Working Paper WP98-1 January 1998

Externalities, Risk and the Private Property-Overgrazing Paradox:

The Case of Private Cattle Farms in Nyabushozi County,

Western Uganda

by

Dick Sserunkuuma

and

Kent Olson

Center for International Food and Agricultural Policy

University of Minnesota
332 ClaOff Building
1994 Buford Avenue
St. Paul, Minnesota 55108-6040 U.S.A.

Phone: (612) 625-8713
FAX: (612) 625-6245

Working Paper WP98-1 **January 1998**

Externalities, Risk and the Private Property-Overgrazing Paradox:

The Case of Private Cattle Farms in Nyabushozi County, Western Uganda

by

Dick Sserunkuuma and Kent Olson*

January 1998

*Graduate Student and Associate Professor, respectively, Department of Applied Economics, University of Minnesota. This project was funded by the Rockefeller Foundation. The authors gratefully acknowledge the Center for International Food and Agricultural Policy (CIFAP) for providing supplemental funding for this study.

EXTERNALITIES, RISK AND THE PRIVATE PROPERTY-OVERGRAZING PARADOX: THE CASE OF PRIVATE CATTLE FARMS IN NYABUSHOZI COUNTY, WESTERN UGANDA.

Dick Sserunkuuma and Kent Olson

Much of the rangeland management policies the world over have been directed towards private ownership of rangelands. In the historically pastoral societies of Africa, tenure reforms (away from the commons and toward private tenure) have often been justified on the argument that pastoralists overstock, overgraze and damage the rangeland resources...because of the mismanagement inherent in the traditional patterns of communal rangeland tenure combined with individual herd ownership--along the lines of the tragedy of the commons (Hardin, 1968 cited in Homewood and Rodgers, 1988). Following this line of reasoning, many economic consultants and planners, as well as researchers (Johnson, 1972 and Picardi, 1974 cited in Runge, 1981; and Demsetz, 1967; Anderson and Hill, 1977; Libecap, 1981 cited in Stevenson, 1991) have often prescribed private property as the <u>only</u> solution to this (overgrazing) “tragedy of the commons”. In other words, they advocate for the imposition of private property schemes as a means of “internalizing” a common property externality. Underlying such a prescription is the belief that privatization is necessary and sufficient to solve the commons dilemma (Ostrom, 1990).

This belief is predicated on two notions. First, all jointly grazed rangelands are bound to be overexploited in the long-run due to the high incentive among the individual grazers to free-ride. This is because the private benefits of grazing an additional head of cattle on the common range exceed the private cost, since the cost of maintaining range quality can be shifted to the group as a whole (Runge, 1981). Thus, the pursuit of self-interest locks each herdsman into a system that compels him to increase his herd without limit—in a world which is limited (Hardin, 1968), which results in overgrazing. Second, a secure, exclusive grazing right incites the grazer to graze at an optimal rate. This is because the private rights holder not only reaps the benefits but also incurs all the costs of adding an extra head of cattle to his/her private range, and a balancing of these benefits and costs is an invisible hand that guides the grazer to an optimal grazing (stocking) rate[1] (Stevenson, 1991).

Examining rangeland tenure and pastoralism in their historical perspective reveals that the legislative mechanisms and policy formulation process in Uganda have been influenced by the need to introduce private rangeland tenure (Kisamba-Mugerwa, 1995). For example, land that was communally grazed in the past in the Ankole-Masaka Ranching Scheme (AMRS), Nyabushozi county, Mbarara district, was subdivided into smaller land parcels by the state appointed Ranch Restructuring Board (RRB) and re-allocated to individual pastoralists starting in the late 1980's. The pastoralists have been encouraged and in some cases assisted to fence off the allocated land. The primary goal of this privatization scheme was to mitigate overgrazing and rangeland resource-use conflicts in the AMRS area. By putting the user rights in the hands of the resource owners, the government thought they had given the pastoralists the necessary incentives for adopting overgrazing mitigating practices. Outside the AMRS in Nyabushozi county, land registration (to private owners) was undertaken as a development project by the local county development association--Nyabushozi Development Agency (NDA). NDA has assisted many residents to acquire land titles; and because of this local development project--coupled with the fact that the privatization scheme has received full support from the stakeholders, i.e., the pastoralists (Sserunkuuma, 1995), it is almost certain that communal rangeland tenure is being phased out in Nyabushozi (Kisamba-Mugerwa, 1992).

However, Ostrom (1990) argues that after dividing the meadow in half and assigning one half to each of two herders, each herder will now be playing a *game against nature* in a smaller terrain, rather than a game against another player in a larger terrain. If rainfall occurs erratically, one part of the meadow may be lush with growth one year, whereas another part may be unable to support half of the original animals. If the location of lush growth changes dramatically from year to year, dividing the commons may impoverish both herders and lead to overgrazing. Behnke and Scoones (1992) also question the advisability of fenced

---

[1] However, Stevenson (1991) argues that for private property to provide the optimal solution, there must be: no divergence between social and private discount rates; no externalities; and no imperfect capital markets or other market imperfections.

ranches--a result of privatization--in the face of high moisture variability, due to unpredictable climatic variations in the semi-arid tropics. They argue that, if a herd is confined to one place, livestock numbers, viability and productivity are limited by the scarcest resource in the scarcest season in that place.

As Peters (1994) put it, the sine qua non of dryland cattlekeeping in Africa has been mobility. Privatization reduces the land area available to individual pastoralists and eliminates the mobility and flexibility in grazing that is crucial in the management of climatic risk. The reduction in land area and cattle mobility worsens the routine scarcity of water and pasture resources in the dry season, since the practice of moving cattle--on a larger terrain--to where these resources are is no longer permissible. Further more, evidence from other studies on pastoralist livestock systems in Africa seems to suggest a widespread reluctance on the part of pastoralists to market cattle regularly--even when faced with forage scarcity. This reluctance stems from a concept that cattle are a store of wealth or a savings account from which withdrawals are made only for special social or ceremonial occasions, or for emergency needs such as payments for education, etc. (de Wilde, p. 55-56 cited in Doran et al., 1979). Hence, as they struggle to maintain herd size on fewer resources--thanks to privatization, the likelihood that the pastoralists overgraze increases.

