

Xth International Rangeland Congress, Saskatoon, SK, Canada

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Summary of Plenary and Keynote Presentations and Contributed Papers and Posters

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Plenary Sessions 1 - 3

The first three sessions of the Xth International Rangeland Congress set the stage for the sessions to follow. They progressed from the foundational topics in Session 1 “State of Global and Canadian Rangeland and Pasture Resources”, to the emerging value of rangeland with Session 2 “Ecological Goods and Services of Rangelands and Pasturelands”, and progressed to the key role of people in association with rangeland in Session 3 “The People of the Grasslands.” The following summary will highlight key aspects from each of these sessions, most importantly the Keynote presentations and Plenary papers. I encourage you to review the congress proceedings to obtain the full scope of these sessions and the entire Xth IRC Congress.

Session 1 - State of Global and Canadian Rangeland and Pasture Resources

The two plenary papers in this session were given by Ed Bork (Professor of Rangeland Ecology and Management, University of Alberta, Edmonton, Alberta, Canada) and Yingjun Zhang (Professor of Rangeland Ecology and Management, China Agricultural University, Beijing, China). These papers provided an introduction for the congress and categorized the status of rangeland and pastures resources worldwide and provided a more detailed assessment on the status of rangeland resources in Canada.

Ed Bork said there was an increased recognition that Western Canada’s rangelands should be managed based on broad definitions of diversity and sustainability. In his presentation “A brief Tour of Canada’s Rangeland and Pasture Resources”, he described the widespread rangeland and pasture resources in Western Canada. They differ greatly in climate, soils, vegetation composition, and their associated potential to support various land uses, including livestock grazing. Ed noted that these lands differ in their stewardship models, occurring under both private and public management. While the primary historical use of these areas may have been for forage and associated livestock production, these lands are increasingly being recognized for their key role in providing a broad diversity of ecological goods and services, further increasing the importance of their sustainable management. Ed summarized that future conservation of native grasslands across the region will rely on developing a better understanding of the benefits society receives from these agro-ecosystems, and the development of market mechanisms that encourage their retention and enhancement.

Yingjun Zhang expanded from Canada to the world in his presentation “Global Range Resources: A perspective on their use.” He shared that rangeland managers are often primarily interested in output of livestock products, but they are also conscious of the resource base and the environmental services these ecosystems provide. Jingjun and co-authors provided specific examples from northern China and Australia on rangeland utilization and the approaches that have been implemented in these countries to determine factors and relationships that affect utilization. He concluded by stating his belief that researchers need to find those common measures (e.g. - herbage mass in grassland

systems) which correlate with productivity and environmental services, and can be used to achieve sustainable management.

The papers and posters of session 1 were categorised in the following five themes and included 27 volunteer oral presentations and 69 poster presentations. Each thematic area began with a keynote presentation by a noted researcher within their discipline.

Theme 1.1 - Ecosite descriptions and ecoregion classification (13 papers)

“Developing Ecological Site Descriptions on Mongolian Rangelands to Enhance Monitoring Condition and Trend” Michael Hale, Bunchgrass Enterprises, Joseph, Oregon, USA

In his keynote presentation Michael Hale stated that the rangeland health assessment within a reference ecological site provides a qualitative assessment for determining condition. Combining this method with the quantitative measurements required at each of PHYGROW point, would provide a robust rangeland monitoring protocol for Mongolia, and across worldwide rangelands. Michael and his collaborators recommend the establishment of a national rangeland monitoring program that utilizes Rangeland Health Assessments over multi-year time frames to determine condition of ecological sites. In addition, this program would use conventional rangeland monitoring techniques to annually assess impacts of large herbivore grazing on defined rangeland units. They also recommend incorporation of the Forage Growth (PHYGROW) Model in a national rangeland monitoring program.

Theme 1.2 - Historical development of rangelands (4 papers)

“Can rangeland livestock systems compete in a global market? Evidence from the past and present”

Karl Behrendt, Charles Sturt University, Orange, NSW, Australia

Karl Behrendt and co-authors used the *agri benchmark* networks' 2014 data and models with comparative results from countries covering over 90% of world beef production and 55% of world sheepmeat production. They concluded that rangeland based beef weaner and sheep meat production systems have the capacity to produce low cost meat protein and compete in a global market. However, the profitability of doing so is influenced by the prices and returns that can be achieved, as well as the cost of inputs (such as labour) and the system's capacity to achieve high enough resource use efficiency. The immediate constraints to achieving higher economic outcomes for many rangeland based systems are their limited capacity to achieve higher reproductive and growth rates and finish young animals, and subsequent total meat production. In the future, the comparative performance of rangelands based systems in providing meat protein will also be influenced by their capacity for achieving adequate animal welfare outcomes, dealing with climate change and variability challenges, their capacity in sourcing quality labour, and the economics of adopting innovative technology.

Theme 1.3 - Conservation of wildlife and natural areas (11 papers)

“The Environmental Impacts of Harvesting Caterpillar-Fungus on the Tibet-Qinghai Alpine Meadows”

Gongbu Zhaxi, Agriculture College of Tibet University, Bayi Ningchi, China

Gongbu Zhaxi gave one of the most interesting keynote presentations of the congress. He shared how people believe that caterpillar-fungus is a medicinal panacea and therefore the demand for it has rapidly increased. Each year more than 2,700,000 people from across China come to the alpine grasslands of the Tibet-Qinghai plateau to harvest the fungus. Traditionally, the economic backbone of the plateau is animal husbandry, which is dependent on the alpine grasslands. In recent decades, caterpillar-fungus harvesters from other provinces have not only deprived pastoral Tibetan communities of this income source, but have damaged the grassland and reduced the efficiency of local animal husbandry. Gongbu proposed that a sustainable approach to watershed preservation on

the alpine grasslands would be to return property rights to the indigenous people and respect their local knowledge and culture. This would be not only good for the Tibetan people but for all of China.

