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COMMON PROPERTY RANGELAND AND INDUCED NEIGHBORHOOD EFFECTS: RESOURCE MISALLOCATION IN BOLIVIAN AGRICULTURE

Deteriorating mountain ecosystems in the developing countries pose an increasingly serious threat to the well-being of a significant proportion of the world's population, according to evidence presented at the recent International Conference on Mountain Environments (Eckholm 1975).[1] Demand pressure, especially from growth in population, has resulted in accelerating damage to and destruction of biomes, especially in the Himalayas, the Andes, and the mountains of Eastern Africa with grave consequences for residents of both the highlands, and adjacent lowlands (UNESCO). Indeed, scientists are now beginning to assess the implications of such depletion of renewable natural resources for world food production (Eckholm 1976). While the existence of the problem has been documented, little is known of cause and effect relationships in man's exploitation of mountainous regions.

This paper presents an economic interpretation of the deterioration of rangelands in the Bolivian Andes which builds on the work of Gordon, Haveman, LeBaron, and Smith. The basic premise of the paper is that such rangelands are exploited as common-property resources with resultant overgrazing, consequent depletion of the range resource, and an inherent external diseconomy in the form of flooding and erosion as vegetative cover is destroyed. The analysis of rangeland production under common-property rights appears to have unique features from that of fisheries and oil pools because of the erosion externality. However, all three cases are related since they are characterized by

supra-optimal equilibriums and all likely exhibit resource stock, and crowding externalities (Smith, Gordon, Haveman, Scott, and Turvey).

The proposition that land tenure might be common in a developing country is somewhat at odds with an argument made by Gordon in his classic article on common-property resources:

> Speaking generally, we may say that stable primitive cultures appear to have discovered the dangers of common-property tenure and to have developed measures to protect their resources. Or, if a more Darwinian explanation be preferred, we may say that only those primitive cultures have survived which succeeded in developing such institutions. (Pages 134-35.)

Primitive civilizations in Bolivia, as will be demonstrated, indeed had developed institutions which protected renewable natural resources from common exploitation. However, in the process of Spanish colonization and more modern economic growth such institutions have been significantly modified or destroyed despite at least partial survival of important ancient cultures such as the Aymara.

Consequently, rangelands in Bolivia, which account for a significant proportion of total area in the highlands, are currently exploited under common tenure rights with resultant serious misallocation of resources. Further, the deterioration of mountain environments throughout the rest of the developing world strongly suggests the existence of common-property land tenure, although direct evidence of such is only presented for Bolivia.

In the next section, an economic model of livestock production adjustments on native ranges will be developed under the assumption of

common-property rights. The historical development and current state of land tenure in Bolivia's highlands are discussed in Section III, while empirical evidence for Bolivia testing the economic model is presented in Section IV. Conclusions and policy recommendations are the subject of Section V.

Economic Model of Rangeland Exploitation Under Common-Property Rights

The theory defining optimum and equilibrium levels of exploitation of forages produced on rangelands, under common-property conditions, is developed in the analysis which follows. The methodology is to employ a static, partial-equilibrium model for a given range to illustrate principal aspects of the dynamic process of moving to equilibrium. The focus is on the behavior of entrepreneurs who utilize a set of intra-marginal rangelands of varying productivity under free access and individualistic competition to graze animals and produce meat, hair, hides, and wool.

Assume the following aggregate production function for any range in the set:

(1) $Y = f(x,z)$, where

Y = animal product

x = variable factor of production (grazing intensity),[2] and

z = fixed unit of rangeland or, alternatively, the stock of forage produced on such land during a production season.

The production function is assumed to exhibit declining marginal product (Roberts 1959, Caton, Stoddart).[3] It is also assumed entrepreneurs sell Y and buy x in a competitive market.[4] Finally, in the initial time period 0, the unit of rangeland z is assumed to be producing forage at its potential (i.e., z is at a maximum in 0), which may be higher or lower than other ranges in the set being exploited.

Under these conditions in period 0, the derived demand for x for use on the rangeland z is $\frac{dY}{dx} \cdot P_Y$, or the value of marginal product of x ($VMP_{x,0}$); the private and social cost of the factor at the margin ($MFC_{x,0}$) is equal to the constant price of x (P_x) which is the same for all ranges in the set; and the optimal level of grazing intensity (x) on the given range (z) is obtained by solving for x:

(2) $\frac{dY}{dx} \cdot P_Y = P_x$, or x_0^* in Figure 1, <u>ceteris paribus</u>.

If z_0 is exploited under common-property rights, this optimum will not be attained. Instead, entrepreneurs will tend to increase grazing intensity beyond x_0^* in an attempt to capture the non-appropriable rents. Equilibrium tends to results when the rent is dissipated or at x_0^{**} where value of average product of x (VAP_x) is equal to P_x (Gordon, Haveman). This supra-optimal equilibrium is only a fiction of the analysis, however, and is not attainable in the case of rangelands at their forage producing potential because of their fragile ecology.

