机械措施控制加拿大萨斯克彻温草场丛生卷柏生长的经济分析

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摘要：对加拿大萨斯克彻温省干旱棕色土壤带、湿润棕色土壤带及黑棕色土壤带上的沙土和壤土草场区所应用的挖鱼鳞坑和犁翻两种机械措施控制丛生卷柏侵蚀天然草场的效果进行了经济效益分析。分析结果表明：当市场折扣率为 8% 和 10% 时，犁翻处理在任何草场区实施均在 20a 内不能收回投入，说明该处理在经济上是不可行的；而挖鱼鳞坑在黑棕色土壤带实施分别需要 10a 和 11a 才能收回投入，在湿润棕色土壤带分别需 12a 和 14a，而在干燥棕色土壤带则分别需 15a 和 22a。但在实际中，这两种处理是否能发挥 20a 以上的经济效益还需进一步研究。草场管理者应根据两种处理控制丛生卷柏效果及饲草产量的增量来确定净现值和内部报酬率，估测收回投入的年限，最终作出合理的经济决策。当然，如果考虑到铲除丛生卷柏所带来的一些生态方面的争议，草场管理者应慎重考虑其他一些改良措施，如改进放牧管理，施化肥及播种目标草种等，以达到取得经济效益的目的。

关键词：丛生卷柏；机械措施；经济分析；草场；萨斯克彻温；加拿大

An economic analysis of clubmoss control with mechanical treatments in Saskatchewan rangeland, Canada

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Abstract: Clubmoss (*Selaginella densa* Rybd.) is a low, dense-matted, slow-growing perennial plant, which occupies large areas of the Northern Great Plains and is common on Saskatchewan rangelands. It rarely exceeds 2.5 cm in height and has an extensive mat of very fine roots penetrating to a depth of about 8 cm. The mat intercepts precipitation and holds it on the surface of the ground. Much of this moisture dose not penetrate this layer of mat and is unavailable to more desirable vegetation. The most common habitats for clubmoss growing are level areas and moderate slopes in plain topography. The plant prefers well developed soil of medium textured and nearly neutral reaction. Knowledge of the ecological role of clubmoss is limited. However, it dominates some native grassland stands, but has no forage value and increases with overgrazing and mismanagement of prairie pasture. The objective of this study was to complete an economic analysis of pitting and chisel plowing mechanical treatments that are commonly used to reduce clubmoss on rangelands in the Northern Great Plains. Cost and benefit analysis of pitting and chisel plowing were determined for the sandy on loamy range sites in the Dry and Moist Brown Soil Zones, and the Dark Brown Soil Zone in Saskatchewan. The levels of costs and benefits per hectare from mechanical range renovation depend upon the additional animal units (AU) raised and return to grazing per AU and the carrying capacity. Additional AU could reached on areas receiving each of the two treatments on loamy and sandy range sites in

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the three selected areas in Saskatchewan. Economic feasibility of treatment varies and a number of factors affect the final results, but weather is more important in determining forage productivity than mechanical disturbance. This study shows that net present values for chisel plowing were negative, indicating this treatment is not economically feasible on any range site at either 8% or 10% interest rate. Results for pitting suggest that it is more desirable on economic grounds than chisel plowing. Recovery of total costs of pitting on a loamy range site occurred at 10 and 11 years post-treatment in the Dark Brown Soil Zone, 12 and 14 years in the Moist Brown Soil Zone, and 15 and 18 years in the Dry Brown Soil Zone at discount rates of 8 and 10%, respectively. It is questionable whether beneficial effects of pitting or chisel plowing on herbage production exceed 20 years. Range managers considering pitting or chisel plowing to reduce clubmoss on rangeland and improve forage productivity will find the net present value, internal rate of return, and the predicted number of years to break even in making economically prudent decisions. Considering the questionable ecological value of removing a cover of clubmoss, it may be prudent for range managers to economic alternatives methods of range improvement, for instance, improved grazing management, fertilizing and/or interseeding on clubmoss dominated rangeland. Such decision may require more reason on rangeland productivity.

