

British Columbia's Grassland Resources and Climate Change

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Abstract

The native grasslands and associated dry woodland ecosystems of the British Columbia Interior are an important economic, biodiversity, and recreational resource. Predicted climate shifts will affect grasses based on their physiology. The balance of trees and grass along the grassland–forest ecotone is particularly susceptible to climate fluctuation but is also influenced by other natural and anthropogenic drivers. Managing for optimum wild and domestic ungulate grazing, fire regimes, and invasive plant control can facilitate enhanced grassland plant community response to climate change. Fire-maintained ecosystem restoration, passive and assisted migration of newly adapted native species, and innovative grazing techniques should be considered when developing future grassland management plans.

KEYWORDS: climate change; dry woodland ecosystems; grasslands

Introduction

The native grasslands and associated dry woodland ecosystems of the British Columbia Interior are an important economic, biodiversity, and recreational resource. These ecosystems also form an integral part of our cultural fabric, contributing to a sense of place-identity for many British Columbians. Although all of the province's ecosystems will experience fundamental shifts as a result of climate change, the unique and complex nature of the Bunchgrass (BG), Ponderosa Pine (PP), and the dry phases of the Interior Douglas-fir (IDF) biogeoclimatic zones deserve a separate treatment. This discussion paper is not intended as a definitive review, but rather to initiate dialogue on an issue that is significant to the livestock and conservation sectors, as well as the interested public.

Summary effects of climate change

A recent paper by Wang et al. (2012), building on earlier work (Hamann & Wang 2006), sets the stage for discussions of climate change impact on British Columbia's ecosystems. Using 1961–1990 weather data, these scientists modelled climate change effects by first documenting the province's climate “envelopes”—a series of biologically relevant climate variables. These data were then correlated with the existing geographical distribution of our 16 biogeoclimatic zones, achieving a good fit. Next, the current biogeoclimatic boundaries were compared with the modelled future (2020) climate data. All three low-elevation zones lose climate habitat from lower-elevation boundaries but gain more along the upper



boundaries. Modelled net gain in area for the 2020 projection is 19% for the BG, 61% for the PP, and 42% for the IDF.

Wang et al. also compared the 1961–1990 biogeoclimatic climate envelopes against 2001–2009 climate data and found that nearly one-quarter of the province's geographic area has already shifted to climates characteristic of different zones. A new and yet unnamed ecological climate envelope, hotter and drier than the current BG zone and not currently found in British Columbia, will emerge, likely in the South Okanagan/Similkameen and the hottest parts of the Thompson River valley. The closest current climatic equivalent of this new zone would most likely be found in the upper Columbia Basin of Eastern Washington.

Wang and colleagues are quick to point out the difference between climate change modelling and the reality on the ground by means of the ecological niche concept. A realized niche is the total geographical area where a species is currently found; a fundamental niche is the area where a species should be found, based on the climatic parameters of its realized niche; and a potential niche is the geographical area where a species could be found, under changed conditions of a future climate. There are many reasons why a realized niche is generally smaller than a fundamental niche: time, soil conditions, insects, disease, fire, pollinators, life cycle length, dispersal ability, terrain barriers, competition, anthropogenic disturbance, and a host of others. These same factors will apply to a species' ability to occupy a potential niche in the future.

In summary, the existing BG, PP, and IDF zones are already experiencing a climate “mismatch” that will become greater in the future; however, for various reasons a lag phase exists in the vegetation response to the mismatch.

Grassland and woodland plant responses to climate change

Direct plant physiological responses to climate change can be divided into three categories: (1) responses to increased temperatures; (2) responses to changed precipitation patterns and amounts; and (3) responses to increased CO₂ concentrations. Amongst the grasses, physiological responses will differ between cool season (C₃) species and warm season (C₄) species (Waller & Lewis 1979). The following physiological generalizations can be made (Eamus 1991; Polley 1997; Alward et al. 1999).

- C₃ grasses, which complete most growth in spring, could stand to gain if an earlier onset of growing degree-days is accompanied by adequate moisture.
- C₃ grasses, forbs, shrubs, and tree species may become more productive with increased CO₂ concentrations, due to reduced photorespiration.
- Increasing nighttime temperatures may increase photorespiration, offsetting any gains from increased CO₂.