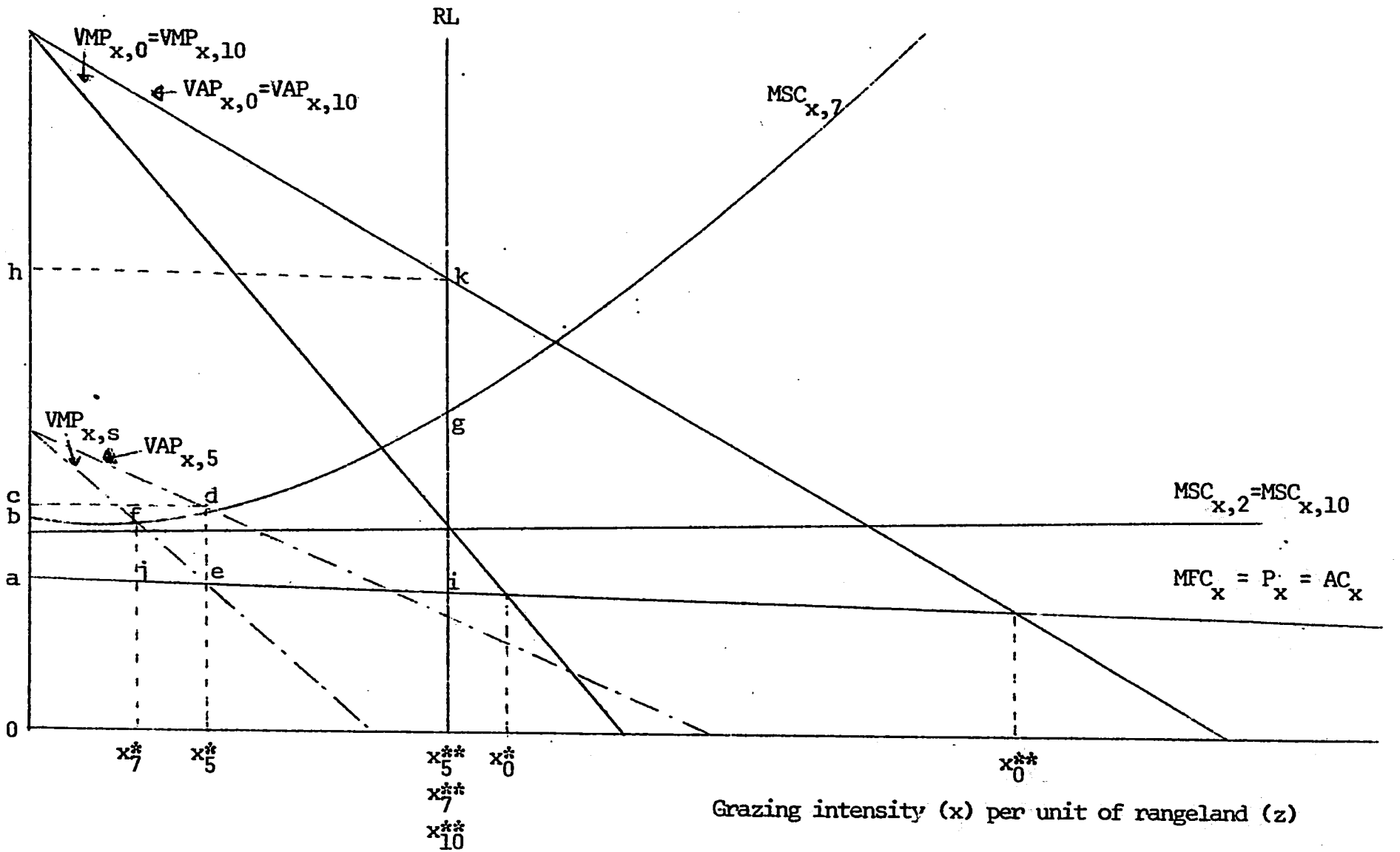

Figure 1. Marginal Production Conditions with Variable Grazing Intensity (x) on Fixed Rangeland (z) Under Free-Access Compared to Property Rights.

It is generally recognized that there is a limit of grazing intensity for any given range which, if exceeded in one season, will cause forage production to decline in ensuing periods (Roberts 1963). This limit is referred to as the renewable limit, RL (Figure 1.)[5]

Apparently, in rangeland ecology, there is a symbiotic relationship between domestic grazing animals and the plant life of the range that permits maintenance of forage production at a maximum approximating z_0 season after season, if RL is not exceeded.[6] But, if RL is exceeded, the relationship is antagonistic with the level of the fixed factor z being reduced in succeeding production periods.

It is very likely that grazing intensity exceeds RL for the range z at its forage producing maximum. Rangelands are generally extremely sensitive to stocking pressure so the renewable limit is at a relatively low level of grazing intensity. Given the low level of RL and z at its forage producing potential, it is probable that $VAP_{x,0}$ is greater than MFC_x.[7] If so, rents to z_0 will exist and entrepreneurs will increase grazing intensity beyond RL in an attempt to capture such rents.

