LIMITED REPORT

Adaptation to Climate Change in Management of Prairie Grasslands

Prepared for
Prairies Regional Adaptation Collaborative (PRAC)

By Jeff Thorpe
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SRC Publication No. 12855-1E12

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SUMMARY

- Options for adaptation to climate change in management of prairie grasslands were examined as part of Terrestrial Ecosystems component of the Prairies Regional Adaptation Collaborative (PRAC).
- Adaptation options were structured according to the "three Rs":
  - Create **resistance** to change (short-term adaptation)
  - Promote **resilience** to change (medium-term adaptation)
  - Enable ecosystems to **respond** to change (long-term adaptation)
- In grazing management, most of the adaptations that have been discussed are based on short-term resistance to drought or other extreme events. These include reducing cattle herds, finding alternative grazing, increased feeding, and addressing stockwater shortages.
- Medium-term adaptations aimed at increasing the resilience of grazing operations include moderate to conservative stocking rates, maintaining litter cover, more flexible herd structure, and improving water supply systems.
- Long-term response options in grazing management include grassland monitoring, revision of range management standards, changes in grazing and land use strategies, and increases in management flexibility.
- In biodiversity conservation, most of the adaptations that have been discussed are medium- to long-term resilience and response strategies. These include incorporating climate change into conservation plans, increasing protected areas, mitigating other threats to biodiversity such as exotic invasion, and improving information on climate change.
- The strategies most focused on long-term response aim at facilitating the northward movement of species to adjust to the warmer climate. There are two broad approaches, with advantages and disadvantages in different situations: increasing landscape connectivity, and assisted migration of selected species.
- Existing government programs that directly or indirectly address climate change in grassland management are reviewed.
- It is recommended that government agencies use the list of adaptation options provided here to review their current policies and programs, with the aim of identifying those that could be modified or expanded to better address climate change. Options that are not addressed by any current policies should be the focus of new policy development.

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1 INTRODUCTION

The Prairies Regional Adaptation Collaborative (PRAC) is a three-year program on adaptation to climate change in the Prairie Provinces. One of the PRAC themes is Terrestrial Ecosystems, encompassing Forests and Grasslands. The vulnerability of prairie grasslands to climate change was examined in a previous report (Thorpe 2011). Major areas of vulnerability included:

- shifts in vegetation zones, with implications for woody cover, grassland structure, and photosynthetic types.
- changes in average grassland productivity
- increased frequency of drought years with low productivity
- shifts in biodiversity including migration of new species and emergence of new communities.
- increased risk of exotic invasion
- loss of wetlands

The current report examines adaptation options for addressing these vulnerabilities.

2 GENERAL ADAPTATION CONCEPTS

A body of general concepts has emerged around adaptation to climate change.

The response of ecosystems can be characterized in several different ways (Smit et al. 2000):

- sensitivity – degree to which a system is affected by, or responsive to, climate stimuli
- vulnerability – degree to which a system is susceptible to injury, damage, or harm (one part of sensitivity)
- stability – degree to which a system is not easily moved or modified
- resilience – degree to which a system rebounds, recoups or recovers from a stimulus
- resistence – degree to which a system opposes or prevents an effect of a stimulus
- adaptive capacity – potential or capability of a system to adapt to climatic stimuli

Perhaps the most widely used concept is resilience. In the context of rangelands, Walker et al. (2009) considered **resilience** to be the capacity of a system to experience shocks while retaining the same structure, functions, and feedbacks. Resilience has been related to state-and-transition models, in which an area of rangeland may have multiple stable states, with transitions between them caused by disturbance or management (Briske et al. 2005). Resilience is considered to be the amount of disturbance that the system can absorb before it passes over a threshold to a different state (Walker et al. 2009, Gunderson 2000). For example, some semi-arid areas can shift between grassland and shrubland depending on the types of disturbances affecting them. A more resilient grassland would be able to absorb more disturbance before shifting to shrubland. Adaptation to climate change is often characterized in terms of increasing the resilience of the system (Hansen and Biringer 2003, Gunderson 2000, Sarewitz 2011).

However, according to some authors, increasing resilience is only one approach to adaptation. Heller and Zavaleta (2009) contrasted **resilience** with **resistance**. For example, in the context of conservation, a resistance approach would focus on intensive management to secure existing populations, whereas a resilience approach would focus on increasing population adaptation capacity. Millar et al. (2007) extended this to three approaches (the "three Rs"), with examples from forest management:

- Create **resistance** to change – e.g. protect high-value plantations near harvest by control of fire and diseases.

- Promote **resilience** to change – help forests to return to their prior condition after disturbance (e.g. help tree regeneration to get through the establishment phase in order to reestablish a forest)
- Enable ecosystems to **respond** to change – intentionally accommodate change rather than resisting it (e.g. assist range shifts by increasing landscape connectivity or by intentionally moving species); Galatowisch et al. (2009) referred to this approach as "facilitation".

Smit et al. (1999) described several ways in which adaptations vary:

- purposefulness (autonomous vs. planned)
- timing (anticipatory vs. responsive)
- temporal scope (short term vs. long term)
- spatial scope (localized vs. widespread)
- function/effects (e.g. retreat/accomodate/protect)
- form (structural/legal/institutional/regulatory/financial/technological)
- performance (cost/effectiveness/efficiency/implementability/equity)

With respect to timing, Berrang-Ford et al. (2010) noted that responses by individual households (e.g. farming operations) are mainly responsive, whereas anticipatory responses are mainly by government. With respect to temporal scope, Fazey et al. (2010) noted that some adaptations address a short-term problem but exacerbate a long-term problem (e.g. building levees to cope with flooding, leading to more development in the floodplain and loss of flood-storage capacity).

The three approaches proposed by Millar et al. (2007) can be characterized in terms of several of the variables given by Smit et al. (1999):

Approach	**Temporal Scope**	**Spatial Scope**	**Timing**
resistance – resist the influence of climate change	short term	localized	responsive
resilience – return to prior state after disturbance	medium term	localized and widespread	anticipatory
response – adaptively respond to change rather than resisting it	long term	widespread	anticipatory

A variety of more general guidelines for adaptation have been proposed:

- Address climate change in the context of the multiple other drivers affecting the system (e.g. habitat degradation, pollution, etc.), rather than in isolation (Heller and Zavaleta 2009). According to Hansen and Biringer (2003), increasing the resilience of natural systems is a general goal for conservation. Natural systems are already affected by an array of stresses, and climate change will add one more.
- "Mainstream" climate adaptation policies into everyday decisions and actions (Henstra and McBean 2009). Policies on climate change adaptation should be seen as a subset of policies on sustainable development and natural resource management) (Howden et al. 2007). In part, this reflects the political reality that society will not incur large short-term costs for uncertain long-term benefits, so the focus should be on near-term paths towards sustainability (Sarewitz 2011).

- Adapt existing conservation programs rather than building new ones for climate change adaptation (e.g. increase funding for easement programs because of the potential to improve habitat connectivity) (Heller and Zavaleta 2009).
- Maintain the diversity of future options (e.g. maintaining biological diversity increases the options for ecosystem response) (Heller and Zavaleta 2009, Fazey et al. 2010).
- Use the "adaptive management" approach, acknowledging that because of uncertainty and unpredictability, plans have to be continually adjusted using results from monitoring (Gunderson 2000, Hansen and Biringer 2003, Millar et al. 2007, Heller and Zavaleta 2009).
- Use a "toolbox" of treatments and practices that can be selected and combined to fit unique situations (Millar et al. 2007). Applying more than one strategy in moderate amounts allows emphasis to be shifted as conditions change (Fazey et al. 2010)
- Emphasize stakeholder engagement (Henstra and McBean 2009).
- Create positive economic outcomes for local people (Heller and Zavaleta 2009).
- Nurture the human capacity to take up response options (Fazey et al. 2010, Sarewitz 2011).
- Emphasize intergovernmental collaboration (Henstra and McBean 2009, Heller and Zavaleta 2009).
- Enhance institutional flexibility (Millar et al. 2007).

3 AGRICULTURAL ADAPTATION

A wide variety of adaptation options have been discussed for the agricultural sector. Adaptations may be made by producers, who see them as part of ongoing management decisions (Smit et al. 1999), or by governments.

Technological adaptations:

- Develop technologies to harvest water and conserve soil moisture (Smit 1999, Howden et al. 2007).
- Develop new drought and heat-resistant crop varieties (Smit 1999, Bizikova and Boettcher 2010).
- Develop climate forecasting and early warning systems to reduce risk (Smit 1999, Howden et al. 2007).
- Monitor changes in soil, pests, diseases (Bizikova and Boettcher 2010).
- Translate information on climate change impacts to the applications that matter to producers (Bizikova and Boettcher 2010).