As a store of wealth, cattle provide satisfaction in terms of numbers; and as a source of food (milk) and income, they provide satisfaction in terms of milk and meat output--an attribute that bestows cash and food values on cattle. The cash and food values are important as far as current consumption needs are concerned; but numbers of animals are often more important than cash and food values as far as the security, prestige and status aspects of wealth are concerned (Doran et al., 1979). In this paper we show that these three attributes of cattle--that is, as a wealth store, and source of food and income--reinforce each other to cause overgrazing on private rangelands. We argue first, that the absence of wealth storage alternatives encourages pastoralists to store all their wealth or savings in form of cattle, which increases the likelihood of overgrazing, especially if there are no alternative feed sources to supplement the natural pastures. We also argue that over-dependence on cattle for food (milk) and income causes pastoralists to over-invest in cattle (overstock), since fewer cattle mean less aggregate milk output and, thus, less food and income. In other words, the current consumption needs make the pastoralists' planning horizon shorter than society's, thereby causing them to "mine" the natural pasture resource at a higher rate than is socially optimal and, thus, imposing a *temporal externality* to society. We also show that in the presence of high *risk of cattle loss*, the seemingly plausible overgrazing abatement strategy of breed improvement[2] only serves to exacerbate the problem of overgrazing.

Definition and Measurement of Overgrazing.

The common definition of overgrazing or rangeland overuse, is the exploitation of a rangeland beyond its carrying capacity (CC), further defined as the number of animals that the rangeland can support on a sustainable basis (Stevenson, 1991). Critics, exemplified by Behnke (1992) argue that it makes little sense to talk about overgrazing as defined in this way--without taking into account the management objectives of the rangeland users. He contends that the confusion between "ecological" and "economic" CC has resulted in misleading CC estimates, and that a distinction ought to be made between the two.

The ecological CC occurs at the point where the production of forage on the rangeland equals the rate of its consumption by animals. At this point, the animal population ceases to grow because the limited feed supplies equate death rates to birth rates, and there is no surplus production either of animals or biomass. On the other hand, the economic CC occurs at the point of maximum sustained yield, i.e., the point at which sustainable animal offtake rate is highest. This point coincides with the stocking density at which the animal population is growing most rapidly. It usually lies at about half to two-thirds of the stocking

[2] Among other things, animal productivity depends on the genetic potential of animals. Based on the argument that pastoralists overstock to compensate for the low productivity of the local-breed cattle, it has often been suggested that breed improvement--which is expected to boost milk productivity per cow--might reduce the need to overinvest in cattle (overstock) as means of obtaining the desired level of aggregate milk output from the herd, and in so doing reduce the likelihood of overgrazing.

density at the ecological CC (Caughley, 1979 cited in Behnke and Scoones, 1992).

To incorporate the range managers objectives, Behnke and Scoones (1992) suggest an alternative definition, which they call "the only embracing definition of CC." They define CC as that density of animals and plants that allows the manager to get what s/he wants out of the system. They argue that under certain conditions and depending on the management objectives of the rangeland manager, it is technically feasible and economically profitable to stock at various points on the CC frontier, that is, at the ecological or the economic CC, or below both. A wildlife manager, for example, may desire a high animal population well above the economic CC to increase the chances that tourists who visit a park for game viewing actually confront the animals they come to see. On the other hand, a rancher who aims at producing maximum kilograms of meat for sale will require a density of animals that provides the maximum sustained yield of meat, that is, the economic CC as defined by Caughley. However, because of the holding costs of domesticated animals, economically optimal stocking densities for commercial ranchers lie below the economic CC (Wilson and Macleod, 1991 cited in Behnke and Scoones, 1992). Pastoralists, who keep cattle mainly for subsistence reasons, to harvest animal output in the form of live animal products such as milk, blood, traction power and transport, can profitably exploit a large standing crop of animals. At some cost in terms of lower output, health and viability of individual animals, these producers may be capable of maintaining high levels of aggregate output at stocking densities approaching ecological CC (Payne, 1990 cited in Behnke and Scoones, 1992). However, these costs could be substantial, making it more profitable to maintain stocking densities that are closer to the economic CC.

On the other hand, some economists argue that social policy should be to maximize net economic yield, which in general is not synonymous with utilization at the CC or the point of maximum output because the latter ignores the economic aspects of range and herd management. Therefore, economists define overgrazing as any level of grazing (stocking) beyond that which would maximize net economic returns from the rangeland (Stevenson, 1991).

Empirical work on measuring overgrazing is complicated by the fact that it is a relative and multifaceted concept, with no known cardinal measure. Using the CC-based definition of overgrazing, overgrazing could be measured as the difference between the CC and the actual stocking density on the rangeland. However, Bartels et al. (1990) criticize the CC-based measure of overgrazing because of the conceptual ambiguity and measurement error inherent in CC estimates. In addition, Behnke and Scoones (1992) argue that CC is an equilibrium concept,[3] and that it is analytically useful only in the context of stable equilibrium environments, where the rainfall is higher and more reliable, and the pastoralists and their livestock are important agents of vegetation changes. They claim that, in non-equilibrium grazing systems, the wide, unpredictable and uncontrollable fluctuations in the climate are more important determinants of range productivity than is stocking rates (Ellis and Swift, 1988 cited in Behnke and Scoones, 1992).

Behnke and Scoones (1992) further argue that rangeland degradation or overgrazing ought to be measured as a permanent (irreversible) decline in the rate at which the rangeland yields livestock products. They propose several biophysical indicators of range degradation, and suggest that these should be examined to determine to what extent they identify permanent losses in livestock output. However, the reliability of these indicators as measures of irreversible decline in livestock production on Africa's rangelands is questionable too. The proposed indicators include: (1) soil changes such as decreased fertility, decreased water holding capacity, decreased infiltration and soil loss significantly in excess of soil formation, (2) vegetation changes such as severe bush encroachment, changes in vegetation productivity over time unrelated to rainfall patterns, changes in vegetation cover, changes in plant species composition of use to animals, and (3) livestock production such as condition scoring of animals, calving rates and death rates (population models) and milk yields.

Literally, the Behnke-Scoones definition of rangeland degradation says that degradation occurs only

[3] Behnke and Scoones argue that any notion of carrying capacity--be it ecological or economic, is predicated on the notion that herbivore numbers are controlled through the availability of forage, and that the availability of forage is controlled by animal numbers. This pattern of negative feed back eventually

after crossing a critical threshold after which productivity losses are irreversible. However, it is very difficult to pinpoint the cut-off line where a range crosses from having temporary rainfall-induced to permanent human-induced vegetation changes. Given that crossing this cut-off line doesn't occur instantly but rather over time, and through observable successive vegetation changes, a lot can and should be done to influence the behavior[4] of pastoralists toward range conservation, before permanent damage is inflicted on Africa's rangelands. This is possible, provided the appropriate policy measures are taken; and the appropriateness of the available policy alternatives can be determined through empirical research. With the overly restrictive Behnke-Scoones definition, however, it becomes very difficult to justify empirical research work to address the dangers of rangeland degradation in Africa--be it real or potential dangers, if one has to first prove that degradation--as defined by Behnke and Scoones--has actually occurred. The idea of waiting until a rangeland is permanently destroyed before we can talk about overgrazing and, hence, do something about it implicitly attaches a positive quasi option value to waiting. However, the validity of this assumption is highly questionable, given the importance of rangeland resources in African economies; and the enormous costs that would have to be incurred to re-instate the rangelands to their original state after damaging them permanently.