Key words: clubmoss; mechanical treatments; economic analysis; rangeland; Saskatchewan; Canada

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1 Introduction

Clubmoss (*Selaginella densa* Rydb.) is a low, dense-matted and slow-growing perennial plant which occupies large areas of the Northern Great Plains and is common on Saskatchewan rangelands. It dominates some native grassland stands, but has no forage value. Knowledge of its ecological role is limited[1,2]. Many mechanical treatments have been developed with the goal to alter clubmoss cover, increase herbage production, and change species composition on rangeland. Commonly used mechanical treatments in the Great Plains are pitting, furrowing, and ripping[3~5]. Because mechanical treatment removes ground cover, clubmoss is generally reduced or destroyed. Increases in forage production have been the primary criterion used to evaluate success of mechanical disturbances[6~9]. The longevity of treatment effects on forage production ranges from 1 to 6 years, depending on location, climate, and treatment[2~3,7,8,10~16]. Despite of increases in forage production following mechanical disturbances, weather is more important in determining forage productivity than mechanical disturbance[17]. However, the economics of mechanical treatments for rangeland improvement by reducing clubmoss cover has not been analyzed in Saskatchewan.

Whether mechanical disturbance of rangeland is economical remains undetermined. Economic analysis of mechanical disturbances on rangeland in Saskatchewan is needed to assist in making decisions regarding the utility of the practices. The objective of this study was to conduct an economic analysis of pitting and chisel plowing, which are commonly used to reduce clubmoss on the Northern Great Plains. An economic model for Saskatchewan rangeland was established using published data on range pitting and chisel plowing.

2 Methodology

2.1 Forage yield after mechanical treatment of clubmoss

Data from studies on the effects of mechanical improved rangeland to control clubmoss in Canada are lacking. Therefore, data from research[13] on pitting and chisel plowing near Havre and Malta, Montana were used in these analyses. The pitting machine used was a modified, heavy breaking disk[13], which made pits about 76 cm long, 20 cm wide and 10 cm deep. About 45% of the ground surface was covered with pits and overturned sod. The ratio of herbage yield on pitted range to untreated control averaged 1.58, indicating a 58% increase in herbage yield.

A heavy duty cultivator was used for chisel plowing by plowing at 5cm depth, followed by chisel plowing at a 10cm depth at right angles, and finally, chisel plowing with 25cm sweeps at 45° angles to the first treatment[13]. Chisel plowing with average herbage yield was 1.34 times greater than that in control.

Loamy and sandy range sites in dry areas in the Brown Soil Zone, moist areas in the Brown Soil Zone, and the Dark Brown Soil Zone[18] were selected for analysis of potential yield increases following mechanical disturbances in southern Saskatchewan. Forage yields were estimated from recommended stocking rates for Saskatchewan[18]. For example, the recommended stocking rate on a fair condition, loamy range site in the dry areas in the Brown Soil Zone is 0.395 AUM/hm^2[19]. This stocking rate was multiplied by 354 kg/AUM, which is the amount of forage required by a 354 kg cow for 1 month[19]. The calculated herbage yield was then divided by 55%, a proper use factor generally accepted on native range[16]. The estimated yield in Saskatchewan is caculated by:

$$Y = (A \times Q)/K$$

Where, Y: The estimated yield, A: Animal Unit Month, Q: The amount of forage required by a cow, K: Proper use factor.

The amount of forage following treatment was then estimated by multiplying the yield ratio of 1.58 and 1.34 for pitting and chisel plowing, respectively (Table 1).

Table 1 Predicted herbage yields on loamy and sandy range sites in 3 soil zones (kg/hm²)

Treatments	Dry Areas in Brown Soil Zone		Moist Areas in Brown Soil Zone		Dark Brown Soil Zone	
	Loamy soil	Sandy soil	Loamy soil	Sandy soil	Loamy soil	Sandy soil
Control	254	206	349	302	460	413
Pitting	401	325	551	477	727	653
Chisel	340	276	468	405	616	553

2.2 Estimated increases in stocking rate after treatments

The additional AUM increment produced by pitting or chisel plowing (Table 2) was calculated yield increasment following mechanical treatment multiplying by the proper use factor, and then dividing by the amount of forage required by a cow for 1 month as shown by:

$$S_i = (Y_t - Y_u) \times K/Q$$

Where, S_i: Increased stocking rate, Y_t: Treated yield, Y_u: Untreated yield.