Management adaptations:

- Alter timing or location of cropping activities (Smit 1999, Howden et al. 2007).
- Increase irrigation, or alter amounts and timing of irrigation (Howden et al. 2007, Smit 1999, Bizikova and Boettcher 2010)
- Manage crops on uplands to reduce runoff (Bizikova and Boettcher 2010).
- Manage excessive water (Howden et al. 2007)
- Change from conventional to conservation tillage (Smit 1999, Bizikova and Boettcher 2010).
- Alter crop varieties/species to those with more climatic suitability (Smit 1999, Howden et al. 2007, Bizikova and Boettcher 2010).
- Change crop rotations (Bizikova and Boettcher 2010).
- Plant shelterbelts (Bizikova and Boettcher 2010)

- Improve effectiveness of pest, disease and weed management (Howden et al. 2007, Bizikova and Boettcher 2010).
- Change land use (Smit 1999)
- Substitute resources and inputs (Smit 1999); e.g. alter fertilizer rates (Howden et al. 2007) or inputs of organic matter (Bizikova and Boettcher 2010)
- Adaptations related to grazing management (discussed in Section 4).

Financial adaptations:

- Diversify income through integration with other activities (Howden et al. 2007, Bizikova and Boettcher 2010).
- Buy private insurance (Smit 1999).
- Government subsidy and support programs (Smit 1999).
- Government ad hoc assistance and compensation (Smit 1999).
- Government programs and policies related to land and water use (Smit 1999).
- Where climate impacts may lead to major land use change, provide support for industry relocation and migration of people (Howden et al. 2007).
- Financial incentives for resiliency (Bizikova and Boettcher 2010).
- Market linkages and integration (Bizikova and Boettcher 2010).

Integrated measures

- Practices that benefit both adaptation and mitigation (e.g. tree planting, wetland restoration, tillage practices that maintain soil carbon) (Bizikova and Boettcher 2010).
- Identify common interests and potential conflicts across sectors (e.g. watershed planning; development of markets; invasive species management; farmland protection for Ecological Goods and Services; land use planning in the urban/rural interface) (Bizikova and Boettcher 2010).

4 ADAPTATION AND RANGE MANAGEMENT

Most of the literature on adaptation in grazing management relates to **short-term actions**, usually in response to drought. In the terminology of Millar et al. (2007), these adaptations represent a **resistance** strategy, in which producers try to resist the effects of an adverse event. While most of the actions are taken by producers, there are also roles for government, such as helping producers to find rental pastures or other alternative grazing.

Grazing management

- Assess your options at the first sign of drought (AARD no date).
- Use seasonal climate forecasts to make stocking decisions; in Australia only 30-50% of land-holders use them (Marshall et al. 2011).
- Evaluate your livestock inventory (AARD no date).
- In drought years, reduce stocking to balance demand with forage supply, preferably making reductions early in the season (BCMAFF 2005, AAFC 2010, AARD no date).
- The yearling component of the herd can be sold or put into the feedlot (AARD no date).
- The next step is to cull the cow herd, culling heavily the older cows, cows with physical defects, open cows, or cows that have difficult births, and keeping healthy, early to middle age cows (AARD no date).
- Wean calves early, and sell early-weaned calves (AARD no date, BCMAFF 2005).

- Graze reserve or buffer fields (AAFC 2010).
- Graze last year's crested wheatgrass litter (AAFC 2010).
- Rent additional pasture (BCMAFF 2005).
- Use forested rangelands if available (BCMAFF 2005).
- Improve distribution of livestock by water, salt, fencing, or herding (BCMAFF 2005, AAFC 2010).
- Distribute cattle across more fields in those areas where rangelands are more sensitive to erosion (AAFC 2010).
- Fertilize to increase grass production (BCMAFF 2005).
- Do not assume that the drought will end next year (BCMAFF 2005).

Cropland and hayland:

- Convert cultivated acres to temporary pasture by seeding annuals (usually oats, also fall rye, winter wheat, triticale); spring-seeded annuals can be grazed in July, giving perennial pasture a rest (AARD no date, BCMAFF 2005, AAFC 2010).
- Graze failed annual crops (AAFC 2010).
- Graze stubble fields after harvest (BCMAFF 2005, AAFC 2010).
- Swath grazing of cereals in winter (BCMAFF 2005).
- Graze hay land (AARD no date).
- Change irrigation practices on hay land (BCMAFF 2005)
    - well-timed to reduce water use
    - select species with some drought resistance
    - reduce expectations if you are forced to reduce water use
    - maintain residual plant material

Feeding:

- Extend the feeding period (AAFC 2010).
- Feed your one-year supply of hay (AARD no date).
- Buy additional feed (BCMAFF 2005).

Stockwater and salt:

- Use fields that will run out of water first (AAFC 2010).
- Spread cattle over more fields where water supplies are low (AAFC 2010).
- Ensure that cattle have adequate salt to prevent use of poisonous plants that are salt accumulators (AAFC 2010).
- Use portable stockwater supply (AAFC 2010).
- Fence off water sources that are low (AAFC 2010).

Many other adaptations can be thought of as **medium-term actions** aimed at increasing the **resilience** of grazing operations so they will be better prepared for future droughts or other extreme events. According to Brown and Thorpe (2008), "climate change does not alter the basic principles of range management; if anything, it increases their importance...the resilience-based approach will continue to be a rational strategy for managing rangelands in the face of the uncertainty of climate change."

- Use good range management practices, including appropriate stocking rates matched with pasture production (Howden et al. 2007). Moderate grazing produces deep-rooted plants which are less affected by drought (AARD no date). Maintaining pastures in good to excellent range condition provides the best protection against drought (AAFC 2010). Careful management of native forage includes allowing grasses to set seed, maintaining 10 cm of stubble, and if possible grazing native range during the dormant season (BCMAFF 2005).

- Avoid over-grazing. According to AARD (no date) the worst drought scenario is when there is a history of over-grazing and a large number of cattle. Heavy livestock grazing impacts reduce resilience by compacting soils, reducing infiltration and drying out the soil surface, as well as favouring exotic invasion (Gelbard 2003). According to Adams et al. (2004), the impacts of the drought of the 1930s in southern Alberta were exacerbated by the heavy stocking rates practised at that time. According to Holechek et al. (1999), several studies have shown that ruinous financial losses can occur under heavy stocking and drought, whereas conservative stocking is one of the surest ways to minimize financial loss. A rancher using conservative stocking will forego at worst 10-25% of the profits possible with moderate stocking. However when drought occurs, conservative stocking will give 30-60% higher net returns than moderate stocking.
- Maintain a good litter cover over the soil. This makes pastures more resilient to drought (AARD no date, AAFC 2010). Litter keeps the soil surface cooler and reduces direct evaporation (Willms et al. 1993). The effect of litter has been tested by comparing production between plots from which litter has been experimentally removed with control plots in which litter is still present. In Mixed Prairie, Willms et al. (1986, 1993) found that litter removal reduced production by more than 50%. However, in the moister Northern Fescue Prairie, Willms et al. (1986) found that litter removal had no effect on yield. These results suggest that litter has the greatest beneficial effect in drier climates. In the more productive grasslands of moister climates (e.g. tallgrass prairie), excessive litter accumulation can actually suppress production (Vogl 1974). In Saskatchewan fescue prairie, Pylypec and Romo (2003) found that production reached a peak at about 3500 kg/ha of litter, suggesting that accumulations beyond this level could suppress production. In the moister types of grassland, the strategy should be one of maintaining an appropriate level of litter cover, neither too low nor too high.
- After a drought, increase stocking rates gradually over a 1-3 year period (AARD no date)
- Rotational grazing systems are often recommended as good range management practice which will keep pastures healthy, build plant vigour, and reestablish litter reserves (AARD no date, Howden et al. 2007, AAFC 2010). However, there is controversy about the benefits of rotational grazing in the range management literature. Reviews of experimental grazing studies have found that rotational grazing has either no effect or only a small effect on forage production and animal production compared to continuous grazing (Van Poollen and Lacey 1979, Holechek et al. 1999, Derner and Hart 2007, Briske et al. 2008). Holechek et al. (1999) found more evidence of a beneficial effect of rotational grazing in humid areas than in semi-arid or desert areas. All of these studies showed that controlling stocking rate is more important than implementing grazing systems. Briske et al. (2009) addressed the conflict between these scientific results and the overwhelming support for rotational grazing among range professionals. One explanation is that the results are based on experiments in which human variables such as goal setting, experiential knowledge, and decision making are intentionally excluded. Investment in rotational grazing may contribute to greater managerial interest, increase the intensity of management, and lead to increased adaptation. These human variables, which are difficult to quantify in an experiment, may explain the observations of pasture improvement resulting from implementing grazing systems.
- For maximum flexibility, combine perennial tame forages (for spring grazing) with native range; seed more cropland to tame pasture to provide more relief for native grassland; crested wheatgrass is very tolerant of drought (BCMAFF 2005, AAFC 2010).