If grazing intensity exceeds RL for z_0, overgrazing occurs and the production function for animal products will shift downward in ensuing seasons at all levels of grazing intensity due to the fall in the quantity of the fixed factor z.[8] As long as grazing intensity exceeds RL, the production function and related marginal and average production curves will continue to shift downward until a supra-optimal equilibrium is established in some ensuing production period such as 5 at x_5^{**} = RL, where $VAP_{x,5} = P_x$ (Figure 1).[9]

The equilibrium at x_5^{**} is stable. Levels of x in excess of RL cause the production function to shift down toward RL as z declines. If grazing intensity is less than RL, the range begins to renew itself in subsequent periods, z increases, and the production function shifts up toward RL. Thus, the renewable limit defines the stable equilibrium of x_5^{**} associated with z_5 at a much lower level of production than at the potential of the rangeland. At the supra-optimal equilibrium, x_5^{**}, the rent to the intra-marginal range z (acde which would exist at the optimum x_5^{*}) is completely dissipated; the marginal cost of x to society (P_x) greatly exceeds the negative value of the marginal product attributable to the marginal factor; excessive resources valued at $Oaix_5^{**}$ - $Oaex_5^{*}$ are utilized in producing Y, and production of animal products is much lower than with z_0.[10]

An equilibrium similar to x_5^{**} for range z is established on all other rangelands in the set being exploited since MFC_x is the same for all rangelands, and the average product of all ranges tends to equality because of unrestrained competition. That is, entrepreneurs tend to exploit the rangeland with the highest average product per unit of grazing intensity and, consequently, cause the productivity of such range to decline both by moving out along a given production function, and by shifting the function down as the renewable limit is exceeded. The end result of all adjustments (as herdsmen shift flocks among ranges in the set in an attempt to earn the highest average product) is an equality of the average product with MFC_x on all ranges

with each range in an equilibrium similar to that illustrated for range z at x_5^{**} in Figure 1.

Both resource stock and crowding externalities may be present in the utilization of rangeland as a common-property resource, especially at relatively high levels of grazing intensity. In the first case, the grazing and reduction of available forage on any given range by the flock of one herdsman may cause the grazing of other flocks to be less efficient. In the second case, the physical presence of one flock may make it more difficult for other flocks to graze since the flocks get in each others way. In both cases, the value of the marginal social product of the rangeland is less than the value of the marginal private product (VMP_x) beyond the level of grazing intensity at which the externality begins, and the social cost of Y exceeds the private cost at the margin. Consequently, in the presence of such externalities, the optimum level of grazing intensity for any rangeland is somewhat less than in their absence. The resource stock and crowding externalities are not shown in Figure 1 and are assumed non-existent at levels of grazing intensity less than RL in order to simplify the ensuing analysis.

There is another more serious externality which is inherent in the exploitation of rangelands under common-property tenure. When grazing intensity exceeds the renewable limit, RL, part of the vegetative cover is destroyed. This results in increased run-off of rain water and accelerated erosion. At the supra-optimal, stable equilibrium for any intra-marginal range, run-off is excessive and erosion rampant since

the vegetative cover is greatly reduced over that which existed with rangeland at its forage producing potential in the initial production period. Further, such erosion tends to feed upon itself and the external diseconomy to grow despite the stability of the equilibrium.

To the extent erosion occurs on the rangeland itself, the stock of forage produced on any given range is reduced, and the externality has exactly the same effect as the resource stock and crowding externalities; the marginal private product of rangeland is greater than the marginal social product. It is also assumed, however, in order to further simplify the analysis, that the erosion externality only affects people outside the set of rangelands.

The erosion externality is similar to that of the environmental pollution case in that producers and consumers outside the rangeland bear the major share of external costs of the production process. The effect of erosion on external producers is to reduce their revenue function through soil losses, sedimentation, and flooding. The effect on consumers of environmental services is to reduce their demand. In either case, the loss to society can be determined. In order to simplify the analysis, these external costs of rangeland production will be added to the MFC_x in order to show the effect on the optimum and equilibrium levels of grazing intensity for the intra-marginal range z. It should be clearly understood, however, that the $MFC_x = P_x$ associated with range use is not changed as a result of the erosion externality. Rather, external costs may be considered analogous to

MFC_x and added to it to determine the marginal social cost of the productive activity (MSC_x) in the convention introduced by Haveman (pp. 285-86).

In essense, the social cost of the factor at the margin (MFC_x) is now increased at every level of x to MSC_x by the effect of the erosion externality on producers and consumers outside the rangeland. Further, the marginal social cost of x likely increases as x increases since the extent of run-off is related directly to grazing intensity for any given production function. Thus, at some period such as 2, the marginal social cost of x is no longer the constant MFC_x but the $MSC_{x,2}$ (Figure 1). The $MSC_{x,2}$ is not stable because of the falling production function, and increased rate of erosion. Despite the stable equilibrium and production function in period 5, the $MSC_{x,5}$ continues to increase because of the cumulative nature of erosion.

In some later production period, such as 7, the social optimum for grazing intensity given the erosion externality is x_7^*, ceteris paribus.[11] Of course, this optimum is not stable unless erosion stabilizes.

However, the supra-optimal equilibrium established at x_5^{**} = RL is maintained in all succeeding periods (i.e., $x_7^{**} = x_5^{**}$) because of the common-property nature of the resource and the fact that external costs from the erosion externality are not internalized to entrepreneurs exploiting the rangeland z. Consequently, excessive resources value at $Obfgx_5^{**} - Obfx_7^*$ are "employed" exploiting the rangeland z as a common-property resource when the erosion externality is present.[12] At

$x_5^{**} = x_7^{**}$, the marginal social cost of the productive activity exceeds the marginal private cost by a substantial margin (ig) because of the erosion externality. The consequence is a much higher social than private cost of Y at the margin.

