Applicability of Criteria and Indicators for Sustainable Grassland Management to Rangelands of Patagonia (Argentina)

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Applicability of criteria and indicators for sustainable grassland management to rangelands of Patagonia (Argentina)

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Key points : One hundred years of pastoral use of Patagonia s rangelands have resulted in severe land degradation . Widespread application of range survey methods to determine grazing capacity of commercial ranches did not begin until the late 1980s . Public awareness about desertification problems and efforts of the science community led to the passing of an important congressional act in 2002 which has created the conditions for the implementation of a region-wide rangeland monitoring system (MARAS) . Although most of the criteria and indicators for sustainable rangeland management proposed by the Sustainable Rangelands Roundtable are relevant to conditions in Patagonia (Argentina) , less than half the indicators are applicable due to the relative paucity of data and validated models . Current monitoring frameworks allow broad spatial scale assessments but are somewhat lacking in fine-scale evaluation of indicators .

Key words : rangeland monitoring , biophysical indicators , socioeconomic indicators , MARAS

Introduction Most of Patagonia s rangelands (approximately 750 000 km^2) lie in the rain shadow of the Andes mountain range and are primarily treeless shrub and grass steppes that give way to dwarf-shrub semi-deserts in the drier areas of the central plateaus (Roig 1998) . Blended in the steppe landscapes are riparian areas (*vegas* or *mallines*) associated with rivers and other permanent water sources . Although *mallines* are a very small proportion of the total land area of Patagonia , they frequently play a key role in livestock production and , in many instances , are the ecosystems most severely affected by improper land management decisions (Golluscio and others 1998) . Approximately 90 percent of soils in the region exhibit some degree of degradation , mostly as a consequence of improper land use . Severe desertification affects about a third of Patagonia (Del Valle et al .1998) ; some of its most dramatic expressions are the *lenguas medanosas* (sand dunes) that covered an area of approximately 85 000 km^2 in the early 1970s .

Commercial sheep grazing enterprises are a fundamental element of rangeland livelihood of most of Patagonia . Almost all of Patagonian rangelands are privately owned and , therefore , grazing use is virtually unregulated . Rangeland science and management tradition is fairly young in most of Patagonia ; widespread application of range survey methods to determine grazing capacity of commercial ranches did not begin until the late 1980s . Surprisingly , invasive noxious weeds are not a widespread problem on Patagonia s rangelands . We report past , present and future of rangeland monitoring in Patagonia and the applicability of a suite of criteria and indicators for sustainable grassland management to conditions in Patagonia .

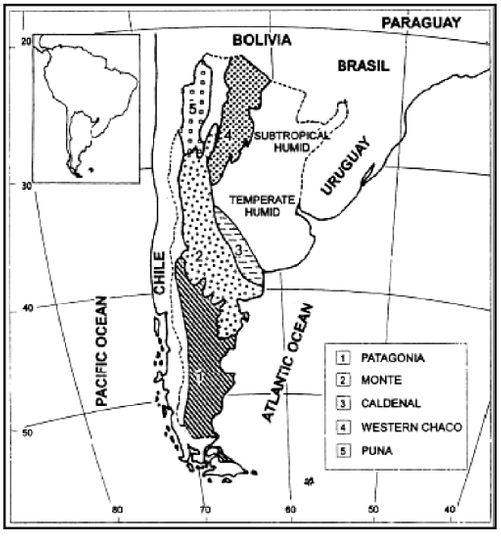

Figure 1 : *Map of rangeland types of Argentina according to Fernandez and Busso (1999) .*