- Fertilize some tame pastures in good moisture years to take pressure off fields that need recovery (AAFC 2010).
- Shift to a more flexible herd structure: two-thirds to three-quarters as a cow-calf operation, the remainder as yearlings for replacements. Depending on the growing conditions expected for the coming year, one-quarter to one-third of the herd may be grazed, sold or put into the feedlot (AARD no date).
- Maintain emergency pastures that can be used in dry years (AARD no date).
- Maintain a year's supply of winter feed (AARD no date).
- Do not be hasty to reseed depleted range – recovery is rapid with good management (AAFC 2010).
- Ensure an adequate water supply, and monitor water supplies for reliability (AARD no date, Howden et al. 2007). Maintain windmills, use plastic pipe to improve water distribution, use snowfences to increase runoff into dugouts (AAFC 2010).

Compared to the short- and medium-term actions discussed above, there is much less discussion about **long-term actions** aimed at helping grazing systems to **respond** to climate change. However a number of general ideas have been discussed:

- Stocking rates and grazing systems will need to be modified where the seasonality, amount, and quality of forage production have been altered (Morgan et al. 2008).
- Ranchers and land-managers will need to be flexible and proactive in dealing with a more variable forage supply. They will need higher tolerance for fluctuations in herd size (Morgan et al. 2008). Managers will need to respond with unprecedented speed and flexibility (Brown and Thorpe 2008).
- Management flexibility should be the goal at all levels. This will require systems that identify effects of global change at an early stage and implement management responses (Brown et al. 2005). Rangelands must be managed at the landscape and ecosystem level as well as the individual management unit (Brown et al. 2005).
- There will be greater dependence on grass banks and hay supplies (Morgan et al. 2008).
- If there is a change in forage quality, there may be a requirement for more nutritional supplements (Morgan et al. 2008).
- If there is change in vegetation zonation, there may be a need to change animal species (e.g. sheep or goats for warmer/drier climate or more woody vegetation) (Morgan et al. 2008).
- If livestock production becomes economically marginal, land use may shift to ecotourism, hunting, open space, wind energy, or carbon sequestration. (Morgan et al. 2008).
- There may be a shift from equilibrium to non-equilibrium systems. Equilibrium theory is the basis of conventional range management. For example, if rangeland is overgrazed, the standard recommendation is to reduce stocking, which will allow overgrazed grassland to return to equilibrium. But rangelands in more variable environments are non-equilibirum systems dominated by abiotic forces such as drought. They are characterised by pulses of plant growth of unpredictable length and magnitude, rather than convergence around an average level of production (Ellis and Swift 1988). Most arid and semiarid rangelands are non-equilibrium systems, and degradation is permanent on human time scales, so the goal of management is avoiding catastrophic changes (Brown et al. 2005). Climate change in the Canadian prairies is expected to increase variability and unpredictability, so may prompt shifts towards non-equilibrium systems. Non-equilibrium systems have been studied in Kenya (Ellis and Swift 1988) and Inner Mongolia (Li and Huntsinger 2011). Traditional grazing practices in these countries responded to the conditions in a given year, by spreading livestock out over a larger area, or by

migrating to a region with better moisture conditions. Modern land administration, in which defined land units are assigned to individual producers, discourages this type of adaptation. But there are elements of it already in use, especially in the drier parts of the prairies. Practices such as keeping reserve pastures for dry years, grazing on annual crops, and moving cattle to rented land in moister regions, are in some ways comparable to the expanded grazing area practices used by traditional pastoralists.

- There is a need for improved prediction of changes in climate drivers and the effects on rangeland ecosystems at relevant spatial scales (e.g. need for early warning systems, especially for drought) (Brown and Thorpe 2008). Decision support systems that address drought response strategies will help in dealing with a more variable and drought-prone climate (Morgan et al. 2008).
- As climates become more variable and extreme, monitoring will become increasingly important (Brown et al. 2005, Morgan et al. 2008). Monitoring combined with decision support systems based on weather forecasting and models of plant production will be essential for tactical (within-year) decisions (Morgan et al. 2008).
- Data collected from range reference areas (i.e. benchmark sites) will improve understanding of changes in species composition and productivity caused by climate change. More consistent monitoring of these areas is needed, but funding has been inconsistent. Information from range reference areas should be correlated with climate data so that managers can see where shifts are occurring, and use the information for adaptive management (BCMFR 2006)
- Current notions of management based on past ecological knowledge might be inadequate, for example if new plant communities arise (Morgan et al. 2008). Research is needed on how soils and vegetation respond to climate change (Brown et al. 2005). State-and-transition models will be used to represent these changes, and manage against undesirable states. However existing state-and-transition models will have to be modified to incorporate the latest information on impacts of climate change (Morgan et al. 2008)
- See additional material on long-term adaptation in Section 6 – Adaptation and Biodiversity.

5 ADAPTATION AND WETLANDS

Adaptation ideas related specifically to wetlands include the following:

Planning:

- Broaden climate change programs beyond emission controls to include ecosystem adaptation, specifically wetland and watershed adaptation. (ASWM 2009).
- Beginning with existing watershed plans and other land use planning, determine the processes and actions needed to increase the resiliency of wetlands and watersheds in the face of climate change (ASWM 2009).
- Incorporate adaptation to climate change in water projects (e.g. safety factors for floods and erosion, low-flow protection for fish and wildlife) (ASWM 2009).
- Prioritize wetlands with regard to management and adaptation. (ASWM 2009).
- Carry out or fund demonstration projects illustrating various measures to protect and adapt wetlands to climate change (ASWM 2009).
- Implement watershed programs (e.g. nonpoint source pollution control with buffer strips) (ASWM 2009).

Conservation and restoration:

- More wetland protection and securement will allow society to retain options in the future under any climate change scenario (Sorenson et al. 1998).
- Strengthen controls on drainage of wetlands (ASWM 2009).
- Prevent fragmentation of wetlands (ASWM 2009).
- Create and protect multi-objective corridors for migration of species (ASWM 2009).
- Establish regulatory buffers for all wetlands and waters (ASWM 2009).
- Restore, create or enhance wetland types most threatened by climate change (ASWM 2009).
- Study and address invasive species in climate-stressed wetlands (ASWM 2009).

Management:

- Install water control structures at the outlets of freshwater wetlands (ASWM 2009).
- Divert sediments to nourish wetlands (ASWM 2009).

Information:

- Wetland inventory and mapping (ASWM 2009):
    - identify wetlands most threatened
    - document current changes in wetlands that may be related to climate change
- Establish wetland reference sites to document the impacts of climate change and to determine the effectiveness of management and adjustment strategies (ASWM 2009). Adaptive management would benefit from a larger network of long-term wetland monitoring sites to detect early signs of warming on water levels and hydroperiod (Johnson et al. 2010).
- Undertake priority research on climate change and wetlands (ASWM 2009):
    - document direct and indirect threats to wetlands
    - prepare and distribute a handbook on BMPs related to wetlands and climate change.
    - document successes and failures of strategies and techniques.
- Study and better understand species that are expected to migrate northward and upslope in order to determine which ones are most likely to support wetland functions and values given climate change (ASWM 2009).

6 ADAPTATION AND BIODIVERSITY

The “three Rs” scheme of adaptation strategies (Millar et al. 2007), used above in the discussion of range management, applies equally to biodiversity management. For example, Galatowitsch et al. (2009) gave examples of **resistance** strategies (e.g. reducing drainage of wetlands), **resilience** strategies (e.g. adding buffers to protected areas), and facilitation (i.e. **response**) strategies (e.g. landscape corridors or assisted migration). However, the literature on agricultural adaptation focuses on the short and medium terms, whereas long-term response strategies are much more prominent in the biodiversity literature.

Many of the adaptation recommendations related to biodiversity have elements of **both resilience and response**. They will improve the ability of species and ecosystems to bounce back from disturbances, but they will also help species and ecosystems to adjust their ranges over the long run. These include the following:

- **Incorporate climate change into biodiversity planning**:
    - Integrate climate change into species and land management plans (protected areas, pest outbreaks, harvest schedules, grazing limits, incentive programs) (Heller and Zavaleta 2009, Mawdsley et al. 2009).
    - Develop dynamic landscape conservation plans, including protected areas and the surrounding matrix, and incorporating predicted shifts in distribution of species (Mawdsley et al. 2009).
    - Review and modify existing laws, regulations, and policies regarding wildlife and natural resource management to account for climate change (Mawdsley et al. 2009).
    - Because of distributional shifts, there will be a need for greater integration of management across wider areas and longer time-scales (Heller and Zavaleta 2009). This will require more coordination between agency jurisdictions and across political boundaries (Hannah et al. 2002, Heller and Zavaleta 2009). Hannah (2009) used the example of a butterfly that is declining in Mexico but stable in California. Conservation of populations in Mexico without considering those in California would be inordinately expensive. In general, planning across a shared border will be more cost-effective than isolated national plans (Hannah 2009).
    - Adapt existing conservation programs rather than starting new ones for climate change (e.g. increase funding for existing conservation easement programs because of their potential to improve habitat connectivity) (Heller and Zavaleta 2009).
    - Develop goals for conservation that take climate change into account. For example, Henderson et al. (2002) presented three alternative models for conservation management, of which the first clearly ignores climate change:
        - the frozen landscape model, which aims to restore the presettlement landscape; this gives an understandable target, but there is no justification for picking a particular point in time as the goal, and becomes increasingly unsupportable with climate change.
        - the as-if-wilderness model, which allows natural processes to take place; this is traditional, inexpensive and painless, but could open the door to sweeping change (e.g. sudden elimination of tree cover).
        - the managed retreat model, in which managers are willing to intervene aggressively (e.g. introduction of new species).
    - Changes in goals may require radical shifts in perspective (Heller and Zavaleta 2009).
        - may need to view a broader range of ecosystem states as desirable, including new communities that maintain function but not necessarily species identity.
        - may need to reevaluate what constitutes an invasive species (e.g. *Pinus radiata* naturalizing in its former range, but outside of its current native range).
        - may need to change restoration guidelines to use species adapted to the future climate, not the current one.
- **Enhance protected areas**:
    - Increase the extent of protected areas (Mawdsley et al. 2009). Modeling shows that creation of new protected areas (i.e. increasing area protected) can improve species conservation as climate changes, and suggests that the best strategy is to add area immediately (Hannah et al. 2007).
    - Increase the number of protected areas, providing redundancy (more than one protected area for each major community type) (Halpin 1997, Heller and Zavaleta 2009, Mawdsley et al. 2009). Because we do not know which types will be most sensitive to climate change,