Theme 1.4 - Grazing management practices (47 papers)

“Herbivore assemblages as a crucial factor in future grazing management on steppe grasslands”

Wang Deli, Northeast Normal University, Changchun, China

In his keynote presentation Wang and Wang said that the influence of herbivore grazing on plant diversity, soil heterogeneity, productivity, and C and N cycling, strongly depended on herbivore species and combination. In addition to grazing intensity, herbivore assemblages should be considered an important factor affecting future grassland management decisions. Herbivore assemblages have varying effects on different grassland functions. Their research showed that sheep grazing reduced plant diversity and NEE, but did not reduce productivity, nor improve the N cycling rate. Cattle grazing improved diversity, soil heterogeneity, NEE, and the N cycling rate, but also greatly reduced productivity. In contrast, mixed grazing improved grassland multifunctionality including diversity, soil heterogeneity, productivity, NEE and N cycling rate. They suggested that mixed grazing of cattle and sheep should be considered an optimal grazing management protocol in steppe grasslands.

Theme 1.5 - Genetic resources and forage development (21 papers)

“Analysis of morphological diversity of five native forage species, used in re-vegetation programs in Chihuahua, Mexico” Federico Villarreal-Guerrero, Autonomous University of Chihuahua, Chihuahua, Mexico

In his keynote presentation, Federico Villarreal-Guerrero explained how he and colleagues had collected an extremely diverse range of native grass ecotypes from ranches across the state of Chihuahua, Mexico. The 573 ecotypes came from the species green sprangletop (*Leptochloa dubia*), sideoats grama (*Bouteloua curtipendula*), plains bristlegrass (*Setaria macrostachya*), Arizona cottontop (*Digitaria californica*) and blue grama (*Bouteloua gracilis*). After evaluation in a common environment, specific ecotypes showed a high potential for forage production, soil retention and seed production. They concluded that the variability present across ecotypes provides an opportunity to start plant breeding programs using these populations within each species for use in rangeland rehabilitation programs.

Session 2 - Ecological Goods and Services of Rangelands and Pasturelands

The two plenary papers in this session were given by David Briske (Professor of Rangeland Ecology, Texas A&M University, College Station, TX, USA) and Don Gayton (Consulting Ecologist, Summerland, British Columbia, Canada). They both provided a thoughtful and wide reaching perspective on rangeland through the emerging value of ecological goods and services.

In his plenary presentation with Richard Woodward, “Rangeland Goods and Services: Identifying Challenges and Developing Strategies for Continued Provisioning,” David Briske said that the Ecosystem Services (ES) from rangelands are constrained by a limited understanding of ES responses and tradeoffs. A major caveat to the valuation of rangeland ESs is that they are diffuse and broadly distributed throughout remote regions – a circumstance that is counter to the successful application of concentrated non-market services adjacent to urban centers. This may require that a global entity be designated to administer and develop market structures to trade these diffuse services in aggregate on continental or global scales. Although the utility of the ES framework remains a work in progress, David and Richard concluded that it has utility for global rangeland application and recommend that it should be explored as a mechanism to guide management decisions and policy recommendations.

Don Gayton gave a stimulating and thought provoking presentation he entitled “Toward a Culture of Range: the role of society in protecting rangeland ecological goods and services.” He stated that we must get society to recognize grasslands as ecosystems by employing culture, art, and spirituality in innovative ways. One example was to use ecological restoration projects as an effective way of getting people engaged with nature. Don described how within mainstream North American culture we maintain a very curious duality in our attitudes toward nature. Our scientists study it, we document its services and we create parks in its honor, but we basically pay it lip service, and any time nature and short term economics enter on to the same playing field, nature is the perennial loser. He concluded with a very appropriate quote from “Wolf Willow” by one of his favorite authors, Wallace Stegner. “One cannot be pessimistic about the West. This is the native home of hope. When it fully learns that cooperation, not rugged individualism, is the quality that most characterizes and preserves it, then it will have achieved itself and outlived its origins. Then it has a chance to create a society to match its scenery.”

The paper and posters of session 2 all centered on the emerging ecological goods and services value of rangeland and included 30 oral presentations and 53 poster presentations.

Theme 2.1 - Nutritional links from soil to plant to livestock to people (32 papers)

“Nitrogen use efficiency and nitrogen surplus in animal production systems” Klaas-Wybo Van der Hoek, Vice Chairman of the Executive Board, Stenden University, Netherlands

In his keynote presentation K.W. Van der Hoek described how nitrogen budgets are a useful tool to monitor the effect and implementation of measures to improve the sustainability of agricultural production systems. They collected a range of measures on individual farms. Some measures like 1, 3, 4, 6 and 7 deal with internal farm management, without impact on other farms. In general these measures lead to increasing NUE and decreasing N surplus. Some measures taken on individual farms have an impact on other farms. Measure 2 leads to NUE profit on the importing farm but the exporting farm does not receive the animal manure and has to buy synthetic fertilizer, meaning a NUE loss. So, there is no NUE improvement on a national scale. Some measures like 3 through 5 aim at more and better use of animal manure as fertilizer and consequently have savings on synthetic fertilizer. As synthetic fertilizer production is associated with high CO₂ emissions, this is a positive side effect. Klaas-Wybo concluded with a plea for mixed farming systems that integrate crops and livestock, with animal manure production and sustainable use of it in a single head of management.

Theme 2.2 - Carbon sequestration in rangelands (21 papers)

“Trade-offs between management of grazing intensity, soil carbon and biodiversity” Cathy Waters, NSW Department of Primary Industries, Trangie, NSW, Australia

In her keynote presentation, Cathy and co-authors related that the emergence of the carbon economy provides a new income source in a pastoral economy dealing with increasing challenges to profitability. However, this new industry brings many challenges for land managers and regulators with a number of conflicting outcomes between traditional pastoral practices and carbon sequestration projects. They conclude, that while trade-offs in biodiversity may occur with the management of grazing intensity, the benefits of increased soil protection through higher perennial ground cover and reduced loss of C will allow long-term sustainable rangeland pastoralism and the reversal of land degradation.

Theme 2.3 - Water supply and quality (10 papers)

“Livestock and fire management influence fundamental supporting and regulating ecosystem services of grassland ecosystems: the interacting roles of species, vegetation structure and rainfall intensity on

the redistribution of water” Elisabeth Huber-Sannwald, Instituto Potosino de Investigación Científica y Tecnológica, San Luis Potosi, Mexico

In her keynote presentation, Elisabeth explained how two short grass species (*Bouteloua gracilis* and *Muhlenbergia rigida*) significantly influence ecohydrological processes of Mexican semi-arid grasslands both at the tussock level and at the community/ecosystem level. This resulted because of their influence on basal and soil cover, microtopography and thus heterogeneous distribution characterizing these grasslands. Semiarid grasslands under continuous grazing pressure cause substantial water loss directly affecting the long-term provisioning of supporting and regulating ecosystem services. Reintroducing fire as an inherent disturbance agent in grassland ecosystems may stimulate primary productivity, however with the trade-off of enhancing water loss.