Thus, there are two components to the divergence between private and social costs in the case of the common-property rangeland resource. One is the tendency for entrepreneurs to equate the average rather than the marginal product among alternative uses, which results in the establishment of a stable, supra-optimal equilibrium at the renewable limit, with a decline in the rangeland production function, and an excess of resources being used with total cost at equilibrium greatly exceeding optimum cost. Second, overgrazing causes an externality in the form of erosion and flooding. The principal impact is on downstream producers and consumers which reduces production revenue and consumer welfare. The consequence can be conceptualized as increased costs of producing animal product on rangeland. The result is social cost of Y in excess of private cost at the margin, excess resources being employed, and overproduction.

Bolivian Rangeland Tenure and Institutions

Under the existing land tenure system in Bolivia's Altiplano and Valleys, common exploitation of rangelands is extensively practiced. In the Altiplano, common pastures are popularly referred to as ahijaderos.[13] In some cases, ahijaderos are for the exclusive use of members of a community, or of several communities. However, such pastures are usually

small relative to the population of the involved community(ies), and there is no further control or regulation of any kind impeding private exploitation of the resource. Thus, these pastures are grazed in common by the flocks of the community or communities. The pastures more remote from population centers are usually at higher elevations and are free to be exploited by anyone on a first-come first-serve basis. These zonal rangelands are utilized in mid-summer through autumn when forage on community ranges is depleted. Finally, both community and zonal rangelands usually comprise disparate and separate grazing sites.

A very similar situation exists in the Valleys where common-property pastures are referred to as hechaderos. However, zonal pastures are relatively unimportant. In the Puna (hilly highlands) area of the Valleys most common pastures are on the relatively steep hillsides which are generally unfit for cultivation. Yet, demographic pressure has increasingly forced cultivation of hechaderos in the Puna to meet subsistence needs. Such encroachment is also occuring on the ahijaderos of the Northern Altiplano. The consequence in both cases is complete destruction of part of the rangeland, and acceleration of the already serious erosion caused by overgrazing.

Common usage of rangelands is apparently of somewhat recent origin since the Spanish chroniclers through their editors indicate rangelands and other natural resources were exploited under strictly enforced public property rights during the Incan (Tahuantinsuyu) Empire, and under private property rights during the Spanish Colonial and Republican periods.

According to Cobo (writing about 1653) in the Incan Empire, the state, represented by the Inca (emperor), owned all land but conferred usufructuary rights in some cases. Cultivable lands were divided into three parts, one for the state, one for the cult (priestly class), and one for the ayllu or community.[14] Members of the community were required to work all three classes of land through communal labor, that is, they maintained themselves the state and the cult.[15] However, exclusive property rights were initially reserved over mines, coca production, wildlife, and forest and grazing lands (Urquidi p. 100).

The lands assigned to the community were divided into two parts, one for immediate subdivision into family plots (topos--literally measurement, of about 2/3 acre) and the other for subdivision for future generations. These plots were subject to reassignment, grouping or further division at the discretion of the state, although the tendency developed to reassign plots within families (Urquidi p. 101).

Flocks of domesticated animals (auchenidae) were also divided into the same three groups (Urquidi p. 102). Community flocks were further divided into groups for family use, and a communal (collective) herd (Cunow). The latter were apparently tended by the community, with communal labor.

The tripartite division of domestic flocks suggests that grazing lands were similarly divided. It is clear the state relaxed exclusive control (noted above) over both forest and grazing lands. In the words of Urquidi, "The areas covered with pastures and forests, in spite of

belonging to the Inca in the beginning, were liberated for the common use of the members of the ayllu." (Page 102, translation by author.)

There is a question as to whether Urquidi, in the above quote, meant by "common use" a communally managed or a common-property resource. The fact that Cobo also described the cultivated lands of the community as a "...common ..." when they were clearly communally managed under usufruct from the state (p.266), suggests the former interpretation. Given the communal management of cultivated lands, and flocks, it is most likely that grazing lands were also managed in this fashion. Thus, the land tenure system in effect during the Incan Empire probably precludes grazing land being exploited as a common-property resource.

During the Colonial (1531-1825) and Republican (1825-1952) periods public ownership and control of property rights in all land which existed during the Incan Empire gradually gave way to a system of private property rights, especially of cultivated and pasture land. The process was, of course, extremely complicated and only a summary can be presented here.[16]

After the Spanish conquest, all land was claimed as belonging to the crown. Private ownership of property rights were established and land in relatively large tracts was given to Spanish settlers (repartimientos). This generally involved deeding the entire lands of an indigenous community to an individual although ecclesiastical groups were also awarded grants. The best lands were first distributed with

gradual encroachment upon more marginal land. The indigenous communities that escaped this loss of lands gen ally maintained their communal system and public ownership of property rights although ownership and control shifted from the Inca to the community.

The new landlord (patrón) worked the lands with the labor of the community. The communal lands of the community as well as those that had belonged to the Inca and cult were worked for the benefit of the patrón. The small plots (topos) were worked by individual families for their subsistence although this usufructuary right was obtained from the patrón.

Apparently, the Spanish did not grant private property rights for forest lands and these remained the property of the crown. This may reflect the fact that such lands had been the exclusive property of the Inca and had not been released for community use to the extent of the grazing lands. In any case, forest lands were apparently exploited in common by the Spaniards, especially timber for the mines. The Altiplano, which at one time was extensively forested, was literally denuded by the uncontrolled exploitation. At least one author argues persuasively that this was at least partially responsible for changing the climate of the Altiplano (Posnansky). This, obviously, has contributed to the increasingly serious problem of erosion which has been alluded to.