Increased ambient CO₂ concentrations allow C₃ plants to limit transpirational gas exchange, so water use efficiency (water required per unit of biomass produced) will increase. C₄ species will show negligible benefits from increased CO₂ but, as their photosynthetic processes are more efficient at warm (25–35°C) temperatures, they may benefit from the longer, warmer summer season if moisture is not limiting.

It is difficult to predict how these mechanisms will operate under field conditions, and to what extent they will offset each other (Hogg & Bernier 2005). Climate change will be experienced by all plants, but the impacts and adaptations will likely be seen first in the herbaceous and shrub community. Trees, with their longer lifecycles, are slower to adapt but also have a greater ability to withstand unfavourable climatic environments (Pielou 1991). One possible outcome is that overall grassland plant productivity may not



change significantly, but the timing of plant growth may shift. The overriding factors are likely to be the availability of moisture and nitrogen, two resources that are typically limiting in dry grasslands and woodlands. A longer frost-free period or more heat units does not equate to greater annual productivity unless additional moisture is available. Reich et al. (2006) suggested that any boost in perennial grass biomass production due to enhanced CO₂ levels would soon be suppressed by a shortage of nitrogen. Other field factors will also affect plant response to climate change.

- Decoupling of plant day-length requirements from seasonal temperature and moisture patterns, leading to reproductive failure
- Increasing frequency and intensity of insect and disease attack
- Changes in soil microflora (such as mycorrhizae), altering plant nutrient status, and resulting in changed community composition
- Decoupling of insect pollinator lifecycles from plant pollination requirements

The predicted longer growing season, coupled with hotter, drier midsummer conditions, will likely favour drought-tolerant plants and those that can take advantage of good spring and fall growing conditions by going summer-dormant. Our key native bunchgrasses, which are all cool-season types, should be able to cope physiologically with increased temperatures, as they do undergo summer dormancy. Most of our important native grasses have extensive ranges to the south of us, so they should have the ability to adapt to longer growing seasons and hotter summer temperatures. Bluebunch wheatgrass (*Pseudoroegneria spicata*) in particular is noted for its ability to adapt to changing moisture regimes (Ganskopp & Bedell 1979; Fraser et al. 2008). A possible exception to this is *Festuca altaica*. Because of its status as a boreal and high-elevation bunchgrass, it is possible that it may be pushed northward out of its current range in the northern areas of the province and extirpated from high-elevation sites in southern British Columbia.

Our grasslands host a few genera in the warm-season C₄ group, such as *Aristida*, *Calamovilfa*, *Panicum*, and *Sporobolus*. These species are currently restricted to specific xeric habitats, but their range may expand with longer, warmer summers if moisture is not limiting. The salt-tolerant riparian C₄ species *Distichlis*, *Spartina*, and *Muhlenbergia* will likely experience habitat losses as shallow ponds go dry but may also gain habitat if larger saline lakes contract and create broader riparian zones. C₄ invasives, such as *Echinochloa*, *Eragrostis*, *Panicum*, *Tribulus*, and *Setaria*, currently of minor importance in the province, may find wider niches, particularly in agricultural settings.

With a longer frost-free season, annual grass species may have increased opportunity to complete spring or fall–spring lifecycles. The invasive annual cheatgrass (*Bromus tectorum*) will be a likely beneficiary; it has the ability to either germinate in the fall, overwinter and mature in the spring, or germinate and mature in spring. Cheatgrass grows at very low temperatures, and is active long before any native grassland species have emerged from winter dormancy and long after they have ceased growth in the fall. *Taeniatherum caput-medusae* and *Eremopyrum triticeum*, two other invasive Mediterranean annual C₃ grasses found in eastern Washington, can be expected to move into the Interior valleys in the future, as could red brome (*Bromus madritensis*), which is currently found in eastern Oregon. The invasion of these Mediterranean annual grasses could be the biggest threat to the province's rangelands in a climate-altered future (Chambers & Pellant 2008).