Theme 2.4 - Wildlife habitat for endangered species (13)

“Bovids, Bugs and Birds: Livestock Avermectins; A Threat to Grassland Birds?” Wes Olson, National Park Warden, Val Marie, Saskatchewan, Canada

Wes Olson conducted a literature review of 908 papers to identify potential linkages between cattle grazing, the timing of avermectin applications, the effects of avermectins on non-target species, and invertebrate prey requirements of grassland birds. He showed how the development of avermectins and their widespread use since the early 1980s has been a major factor in the large reduction in invertebrate biomass. This combined with changes in grazing practices that resulted in less cattle in the early spring and no dung pats, was correlated with the declines of grassland birds.

Theme 2.5 - Aesthetic and spiritual value of wild lands

Due to difficulties in the granting of visas and other travel issues there were no specific papers within this theme at the congress.

Session 3 - The People of the Grasslands

The two plenary papers in this session were given by Ann Waters-Bayer (Senior Associate, Royal Tropical Institute, Amsterdam, Netherlands) and Ryan Brook (Associate Professor of Indigenous Land Management, University of Saskatchewan, Saskatoon, SK, Canada). Both of their presentations were novel, thought provoking, and very interesting.

In her plenary presentation entitled “Pastoralists in the 21st century: ‘Lo-Tech’ Meets ‘Hi-Tech’ Ann Waters-Bayer related that in dry rangelands, pastoralists manage to produce food for themselves and others in mostly an ecologically sound way. Whether in Africa, Mongolia, Australia or the Americas, information and communication technologies (ICT) and transport innovations make pastoralists much more strongly and quickly connected with the rest of the world than in the past. In Mongolia, the wide availability of cell phones and mobile charging stations is reversing urbanisation: some pastoralists have abandoned the urban congestion and scramble for low-level service jobs and gone back to the range, as they now see pastoralism as a viable lifestyle. Although pastoralists in many countries are still threatened by hi-tech projects that are not economic and waste scarce resources, there is growing awareness of the non-sustainability of these interventions. With greater understanding of pastoralists’ valuable role in producing nutritious food from ephemeral resources, conserving biodiversity and maintaining society in remote areas, hi-tech options that suit a mobile production system and are applied in a socially responsible way could indeed modernise pastoral life and help ensure its future.

Ryan Brook gave a stunning and insightful presentation on “Canadian Indigenous People and Arctic/Grassland Use”. Although he does not have a paper in the congress proceedings, he gave new perspectives to many in the audience who heard his presentation. He spoke about his research that

focuses on wildlife ecology and health issues that intersect with indigenous and rural communities in central and northern Canada. His research combines local and traditional knowledge with ecological and social research to answer theoretical and applied questions about wildlife movements and disease. Ryan challenged the audience to consider how we respect or disrespect local knowledge, beliefs, culture, and traditions and use and apply our scientific findings at the same time. Especially if they disagree. He asked the audience to carefully consider “Are they right? Are we right?” and answered his own questions by stating that likely things are somewhere in-between. Success in working between indigenous groups and research scientists comes from respect and relationships of trust. Ryan left the audience with a quote “have humility toward one another”.

The papers and posters of session 3 focus on the most important aspect of rangeland which are the people and included 28 oral presentations and 32 poster presentations.

Theme 3.1 - Changes to pastoral systems around the globe (18)

“New way to manage grazing livestock system in degraded grassland based on system economics”

Guodong Han, Inner Mongolia Agricultural University, Hohhot, Inner Mongolia, China.

Guodong introduced his presentation by describing the challenge to improve the efficiency of grazing livestock systems while conserving grassland. He described large scale on-farm experiments in northern China comparing traditional whole-year grazing to an alternative practice of lower summer stocking rate plus three months of winter greenhouse feeding. The results indicated that the alternative practice is a suitable improved grazing livestock system in pastoral areas in northern China. This management system is innovative in that it both enhances livelihood outcomes and conserves the grazing lands. The key points for this new system are estimation of forage and feed supply and animal requirements, grazing livestock management improvement, assessment based on maximum net income, integration of Dorper sheep and improved management.

3.2: Privately owned and leased rangeland systems (6)

“Cowboys or grass farmers?” Colin Paton, Northern Australian Pastoral Company, Roma, Queensland, Australia.

Colin Paton gave an interesting presentation on how improved infrastructure, rotational grazing, resting pastures from grazing and stocking to carrying capacity has improved their land condition from poor in many paddocks to excellent or fair. By using photos to measure soil, pasture and tree condition they can monitor changes that occur over time and obtain objective information on resource condition. This data can be used to identify management strategies required to improve land condition and carrying capacities, or objective assessment of current strategies. Forage budgets help to determine the safe short-term carrying capacity of a property or paddock, are an objective measure for matching feed supply with stock numbers, and assist communication with management. Using the Stocktake approach of measuring land condition and doing forage budgets has allowed the manager to take control of his property management situation. Also, this information could be useful for legitimising the company’s “green credentials” and perhaps obtain premium prices for their product in the future.

3.3: Urban and sub-urban grassland societies (10)

“Improving the value of cattle grazing and ecosystem services on open space through curriculum and interpretative trail signage” Stephanie Larson, University of California, Santa Rosa, CA, USA

In her presentation, Stephanie shared about their highly successful program to connect working ranches in the Bay area with the general public through improved trail access and other programs. A more informed public will lead to a stronger social cohesion between beef cattle grazers and the park users. This program has helped strengthen the health and outdoor connections on working

landscapes, (i.e. rangelands), through ecosystem services curriculum and interpretive trail signage. Signage entitled “Why Cows”, “California Grazing”, and “Sharing the Lands” was placed at trail heads to ensure that optimal usage was obtained. Providing comprehensive, research-based information that promotes animal agriculture literacy is a key first step to educating park users, public and decision makers on the importance of grazing as a tool in urban and suburban societies.