The historical perspective suggests common tenure of rangelands is of recent origin. The Agrarian Reform Law of 1953 recognized two general classes of ownership of property rights, public and private (Villarroel and Avila, p. 10). Private property includes homesites,

small properties, medium properties, communal properties, cooperative properties, and agriculture enterprises. The emphasis has been on dividing the cultivable land of large estates (haciendas) into homesites and small properties, and community or cooperative properties for redistribution to the campesino sector. In contrast, ahijaderos were either deeded to communities for collective use, or remained in the public domain.[17]

Unfortunately, the Agrarian Reform Law did not provide for controlled use of either private communal or public pasture lands. Legally, the community ahijadero lands are private communal property, but property rights are not enforced as demonstrated by uncontrolled and unregulated exploitation (except for limiting their use to members of the community or communities). In contrast, private communal lands that are cultivated (aynocas) are subject to a complex of regulations developed by the community.

The state does not enforce the property rights to public ahijadero lands and there is no control over the use of such lands; indeed there is no public agency responsible for their management. Thus, ownership of property rights to public and private communal pasture lands in the Altiplano and Valleys of Bolivia are generally nominal; such lands are exploited as common-property resources.

These rangelands are relatively important accounting for an estimated 56 percent of the total land area of the Altiplano and Valleys, more than seven times the amount of land dedicated to crop production

and fallow (MACA). Consequently, their exploitation as a common-property resource is a problem of highest priority for Bolivia.

Range Production, Erosion, and Flooding

The effects of managing the extensive natural pastures as common property resources in Bolivia can be readily observed in: (a) the low productivity of these rangelands relative to their potential; and (b) the incidence of erosion and flooding.

The results of several experiments and extension demonstrations relating reduction and deferment of grazing to rangeland productivity strongly suggest natural pastures in traditional production areas are seriously overgrazed with existing ranges and animal populations at relatively low and declining levels of productivity (Parker 1975, pp. 3-4; Utah State University Advisory Group and Alzérreca, p. 14).[18] First, protected areas are capable of producing from three to ten times as much forage as in adjacent areas with uncontrolled grazing, depending on the location. Second, root growth is much more dense with reduced grazing intensity assuring more rapid and deeper penetration of rain water. Finally, plants which have never been observed to produce viable seed under common-property conditions readily do so when protected from excessive grazing. While these preliminary findings require further corroborative research to measure the nature and extent of the response, the implications are clear. Forage production on native ranges can be significantly increased and run-off and erosion reduced, if grazing intensity is reduced.

Simultaneously, over 150 native grasses, forbs and shrubs were collected and classified including several native grass species (e.g., Poa candamoana and Poa horridula) found comparable or superior in terms of palatability and nutrition to the best introduced pasture species, as well as several native species that were thought to be extinct. An excellent genetic base of native materials is still viable with no need for introduced varieties in order to get significant response to proper management (Parker 1974).

According to Parker, the demonstrated response of rangeland to deferred grazing can be partially explained by relatively ideal production conditions in the Altiplano (1975). The rarified atmosphere stimulates leaf growth, and permits much higher levels of solar radiation, while the cool climate contributes to a relatively low level of evapotranspiration. These factors, along with the genetic base, contribute to very favorable conditions for forage production on native Altiplano and Valley ranges in Bolivia. Part of the production response can also be explained by the very low level of productivity of the range. That is, significant increases to deferred grazing can be initially expected since current productivity is at very low levels.

The serious nature of water erosion in Bolivia has been clearly articulated (Arce, Grover, and Terrazas). Erosion is extensive and affects all of Bolivia, but the problem is especially serious in the Valleys which have over 1/3 of Bolivia's cultivated land and almost 40 percent of its predominantly rural population.

Further, erosion in Bolivia has accelerated, resulting in significant losses of topsoil and farmland, and destructive flooding. Natural, or geologic erosion is, of course, necessary to man's existence for it is through this process that soils are formed. But whenever water erosion in any of its forms (splash; sheet, rill; gully; and stream bank) are in evidence, there is accelerated erosion. All forms are found extensively throughout Bolivia (Grover).

Extremely limited time series data preclude attempts to measure the rate of change in erosion. However, a point estimate indicated that in 1969 topsoil was being lost from the Valleys at the rate of 1 centimeter every ten years (Arce). The same source indicates that La Angostura reservoir in Cochabamba has lost more than 30% of its storage capacity in less than twenty years, due to sedimentation.

Lack of data also preclude measuring economic losses due to flooding and landslides. But every rainy season (December-March), several important bridges are damaged or destroyed, and roads and railroads closed for days or even weeks in both rural and urban areas. When one considers the additional destruction of personal property, and farmland, it is obvious the economic losses are significant.

Finally, researchers generally agree that overgrazing and denudation of Altiplano and Valley rangelands is the principal cause of accelerated erosion. In Grover's words, "The excessive removal of plant cover by grazing animals must be reduced ..." (Page 8.) This will require, of course, that common tenure of rangeland be changed to a system of property

rights where the private equilibrium of grazing intensity approaches society's optimum.