In conclusion, the critics have been quite successful in clarifying the misconceptions regarding the utility of the CC concept, however, they do not offer much in the way of a working alternative. We, therefore, concur with Hocking and Mattick (1993) that until a more user-friendly alternative is presented, in a practical, rather than conceptual framework, CC remains the best practical tool available to planners; and we offer no apologies for using CC in this study. Moreover in our case, the rainfall in the study area is fairly reliable and

---

produces a stable equilibrium between animal and plant populations.

[4] While pastoralists have no control over the climate, their choices in terms of species, number, breed, sex and age composition of their herds affect the primary and secondary productivity of their rangelands. Government policies can influence these choices via their effect on the structure of incentives and constraints facing the pastoral households.

high (about 900 mm annually[5]), thus, the environment in the study area can be characterized as relatively stable, with an equilibrium pattern between animal and plant population; which makes the concept of CC applicable.

In this paper, overgrazing has been defined as rangeland use that depresses net economic yield below its maximum. By definition, therefore, overgrazing is measured as the departure of the actual stocking rate from the one that maximizes net economic returns from the rangeland, hereby referred to as the economic optimum stocking rate (OSR). Since the economic optimum or most profitable stocking rate occurs at the point where the net economic yield is at a maximum, the OSR can be determined using profit maximization principles. Hildreth and Riewe (1963) used data from stocking density experiments at Texas Agricultural Experiment Station to determine the OSR. Assuming a linear biological relationship between weight gain per animal and the stocking rate, they defined the net economic yield (net return per acre of grazing land) as the ending value of the animals less the initial value, and the costs of grazing and pasture improvement. They set the first derivative of the net economic yield equation--with respect to stocking rate--equal to zero and solved for the OSR as a function of the biological weight gain, adjusted down by the costs of production relative to the selling price.

Torrell et al. (1991) added a dynamic component to the Hildreth-Riewe model, arguing that because of ignoring the impact of grazing on future range condition and production, stocking rates determined to be economically optimal over the single period model may not be optimal at all when dynamic forage production impacts are considered. Surprisingly, however, Torell et al. found that optimal stocking rates determined by the dynamic model are not greatly different from those of the single period model. Holecheck (1988) suggests an alternative method for determining the optimum stocking rate that is based on livestock feed supply and demand. Though largely based on non-economic factors, Holecheck's method can yield

---

5 In areas where the annual rainfall is below 700 mm and unreliable, rainfall alone is a reasonable indicator of herbage production (Hocking and Mattick, 1993). Which implies that in such environments, range productivity may be more a function of rainfall than of stocking densities--past and present.

results that are remarkably close to the average economic optimum stocking rate (Torell et al., 1991).

Modelling The Pastoralist's Stocking Decision

According to Kisamba-Mugerwa (1992), milk is the main product of the pastoral households in Nyabushozi. However, cattle are also kept for prestige, social and cultural reasons. When faced with emergency cash problems, pastoralists sell adult live animals for cash. Usually these are adult females because most of the males are sold off young, to reduce competition for the limited feed resources, which would otherwise have a negative effect on the milk yield from the lactating cows. The pastoralists surveyed for this study depend entirely on natural pastures to feed their livestock. Although some have started growing food for home consumption, milk remains their major food. Therefore, it is only after meeting the household's consumption requirements that the surplus milk is sold to the market. The proceeds from milk sales are used to buy solid food (especially for those who don't grow any food crops) and to meet other cash needs for the family. Thus, the net economic returns from the rangeland in each grazing period t, Π_t are defined as:

$$\Pi_t = \quad P_t^m(QM_t - CONS_t) - X_t(C_t+I_t) + X_{st}[P_{st} - (C_{st}+I_{st})] - C_t^p \qquad (1)$$

where:

P^m_t is the selling price per liter of milk less marketing costs in period t.

QM_t is the total quantity of milk produced in period t.

$CONS_t$ is the total amount of milk consumed by the family in period t.

X_t is the number of tropical livestock units (TLUs)[6] grazed on the range in period t and retained on the

[6] TLU is a unit representing a ruminant of 250 kgs liveweight. The profit function (equation 1) assumes that the selling price of cattle is determined by market forces outside the pastoralist's control. However, it is true that individual head of cattle from different pastoralists will sell for different prices because of size--and probably quality--differences, which are influenced by stocking rate, age, and breed of cattle. By standardizing cattle input and sales to TLUs, we allow the net revenue received by pastoralists for each cattle sold to vary accross pastoral households while keeping the per unit (TLU) price constant. For example, a pastoralist with a low stocking rate and hopefully bigger/better quality cattle worth about two TLUs each will receive $2P_{st}$ for each head of cattle sold; while his colleague with a higher stocking rate and smaller cattle worth, say 0.75 TLUs each will receive 0.75 P_{st} for each head of cattle sold.

farm to build the stock for period t+1.

X_{st} is the number TLUs grazed on the range in period t and sold for cash at or by the end of period t.

C_t are the costs incurred per TLU not sold in period t. (Includes veterinary costs, labor, etc.)

C_{st} are the costs incurred per TLU sold in period t.

I_t is the interest cost or opportunity cost per TLU not sold in period t.

I_{st} is the interest cost per TLU sold in period t.

C^p_t is the pasture improvement cost in period t.

P_{st} is the selling price per TLU less marketing costs in period t.

In the remaining part of this section, we develop a milk production function, starting with a simple biological relationship between the yield of milk (main product) and range stocking rate. We then introduce the dynamics of cattle and forage in the stocking decision model, substitute the milk production function for QM_t in equation 1, and define the constrained profit maximization problem faced by a typical household. Finally, we set up the Lagrange for this problem and solve it for the OSR--which is used to develop a theoretical measure of overgrazing (OG_t).