Table 2 Estimated increased stocking rates on loamy and sandy range sites in 3 soil zones after treatments (AUM/hm²)

Treatments	Dry Areas in Brown Soil Zone		Moist Areas in Brown Soil Zone		Dark Brown Soil Zone	
	Loamy soil	Sandy soil	Loamy soil	Sandy soil	Loamy soil	Sandy soil
Pitting	0.23	0.19	0.32	0.28	0.43	0.38
Chisel	0.14	0.11	0.19	0.16	0.25	0.22

2.3 Framework and information used in analyses

2.3.1 Cost of treatment Cost of pitting or chisel plowing clubmoss varies depending upon the kind of mechanical treatment used, type of equipment, difficulty of job, size of the area, and condition of area being treated. Other costs include operating and fixed costs, and grazing deferment.

2.3.2 *Original forage production and predicted increase in forage production* The original forage production on a given range site must be known to calculate the cost of grazing deferment after treatment and the increase in forage production. 55% of forage is only available for animal consumption.

2.3.3 *Value of predicted increase in forage production per AUM* Determining value of predicted increase in forage production per AUM is key in economic analysis. In this analysis, the annual economic return in terms of AUMs is calculated as follows:

$$A_i = S_i/T_m$$

$$G_w = A_i \times T_d \times W_d$$

$$R_i = G_w \times V$$

$$P = (R_i - C)/T_m$$

Where, A_i: Increased AU/hm², T_m: Month of grazing in a growing season; G_w: Gain in AU/hm², T_d: days of grazing, W_d: average daily gain, R_i: Increased revenue from increased AU/hm², V: Gross value/kg, P: Profit in AUM/hm², C: Cost of raising cattle per AU/hm².

2.3.4 Expected productive life of treating range with clubmoss The effective life of treating clubmoss depends upon the mechanical treatment used, range site, climate, and management practices. Longevity of treatment effects on forage production ranges from 1 to 6 years, depending on location, treatment, and climate[2~4, 10, 12, 14, 16, 20]. Until more information becomes available from long-term studies, beneficial effects of mechanical treatment on forage yield on rangeland should be expected to exceed 15 years[15]. However, analyses were completed at 5-year intervals to allow assessment for up to 20 years after treatment.

2.3.5 Market interest rate or opportunity cost of money *Market interest rate is the rate at which money can be borrowed or the best alternative use of capital will return.* In this study, the market rate of interest was assumed at 8% and 10%.

2.4 Determinants of Economic Feasibility

Two analysis techniques, net present value (NPV) and internal rate of return (IRR) were used to determine economic feasibility of treating clubmoss.

The usual procedure of net present value is to compare initial investment cost with the sum of discounted future net returns resulting from the investment. For a project to be economically feasible, net present value must be positive. The sum of discounted future return can be expressed mathematically as follows[21]:

$$NPV = \sum_{n=1}^{N} \frac{(R_n - C_n)}{(1+i)^n}$$

Where, R_n: *Gross benefit resulting from the investment*, C_n: Annual costs of the investment, i: Discount rate, n: Effective life of the project.

Internal rate of return is the interest rate that forces a future stream of benefits to just equal the investment and other related costs required to produce the flow of returns[22]. Projects are not economical feasible unless the internal rate of return is greater than the discount rate. The formula used for such calculation is as follow:

$$IRR = \sum_{n=1}^{n} (Rn - Cn)/(1+i)^n$$

Where, IRR: Internal rate of return.

Costs and benefits are required to determine if pitting or chisel plowing clubmoss is economically feasible. Before analyzing costs and benefits, specific assumptions[19] were made. These included:

(1) Size of each range site in each area is 1000 hm^2; (2) Grazing is deferred 2 years after treatment of range; (3) The grazing season averages 3.5 months or 110 days; Each cow gains 0.79 kg/d; (4) Average feeder price is \$2.25/kg; (5) Increased carrying capacity will last for 5, 10, 15, or 20 years after pitting or chisel plowing.

One should view these *assumptions as stipulations, since these can be changed for performing sensitivity.*

3 Cost and Benifit

3.1 Estimation of Treatment Costs

Treatment costs considered in this analysis are only the changes after pitting or chisel plowing and vary with kind of machinery used, increment in animal carrying capacity, and years required for deferment. They include agricultural machinery costs, operation costs, and grazing deferment.