Policy Implications

The obvious policy recommendation from this analysis is that property rights to rangelands in Bolivia must be given and enforced in such a way that grazing intensity is initially reduced below the renewable limit.

In terms of the conceptual model recuperation of the range z will begin as the grazing intensity (x) is reduced below RL. As long as grazing intensity is less than RL, recovery will continue until the range is at its forage producing potential in some period such as 10 where $VMP_{x,10} = VMP_{x,0}$. The rate of recovery for any intra-marginal range depends on the extent of damage and the degree to which grazing intensity is reduced. Also, the rate of recovery can be accelerated by the use of other modern management practices such as pitting, subsoiling, contouring, and reseeding.

On ranges where damage is slight, recuperation may be achieved in a relatively short time by a small reduction in grazing intensity. On others, large reductions or complete deferment for longer periods may be necessary while cases of extreme damage deferment may need to be accompanied by other modern management practices.

Once the rangeland z has recovered to its forage-producing potential, grazing intensity can be increased to RL (through the assignment of additional property rights) without causing the production function to shift back down. This establishes an equilibrium and socially optimal

level of grazing intensity at x^*_{10} = RL. As the rangeland recovers, vegetation increase and the level of run-off and the external diseconomy is reduced. However, because of permanent damage from erosion and flooding the MSC_x will never fall back to MFC_x and will stabilize at some level such as $MSC_{x,10} = MSC_{x,2}$ (Figure 1). Consequently, the socially optimum level of grazing intensity for rangeland z after rejuvenation to its forage producing potential may be somewhat less than RL depending on the degree to which erosion has affected permanent damage on downstream producers and consumers, although in the case illustrated in Figure 1, RL is the optimum since $MSC_{x,10} \lesseqgtr MVP_{x,10}$ at RL.

While the general solution is obvious, defining and implementing a national rangeland use policy is complicated by four interrelated factors. First, what is the renewable limit for intra-marginal rangelands? Second, how can resistence to reduction or deferment of grazing, which is caused by income losses, be obviated? Third, how should property rights be conferred and enforced? Fourth, how should rents to rejuvenated rangelands be distributed between private users and society?

Unfortunately, there is a general paucity of knowledge regarding the renewable limit of grazing intensity for Bolivian rangelands. Thus, a vital and important requirement in establishing a national rangeland use policy is measurement of the renewable limit. Such measurement is complicated by the wide diversity in quality among various rangelands.

Also, the renewable limit may vary over time for a given range due to the vagaries of weather, type of livestock, and management.

However, range ecologists and managers are able to approximate the renewable limit for a wide variety of rangeland types and conditions. It will be necessary to bring such experts to Bolivia to determine the approximate renewable limits for the major ranges of the Altiplano and Valleys.

Imposed reduction or deferment of grazing intensity on any rangeland through conferral and enforcement of property rights may encounter resistance among users because of the immediate effect upon incomes. Weitzman has proven that the returns to variable factors used in conjunction with a common-property resource will always be higher than under a property right scheme. Since campesino producers are almost always the owners of the variable factors (labor and animals) that are applied to common-property rangelands, it follows that their returns will be reduced with the change to a property right system, <u>ceteris paribus</u>. In terms of the conceptual model, income earned by the variable factor x will fall from $Oaix_5^{**}$ to $Oaex_5^{*}$ if grazing intensity is initially reduced to x_5^{*} through assignment of property rights. If such resources have no alternative employment, income losses are permanent and may last for several weeks or months in any case while alternatives are located and necessary adjustments made.

The loss in producer income from decreased use of variable factors may be partially or completely offset, if society is willing to let campesino producers earn the rent (acde) which accrues to z_5 at a grazing

intensity of x_5^* . Whether or not total income from exploiting a rangeland in its depleted condition under property rights is greater than under free access depends on the MFC_x.[19] Of course, if grazing is completely deferred, there will be no income or rents until the rangeland is sufficiently recovered to permit grazing.

However, reduction of grazing intensity below the renewable limit or complete deferment will cause forage production to increase in succeeding periods and the production function to shift up until rangeland reaches its forage producing potential. When rangeland has reached its forage producing potential ($z_{10} = z_0$) grazing intensity can be increased from x_5^* to RL = x_{10}^* (through assignment of additional property rights) and the income earned by the variable factors will increase to the level they were at the free-access equilibrium at $x_5^{*\prime}$ = RL. Concomitantly, the rents earned by the rejuvenated rangeland (ahki) greatly exceed those at x_5^* with rangeland z_5. Further, it is probable that this will have been the case for several production seasons as the rangeland improves over z_5. As long as society is willing to let the rents accrue to the users of the rangeland (owners of the variable factor), resistance to conferral and enforcement of property rights should be greatly obviated.

Because the immediate income loss from reduction in variable factors is so much more tangible (for example, from reduction in size of flock or use of family labor with no apparent alternatives) than supposed gains from rangeland rents, especially those which are likely to occur in the future, a national rangeland use policy must include a research and

extension component which focuses on demonstrating to rangeland users the potential benefits of reduced and deferred grazing. In Bolivia, an immediate effort should be made in demonstrating, throughout the principal rangelands, the economic consequences of controlled and deferred grazing. This could probably be most effectively done by the extension services and should be limited to simple demonstrations of deferment of grazing and improved management practices.