3.4: Professional extension and technology-transfer (17)

“Western Beef Development Centre 1998 to 2018: combining research and extension for the benefit of the Saskatchewan beef industry,” Paul Jefferson, Western Beef Development Centre, Humboldt, Saskatchewan, Canada

Paul Jefferson presented the history and the success of the Western Beef Development Centre (WBDC). The Centre is a unique and innovative partnership among ranchers, industry, government and academics that has successfully provided applied research, extension, and demonstration in beef cow-calf production and grazing research for Saskatchewan for nearly 20 years. In recent years some of the most effective outreach has been in the form of Technology transfer vehicles such as webinars to share research with dispersed audiences. Factsheets continue to be published on the website (WBDC 2016), but short videos of research results posted to Youtube™ have become an increasingly popular part of the research extension efforts. One video has received close to 35,000 views. WBDC also has embraced social media as a way to connect with producers, with Twitter and Facebook.

3.5: Social justice issues in rangelands (9)

“Environmental imperialism & greening dispossession: social justice issues in East Africa’s rangelands” Corey Wright, McGill University, Montreal, Quebec, Canada

Corey Wright gave one of the most provocative presentations of the congress. Much of what he had to say was not easy to hear, but it was important for congress participants to hear about social justice issues related to rangelands. As indicated in the paper’s title, a key issue is what Corey and colleagues term “greening dispossession,” whereby purportedly innocuous processes of conservation and ‘ecotourism’ underpin a growing exclusion of pastoralists from their ancestral lands. The challenge left for international researchers, advocates, and organizations, including the International Rangeland Congress, is how can we build alliances with pastoralists and support their social and political struggles. Corey reawakened within me a perspective I had not thought about for a long time. What are the real effects of my actions, of my influence and advice? Have they had the desired effect of preserving the land, the people, and the environment or have I made the situation worse. It’s no good to just say, “I wanted to help or I thought this would help.” It is our responsibility to insure that our actions will have the intended effect (or at least a strong likelihood).

Summary Sessions 1-3

The presentations and papers in Sessions 1-3 provide a major contribution to rangeland literature in the area of Global Rangeland and Pasture Resources, Ecological Goods and Services, and the People of the Grasslands. Although I mainly reviewed the plenary and keynote presentations, I encourage you to review the entire congress proceedings carefully, to obtain the full scope of all the sessions of the Xth IRC Congress.

Session 4 Multiple Use of Rangelands
Session 5 Range and Forest of High Latitudes and Altitudes
Session 6 Climate Change in Rangelands

María E. Fernández-Giménez, Colorado State University, Fort Collins, CO, USA

Session 4 Multiple Use of Rangelands

The session on Multiple Use of Rangelands comprised 5 streams focused on 1. Energy development and reclamation of industrial disturbances, 2. Fire management and restoration in rangelands, 3. Cropland abandonment, revegetation and re-use of rangelands, 4. Invasive species impacts and management, and 5. Wildlife conflicts and commercial opportunities. Two plenary presentations highlighted the complex interactions of biophysical and socio-economic processes in energy production on US rangelands, and the profound environmental, socio-economic and cultural impacts of mineral and energy development in Mongolia. The questions and discussion following these presentations focused attention on the politically and emotionally charged nature of energy and mineral development in both the more developed global north and the less developed nations of the global south, as well as the linkages between these activities across the globe via multi-national corporations. This discussion complicated simplistic narratives about the environmental, economic and social impacts of energy or mineral development, and illustrated the need for more nuanced, interdisciplinary analyses that focused on trade-offs among ecosystem services, including cultural services. One contributed paper applied qualitative social science methods to address these themes, reporting on local residents' perceptions of energy-development impacts to natural, agricultural and social resources in the Bakken oil field, North Dakota, US (McGranahan and Kirkwood).

Most other contributions across the five themes provided biophysical perspectives on multiple use impacts, development of bioenergy crops, or mitigation or restoration of ecosystem structures (e.g. plant communities) or processes (e.g. fire). Several papers focused on planning and management for multiple use, through the development of decision-support tools for allocating multiple uses at a landscape scale (e.g. Mohart and Cameron). The stream of papers on fire ecology, management and restoration was rich, led by a review paper (Thompson) that synthesized key advances in restoration of fire to rangelands, drawing attention to the need for additional research on the role of fire in rangeland management in Africa, Asia and South America, the need to update traditional burning practices with new knowledge, and to balance use of fire as a management tool with demands to preserve air quality and reduce greenhouse gas emissions. Other contributions focused on refinement of recommendations for timing and frequency of burns in different systems (e.g. Vermeire), or use of grazing to limit wildfire risk (e.g. Swanson; Launchbaugh). Kreuter et al. examine social and regulatory influences on prescribed fire use by landowners, bringing a valuable social science perspective to this thread on restoration of fire to rangelands.

The stream on abandoned croplands and revegetation included technical advances in seeding and other revegetation and restoration techniques, and the development of plant materials and forages. This stream was dominated by contributions from developed countries. However, two papers from the global South highlight the importance of forage and

plant material research in improving food security and livelihoods. Khan et al. found that feeding cross-bred dairy heifers chopped rather than full length para grass increased daily gains, which is important in Bangladesh, where the main constraint to dairy production is insufficient quality and quantity of livestock feed. Ramamoorthy showed the importance of wild plant foraging in fallow semi-arid lands to subsistence and income generation of tribal and rural communities in Tamilnadu, India.

Like the previous stream, the papers on invasive species impacts and management emphasize biophysical studies, and largely lacked consideration of the social or policy dimensions of invasive species management. Biophysical studies emphasized the patterns, causes and impacts of invasive species distributions (e.g. Cahill et al, Lin and Wang, Klich, Akbarlou and Nodeji), the effectiveness of various control measures (e.g. Mori, Fick, Gebru et al, Hendrickson), and strategies for monitoring, living with or restoring invaded rangelands (e.g. Desalegn et al, Klich et al., Mokwala et al, Wirngo et al). One exception to the limited treatment of social dimensions in this thread was Nenkari et al's paper on pastoralist field schools in Kajiado County, Kenya, which reported on a participatory, adaptive approach to education and mobilization of local Maasai to control the invasive *Ipomoea* species. An innovative institutional approach to wild dog management was reported by Crowden and Healy, who describe Collaborative Area Management in South West Queensland. There, adjoining landowners cooperated to fence out predators, resulting in dramatically improved lambing rates and some evidence of increased native wildlife.