Recent studies on stocking rate have standardized the grazing input to grazing pressure (GP), which is the animal days--TLUs days in this case--of grazing per unit of forage (F). Stocking rate (SR) is the number of TLUs grazing per hectare over a grazing period of length D days (Hart et al, 1988; Vallentine, 1990). Using these definitions, GP can be expressed as a function of SR: let X be the number of TLUs grazing on a rangeland of A hectares for D days, and let FH be the forage produced per hectare on this rangeland, such that SR = X/A and FH = F/A. From the above definitions:

$$GP = D*X/F = D*(X/A)/(F/A) = D*SR/FH = D*X/F \qquad (2)$$

The quantity of milk produced in each grazing period is obviously related to the number of lactating cows, the length of the lactation period and the milk yield per lactating cow per day. The relationship between milk yield per lactating cow per day (Average Daily Milk Yield, ADMY) and the stocking rate (SR) is defined to be a concave function given by ADMY = f(GP(SR)), with $df/dSR < 0$ and $d^2f/dSR^2 \leq 0$ over the economically relevant range of production. A linear equation has been the most commonly used functional form in defining the relationship between animal productivity and grazing pressure in past grazing research, particularly in the measure of Average Daily Weight Gain (ADWG) response to grazing pressure (Torell et al., 1991; Bransby et al., 1988; Hart et al., 1988; Hildreth and Riewe, 1963). Using the data collected for this study, ADMY (a measure of animal productivity) was plotted against TLUs/rangeland area ratio (a measure of grazing pressure). The scatter-plot is consistent with a linear relationship, thus, the linear functional form is used to define the relationship between average daily milk yield and grazing pressure. That is,

$$ADMY = k - dGP \qquad (3)$$

where k is the intercept and d is the regression coefficient of ADMY on GP.

The total quantity of milk (QM_t) produced by a typical pastoral household in grazing period t is the product of the average lactation length (in days), the number of lactating cows and the ADMY per lactating cow per day in grazing period t:

$$QM_t = z_t \mathsf{F}_t X_t (ADMY_t) \qquad (4)$$

where: z_t is the average length (in days) of the lactation period for cows in period t. F_t is the proportion of the herd in period t that constitutes the lactating cows, and the other variables are as defined before. Assuming that all lactating cows in period t are retained to build the stock of cattle in period t+1, the number of lactating cows in period t is equal to $\mathsf{F}_t X_t$. Substituting the right-most expression for GP in equation 2 into equation 3 and adding a time-subscript gives:

$$ADMY_t = k - dD_t(X_t + X_{st})/F_t. \qquad (5)$$

where: D_t is the actual number of days grazed in period t, F_t is the quantity of herbage (in metric tons) produced in period t, and k, d, X_t, X_{st} are as defined in equations 1 and 3. Therefore:

$$QM_t = z_t \mathsf{F}_t X_t [k - dD_t(X_t + X_{st})/F_t] \qquad (6)$$

which implies a quadratic production function for milk.

The stocking decision is inherently dynamic, which makes the decisions made in the present affect future decisions and outcome. When making stocking decisions, the pastoralist must bear in mind the fact that the current stocking rate affects future production of forage on the range, thereby affecting the number of livestock units that the range can support in the future. Likewise, the pastoralist cannot ignore the fact that the future stock of cattle depends on the stock of cattle today. This means that equations that define the dynamics of cattle and forage must be included in stocking decision models.

The forage at the beginning of period t+1 is given by the first order difference equation:

$$F_{t+1} = (1+\alpha-\theta F_t)F_t - gD_t(X_t+X_{st}) \qquad (7)$$

where: g is the average daily forage intake per TLU (as a percentage of body weight) in period t (Holeckeck, 1988) suggests that range cattle consume 2.5% of body weight/day in dry matter; $gD_t(X_t+X_{st})$ is the total forage intake by cattle in period t; and $(\alpha-\theta F_t)$ is the forage growth rate which is a function of rainfall, soil characteristics, prior grazing pressure, and prior investments in pasture improvement and range management in general. The forage growth rate decreases as the forage matures or as vegetation biomass increases. Losses of forage due to causes other than herbivory in period t are assumed to be small and, thus, have been ignored in this study. The stock of cattle (in TLUs) held by each pastoralist at the beginning of period t+1 is given by the first order difference equation:

$$X_{t+1} = (1+\eta)X_t - X_{st} \qquad (8)$$

where: η is net birth rate of cattle. η is among others influenced by range condition (forage quantity and quality), health of cattle, the breed of cattle, animal care, etc.

$V_{T+1} = V(F_{T+1}, X_{T+1})$ is the function that defines the value of the terminal stock of cattle and forage in period T+1. The overall problem faced by the pastoralist is to choose the OSR, X^* that maximizes the present value of net returns from the range for the entire planning horizon T. This problem is expressed as:

$$\Pi = \quad Max\ (w.r.t.\ X_{st})\ \Sigma^{T}_{t=0}\ \beta^t\{\ P_t^m(z_t\Phi_t X_t[k - dD_t(X_t+X_{st})/F_t] - CONS_t) - X_t(C_t+I_t) + X_{st}[P_{st} - (C_{st}+I_{st})] - C_t^p\ \} + \beta^T V(F_{T+1}, X_{T+1}) \qquad (9)$$

Subject to:

$$F_{t+1} = (1+\alpha-\theta F_t)F_t - gD_t(X_t+X_{st}) \qquad (10)$$

$$X_{t+1} = (1+\eta)X_t - X_{st}. \qquad (11)$$

$$\{X_t, X_{st}, F_t\} > 0,\ t = 0,1,2,3,...T \qquad (12)$$

where X_{st} is the control variable, X_t and F_t are state variables.

The Lagrangian (L) for the above optimization problem (Max Π--equation 9--subject to equations 10, 11 and 12) is:

$$L = \Sigma^{T}_{t=0}\, \beta^t\{ P_t^m(z_t\Phi_t X_t[k - dD_t(X_t+X_{st})/F_t] - CONS_t) - X_t(C_t+I_t) + X_{st}[P_{st} - (C_{st}+I_{st})] - C_t^p +$$

$$\lambda_t[(\alpha-\theta F_t)F_t - gD_t(X_t+X_{st})] + \gamma_t[\eta X_t - X_{st}] + \mu_1 X_t + \mu_2 X_{st} + \mu_3 F_t. \qquad (13)$$

where λ_t and γ_t are the shadow values of the stocks of forage and cattle respectively, and $\mu_1,...,\mu_3$ are Lagrange multipliers. The solution for the optimum stocking rate (X_t^*) is:

$$X_t^* = [\lambda_{t+1} - \lambda_t(1-\alpha+2\theta F_t)]F_t / [P_{st} - (C_{st}+I_{st}) - P_t^m z_t\Phi_t k + (C_t + I_t) - \gamma_{t+1} - \eta\gamma_t] \qquad (14)$$