3.3.1 Machinery costs Machinery costs for pitting or chisel plowing depend upon type of equipment used, size of area being treated, and range site. In this study, a heavy breaking disk for pitting was substituted at a cost of \$32.00/hm^2[19]. For chisel plowing, a heavy-duty cultivator was utilized at a cost of \$47.40/hm^2.

3.1.2 Cost of Raising Cattle Raising cattle costs start in the third year after pitting or chisel plowing. In this analysis, costs of purchasing and selling feeder animals, veterinary medicine and supplies, fuel and repair, insurance on investment, office supplies, and death loss were included. Feeder cost was excluded because the weight change between before and after grazing was considered. Water facilities were assumed to be sufficient for raising additional animals in each area. Fencing did not change after treatment. Taxes for pasture improvement were not included because the tax rate in Saskatchewan is determined in terms of area, based on 3 factors: climate, range site, and topography. None of these factors were affected by mechanical treatments. Operation costs for different soil zones and range sites are presented in Table 3.

Costs of feeder purchasing consists of buying *commission and trucking. A buying commission is* \$6.00/animal was assumed[19], but trucking costs vary with the number of animals. Trucking costs were calculated as follows:

$$C_t = N_f / N_a \times V_t$$

Where, C_t: Trucking costs, N_f: Additional No. of feeders per hm^2, N_a: Number of animals per load (80), V_t: \$ /load (150)[19].

Cost per animal was converted into cost/hm^2. Selling costs included selling commission, selling cost, and trucking. Selling commission and selling cost were \$15/animal and \$ 3.05/animal, respectively. Cost of trucking for sale was calculated the same as with purchasing, except that it costs \$55 animal/load, and 1.5% death loss was considered. All other operational costs were calculated based on the cost/animal[19] times the additional number of animals/hm^2.

Table 3 Cost associated with raising additional cattle under treatments in 3 soil zones (CN\$ / hm^2)

Items	Dry Areas in Brown Soil Zone				Moist Areas in Brown Soil Zone				Dark Brown Soil Zone			
	Loamy soil		Sandy soil		Loamy soil		Sandy soil		Loamy soil		Sandy soil	
	Pitting	Chisel	Pitting	Chisel	Pitting	Chisel	Pitting	Chisel	Pitting	Chisel	Pitting	Chisel
Feeder purchase	0.56	0.39	0.48	0.42	0.71	0.42	0.63	0.45	1.04	0.58	0.95	0.54
Veterinary	0.96	0.56	0.78	0.46	1.32	0.46	1.15	0.71	1.76	1.02	1.57	0.92
Fuel and repair	0.13	0.08	0.11	0.06	0.18	0.06	0.16	0.10	0.24	0.14	0.22	0.13
Insurance	0.05	0.03	0.04	0.02	0.07	0.02	0.06	0.04	0.09	0.05	0.08	0.05
Office supplies	0.02	0.01	0.01	0.01	0.03	0.01	0.02	0.01	0.03	0.02	0.03	0.02
Death loss	0.77	0.45	0.62	0.37	1.06	0.37	0.92	0.57	1.41	0.82	1.26	0.74
Labor	0.60	0.35	0.49	0.29	0.81	0.29	0.72	0.44	1.10	0.64	0.98	0.58
Feeder selling	1.37	0.80	1.13	0.89	1.97	0.89	1.76	1.05	2.51	1.44	2.28	1.31
Total cost	4.47	2.66	3.65	2.53	6.17	2.53	5.42	3.36	8.19	4.71	7.38	4.28

3.1.3 Grazing deferment In this study, grazing was not allowed in the first 2 years after treatments to allow plants on the site to recover or new plants to establish. Costs of grazing deferment was calculated as:

$$C_d = Y_u \times K/(Q \times T_m) \times V_c$$

$$V_c = (G_d \times T_d \times V_k) - C_r$$

Where, C_d: Cost of grazing deferment, V_c: Value per cattle, G_d: Grazing period (days)/a, V_k: \$/kg, C_r: Total cost of raising cattle.

Results are shown in Table 3. Generally speaking, cost of deferring grazing was greater on loamy than sandy range sites, and greatest in the Dark Brown Soil Zone.