Short-lived (annual and biennial) species are generally well adapted to changing conditions, and it is not surprising that many of our invasive species have short lifecycles. These species will definitely have a competitive edge as climate envelopes alter and existing perennial vegetation becomes maladapted. Long-lived trees, shrubs, and perennial bunchgrasses will respond more slowly to changing climates and, in fact, may already be products of a previous climate rather than the current one.

Several of our common grassland shrubs (*Amelanchier alnifolia*, *Artemisia*, *Chrysothamnus*, *Purshia*) have deep rooting habits, and may be able to cope with increased summer drought by tapping subsurface moisture until that source is depleted as well.

Every grassland in British Columbia is bounded by a forest. In the southern Interior, percent tree cover (from aerial imagery) is a crude but effective way of characterizing this grassland–woodland–forest ecotone. An open grassland or shrubland will contain up to 10% tree cover, as scattered individuals growing on north slopes or in depressions. Moving upslope (or, in the case of plateau terrain, toward a north slope or depression) into woodland, tree cover values are in the range of roughly 10–30%. This woodland is the true ecotone, where forest and grassland vegetation compete on an equal footing, and the broad boundary shifts back and forth with variations in climate, fire regime, ungulate herbivory, and forest insect infestations. Proceeding into denser tree cover, beyond 30%, sites tend to function as closed forest, with minimal amounts of sunlight reaching the ground, a duff layer, and cooler, more acid soils (B.C. Ministry of Sustainable Resource Management 1997; Taylor & Baxter 1998).

The perennial grasses, forbs, and shrubs of our native upland grasslands are predominantly sun-loving species, and do not thrive under a forest canopy, due to shading and increased competition for nutrients (Moir 1966). At tree cover values of around 15–50% or greater, understorey biomass production drops off, and the sun-loving species are replaced by more shade-tolerant forest understorey vegetation (e.g., Jameson 1967; Dodd et al. 1972).

The lower elevational limit for tree growth is generally determined by moisture availability (Hogg & Bernier 2005), so trees in the woodland ecotone will be the first to experience drought stress induced by climate change. As this stress increases, ecotone trees become less competitive, are more prone to insect and disease attack, and produce fewer progeny (Saporta et al. 1998). Henderson et al. (2002) predicted an eventual near-total loss of the “island forests” of the Canadian prairies because of a predicted decrease in the climate moisture index. These authors also suggested that the decrease in forest cover will not be linear over time but will rather be abrupt, resulting from combinations of drought, insects, and wildfire. Similarly, the contemporary trend of forest ingrowth and encroachment along British Columbia’s grassland–woodland ecotone may reverse itself at some point in the future.

Vegetation changes at the community and ecosystem level

The ecological literature is unanimous in stating that ecosystems and plant communities do not respond *en masse* to climate change, but rather that each species responds individually (e.g., Hebda 1994; Iverson & Prasad 1998; Huntley 2005). Existing ecosystems and plant communities will break up and re-form into totally new groupings as climate change progresses. At that point, our current biogeoclimatic classifications will have to be rewritten.

Plant species respond to changes in climate by adapting in place, migrating, or going extinct. The exact nature of each species’ response will depend on intrinsic factors, such as genetic plasticity, adaptability, lifecycle length, dispersal ability, and competitive ability.



Their response will be further tempered by extrinsic factors, such as insect and disease attack, herbivory, nutrient availability, pollinator availability, and changes to soil microflora. Species with wide distribution and high rates of fecundity will have a competitive edge despite climate change (Aitken et al. 2008).

Climate change-induced ecosystem reorganization can take several different forms (Neilson et al. 2005), including

- *in situ*, with newly maladapted native dominants giving way to minor native species better suited to the new climate;
- native dominants giving way to newly adapted native species from offsite;
- native dominants giving way to non-native invasives; or
- some combination of the above.