Following the definition of overgrazing--actual stocking rate (ASR) less optimum stocking rate (OSR), the measure of overgrazing (OG_t) is defined as:

$$OG_t = X_t - X_t^* \qquad (15)$$

Linking the Theory to the Estimated Empirical Model

As equation 14 indicates, the OSR (X_t^*) is among other factors influenced by: the natural growth rates and shadow values of forage and cattle, the standing crop of forage (F_t), the prices of milk and live animals received by farmers, the cost of production (C_t and C_{st}), the intercept parameter (k) of the ADMY-GP biological relationship (equation 3), etc. Due to various reasons, pastoral households experience differences in the standing crop of forage, the natural growth rates and shadow values of forage and cattle,

the ADMY per lactating cow, etc. Since these variables combine to determine the OSR on each farm (as shown in equation 14), they are responsible for the variation in OSR across farms, and for the fact that some farms overgraze and others don't. That is, the factors responsible for the differences in the growth rates and shadow values of forage and cattle across pastoral households, for example, also explain why some households overgraze their private farms and others don't.

We hypothesize that the differences in the bio-physical and socio-economic environment within which the pastoral households operate are responsible for the differences across pastoral households in terms of milk yield per cow, shadow values and natural growth rates of forage and cattle, etc., and, thus, OSR. This environment is characterized by: (1) natural factors such as rainfall, soil characteristics, etc., (2) household specific characteristics such as level of education of the head of the household, size of farm or rangeland owned by the household, family size, etc., (3) economic or price factors, namely input and output prices (adjusted for distance to the markets) and interest rates facing the pastoralists, and (4) other factors such access to extension services, government intervention, etc.

To illustrate the link between the socio-economic environment faced by the pastoral households and the likelihood of overgrazing, we use the example of a household that is characterized by complete dependence on cattle for food and income, limited farm size, and a large family. We hypothesize that the current consumption needs of this household--manifested in family size--dictate the choice of number (and possibly breed) of cattle that the household needs to stock in order to subsist. The chosen herd size then combines with the natural factors such as rainfall, to influence the standing crop of forage and ADMY, for example, which in turn influence the OSR, and finally, the likelihood of overgrazing (OG)--via equation 15. Determining the relationship between the likelihood of overgrazing and the socio-economic environment within which the pastoral households operate (which environment is characterized by household-specific characteristics and choices) is the core of the empirical analysis in the next section of this paper. Thus, the theoretical and empirical models presented in this paper are linked by equation 14 (OSR function), upon which we based the choice of the right-hand-side variables in the overgrazing explanatory model.

Data Collection and Empirical Analysis

The data used in this study was obtained through a survey of 125 pastoral households with private grazing land outside the Ankole-Masaka Ranching Scheme (AMRS), in the sub-counties of Nyakashashara and Kenshunga, in Nyabushozi county, western Uganda. These participants were randomly and independently drawn from the list of cattle owning (pastoral) households in Nyabushozi county. This list was prepared by the Mbarara District Veterenary Office, shortly before starting the county-wide vaccination exercise against foot and mouth disease (FMD) in December, 1995. However, some of the data needed to determine the OSR (equation 14) for each participating household--such as the natural growth rates of cattle and forage, the standing crop of forage, etc.--could not be obtained within the time and financial constraints faced by this study. As a result, an alternative model, ILCA'S[7] BIO-ECONOMIC HERD MODEL (IBIEHM)--a dynamic bio-economic simulation model developed at ILCA by von Kaufmann et al. (1990), was used to rank pastoralists according to the severity of overgrazing. The IBIEHM uses Holecheck's method to determine the OSR (Holecheck, 1988), which is based on Total Usable Forage (TUF) available and Total Forage Demand (TFD) of the grazing animals for the entire grazing period. It also uses a standard measure of livestock input on the range known as the Tropical Livestock Unit (TLU) to calculate the Carrying Capacity (CC) of the range utilized. The following formulae in the IBIEHM are used to calculate the CC utilized:

$$TLU^R = DM^A * BDFI * DGP * LW \qquad (16)$$

$$DM^A = ARF * GA * DMPP^{RH} * \%DMEA \qquad (17)$$

$$TLU^H = HTLW/LW \qquad (18)$$

$$CC^U = TLU^H/TLU^R \qquad (19)$$

Where:

TLU^R is the number of tropical livestock units that the range can support.

---

7 ILCA stands for International Livestock Centre for Africa. This name has been changed to International Livestock Research Institute (ILRI).

DM^A is the annual dry matter provision from the pastures.

BDFI is the base daily feed intake as a percentage of liveweight.

DGP is the number of days in one grazing period (this figure was set at 365 days because cattle graze throughout the year).

LW is the liveweight of one tropical livestock unit (250 kgs).

ARF is the annual rainfall.

GA is the grazing area in hectares.

$DMPP^{RH}$ is the kilograms of dry matter pasture production per mm of rainfall and hectare.

%DMEA is the percentage of dry matter effectively available to the livestock.

TLU^H is the number of tropical livestock units in the herd.

HTLW is the herd total liveweight (summation of the number of cattle in the herd multiplied by their respective liveweights).

CC^U is the carrying capacity utilized, usually expressed as a percentage. When CC^U = 100%, the available pastures provide just enough dry matter for the animals on the range. If CC^U < 100%, the range is understocked; if CC^U >100%, it is overstocked.

The pastoralists that participated in this study rely entirely on natural pastures to feed their cattle. There was absolutely no use of supplemental feeds or fodder from cultivated forage. Without any form of supplementation, it is logical to assume that overstocking would result in overgrazing in the long-run. Therefore, in the absence of an empirically determined OSR, the difference between the actual % CC^U and the 100% CC^U mark--the point at which the available pastures provide just enough dry matter for the animals on the range--is used to measure the likelihood of overgrazing (OG). In other words,

$$OG = Actual\ \%\ CC^U - 100\%\ CC^U \qquad (20)$$

Data on herd structure, liveweights, offtake rates, calving rate, mortality rate, annual rainfall and grazing area was entered into the IBIEHM model and values of % CC^U --projected over a period of 10 years--were obtained for each farm. However, because it is hard to predict the likely behavior of each pastoral household 10 years into the future based on the one-year data collected, only the values of % CC^U for the first year--for which data is available--are used for the subsequent analysis in this study. Therefore, for the remaining part of this paper, % CC^U refers to *first year's* CC^U.

Variables and Estimation Procedure

A standard linear regression model is used to explain overgrazing on the private farms, that is, OG (equation 20) is regressed against a set of explanatory variables chosen on the basis of their theoretical importance to the study. The explanatory variables used are described in table 1 below.