represent all grassland types across environmental gradients in protected areas (Gelbard 2003). However, representation of community types will become less relevant as climate change leads to new combinations of species (Mawdsley et al. 2009).

- Select protected areas that provide habitat diversity: as large as possible, as much altitudinal and latitudinal variation as possible; areas of high topographic heterogeneity; major transition zones (Halpin 1997, Gelbard 2003, Heller and Zavaleta 2009). Establish a network of protected areas along the elevation gradient, allowing species to shift upward as climate changes (Mawdsley et al. 2009).
- Expand the spatial scale of protected areas through buffer zones (Halpin 1997, Hansen and Biringer 2003, Gelbard 2003, Heller and Zavaleta 2009). This may require restoration of area outside the protected area (Galatowitsch et al. 2009).
- Take climate change into account in selecting new protected areas (Hansen and Biringer 2003). According to Halpin (1997), "A fundamental philosophical question in selecting protected areas... is whether the protected areas are intended to protect the current mix of species over time, or intended to represent arenas for changing species diversity". Many vegetation types and species are expected to lose representation in protected areas with climate change (Hannah et al. 2007, Heller and Zavaleta 2009). Because of constantly changing mixes of species, protected areas cannot be built around particular communities (Hannah et al. 2002). The alternative is to manage and restore ecosystem function rather than focusing on specific components (i.e. stop using historic reference communities as a target) (Mawdsley et al. 2009).Some argue that future protected areas should be in areas predicted to be biodiversity hotspots, whereas others argue that, given the uncertainties, the priority should be on planning protected areas to minimize the distance among them (i.e. increase connectivity) (Heller and Zavaleta 2009).
- Include climate refugia (e.g. cool, moist microsites that allow species to survive heat or drought) in protected areas (Hansen and Biringer 2003, Gelbard 2003, Galatowitsch et al. 2009).
- Enhance genetic diversity by incorporating outliers, areas of high endemism, ecotones, and refugia, because diverse populations are more adaptable (Heller and Zavaleta 2009).

- **Mitigate other threats to biodiversity** besides climate change, such as invasive species, fragmentation, and pollution (Halpin 1997, Hansen and Biringer 2003, Czucz 2010). Non-climatic stresses are often more locally controllable than climate change (Hansen and Biringer 2003).
  - Prevent and control the spread of invasives (Galatowitsch et al. 2009). Manage disturbances so they do not trigger a shift to an invasive-dominated state (Galatowitsch et al. 2009).
  - Maintain natural fire regimes or other disturbance regimes (Halpin 1997, Gelbard 2003). Fire is often used in grasslands to keep out invasives (Galatowitsch et al. 2009). However, fire suppression may slow the transition from forest to grassland, so policy on fire depends on whether the goal is to maintain forest or to allow the transition to occur (Hannah et al. 2002). In some cases fires are suppressed in order to maintain fire-sensitive communities (Galatowitsch et al. 2009). Disturbance prescriptions (e.g. for prescribed burning) may have to be adjusted in accordance with new climates (Galatowitsch et al. 2009).
  - For high-priority species, practice intensive management to secure populations (Heller and Zavaleta 2009). Focus conservation resources on species that might become extinct (but traditional in situ conservation will become increasingly difficult) (Mawdsley et al. 2009).
- **Improve information on biodiversity and climate change**:
  - Study species responses to climate change (Heller and Zavaleta 2009)

  - Increase and maintain biodiversity monitoring programs (Heller and Zavaleta 2009). The need for adaptive management should drive a serious commitment to biological monitoring (Galatowitsch et al. 2009).

Strategies that more specifically address **response**, by helping species and ecosystems to shift their ranges, fall into two broad approaches.

- **Increase landscape connectivity:**
  - Predicted shifts in species ranges are much larger than can be accommodated by expanded protected areas (Krosby et al. 2010).Therefore one of the most frequent recommendations is to increase landscape connectivity by designing connective corridors, removing barriers to dispersal, locating protected areas close to each other, and protecting stepping stones and refugia (Heller and Zavaleta 2009, Mawdsley et al. 2009). Connectivity is one of the main indicators of the climatic adaptive capactiy of natural ecosystems (Czucz et al. 2011). Minor et al. (2009) found that invasive plant species are less limited by connectivity than native plants.
  - There has been extensive research on the biological functions of habitat corridors. A meta-analysis of well-designed experiments showed that corridors increase movement between habitat patches by 50% compared to patches not connected by corridors (Gilbert-Norton et al. 2010). Corridors are more important for invertebrates, non-avian vertebrates, and plants, and less important for birds (Gilbert-Norton et al. 2010). Natural corridors show more movement than manipulated corridors (Gilbert-Norton et al. 2010). The largest experimental study on plants used connected and unconnected clearings in a large, uniform pine plantation (Damschen et al. 2006, 2008, Brudvig et al. 2009). Connected clearings showed higher richness of native plants, including bird-dispersed, wind-dispersed, and unassisted-dispersal species. However this study was small in scale, with corridors 150 m long, compared to the range shifts associated with climate change.
  - Protecting riparian habitats increases connectivity, but can also be detrimental as a conduit for spread of invasives (Gelbard 2003). Existing linear features such as ditch banks and hedgerows are often suggested as corridors, but Dorp et al. (1997) found that they are usually ill-suited because they are too narrow and too disturbed. Modeling showed a strong positive effect of corridor width, with wide corridors having seed migration rates similar to continuous habitats. However, in all situations migration rates of plants were less than 5 m/year (Dorp et al. 1997).
  - More information is needed on optimal design of corridors, with mostly general, common-sense ideas at present (Heller and Zavaleta 2009). There are few examples of corridors designed for species shifts under climate change.
  - The practical effectiveness of landscape corridors has been questioned. Linkage needs differ among species, and protection of large-scale corridors will be very expensive (Mawdsley et al. 2009). According to Galatowitsch et al. (2009), “Landscape corridors, often touted as a way to foster range shifts, are unlikely to be an effective strategy for much of Minnesota given the amount of acquisition and restoration required to create corridors through agricultural landscapes and the low probability that many plant species will jump to these corridors and move at a rate that keeps pace with climate change.” Many grassland plants are slow dispersers, which limits the rate at which they can be expected to migrate even if there are corridors (Dorp et al. 1997, Bischoff 2002, Galatowitsch et al. 2009).
  - A more general approach is to manage the matrix of land uses surrounding protected areas in order to increase the “permeability” to migration of species. Biodiversity-friendly land uses in the matrix (e.g. conservation agreements with landholders) increase the chances for

persistence when climate change affects populations within protected areas (Hannah et al. 2002, Hannah 2009). Minimize fragmentation by land use changes and roads, and protect roadless areas (Gelbard 2003). Restore grasslands (Gelbard 2003), taking into account future climatic conditions (Halpin 1997).
- Protected areas should be close to other protected areas as well as similar unprotected habitat types (Halpin 1997).