Species movement

Only a few studies address the rate of species migration in response to current and past climate change. Kelly and Goulden (2008) tracked species cover over a 40-year period along an elevational gradient in California. The dominant trees and shrubs moved upward on average 65 m in elevation in response to climate warming, increased precipitation variability, and decreased snowfall over the period. A metadata analysis by Parmesan and Yohe (2003) suggested an average northward migration rate of 6 km per decade, based on existing studies. Malcolm et al. (2002) estimated post-glacial plant migration rates at 20–200 km per century, and noted this rate would not keep pace with the future movement of climate envelopes in a doubled CO₂ scenario. They also pointed out that developed areas (cities, suburbs, agricultural lands, etc.) pose a significant barrier to native plant migration.

In a warming climate, adaptation and migration is more successful at the northern limits of a plant's range than at the southern limit (Harding & McCullum 1997). This is favourable for southern Interior grasslands, since most of our species are either in the middle or toward the northern edge of their geographical limits. Thus northern and up-slope population outliers, beyond the contiguous range of a species, could be a valuable genetic resource for both passive and assisted migration.

Rose and Burton (2009) introduced the concept of “temporal corridors” for biogeoclimatic zone and species migration over time. A temporal (as opposed to spatial) corridor is an area currently within the geographical range of a biogeoclimatic zone or species, whose climate parameters will stay within the tolerances of that zone or species into the future. In other words, the temporal corridors constitute “climate refugia.” The BG climatic zone, which currently occupies some 3300 km², is predicted to increase to 44 000 km² by 2080; however, 2300 km² of its current geographical range will remain within the climate tolerances of its dominant species. These refugia can potentially supply propagules to the newly suitable areas. Conversely, the PP climatic zone is also poised for a major expansion, but it will have no temporal corridors.

Correlating existing species ranges with climate parameters, and predicting future movements based on these correlations, is now a well-established process that is continuously being refined with better data and better models. Nevertheless, evidence abounds that extreme climate years and extreme weather events influence species distribution more than yearly mean climate (Parmesan 2005, and references therein). Unfortunately, we have little local understanding of how extreme droughts, frosts, or El Niño–Southern Oscillation events shape grassland plant distribution. We do know, however, that extreme weather events are increasing in magnitude and frequency (Easterling et al. 2000).



Climate change and forage production

Climate change will affect forage quality and quantity for livestock and wildlife. The combination of increasing CO₂ levels, warmer summer temperatures, and declining summer precipitation will result in reductions in forage dietary crude protein and digestible organic matter (Allen-Diaz 1996; Craine et al. 2010). Thorpe et al. (2008) modelled Canadian prairie grasslands for 2050 conditions and found very modest changes in productivity. Following the predicted climate trends, the springtime peak of forage biomass production will likely shift to an earlier date.

Two profound unknowns surround the productivity of British Columbia's future rangelands.

- How successfully will existing grasslands adapt to the new climate?
- Will previous woodland and dry forest sites transition to productive grasslands once they are under the influence of a grassland climate?

These questions form part of a larger discussion of the factors that influence ecological resilience, inertia, and thresholds (see Gunderson et al. [editors] 2010).

The grassland–forest interface

Although native grasslands are complex, dynamic ecosystems, the woodland ecotone is even more complex, as ecotones have high biodiversity and are quite sensitive to changing weather and climate patterns. Fire, forest insects, and ungulate herbivory also play a major role.

The southern Interior's low-elevation woodland interface lies in Natural Disturbance Type 4 (NDT4); that is, "ecosystems with frequent, stand maintaining fires." This classification includes the BG, PP, and dry variants of the IDF (B.C. Ministry of Forests & B.C. Ministry of Environment, Lands and Parks 1995). The frequent fire regime has been almost completely altered as a result of fire suppression and exclusion, triggering forest ingrowth, forest encroachment on to traditional grasslands, and forest fuels accumulation (Strang & Parminter 1980; Taylor & Baxter 1998; Daniels et al. 2007). One of the outcomes of fire suppression in these areas is severe wildfires, resulting from fuel accumulation (Blackwell & Gray 2003). These types of fires (e.g., the 2003 Okanagan Mountain Park fire) often result in loss of biodiversity, forest structure, and soil components. Nitschke and Innes (2008) predicted that climate change will lengthen the province's fire season and increase the severity of fires.