Table 1: Description of the explanatory variables

Variable	Description
ALT.INC	***Alternative income***: The household income earned from other sources--off-farm or on-farm--that are not related to cattle. It captures the effect of alternative sources of income on the likelihood of overgrazing.
HSE	***Value of house*** (scale: 5-10): Derived by summing up the scores for the materials used to construct the house inhabited by the pastoral household. The value of the house inhabited by a household is often used as a proxy for household income or wealth in empirical research. However, among the pastoralists, wealth is measured by number of cattle owned. It is not uncommon to find a household with several hundred of cattle staying in a temporary grass-thatched house, and another household with fewer cattle staying in a permanent iron-roofed/brick-walled house. Whereas using number of cattle as a measure of wealth would rank the former household as being richer, using value of house would do the opposite. In this case, the value of the house is an indicator of how settled a household is in the place where the interview was conducted. This variable captures the effect of a pastoral household's decision to settle in one area (to practice settled livestock farming) on the likelihood of overgrazing.
B/Acc.	***Type of Bank Account held by the head of household***: This variable is used as a proxy for the pastoralists' use of banking services to store wealth or savings. It takes on a score of 0 if no bank account; 1 if savings account; and 2 if current account. This variable measures the effect of a wealth storage alternative on the likelihood of overgrazing; and the scoring (0 to 2) represents increasing use of banking to store wealth. The current account was given a higher score than the savings account for two reasons: (1) the primary purpose of opening the account; and (2) the length of time the account has been in use. In 1995, all pastoralists who sell their milk to the Dairy Corporation Milk Collection Centers were told to open savings accounts, so that the Corporation would fortnightly deposit their proceeds directly into their accounts. Those who had bank accounts (mainly current accounts) before 1995 were not required to open new accounts, and we assume that they opened these accounts voluntarily for the purpose of storing their wealth/savings. On the other hand, those who opened savings accounts in 1995 didn't do so for the purpose of depositing their savings, but for receiving payment from the Corporation, and their accounts have been in use for a shorter time than the current accounts. That is why holders of current accounts were given a higher score, to represent more use of the bank to store wealth.
CROPLND	***Cropland***:The amount of land allocated to growing food crops; an alternative food source.
FMLY	***Family Size***: The number of people living and eating together in a household. It captures the effect of current consumption needs of a pastoral household on the likelihood of overgrazing.
ALT.LND	***Alternative grazing land***: This variable takes on a score of 1 if in addition to the private land, the pastoralist has access to some other land (rented or communal land); and 0 otherwise.
BIP	***Breed Improvement Practice***: Scores 1 if pastoralist practices breed improvement, 0 otherwise.

The ordinary least squares (OLS) estimation method is used to estimate the parameters for the overgrazing explanatory model. Earlier on, we hypothesized that the pastoralist's choices regarding number and breed of cattle to stock, for example, influence the likelihood that they overgraze their private land. Thus, the choices made on number and breed of cattle ought to enter the overgrazing explanatory model. In addition, it was presumed that these choices are influenced by household specific characteristics such as family size. The possibility of dependence of some explanatory variables (in this case the "choice" variables, e.g., number and breed of cattle to keep) on other variables (household characteristics) in the model provides grounds for arguing that the choice variables are endogenous. This would render the OLS method inappropriate as it would result in inefficient parameter estimates, because of the correlation between the endogenous variables and the error terms.

However, the problem of endogeneity of explanatory variables does not arise in this study for two reasons. First, a t-test of the correlation between the choice variables and the residuals of the OLS regression in which these variables are used as regressors shows no evidence of correlation. Second, the analysis for this study is based on a one-year data set, and the choice variables considered in this paper (such as choice of breed of cattle to stock) were decided upon prior to the year when this data was collected. Therefore, based on the study period, these variables are considered pre-determined and, thus, exogenous to the model.

Thus, the OLS estimation method is appropriately used to estimate:

$$OG = f(BIP, ALT.INC, CROPLND, B/Acc., FMLY, ...) \qquad (21)$$

Regression Results[#]

$$OG = \underset{(4.406)^{***}}{2.194} - \underset{(-2.230)^{**}}{0.004\ ALT.INC} - \underset{(-3.158)^{***}}{0.179\ HSE} - \underset{(-2.554)^{**}}{0.397\ B/Acc.} - \underset{(-2.372)^{**}}{0.077\ CROPLND} +$$

$$\underset{(1.780)^{*}}{0.05\ FMLY} + \underset{(2.806)^{***}}{0.702\ ALT.LND} + \underset{(2.295)^{**}}{0.494\ BIP}$$

$R^2 = 0.41$
F-Statistic = 8.40.

[#] *Numbers in parentheses are t-values*
[*,**,***] *Implies statistically significant at the 10%, 5% and 1% levels of significance respectively.*

The regression results show a clear negative relationship between the likelihood of overgrazing and the existence of alternative income (ALT.INC) and food (CROPLND) sources. That is, pastoral households that depend entirely on cattle for food and income are more likely to overgraze than those with alternative food and income sources. This suggests that over-dependence on cattle for food (milk) and income causes pastoralists to over-invest in cattle (overstock), since fewer cattle--particularly of the local breed type--mean less aggregate milk output and, thus, less food and income. The results also indicate that the likelihood of overgrazing significantly increases with family size (FMLY). In other words, other things being equal, pastoral households with larger families are more likely to over-invest in cattle (overstock) than those with smaller families. The explanation for this result is built on the previous one--over-dependence on cattle for food and income; and the reason for doing so will become apparent in a moment.

During the survey, we asked the participants a series of questions to enable us determine the percentage of respondents who think they overgraze. This was done to establish whether those who overgraze know that they actually do, so as to rule out ignorance as a major reason for overgrazing. In reply, 74.4% of the respondents who were actually found to be overstocking (overgrazing) thought they overgraze. Those who thought they overgraze were further asked why they overgraze, knowing the potential costs (losses) involved. They said that they have no alternative land to graze the extra animals, and cannot sell them off, because if they did, the aggregate production of milk (staple food among pastoral households) from the remaining animals wouldn't be enough to feed the family and have a surplus for sale. If this is true, then other things being equal, larger families would be more likely to overgraze than the smaller ones, which is exactly what the results show. Therefore, in the absence of alternative food and income sources, or when there is over-dependence on cattle, pastoralists overstock as they pursue the goal of balancing the number of cattle and people in the household so as to guarantee a consistent supply of milk (food) for the entire family. In other words, current consumption needs--manifested in the size of the family--make the pastoralists' planning horizon shorter than society's. This shorter planning horizon causes them to "mine" the natural pasture resource at a higher rate than is socially optimal (overgraze); and by so doing, they impose a temporal externality to society.