History of Patagonian land use Pastoral use history of rangelands in Patagonia is relatively recent . Colonization took place in the

late 1880's , after military desert" campaigns subjugated native peoples and offered land for settlement , mainly to Argentine and Chilean *criollos*" but also to settlers of European or Middle-Eastern descent , including Spaniards , English , Scottish , Italians , Syrian-Lebanese and Yugoslavians . Native peoples were mainly hunters and gatherers : the Tehuelche in the south did not endure the cultural impact of colonization and are now severely reduced in number , while the Mapuche people , in the north , recovered after an initial decrease in number . Both groups add up to 23 to 50 thousand people , about 1 .4 - 3 .5% of current residents of the region . Early (1880-1900) colonization was actively encouraged by the government and settlers were given access to pastoral leases in large areas of the most productive or readily accessible land . At the turn of the 19th century , poorer settlers took part in the colonization of more arid or less accessible areas . The land was divided geometrically into allotments of about 10 to 20 thousand hectares without considering environmental factors or the balance of range types , water points or wintering areas within the properties (Barbería 1995) . Native Americans remained on the land in small subsistence allotments of about 500 to 2500 hectares or in a few reservations . Freehold rights consolidated land tenure of most of the big *estancias*" at the turn of the 20th century , but small allotments remain mostly with informal or traditional occupation , a great number of them unfenced .

History of Patagonian sheep industry The sheep industry flourished until 1920 , while prices of wool were high and undisturbed grasslands could take heavy grazing pressures . Sheep numbers peaked in 1937 (approx . 20 million) and remained stable for the following 50 years (Escobar 1997 ; Mendez Casariego 2000) . In the 1980 s , a generalized stock reduction process (approx 8 million) was triggered by a combination of lower international wool and meat prices , loss of productivity due to rangeland degradation , and macroeconomic policies that inflated the value of local currency (Borrelli and others 1997 ; Mendez Casariego 2000) .

These factors put most sheep ranching enterprises in a difficult financial position ; by the end of the 20th century most ranchers had become heavily indebted and had drastically reduced their work force . This crisis primarily affected mid-sized (20 .000 hectares) family-owned ranches in the Central Plateau of Santa Cruz , where about 440 (40% of the total) *estancias* were abandoned or remained occupied by caretakers with no pastoral activities . Rural population in Santa Cruz fell from 24 .500 in 1960 to 13 .700 in 1991 (Mendez Casariego 2000) . Changes in macroeconomic policies implemented in 2002 have increased the profits of the sheep ranching industry (Teran and Claps 2002) , and there is currently a strong predisposition to re-colonize vacant lands .

Environmental degradation and the role of central government Grazing-induced degradation processes were described early on by Bailey Willis (1914 , as cited in Castro (1983) , Morrison (1917) , Auer (1951) , and Soriano (1953) . Soil erosion was treated using dune control techniques as early as 1950 (Castro 1983) . Nonetheless , the underlying causes of degradation were not addressed , and heavy stocking rates remained in place until the 1980 s . Regional evaluation of desertification using satellite imagery which began in the early 1990 s , showed that severe or very severe desertification had affected approximately 34% of Patagonia (Del Valle et al . 1998) .

According to the Argentine constitution , natural resources , including rangelands , are under the jurisdiction of provincial governments . Sadly , environmental consequences of improper grazing have rarely been addressed by provincial or national government policies due to the fact that most of the land is under freehold tenure and there is no constitutional mandate to monitor the state and management of rangelands . Grazing has , therefore , gone unregulated and conservative management has depended mostly on the perceptions and goodwill of landowners . Due to social and political influence of traditional rancher associations , significant amounts of public funds have frequently been directed towards the maintenance and expansion of the sheep industry through subsidies and financial support regardless of the grazing capacity of rangelands .