Much of the forest cover along the lower (or drier) edges of the woodland ecotone is of recent post-suppression origin, as evidenced by comparing contemporary and archival aerial photographs (Gayton 1997; Ross 2000; Turner & Krannitz 2000; Gyug & Martens 2002; Bai et al. 2005). Taylor and Baxter (1998) used a similar airphoto approach to determine the rate of ingrowth in two southern Interior NDT4 sites, and then projected forward four decades, assuming current levels of fire suppression. In both sites, a dramatic decrease was evident in areas with less than 15% cover, with a concomitant increase in closed forest types.

Blackwell and Gray (2003) mapped the areas of the southern Interior that fell into a frequent, low-, or mixed-severity historic natural fire regime (Types I and II, similar to the NDT4) and then determined that only 35% of the area was still within its historic natural fire return interval.

Managing grasslands and woodlands for climate change

Richard Hebda (1999) proposed the most effective preparation for climate change is to manage current ecosystems so they are in the healthiest possible state. This does not de-



scribe the current conditions of most of our grasslands and woodlands, particularly those in the southern Interior, which have been subject to long-term overgrazing, fire suppression, soil disturbance, fragmentation, and weed invasion (Demarchi 1971; Forest Practices Board 2002; Gayton 2003; Miller & Fraser 2003; Fraser 2005; Grassland Conservation Council of British Columbia 2005).

The typical benchmark we use for judging ecosystem health is the pre-European contact condition; in other words, we are using past ecosystem states to help us prepare for future ones. This seems ironic until we remind ourselves that the magnitude of the direct changes we have imposed on our grasslands and woodlands over the past 130 years (of European settlement) far exceeds the magnitude of climate change over that same time period.

Several jurisdictions have recently become involved in ecosystem restoration in historically fire-maintained areas of the province, employing proactive thinning and prescribed burning along the grassland–woodland ecotone (Neal & Anderson 2009). These treatments can lessen the likelihood of severe wildfires and increase the resilience of these plant communities to climate change (Fitzgerald 2005; B.C. Ministry of Forests and Range 2009, 2010; Jump et al. 2010).

Many remnant grassland species will survive underneath a recently established post-suppression tree canopy, and these remnants will constitute the main resource for recolonization as climate change begins to inhibit tree growth and reproduction along the woodland ecotone. Reducing grazing pressure in these areas, through longer rotations, reduced stocking, and selective increases in wild ungulate removal via hunting opportunities, may promote grassland species seed set and regeneration. Invasive plants should be controlled along this recolonization band by reducing off-road disturbance, spot-spraying new infestations, and aggressive biocontrol.

The upslope or wetter edges of the low-elevation woodland ecotone consist of semi-closed or closed Douglas-fir, ponderosa pine, or lodgepole pine forests. This is a more problematic zone, since the herbaceous vegetation will consist of either a depauperate remnant grassland community, or forest understorey grass genera such as *Calamagrostis* or *Elymus*. If a delay occurs between the breakdown of the lower woodland ecotone and the upper, closed or semi-closed dry forest types, then some form of sequential or “relay recolonization” can be expected; however, if the collapse occurs simultaneously, then recolonization in the denser forest types may falter.

As tree mortality proceeds along the woodland ecotone, tree litter and coarse woody debris accumulation can trigger a substantial immobilization of key soil nutrients, making it more difficult for grassland species to colonize (or recolonize) the site. In the case of both the closed/semi-closed dry forests and the lodgepole types, the management of downed wood will be an important issue. Managers of these sites will need to find the tricky balance between coarse woody debris, fuel loading, site productivity, and understorey recolonization.

Forest insects play an active role in the grassland–woodland ecotone. The mountain and western pine beetles (on ponderosa and lodgepole pine) and the tussock moth (on Douglas-fir) will respond positively to longer summers and warmer winters (Dale et al. 2001; Cudmore et al. 2010). The woodland ecotone is at the lower moisture threshold for tree growth; thus, as climate warming increases evapotranspirational demand, trees in the ecotone will become stressed and more susceptible to these and other pests.

Some areas of mid-elevation lodgepole pine and Douglas-fir forests, particularly those on level and south aspects, were formerly open grasslands and woodlands (Bai et al. 2000;



Grasslands Conservation Council of British Columbia 2003) and have the potential of reverting to a more productive and resilient woodland state if managed properly.