Table 4 Cost of deferring grazing for 2 years on loamy and sandy range sites in 3 soil zones after treatments (CN\$ / hm^2)

Treatments	Dry Areas in Brown Soil Zone		Moist Areas in Brown Soil Zone		Dark Brown Soil Zone	
	Loamy soil	Sandy soil	Loamy soil	Sandy soil	Loamy soil	Sandy soil
Pitting	14.06	11.30	25.37	19.26	30.63	22.68
Chisel	13.87	10.94	25.53	19.15	30.61	22.82

3.1.4 Discounting of future benefits and costs Costs and benefits from different treatments must be compared on a common time base, which is present value. Table 5 shows the investment time pathway in accumulated present value at 5, 10, 15, and 20-year intervals for the 2 mechanical treatments.

Table 5 PV of costs of treatments on loamy and sandy range sites in 3 soil zones at 8% and 10% discount (CN\$ / hm^2)

Treatments	Year	Dry Areas in Brown Soil Zone				Moist Areas in Brown Soil Zone				Dark Brown Soil Zone			
		Loamy soil		Sandy soil		Loamy soil		Sandy soil		Loamy soil		Sandy soil	
		8%	10%	8%	10%	8%	10%	8%	10%	8%	10%	8%	10%
Pitting	5	65.0	63.0	57.9	56.2	77.6	75.2	71.2	69.0	93.0	90.0	86.4	83.6
	10	77.7	74.1	67.8	64.8	94.4	89.7	85.9	81.8	115.2	109.2	106.4	101.0
	15	86.3	80.7	74.6	70.2	105.8	98.7	95.9	89.7	130.4	121.2	120.7	111.8
	20	92.2	85.1	79.2	73.5	113.6	104.3	102.8	94.6	140.7	128.6	129.4	118.5
Chisel	5	74.5	72.7	69.0	67.3	86.1	83.9	80.7	78.6	99.8	97.1	94.1	91.5
	10	81.8	78.9	75.9	73.2	96.1	92.5	88.8	86.5	112.6	108.2	105.7	101.6
	15	86.7	82.8	80.6	76.9	102.8	97.8	96.0	91.4	121.3	115.1	113.6	107.8
	20	90.1	95.2	83.7	79.2	107.4	101.1	100.3	94.4	127.3	119.3	119.0	111.7

3.2 Benefits from Treatments

Benefits from treatment of clubmoss in this study were estimated as the value of incremental animal units resulting from the increased grazing capacity under a given treatment. In this calculation, a death loss of 1.5% was taken into account:

$$B = (S_i/T_m) \times (V_c/L)$$

Where, B: Benefits, L: death loss.

Generally speaking, expected economic benefits are greater on loamy than sandy range sites, and within range sites benefits increased from Dry Brown to Dark Brown Soil Zones (Table 6).

Table 6 Economic benefits of treatments on loamy and sandy range sites in 3 soil zones (CN \$ / hm²)

Treatments	Dry Areas in Brown Soil Zone		Moist Areas in Brown Soil Zone		Dark Brown Soil Zone	
	Loamy soil	Sandy soil	Loamy soil	Sandy soil	Loamy soil	Sandy soil
Pitting	12.97	10.45	17.81	15.48	23.61	21.09
Chisel	7.55	6.19	10.45	9.48	13.74	12.38

3.3 Time pathway of accumulated benefits

Present value of income on loamy range sites in the Dark Brown Soil Zone is highest, and that for sandy range sites in dry areas in Brown Soil Zone is lowest (Table 7).

Table 7 PV of benefits of treatments on loamy and sandy range sites in 3 soil zones at 8% and 10% discount (CN \$ / hm²)