Joint desertification projects sponsored by the Instituto Nacional de Tecnología Agropecuaria (INTA , Argentina) and the Deustche Gesellschaft fur Technische Zusammenarbeit (GTZ , Germany) from 1989 to 2002 helped increase public awareness regarding the threat that desertification posed to the region , and stimulated the design and fairly extensive application of rangeland survey and monitoring techniques . The trend in public fund allocation has changed in recent years since the passing of a Sheep Act in 2002 (Poder Legislativo Nacional 2004) that assigns about u $ 7 M yearly to projects that can demonstrate ecological sustainability through certified range evaluation . Rancher associations participate in the distribution of these funds that support the development of a regional-scale monitoring system . A project with funding currently under consideration by the Global Environment Facility Program of the World Bank (GEF) will address three aspects that the Sheep Act of 2002 does not include , namely : 1) rangeland monitoring ; 2) education ; and 3) diversity conservation through public and private protected areas . Such recent developments allow moderate optimism regarding a change in long-term government rangeland conservation policies .

Past , present , and future of rangeland monitoring in Patagonia The use of rangeland science to address management problems in Patagonia is fairly recent . It was not until the early1980s that researchers began using traditional range condition analysis to develop utilization guides for a few selected range sites in the region (Borrelli *et al* . 1984 ; Borrelli *et al* . 1988) . Because no

vegetation-based rangeland assessment techniques had been calibrated for extensive use across Patagonia , concurrent eforts were also made during the 1980s to develop range assessment methods that would provide region-wide stocking rate guidelines for sheep ranchers (Borrelli and Oliva 1999) . Starting in 1992 , range scientists began working on transforming old" range condition guides into state and transition models (Paruelo *et al* . 1993) . Unfortunately , ecological site description work associated with this effort was soon put on hold ; all efforts were progressively directed to train extension personnel and private consultants to use the newly developed range assessment methods in the field . Region-wide programs funded by the federal government were basically aimed at mitigating the effects of desertification . Their basic assumption was that desertification processes were being driven by sheep-grazing ; consequently , development and application of tools to adjust stocking rates were given highest priority .

Although some range assessment data were compiled into regional databases , their detail was insufficient to make reliable inferences about regional vegetation trend . These shortcomings were somewhat offset by the development of a regional GIS that used 1986 Landsat 7 satellite images to generate an inventory of land degradation status in selected areas of Patagonia . This effort , allowed a first approximation to quantifying the problem of desertification . The last stage of this project involved a socio-economic survey of ranchers across some key areas of Patagonia that was completed recently . This was possibly the first survey in Patagonia , documenting individual rancher s perceptions of land management issues . Detailed long term plant cover and soils data exist for a handful of sites across Patagonia , mostly on federal government experimental ranges .

The need for an independent method to determine rangeland state and trend at the scale of range types (from 0 .4 to 14 .3 M ha) and at relevant time scales (decades) has been acknowledged recently . Range scientists from across Patagonia have developed the MARAS" monitoring system (*Monitoreo Ambiental de la Región Arida y Semiárida de Patagonia* , (Oliva and others 2004) based on Australia's WARMS method (Western Australia Monitoring System) , that includes point intercept transects or frequency samples to evaluate herbaceous vegetation and Canfield transects to monitor shrubs . Soil surface stability sampling is also performed to monitor topsoil integrity . Monitoring stations will be set up at a rate of 1 : 20 .000 hectares and will be measured every five years . MARAS has received funding from a federal Sheep Act of 2002 to train field personnel , install the first monitoring sites , and design a web-based data bank that will be accessed by government agencies and NGO's . In the future , MARAS could supply information to monitor vegetation cover , species composition , forage biomass and soil condition of rangelands in Patagonia . To date , there are no plans in place to incorporate social or economic variables into this monitoring system .

Rangeland monitoring and issues of scale Ecological problems , such as rangeland sustainability , occur at temporal scales of several decades and at spatial scales of entire ecosystems . However , many indicators of sustainability can only be measured directly in small areas over relatively short periods of time . Because patterns and processes that occur at fine spatial scales do not necessarily prevail at broader scales (Allen and Starr , 1982) , it is not possible to simply aggregate across scales from local to regional or national levels to make inferences about sustainability of rangelands (Mitchell , 2002) . The suite of criteria and indicators such as those developed by the Sustainable Rangeland Roundtable (SRR) were intended to ... guide monitoring efforts to measure rangeland sustainability ..at multiple scales [and to] ensure that .... appropriate temporal and spatial scales for assessing the criteria [were used] ..." (SRR 2005) .