Maintenance of a healthy litter layer in open grasslands is achievable through proper grazing management, which improves soil moisture status by retarding evaporation (Deutsch et al. 2010); however, excessive litter buildup through the elimination of fire and (or) grazing can weaken bunchgrasses and encourage forest encroachment.

Control of invasives is a critical component of a proactive management approach to grasslands and dry woodlands. MacDougall et al. (2013), working in Garry oak meadows, showed that a pyrogenic meadow dominated by introduced grasses was subject to ecosystem collapse when fire was reintroduced. Early detection and eradication of newly arrived invasives is the most important implement in the weed control toolbox, followed closely by maintaining native vegetation in a vigorous, competitive state. Insect biocontrol of established invasives has been proven not only effective but cost-effective (Frid et al. 2009; Gayton & Miller 2012), and therefore should continue.

The migration of our grassland and woodland understorey species to newly suitable habitats is of fundamental importance, and will depend on individual species dispersal abilities and the ecological condition of the new habitat. Native perennial bunchgrasses do not typically produce large amounts of seed, and respond to grazing pressure by reducing seed set and flowering culm height. The bunchgrasses are long-lived species, and successful establishment of new seedlings is not a common event in dry grasslands (Young & Young 1999). Thus, maintaining the vigour and reproductive capacity of our existing bunchgrasses should be a major management objective. Fragmentation of habitat is a major stumbling block for plant migration and dispersal (Honnay et al. 2002). Low-elevation southern Interior grasslands and woodlands are highly fragmented, as they share valleys and plateaus with urban, industrial, and agricultural developments.

Rose and Burton's (2009) temporal corridors point us to areas where the existing suite of vegetation is likely to persist the longest. These areas, along with the woodland ecotones, can act as healthy genetic reservoirs from which species can migrate northward and upslope to newly habitable areas. Management of these areas could include deferred rest-rotation grazing and the maintenance of ecologically appropriate burning intervals to promote vigour and flowering of the dominant bunchgrasses. Paradoxically, areas of low soil fertility are also more resistant to climate change (Grime et al. 2008) and to weed invasion, and should also be seen as genetic reservoirs.

Assisted colonization (Seddon 2010) can take various forms, and can either be within the current range of a species or strategically placed outside of its range, in anticipation of climate change. A corollary to assisted colonization is the provision of northward and upslope migration corridors for natural movement of species. Many of the critical migration pathways for grassland and woodland species pass through developed and urban areas. For assisted migration and corridor development to be successful, the urban, transportation, and agriculture sectors must be engaged.

We currently lack a short-lived (3–5 year), dryland, agronomic grass species that can be used for stabilizing degraded grasslands and woodlands on a temporary basis; that is, one that would suppress weed invasion, gradually give way to native species, and not persist. The development of such a grass would be of great benefit in restoring degraded sites and enhancing ecosystem resilience.



Biodiversity and species at risk

British Columbia's grasslands and dry woodlands are known hotspots for biodiversity and for species at risk (Austin et al. 2008). Our goal should be to maintain similar amounts of *native* biodiversity over time, not necessarily the current suite of species. Nearly all of our grassland and woodland species at risk are more common to the south of us, and so they should theoretically be favoured by climate change. However, it is safe to say that grassland biodiversity and species at risk face far greater threats from direct human disturbances—such as fragmentation, loss of habitat, and alien species invasion—than they do from climate change, at least on the medium term.

Livestock grazing and climate change

Livestock grazing in the province's southern Interior is currently constrained at lower elevations by urban communities, suburban developments and intensive agriculture, and at upper elevations by the limited forage found under closed forest canopies. If we successfully manage the climate change transition, livestock should have a broader elevational range in which to graze. This may provide the opportunity for some ranchers to move their livestock further away from communities and reduce conflicts; however, the inherent difficulties of mixing forest grazing and silviculture will still remain.