Treatments	Year	Dry Areas in Brown Soil Zone				Moist Areas in Brown Soil Zone				Dark Brown Soil Zone			
		Loamy soil		Sandy soil		Loamy soil		Sandy soil		Loamy soil		Sandy soil	
		8%	10%	8%	10%	8%	10%	8%	10%	8%	10%	8%	10%
Pitting	5	28.7	26.7	23.1	21.5	39.3	36.6	34.2	31.8	52.2	48.5	46.6	43.3
	10	63.9	57.2	51.5	46.1	87.7	78.5	76.3	68.3	116.3	104.1	103.6	92.9
	15	87.9	70.1	70.8	61.4	120.7	104.5	104.9	90.9	160.0	138.6	142.8	123.8
	20	104.2	87.9	84.0	70.8	143.1	120.7	124.4	105.0	189.7	160.1	169.4	142.9
Chisel	5	16.7	15.5	13.7	12.7	23.1	21.5	21.0	19.5	30.4	28.2	27.4	25.5
	10	37.2	33.3	30.5	27.3	51.5	46.1	46.7	41.9	67.7	60.6	61.0	54.6
	15	51.2	44.3	42.0	36.4	70.8	61.4	64.3	55.7	93.1	80.7	83.9	72.7
	20	60.7	51.2	49.8	42.0	84.0	70.8	76.2	64.3	110.4	93.1	99.5	84.0

4 Results

Generally, pitting and chisel plowing range in the Dark Brown Soil Zone had the highest net present value, and lowest returns are predicted in the Dry Brown Soil Zone. All net present values for chisel plowing were negative, indicating this treatment is not economically feasible on any range site in all soil zones at either 8% or 10% interest rate over a 5 to 20 year period (Table 8). At 8% discount rate, pitting is economically feasible for within 10 years on all range sites and soil zones, except on sandy range sites in the Brown Soil Zone, where over 15 years were needed to recover costs. At a 10% discount rate, benefits of pitting could cover the total cost in a 15-year period except on sandy range sites in the Dry Brown Soil Zone.

Table 8 NPV of two treatments on loamy and sandy range sites in 3 soil zones after treatments (CN \$ / hm²)

Treatments	Discount Rates	Year	Dry Areas in Brown Soil Zone		Moist Areas in Brown Soil Zone		Dark Brown Soil Zone	
			Loamy soil	Sandy soil	Loamy soil	Sandy soil	Loamy soil	Sandy soil
Pitting	8%	5	−36.36	−34.78	−38.26	−36.85	−40.80	−39.80
		10	−13.80	−16.32	−6.64	−9.62	−6.03	−2.57
		15	1.55	−3.76	14.87	8.98	29.64	22.77
		20	12.00	4.80	29.53	21.63	49.06	40.01
	10%	5	−36.43	−34.75	−38.60	−37.17	−41.43	−40.29
		10	−16.89	−18.76	−11.21	−13.50	−6.21	−8.04
		15	−4.71	−8.83	5.80	−1.20	17.42	11.98
		20	2.77	−2.66	16.36	10.32	31.42	24.41
Chisel	8%	5	−57.84	−55.31	−63.04	−59.72	−69.46	−66.69
		10	−44.57	−45.38	−44.57	−43.08	−44.92	−44.65
		15	−35.54	−38.58	−32.01	−31.76	−28.22	−29.67
		20	−29.39	−33.97	−23.46	−24.05	−16.86	−19.46
	10%	5	−57.14	−54.56	−62.37	−59.07	−68.84	−66.04
		10	−45.64	−45.93	−46.38	−44.66	−47.58	−46.96
		15	−38.50	−40.58	−36.45	−35.72	−34.39	−35.12
		20	−34.07	−37.26	−30.29	−30.16	−26.19	−27.76

Internal rate of return overcomes the disadvantage of net present value, which forces selection of interest rates or discount rates. Internal rate of return compares with market interest rates directly to determine economic feasibility (Table 9). Pitting or chisel plowing is not economically feasible unless the internal rate of return of the specific treatment on the corresponding range site is greater than market interest rate. Internal rates of return are greater for pitting than chisel plowing, and rates are greater in the Dark Brown than the Dry Brown Soil Zone.

Break-even analysis indicates the time required to recover costs of treatment for pitting or chisel plowing vary with range site, soil zone, and interest rate (Table 10). Fewer years are needed to recover costs of pitting than chisel plowing on the same range site in the same soil zone; more time is needed to recover costs with higher discount rates. More than 30 years are required to recover costs of chisel plowing regardless of soil zone, range site, and discount rate.