Overall, this session encompassed a wide array of topics with an emphasis on understanding the ecological impacts, and to a lesser extent the social impacts, of multiple use. Multiple use in this session included use of rangelands for energy and mineral development and the use of fire as a management and restoration tool. The biophysical contributions suggest that much current research focuses on documenting and predicting impacts over broad areas and developing applied solutions using technical interventions fine-tuned to local systems and conditions. With a few notable exceptions, consideration of the human dimensions of multiple use was largely missing, suggesting that future research could better integrate policy, economic and social drivers and consequences of rangeland change from multiple use, with assessment of impacts and development of technical solutions.

Session 5 Range and Forest of High Latitudes and Altitudes

Rangelands of the high latitudes and altitudes are among the most remote and challenging in which to live, work and do science. As a result, these landscapes are among the least altered and fragmented by anthropogenic activities, and the human societies that evolved with them have maintained many aspects of their indigenous cultures. These ecosystems and the people and livelihoods they support are threatened by changing climate, policies and markets. The plenary on subarctic and arctic North America and Europe (Downing) drew attention to the extreme environmental conditions of these regions, and the utility of regional ecological classifications as benchmarks for assessing change and as the basis for monitoring frameworks. Among the large grazers indigenous to the Arctic, caribou (reindeer) are vitally important to human populations in both North America and Europe, where they provide food, clothing, transportation and cultural identity. Use and management of these herds occurs via hunting (in North America) or herding (in Europe and Asia). Continued sustainable harvest depends on a precise understanding of population dynamics where

migratory herds are hunted, and on support for traditional management institutions that allow for herd migrations and resource sharing where herds are domesticated.

On the Tibetan Plateau, traditional management institutions are threatened by modernization policies that seek to settle nomadic pastoralists, convert common property pastures into individual tenure, and increase herder participation in a market-based economy, in place of subsistence livelihoods (Foggin). Rangeland conditions are reportedly deteriorating, but the causes are contested and vary with the observer's ideology (Foggin). Foggin's plenary draws attention to important yet often overlooked attributes of pastoralism, including the importance of livestock mobility to healthy rangelands; the productivity, sustainability and resilience of extensive livestock production systems in comparison to intensive livestock systems; and the common challenges shared by pastoralists in both the developed and developing worlds. Further, he points to the multiple services provided by yaks in the remote, high-elevation rangelands of Tibet. As with caribou in the Arctic, yaks in Tibet provide food, transportation and cultural identity, making life possible, and giving it meaning, in this harsh high-altitude environment. Foggin's plenary concludes with two case study examples of participatory community-based protected area management in the region, which illustrate the importance of pastoralist empowerment and cultural identity in adapting to socio-economic and environmental change, and improving ecological and social conditions for herders.

Other papers in this stream describe the characteristics of high-elevation and high-latitude rangelands (e.g. Yang et al, Li et al); the response of these systems to domestic livestock grazing (e.g. Wang et al., Forster Furquim et al, Shi et al); monitoring frameworks and methods (Calvo and Fores); and livestock breeding, management and feeding practices (e.g. Bongadzem et al, Barsila et al, Cupido et al., Li et al). Several papers address social dimensions of management in high latitude/altitude rangelands. Herzog et al. reported on the challenges of land abandonment and climate change in the Swiss Alps, and their ecological and social consequences. Drawing on existing research, Roy report on herder perceptions of the causes of rangeland degradation and potential improvement strategies. Altmann et al used interviews and participatory mapping to document Mongolian herders' management practices and associated motivations, which can be used as a basis for discussions with herders to identify areas vulnerable to overgrazing, and the remediation measures they recommend.

In summary, high latitude and altitude rangelands face complex and interacting challenges of changing climate, policy, economy and social values. Their remoteness and isolation is both a challenge and an opportunity for locally-driven culturally relevant and ecologically appropriate development solutions.

Session 6 Climate Change in Rangelands

The first plenary in this session (Sauchyn et al.) placed 80 years (1930-2014) of climate and vegetation change at the Onefour Manyberries Research Station (Alberta, Canada) into the long-term context of 9,000 years of climate variability in the region. The past 80 years show significant linear increases in precipitation and decreases in pan evaporation, and significant (quadratic) increases in forage production, with a concurrent shift in plant community composition towards more C₃ grasses and fewer C₄ grasses. Over a longer sweep of time, grasslands established in the southern Canadian prairies following the last deglaciation ~ 9,000 years before present. Pollen records from lake sediments reveal multiple cycles of extended droughts, characterized by extreme declines in grass pollen. More recent climate

variability (since 1575) has been studied using tree-rings, which allow for a more precise determination of the timing and duration of climatic events and changes. Tree-ring models also indicate repeated periods of extreme water deficits, including 34 years with droughts more extreme than the driest years recorded with instruments in the 20th century: 1936 and 1961. Sauchyn et al. conclude that although the system has been resilient to past climate variability, future droughts will occur in a warmer climate, increasing the potential for destabilizing change in prairie landscapes. The largest impact of climate change is likely to be increased short-term variability in production, rather than declines in total productivity.

In the second plenary of this session, Ruppert considers climate change impacts on rangelands in a global context, placing emphasis on the implications for ecosystem services, especially provisioning services linked to livelihoods. Precipitation is the primary predictor of rangeland production (ANPP) and the relationship between precipitation fluctuations and ANPP are well-understood. The direct effects of temperature on production are less, but indirect effects may be important in terms of litter decomposition and shifts in grassland species composition. Similarly, effects of grazing timing, intensity and duration on rangelands are well studied across systems of different evolutionary histories of grazing. However, the interacting impacts of changing climate and grazing regimes are poorly understood. At a global scale, most rangelands are subject to increased surface temperatures. Predictions for precipitation patterns under climate change are more variable, but many rangelands will also face declines in moisture. These combined impacts are likely to have a negative effect on livestock and crop productivity in drylands, as well as altering vegetation composition and dynamics, challenging both livelihoods and knowledge systems used to manage and derive a living from these lands. Ruppert concludes his contribution with a call to reconsider a research agenda for rangeland climate change. He advocates for research programs that leverage networks of research cooperation across the globe for data sharing, coordinated distributed experiments, and data-fusion and meta-analysis.