Catastrophic events that have long-lasting effects on rangeland ecosystems (e .g . desertification , wildfires) exhibit non-linear behaviors that are thought to be driven by cross-scale interactions and complex feedbacks among ecosystem components (Peters *et al* . , 2004) . Although significant progress has been made in describing thresholds of vegetation change (Bestelmeyer *et al* . 2003 , and references therein) , the ability to predict the point at which ecosystems are likely to cross a threshold is still in its infancy . Peters *et al* . (2004) proposed that threshold behavior is the result of cross-scale interactions in which broad-scale processes , such as drought or wildfires , eventually overwhelm fine-scale processes and control the dynamics of the system . For example , in a highly degraded rangeland ecosystem , landscape-level transport of materials by wind and water may override micro-patch conditions that control plant recruitment and determine overall vegetation trend . Peters *et al* . (2004) argue that in such conditions , grazing may be irrelevant to overall system dynamics . Monitoring indicators of rangeland sustainability should , therefore , be based on a basic understanding of the processes currently driving the system and the spatial and temporal scales at which they operate . Data from plots or transects should be interpreted in the context of landscape dynamics to meet these challenges (Peters and Havstad 2006) . Although rangeland scientists in Patagonia have recognized the non-linear nature of rangeland plant community dynamics (Oliva *et al* . 1998 ; Parizek *et al* . 2002) , current monitoring efforts do not explicitly address issues of scale .

Scale issues may be of a somewhat more complex nature when social and economic variables are considered . Scaling up in time and level of organization (from individuals to institutions) by simple aggregation is , conceivably , also an inadequate means of predicting behavior of social systems . Complex social and economic behavior interactions may also exhibit non-linear dynamics with critical thresholds and transitions that may be irreversible for time frames relevant to rangeland managers .

Table 1 *Qualitative analysis of scales at which applicable SRR indicators can currently be monitored in Patagonia (Argentina)*

Short list of criteria and indicators that could be monitored in Patagonia		Spatial scale		Temporal scale	Methods
		Extent (*)	Grain (**)		
I	**4.** Area …with significant change in …bare ground **5.** Area …with accelerated soil erosion by water or wind	Pasture to landscape	Pixel size	Every 5-10 years	Satellite image analysis
II	**12.** Rangeland area by plant community **15.** Density of roads and human structures				
	17. Extent and condition of riparian systems	Floodplain to watershed			
	18. Area of infestation…of invasive plant…species….	Plant communities	0.1 m^2 quadrats to pixels		Satellite image analysis- plot or transect monitors
III	**21.** Rangeland aboveground biomass	Pastures		Yearly	
	22. Rangeland annual productivity	Plots to landscapes			
	23. Percent available rangeland grazed by livestock	Ranches to landscapes	Ranch	Every 5 years	National or Provincial population surveys
	24. Number of domestic livestock on rangelands	Counties	Counties	Every 4 - 6 years	
IV	**29.** Number of visitor days by activity and recreational…	National Parks	Nat. Parks	Yearly	
	32. Rate of return on investment for range livestock…	Ranch to regional	Ranch	Occasional	
	36. Poverty rate (general)	Province	Province	Every 4 – 6 years	
	37. Poverty rate (children)			Every 4 - 6 years	
	38. Income inequality			Yearly	
	41. Federal transfers by categories…..			Yearly	
	45. Agriculture (ranch/farm) structure	County	County	Every 4 - 6 years	
	46. Years of education	Province	Province	Every 4 - 6 years	
	47. Value produced by agriculture and recreation…			Occasional	
	48. Employment, unemployment, underemployment…			Every 6 months	
	49. Land tenure, land use, and ownership patterns…	County	County	Every 4 years	
	50. Population pyramid and population change	Province	Province	Every 4 - 6 years	
V	**56.** Institutions and Organizations **59.** Professional Education and Technical assistance **63.** Measuring and Monitoring **64.** Research and Development	Region	Region	Occasional	