Table 9 IRR for two treatments on loamy and sandy range sites in 3 soil zones after treatments

Treat-ments	Years	Dry Areas in Brown Soil Zone		Moist Areas in Brown Soil Zone		Dark Brown Soil Zone	
		Loamy soil	Sandy soil	Loamy soil	Sandy soil	Loamy soil	Sandy soil
Pitting	5	—	—	—	—	—	—
	10	2	0	6	4	8	7
	15	8	7	12	10	14	13
	20	11	9	13	12	16	15
Chisel	5	—	—	—	—	—	—
	10		—	—	—	—	—
	15	—	—	0	0	2	2
	20	2	0	4	3	5	5

— negative

Table 10 Predicted number of years required to recapture costs of two treatments on loamy and sandy range sites in 3 soil zones

Treat-ments	Discount Rates	Dry Areas in Brown Soil Zone		Moist Areas in Brown Soil Zone		Dark Brown Soil Zone	
		Loamy soil	Sandy soil	Loamy soil	Sandy soil	Loamy soil	Sandy soil
Pitting	8%	15	17	12	13	10	11
	10%	22	24	14	15	11	12
Chisel	8%	>20	>20	>20	>20	>20	>20
	10%	>20	>20	>20	>20	>20	>20

5 Conclusions

Pitting and chisel plowing can increase forage yields and stocking rates on rangelands infested by Clubmoss in Saskatchewan. However, weather is more important in determining forage productivity than mechanical disturbance[17]. Based on results of studies in Montana[13, 20], chisel plowing improves yield less than pitting. The economic feasibility of pitting or chisel plowing rangeland depends upon treatment used, costs of treatment, forage production before treatment, increment of forage production after treatment, value of increased forage production, effective life of the treatment, interest rate, and grazing deferment. Costs and benefits from mechanical disturbance on range depend upon the additional animal units produced, return to grazing per animal unit, and carrying capacity. Additional grazing can be expected following mechanical disturbance on loamy or sandy range sites in the 3 soil zones tested. Economic feasibility of mechanical disturbance of loamy range sites is greater than sandy range sites, and expected rates of return are higher in Dark Brown Soil Zone than in the Dry or Moist Brown Soil Zone.

Methods of mechanical disturbance are characterized by high initial costs and low rates of return. Furthermore, costs and benefits must be compared to complete economic analysis, depending on the level of discount rate used. Of the 2 treatments evaluated, economic feasibility appears greater for pitting than chisel plowing. Period of recovery of total costs of pitting ranged from a low of 10 to 11 years on loamy range sites in the Dark Brown Soil Zone to 17 to 24 years on sandy range sites in the Brown Soil Zone depending on discount rate. Recovery of costs associated with chisel plowing would take over 30 years at 8% or 10% discount rate, regardless of range sites and soil zone. It must be stressed that these values assumed a constant level of increased herbage yield over the duration of the project. However, the validity of this assumption must be questioned for published data suggest that herbage production may diminish in 1 to 6 years[2~4, 10, 12~16] in which case mechanical disturbance is not economically feasible.

Cost-benefits analysis suggests that decision-makers must understand completely each situation before deciding whether to proceed with mechanical disturbance of rangeland. The decision must be based on the equipment used, whether equipment is being rented or owned, the length of time grazing is deferred, size and location of the area treated, range condition, range site, time of year treated, life of the project, interest rate, market price, and expected returns from mechanical disturbance. However, weather is more important in determining forage productivity than mechanical disturbance[17]. Comparison of net present value of costs and benefits or internal rate of return will show if the proposed mechanical disturbance of range is economically desirable in a certain period of time.

Because of the lack of production data following disturbance of rangeland in Saskatchewan, this study was carried out using yield data from Montana to estimate the yield increases. Relationships developed for other rangelands could lead to over or under-estimate the yield increases in Saskatchewan. Estimated forage yield in Saskatchewan was based on a simplistic assumption that the yield ratio of each mechanical treatment was constant across range sites and soil zones. This assumption could also bias estimates of yield.

The scope of the evaluation adopted in this analysis only considered direct market value and excluded indirect values such as environmental value or recreational value, option value, existence value, or bequest value for mechanical improvements, which would further imply that the total value and economic worth of the treatments are higher than the estimated value. Price of livestock and other productive inventory were constant and ignored inflation. Furthermore, the life of the mechanical disturbance was difficult to determine because no such treatments have been studied in Saskatchewan. It is questionable whether beneficial treatment effects on herbage production exceed 10 years.