- **Assisted migration:**
  - Natural movement may be insufficient for species to keep pace with climate change (McLachlan et al. 2007, Hoegh-Guldbert et al. 2008). Assisted migration is often recommended for species unable to migrate because of poor dispersal or restriction to specific habitats (Heller and Zavaleta 2009).
  - Assisted migration is often contrasted with the goal of maintaining natural species composition. Species brought into an area by assisted migration are by definition exotic to that area, and modern biodiversity policies are opposed to introduction of exotics. However, Johnson and Mayeux (1992) used the paleobotanical evidence of shifts in natural communities through time to argue against the need to conserve any particular plant community. Johnson and Mayeux (1992) took the extreme position that no special significance should be attached to the label "native", but this position appears to ignore the destructive effects of some exotic invasions. A middle-ground approach is to accept short-distance migration within a particular continent. Most invasive problems have been caused by continent-to-continent movement, whereas most assisted migration proposals deal with movement within the same broad biogeographic region (Hunter 2007, Hoegh-Guldbert et al. 2008).
  - Assisted migration is contentious because of difficulty, poor success, and unintended consequences (Heller and Zavaleta 2009). Ricciardi and Simberloff (2008) emphasized the risks, which they say are underestimated by proponents. Movement into regions with close relatives promotes introgression (i.e. gene transfer by interbreeding) that can erode native populations. Guiding the decision by cost/benefit analysis ignores our limited ability to forecast ecological costs. Using invasive behaviour elsewhere as an indicator of invasive potential can give wrong answers (e.g. Australian paperbark tree, which is a threatened species in its native Australia, became highly invasive after introduction to Florida). Introduced species may undergo rapid evolution in the new environment, becoming invasive there. Even movement within continents can cause problems. For example, the widespread planting of eastern redcedar (a small tree of eastern North America) in the Great Plains states has led to invasion of native woodlands and grasslands (Ganguli et al. 2008).
  - Mueller and Hellmann (2008) found that the risk of a species becoming invasive after intra-continental movement are much higher for some groups (e.g. fish) than for others (e.g. plants). They pointed out that there are risks on all sides of the decision: risk of inaction, risk of unsuccessful action, and risk of being too successful (i.e. creating invasion problems). Thorpe et al. (2006) and Ganguli et al. (2008) argued for a risk-assessment procedure for species proposed for introduction, considering such factors as potential for interbreeding with native species, transport of diseases, and invasive behaviour.
  - Assisted migration may be more suitable for some species and sites than others (Hunter 2007):
    - Species that are unlikely to disperse on their own are good candidates; species that have major ecological roles (dominants, keystones, strong interactors) are riskier to

move than those whose role is redundant with others (e.g. an uncommon forest herb); however ecological roles can change over time and space.
    - Candidate sites also differ; a mine site under restoration is more acceptable than a pristine wilderness; an isolated site with unique biota is less acceptable; a site that is currently surrounded by human-dominated landscapes is more acceptable; a site within the previous range of the species is more acceptable.
    - The feasibility of assisted migration depends on the costs and practical knowledge of techniques for safe movement.
  - McLachlan et al. (2007) summarized the contrasting positions on assisted migration in terms of three policy options (more extreme policy options, either maverick unsupervised assisted migration or the opposite "business-as-usual" policy which ignores the risks of climate change, are rejected):
    - Aggressive assisted migration – based on high confidence in predictive models; apply assisted migration to a wide range of species, extensive translocation well beyond the native range.
    - Avoidance of assisted migration – based on high perception of perceived risk, and low belief in our ability to predict which species will become invasive.
    - Constrained assisted migration – based on the balance between benefits and risks, and the belief that assisted migration is necessary to preserve biodiversity despite the risks.
  - In Minnesota, Galatowitsch et al. (2009) argued that the risk is low for gradual shifts of common species. One straightforward way to do this is to make minor changes to restoration practice: broaden seed zones in the geographic direction of projected climate shifts; include many seed sources to maximize genetic diversity; and include some species from climates expected in the near future. Restorations for wildlife habitat, legally required mitigation, and expanding protected areas should provide significant opportunities for assisted migration without introducing species into remnant natural ecosystems. Following large-scale forest mortality, overseeding with mixes including species from adjacent warmer climates may be an effective adaptation strategy that reduces the likelihood of exotic invasion. Assisted migration will be less certain for uncommon species that may have specific habitat requirements, poor dispersal or small populations (e.g. species of calcareous fens or ombrotrophic bogs). But it should be attempted, because these species are most at risk of extinction (Galatowitsch et al. 2009). Planting trees a short distance north of their current range will create habitat for other associated species (Krosby et al. 2010).
  - While assisted migration is usually thought of at the species level, movement of warm-adapted populations within a species is another option (Hoegh-Guldbert et al. 2008). This is being actively pursued in forest regeneration (Ledig and Kitzmiller 1992, Spittlehouse and Stewart 2003, Rehfeldt et al. 1999).
  - At present, there are few legal restrictions on moving non-vertebrate species apart from a few recognized pests (McLachlan et al. 2007, Mueller and Hellmann 2008).

- **Several studies have directly compared the connectivity and assisted migration approaches:**
  - According to Krosby et al. (2010), there is a lower probability of unintended consequences from the connectivity approach compared to assisted migration. Introduction of warm-adapted genotypes can reduce the adaptation of local populations, whereas connectivity allows spread from local populations. Assisted migration may also introduce invasives.

- According to Heller and Zavaleta (2009), there is a continuum of approaches depending on the tolerance for risk:
  - risk-averse - boost resilience, mitigate other threats, protect as much area as possible
  - intermediate – experimentation, build connectivity, diversify cultivars for a range of climatic tolerances
  - risk-tolerant - pre-emptive interventions in response to model predictions, translocate organisms, limit land purchases to future hotspots
- Similarly, Lawler et al. (2010) characterized adaptations by the uncertainty of their outcomes. Lower-uncertainty strategies are likely to be useful regardless of the exact nature of climate change. They may not adequately address climate change impacts, but they are unlikely to have adverse effects. The success of the higher-uncertainty strategies will depend on the nature of future climate change.

high uncertainty	shifting management efforts to new sites, assisted migration
↕	habitat restoration
	restoring flow regimes
	removal of exotics
low uncertainty	increasing connectivity

- Hoegh-Guldbert et al. (2008) presented a decision tree for assisted migration. If the risk of extinction is low to moderate, or if the risk is high but the benefits of assisted migration are outweighed by biological and socioeconomic costs, then the practice should be rejected in favour of less drastic measures such as improving connectivity.

7 SUMMARY OF ADAPTATION OPTIONS RELATED TO GRASSLAND MANAGEMENT

SHORT TERM – RESISTING CHANGE

Adaptation Options	**Producers**	**Government**
Use of drought forecasting tools – monitor precipitation to evaluate current year's growth potential	X	
Reduce stocking • increased sales of yearlings • increased culling of cow herd • reduce stocking rate early, at first sign of drought	X	
Earlier weaning, sell early-weaned calves	X	
Move livestock to alternative grazing • rent pasture in moister regions	X	

• use reserve pastures • seed annual forages on cultivated land • graze failed annual or hay crops		
Improve livestock distribution to make use of underused areas (may require hauling water)	X	
Increase feeding • Feed reserve supplies of hay • Buy additional feed	X	
Address shortages of stockwater: • Use fields that will run out of water first • Haul water	X	
Ensure cattle have adequate salt	X	
Spread cattle over more fields in areas sensitive to erosion, or where water supply is low	X	
Government programs to facilitate the above producer-level adaptations		X
Rental of crown land for emergency grazing		X
Forage insurance programs		X
Ad hoc assistance and compensation programs		X

MEDIUM TERM – PROMOTING RESILIENCE TO CHANGE

Adaptation Options	**Producers**	**Government**
Change herd structure (e.g. increased proportion of yearlings, which can be grazed, sold, or put in the feedlot depending on forage production in a given year)	X	
Plan for alternative grazing areas • plan grazing systems to include lightly used fields as an emergency grass reserve • make contacts for emergency pasture rental	X	
Sustainable grazing management, improving rangeland health • goals: – maintain good to excellent range condition – build plant vigour, deep roots – prevent soil compaction which reduces infiltration – restablish litter reserves (maintain 10 cm of stubble); maintain high litter cover except in moistest regions/sites where litter can be excessive – allow grasses to set seed [?]	X	

• most important factor is controlling stocking rates; follow recommended stocking rates for the region, site, and range condition; adjusting to more conservative stocking rates, especially in drier climates, will increase resilience; avoid over-grazing which increases vulnerability to climate change • rotational grazing systems are often recommended, but note controversies over scientific basis. • use tame pastures to defer grazing on native pasture in spring. • if possible, graze native grasslands during the dormant season • do not assume that drought will end next year • increase stocking rate gradually over 1-3 years after drought		
Convert cropland to annual or perennial forages (provide more relief for native range by complementary grazing)	X	
Plan for increased feed reserves (1 year or more)	X	
Protect stockpiled feed from wildlife	X	X
Improve water storage or water distribution systems • monitor water supplies for reliability • maintain windmills • deepen dugouts • use snowfencing to increase runoff into dugouts • install plastic pipe to extend water supply from a reliable source	X	X
Support programs for conversion to permanent cover		X
Community pasture programs to provide reserve grazing for drought years		X
Increase stakeholder awareness and engagement related to climate change		X
Develop tools for drought monitoring and prediction		X

LONG TERM – HELPING SYSTEMS TO RESPOND TO CHANGE

Adaptation Options	**Producers**	**Government**
Increase stakeholder education, awareness and engagement related to climate change	X	X
Promote flexibility on the part of producers, land-managers, and government agencies in dealing with a more variable forage supply (e.g. consider changing grazing systems or even type of grazing animals).	X	X
Sustainable grazing management, improving rangeland health • goals: – maintain good to excellent range condition – build plant vigour, deep roots	X	X