* Extent is the largest area monitored

* * Grain is the smallest unit that can be monitored and is therefore indicates the level of resolution of the data

Applicability of criteria and indicators (C&I) for sustainable grassland management in Patagonia Cibils and Oliva (2006) assessed the relevance of the Sustainable Rangelands Roundtable (SRR) C&I to conditions in Patagonia and found that : **a)** Most C&I were relevant to conditions in Patagonia and that only a few indicators , mostly within the criterion dealing with conservation and maintenance of plant and animal resources on rangelands (SRR s criterion 2) , were classified as not being applicable to Patagonian rangelands ; **b)** available data or models could only assess 26 of the 53 relevant indicators for sustainable rangeland management proposed by the SRR ; and **c)** relative lack of quality data and scarcity of validated models were the factors that limited the applicability of SRR C&I to Patagonian rangelands the most .

Cibils and Oliva (2006) suggested that their assessment exercise could be indicative of the kinds of challenges associated with applying the SRR C&I to rangelands in developing countries. They further suggested that the application of rangeland monitoring assessments in such countries following the framework proposed by SRR may require a shorter bare-bone list of essential criteria and indicators (Table1). The development of a condensed list of essential indicators could serve as a guide to help land managers and local enforcement authorities in developing countries prioritize the use of scarce funds allocated to monitoring efforts.

Can applicable criteria and indicators be measured at appropriate scales in Patagonia? Because not all indicators can be monitored in Patagonia, a second qualitative assessment was conducted to determine whether monitoring the reduced subset of indicators mentioned above would provide reliable information at multiple scales.

This assessment showed that most biophysical indicators on the short list (Table 1) could only be currently monitored at broad spatial scales ranging from pastures to watersheds and landscapes. The grain of the scale at which most indicators could be monitored ranged from $30m^2$ to1 km depending on pixel size of the satellite image used. For indicators related with area of infestation of noxious or invasive plants, rangeland aboveground biomass, and annual aboveground productivity transect or plot data were available for a reduced number of sites across the region. Prior analysis of satellite images that provide baseline data to determine several soil and plant indicators was also circumscribed to 4 pilot areas that cross most of the Patagonian steppe from W to E at different latitudes.

Limitations associated with the spatial grain of the data are greater when socio-economic indicators are considered (Table 1). Although most surveys are conducted at the level of individual households or ranches, the data made available to the general public (including researchers) cannot be disaggregated beyond the level of provinces and, sometimes, counties. In addition, regional and national censuses are subject to sporadic federal funding pulses and are, therefore, conducted at irregular intervals. Hence, it is difficult to overlay watershed or landscape scale trends with corresponding socio-economic changes.

Conclusions Most of the C&I for sustainable rangeland management proposed by the SRR are relevant to conditions in Patagonia (Argentina). Less than half the indicators are applicable, however, due to the relative paucity of data and validated models. A shorter list of essential indicators may be necessary to realistically conduct regional long-term assessments of overall sustainability of rangeland ecosystems in developing countries.

Current monitoring frameworks of bio-physical indicators of rangeland sustainability in Patagonia allow broad spatial scale assessments but are somewhat lacking in fine-scale evaluation of indicators. Broad-scale bias is even more accentuated if socio-economic indicators are considered. A new monitoring framework developed by scientists in Patagonia (MARAS) will tend to increase fine-scale assessment of bio-physical indicators. This monitoring framework could be enhanced by explicitly addressing cross-scale interactions following a novel conceptual model developed for arid rangeland ecosystems of North America (Peters and Havstad 2006).

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