The contributed papers within this session included a greater proportion of presentations by researchers from the Global South (70%) than session 4 (Multiple Use, 49%), as well as a greater proportion of social science and interdisciplinary contributions (40%) compared the papers in the Multiple Use session (11.5%). The stream on plant adaptation to climate change highlighted how understanding climate variability and change effects on plants, and studies of plant adaptations to climate, can be applied to adaptation strategies in production systems. The papers on livestock and grazing system adaptations to climate change comprised a large and diverse group of papers, ranging from adaptation and mitigation (Derner et al., Kingi et al), early warning and risk assessment (Gutierrez et al, Ma et al), impacts on animal health (Gitao and Chepkwony, Leuret et al), education and outreach (Ojima et al), and local knowledge and traditional strategies used by pastoralists (Nunuu and Nunuu, Samuels et al., Ntombela et al), and institutional (Densambu), economic (Broad et al., Ritten et al, Hodgkinson et al, Schlossler et al), and technological (Hao et al) impacts and innovations. Hawkins' meta-analysis of holistic planned grazing makes a valuable contribution to the literature on short-duration, high-intensity grazing systems. The stream on water supply and quality impacts encompassed three papers, focused on the role of riparian systems (Booth et al), climate compatible development in Mongolia (Ojima et al), and outreach to urban audiences about rangelands (Smith). The fourth stream focused on modelling future human and climate change, such as the spatial distribution of a sylvopastoral tree in Morocco (Said), impacts on the *Stipa Tenacissima* steppe of North

Africa (Louhaichi), and the degradation and resilience of rangelands in Central Asia (Aralova).

Overall Conclusions Sessions 4-6

Session 4 focused on problems perpetrated by industries based in the Global North and technological solutions to them, such as prescribed fire, seeding and herbicide. In contrast, Sessions 5 and 6 focused on the impacts of environmental extremes and climate change, and included more contributions from less developed nations, generating creative institutional and management innovations, and including more interdisciplinary and social science contributions. Technological, institutional, economic and educational solutions all have roles to play in restoring and maintaining sustainable rangelands, and adapting to change, worldwide. To ensure a sustainable future, researchers must continue to strive for greater interdisciplinary integration and adopt transdisciplinary approaches that engage resource users and managers and blend their knowledge and experience with scientific insights and innovation.

Session 7

'Grazing Land Assessment & Management in a High Tech World'

Donald Burnside, Australian Rangeland Society, Perth, Australia

Themes and papers and posters

This Session included a wide range of contributions presented in the Proceedings dealing with technology in rangeland science and management, with papers and posters categorised in the following five themes:

Technology in

Theme 1. Land resource data acquisition and modelling	33
Theme 2. Social and psychological data acquisition and modelling	7
Theme 3. Animal movement data acquisition and modelling	7
Theme 4. Education and extension	10
Theme 5. Fencing, water supply and livestock health	7

The approach taken in summarising this section was to turn the title around and review the keynote presentations and contributions with the point of departure being '*What uses and benefits are we getting from high tech?*'

Invited Keynote Presentations

The two invited papers by Barry Adams (Rangeland Extension Specialist, Lethbridge, Alberta, Canada) and Ed Charmley (Program Leader, Livestock Environmental System, Australian Tropical Sciences and Innovation Precinct, James Cook University, Queensland, Australia) presented complementary opportunities for the use of high technology in grazing management.

Barry Adams highlighted how a large amount of basic and applied research has been used in developing a number of spatial and point-based data layers that in turn have been interpreted into the Alberta Rangeland Ecology Toolkit. This toolkit is used as a basis for training rangeland ecologists, informing ranchers about their operating environment, and decision making at strategic (i.e. objectives for management) and tactical (i.e. day-to-day management) scales. Thus, the toolkit – in itself a technology – is a form of applied knowledge that is used by the stewards of the Alberta rangelands (rangeland ecologists and ranchers) to better monitor and manage the 7m ha of provincial rangelands. Other uses of the toolkit include: development of codes of practice for wildlife management, preparation of a range recovery strategy and regulation of lease turnover in the province.

Besides informing rangeland management 'on the ground', Barry highlighted the role that the toolkit is playing in building capacity to manage adaptation to climate change. Further, the stewardship practices identified within the toolkit can be verified and continually refined through observation and measurement. While all this is very positive, Barry's final salutary message was the 'sole measure of success [of the toolkit and its use] will be the state of the range'.

Ed Charmley's presentation focused on a number of 'hard' technologies that are under various stages of development and application in the extensively grazed tropical woodlands and grasslands across northern Australia. These technologies are relying on the growing power and utility of computing, remote sensing, internet and telecommunications that collectively have the capacity to increase the effectiveness and efficiency, and integration of the management elements across large properties (which may cover well over 1,000 km²). These tools, which are variously progressing from initial development through to field-scale testing and then to commercialisation include: remote 'walk over weighing' of cattle, forage estimation across large areas, animal distribution across the landscape,

remote monitoring of water supplies, and virtual fencing. Initial concerns from managers about the 'spy in the sky' are dissipating as the value of this remotely sensed information is appreciated. In addition, interest is growing in how unmanned aerial vehicles (UAVs or 'drones') can be used in these environments. These tools likely will transition from being useful now to being essential in the future. The concept of the 'digital homestead' was presented, where streams of data and information from a range of on- and off-property sources (the latter can include market information) can be used by management in making finer-tuned and more timely management decisions.

Ed addressed some of the issues associated with achieving adoption of these technologies. There is a contrast between rapidly increasing computing power and the innate conservatism of many graziers. Access to these technologies may be an issue, with the risk of 'tech-rich' and 'tech-poor' sectors of the industry developing. Ed highlighted the paradox of Australia, a developed nation that has generally poor mobile phone coverage across most of the rangelands, compared to Kenya, a developing nation with excellent coverage. As Ann Waters-Bayer described in an earlier keynote presentation, mobile phones are being used by traditional pastoralists in managing their herds, purchasing supplies and marketing meat and milk.

Ed concluded by noting that for these relatively new technologies to be adopted widely, they need to be widely accessible, reliable in sometimes tough environments and easy to use. His take-home message was 'take the technology along, and bring people along with it'.

Contributed Papers and Posters

The contributed papers and posters have been analysed in Table 1 according to the origin of their authors, the technologies presented and the applications of these technologies. This is obviously a personal analysis and has been done in an attempt to address my over-arching question about how the high tech world is contributing to rangeland science and management.