At a certain point in time, the current fencing and watering arrangements may no longer be appropriate. This will mean significant investment in new infrastructure (plus the opportunity to improve on existing fence layouts). In the future, industry and government range managers may want to consider innovative and cost-effective alternatives to the current individual grazing tenures and small, fenced Crown range units. Although challenging to achieve, substantial economies of scale can be gained by amalgamating herds for the grazing season and hiring riders to manage them.

Carbon sequestration on rangelands

Although grasslands and woodlands are a miniscule part of the province's carbon budget, these areas can play a positive role in carbon sequestration. It is useful to remind ourselves that soils hold more carbon, in the form of soil organic matter, than the atmosphere and vegetation combined, and have the potential to hold more (Lehmann & Joseph 2009). Maintaining and enhancing root growth of the dominant bunchgrasses will be the most effective means of contributing to carbon sequestration on provincial rangelands. Research in the United States has shown that proper grazing management can increase soil carbon storage (Schuman et al. 2002). Overgrazed rangelands would likely have the greatest potential for increased soil carbon storage since soil organic matter levels would be below maximum.

Other issues

Charcoal (biochar) from wood waste is a very stable form of carbon, and researchers are currently looking at its potential as an agricultural soil amendment (Lehmann & Joseph 2009). In an ideal scenario, biochar could be produced from woodland restoration thinning treatments and used in adjacent agricultural lands.

Cattle produce methane, which is a very potent greenhouse gas. To date, no breakthroughs have been made in reducing methane production, but livestock contributions to greenhouse gas emissions should be viewed alongside the positive environmental benefits that livestock grazing can provide (Beauchemin et al. 2010).



Management implications

To achieve Hebda's (1994) dictum for our grasslands and woodlands, enhanced management and the techniques of ecosystem restoration will be required; however, these same landscapes produce relatively low rates of economic return, making it difficult to justify enhanced investment. We are slowly moving toward a social and economic valuation of ecosystem goods and services, which should strengthen the rationale for investment.

Managers of British Columbia's grasslands and woodlands should consider the following proactive approaches.

- Encourage research and long-term monitoring that focusses on the key issues of plant community resilience, successional change, the effects of fire and fire exclusion, grazing interactions, species at risk, assisted migration, and the dynamic balance between trees and grass.
- Facilitate fire-maintained ecosystem restoration treatments along the woodland ecotone to enhance the health and resilience of plant communities. Link these with urban-interface fuel reduction treatments where possible.
- Reduce ungulate grazing and browsing pressure along the ecotone by undertaking restoration treatments that produce more forage, by facilitating longer rest periods in grazing rotations, and by developing targeted wild ungulate population control strategies where required.
- Remain vigilant with existing invasive plant control and biocontrol; practice early detection and eradication of newly arrived invasives.
- Incorporate vegetation temporal corridors upslope and north–south connectivity corridors into land and resource planning.
- Encourage the development of a native seed industry through innovative policies.

Conclusion

A unique feature of our grasslands and woodlands is the multiplicity of interest groups and ownerships. The hunting, ranching, conservation, recreation, and urban–wildland interface sectors, the four levels of government, plus the ENGO sector, even though they rarely see eye-to-eye, all have a vital stake in the future of these lands. By doing the hard work of interest-based negotiation and consensus-building, these groups can pool resources to get the necessary planning, monitoring, research, fieldwork, and management accomplished. A major component of these discussions will be determining the balance of public and private dollars to fund the required investments. Our grasslands and woodlands are important to all of us, and we owe it to them to undertake these negotiations, and get out ahead of the climate change curve.

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Test Your Knowledge

How well can you recall the main messages in the preceding article?
Test your knowledge by answering the following questions

British Columbia's Grassland Resources and Climate Change

1. The biogeoclimatic climate envelope that is predicted to expand most rapidly is the:
 - a. Alpine Tundra
 - b. Bunchgrass
 - c. Interior Cedar–Hemlock

2. The three categories of ecological niche are:
 - a. Theoretical, dynamic, and fundamental
 - b. Realized, potential, and indeterminate
 - c. Fundamental, realized, and potential

3. Potential increased plant growth based on a longer growing season may be offset by:
 - a. Moisture shortages
 - b. Late spring frosts
 - c. Daylength response