Based on the pastoralists' claim that the need to maintain a certain level of aggregate milk output from their herds causes them to overstock, breed improvement sounds like a plausible overgrazing abatement strategy. This is because it is expected to increase cattle productivity.[8] Thus, for the purpose of milk production alone, breed improvement would be expected to eliminate the need to over-invest in cattle (overstock) as means of achieving the desired level of aggregate milk output, and by so doing reduce stocking densities and, hence, the severity of overstocking (overgrazing). Paradoxically, however, the results show that the likelihood of overgrazing significantly increases with breed improvement (BIP). In their 1979 AJAE paper, Doran et al. predicted this counter-intuitive result arguing that the increase in quality and value of the cattle stock due to breed improvement would result in a reduction in offtake (or an increase in the reluctance of the pastoralists to sell their high value and more prestigious cattle) and a consequent exacerbation of the overgrazing situation.

While the results of this study support the claim of exacerbated overgrazing as a result of breed

[8] The data used in this study shows a positive and strong statistically significant ($p<0.01$) relationship between the percentage of improved breed cattle in the herd and two cattle productivity measures, namely: average daily milk yield and calving rate.

improvement, there is no evidence that offtake rate decreases with breed improvement.[9] Rather, the explanation for this result is rooted in the fact that most of the pastoralists involved in breed improvement also practice breed diversification. They raise two separate herds on the same land--an improved breed herd alongside a herd of pure local cattle--as a risk management strategy, which often results in high stocking densities and a higher likelihood of overgrazing. The practice of breed diversification is predicated on the notion that local cattle are better adapted to environmental stress than cross bred or pure exotic cattle; but it is also a result of past experience. Pastoralists who rushed into breed improvement prior to adopting better animal husbandry practices experienced heavy animals losses, to the extent that some pastoralists are reluctant to start breed improvement, despite knowing that it would enhance the productivity of their herds. The few who have embarked on breed improvement are maintaining two separate herds, to ensure that if disaster hits, they are guarded against total loss of cattle.

It is often argued that cattle are used as a store of wealth among pastoral households (Doran et al., 1979) and that pastoralists overinvest in cattle because of lack of wealth storage alternatives or because they choose not to use the alternatives where they exist. That is, instead of using banking services, for example, it has been argued that pastoralists store all their wealth/savings in form of cattle, and as a result over-invest in cattle and, hence, overgraze. This argument is supported by the results of this study, which show a significant negative relationship between the use of banking (B/Acc.) as a wealth or savings storage alternative and the likelihood of overgrazing. Thus, the more the pastoralists used banking as a wealth or savings storage alternative, the less likely they were to overgraze.

The value of the house (HSE) inhabited by the pastoral household significantly decreased the likelihood of overgrazing. That is, other things being equal, the more settled the pastoral households, the less likely they are to overgraze their private land, which suggests that the lack of commitment to settle in

---

[9] The data used in this study shows a positive but very weak and insignificant correlation between offtake rate and the percentage of improved breed cattle in the herd (*r*=0.0612); and between offtake rate and BIP (*r*=0.0774)

one place encourages overgrazing. This finding is explained by the fact that, even after acquiring private property status, some pastoralists continue to practice semi-transhumance[10] pastoralism, whereby during the dry season (when pastures and water are scarce) the whole or part of the family moves to set up another temporary home in some other area with a better supply of water and pastures. Such people don't care to put up permanent (high value) houses, because they know they will have to desert them for as long as the water and pastures remain scarce on their private land. For the same reason, such pastoralists hardly ever control the size of their herds for the sake of balancing the number of animals with available pastures, because they know that they can move some or all their animals to some other place in case the pastures at the current homestead get depleted. On the other hand, the pastoralists with permanent houses would be less willing to move and abandon their good homes; and they try to avoid this by not overstocking (overgrazing) their private land.

The relationship between access to alternative grazing land (ALT.LND)--over which the pastoralist doesn't hold secure, exclusive rights--and the likelihood of overgrazing is positive and significant, implying that with other things being equal, the pastoralists with access to alternative grazing land are more likely to overstock than those without. This is so because of the feeling that there is some place to run to after depleting pastures on their private rangelands.

Policy Implications.

Over-dependence on cattle for food and income has been established as a major cause of overstocking (overgrazing) among pastoralists with private rangelands. Thus, the most important implication of this study is the need for the diversification of food and income sources in order to abate overgrazing on private rangelands. The diversification of food sources requires pure pastoralists to evolve

---

[10] Although this practice has greatly decreased in Nyabushozi, a few pastoralists that we talked to during the survey said they would do it if necessary, and some had temporarily moved part of their herds to places outside the study area when the survey was conducted.

into agro-pastoralists, so that they can grow some food for their own consumption--in addition to grazing cattle, instead of relying entirely on cattle for food. The diversification of income sources, on the other hand, may not be easy without government or private sector involvement in the creation of off-farm jobs. Investments in food processing plants--particularly those that process cattle outputs, or in industries that manufacture cattle inputs such as chemicals and animal feeds--would bring jobs to the study area, and help pastoralists to diversify their income sources. However, an increase in income earning potential without a corresponding increase in acceptable alternative investment opportunities or wealth stores may, in fact exacerbate the overgrazing problem because surplus cash will tend to be invested in cattle (de Wilde, vol.2, p. 423; and Belshaw cited in Doran et al., 1979). This claim is corroborated by the results of this study which show that the less the pastoralists used banking as a wealth or savings storage alternative, the more likely they were to overgraze. Thus, by encouraging banks to open branches in the study area to mobilize savings from the pastoralists; and by educating the pastoralists on the benefits of wealth storage diversification; or even by adopting measures that make cattle less attractive as a wealth store (e.g., taxing the cattle held beyond an empirically determined appropriate stocking density for the study area) over-investment in cattle might reduce, and so would the severity of overgrazing.

The results also indicate that while breed improvement significantly increases cattle productivity, it doesn’t mitigate overgrazing tendencies. Therefore, as an overgrazing abatement strategy, breed improvement matters--insofar as it reduces the need to overstock as a means of attaining the desired level of aggregate milk output, but so does the improved feeding and health care of the animals. Without the recommended animal husbandry practices, the risk of total loss of improved breed herds will remain high, and so will the practice of breed diversification as a risk management strategy--which increases the likelihood of overstocking. Besides, without proper animal husbandry, the improved breeds will not perform to their full production potential--let alone survive--as the genetic improvement will be negated by environmental constraints. Thus, those pastoralists who overstock and, hence, overgraze as a means of getting higher milk output from their herds will probably continue to do so--even after genetically improving their herds. Therefore, any program whose aim is to enhance range productivity and mitigate overgrazing in Nyabushozi should attach as much weight to animal feeding and health care, as it does to breed improvement.