Table 1. Analysis of contributed papers and posters*

Where are the authors from?		What technologies are being reported?		What applications are being reported?	
North America	29	Field research/ investigation and management	26	Inventory – 'what have we got?'	6
South America	9	Remote sensing	23	Processes – 'How does it work?'	23
Australasia	8	Modelling development/ simulation/ validation	15	Condition/ production assessment – 'What use is it fit for?'	30
Middle East & S. Asia	7	Communication	7	Decision support – 'How do we manage it?'	16
North and East Asia	6	Data and information management	5	Monitoring – 'How is it changing?'	7
Europe	6				
Northern Africa	6				
Southern Africa	4				

* numbers in the columns exceed the number of papers reviewed, given that most papers had multiple authors, and many covered multiple technologies and applications

The origin of the papers and posters

About half the contributions had North American authors, although many of these papers and posters were co-authored by people from other parts of the world. The situation is not surprising, given that access to state-of-the-art remote sensing and telecommunications technologies (often initially developed for uses in other industries) will be greater in developed countries. The number of multi-

authored, multi-country papers indicates a growing level of collaboration across the world's rangelands, which will be required if widespread adoption of 'high tech' is the goal.

The technologies being reported

The largest number of papers and posters presented described technologies that can improve the validity and reliability of field measurements, and the efficiency of data collection. In some cases, such as those presented by Zahran and Kirkman, refinement of existing techniques for measuring forage availability in the field is improving the validity of the measurements and value for management. Improving range monitoring and grazing management systems in Argentina were reported by Oliva and his colleagues. Field measurements and remote sensing data are being combined to investigate ecosystem functions and productivity (e.g. Guo, Palmer and Yunusa, Sales *et al.*). Developing workable correlations between important rangeland descriptors measured in the field were reported, which allows more efficient estimations of important characteristics such as forage biomass (see Soares *et al.* and Guo-Mei *et al.*).

Remote sensing is now a mature technology, able to be used at all geographic scales from site-based to continental. This parcel of technologies (e.g. NDVI, Landsat, MODIS etc.), which were experimental barely a generation ago, are now able to produce high quality, real-time, site-based, regional, national and global information that can be accessed by I-pads, mobile phones and similar devices. Excellent examples were presented by Lindsay *et al.*, Xulin Guo, Anchorena *et al.*, Chaieb *et al.* and others. At site scale, drones are being used to aid plant identification (Gallacher *et al.*), and forage biomass is being estimated using digital photography and reflectance (Sales *et al.*). Other aspects of remote sensing reported in several contributions include the remote tracking of animal behaviour via GPS-fitted collars, which in a couple of decades has gone from being an expensive specialist tool, to a readily accessible, widely applied methodology that is providing valuable information for applied research and day-to-day management (see Ingram *et al.*, Manning *et al.* and Moore *et al.*).

Model development and the validation of operating models were described in several papers and posters. Improving the utility and applicability of models such as the Rangeland Hydrology and Erosion (RHEM) model (Nesbit *et al.* and Williams *et al.*) and the Grazing Response Index (Kayter *et al.*, Gardner *et al.*) and 'operationalising' State and Transition Models (e.g. Hernandez *et al.* and Rajabov and Mardanov) is evidence that these and other models can and are providing support for land managers' decision-making across a range of management needs. Modelling is also being used to estimate ecosystem services, another area where concepts are being quantified (as in Iravani *et al.*, for estimation of carbon dynamics in the Alberta prairies).

Communication technologies were less reported. However, one paper (Vahobov *et al.*) describing new technologies in networking management (and hence information sharing) in Central Asia perhaps is pointing the way for the increasing sophistication in telecommunications being used to develop rangeland management capacity across sparsely populated regions. Similarly, technologies used in data and information management were less well represented, although there are interesting developments in how web-based information and knowledge is becoming accessible to land managers in remote environments via the NRM Hub in Australia (Tickle *et al.*), the previously mentioned 'digital homestead' (Bishop-Hurley *et al.*), web-based feed budgeting tools in New Zealand (Stevens and Casey) and the Alberta Rangeland Ecology Toolkit (Adams).

The applications for these technologies

In keeping with my approach to summarising Plenary Session 7 (having considered the technologies described in the contributed papers and posters), this section provides an analysis of where across the 'rangeland science and management spectrum' they are being applied.

Inventory – what have we got?

A few papers dealt with inventory, describing rangeland characteristics at various spatial scales. As mentioned earlier, our capacity to do this for almost any part of the rangeland world is now very impressive, with a capacity to present high quality information for policy makers, government administrators and land managers at all scales. Developing and presenting rangeland inventories is now a very mature activity, which allows easier access to information concerning the state of the world's rangelands.

Processes – 'How does it work?'

About a third of the presentations in Plenary Session 7 dealt with building our understanding of rangeland processes, such as soil and water dynamics, nutrient and carbon fluxes, vegetation changes and identification of thresholds between various rangeland states. This is largely 'basic rangeland science' and the technologies being applied are increasing our ability to understand the processes and build them into management systems.

Condition/ production assessment – 'What use is it fit for?'

About half the papers and posters dealt with the application of a range of technologies to the mainstream issues of rangeland management, being determining range condition, how the land can be used, and what management is required. These applications likely will continue to be a focus for technology adoption in rangeland science.

Decision support – 'How do we manage it?'

Based on the papers and posters presented at this IRC, the emphasis in rangeland decision support appears to be shifting from the more prescriptive computer-based models to data and information systems that provide a relevant body of information and knowledge to the decision maker, who then uses this information as an input to the decision-making process. The corollary is that the decision maker needs to have confidence in the information and the capacity to use it in making sound decisions.

Monitoring – 'How is it changing?'

Compared to some past IRCs less discussion was focussed on how new technology is contributing to the effectiveness and efficiency of rangeland monitoring. Perhaps this reflects that range monitoring is now a mainstream and/or institutional activity in many rangeland environments. Conversely does this suggest that there is little new to report? Some comments are presented in the following section.

Conclusions Session 7

In this section, some personal observations are made about what the papers and posters in Plenary Session 7 of the IRC showed that we are achieving in the application of 'high tech' to rangeland management, and some perceived challenges.

