeding grassland birds. *Wildlife Society Bulletin*, 32(3):807-818.

Deschamps, C. 2011. Personal Communication- wetland change. Regina, SK.

Entem A., Unterschultz J., and Jeffery S. 2009. Ecological Goods and Services Survey Summary Prepared for: Lower Souris Watershed Committee. Project Report #09-01, Department of Rural Economy, Faculty of Agricultural, Life and Environmental Sciences. University of Alberta, Edmonton, Canada

Foody G.M., and Dash, J. 2010. Estimating the relative abundance of C3 and C4 grasses in the Great Plains from multi-temporal MTCI data: issues of composting period and spatial generalizability. *International Journal of Remote Sensing*, 31(2):351-362.

Forrest, S.C., H. Strand, W.H. Haskins, C. Freese, J. Proctor and E. Dinerstein. 2004. Ocean of Grass: A Conservation Assessment for the Northern Great Plains. Northern Plains Conservation Network and Northern Great Plains Ecoregion, WWF-US, Bozeman, MT.

Gauthier D.A., Patino L., and McGovern K. 2002. Status of native prairie habitat, Prairie Ecozone, Saskatchewan. Project report to Wildlife Habitat Canada, Number 8.65A.1R-01/02, Canadian Plains Research Centre, Regina, 355 pp.

Gauthier D. A. and Wiken E.B. 2003. Monitoring the Conservation of Grassland Habitats, Prairie Ecozone, Canada. *Environmental Monitoring and Assessment*, 88: 343–364.

Grant T.A., Madden E., and Berkey G.B. 2004. Tree and shrub invasion in northern mixed-grass prairie: implications for breeding grassland birds. *Wildlife Society Bulletin*, 32(3):807-818.

Hammermeister A.M., Gauthier G.A., and McGovern K. 2001. Saskatchewan's Native Prairie: Statistics of a Vanishing Ecosystem And Dwindling Resource. Native Plant Society of Saskatchewan Inc., Saskatoon, SK.

Higgins K.F., Naugle D.E., and Forman K. J. 2002. A Case Study of Changing Land Use Practices in the Northern Great Plains, U.S.A.: An Uncertain Future for Waterbird Conservation. *Waterbirds: The International Journal of Waterbird Biology*. 25: 42-50.

Kerr J. T., and Cihlar J. 2003. Land use and cover with intensity of agriculture for Canada from satellite and census data. *Global Ecology & Biogeography*, 12:161–172

Kirby, D. 2010. The Northern Great Plains as Viewed by the Lewis and Clark Expedition. *Rangelands*, 32(5):2-4.

Koper N., Mozel K.E., and Henderson D. 2010. Recent declines in northern tall-grass prairies and effects of patch structure on community persistence. *Biological Conservation*, 143:220-229.

Latifovic R., and Pouliot D. 2005. Multitemporal land cover mapping for Canada: methodology and products. *Can. J. Remote Sensing*, 31(5): 347–363.

Nernberg D., and Ingstrup D., 2005. Prairie Conservation in Canada: The Prairie Conservation Action Plan Experience. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191.

Riley J.L., Green S.E., and Brodribb K.E. 2007. A Conservation Blueprint for Canada's Prairies and Parkland. Nature Conservancy of Canada. Toronto, Ontario. 226 pp.

Samson F.B., Knopf F.L., and Ostlie W. 2004. Great Plains Ecosystems: Past, Present, and Future. US Geological Survey, USGS Staff Published Research, University of Nebraska, Lincoln NB.

Samson F., and Knopf F. 1994. Prairie Conservation in North America. *BioScience*, 44(6):418-421.

Saskatchewan Watershed Authority. 2005. Voluntary Stewards Survey. Unpublished data, Regina, SK.

Skinner, S.P., and Clark R.G. 2008. Relationships between duck and grassland bird relative abundance and species richness in southern Saskatchewan. *Avian Conservation and Ecology* - 3(1): 1. [online] URL: <http://www.ace-eco.org/vol3/iss1/art1/>

Spring Creek Consulting. 2010. Personal Communication- Biofuels and corn markets. Outlook, SK.

Stephens S.E., Walker J.A., Blunck D.R., Jayaraman A., Naugle D.E., Ringelman J.K., and Smith A.J. 2008. Predicting Risk of Habitat Conversion in Native Temperate Grasslands. Conservation Biology.

Thorpe J., and Godwin B. 2009. Prairie Ecozone Status and Trends Assessment. Draft report submitted to Environment Canada. Saskatchewan Research Council.

United States Government Accountability Office (GAO). 2007. PRAIRIE POTHOLE REGION At the Current Pace of Acquisitions, the U.S.Fish and Wildlife Service Is Unlikely to Achieve Its Habitat Protection Goals for Migratory Birds. GAO Report to the Subcommittee on Interior, Environment, and Related Agencies, Committee on Appropriations, House of Representatives. GAO-07-1093.

Warnock R.G., and Skeel M.A. 2004. Effectiveness of Voluntary Habitat Stewardship in Conserving Grassland: Case of Operation Burrowing Owl in Saskatchewan. Environmental Management. 33(3): 306–317

Watmough M.D., and Schmoll M.J. 2007. Environment Canada's Prairie & Northern Region Habitat Monitoring Program Phase II: Recent habitat trends in the Prairie Habitat Joint Venture. Technical Report Series # 493, Canadian Wildlife Service Prairie and Northern Region.

Wilsey B.J., Martin L.M., and Polley H.W. 2005. Predicting Plant Extinction Based on Species-Area Curves in Prairie Fragments with High Beta Richness. USDA Agricultural Research Service, University of Nebraska, Lincoln, Nebraska.

Young J.E., Sanchez-Azofeifa G.A., Hannon S.J., and Chapman R. 2006. Trends in land cover change and isolation of protected areas at the interface of the southern boreal mixedwood and aspen parkland in Alberta, Canada. Forest Ecology and Management, 230:151-161.

Zhang C., and Guo X. 2008. Monitoring northern mixed grass prairie health using broadband satellite imagery. International Journal of Remote Sensing, 29(8):2257-2271.