Lack of commitment to settle in one place--manifested in the form of temporary-low value houses--has been identified as one of the factors that significantly increase the propensity of the pastoral households to overgraze their private land. This implies that government policies that incite pastoralists to settle in one place could reduce the severity of overgrazing in Nyabushozi. One incentive that would undoubtedly induce pastoralists to settle is subsidizing the cost of guaranteeing water availability on their private land throughout the year--even in the case of prolonged droughts. Despite the fact that all the surveyed pastoral households had private water sources on their land--in the form of water ponds, valley dams, etc.--many indicated that their private water sources would sometimes run dry in the dry seasons, forcing them to turn to nearby communal sources, or even distant sources if necessary. Some reach the extent of moving their families to set up temporary homes in distant areas--e.g. near lakes, during periods of acute water shortages. In other words, the periodic shortage of water encourages semi-transhumance pastoralism, which gives the pastoralists little incentive to preserve the quality of their private rangelands, via stinting. This is because they are aware that even if they controlled the size of their herds to balance the number of animals with the available pastures on their private land--which they are reluctant to do in the first place--they may still have to temporalily move if their private water sources run out. The surveyed pastoralists--particularly the small ones--claimed that the cost of establishing large water sources that can enable them pull through drought periods is prohibitively high. It is, therefore, imperative that pastoralists be assisted to expand the available water sources on their land, to encourage them to settle in one place--since there is evidence from this study that once settled, the likelihood that pastoralists overgraze their private land significantly decreases. The construction of several communal water sources in the area--that can withstand long dry seasons--could produce comparable results at a lower cost.

The results also show that access to alternative grazing land over which the pastoralist has no secure, exclusive rights significantly increased the likelihood that pastoralists overgraze their private land. The current trend of rangeland tenure reform suggests that communal rangeland tenure will be completely phased out of Nyabushozi soon. By the time this happens, the pastoralists that are driven to overstock their private land by the existing opportunity of communal grazing land will probably have adjusted their stocking decisions toward balancing herd size with the available private natural pasture resources. But before getting to that stage, the recommended policies that provide increased access to alternative food and income sources, abundant water supply (which encourages pastoralists to settle and stint), and wealth storage alternatives or alternative investment opportunities would probably provide enough incentives to the pastoralists to manage (control) their herd sizes--via destocking. This would trim the sizes of their herds to such levels that it would no longer be necessary to seek alternative grazing land to feed their animals. Eliminating the need to seek alternative grazing land would probably eliminate the perverse incentives inherent in the pastoralists' access to alternative grazing land, which is not to preserve the quality of their private rangelands via stinting, since there is an alternative place to graze their cattle, after ruining their private rangelands.

REFERENCES

Bartels, G. B., Perrier, G. K. and Norton, B. E. 1990. *The Applicability of the Carrying Capacity Concept in Africa*. In Comments on PDN 29b, *The Concept of Rangeland Carrying Capacity in Sub-Saharan Africa: Myth or Reality*, by de Leeuw, P. N. and Tothill, J. C. 1990. PDN Paper 30e, ODI, London.

Behnke, R. H. 1992. *New Directions in African Range Management Policy*. PDN Paper 32c, ODI, London.

Behnke, R. H. and I. Scoones. 1992. *Rethinking Range Ecology: Implications for Rangeland Management in Africa.* World Bank Sector Policy and Research Staff. Environmental Department Working Paper # 53

Doran, M. H., Low, A. R. C. and Kemp, R. L. 1979. *Cattle as a Store of wealth in Swaziland:Implications for Livestock Development and Overgrazing in Eastern and Southern Africa.* American Journal of Agricultural Economics, Vol. 61: 41-47

Hardin, Garrett.1968. *The Tragedy of the Commons.* Science 162(3859):1243-48.

Hart, R. H., Samuel, M. J., Test, P. S. and Smith, M. A. 1988. *Cattle, Vegetation, and Economic Responses to Grazing Systems and Grazing Pressure.* Journal of Range Management, Vol. 41: 282-286.

Hildreth, R. J. and Riewe, Marvin E. 1963. *Grazing Production Curves.II. Determining the Economic Optimum Stocking Rate.* Agronomy Journal, Vol.55: 370-372.

Hocking, D. and Mattick, A. 1993. *Dynamic Carrying Capacity Analysis as a Tool for Conceptualising and Planning Range Management Improvements, with A Case Study from India.* PDN Paper 34c, ODI, London.

Holecheck, Jerry L. 1988. *An Approach for Setting the Stocking Rate*. Rangelands, Vol. 10: 10-14.

Homewood, K. and Rodgers, W.A. 1988. *Pastoralism, Conservation and the Overgrazing Controversy*. In "Conservation in Africa: People, Policies and Practice" (pg. 111-128).

Kisamba-Mugerwa, Wilberforce. 1992. *Rangeland Tenure and Resource Management: An Overview of Pastoralism in Uganda.* Makerere Institute of Social Research (MISR).

Kisamba-Mugerwa, Wilberforce. 1995. *The Impact of Individualization on Common Grazing Land Resources in Uganda.* Ph.D Thesis, Makerere University.

Ostrom, E. 1990. *Governing the Commons*. Cambridge: Cambridge University Press.

Peters, Pauline. 1994. *Dividing The Commons: Politics, Policy, and Culture in Botswana*. University Press of Virginia.

Runge, C. F. 1981. *Common Property Externalities: Isolation, Assurance, and Resource Depletion in a Traditional Grazing Context*. American Journal of Agricultural Economics (November) :595-606

Sserunkuuma, Dick. 1995. *Findings of a Pre-dissertation Field Trip*, Unpublished report, Dept.of Agric.Economics, Makerere University, Kampala.

Stevenson, Glenn G. 1991. *Common Property Economics: A General Theory and Land Use Applications.* Cambridge: Cambridge University Press.

Torell, Allen L., Lyon, Kenneth S. and Godfrey, Bruce E. 1991. *Long-Run versus Short-Run Planning Horizons and the Rangeland Stocking Rate Decision*. American Journal of Agric. Economics, Vol.73 No.3: 795-807.

Vallentine, J. F. 1990. *Grazing Management*, Academic Press, San Diego.

von Kaufmann, R., McIntire, J. and Itty, P. 1989. *Bio-economic Herd Model for Micro-Computer*. International Livestock Center for Africa, Addis Ababa.