In summary this economic analysis will prove useful in prioritizing range management practices. Range managers considering pitting or chisel plowing to reduce clubmoss and improve forage productivity will find the net present value of mechanical disturbance (Table 8), internal rate of return (Table 9), and the number of years to break even (Table 10) useful in making economically prudent decisions.

References:

[1] Coupland R T. Ecology of Mixed Prairie in Canada. *Ecol. Monogr.*, 1950, **20**:271~315.

[2] White L M. Stand age, precipitation, and temperature effects on forage yield. *J. Range Manage.*, 1985, **38**:394~3.

[3] Rauzi F. Mechanical and chemical range renovation in southeastern Wyoming. *J. Range Manage.*, 1974, **27**:48~52.

[4] Rauzi F. Severe mechanical and chemical range renovation in northeastern Wyoming. *J. Range Manage.*, 1975, **28**:319~326.

[5] Griffith L W, Schuman G E, Rauzi F, *et al.* Mechanical renovation of shortgrass prairie for increased herbage production. *J. Range Manage.*, 1985, **38**:7~10.

[6] Barnes O K. Mechanical treatments on Wyoming rangelands. *J. Range Manage.*, 1950 **3**:198~203.

[7] Barnes O K, Anderson D, and Heerwagen A. Pitting and range improvement in the Great Plains and the southwestern desert regions. *U. S. Dept. Agric. Prod. Res. Report*, 1958, **23**: 46~69.

[8] Lang R L. Range pitting trials in the Big Horn Mountains of Wyoming. *Wyoming Agric. Exp. Sta. Bull.*, 1958, **357**:1~9.

[9] Thomas G W and Young V A. Range pitting and reseeding trials on Texas range station near Barnhart, 1950~1955. Texas Agric. *Exp. Sta. Prog. Rep.*, 1956. 1882~1889.

[10] Houston W R. Renovation and fertilization of crested wheatgrass stands in the Northern Great Plains. *J. Range Manage.*, 1957, **10**:9~11.

[11] Houston W R. Annual progress report, U. S. Range Livestock Experiment station (ARS-USDA), Crops Research Division Forage and Range Branch, Arid Pasture and Range Section. *Mimeo.*, 1963, 56~68.

[12] Lorenz R J. and Rogler G A. A comparison of methods of renovating old stands of crested wheatgrass. *J. Range Manage.*, 1962, **15**: 215~219.

[13] Ryerson D E, Taylor J E, Baker L O, *et al.* Clubmoss on Montana rangelands. *Montana Agric. Exp. Sta. Bull.*, 1968, 645~650.

[14] Wight J R and White L M. Interseeding and pitting on a sandy range site in eastern Montana. *J. Range Manage.*, 1974, **27**: 206~210.

[15] White E M, Gartner F R, and Butterfield R. Range claypan soil improvement: Response from furrowing and ripping in northwestern South Dakota. *J. Range Manage.*, 1981, **34**:1191~25.

[16] Hart M, Waller S S, Lowry S R, *et al.* Discing and seeding effects on sod bound mixed prairie. *J. Range Manage.*, 1985, **38**:121~125.

[17] Haferkamp M R, Volesky J D, Borman M M, *et al.* Effects of mechanical treatments and climatic factors on the productivity of Northern Great Plains rangelands. *J. Range Manage.*, 1993, **46**:346~350.

[18] Abouguendia Z M. A practical guide to planning for management and improvement of Saskatchewan rangeland: *Range plan development.* New Pasture and Grazing Technologies Project. Regina, SK, 1990. 1~50.

[19] Saskatchewan Agriculture and Food. Backgrounding beef cattle in Saskatchewan. http:/www. gov. sk. ca/agfood/mgt/bkgrdgb. htm. 1997.

[20] Ryerson D E, Taylor J E, Baker L O, *et al.* Vegetation response to nitrogen fertilization and pitting on a clubmoss infested range in Northern Montana. *Montana Agric. Exp. Sta. Res. Report*, 1974, 61~76.

[21] Workman J P. *Range economics.* Macmillan Publ. Co., New York, N. Y. ,1986. 50~56.

[22] Nielsen D B. *Economics of range improvements.* Utah Agric. Exp. Sta. Bull., 1967. 466~468.