– prevent soil compaction which reduces infiltration – maintain desirable levels of litter cover • most important factor is controlling stocking rates; follow recommended stocking rates for the region, site, and range condition; adjusting to more conservative stocking rates, especially in drier climates, will increase resilience; avoid over-grazing which increases vulnerability to climate change		
Adjust range management standards if monitoring shows directional trends • adjust recommended stocking rates to reflect changes in productivity • adjust range condition standards and/or state-and-transition models to reflect changes in vegetation composition • emphasize ecosystem function rather than similarity to historic reference communities		X
Promote retention of native grasslands • agricultural incentive programs • land use planning • increase protected areas – make PAs as large as possible – provide buffer zones around protected areas – protect past climatic refugia so they can again act as refugia under future climate change – select areas of high topographic heterogeneity, large elevational gradients		X
Restore grasslands in strategic areas		X
Reduce fragmentation and improve connectivity of grassland areas to facilitate migration of species from the south • develop dynamic landscape conservation plans – control proliferation of residential properties, roads • promote biodiversity-friendly land uses in non-protected areas (e.g. by agricultural incentive programs) • protect riparian areas • select new protected areas in locations that will act as corridors and enhance connectivity • research on optimal design of corridors		X
Wetland inventory and mapping – identify wetlands most threatened by climate change		X
Retain wetlands by restrictions on artificial drainage		X
Restore or enhance wetland types most threatened by climate change		X
Assisted migration for selected plant species • emphasize modest shifts within the same broad biogeographic region, not inter-continental translocation • modify restoration guidelines to facilitate shifts in common species • target programs for species that are dispersal-limited or		X

restricted to uncommon habitat types • following large-scale forest mortality, overseed with mixes including species from adjacent warmer climates • require risk assessment for any translocation		
Reduce other threats to grasslands: breaking, exotic invasion, pollution, overgrazing, off-road vehicle impacts		X
Increase surveillance and control of invasive species		X
Coordination among agencies and institutional flexibility • future range shifts require integration of management across wider areas and longer time-scales • promote institutional flexibility (e.g. managers of crown forest may need to shift from a focus on forestry to focus on livestock grazing, wildlife habitat, etc.)		X
Review of government policies to incorporate climate change • review and modify existing laws, regulations and policies • identify existing government programs that contribute to adaptation, and expand the role of climate change in those programs. • incorporate climate change into planning (e.g. land use plans, watershed plans, conservation plans) • incorporate climate change into BMPs		X
Shift in conservation thinking: • shift from thinking of protected areas as protecting the current mix of species, to being arenas for changing species diversity • reduce emphasis on "representativeness" of protected areas • reduce use of historic plant communities as the goal • accept a broader range of ecosystem states as desirable, including new communities that maintain ecosystem function but not necessarily species identity • reevaluate what constitutes an invasive species • modify fire suppression policy depending on objectives (e.g. retain forest vs allow transition to grassland)		X
Implement monitoring systems to provide information on trends and provide feedback for adaptive management • remote sensing of land cover changes • grassland benchmark sites • wetland monitoring • wildlife surveys, species-at-risk monitoring • analysis of relationships among monitoring results • monitoring of agricultural trends • ranch-level monitoring		X
Ongoing research on how soils, vegetation, biota, land use, and society respond to climate change; develop models for predicting responses.		X

8 PUBLIC POLICY RELATED TO CLIMATE CHANGE AND GRASSLANDS

Public programs and policies related to climate change adaptation in management of grasslands were reviewed for a number of North American jurisdictions.

A review by the Association of State Wetland Managers reported that **Wyoming, North Dakota, South Dakota, Nebraska,** and **Kansas** have not developed climate action plans or taken other actions directly related to climate change (http://aswm.org/wetland-science/81-climate-change-adaptation-summaries/, accessed Oct 26, 2011). A few programs mentioned in this review that are indirectly related to climate change adaptation include regulation of water extraction during drought years (Nebraska), invasive species control (Nebraska), development of a predictive model for invasive species (North Dakota), and development of methodology for wetland inventory (Kansas).

Montana's Climate Change Action Plan (CCAC 2007) deals exclusively with mitigation, not adaptation. A review by the Association of State Wetland Managers reported that Montana is not developing an adaptation plan at this time (http://aswm.org/wetland-science/81-climate-change-adaptation-summaries/1170-climate-change-adaptation-montana, accessed Oct 26, 2011). One current program mentioned in this review carries out beaver relocation, and is intended to promote resiliency of stream/riparian ecosystems during climate change (particularly droughts), including habitat for the rare Arctic Grayling in the Big Hole River watershed.

Colorado's Climate Action Plan mainly addresses mitigation, but has a short section on adaptation. (http://rechargecolorado.org/images/uploads/pdfs/5f7e2afe6caecefd248d140d0514895a.pdf, accessed Oct 26, 2011)

- Water:
    - will pursue a water adaptation plan
    - development of regional hydrological models
    - analysis of water rights and compacts
    - comprehensive drought planning
        - revision of the State Drought Mitigation and Response Plan
        - ongoing drought and water supply assessments
        - development of drought planning and decision support tools
        - participation in the National Integrated Drought Information System
    - ongoing education education and outreach on the importance of drought preparedness
    - information exchange and education
        - with technical, research and education experts
        - maintain a clearinghouse of climate projection data
- Forests:
    - reduce risk of fire by restoring health of forests (thinning, timber cutting, prescribed fire, replanting)
    - use of forest biomass for energy

Minnesota

A review by the Association of State Wetland Managers reported that Minnesota has undertaken a number of actions related to adaptation (http://aswm.org/wetland-science/81-climate-change-adaptation-summaries/1170-climate-change-adaptation-minnesota, accessed Oct 26, 2011).

- Climate change is recognized by the Department of Natural Resouces (DNR) as a key trend on their Conservation Agenda
  - planned adaptations include efforts to create wildlife corridors, improve habitat connectivity, and expand habitat buffers to facilitate plant and animal migration as climate changes (www.dnr.state.mn.us/conservationagenda/direction/climate_change.html, accessed Oct. 27, 2011)
  - will be coordinating monitoring systems and participating in research to detect climate change impacts on natural resources, and track the effectiveness of mitigation and adaptation efforts (www.dnr.state.mn.us/conservationagenda/direction/climate_change.html, accessed Oct. 27, 2011)

- DNR has formed several work groups around specific aspects of adaptation and mitigation. Galatowitsch et al. (2008) (discussed in Section 6 above) is the key foundation document being used.
- Programs:
  - wetlands trends and status monitoring – provides data on achievement of state goal of no net loss in the quantity, quality, and biodiversity of wetlands
  - peatland restoration project
  - study of carbon cycling in peatlands
  - study of carbon burial in shallow lakes
  - study of methane flux in peatlands

In **Canada**, Jacques et al. (2010) reviewed work in climate change adaptation in the agriculture sector (only western provinces shown here):

- British Columbia
  - mostly aimed at securing water supply;
  - planning to ensure that BMPs are geared more to adaptation; support for research;
  - system of protecting agricultural land is considered one of the best policies for climate change adaptation.
- Alberta
  - Alberta Environment's Climate Change Strategy called for adaptation strategies in various sectors;
  - Alberta Agriculture, Food and Rural Development is developing its own strategy
  - Alberta Land Stewardship Act requires watershed committees to produce a land use plan that accounts for climate change;
  - Irrigation Management Climate Information Network provides up-to-date info on irrigated crop water use;
  - Agriculture Financial Services Corporation (i.e. crop insurance) funds weather stations;
  - Environmentally Sustainable Agriculture Initiatives Program supports projects with indirect benefits for adaptation in agriculture
  - Alberta is a member of the Prairie Adaptation Research Collaborative (PARC), which does research on impacts of climate change.
- Saskatchewan
  - Bill 95 calls for the creation of various climate change research and funding organizations

   - Technology Fund could open the door for projects on adaptation in agriculture
   - Saskatchewan Agriculture is working on a climate change adaptation strategy
   - Saskatchewan Agriculture and Saskatchewan Watershed Authority are active in monitoring drought and building the capacities of businesses and communities to deal with drought [not too specific]
   - agreement with University of Victoria for research on climate change impacts
   - Saskatchewan is relying mainly on PARC to assess climate change impacts
- Manitoba
   - Climate Change and Emissions Reduction Act requires Manitoba to report regularly on climate change impacts and adaptation
   - Manitoba Agriculture, Food, and Rural Initiatives plans to work more on adaptation (mostly mitigation up to now)
   - There are plans for extension, communication, policy, agricultural insurance, crop research
   - Participation in PARC
   - Manitoba Sustainable Agricultural Practices Program focuses on mitigation
   - Agricultural Sustainability Initiative encourages sustainable agro-environmental practices (including water quality, environmental goods and services, improvements in crop system efficiency) which contribute indirectly to adaptation
   - Wetland Restoration Incentive Program, Integrated Watershed Management Planning, and Manitoba Ecological Goods and Services Initiative Working Group could also help adaptation
- Summary of main government initiatives
   - research
   - raising producer awareness
   - agricultural insurance
      - premiums are adjusted based on previous losses, so indirectly shift with climate change
      - no more direct effort to integrate climate change into crop insurance
   - indirect support for adaptation through existing programs