Achievements

The papers and posters presented show that a range of technologies, especially in remote sensing has given us a huge ability to accumulate spatial and temporal data and transform it into information products for application at the paddock to global scale. This information should support sound decision-making by policy makers and decision-makers at regional, national and global scales. We can also anticipate that future IRCs will see still further improvements in the ability to detect and report rangeland phenomena at a wide range of scales.

Papers and posters in this Session have showcased a number of sophisticated and widely accessible information systems such as Alberta Rangeland Ecology Toolkit, the 'digital homestead', the NRM

hub and the feed budgeting tools being developed in New Zealand. The body of available information, and its aggregation into accessible packages is increasing rapidly. However, using the packages effectively remains a challenge (see below).

New and/or refined technologies are providing us with an increased ability to 'operationalise' and validate a range of models (e.g. State and Transition Models, RHEM, GRI, etc.) which in turn will provide better information to land managers, especially in addressing growing areas of importance (see under 'Challenges').

The technologies are available to build cost-effective, valid and reliable monitoring systems that can identify what changes are occurring and in most cases why these changes are occurring.

Finally, rapid improvements in internet and telecommunications capacity across the globe can assist people in networking and learning across large areas. Currently, it seems the human systems to exploit the technologies are the limiting factor, not the technologies themselves.

On-going and New Challenges

As noted in the papers, posters, and keynote presentations in this Session our ability to access, collate, interpret and present large amounts of data and information is huge. The challenge will be to build the capacity of the target users of this information – from pastoralists to policy makers – and their confidence in the material. Further feedback loops are required to ensure that the 'data generators' efforts are informed by users' needs.

Given the importance of mobile phones to traditional pastoralists in Africa reported in other Sessions (as in 'mobile technologies for mobile societies'), papers about how their use can be exploited for maximum benefit were lacking. Papers in this area should be encouraged at the joint IRC/IGC in Kenya in 2020.

Two areas of rangeland management are growing: (1) ecosystem services delivery and the measurement of ecosystem services, and the distribution of the costs and benefits of these services and (2) how rangeland regions and communities can adjust to climate change. Progress was made at this IRC concerning these two relatively new focal areas, but considerably more work needs to be done.

The limited reporting of economic technologies in addressing rangeland management issues – at all scales from grazing enterprise to national accounting – was surprising. A related challenge will be how rangeland communities manage the equity issues between those who can afford to be 'tech rich' and those who are compelled by economic and social constraints to be 'tech poor'.

Finally, access to emerging technologies in transportation, energy and water management etc. received almost no mention. These are important matters in achieving sustainable livelihoods in arid rangelands which are extensive and poorly linked. The topics need to be considered in future IRCs.

**Voices of the IRC
Synthesis Poem for Sessions 4, 5 and 6**

María E. Fernández-Giménez

1. Prelude—Paleo-ecology

Earth thrusts and floods
Sands shift, ice over
Carbon we dig today
Squeezed into being
Held in folds
Of rock and time

The planet's skin
Greens over
Cryptograms and saxifrage
On barren islands of the north
Lichen, moss and shrubs
Prairies fine with grass and buffalo
Steppes alive with birds
Savannah, where wildebeest teem
All this a paleo-ecological
dream

We came out of Africa
Followed the caribou
Tamed the yak
Grew our herds of sheep and beef
Mounted our horses, boarded our boats
And peopled the world

We watched and learned
Experimented, observed
Lived, worked, loved, played
We shared, we fought
Eden it was not
And yet
We knew who we were
And how to be
Together
With our beasts, the land
And one another

2. Multiple Use

The carbon buried deep below
We need it now
To make things go
Tear back the skin
Scrape off the grass
Reap the treasure
Oil, coal and gas

From Boroo Gold

To the Bakken Field
Wounded earth and
Poisoned waters
A legacy for
Our sons and daughters?
Jobs, profit, royalties
Impacts on communities

Science helped to hone the blade
Can science heal the mess we made?

Bring back the fires
Kill the weeds
Harvest and replant native seeds
Teach our people
Help them learn
What we grow is
What we earn.

Science loves simplicity
Elegance, replication, and objectivity
Yet simple solutions
Seldom succeed
Diversity and complexity
Are what we need.

3. High Altitudes and Latitudes

Life is hard
On the roof of the world
For plants, animals, people

In Tibet,
Yaks: without them life would be impossible
Rangeland deterioration
Rooted in ideologies, policies and paradigms
Of modernization
Development the cost of
Traditional knowledge, management
Culture, identity
Yaks are more than income
More than food
Yaks are who we are
We made this place with fire
And kept it with our animals
We move and keep moving
Adaptive and flexible

In the Swiss Alps:
Summer farming
In the high meadows
Ancient practice
Embedded
In custom and place

Farmers do it for
Cheap grass
But also for the pleasure
Of grazing summer pastures
Labor is hard to find
Now younger people
Women, city folk
And foreigners
Take to the mountains
For meager pay
Learn the work,
Tend the stock
And make the cheese
Like my favorite childhood story,
Heidi.

Tibet, again.
Parks and people
Can be compatible
If managed cooperatively
Pastoralist communities,
Empowered,
Feel identity with place
Know who they are
And how to be
In this high,
Cold country.

4. Climate Change

Rangelands 50% of earth's land
Fodder for poetry
ANPP
A core ecological currency
For ANPP
Rainfall is the key
Grazing effects vary
With evolutionary
History
We know well
How these work
Independently
But not so much
Simultaneously

The world will warm
Less rain will fall
In many rangelands, anyway
Extreme events
Uncertainty
Potential famine
And calamity

So...

In the heat of the future
The drought of the day
The dzud of the winter
What can we say?
How can we adapt
Or mitigate?

Indigenous herders use what they know
Move with the grass, stay on the go

Flexible stocking if it doesn't rain
Adaptive planned grazing, out on the Plains

Climate Clever Beef say the Aussies down under
Reduce stocking and wait for the thunder

To capture the carbon, let the shrubs grow
Use multiple measures, New Zealanders know

Find the fodder with the lowest methane emissions
Treat urine patches to reduce nitrous dioxide emissions

Resilience-based management is the word on the steppe
Co-produced knowledge will get us there yet

How to empower the people to act
Pay them for services, make a firm pact?

Build on the knowledge they already hold
Workshops, Theater, Poetry, be bold!

How can we understand better their choices?
Be quiet, and listen to pastoralist voices.