More sophisticated demonstrations should be established in a limited number of pilot communities in the principal rangelands. The National Community Development Service (SNDC) should probably execute this phase because of their excellent reputation and experience. Such pilot communities should implement communal control of what are now common-property rangelands under advisement of range-management specialists. The beneficial results to cooperators in the pilot communities should reduce resistance to control in the region as leaders from other communities are exposed to the results through periodic field days and other education programs.

Finally, in regions where significant reductions in grazing or complete deferment are necessary, emphasis should also be given to developing alternative income sources.

Development of a viable institutional mechanism for implementing and administering a national rangeland use policy is complicated by the practical consequences of the agrarian reform. In nominal terms, property rights to both collective-private and public rangelands exist but

are not enforced. Perhaps the most pragmatic way to proceed would be to create a public agency charged with control and management of all public and collectively owned rangelands and watersheds. The modus operandi of this agency would be to determine the renewable limit of major rangelands in the Altiplano and Valleys as part of a general resource inventory. Since this is a time consuming process, the agency could simultaneously begin to reduce and control the level of grazing intensity on important and key ranges in conjunction with the research and extension programs referred to above. The limits initially imposed could then be modified as the renewable limit of each rangeland is more precisely measured.

The actual instrument for conferral of property rights must be carefully considered since it has serious implications for ease of enforcement, for whether the right is public or private, and for the division of rents within the private sector and between the state and private sector.

One possible course is to levy a tax per animal unit (i.e., per unit of grazing intensity) which will restrict grazing intensity to the initial desired level at some point less than RL. This, however, is probably not tenable for several reasons. First, determination of the size of the tax requires knowledge of the average product at the desired level, and the marginal factor cost. If, for example, the tax were set at a level so that the tax plus the constant marginal factor cost were less than the value of the average product, grazing intensity would exceed the desired level and the tax would be paid on additional animal units

until all rent was dissipated. This is complicated by the fact that the production function shifts up over time as long as grazing intensity is less than RL. Thus, the size of the tax would constantly have to be increased until at the social optimum at RL it equaled the average product less the marginal factor cost. Determination of the value of average product, and marginal factor cost for a shifting production function would be difficult even in a sophisticated economy and seems impossible in the Bolivian setting. Second, administration of such a tax is unwieldly; not only must the tax be collected, but animals must be appropriately marked if policing is to be possible. Third, the property right would clearly be public and is contrary to the tradition of private property rights for campesinos as established in the agrarian reform; Fourth, the tax scheme just described does not address the equitable division of the optimal level of grazing intensity among those who exploited it as a common-property resource. Finally, under the described tax scheme all rent from the rangeland would accrue to society. While this could be addressed by taxing only animal units that are in excess of the optimum, other issues would be unresolved.

A more viable alternative is to grant grazing permits (in terms of animal units) as a private property right for a specified period consistent with the initially desired level of grazing intensity (less than RL) for a given range. This approach requires only knowledge of the renewable limit if the state is content to let the private sector earn all the rents. The distribution of permits among users could proceed

on several bases. One could be to simply divide the initially desirable level by users, and grant a permit for an equal number of animal units to each user. A second approach would be to grant a permit to a user in proportion to his land base, herd base, or some other index of past usage of ranges. Once the range was sufficiently recovered, the number of permits could be increased on some equitable basis until the renewable limit was reached.

Whatever the basis for dividing the renewable limit of animal units among users, care must be taken in how permits are given. In the United States, permits were tied to private property, and issued for relatively long time periods when the state began to control private use of public rangelands (Gardner). Given the bargaining power of the rural populace, fees for using rangelands were set at a relatively low level, and most of the rents accrued to ranchers. Since the permits were good for several years, and tied to private rangeland, privately earned rents from using rangeland were capitalized both into the permits and the private land holdings which increased in value in an artificial capital structure (Roberts 1963). When the private holdings and grazing permits were sold, the original owner received a windfall gain, and the new owner had paid the full resource cost of using the public rangeland. However, in succeeding generations, bargaining power shifted from the rural to urban sector, and grazing fees have increased. The consequence has been to impose capital losses on ranchers who paid the full resource cost for grazing permits and private rangeland and permit and land values

were decreased. The result has been painful adjustment to the new capital structure.

Thus, any system of granting grazing permits in Bolivia should probably have these features. First, permits should not be tied to a base property although living in a community, and owing livestock and property in the area may be prerequisites to obtaining the permits. Second, permits should be negotiable without government approval or restriction. Third, permits should have a relatively long life. This, coupled with the private property right, will insure proper management and policing of the range by the permittees, especially if permits are set up in community allotments and may make private investments for improving the rangeland profitable.

The question of how rents to rangeland should be distributed between private users and society seems clear in the case of Bolivia. Incomes of rural people, who account for 70 percent of the population, are extremely low compared to those in urban areas. Given this large divergence and the vested interest of society in reducing the erosion externality as well as integrating the large campesino sector into the market economy, no fees should be assessed and rents should accrue to the campesino producer.

If it is found desirable to capture some part or all of the rents for society, user fees are the mechanism. Establishing the level of the fee requires knowledge of rents to the rangeland. The fee which extracts all rent for society is total rent divided by the number of animal units

(level of grazing intensity) at the optimum. Alternatively, this is the value of average product less the marginal factor cost at the optimum. If fees plus marginal factor costs exceed the VAP_x private use of the range will be less than the social optimum and there will be an excess of permits and wasted forage.