Alberta Sustainable Resource Development is developing an adaptation framework for its departmental operations. Adaptation options that have been identified for rangeland management include:

Climate Change Impacts	**Risk**	**Potential adaptation options**

Hydrology and Water Resources

Water quality	M	**People** - Educate public and livestock industry on importance of riparian health
		Process - Cooperatively work with other Alberta Government ministries to create a climate change adaptation strategy for water resource and riparian vegetation

		Technology - Develop long-term monitoring protocol in order to investigate riparian health
		Governance - Market-based policy instruments for rewarding ecological goods and services for achieving healthy riparian areas
Water-use conflicts (quantity)	H	**People** - Multi-stakeholder consultation to ensure open lines of communication and the prevention of disinformation
		Process - Cooperatively work with other Alberta Government ministries to create a climate change adaptation strategy for Alberta's water resources
		Technology - Development of off site watering and water development (wells etc.) or implement grazing management to control livestock distribution and access
		Governance -Need for policy on water development

Biodiversity

Habitat loss and fragmentation of rangeland communities	H	**People** - Multi-stakeholder consultation to ensure open lines by creating a Biodiversity Implementation Plan
		Process - Cooperatively work with other Alberta Government ministries to create a cumulative effects management plan or Land use planning framework
		Technology - Develop inventories and detailed ecological maps and long-term monitoring protocol
		Governance - Market-based policy instruments for rewarding ecological goods and services
Invasive species	H	**People** - communication and awareness on invasive species
		Process - Cooperatively work with other Alberta Government ministries to create a invasive plant species policy
		Technology - Databases to monitor compliance and inventory weed infestations and weed migrations.
		Governance - Develop provincial invasive species policy and branch

Agriculture

Shifting vegetation and	H	**People** -Active involvement of the ranching community to address changes to carrying capacity

grazing zones		**Process** - Shift allowable grazing zones in highly sensitive areas to highly adaptive areas (i.e. sandy areas), may include reducing grazing capacity for all areas
		Technology - Use modeling software to identify areas where grazing is more suited
		Governance - Alter rangeland management practices to target species at the edge of their range where early impacts will be evident (inventory and PVI)
Reduced overall bioproductivity due to poor soil moisture	H	**People** -Active involvement of the ranching community to address issues on drought and riparian grazing
		Process - Identify sensitive grazing areas (develop a policy and identify areas which may have temporary grazing opportunities)
		Technology - Use modeling software (GIS) to identify areas where grazing is more suited, requires detailed ecological information and long-term monitoring
		Governance - Alter rangeland management practices to ensure rangeland health is maintained on all public grazing land

Saskatchewan programs were evaluated by Steinley and Mowchenko (2011) with respect to adaptation to drought and flooding:

- Canada-Saskatchewan Farm Stewardship Program – intended to reduce environmental risk and provide benefits to soil, water, air, and biodiversity; funding support for adoption of BMPs (e.g. improved storage of chemicals and wastes, remote watering systems and riparian area management, conversion to permanent cover, low-disturbance openers, precision farming technology); conversion to permanent cover increases preparedness for both flood and drought.
- Farm and Ranch Water Stewardship Program – intended to assist producers in developing secure water sources for livestock; provides funding support for wells, pipelines, and dugouts; these increase drought preparedness and facilitate improved range management.
- Agri-Environmental Group Planning Program – mostly address water quality within a particular watershed
- Environmental Farm Program – provides funding for all BMPs; e.g. high rate of adoption of precision farming and low disturbance openers.
- These programs have benefits for drought and flood preparedness, but these are co-benefits (programs had other objectives)
  - benefits of conversion to permanent cover increases preparedness – reduces impact of high moisture events and protects soil during droughts.
  - drought preparedness is already a big part of range management practice
- Evaluation of BMPs
  - Pasture management (fencing and remote watering systems) - co-benefit of improved range management (e.g. increased litter reduces soil evaporation)

- Water quality protection (relocation of livestock confinement facilities, farmyard runoff control, modifying and revegetating waterways) – does not help with drought, but does help in reducing pollution and erosion during flood events.
- Forage establishment (convert cultivated land to perennial forages) – co-benefit of forage crop yields being more predictable and stable compared to annual crops; also reduce erosion during droughts and floods; also more likely to yield a hay crop during flood years, compared to annual crops.
- Protection of stockpiled feed from wildlife – co-benefit of increasing storage for drought years

Manitoba has developed a list of initiatives, programs and policies that may promote adaptation to climate change in the agriculture sector:

Initiative/Program/Policy	Objective	Activities	Instrument Type
Provincial Flood Mitigation Strategy	To develop a province-wide flood mitigation strategy for flood proofing flood prone communities and individual residences	Flood forecasting initiatives, construction of dikes, feasibility assessment of flood infrastructure and other flood mitigation activities	Information; infrastructure
Environmental Farm Action Program (EFAP)	Improved environmental performance and sustainability	Producer incentives for BMP adoption	BMP Incentive; Extension
Manitoba Sustainable Agriculture Practices Program (MSAPP)	Climate change mitigation and adaptation	Producer incentives for BMPs, R&D and extension activities	BMP Incentives; Extension
Agro-Woodlot Program Climate Friendly Woodlot Practices	Promote environmentally sensitive logging and forest regeneration	Rejuvenate woodlots & train micro-forestry entrepreneurs	Incentive; Extension
Wetland Restoration Incentive Program (WRIP)	Carbon sequestration, improvements to water quality and quantity	Producer incentive program to restoration previously drained wetlands on private land	Incentives; Technical Support
Integrated Watershed Management Planning (IWMP)	Create common goals for the watershed and a prioritized and targeted action plan	Public consultations, technical and advisory support	Planning; Incentives; Education
Manitoba Organic Transition Program	Increase organic agriculture production and processing in MB	Financial support to help establish an organic operation	Certification; Incentives
Sustainable Development Innovation Fund (SDIF) - Manitoba Water Stewardship Fund (MWSF)	Promote sustainability of Manitoba's environment, human health, social well-being and economy	Financial assistance for research and activities related to Water Protection Act, Watershed management plans.	Incentives

Riparian Tax Credit	Encourage green practices on riverbanks and lakesides	Applicable to agricultural land only	Tax Credit
Odour Control Tax Credit	Reduce odour emissions by reducing cost of equipment required	Available to corporations or individual farmers	Tax Credit
Manitoba Agricultural Services Corporation (MASC)	Support the Manitoba's producers and rural communities, through innovative and targeted risk management and financial programs	Provide a variety of lending and insurance programs for agricultural producers in Manitoba	Loans; Insurance
Environmental Enhancement Loan	Assist financing of more costly BMPs	Finance producer's share of project costs and provide advance on fed/prov contributions	Loan (up to $150,000)
Alternate Energy Loan	Assist with smaller ethanol, bio-diesel, wind and biomass operations	Increase processing of Manitoba agricultural products while encouraging sustainable alternate energy sources	Loan of 0.75 million for individuals and 1.5 million for businesses
Agri-Recovery	Help affected producers resume business operations and/or take actions to mitigate the impacts of a natural disaster as quickly as possible.	Payments to producers who have suffered from a natural disaster.	Financial assistance
Agri-Stability	Provides support when a large margin decline is experienced.	Payments to producers who suffer a large margin decline.	Financial assistance
Trees for Tomorrow Manitoba	Assist in reduction of GHG emissions	Plant 6 million trees by 2012. Free seedlings, site preparation	Free seedlings; Technical Support
Biomass Energy Development	Develop opportunities for the use of biomass energy in Manitoba	Research and demonstration of biomass energy projects	Research; Extension; Information
MAFRI's Diversification Centres (CMCDC, PESAI, PCDF, WADO)	To support innovation, diversification and value-added opportunities in Manitoba	Focuses on applied research and extension on innovation, diversification, value-added, advanced technology, market development and sustainability initiatives that directly benefit producers	Research; Extension; Information