In this paper, an analysis of the serious misallocation of resources from exploitation of Bolivian rangelands as a common-property resource has been set forth. The misallocation encompasses both the traditional common-property misallocation, plus the serious external diseconomies in the form of erosion and flooding. A general policy prescription and some of its ramifications for improving resource allocation through public control and management of rangeland use have been suggested. If needed reforms are not immediately implemented, destruction of a significant proportion of the arable lands of Bolivia's traditional production areas is inevitable, as well as increasingly serious floods and erosion in the lowlands. The result will be more widespread poverty and hardship in the traditional production areas, and strong pressures for displacement of the majority of the population. The issues related to common-property rangeland use and the associated erosion constitute the highest priority for the agricultural sector.

NOTES

1. The Conference, sponsored by the German Foundation for International Development was held at Munich in December of 1974. The Eckholm reference is an interpretation and summarization of conference findings.

2. In actuality, several variable factors including animals and labor are used in the production process. This analysis abstracts by assuming only one variable factor described as grazing intensity but which may be thought of as animal units.

3. Declining marginal product to increased grazing intensity may be due to both the law of diminishing returns, and the effect of grazing intensity on the stock of forage for a given production function. Traditional diminishing marginal returns would appear to result from increasing grazing livestock on a fixed land base. At the same time, the stock of forage is reduced as grazing intensity increases, which may also account for production increasing at a diminishing rate (see e.g. Gordon, pp. 135-40).

4. These assumptions are based on Bolivia where it can be argued competitive markets exist for both products of and factors used in rangeland agriculture.

5. The actual level of allowable domestic grazing intensity would be less than RL in order to account for use of range by wild animals and for other human use. In the analysis, this problem is abstracted.

6. The vagaries of weather are assumed constant.

7. The MFC_x is especially likely to be low in a developing country since it may consist primarily of herding labor undertaken by women and children whose marginal productivity is low or zero (Kao).

8. This is one point of departure between the fisheries model developed by Gordon and the range model. Gordon's landings function was assumed to exhibit diminishing marginal product because of the effect of catch (fishing effort) on landings (production) during a production season. The range model permits the same possibility for a given range production function (see note 3). But, grazing beyond the renewable limit reduces the stock of the fixed factor (range produced forage) in future seasons and this reduces the level of animal production in succeeding periods at all levels of grazing intensity.

9. It is assumed the P_x and P_y remain constant over time for sake of exposition.

10. Note that in the case illustrated (equilibrium exploitation of a common-property resource), there is no divergence between marginal private and social costs at the equilibrium. The divergence is between actual (private) and optimum (desired) total costs. It is not until externalities are introduced that marginal private and social costs diverge (see below).

11. If erosion occurs on the rangeland itself or the resource stock or crowding externalities are present, the optimum is at some level of grazing intensity less than x_7^* .

12. The excess of resources actually employed is $0aix_5^{**} - 0ajx_7^*$ The area abfgi is the total cost imposed on producers and consumers outside the production area by the erosion externality.

13. Originally, ahijadero was used to describe a low, poorly drained area with heavy soils that produced native forage plants and grasses and was only fit for grazing (Braun). Indeed, much of the rangelands of the Altiplano are of this type. But the term has taken on a more generic meaning, referring to any pasture that is commonly grazed.

14. The Inca and the Priestly class were astute enough to assign themselves that part of the land that was excess to the needs of the community (Urquidi, p. 100).

15. Several institutions for providing communal labor developed including the chunca (classification of work teams for preparing the land); mincca (collective and gratuitous work for public or private benefit with food provided); mitta (rotating work assignments for the state); and ayni (private loan of labor with reciprocity expected).

16. For a detailed account of how the land tenure system was changed, see Pozo.

17. No data are currently available for distinguishing the relative importance of the two classes of ahijaderos.

18. Several other studies only exist as unpublished reports or data in the Ministry of Agriculture, La Paz. Included are studies of: (1) deferment of grazing on Central and Northern Altiplano rangelands through placement of protective wire "cages" (Karl Parker and Humberto Alzérreca); (2) Karl Parker, "Response of Alta Fescue to Three Intensities of Harvest," (mimeograph); and (3) response of

native rangelands on the Patacamaya Experiment Station to deferred grazing and improved management practices (K. Parker and H. Alzérreca). The results of these studies have been presented in public seminars in Bolivia and personally articulated to the authors by Parker and Alzérreca, and are a partial basis for the three findings presented immediately below.

19. If P_x = 0a is greater than ac, the loss in income from unemployment of variable factors is greater than the increased rents earned at x_5^*. First, the equilibrium at x_5^* is at half the level of grazing intensity at x_5^{**} because the marginal product has a slope twice as great as the average product. Thus, the bases of the rectangles representing loss in variable factor income ($x_5^*eix_5^{**}$) and increase in rent (acde) are equal. The height of the rectangle representing loss in variable factor income is P_x and if this exceeds the height of the rectangle representing rents, it is clear rents are not sufficient to offset income loss from variable factors. In Bolivia, where the MFC_x is likely to be relatively low increased rents probably more than offset losses from variable factors.

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