Sustainable Development Innovation Fund (SDIF) - Manitob Climate Change Action Fund (MCCAF)	Promote sustainability of Manitoba's environment, human health, social well-being and economy	Increased public awareness on climate change and measurement of long term GHG reductions;	Information; Extension
Agricultural Sustainability Initiative (ASI)	Improve agricultural ecosystems in Manitoba by encouraging adoption of sustainable practices	Financial incentives for demonstrations of technology transfer projects or sustainable agriculture practices	Extension; Information
Crop Residue Burning Reduction Program	To control smoke dispersion caused by burning crop residues	Provide assistance and extension to producers in terms of proper crop residue burning	Extension; Information
Environmental Farm Plan (EFP)	Identify and reduce on-farm environmental risks	Information workshops, workbook completion and EFP verification	Extension; Information
MAFRI Growing Opportunities (GO) Teams	Provide front line service for MAFRI to the agricultural community in Manitoba	Provide agricultural extension, support and assistance to agricultural producers and industry	Extension; Information
Wetlands - Health of Manitoba's Coastal Marshes: Delta and Netley-Libau	To look at the status and health of Delta and Netely-Libau Marshes with regards to excess nutrients, dredging and invasion of non-native species	Developing management strategies and restoration work at Delta and Netely-Libau Marshes. Studies on historic roles of marshes in reducing the nutrient load from the Red River Basin	Information; Research
Beyond Kyoto – Provincial Climate Change Actions	To reduce GHG emissions to 6% below 1990 levels by 2012.	Implementation of new regulations and policies to protect water resources, improve emergency preparedness for extreme weather events, assess MSAPP for its ability to build resiliency to climate change on the farm	Information; Research and Development
Ecological Goods & Services (EG&S) Pilot Projects	Test and select EG&S policy instrument(s) suitable for Manitoba’s landscape	Conduct EG&S research studies and pilot projects	Research; Information

Adapting Agriculture to Climate Variability on the North Central Great Plains of North America	Gather information and provide guidance concerning the implications of rapid climate change in the north central Great Plains region	Consultations, technical and advisory support	Information
Agro-Meteorology Information System	Provide supportive Ag-Met information for agro-Manitoba	Monitor meteorology patterns, develop decision support systems	Information
EG&S Working Group	Develop an innovative EG&S approach for agro-Manitoba by integrating existing and new policies to provide environmental and socio-economic benefits	Examined policy tools, recommend pilot studies for Manitoba to optimize environmental, social and economic benefits	Information
Prairie Regional Adaptation Collaborative	Build adaptive capacity for decision makers and policy makers to climate change	Three major themes: Water Resources, Drought and Excessive Moisture, and Terrestrial Ecosystems (Forests and Grasslands)	Information
Soil Survey Program	Provide an inventory of soil properties to direct agricultural management practices	Soil sampling and analysis, information presentation	Information
Bioenergy X Bioproducts Team	Coordinate provincial, federal and industry efforts and resources to grow the bioenergy and bioproducts sectors that contribute to environmental sustainability, economic growth and social revitalization.	Develop projects in the context of Manitoba bio-products strategy	Information
Drought Management Planning for Manitoba	To develop indicators and strategies for managing short, medium and long term drought including assuring resiliency for long term events associated with climate change	Collecting background information, analysis and identification of potential indicators for different types of drought, public consultation and development of draft drought management plan.	Information

Western Water Stewardship Council	ADM-level council that addresses issues of common interest among the western provinces and territories such as water efficiency, drought preparedness, watershed governance, and flood management	Collecting background information, analysis and identification of potential indicators for different types of drought, public consultation and development of a draft drought management plan.	Information
Water quality flood sampling for spring 2011	To collect water samples to understand the impacts of flooding on water quality	Flood and water sampling analysis	Information
Re-Evaluation of Flood Mitigation Infrastructure	Re-evaluate effectiveness of existing flood mitigation infrastructure in the light of changing hydrologic realities	Re-calculation of flood frequencies and assessment of the capability of existing flood mitigation	Information
Memorandum of Understanding with South Australia	Develop collaborative projects to deal with reducing flood hazards, long term droughts, and preserving ecological goods and services affected by climate change	Sharing of best practices and learning on issues relating to drought and drought preparedness and flooding and flood mitigation.	Information
Strategic Directions for Water	Three year action plan to develop policy and recommendations for Canada wide water strategy to protect aquatic ecosystems, promote wise use of water, water quality and water quantity management, adaptive strategies to reduce impact of climate change.	Promote positive changes to conserve water and water quality, transition science into policy, develop water valuation and guidance document for water managers. Develop tools to facilitate sharing of water data Canada-wide. Identify and share BMPs	Information
Hydrometric Monitoring System	Bilateral agreement with the federal government to monitor water levels and stream flow	Monitor and measure water level and stream flow using sophisticated monitoring equipment and methods to collect and process the hydrometric data	Information

Agricultural Crown Land Leasing Program	Manage 1.5 million ac of crown land within a multiple resource use framework	Provide crown land to agricultural producers via leases and permits, providing pasture and hay to 20-25% of the province's beef herd.	
The Manitoba Benchmark Project Crown Lands	Verification of crown lands classification and provide basis for crop and livestock extension.	Monitor forage yield and quality on historically grazed native pasture in Manitoba taking into account different soil types and 4 different eco-regions in Manitoba.	Information
Agri-Extension Environment Program	Changes in practice to encourage the adoption of environmentally sustainable agriculture practices	Extension	Extension
Provincial Land Use Planning	To express the provincial interest in the use of land and resources to provide guidance to local planning authorities in the preparation of local land use plans	Advice and education to local planning authorities regarding the preparation of land use plans that integrate social, environmental, economic, and cultural considerations and support community sustainability	Extension
Agri-Food Research and Development Initiative (ARDI)	Provides funding for research and development in agri-food production and processing in Manitoba	Provide an avenue for research and development for projects that result in new farm income streams, growth in the value-added sector, reduced costs for primary production and also those that expand knowledge, translate knowledge into new products and practices, or verify new technology and practices under Manitoba conditions.	Research & Development

9 CONCLUSIONS

The summary of adaptation options (Section 7) represents the main ideas that have been found in the scientific and extension literature. It is recommended that government agencies use this list of options for internal review:

1. Review the list to identify any additional adaptation options that should be included.
2. Review existing programs and policies to identify those which address (directly or indirectly) particular adaptation options.
3. Identify existing programs and policies that could be modified or expanded to better address climate change concerns.
4. Identify adaptation options that are not addressed by any current programs or policies.
5. Develop new programs and policies to address these gaps.

This review has emphasized that there are different adaptation approaches depending on the time-scale:

- In the short term, create **resistance** to change
- In the medium term, promote **resilience** to change
- In the long term, enable ecosystems to **respond** to change

Many existing public policies help to address short and medium term adaptations in management of grasslands. This is because droughts and other extreme events have always been recognized as threats to livestock producers. Existing policies help producers to cope with current droughts, and to increase their resilience to future droughts. Adaptation to climate change will be achieved by "mainstreaming": building on existing policies and programs, and identifying those that need to be modified or expanded if the frequency of extreme events increases with climate change.

However, there is much less public policy that addresses long-term adaptation to climate change. This is largely because of the lack of political support for incurring large present costs to address risks that are somewhat uncertain and that will mostly affect us decades in the future. However certain aspects of long-term adaptation can be mainstreamed into current programs.

- Keeping grassland systems healthy will enhance their ability to respond to future changes. Ongoing programs, including support for sustainable range management practices and control of invasive species, contribute to keeping grasslands healthy.
- Programs aimed at conserving our remaining grasslands and wetlands will help to keep our options open for the future. However, these programs need to be greatly expanded, with adaptation to climate change providing one more reason to do this.
- Ongoing research on climate change impacts will better prepare us for future adaptation.

Other aspects of long-term adaptation present greater challenges:

- The review of adaptation options underscored the need for long-term grassland monitoring. This is needed to detect the rate at which grasslands are changing in response to climate change, to trigger changes in management such as revision of recommended stocking rates, and to measure the success of adaptation programs. However current attempts at grassland monitoring programs, while sustained in some jurisdictions, have lost funding in others. Maintaining support for long-term monitoring through short-term budget cycles will be challenging.
- Helping grasslands (and other ecosystems) to respond to climate change will eventually require measures to help southern species to migrate northward. Whether this is done by designing

landscape corridors, by assisted migration of key species, or by some combination of approaches, this work is not addressed by any current programs.

Mainstreaming climate change considerations into current programs is important, and will probably be the main way in which progress on adaptation is made. However, long-term adaptation will also require raising awareness among governments on the need for new programs.

Native grassland is a vital asset in our future ability to adapt to climate change. The grasslands of the Great Plains evolved in a highly variable climate, and as a result they are more tolerant of climatic extremes than croplands or woodlands. They are made up of a mix of species: taller and shorter species; warm-season and cool-season species; drought-tolerant and moisture-requiring species. Grassland communities vary continuously over a huge area, from Canada to Mexico. Research on previous droughts showed that grasslands adjust by shifts in the proportions of species, while maintaining a grassland ecosystem (Thorpe 2011). Healthy native grassland can do this without expensive management inputs – it is an autonomous system. And this system will continue to support livestock production.

Because of conversion to cropland, native grassland has already been reduced to about 20% of its former extent in the Prairie Provinces (and much less in some regions). While it is easy to shift land use between cropland and tame pasture, it is difficult to recreate native prairie after it is lost. For this reason, destroying our remaining native prairie reduces our future options. In the future climate, we may well find that land now considered suitable for cropland would have been better left in native grassland. Conserving our remaining native grassland, keeping it healthy by reducing threats such as overgrazing and exotic invasion, and helping it to respond to climate change by facilitating northward movement of species, will help the prairies to cope with the coming change.

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